Chapter XII. Appendix F. CSEO Policy Option Documentation

This appendix provides the detailed documentation of Climate Solutions & Economic Opportunities (CSEO) policy option development and direct impacts analysis. The appendix is divided into six subsections that address each sector:

1. Energy Supply
2. Residential, Commercial, Institutional and Industrial
3. Transportation and Land Use
4. Agriculture
5. Forestry and Other Land Use
6. Waste Management
7. Clean Power Plan

Each subsection opens with two summary charts of the direct impacts expected for each CSEO policy option that was taken through full development and direct impacts and microeconomic analysis as well as indirect and macroeconomic analysis (with the exception of the Clean Power Plan analysis subsection). The first chart summarizes the "stand-alone" policy option impacts (results assume that this policy option is implemented without any overlaps or interactions with other CSEO policies). Impacts include: the expected in-State GHG reductions for the years 2020 and 2030; cumulative in-State reductions through 2030; total cumulative GHG reductions through 2030 (these include the expected upstream GHG emission reductions that may occur out of State); the net present value (NPV) of direct societal costs or savings of policy option implementation; and the cost effectiveness (CE) for each policy option (total cumulative reductions divided by the NPV of direct societal costs).

The second summary chart provides results that have been adjusted to account for any intra-sector interactions and overlaps (those occurring within the sector). A summary is also provided that describes the intra-sector policy option overlaps/interactions identified and what was done to adjust the results for each policy option. Inter-sector overlaps/interactions (those occurring among policies in other sectors are described and summarized in Chapter III of the final report).

The third summary chart provides results for macroeconomic analysis of policy options and combined option scenarios using results of fully integrated direct impact analysis as inputs to macroeconomic analysis using the REMI PI+ model.

Following the direct impacts assessment summary tables, the detailed policy option development and analysis documents are presented. Each policy option development and analysis document used the same template for policy option development. The sections in the template include:

- Policy Option Description
- Causal Chain for GHG Reductions
- Policy Option Design, including timing, level of effort or goals, coverage of parties, eligibility and definitions
- Implementation Mechanisms, such as codes and standards, incentives, technical and financial assistance, credits and trading, pricing, voluntary agreements, information and education, disclosure, and others
- Related Policies/Programs in Place and Recent Baseline Actions
- Estimated Net GHG Reductions and Net Costs or Savings, including choices of data sources, analysis methods, and key assumptions
- Estimated Macroeconomic Impacts, including jobs, growth, and income
- Key Uncertainties
- Additional Benefits and Costs
- Key Feasibility Issues

Each policy option has been custom selected by Minnesota with Center for Climate Strategies (CCS) assistance, and designed, and analyzed by CCS based on Minnesota agency conferrals and concurrence. Results of each of these specific decisions are documented for each individual CSEO policy option in the following policy option document sections.

Chapter XIII. Appendix F-1. Energy Supply Policy Option Recommendations

Overview

The tables below provide a summary of the direct impacts and microeconomic analysis of Climate Solutions & Economic Opportunities (CSEO) policies in the Energy Supply sector. The first table provides a summary of results on a stand-alone basis, meaning that each policy option was analyzed separately against baseline (business as usual or BAU) conditions. Details on the analysis of each policy option are provided in each of the Policy Option Documents (PODs) that follow within this appendix.

Direct Impacts

The stand-alone results provide the annual greenhouse gas (GHG) reductions for 2020 and 2030 in million metric tons (MMt) of carbon dioxide equivalent reductions (CO_2e), as well as the cumulative reductions through 2030. The reductions shown are only those that have been estimated to occur within the state, that is, the net emissions reduction from fuels combustion plus the estimated emissions reduction from the decrease in demand for electricity generation. Additional GHG reductions, typically those associated with upstream emissions in the supply of fuels or materials, have also been estimated, and upstream emissions results are reported within each of the analyses in each POD.

CCS did not utilize any generalized co-benefit estimate (such as a social cost of carbon) or estimate a consistent suite of co-benefit impacts across all policies. In some policies, however, aspects of specific co-benefits were isolated and quantified. For the transit policy, as one example, a small improvement in access to employment was applied to the macroeconomic modeling. The larger economic benefit of any savings to either businesses, households or the government is captured in the macroeconomic impact analysis (as is, by the same token, the economic burden of any increases in prices or costs of living/doing business).

Also reported in the stand-alone results is the net present value (NPV) of societal costs/savings for each policy option. These are the net costs of implementing each policy option reported in 2014 dollars. The cost effectiveness (CE) estimated for each policy option is also provided. Cost effectiveness is a common metric that denotes the cost/savings for reducing each metric ton (t) of emissions. Note that the CE estimates use the total emission reductions for the policy option (that is, cumulative emissions reductions counting reductions occurring both within and outside of the state).

The summary tables show the results for selected scenarios for the ES policies, ES-1 (40% goal) and ES-2. Results for a second policy option scenario for ES-1 (50%) is reported within the POD for that policy option.

Integrative Adjustments & Overlaps

The second summary table below provides net GHG emissions reductions and net costs for each option after an assessment was made of any policy option interactions or overlaps between ES options.

Macroeconomic (Indirect) Impacts

Table F-1.3 below provides a summary of the expected impacts of ES policies on jobs and economic growth during the CSEO planning period. This table focuses on the impact of policies on Gross State Product (the total amount spent on goods and services produced within the state), Employment (the total number of full-time and part-time positions), and Incomes (the total amount earned by households from all possible sources). These metrics represent three valuable indicators of both the overall size of the economy and that economy's structural orientation toward supporting livelihoods and utilizing productive work.

For the purposes of macro-economic analysis of CSEO policies, CCS utilized the Regional Economic Models, Inc. (REMI) PI+ software. This particular REMI model is developed specifically for Minnesota, and is developed consistently with the design of models in use by state agency staff within Minnesota for a range of economic analyses. Its analytical power and accuracy made REMI a leading modeling tool in the industry used by numerous research institutions, consulting firms, non-government organizations and government agencies to analyze impacts of proposed policies on key macro-economic parameters, such as GDP, income levels and employment.

The main inputs for macro-economic analysis are microeconomic estimates of direct costs and savings expected from the implementation of individual policy options. These inputs are supplemented with additional data and assumptions necessary to complete the picture of how these costs and savings (as well as price changes, demand and supply changes, and other factors) influence Minnesota's economy. These additional data and assumptions typically regard how various actors around the state (households, businesses and governments) respond to change by changing their own economic activity. A full articulation of the general and policy-specific assumptions made by the macroeconomic analysis team is provided in the Policy Option Documents, contained as appendices to this report.

Table F-1.1 Energy Supply Policy Options, Direct Stand-Alone Impacts

Stand-Alone Analysis						
Policy Option ID	Policy Option Title	GHG Reductions			Costs	
		Annual CO_2e Reductions[a]	2030 Cumulative[a]	2030 Cumulative[b]	Net Costs[c] 2015-2030	Cost Effectiveness[d]

		2020 MMt	2030 MMt	$MMtCO_2e$	$MMtCO_2e$	$Million	$/tCO_2e$
ES-1	Increase Renewable Energy Standards (40% goal)	1.9	7.5	67	75	-$620	-$8.2
ES-2	Efficiency Improvements, Repowering, Retirement, and Up Grades to Existing Plants	0.00	6.3	44	39[e]	$752	$19
Totals		**1.9**	**14**	**111**	**114**	**$132**	**$1.16**

Notes:
[a] In-state (Direct) GHG Reductions.
[b] Total (Direct and Indirect) GHG Reductions.
[c] Net Present Value of fully implemented policy option using 2014 dollars ($2014).
[d] Cost effectiveness values include full energy-cycle GHG reductions, including those occurring out of state. Dollars expressed in $2014.
[e] Total GHG reductions are lower than in-state GHG reductions for ES-2 because upstream emissions for natural gas are higher than for coal; therefore, switching from coal to natural gas results in lower in-state emissions but higher out-of-state emissions.
Note: Each policy option analysis was done over a fifteen year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

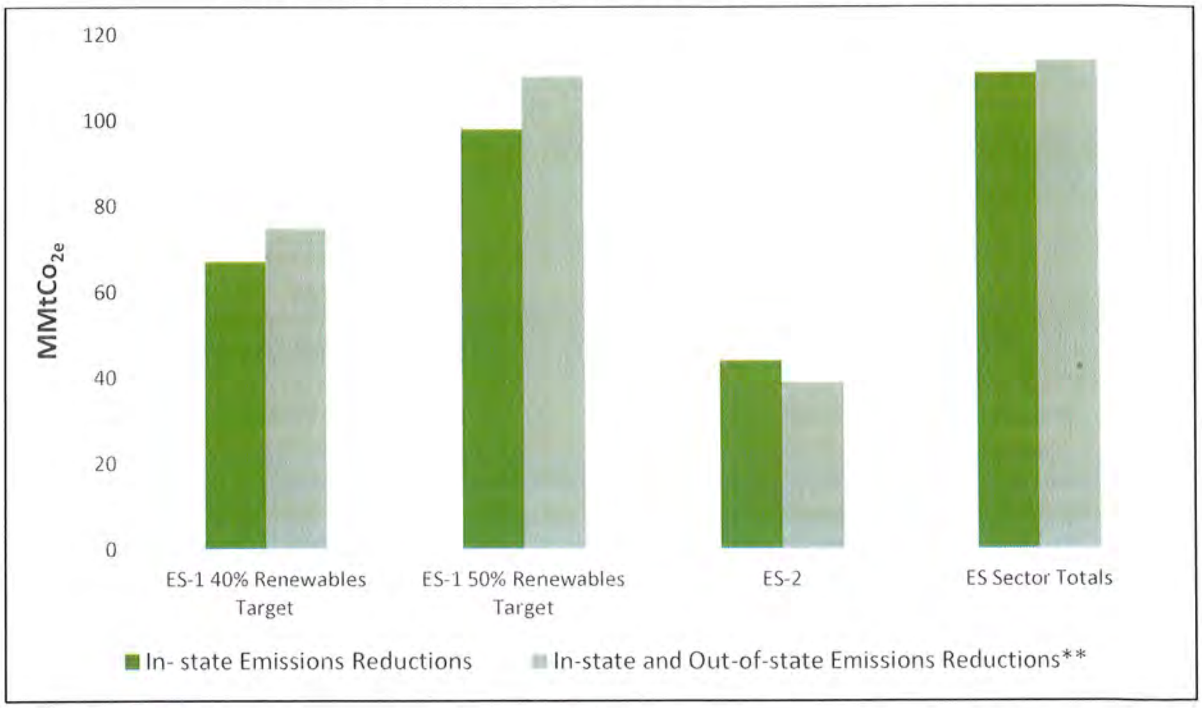
Table F-1.2 Energy Supply Policy Options, Intra-Sector Interactions & Overlaps

Intra-Sector Interactions & Overlaps Adjusted Results							
Policy Option ID	Policy Option Title	GHG Reductions				Costs	
		Annual[a]		2030 Cumulative[a]	2030 Cumulative[b]	Net Cost[c] 2015-2030	Cost Effectiveness[d]
		2020 MMt	2030 MMt	$MMtCO_2e$	$MMtCO_2e$	$Million	$/tCO_2e$
ES-1	Increase Renewable Energy Standards (40% goal)	1.9	6.9	63	74	-$430	-$5.8
ES-2	Efficiency Improvements, Repowering, Retirement, and Up Grades to Existing Plants	0.00	5.8	41	38	$854	$22

Total After Intra-Sector Interactions/Overlap	**1.9**	**13**	**104**	**112**	**$424**	**$3.8**

Notes:
[a] In-state (Direct) GHG Reductions.
[b] Total (Direct and Indirect) GHG Reductions.
[c] Net Present Value of fully implemented policy option using 2014 dollars ($2014).
[d] Cost effectiveness values include full energy-cycle GHG reductions, including those occurring out of state. Dollars expressed in $2014.

Figure F-1.1 ES Policies GHG Emissions Abatement, 2015-2030



Notes:
All Policies Total's comprise emissions reductions achieved by ES-1 40% (default) policy and ES-2 policy.
Total in and out-of-state emissions reduction are the reductions associated with the full energy cycle (fuel extraction, processing, distribution and consumption). Therefore, the emissions reductions that occur both inside and outside of the state borders as a result of a policy implementation are captured under this value.

Table F-1.3 Macroeconomic Impacts of ES Policies

Macroeconomic (Indirect) Impacts Results			
Scenario	**Gross State Product** (GSP, $2015 Millions)	**Employment** (Full & Part-Time Jobs)	**Income Earned** ($2015 Millions)

	Year 2030[d]	Average (2016-30)[e]	Cumulative (2015-2030)[f]	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)
ES-1 40% Renewables Target (Default)	$394	$177	$2,652	2,900	1,510	22,580	$311	$138	$2,075
ES-1 50% Renewables Target	$538	$228	$3,416	3,690	1,820	27,290	$434	$180	$2,695
ES-2	-$73	-$39	-$309	170	310	2,470	-$16	-$3	-$22
ES Sector (ES-1 40%) (Default)	**$319**	**$156**	**$2,336**	**3,070**	**1,670**	**25,020**	**$294**	**$137**	**$2,050**
ES Sector (ES-1 50%)	**$542**	**$239**	**$3,579**	**4,720**	**2,380**	**35,650**	**$485**	**$204**	**$3,058**

Notes:
[a] Gross State Production changes in Minnesota. Dollars expressed in $2015.
[b] Total employment changes in Minnesota.
[c] Personal Income changes in Minnesota. Dollars expressed in $2015.
[d] Single final year value. Year 2030 is the final year of analyses in this project.
[e] Average value from the year 2016 to the year 2030. The average value is calculated from the first year of the policy implementation through the year 2030 if implementation of the policy starts after year 2016.
[f] Cumulative value from 2015-2030 time period.
Note: Each policy option analysis was done over a fifteen-year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

Figure F-1.2 Net Job Creation for ES Policies and ES Sector by Ascending Order, 2015-2030

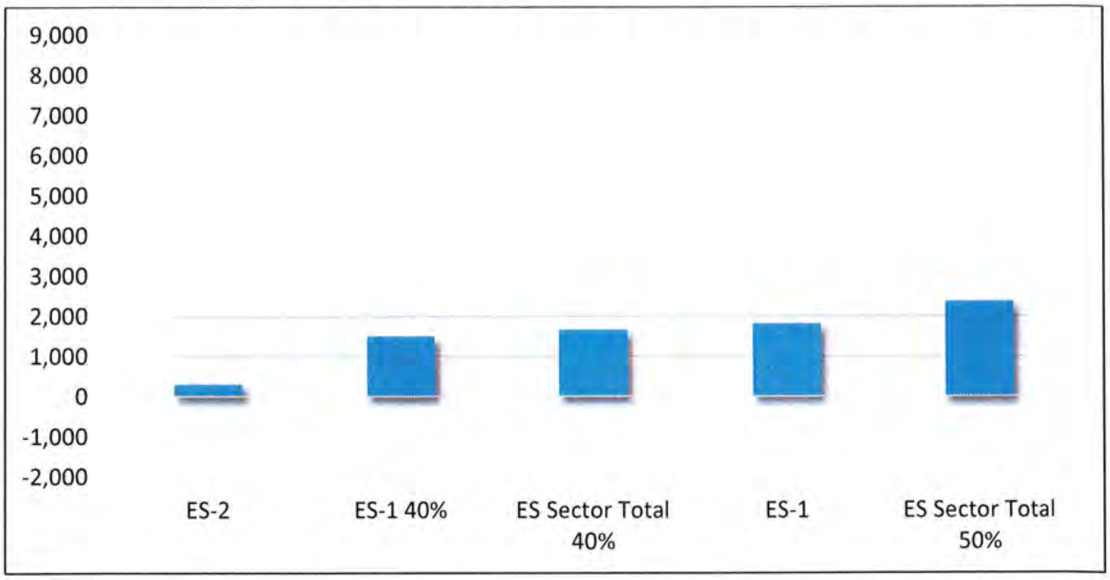
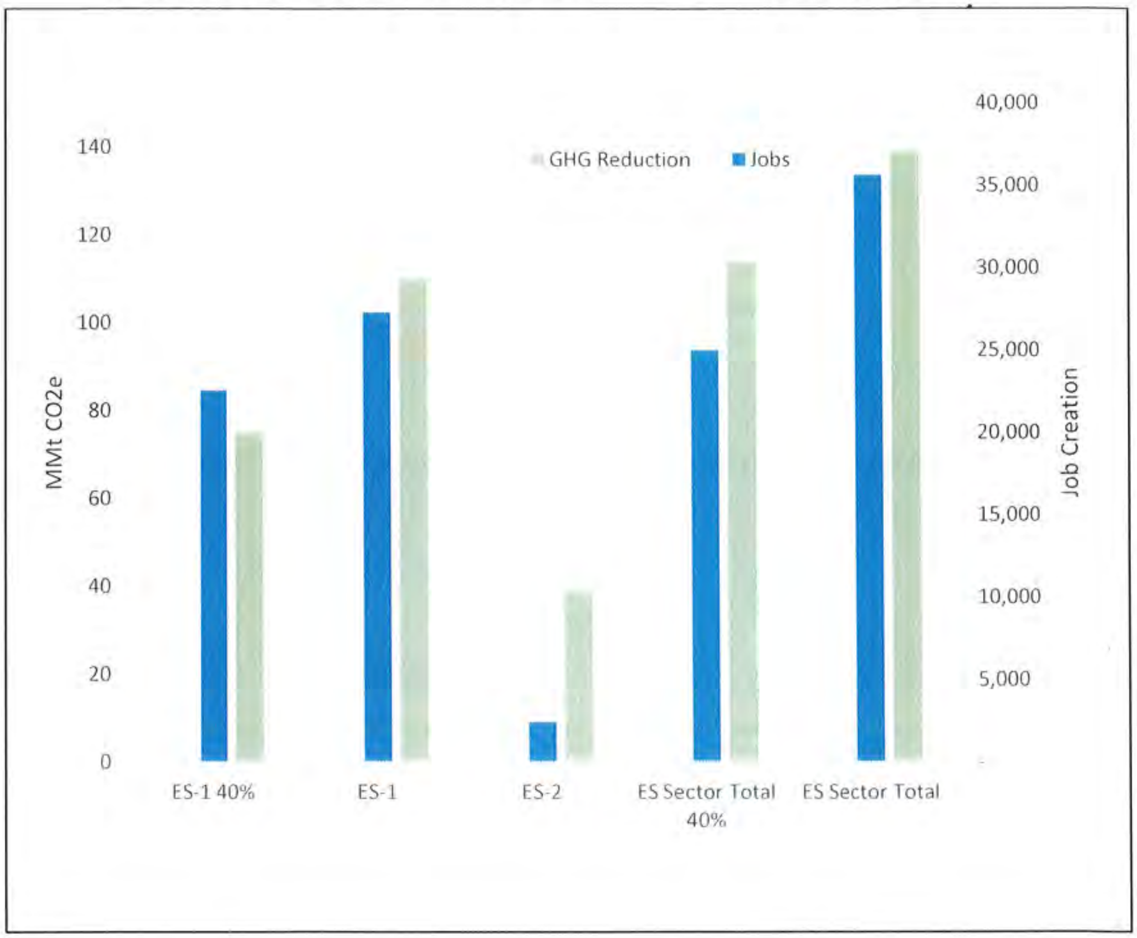


Figure F-1.3 below summarizes a potential for job creation and GHG emissions abatement of ES sector policies on the same graph. This allows for a simultaneous assessment of performance of individual CSEO options against two crucial environmental and economic indicators.

Figure F-1.3 Job Gains and GHG Reduction by ES Policy Options, 2015-2030



Macroeconomic Index

The graph below expresses the overall economic impact from each scenario in a single score, and compares those scores. CCS created this single score (a Macroeconomic Impact Index) in order to encapsulate in one measurement the relative macroeconomic impacts (including jobs, GSP and incomes) of each policy. We have found in our own work and in the literature that indexed scores can be helpful to many readers when comparing options with multiple characteristics.

To produce this score, CCS set the results from the absolute best-case scenario (i.e. the implementation of all CSEO policies with all their optimal sensitivities in place) equal to 100, with that scenario's jobs, GSP and incomes impacts weighted equally at one third of the total score. Each policy's jobs, GSP and income impacts are scaled against that measure, and given a total score. The overall score indicates how significant a policy's impact is projected to be. Negative impacts are scaled the same way, except that those impacts are given negative scores and pull down the total score of the policy.

These scores are calculated separately for the final year of the study (2030), the *average* impact over the 2015-2030 period, and the *cumulative* impact of the policies over that period. While each scenario has one line, the relative importance of jobs, income and GSP remain visible as differently-shaded segments of that line.

Figure F-1.4 ES Macroeconomic Indicators, Final Year 2030

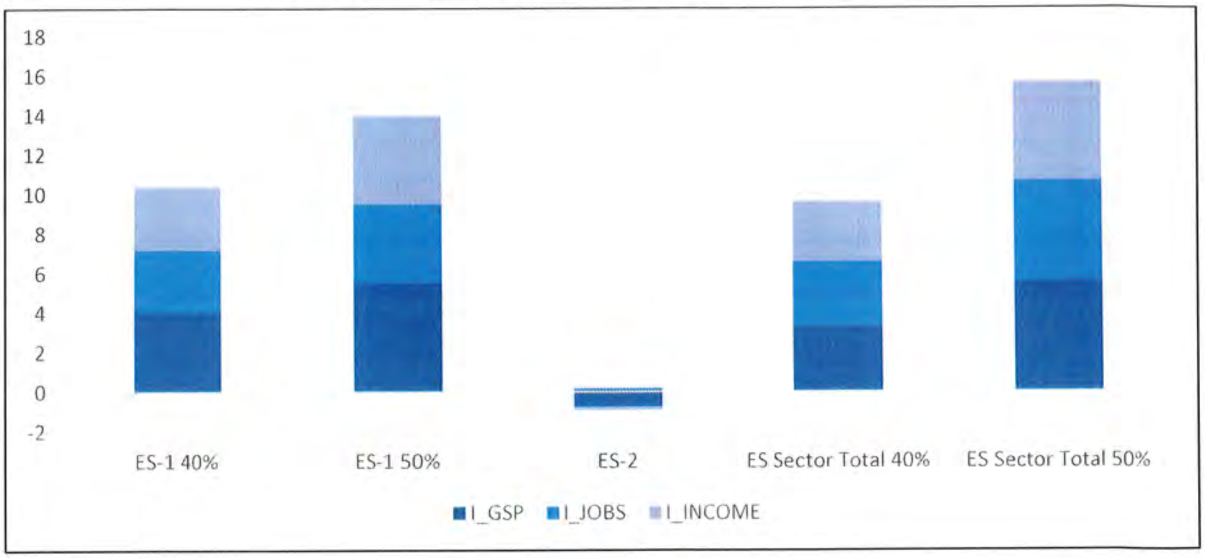


Figure F-1.5 ES Macroeconomic Indicators, Average Annual (2015-2030)

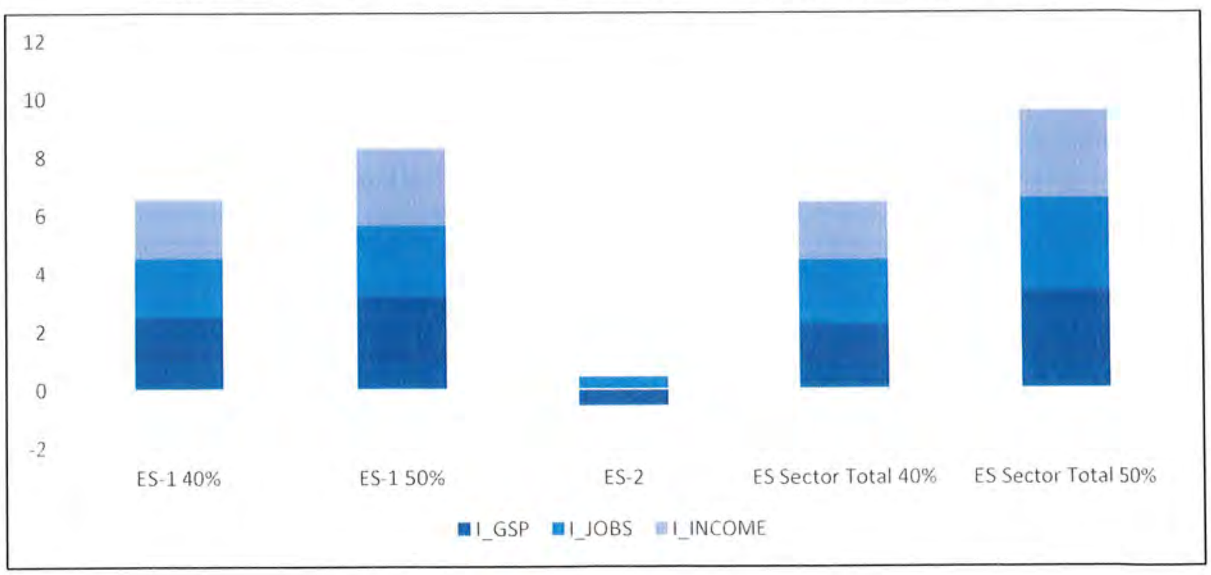
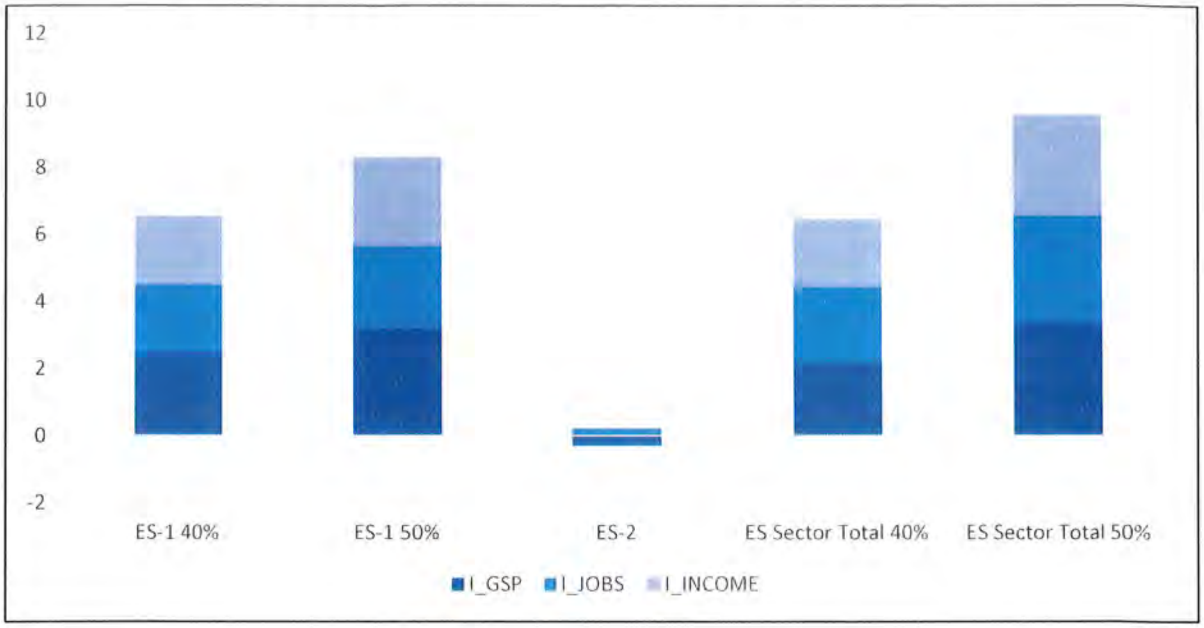


Figure F-1.6 ES Macroeconomic Indicators, Cumulative 2015-2030



From the line and bar graphs that follow, it is evident that the renewable energy standard (ES-1) has by far the larger impacts than the partial shut-down and partial repowering of the Sherburne County facility (ES-2). Its impact on the broader economy, driven by a cost-effective shift to renewables, generates progressively more and more economic activity (measured by GSP) over time. New jobs appear, at a rate of between 100 and 200 per year, as a result of this growth.

The more aggressive version of ES-1, which targets the higher 50% of total energy supply from renewables, outperforms its 40% alternative as well. The fundamentals of the policy are magnified by scaling up the spending shifts involved in this policy.

ES-2, by contrast, produces a small number of new employment positions, but drives slightly negative changes to overall GSP, and to total incomes. The relative savings involved with shutting down and the cost of developing new resources balance out somewhat differently in this policy, and it does not produce the same upward pressure on the total size of the economy.

In the line graphs below, dashed lines represent chosen sensitivity scenarios. In bar graphs following, those sensitivity scenarios are presented in light colors.

Figure F-1.7 ES GSP Impacts ($2015 MM)

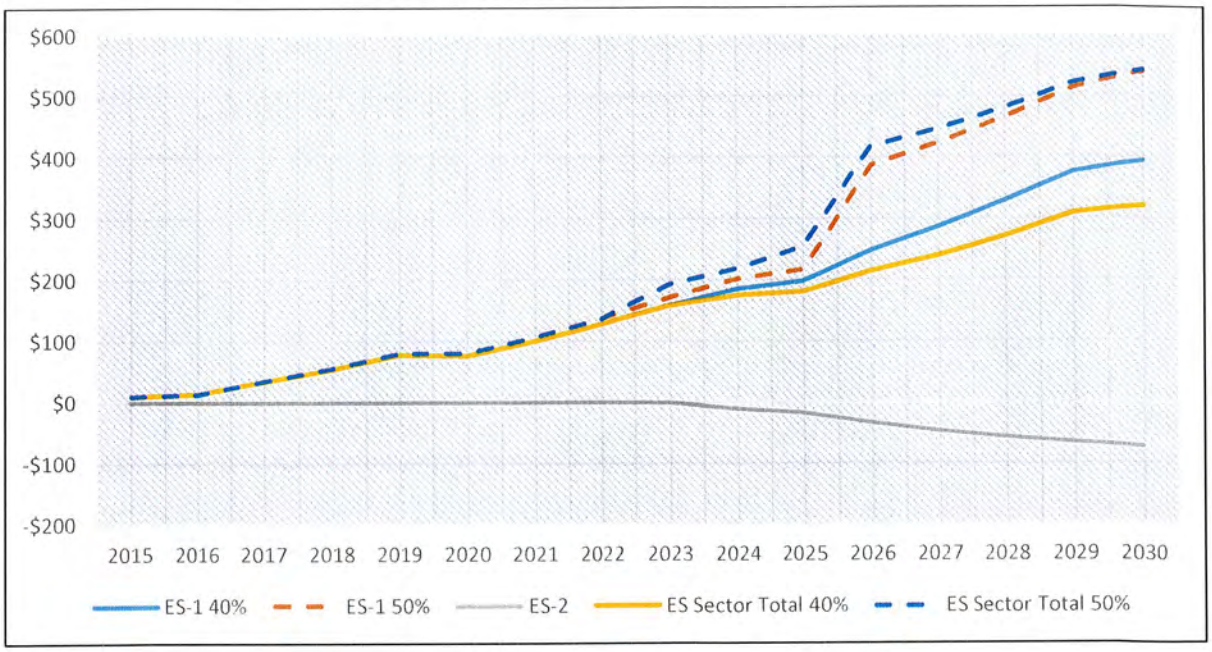


Figure F-1.8 ES Employment Impacts 2015-2030 (Jobs)

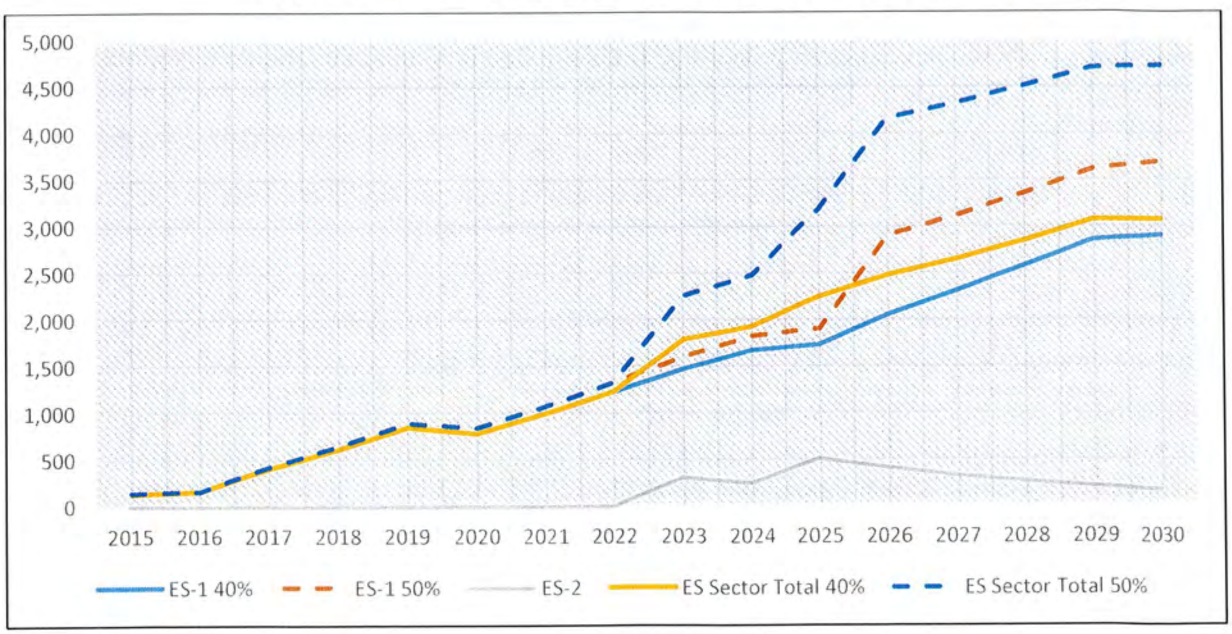


Figure F-1.9 ES Income Impacts ($2015 MM)

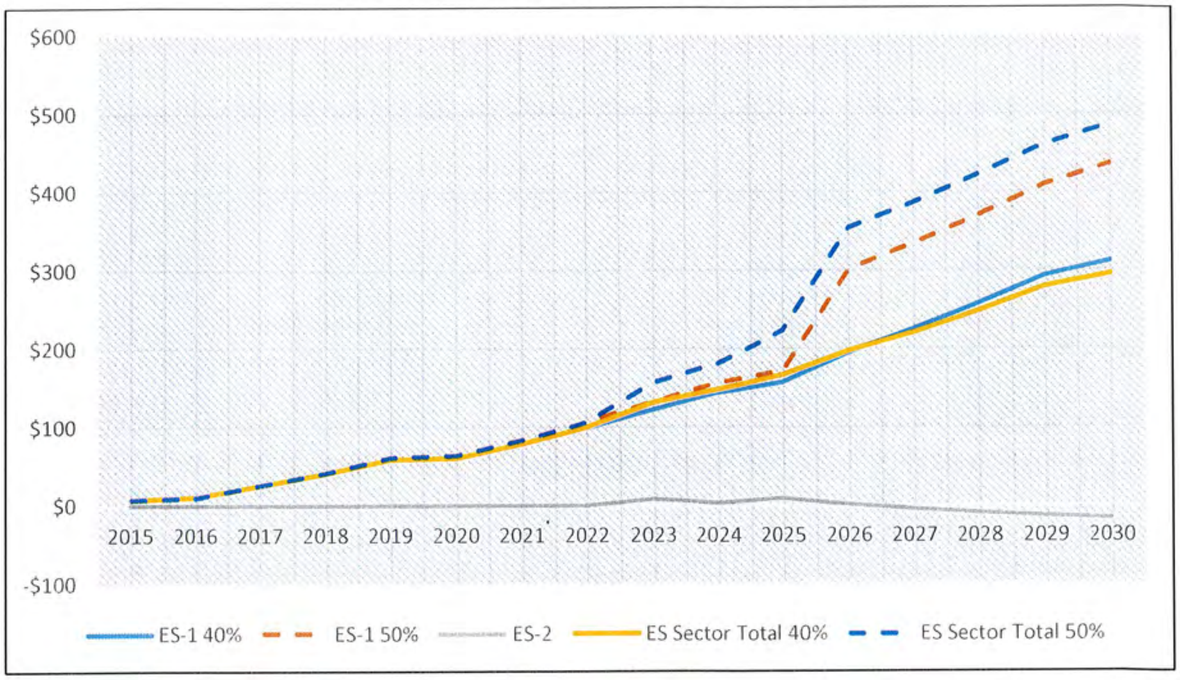


Figure F-1.10 ES GSP Impacts, Average Annual ($2015 MM)

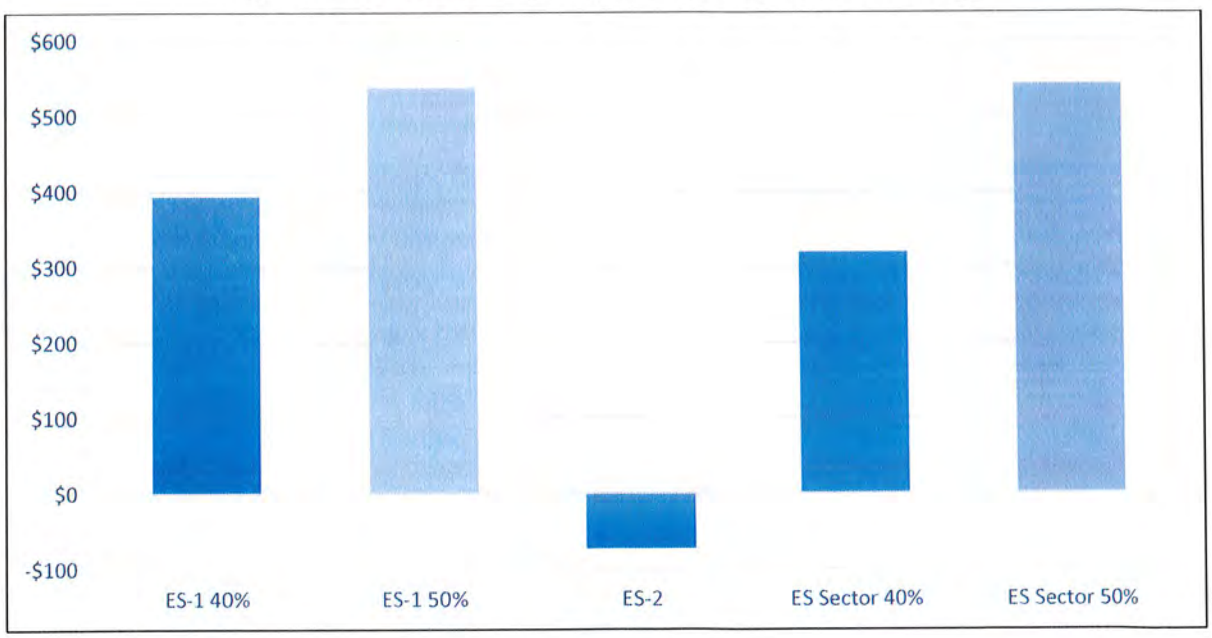


Figure F-1.11 ES GSP Impacts, 2015-2030 ($2015 MM)

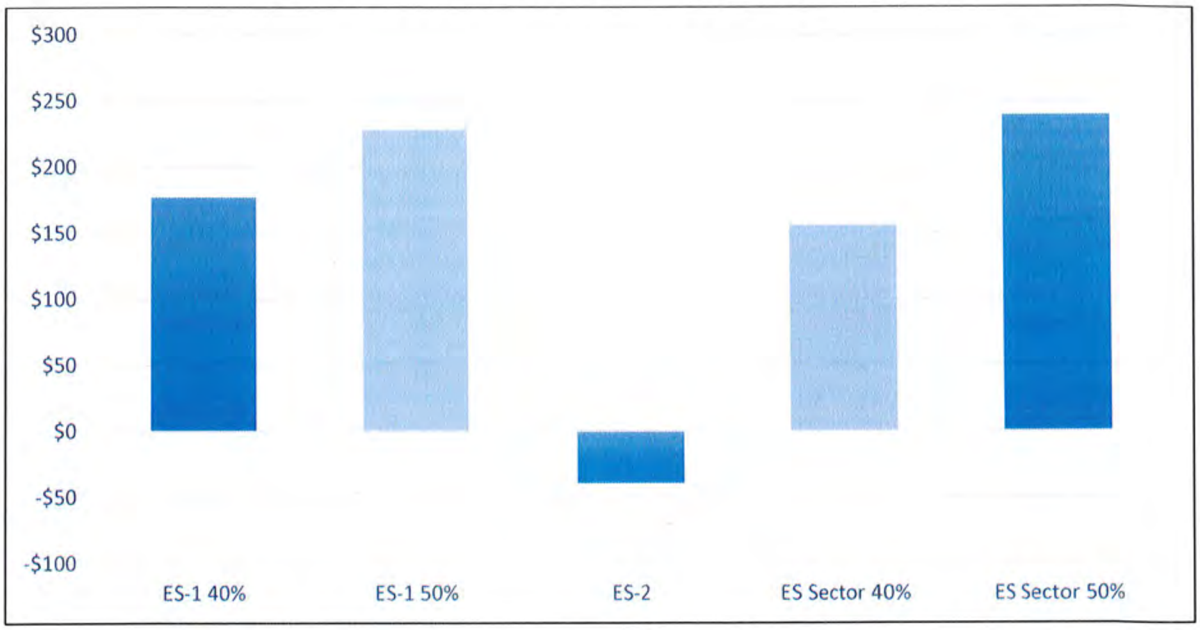


Figure F-1.12 ES GSP Impacts, Year 2030 ($2015 MM)

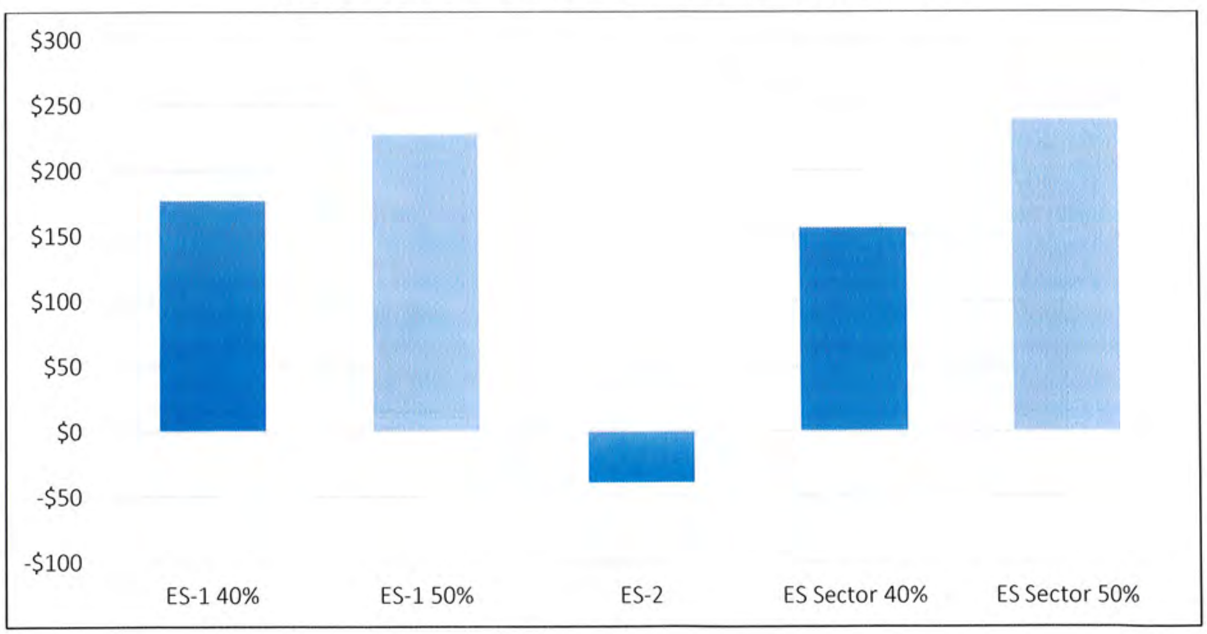


Figure F-1.13 ES Employment Impacts, Average Annual (Jobs)

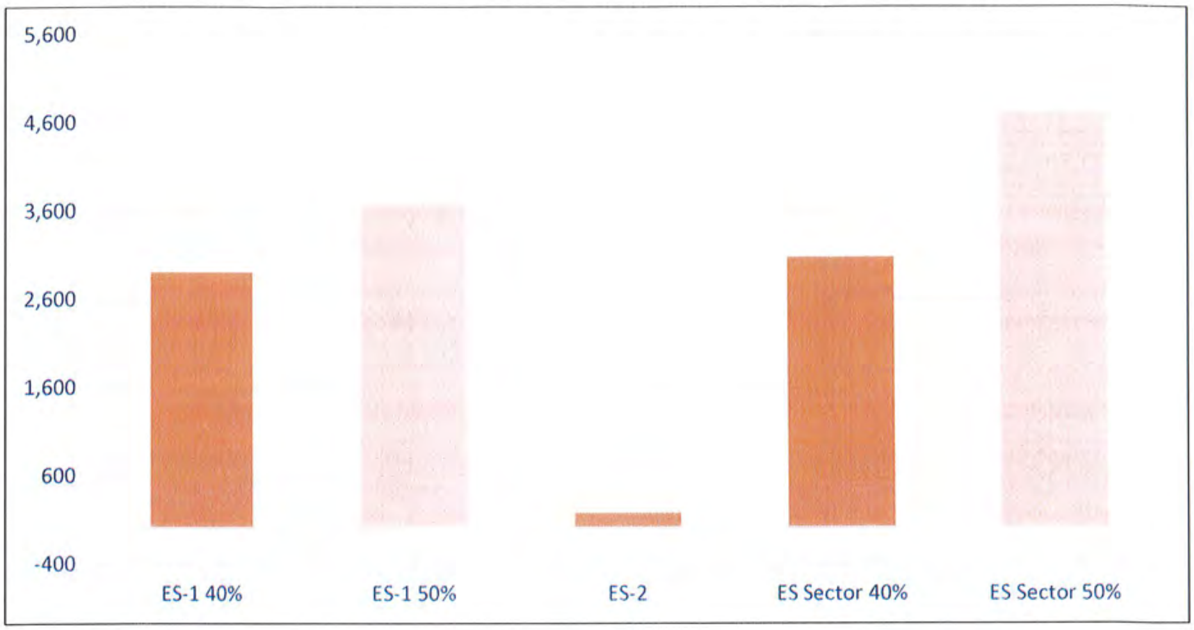


Figure F-1.14 ES Employment Impacts, 2015-2030 (Job Years)

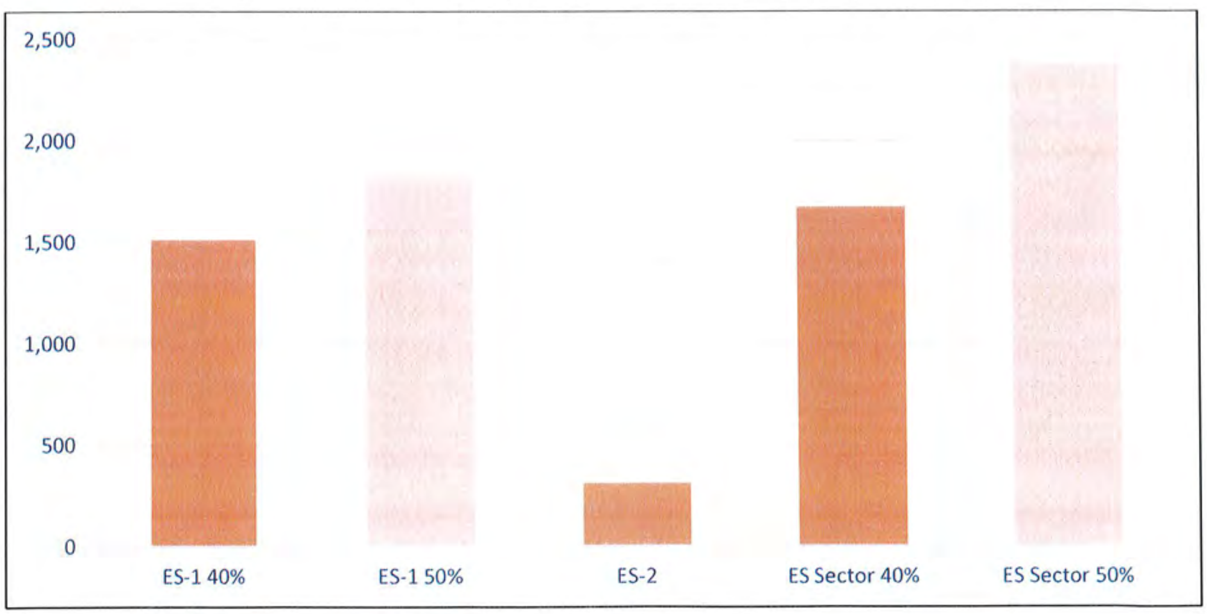


Figure F-1.15 ES Employment Impacts, Year 2030 (Jobs)

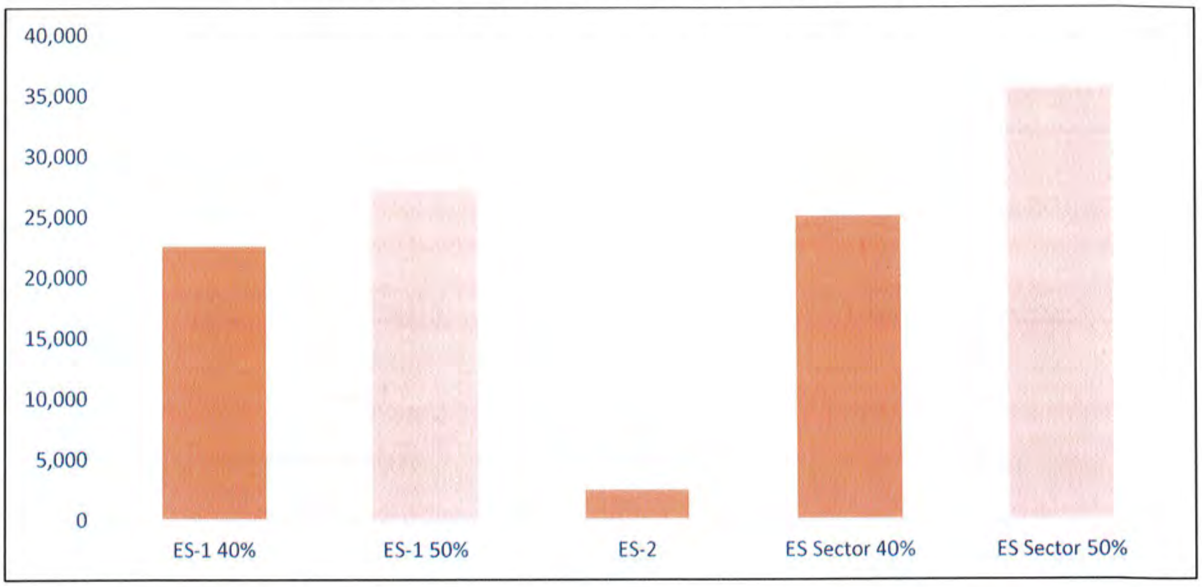


Figure F-1.16 ES Income Impacts, 2015-2030 Average Annual ($2015 MM)

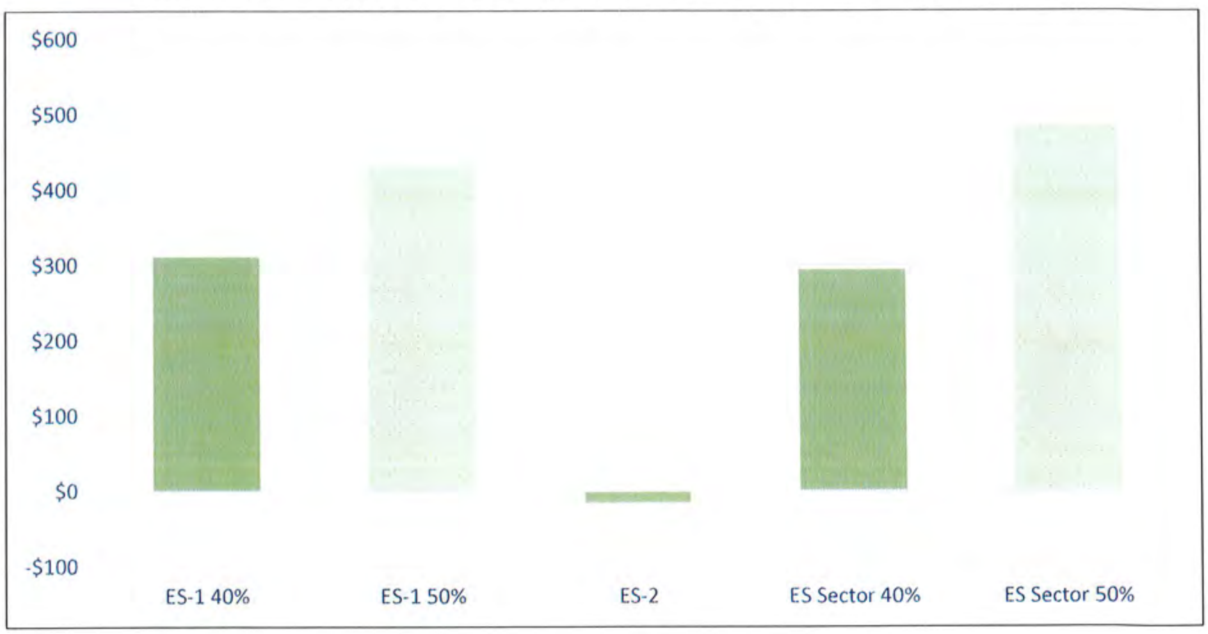


Figure F-1.17 ES Income Impacts, 2015-2030 ($2015 MM)

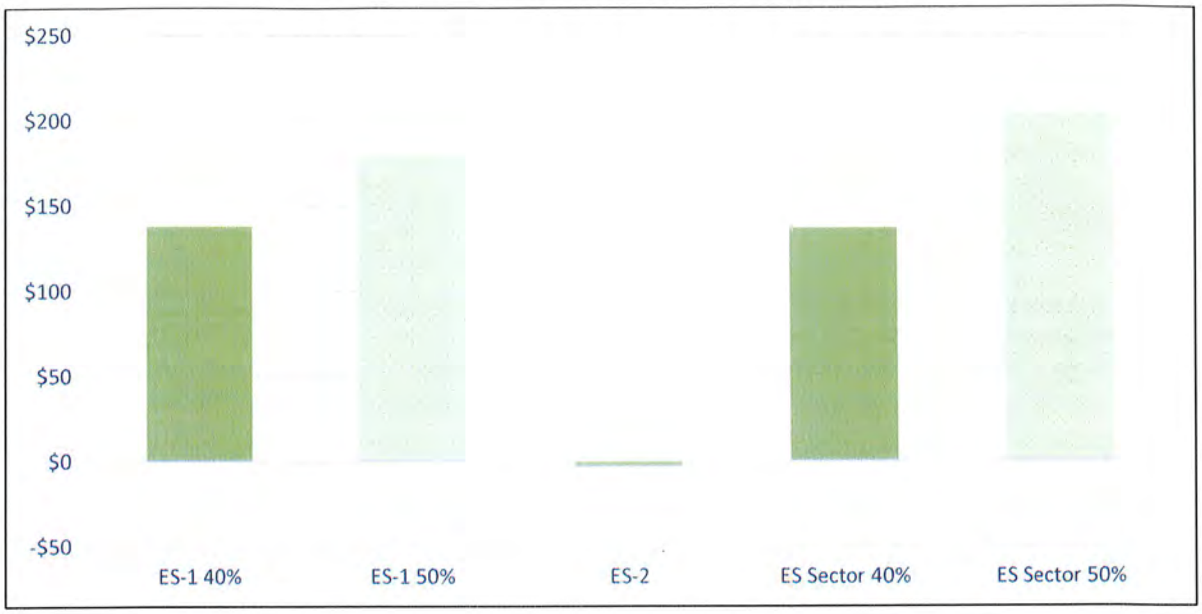
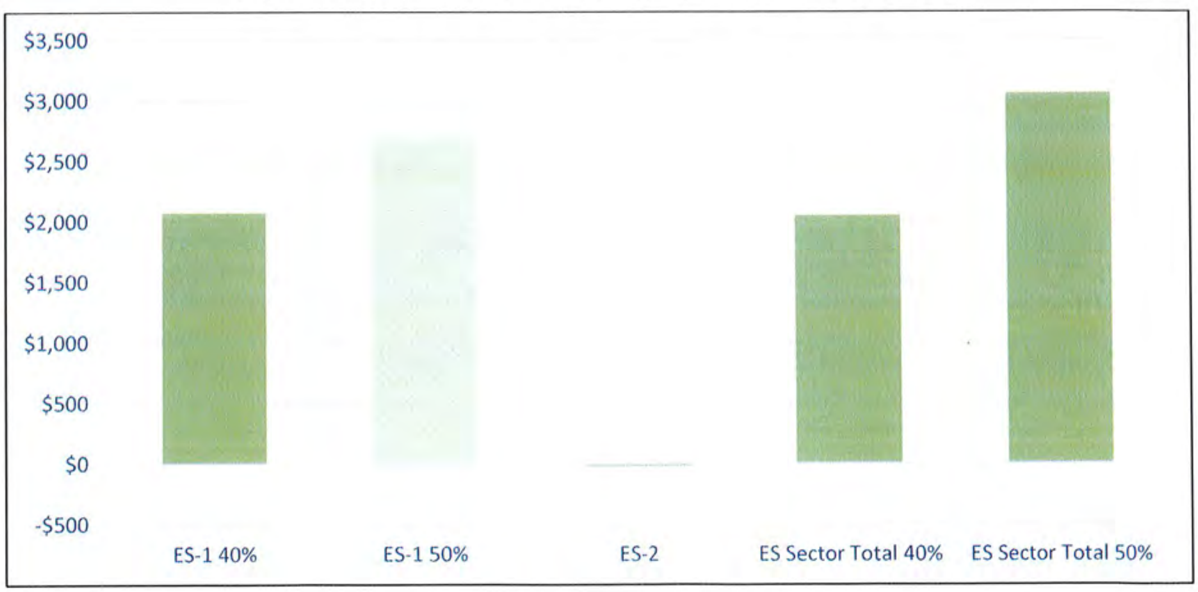


Figure F-1.18 ES Income Impacts, Year 2030 ($2015 MM)



ES-1. Increase Renewable Energy Standards

Policy Option Description

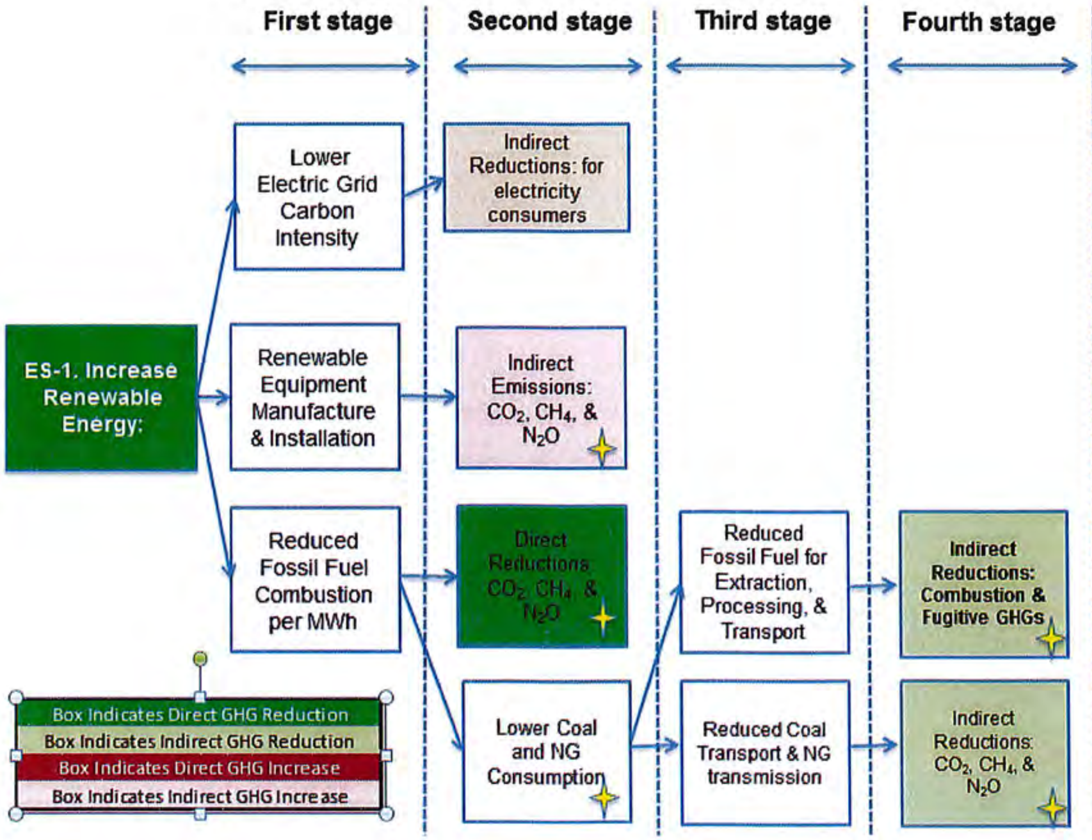
Renewable Energy Standard is a state mandate that requires different categories of electricity providers (investor-owned utilities, publically owned municipal utilities and cooperatives) to source certain amount of electricity they produce, or purchase, from eligible renewable energy technologies. Legislation passed in 2013 supports the investigation of higher levels of renewable energy use in Minnesota, starting with increasing the Renewable Electricity Standard to 40% by 2030, and to higher proportions thereafter (Minnesota Laws 2013, Chapter 85 HF 729, Article 12, Sections 1, 4, and 7). State legislation also sets the goal that by 2030, 10% of the retail electric sales in Minnesota be generated by solar energy (Minnesota Stat. §216B.1691). This policy option aims to expand RES to 40% by 2030. A 50% RES was also evaluated.

Causal Chain for GHG Reductions

The diagram below illustrates how the policy option leads to GHG reductions.

- "First Stage" refers to the direct physical impacts of the policy option, namely a lower CO_2e intensity of the electric system, increased manufacture of renewable systems, and lower fossil fuel use for every MWh of electricity produced;
- "Second Stage" refers to indirect physical impacts of the policy option, namely GHG reductions allocated to consumers, GHG increases associated with increased renewable manufacturer activity, and lower absolute levels of GHGs and primary energy;
- "Third Stage" refers to reductions in direct upstream GHGs and fossil fuel use; and
- "Fourth Stage" refers to indirect upstream GHGs and fossil fuel use.

Figure F-1.19 Causal Chain for ES-1 GHG Reductions



Policy Option Design

Goals: Model the GHG impacts of increasing the Renewable electricity standard to:

- Forty percent by 2030 – (modeling assumptions: 31% wind + 3% hydro + 3% biomass combined heat and power (CHP) + 3% solar)
- Fifty percent by 2030 – (modeling assumptions: 34% wind + 3% hydro + 3% biomass CHP + 10% solar)
- Goals are stated as a percent of annual Minnesota retail electricity sales (representing total contribution and not 'new' or 'incremental').

Note: Large industrial ratepayers are exempted from the current Solar Electricity Standard (216B.1691, Subd 2f. (d)), but as the specifics of the exemption were in progress at the time this policy option was developed, for the purpose of modeling the proposed goals these ratepayers were included in calculations of retail sales.

Timing: Current standards are ~28.5% by 2025:

- Thirty percent by 2020 for Xcel,

- Twenty-five percent x 2025 for all other utilities, and
- 1.5% additional Solar Electricity standard for Investor Owned Utilities (this works out to ~1% of Minnesota total retail sales)

Parties Involved: This requirement would apply to all retail electricity sales in Minnesota. Implementation of this policy option would require the enactment of enabling legislation and subsequent regulation by the Public Utility Commission (PUC). Affected parties include ratepayers, utilities, transmission owners, power producers, renewable energy providers (in Minnesota and neighboring states), and the Midwest Independent Transmission System Operator (MISO).

Entities subject to RES Statute[1]:

- Basin Electric Power Cooperative
- Central Minnesota Municipal Power Agency (CMMPA)
- Dairyland Power Cooperative
- East River Electric Cooperative
- Great River Energy (GRE)
- Heartland Consumer Power District
- Interstate Power and Light
- L&O Power Cooperative
- Minnkota Power Cooperative
- Minnesota Municipal Power Agency (MMPA)
- Minnesota Power
- Missouri River Energy Services
- Northwestern Wisconsin Electric Company
- Ottertail Power Company
- Southern Minnesota Municipal Power Agency (SMMPA)
- Xcel Energy

Note: Large industrial ratepayers are exempted from the current solar electricity standard (216B.1691, Subd 2f. (d)), but as the specifics of the exemption were in progress at the time this

1 In the Matter of Detailing Criteria and Standards for Measuring an Electric Utility's Good Faith Efforts in Meeting the Renewable Energy Objectives Under Minn. Stat. §216B.1691, Docket No. E999/CI-03-869, Order Setting Filing Requirements and Clarifying Procedures, (November 12, 2008).

policy option was developed, for the purpose of modeling the proposed goals, these ratepayers were included in calculations of retail sales.

Other: Renewable Energy Credits used for compliance have a four year shelf life.

Implementation Mechanisms

Regulatory Framework: Regulatory framework for wind, solar and hydro based on existing statute (Minnesota Statute 216B.1691) and PUC orders

Relevant PUC dockets/orders:

- Docket No. E-999/M-08-1163, In the Matter of Commission Consideration and Determination on Compliance with Renewable Energy Obligations and Renewable Energy Standards,
- E-999/CI-04-1616, In the Matter of a Commission Investigation into a Multi-State Tracking and Trading Systems for Renewable Energy Credits
- Docket No. 14-12 / E999/PR-14-237, In the Matter of Commission Consideration and Determination on Compliance with Renewable Energy Standards
- Docket No. 13-542 – In the Matter of the Implementation of Solar Energy Standards Pursuit to 2013 Amendments to Minnesota Statutes, Section. 216B.2691
- Docket No. 11-852 - In the Matter of Utility Renewable Energy Cost Impact Reports Required by Minnesota Statutes Section 216B.1691, Subd. 2e

Table F-1.4 RES Milestones

	Minnesota Utilities Milestone	Xcel Milestone
2010	7.0%	15.0%
2012	12.0%	18.0%
2016	17.0%	25.0%
2020	20.5%	31.5%
2025	25.5%	31.5%

Related Policies/Programs in Place and Recent Actions

Minnesota Renewable Energy Integration and Transmission Study (MRITS) - Legislation passed in 2013 required an engineering study of increasing the state's Renewable Energy Standards (RES) to 40% by 2030, and to higher proportions thereafter, while maintaining system reliability. The study must incorporate and build upon prior study work.

The study was conducted by Minnesota utilities and transmission companies in coordination with MISO and directed by the Minnesota Department of Commerce. Review and input was provided by a Technical Review Committee (TRC) comprised of engineers with expertise in electric transmission system engineering, electric power system operations, and renewable energy generation technology.

The study was Minnesota centric with a study area focused on Minnesota within the MISO footprint and adjoining neighboring regions of the Integrated System (IS – Basin & WAPA) and Manitoba Hydro (MH).

The engineers conducted three analyses:

- The development of a conceptual transmission plan.
- The evaluation of the power system over one year, hour-by-hour to understand operational impacts.
- The overall system strength and stability of the region power system.

Study scenarios for MRITS:

- Baseline: 28.5% of Minnesota Retail sales in 2028 from wind/solar (current Minnesota RES & SES) with 13% MISO in 2028 from wind/solar (current MISO state RESs)
- S1: 40% of Minnesota retail sales in 2028 from wind/solar; with 15% MISO in 2028 from wind/solar (current non-Minnesota RESs + Minnesota @40%)
- S2: 50% of Minnesota retail sales in 2028 from wind/solar; with 25% MISO in 2028 from wind/solar

The final study completed November 1, 2014 included: 1) A conceptual plan for transmission for generation interconnection and delivery and for access to regional geographic diversity and regional supply and demand side flexibility, and 2) Identification and development of potential solutions to any critical issues encountered.

The results from the study show that the addition of wind and solar generation to supply 40% of Minnesota's annual electric retail sales can be reliably accommodated by the electric power system.

Additional analysis would need to be done for adding renewables at levels significantly higher than 40%.

Note: Modeling assumptions for the Minnesota Renewable Energy Integration and Transmission Study differ from those assumptions used in the CSEO modeling (e.g. total load, energy consumption, siting, and percent wind and PV)

Estimated Policy Impacts

Direct Policy Impacts

Table F-1.5 ES-1 Estimated Net GHG Reductions and Net Costs or Savings

Scenario	2030 In-State GHG Reductions (MMt CO_2e)	2015 – 2030 Cumulative In-State Reductions (MMt CO_2e)	Net present Value of Societal Costs, 2015 – 2030 (MM $2014)	Cost Effectiveness ($2014/ ton CO_2e)	Net Discounted Incremental Cost $2014/kWh
40% Scenario	7.5	67	-$620	-$8.2	-$0.00052
50% Scenario	13	98	-$404	-$3.7	-$0.00034

Data Sources

- Common Forecast assumptions spreadsheet developed for the Minnesota CSEO project by Steve Roe
- Electric system assumptions: final version of the power sector forecast prepared by the Pollution Control Agency.
- Utility RES compliance reporting data in docket 14-12
- Generator data from the Midwest Renewable Energy Tracking System.
- Siler-Evans et al "Marginal Emissions Factors for the U.S. Electricity System," 2012
- Final Report - 2006 Minnesota Wind Integration Study Volume I[2]
- Wind, solar PV and NGCC cost and performance assumptions from Lazard's Levelized Cost of Energy Analysis – Version 8.0[3] (*Note: levelized costs in Lazard v. 8.0 did not assume extension of the PTC or ITC).*
- For Biomass CHP, cost and performance assumptions are for commercial and industrial facilities as per the RCII-1 analysis. Note that heat rate for biomass CHP plants are in reference to electric generation efficiency only
- Sensitivities: there were several sensitivities that were run for the 40% and 50% scenarios. These are as follows:

[2] http://www.uwig.org/windrpt_vol%201.pdf
[3] https://www.lazard.com/media/1777/levelized_cost_of_energy_-_version_80.pdf

- CO_2e emission intensity of resources on the margin: these were considered for a) point-of-generation (i.e., in-state), b) upstream (i.e., out-of-state), and c) total (i.e., point-of-generation plus upstream. The default assumption was total.
- Retail electricity sales: these were considered as a) benchmarked to the statute in 2020 and 2025 and b) relative to a 2% reduction in projected retail electricity sales. The default assumption was benchmarked to the statute in 2020 and 2025.
- Costs of resources on the margin: these were considered as a) energy and capacity and b) energy only. The default assumption was energy and capacity.
- Cost & performance options for new units: these were considered as from a) Lazard (low end of range), b) EIA's AEO2014, and c) user-defined. The default assumption was Lazard (low end of range)

Quantification Methods

Using the assumptions below regarding resources on the electric margin, a spreadsheet analysis was undertaken using the methods summarized in the bullets below:

- Incremental renewable energy generation over and above the levels in the BAU were developed over the period 2015-2030 and costed using real levelized assumptions.
- Annual decreases in marginal generation levels due to the penetration of renewable generation was calculated on the basis of the margin assumptions below.
- The avoided CO_2e emissions associated with process heat from biomass CHP facilities was calculated on the basis of the same estimates that were developed for industrial and commercial facilities analyzed in the RCII-1 policy option.
- The annual net amounts of CO_2e emissions and costs for each of the above categories was calculated and discounted using a 5% real discount rate.
- Avoided emissions costs were not calculated due to uncertainty in the valuation method for proposed regulation.
- Cost of new transmission to deliver increased levels of renewable energy were not calculated in the CSEO model due to uncertainty in assigning such costs to renewables, which vary considerably from project to project.[4]

[4] While renewable energy can be a driver for new transmission investment, transmission improvements are long-term investments that are made for a variety of reasons with multiple benefits from reduced congestion, improved reliability, and economics. Allocation of a specific percentage of the cost of transmission investments to a general increment of renewable generation can be contentious without adequate documentation. Note: in the recent MRITS study, costs of a conceptual transmission plan for similar levels of renewables were identified (the modeling assumptions used in MRITS differ from those assumptions used in the CSEO modeling (e.g. total load, energy consumption, siting, and % wind and PV). MRITS modeled higher levels of variable renewables with 40 and 50% from wind and solar only. CSEO includes biomass and hydro in the 40 and 50% modeling.

- Indirect costs and emissions of ancillary services were not calculated due to uncertainty in assessing the portion on ancillary services attributable to renewable energy compared to the ancillary services needed to support conventional generation that that would be offset by additional renewable generation.[5]

Key Assumptions

- *Marginal resource ratios for energy and emissions:* A key assumption concerned the resources on the electric margin that would be displaced by incremental renewable generation. These assumptions are outlined in the following bullet.
    - Siler-Evans et al "Marginal Emissions Factors for the U.S. Electricity System," April 2012 and "Regional variations in the health, environmental, and climate benefits of wind and solar generation," July 2013 were two sources used to estimate marginal resources. The Siler-Evens et al analyses provide regional estimates of the share of generation resource on the margin based on hourly gross power output data over the 2006-2011 time period from the Continuous Emissions Monitoring System (CEMS).
    - With increasing coal retirements and natural gas plant installations, the coal fraction is expected to decrease as the marginal resource over the CSEO modeling period from 2014 – 2030. Marginal resource fractions in 2014 are based on estimates from Siler-Evans et al and then extrapolated linearly out to 2030 using an assumed marginal resource blend displaced by incremental renewable generation.
    - The marginal resource being displaced by wind energy was assumed to be 80%Coal/20%Gas in 2011 and trending linearly to 50%Coal/50%Gas in 2030. The 2011 ratio is supported by a marginal emissions factor of 830 kg CO2/MWh from Siler-Evans et al 2013 estimation[6]and comparison with the Marginal resource mix from Siler-Evans et al 2012 work[7].
    - The marginal resource being displaced by solar photovoltaic energy was assumed to be 60%Coal/40%Gas in 2011 trending linearly to 40%Coal/60%Gas in 2030. The 2011 ratio is supported by a marginal emissions factor of 780 kg

[5] If ancillary service cost is calculated for renewables, then it will also need to be calculated for other technologies displaced by renewable energy. Furthermore, large coal plants are a driver of contingency reserves on the bulk electric grid, but MISO has confirmed that dispersed generation such as wind does not require contingency reserves.

[6] Siler-Evans et al, Regional variations in the health, environmental, and climate benefits of wind and solar generation, July 2013. The data for this work is on the Carnegie Mellon website: http://cedmcenter.org/tools-for-cedm/marginal-emissions-factors-repository/)

[7] Siler-Evans et al, Marginal Emissions Factors for the U.S. Electricity System, April 2012. The data for this work is on the Carnegie Mellon website: http://cedmcenter.org/tools-for-cedm/marginal-emissions-factors-repository/)

CO_2/MWh from Siler-Evans et al 2013 estimation and comparison with the Marginal resource mix during daylight hours from Siler-Evans et al 2012 work.

- The marginal resource being displaced by biomass CHP energy was assumed to be 80%Coal/20%Gas in 2011 and trending linearly to 50%Coal/50%Gas in 2030. The 2011 ratio is supported by the average (across all hours) over the 2006 – 2011 period of the marginal emissions fractions for the MRO region provided by Siler-Evans et. al. (2012).

- *Capacity factor for natural gas combined cycle units:* The CSEO modeling assumes a capacity factor of 40% for new and existing natural gas combined cycle (NGCC) units for the modeling period (2015-2030). The 40% assumption is based on the upper range of capacity factors observed in state Strategist modeling and is considerably lower than the EPA's expectations set in the final version of the Clean Power Plan. Under EPA's performance rate-setting methodology, building block 2 gradually shifts, over the entire interim period, fossil steam generation from coal-fired to the existing NGCC units until their proposed maximum capacity factor reaches 75% in all the regions. The reason for these differences lies in the fact that Midwestern states, with significant coal and renewable generation, use their NGCC units primarily to balance load during peak daytime hours, especially in the summer. Wind turbines have no fuel cost and no emissions so they are more economical to operate compared natural gas or coal. As a result, NGCC units in the Midwest are dispatched to a much lesser degree than in states with high penetration of natural gas generation. Minnesota ranks seventh in the nation for both wind energy capacity installed and wind electricity generation, and over 15% of its net electricity generation in 2013 was supplied by wind turbines. Therefore, Minnesota authorities are expecting to meet federal requirements relying more on renewable energy than on generation shift among existing affected energy generation units. Flexibility to do so is corroborated by EPA's note that the proposed 75% capacity factor for NGCC is subject to regional limits informed by historical growth rates.
- *Avoided cost of energy:* The avoided cost of energy from coal, natural gas combustion turbine (NGCT), NGCC, and oil-fired units accounted for real escalation in fuel prices as well as fixed and variable O&M costs. For avoided energy costs and emissions, the CSEO analysis assumes a capacity *value* of 45% for wind and 20% for solar.[8]
- *Avoided cost of capacity:* This analysis used the low-end range of levelized cost of energy (LCOE) numbers published in Lazard's Levelized Cost of Energy Analysis – Version 8.0.[9] Lazard's analysis breaks down the LCOE numbers by region for resource dependent variable generation like wind and solar instead of just giving a wide national range and the low end of the range is closer to the prices observed in the Midwest. In calculating the avoided cost, efficiency measures, new wind, and solar will displace/delay the need

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[8] Capacity factor is a simple measure of the total annual energy production relative to nameplate. =(Annual energy production in MWh/yr) / (nameplate capacity in MW) / (8760 hours/yr)

[9] https://www.lazard.com/media/1777/levelized_cost_of_energy_-_version_80.pdf

for new natural gas CC & CT units. For the avoided cost of new capacity, the analysis uses a capacity *credit* of 14% for wind and 45% for solar[10]. *Note: levelized costs in Lazard v. 8.0 did not assume extension of the PTC or ITC.*

- *Generation siting in-state vs out-of-state:* Under the statute governing Minnesota's RES, renewable generation at eligible renewable capacity located in any of the MRETs states may be used to generate RECs for compliance purposes. For the modeling here to simulate the RES, for both the business as usual case and the increased RES scenarios, we are including generation that counts toward the Minnesota RES even if it is sited out-of-state. [Note: Under the MPCA's reporting framework for Next Generation Energy Act goals, renewable energy generation that occurs outside of Minnesota, whether earning Minnesota RECs or not, does not figure in emissions (or emissions-avoided) calculations.]
- *Policy option model interactions:* Increased efficiency on the demand-side will amplify the effect of existing renewable generation resources but it will also reduce the need for new capacity from renewable or fossil resources. Additional CHP capacity may have the effect of reducing electric demand if it is in must-run mode. Although it is a supply-side resource, its effect on the operation and dispatch of other resources in the region may be similar to demand-side efficiency.
- *Out-of-state renewable generation:* The assumed BAU out-of-state renewable generation shares of retail sales was 8.8% in 2020, 5.6% in 2025, and 5.2% in 2030.

Macroeconomic (Indirect) Policy Impacts

Table F-1.6 below provides a summary of the expected impacts on jobs and economic growth during the CSEO planning period.

[10] Capacity value (a.k.a capacity credit or Effective Load Carrying Capability (ELCC)) is a statistical measure of the ability of a generation resource to maintain a reliable system and meet demand. Essentially this is the amount of capacity output, relative to nameplate, that is coincident with peak system load.

Table F-1.6 ES-1 Macroeconomic Summary Impacts on GSP, Employment and Income

Scenario	Gross State Product (GSP, $2015 Millions)			Employment (Full & Part-Time Jobs)			Income Earned ($2015 Millions)		
	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)
ES-1 40% Renewables Target (Default)	$390	$180	$2,650	2,900	1,510	22,580	$310	$140	$2,080
ES-1 50% Renewables Target	$540	$230	$3,420	3,690	1,820	27,290	$430	$180	$2,700

The following three graphs illustrate a trend in annual impacts of ES-1 policy (both default and 50% sensitivity scenario, which is presented by dashed line) on GSP, total personal income and employment in the state of Minnesota. Annual fluctuations can be seen. It is evident from those illustrations that ES-1 50% sensitivity scenario has a superior performance against all three macroeconomic parameters then the default, ES-1 40% policy.

Figure F-1.20 ES-1 GSP Impacts ($2015 MM)

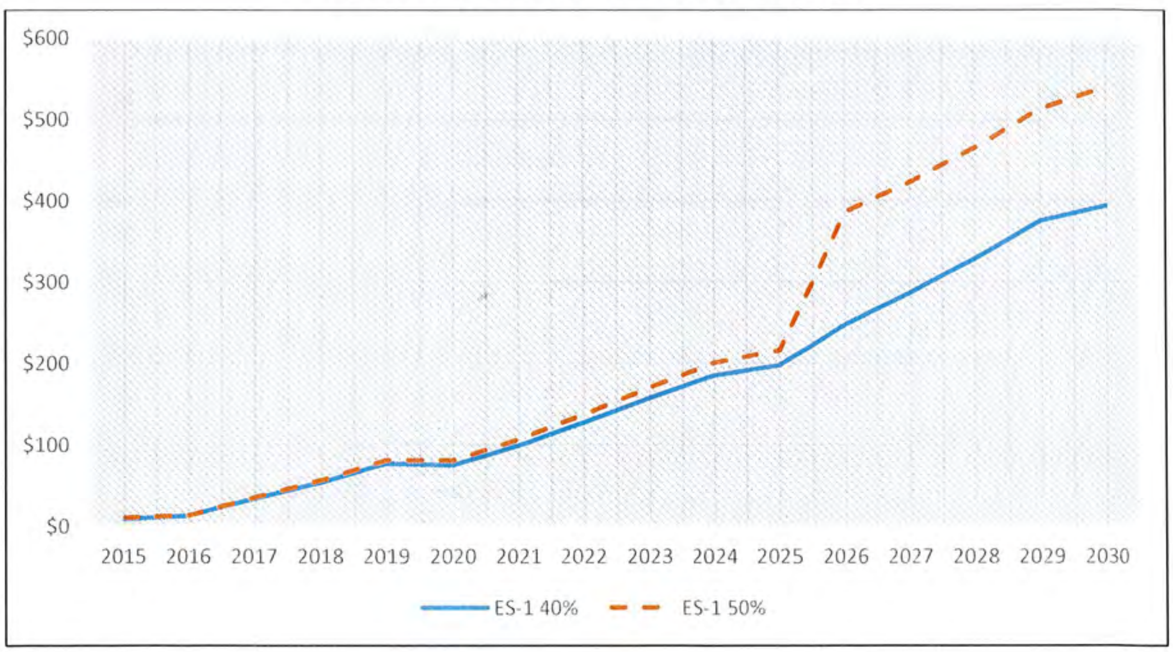


Figure F-1. 21 ES-1 Employment Impacts (Individual Jobs)

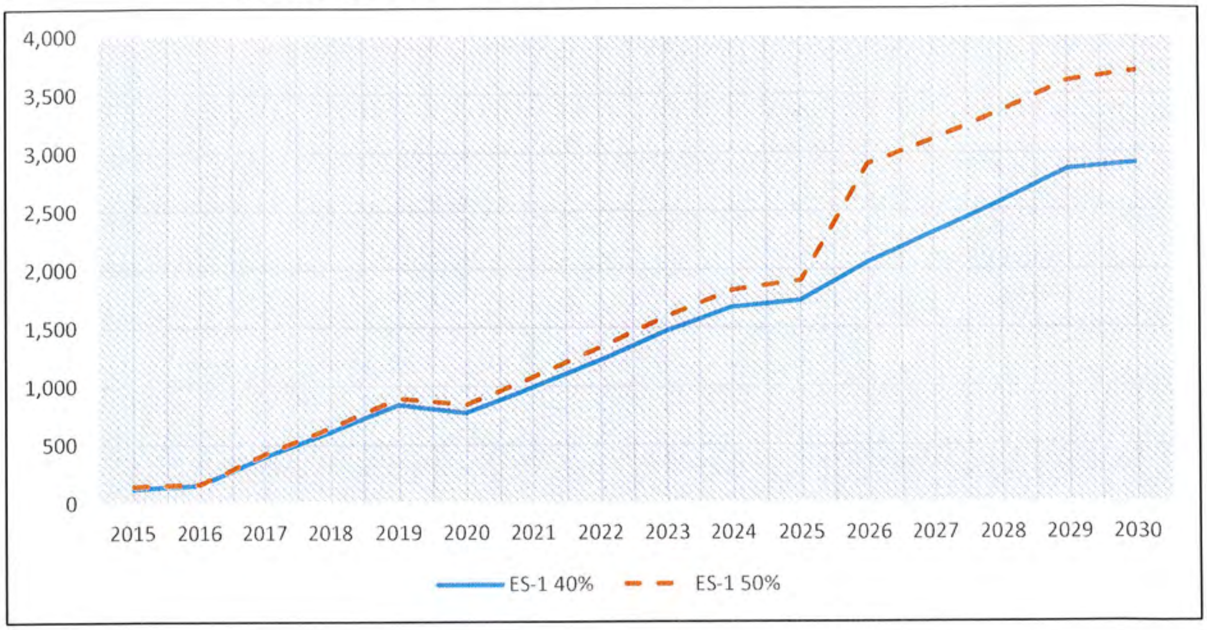
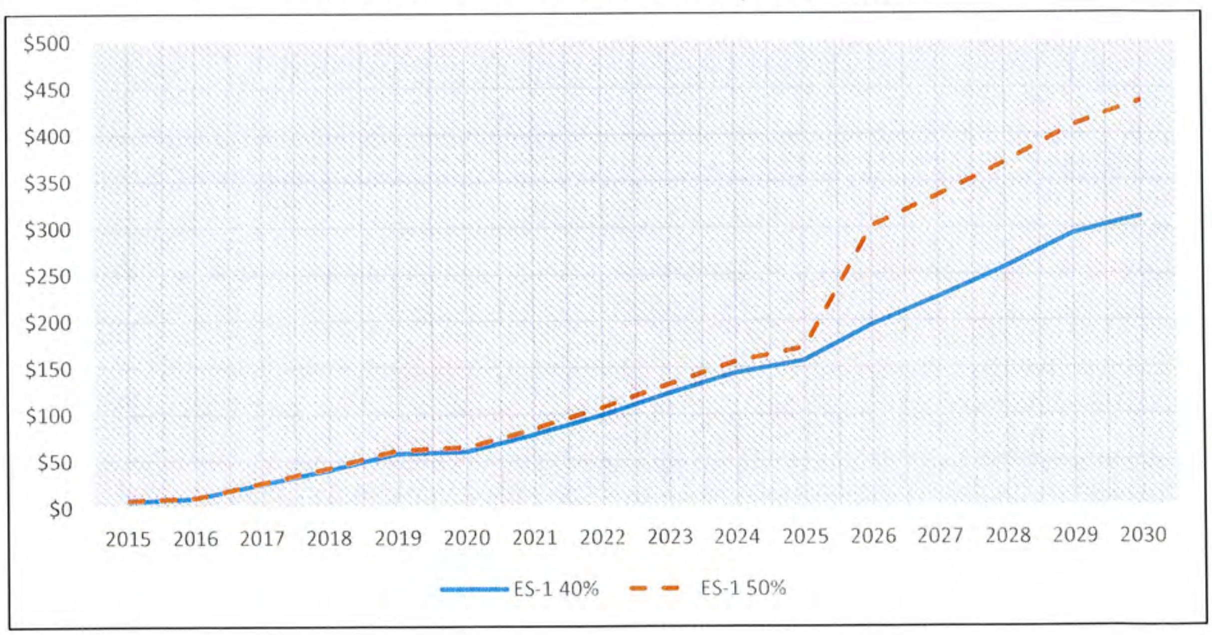
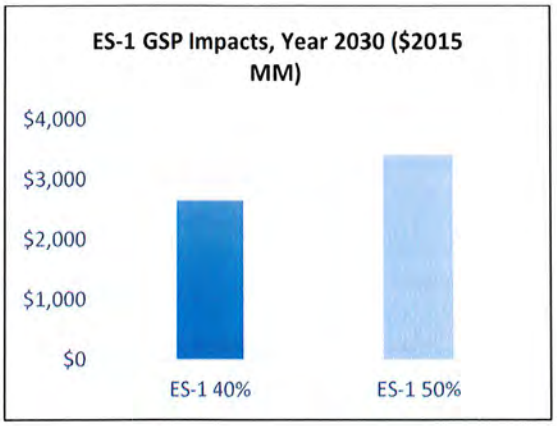
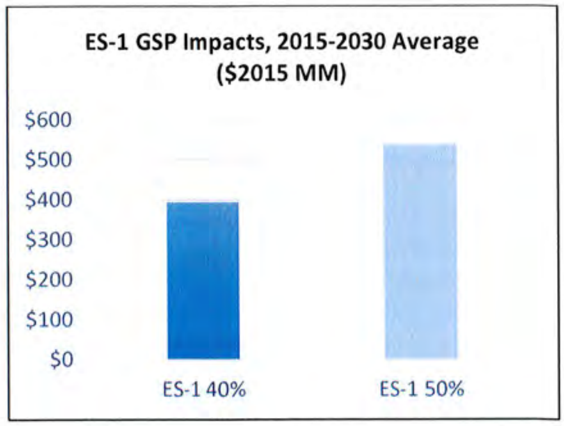


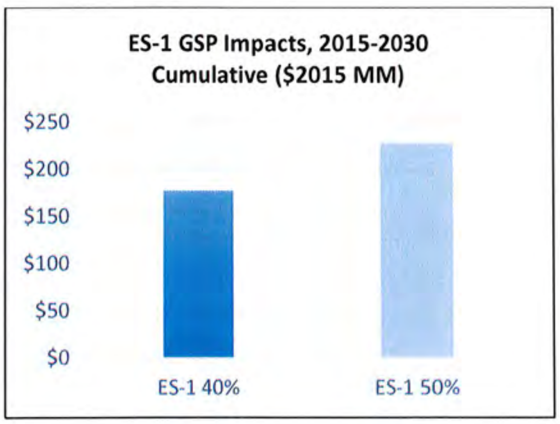
Figure F-22. 21 ES-1 Income Impacts ($2015 MM)

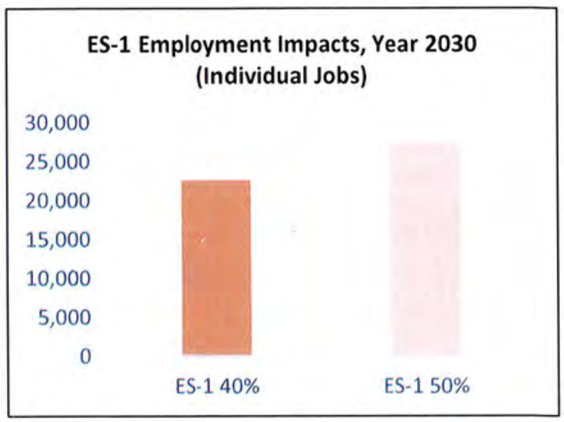


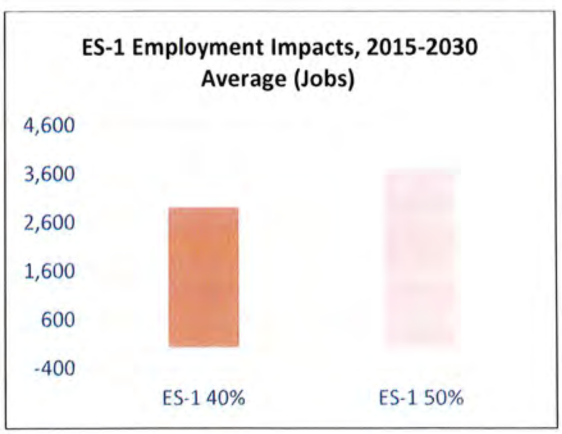
The following nine bar charts show the average, final year and cumulative impacts of ES-1 policy against the same macroeconomic indicators (annual fluctuations cannot be seen here).

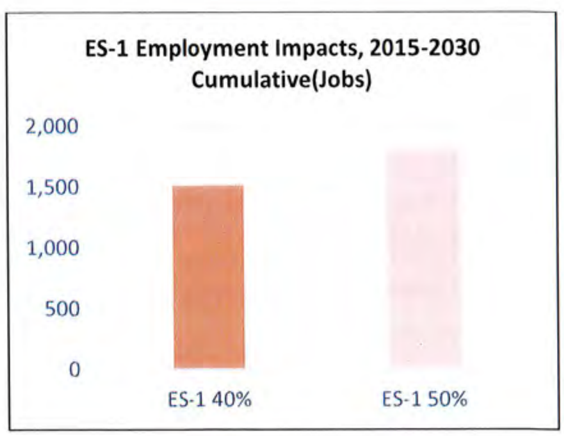

ES-1 GSP Impacts, Year 2030 ($2015 MM)
$4,000
$3,000
$2,000
$1,000
$0
ES-1 40%
ES-1 50%

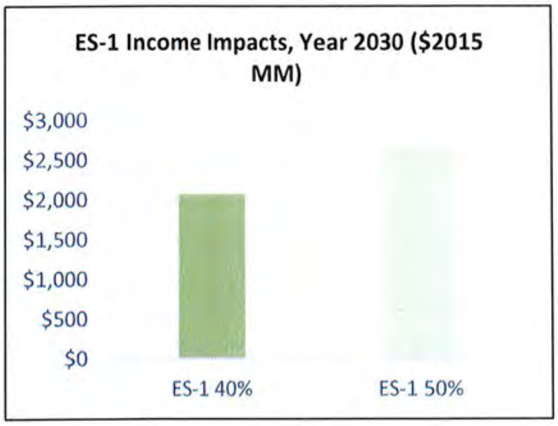

ES-1 GSP Impacts, 2015-2030 Average ($2015 MM)
$600
$500
$400
$300
$200
$100
$0
ES-1 40%
ES-1 50%

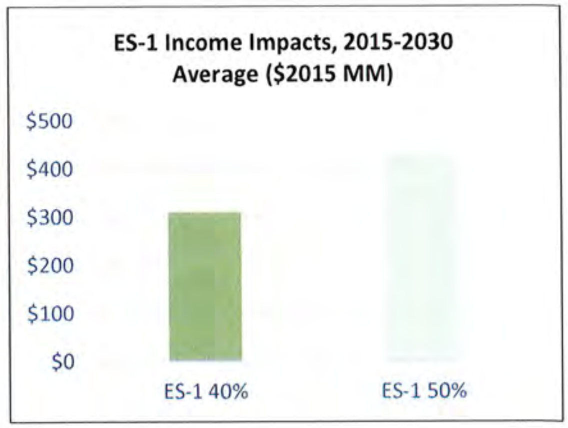

ES-1 GSP Impacts, 2015-2030 Cumulative ($2015 MM)
$250
$200
$150
$100
$50
$0
ES-1 40%
ES-1 50%

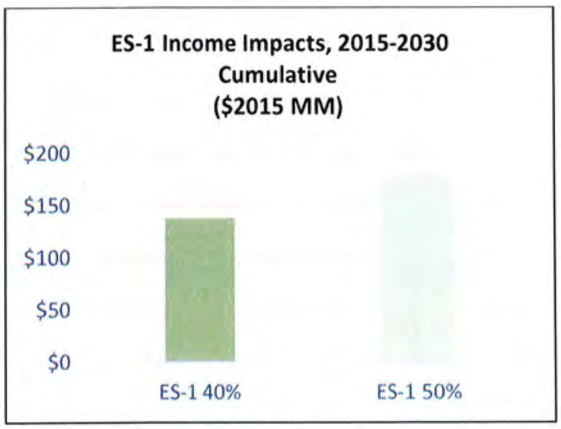

ES-1 Employment Impacts, Year 2030 (Individual Jobs)
30,000
25,000
20,000
15,000
10,000
5,000
0
ES-1 40%
ES-1 50%


ES-1 Employment Impacts, 2015-2030 Average (Jobs)
4,600
3,600
2,600
1,600
600
-400
ES-1 40%
ES-1 50%


ES-1 Employment Impacts, 2015-2030 Cumulative(Jobs)
2,000
1,500
1,000
500
0
ES-1 40%
ES-1 50%

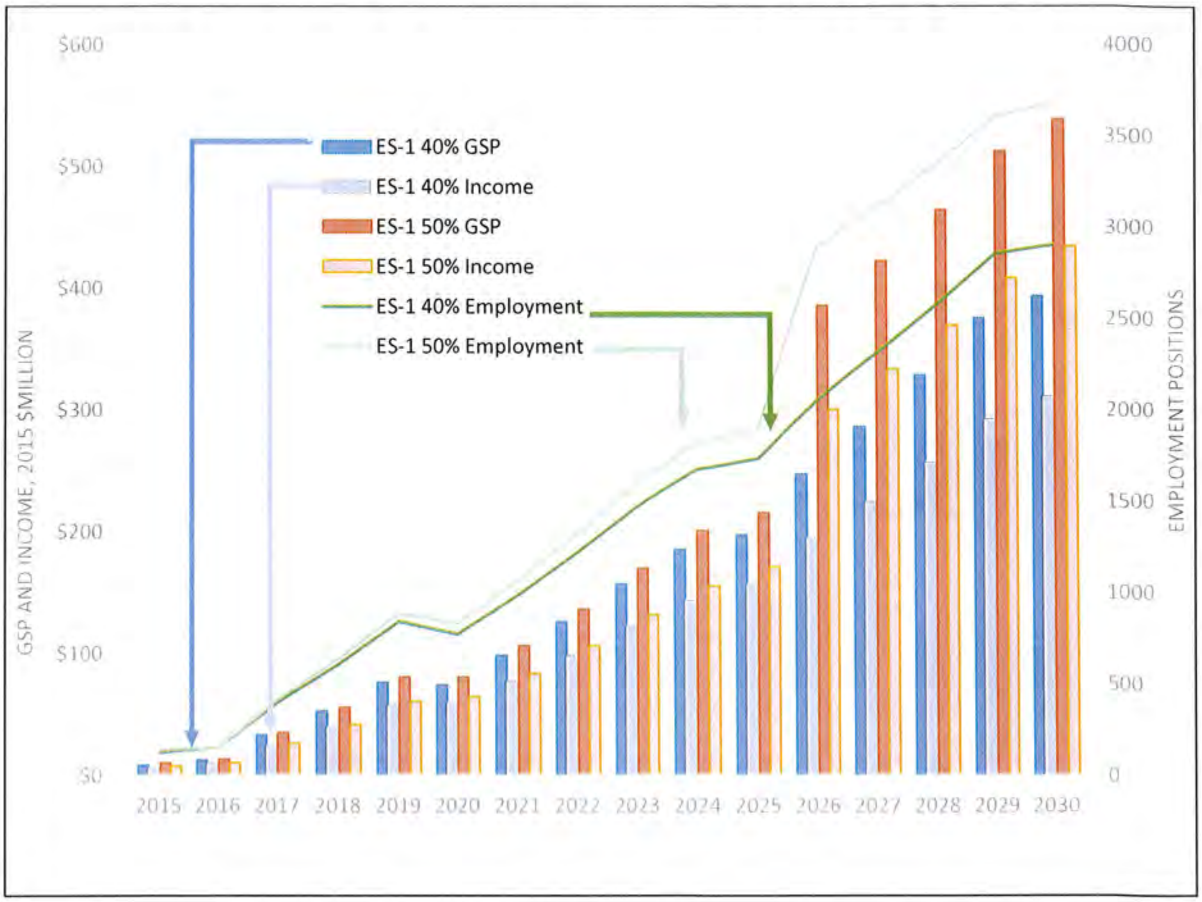






Graph below shows the magnitude of expected differences in impacts between the ES-1 default and sensitivity scenario.

Figure F-1.23 ES Policies Macroeconomic Impacts of Raising ES-1 Target to 50%



Principal Drivers of Macro-Economic Changes

The principal drivers of macroeconomic changes (in income, jobs and GDP) are investments into new renewable technology generation capacity that Minnesota's electricity utilities are projected to make (to meet the electric sales requirements under the expanded RES), and monetary savings the utilities are achieving. These investments are increases in production costs for the utilities.

The savings consist of avoided fuel (primarily coal and natural gas) and capital cost spending on conventional generation that would be required to meet forecasted electric demand under business and usual scenario (without RES in place).

The investments into new renewable generation expand the following sectors: construction, truck transportation, machinery and electric equipment manufacturing etc.

Starting in 2020, the savings utilities are achieving are consistently higher than production costs in that sector. By 2030, that difference is nearly $100 million statewide. This continuous net savings lowers production costs, leading to a mix of expansion of the industry (likely very little) and lower prices (likely almost all of the effect). This savings trend, through the consequences it creates, is a primary driver of a general upward trend in GDP in the entire state, induced by the implementation of the policy. It also suggests that the electricity sector is essentially saving money with the realization of this policy.

Sectors of Economy Most Affected by the Policy

- Economic impacts from policies run around the economy, affecting sectors that are sometimes far from the direct target of a policy. For ES-1, which targets the utility sector first and foremost, it is in fact a range of other, related sectors that most benefit from the economic gains found within. The utility sector itself, while the initial target of this policy, sees almost no change in the total scale of its operations or labor required, as the demand for electricity itself is not changed by this policy.
- However, sectors related to the conversion of so much power from one set of sources to others see significant growth. Chief among these is the construction sector, which immediately begins to gain jobs as the policy begins and ends up supporting over 1,300 new employees in the 50% scenario. Back-office positions and retail positions throughout the economy each end up expanding by up to 400 positions in 2030, and other service-sector positions in technical and professional fields, health care, food service, administration and transportation all add at least 100 new positions. The cause of these jobs all around the economy is most likely the relatively low cost of expanding renewables – per unit of energy, the expansion is cheaper than the baseline scenario of expanding conventional energy. These savings translate to a mix of price drops and utility expansions, which drive consumer gains throughout the state in ways unrelated to energy production.

Data Sources

The principal data sources for the macroeconomic impacts analysis of this and all other policies in the CSEO process are the direct spending, saving, cost and price impacts developed as part of the microeconomic (direct impacts) analysis. For each policy, the cost-effectiveness analysis described above develops year-by-year estimates of the costs, savings prices, and changes demand or supply that households, businesses and government agencies are expected to encounter in a scenario where the policy is implemented as designed.

A secondary data source is developed by balancing financial flows for each direct impact identified. This balancing identifies and quantifies the responsive change that occurs by another party as a result of the direct impact in question. For example, if a household is anticipated to save $100 per year on electricity bills on a policy, that is a $100 savings to the household (which expands its spending capacity for other things) but a $100 loss in revenue and demand to the utility provider (which reduces its ability and need to spend on labor, capital, profit, and other inputs). The quantitative measure of both sides of a change is of importance to a complete macroeconomic analysis. This balancing ensures that both the supply and the demand side of each economic change is fully represented in the analysis.

A third data source is direct communication with Minnesota agency staff and others involved in policy design or in a position to understand in detail the financial flows involved in the policy. These people assisted in clarifying the nature of economic changes involved so that the modeling and analysis would be accurate.

The final crucial data source is the baseline and forecast of economic activity within the REMI software. This data is compiled into a scenario that is characterized not only by the total size of the economy and its many consuming and producing sectors, but also the mechanisms by which impacts in one sector can change the broader economy – such as intermediate demands, regional purchase coefficients, and equilibria around price and quantity, labor and capital, and savings and spending, to name a few of many. REMI, Inc. maintains a full discussion of all the sources of the baseline data on its own website, www.remi.com.

In the case of the ES-1 policy, important data included:

- Capital, operating, maintenance, and fuel costs for a range of electricity generation technologies, including existing coal, existing and potential natural gas (NGCT and NGCC), wind, solar, hydroelectric, and biomass-fired combined heat and power.
- The exact amounts of increased or reduced spending on each of those items, in each year of the period of analysis.
- The geographic location of each activity, to differentiate and accurately model wholly domestic transactions from imports and exports.
- The identities of the parties on each side of every transaction. Government spending affects the economy differently from spending by households, and differently again from spending by entities in the productive sectors of the economy.

Quantification Methods

Utilizing the data developed from the microeconomic analysis, CCS analysts established for each individual change the following characteristics:

- The category of change involved (change in spending, savings, costs, prices, supply or demand)
- The party involved on both sides of each transaction
- The volume of money involved in this change in each year of the period of analysis

These values, so characterized, were then processed into inputs to the REMI PI+ software model variant built specifically for use by CCS and consistent with that in use by state agencies within Minnesota. These inputs were applied to the model and run. Key results were then drawn from the model and processed for consistency of units and presentation before inclusion in this report.

Key Assumptions

The macroeconomic impact analyses of this policy, as well as of the others in the CSEO process, rely on a consistent set of key assumptions:

- State and local spending is always budget-constrained. If a policy calls for the state or local government to spend money in any fashion, that spending must be either funded by a new revenue stream or offset by reductions in spending on other programs. Savings or revenues collected by the government are also expected to be returned to the economy as spending in the same year as they are collected.
- Federal spending is not budget-constrained. The capacity of the federal government to carry out deficit spending means that no CSEO policy is held responsible for driving either an increase or decrease in federal tax spending by businesses or households in the state of Minnesota.
- Consumer spending increases are sometimes financed. Small-scale purchases or purchases of consumer goods are treated as direct spending from existing household cash flows (or short-term credit). Durable goods, home improvements or vehicle purchases, however, are treated as financed. Consumers were assumed to spread out costs based on common borrowing time frames, such as five years for financing a new vehicle or 10-20 years for home improvements that might be funded by home-equity or other lending. The assumption of financing and the term of years applied was considered anew in each case.
- Business spending increases are often financed. Where spending strikes a sector which routinely utilizes financing or lines of credit to ensure steady payment of recurring costs, significant spending of nearly any type was considered a candidate for financing, thus allowing costs to spread out over time. This methodology is preferable for the modeling work, as sudden spikes or dips in business operating costs can show up as volatility when the scenario may depict a managed adoption of new equipment in an orderly fashion. The assumption of financing and the term of years applied was considered anew in each case.
- Unless otherwise stated, all changes to consumer spending or to the producers' cost of producing goods and services were treated in a standard fashion. Consumers are assumed to spend on a pre-set mix of goods, services, and basic needs, and businesses spend (based on their particular sector of the economy) on a mix of labor, capital, and intermediate demands from other sectors. Unless a policy specifically defines how a party will react to changes in cost, price, supply or demand, these standard assumptions were applied.
- State and local spending gains and reductions driven by policy are assumed to apply to standard mixes of spending. Again, unless a policy specifically states that a government entity will draw from a specific source or direct savings or revenues to a specific form of

spending, all gains and losses were assumed to apply to a standard profile of government spending within the economy.

Key Uncertainties

PTC/ITC extension: Uncertainty in Federal renewable policy option, such as extension of the Production Tax Credit (PTC) for wind energy and Investment Tax Credit (ITC) for solar electricity, may impact the cost to implement a higher RES. The fact that many utilities have reached RES compliance early may have been influenced by the expected expiration of the PTC & ITC; but if the PTC or ITC is not extended, it's not certain whether this trend will continue.

A December 2015 omnibus spending bill passed with extensions of both the PTC and ITC for five years. This development comes after the completion of the analysis in this report. While this legislation is likely to dramatically improve the cost-effectiveness and macroeconomic impacts while its provisions are in place, its limited duration means that the uncertainty here described remains relevant to the 2022-2030 period.

Increased energy efficiency will amplify the effect of existing renewable energy resources on percent goals.

Additional Benefits and Costs

- Job creation (construction, maintenance, project design, manufacturing, forest product harvesting, etc.).
- Reduced GHG emissions from fossil fuels.
- Increased county property tax income from wind and solar energy production taxes.

Potential Health Impacts

Decreasing reliance on fossil fuels and increasing the use of renewable energy sources is likely to reduce health risks for the public and energy workers. Shifting to renewable energy sources from coal will decrease emissions of a variety of pollutants, including particulate matter ($PM_{2.5}$), carbon dioxide, sulfur dioxide, nitrogen oxides, and mercury compounds. (EPA; Kappos) These pollutants have been shown to have a variety of negative cardiac and pulmonary health effects. $PM_{2.5}$ can have especially serious effects, including significant increases in cardiovascular and cardiopulmonary disease and cancer mortality, exacerbation of respiratory illness, and long-term effects on respiratory function, particularly in children and older adults. (Pope 2002, Pope 2000, Bernard) Reducing these emissions may have a notable impact on morbidity and mortality associated with electricity generation, as health and environmental damages from electricity generation in Minnesota total an estimated $2.1 billion, with coal combustion-related emissions accounting for 94% of these damages. (Goodkind and Polasky)

This shift is also likely to decrease occupational injuries and deaths associated with energy extraction, generation, and distribution. Mining is the second most dangerous industry in the

United States, with 15.6 fatal occupational injuries per 100,000 workers having occurred in 2012, and conventional energy generation and distribution also present significant occupational risks. (Bureau of Labor Statistics, Sumner) By contrast, occupational risks appear lower in both the wind and solar industries. (Fthenakis, Sumner)

Figure F-1.24 Potential Health Benefits ES-1

Reducing energy-related emissions is likely to reduce the risk for respiratory and cardiovascular illness, and cancer in exposed populations.

Feasibility Issues

Reliability study - The results from the study show that the addition of wind and solar generation to supply 40% of Minnesota's annual electric retail sales can be reliably accommodated by the electric power system. The analyses show that with upgrades to existing transmission, the power system can be successfully operated for all hours of the year with wind and solar to achieve 40% renewable energy. Additional analysis would need to be done for adding renewables at levels significantly higher than 40%. (More details above in the section on Related Policies and Recent Actions)

EPA 111(d) – An increased RES could be an effective component in Minnesota's plan to meet EPA targets for reducing carbon pollution from existing power plants.

Large Hydro - Certain interests (e.g. Utilities, MH) will push to allow large hydro in an increased RES.

Cost - Large Industrial/commercial & low income customers may resist higher RES based on the assumption of higher cost. A Lawrence Berkeley National Lab Report Lawrence Berkeley National Lab Report suggests that the RES in Minnesota is saving ratepayers' money in some cases or that there is a modest cost increase associated with it in other cases:

Minnesota's Renewable Portfolio Standard (RPS)[11] requires Xcel Energy (Northern States Power) to obtain 31.5% by 2020, including 1.5% solar. Other utilities have separate requirements. Public utilities are required to obtain 26.5% renewable energy by 2025, including 1.5% solar. Non-public utilities are required to obtain 25% renewable energy by 2025 but do not have a solar requirement (DSIRE 2013). In 2012, Northern States Power met the RPS requirement of 13% with 5,637,456 MWh of RECs. Northern States Power has generated surplus RECs each year since 2008. The REC bank provides them the flexibility to defer the

[11] http://emp.lbl.gov/sites/all/files/lbnl-6589e.pdf

installation of new renewables and use banked RECs to comply with RPS obligations (Xcel Energy 2011).

Of the fourteen utilities that submitted compliance reports, eight stated that complying with the RPS has resulted in little or no additional costs, if not slight savings for customers. Northern States Power reported that its renewable investments have been cost-effective and actually kept prices in 2008-2009 about 0.7% lower than they would have been without renewables. Northern States Power calculated the rate impact by determining the difference between the costs of implementing and not implementing the RPS, and then by determining the cost difference on a ¢/kWh basis by dividing the costs by total retail sales (Xcel Energy 2011).

Six utilities, including Great River Energy (GRE), reported that their efforts to comply with the policy option are leading to increased costs for customers. GRE found that its wind energy purchases increased retail customer bills by about 1.6%, or about $1.50/month for an average residential customer (Haugen 2011).

ES-2. Efficiency Improvements, Repowering, Retirement, and Upgrades to Existing Plants

Policy Option Description

Of the 24 utility-owned coal-fired boilers operating in Minnesota, most have been retrofitted to meet Clean Air Act requirements (1758 MW's), repowered with natural gas (776 MW's), or are retired or scheduled to retire by 2020 (734 MW's). While it is not inconceivable that plants retrofitted within the last 10 years would be soon repowered or retired, it is unlikely given the size of these recent investments and resulting impacts to ratepayers.

Decisions remain pending on the future of Minnesota's three largest coal-fired boilers at Xcel Energy's Sherburne County (Sherco) generating plant. Due to their size, they are also the largest emitters of CO_2 in the state. The newest and largest of these boilers, Sherco 3, has been retrofitted with advanced mercury controls and is the most efficient boiler in the Minnesota fleet. However, Units 1 and 2 are susceptible to both mercury and Regional Haze requirements, and may therefore be useful to analyze for some combination of repowering or retirement strategies.

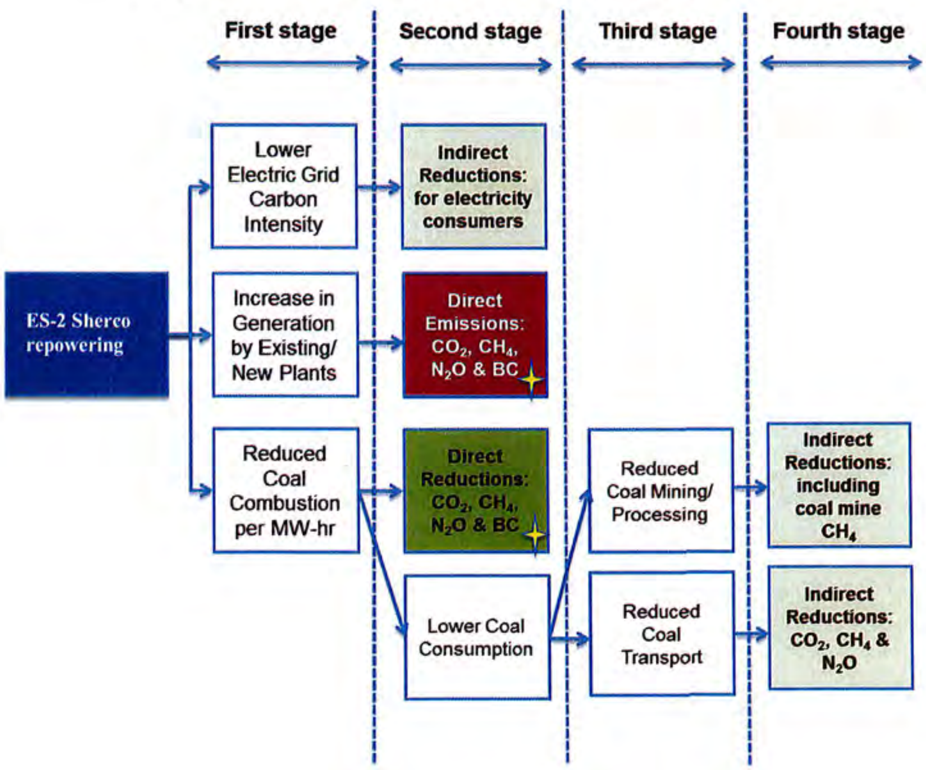
The purpose of this exercise is to analyze one scenario for the Sherco Units 1 and 2 as follows: Repower Sherburne County unit 1 by 2025; retire Unit 2; replace with NGCC by 2023.

Causal Chain for GHG Reductions

The diagram below illustrates how the policy option leads to GHG reductions.

- "First Stage" refers to the direct physical impacts of the policy option, namely a lower CO2e intensity of the electric system, increased generation from lower CO2e-emitting resources, and lower coal use for every MWh of electricity produced;
- "Second Stage" refers to indirect physical impacts of the policy option, namely GHG reductions allocated to consumers, GHG increases associated with natural gas-fired generation, and lower absolute levels of GHGs and coal use;
- "Third Stage" refers to reductions in direct upstream GHGs from coal mining and coal use; and
- "Fourth Stage" refers to indirect upstream GHGs and coal use.

Figure F-1.25 Causal Chain for ES-2 GHG Reductions



Policy Option Design

Goals: Each scenario described above will have its own CO_2 reduction goal, as follows:

- Scenario 1: Repower Sherburne County unit 1 by 2025; retire unit 2 and replace it with NGCC by 2023
- Scenario 2: Retire both units and replace them with NGCCs by 2020
- Scenario 3: Repower unit 1 by 2020 and retire unit 2 and replace it with NGCC by 2020
- Scenario 1 was chosen for the purposes of analyzing integrative effects with other sectoral policies.

Timing: This analysis assumes that repowering or retirements are completed in 2023 and 2025.

Parties Involved:

- State regulators: Public Utilities Commission, Minnesota Department of Commerce, Pollution Control Agency, State Legislature.
- Plant owner: Xcel Energy.

Implementation Mechanisms

To be implemented, this policy option will require action by state regulators (PUC, Commerce, and PCA) to review and approve the planned actions at Sherco 1 and 2, based on plans submitted by the plants' owner, Xcel Energy. Initially, decisions would need to be made in the context of an Integrated Resource Plan submitted by Xcel, and pending approval by the Public Utilities Commission. Xcel is under an order from the Commission to review these issues in its 2015 plan. It is possible that legislation would be needed to authorize the plan or approve special cost recovery authority.

Related Policies/Programs in Place and Recent Actions

- Clean Air Act requirements: Sherco Units 1 and 2 susceptible to mercury and Regional Haze requirements.
- Current Minnesota law allows investor-owned electric utilities to propose emission reduction projects and receive expedited cost recovery on approval from the Public Utilities Commission.

Estimated Policy Impacts

Direct Policy Impacts

Table F-1.7 ES-2 Estimated Net GHG Reductions and Net Costs or Savings

	2030 In-State GHG Reductions (MMt CO_2e)	2015 – 2030 Cumulative In-State Reductions (MMt CO_2e)	Net present Value of Societal Costs, 2015 – 2030 ($2014)	Cost effectiveness ($2014/ MMt CO_2e)
Repower Unit 1 & Retire Unit 2	6.3	44	$752	$19

Data Sources

- Common Forecast assumptions spreadsheet developed for the Minnesota CSEO project by Steve Roe.
- Electric system assumptions: final version of the power sector forecast prepared by the Pollution Control Agency.
- U.S. Department of Energy, The Energy Information Administration (EIA); EIA-923 Monthly Generation and Fuel Consumption Time Series File, 2012 Final Release; Sources: EIA-923 and EIA-860 Reports
- Operating cost data by plant provided by the Pollution Control Agency to Bill Dougherty on 3 October 2014
- Xcel report entitled: "Life Cycle Management Study for Sherburne County (Sherco) Generating Station Units 1 and 2", Minnesota Public Utilities Commission Docket Number E002/RP-13-368, July 1, 2013
- ES-2 data request.

Quantification Methods

Using the assumptions below, a spreadsheet analysis was undertaken using the methods summarized in the bullets below:

- The cost and performance characteristics of Sherco Units 1 and 2 was obtained and projected based on the assumption in the Xcel report cited above.
- The costs and performance characteristics of the repowered NGCC were assumed based on a combination of Xcel and Energy Information Administration (EIA) sources.
- The annual difference in costs and CO_2e emissions was calculated.

- The present value of the incremental cost using a 5% real discount rate was determined and divided by the undiscounted cumulative CO_2e reductions to obtain an estimate of the cost effectiveness of the policy option.

Key Assumptions

- The analysis assumed the costs and performance of Sherburne County units 1 & 2 based on the Xcel report entitled: "Life Cycle Management Study for Sherburne County (Sherco) Generating Station Units 1 and 2", Minnesota Public Utilities Commission Docket Number E002/RP-13-368, July 1, 2013. These assumptions are summarized in the bullets below:
  - Year of unit replacement: 2025 for Sherco 1; 2023 for Sherco 2
  - Maximum capacity: 681 MW for Sherco 1; 682 MW for Sherco 2
  - Average Heat Rate (approximately 75% load HR): 10,507 Btu/kWh for Sherco 1; 10,513 Btu/kWh for Sherco 2
  - Average annual capacity factor: 70% for Sherco 1; 70% for Sherco 2
  - Variable O&M cost in 2012 (including activated Hg control): $0.33/MWh escalating at 1.8%/yr for Sherco 1; $0.34/MWh escalating at 1.8%/yr for Sherco 2
  - Fixed O&M cost in 2012: $21,214,000 escalating at 2.18%/yr for Sherco 1; $21,214,000 escalating at 2.18%/yr for Sherco 2
  - Annual ongoing capital improvement cost in 2012: $17,572,000 escalating at 2.24%/yr for Sherco 1; $13,244,000 escalating at 2.24%/yr for Sherco 2.
- The analysis assumed the costs and performance of an NGCC providing annual generation equivalent to the same annual generation projected for Sherco 1 and 2. These assumptions differed from Xcel assumptions in the aforementioned report and are summarized in the bullets below:
- Average annual capacity factor: 40%
- Levelized electric generation costs: $70.26/MWh
- CO_2e intensity: 0.414 tons/MWh
- Average Heat Rate (approximately 75% load HR): 7,050 Btu/kWh

Macroeconomic (Indirect) Economic Impacts of RCII Policies

Table F-1.8 below provides a summary of the expected impacts on jobs and economic growth during the CSEO planning period.

Table F-1.8 ES-2 Macroeconomic Summary Impacts on GSP, Employment and Income

Scenario	Gross State Product (GSP, $2015 Millions)			Employment (Full & Part-Time Jobs)			Income Earned ($2015 Millions)		
	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)
ES-2	-$73	-$39	-$309	170	310	2,470	-$16	-$3	-$22

Figure F-1.26 ES-2 GSP Impacts ($2015 MM)

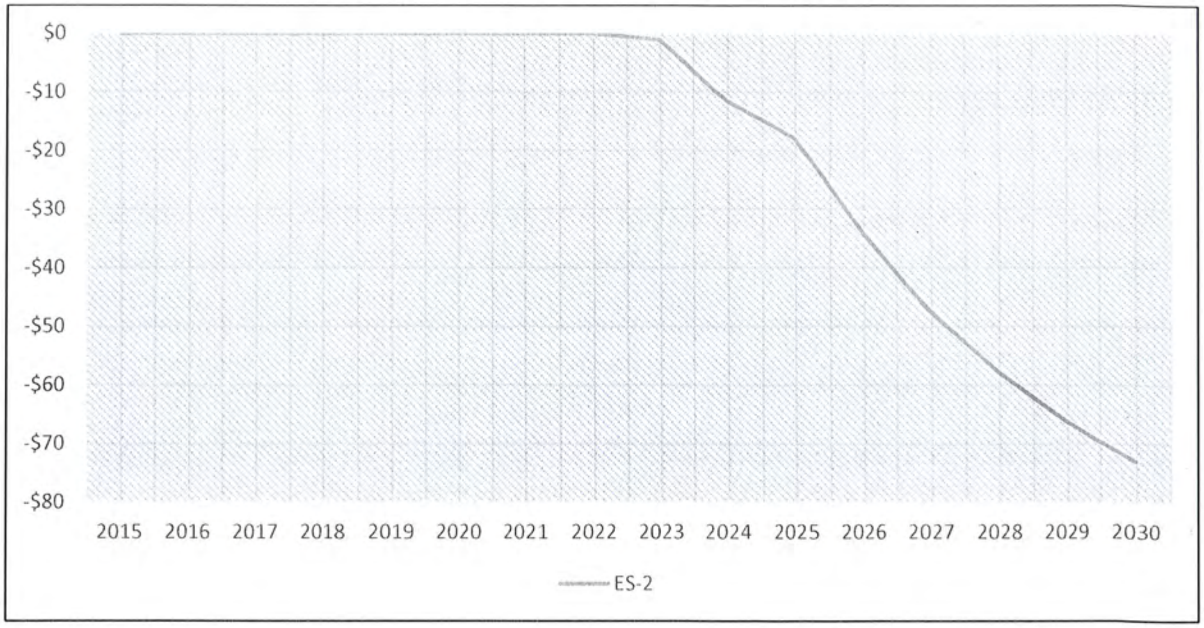


Figure F-1. 27 ES-2 Employment Impacts (Individual Jobs)

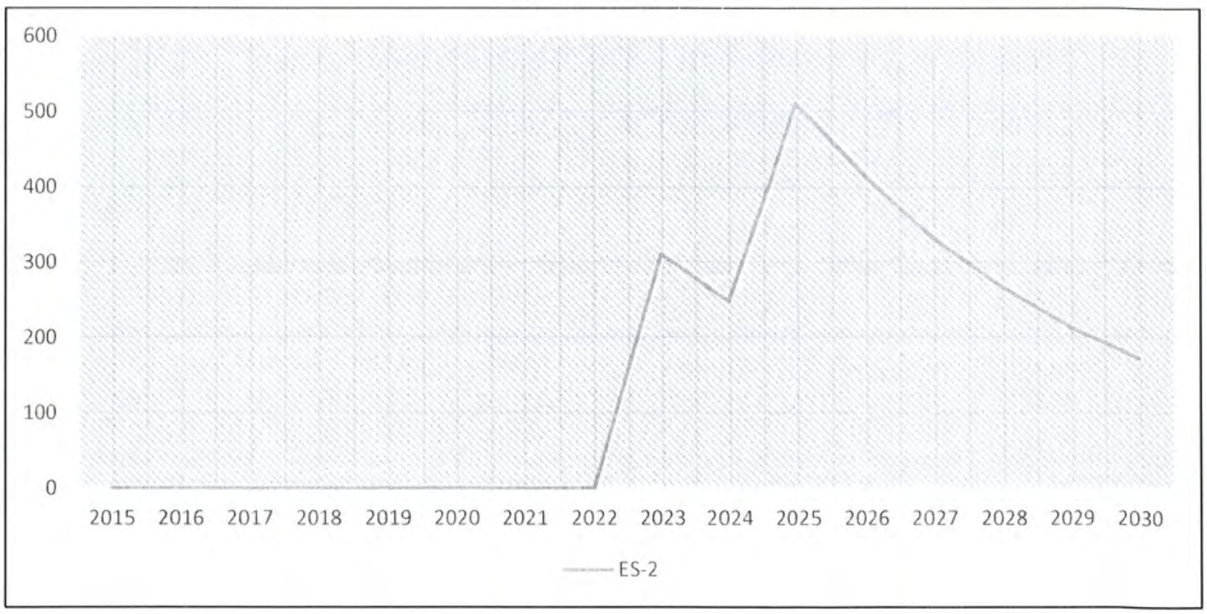
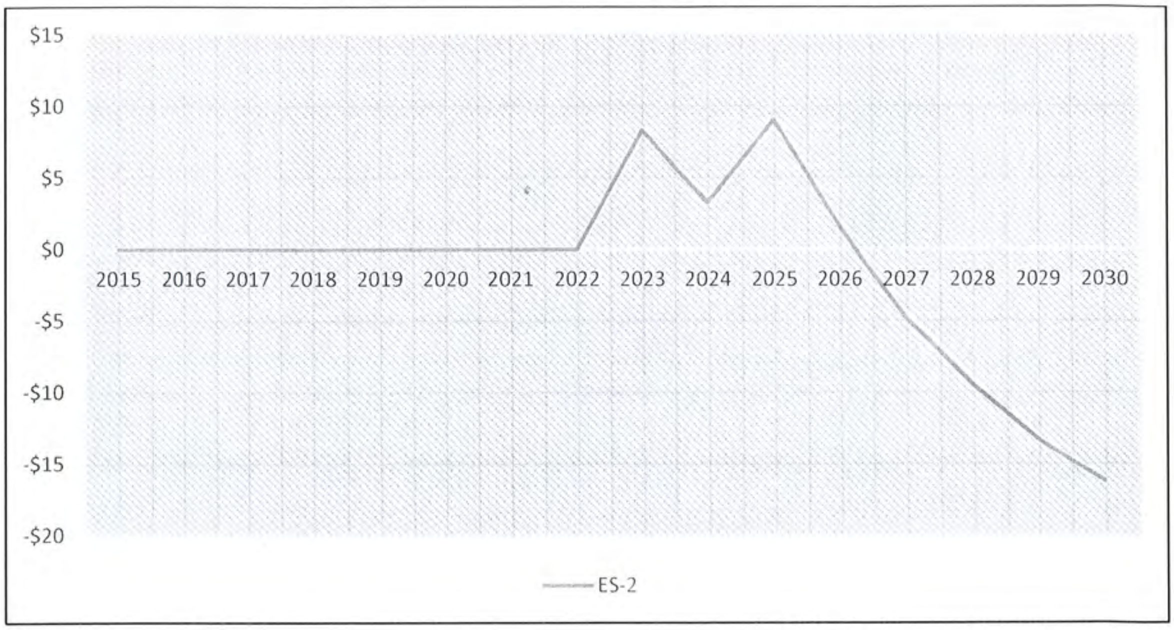
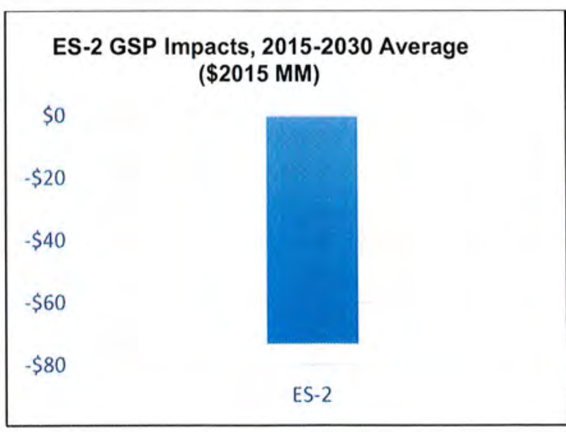
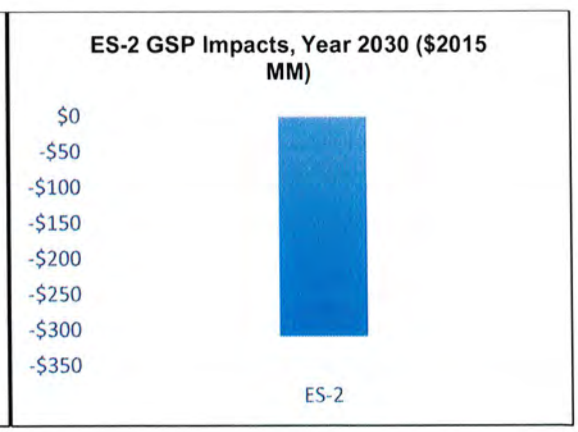


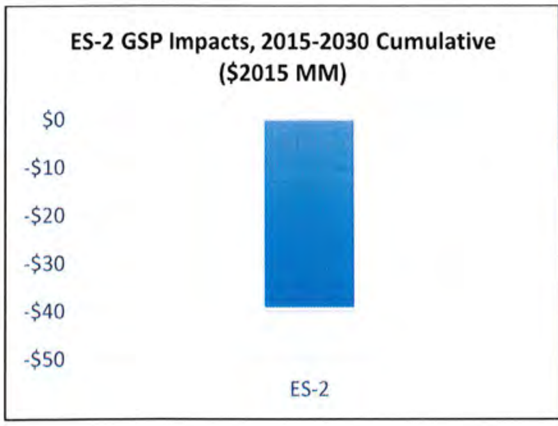
Figure F-1.28 ES-2 Income Impacts ($2015 MM)

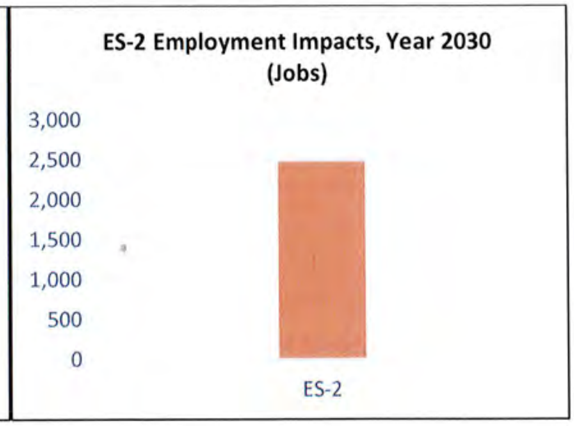


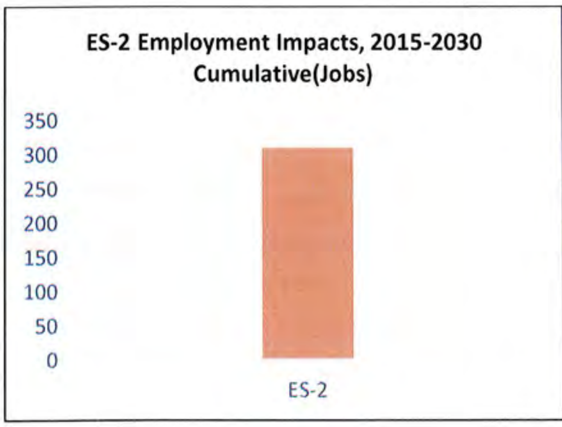
Graphs below show macroeconomic impacts on GSP, personal income, and employment in the final year (2030), in average (2015-2030) and in cumulative (2015-2030).

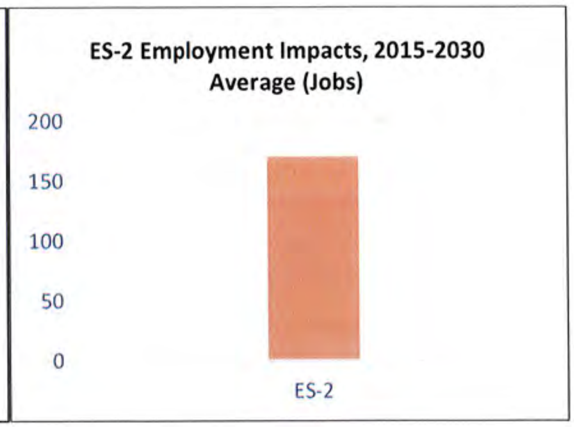


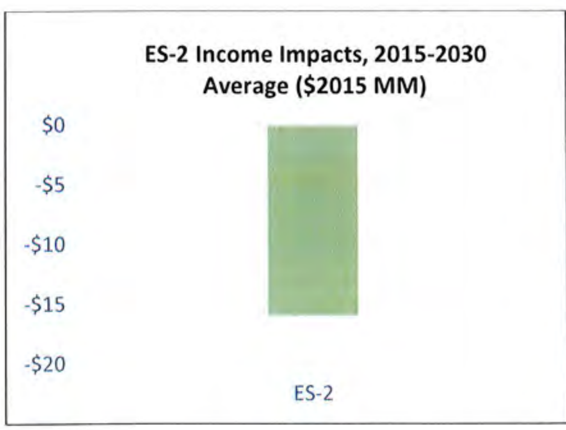


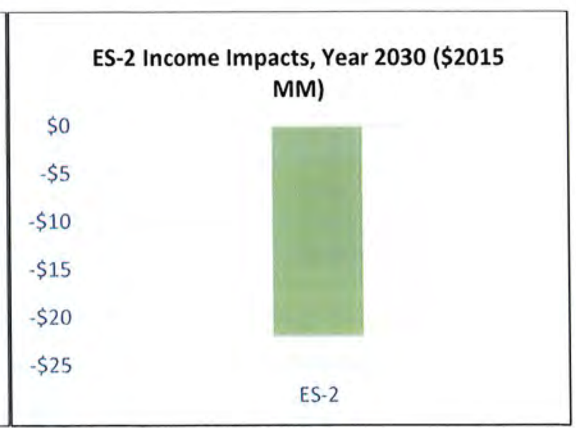

ES-2 GSP Impacts, 2015-2030 Cumulative ($2015 MM)
$0
-$10
-$20
-$30
-$40
-$50
ES-2

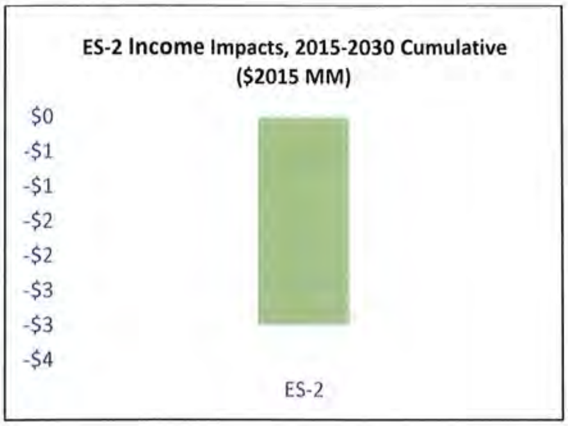

ES-2 Employment Impacts, Year 2030 (Jobs)
3,000
2,500
2,000
1,500
1,000
500
0
ES-2


ES-2 Employment Impacts, 2015-2030 Cumulative(Jobs)
350
300
250
200
150
100
50
0
ES-2


ES-2 Employment Impacts, 2015-2030 Average (Jobs)
200
150
100
50
0
ES-2


ES-2 Income Impacts, 2015-2030 Average ($2015 MM)
$0
-$5
-$10
-$15
-$20
ES-2


ES-2 Income Impacts, Year 2030 ($2015 MM)
$0
-$5
-$10
-$15
-$20
-$25
ES-2



Principal Drivers of Policy Impact on the Broader Economy

The principal drivers of macroeconomic change are investments into new natural gas generation capacity that Minnesota's electricity utilities are projected to make in order to replace the capacity currently met by the generation facilities at the Sherburne County facility. In addition, the reduced flow of costs because Xcel Energy would no longer be operating, fueling, maintaining and eventually upgrading the existing coal-fired generation is the other major driver. This produces a mix of positive direct impacts, and higher operating costs which create a downward pressure on the larger economy. As a result, GDP falls, but total jobs rise and incomes hold close to neutral.

Unlike the impact of the Renewable Energy Standard in ES-1, which resulted in a net monetary savings to the utilities achieve as a result of the shift in sources, this policy produces a net cost. The savings resulting from shutting down Sherco did not fully offset the cost of constructing. The investments in natural gas facilities take the form of increases in production costs for the utility, but the reduced flow of spending on coal-fired energy generation is by the same token a reduction in those production costs. The net production cost to the utility sector increases somewhat, which macroeconomic models anticipate will drive a combination of price increases and fewer available funds. This net cost increase to the utility, more than any other single factor, applies a downward pressure to the broader statewide economy. As a result, total GDP (the amount spent in the economy drops). Much of this is likely a reduction in spending on electricity – that sector will shrink most.

Sectors of Economy Most Affected by the Policy

Economic impacts from policies run around the economy, affecting sectors that are sometimes far from the direct target of a policy.

For ES-2, while the operating-cost shift sends some downward pressure through the economy, the direct impact of the policy (from the investment in building the new facilities) drives direct positive gains. The start of the repowering and retirement construction phases, in 2023 and 2025, drive net gains in employment that are larger than the losses created. The construction sector gains the most – between 200 and 400 jobs per year as it expands to build this new capacity. Natural gas production also grows, as does machinery manufacturing. The utility sector is the only sector to see a noticeable reduction in scale, though even that is never larger than a loss of about 75 positions – a number that should be taken as an indicator of slight downward pressure on the overall scale of the utility sector.

Data Sources

The principal data sources for the macroeconomic impacts analysis of this and all other policies in the CSEO process are the direct spending, saving, cost and price impacts developed as part of the microeconomic (direct impacts) analysis. For each policy, the cost-effectiveness analysis described above develops year-by-year estimates of the costs, savings prices, and changes demand or supply that households, businesses and government agencies are expected to encounter in a scenario where the policy is implemented as designed.

A secondary data source is the policy design. Balancing financial flows for each direct impact identified are established based on understanding the implementation mechanism, and quantitative values for these flows are developed for each direct impact identified. This balancing identifies and quantifies the responsive change that occurs as a result of the direct impact in question. For example, if a household is anticipated to save $100 per year on electricity bills as a result of a policy, the direct impact is a $100 savings to the household (which expands its spending capacity for other things) but the balancing impact is a $100 loss in revenue and demand to the utility provider (which reduces its ability and need to spend on labor, capital, profit, and other inputs). The quantitative measure of both sides of a change is of importance to a complete macroeconomic analysis. This balancing ensures that both the supply and the demand side of each economic change is fully represented in the analysis.

A third data source is direct communication with Minnesota agency staff and others involved in policy design or in a position to understand in detail the financial flows involved in the policy. These people assisted in clarifying the nature of economic changes involved so that the modeling and analysis would be accurate.

The final crucial data source is the baseline and forecast of economic activity within the REMI software. This data is compiled into a scenario that is characterized not only by the total size of the economy and its many consuming and producing sectors, but also the mechanisms by which impacts in one sector can change the broader economy – such as intermediate demands, regional purchase coefficients, and equilibria around price and quantity, labor and capital, and savings and spending, to name a few of many. REMI, Inc. maintains a full discussion of all the sources of the baseline data on its own website, www.remi.com.

Quantification Methods

Utilizing the data developed from the microeconomic analysis, CCS analysts established for each individual change the following characteristics:

- The category of change involved (change in spending, savings, costs, prices, supply or demand)

- The party involved on both sides of each transaction
- The volume of money involved in this change in each year of the period of analysis

These values, so characterized, were then processed into inputs to the REMI PI+ software model built specifically for use by CCS and consistent with that in use by state agencies within Minnesota. These inputs were applied to the model and run. Key results were then drawn from the model and processed for consistency of units and presentation before inclusion in this report.

<u>Key Assumptions</u>

The macroeconomic impact analyses of this policy, as well as of the others in the CSEO process, rely on a consistent set of key assumptions:

- State and local spending is always budget-constrained. If a policy calls for the state or local government to spend money in any fashion, that spending must be either funded by a new revenue stream or offset by reductions in spending on other programs. Savings or revenues collected by the government are also expected to be returned to the economy as spending in the same year as they are collected.
- Federal spending is not budget-constrained. The capacity of the federal government to carry out deficit spending means that no CSEO policy is held responsible for driving either an increase or decrease in federal tax spending by businesses or households in the state of Minnesota.
- Consumer spending increases are sometimes financed. Small-scale purchases or purchases of consumer goods are treated as direct spending from existing household cash flows (or short-term credit). Durable goods, home improvements or vehicle purchases, however, are treated as financed. Consumers were assumed to spread out costs based on common borrowing time frames, such as five years for financing a new vehicle or 10-20 years for home improvements that might be funded by home-equity or other lending. The assumption of financing and the term of years applied was considered anew in each case.
- Business spending increases are often financed. Where spending strikes a sector which routinely utilizes financing or lines of credit to ensure steady payment of recurring costs, significant spending of nearly any type was considered a candidate for financing, thus allowing costs to spread out over time. This methodology is preferable for the modeling work, as sudden spikes or dips in business operating costs can show up as volatility when the scenario may depict a managed adoption of new equipment in an orderly fashion. The assumption of financing and the term of years applied was considered anew in each case.
- Unless otherwise stated, all changes to consumer spending or to the producers' cost of producing goods and services were treated in a standard fashion. Consumers are assumed to spend on a pre-set mix of goods, services, and basic needs, and businesses

spend (based on their particular sector of the economy) on a mix of labor, capital, and intermediate demands from other sectors. Unless a policy specifically defines how a party will react to changes in cost, price, supply or demand, these standard assumptions were applied.

State and local spending gains and reductions driven by policy are assumed to apply to standard mixes of spending. Again, unless a policy specifically states that a government entity will draw from a specific source or direct savings or revenues to a specific form of spending, all gains and losses were assumed to apply to a standard profile of government spending within the economy.

Key Uncertainties

- The type of replacement power to meet Minnesota demand during the repowering construction period (assumed to be zero).
- The ratio of the capital cost of a repowered facility to a new facility, as well as impact on combustion efficiency and operating costs.
- The system performance and cost impacts associated with replacing the total annual generation for Sherco 1 and 2 with generation from NGCC.

Additional Benefits and Costs

- Reduced degradation of air quality and other urban heat island impacts
- Improved surface/ground water quality
- Mitigated health care costs for air quality and carbon emissions related illness in Minnesota.
- Costs could include employment impacts at the power plant and any incrementally higher costs of power.

Health Impacts: Retiring the Sherco coal-fired boilers will reduce emissions of air toxics that negatively impact health by eliminating those emissions. Repowering the Sherco coal-fired boilers with natural gas would also benefit health because the health burdens associated with natural gas are much lower than those associated with coal; in fact, one recent study estimated that the number of deaths per TWh for natural gas was only 2.8, compared with 24.6 deaths per TWh for coal. (Markandya)

Figure F-1.29 Potential Health Benefits ES-2

Reducing energy-related emissions is likely to reduce the risk for respiratory and cardiovascular illness, and cancer in exposed populations.

Feasibility Issues

Power plant repowering projects involve detailed engineering analyses to determine if existing equipment can be reused or completely replaced, which can affect feasibility and project timelines. Natural gas must also be available in sufficient quantity to the site.

Chapter XIV. Appendix F-2. Residential, Commercial, Institutional, and Industrial Policy Option Recommendations

Overview

The tables below provide a summary of the direct impacts and microeconomic analysis of Climate Solutions & Economic Opportunities (CSEO) policies in the Residential, Commercial, Institutional, and Industrial (RCII) sector. The first table provides a summary of results on a "stand-alone" basis, meaning that each policy option was analyzed separately against baseline (business as usual or BAU) conditions. Details on the analysis of each policy option are provided in each of the Policy Option Documents (PODs) that follow within this appendix.

Direct Impacts

The "stand-alone" results provide the annual greenhouse gas (GHG) reductions for 2020 and 2030 in million metric tons (MMt) of carbon dioxide equivalent reductions (CO_2e), as well as the cumulative reductions through 2030. The reductions shown are only those that have been estimated to occur within the State, that is, the net emissions reduction from fuels combustion plus the estimated emissions reduction from reduction of the need for electricity generation. Additional GHG reductions, typically those associated with upstream emissions in the supply of fuels or materials, have also been estimated, and upstream emissions results are reported within each of the analyses in each POD.

Also reported in the stand-alone results is the net present value (NPV) of societal costs/savings for each policy option. These are the net costs of implementing each policy option reported in 2014 dollars. The cost effectiveness (CE) estimated for each policy option is also provided. Cost effectiveness is a common metric that denotes the cost/savings for reducing each metric ton (t) of emissions. Note that the CE estimates use the total emission reductions for the policy option (that is, cumulative emissions reductions counting reductions occurring both within and outside of the State).

CCS did not utilize any generalized co-benefit estimate (such as a social cost of carbon) or estimate a consistent suite of co-benefit impacts across all policies. In some policies, however, aspects of specific co-benefits were isolated and quantified. For the transit policy, as one example, a small improvement in access to employment was applied to the macroeconomic modeling. The larger economic benefit of any savings to either businesses, households or the government is captured in the macroeconomic impact analysis (as is, by the same token, the economic burden of any increases in prices or costs of living/doing business).

Integrative Adjustments & Overlaps

Table F-2.2 below provides the GHG emissions reductions and net costs for each option after an assessment was made of any policy option interactions or overlaps between RCII options. In the RCII sector, overlaps were identified between the RCII-1 policy option promoting combined heat and power (CHP) and RCII-2, which sets combined energy efficiency and renewable energy

production/use requirements for new and renovated buildings. RCII-4, which increases energy efficiency targets for electric and gas utility programs that apply to both new and existing consumers, also has some overlap with RCII-2. The RCII-4 overlap with RCII-2 was calculated based on estimates of the fraction of state building floor area that participates in RCII-2, relative to estimates of the total state building floor area in a given year.

As indicated in the summary table, RCII-5 overlaps with both RCII-2 and RCII-4. The overlap with RCII-2 is the gas savings in RCII-2 resulting from renewable energy use in new homes. The overlap with RCII-4 is the fraction of gas savings resulting from the application of renewable energy systems included in RCII-4. These gas savings are not explicitly included in the RCII-4 Policy Option Document, nor explicitly calculated in the estimate of the costs and impacts of RCII-4. The overlap between RCII-5 and RCII-4 was therefore estimated to be 10% of the natural gas impacts of RCII-4 and a corresponding share of the gas-related costs of RCII-5.

Macroeconomic (Indirect) Impacts

Table F-2.3 below provides a summary of the expected impacts of RCII policies on jobs and economic growth during the CSEO planning period. This table focuses on the impact of policies on Gross State Product (the total amount spent on goods and services produced within the state), Employment (the total number of full-time and part-time positions), and Incomes (the total amount earned by households from all possible sources). These metrics represent three valuable indicators of both the overall size of the economy and that economy's structural orientation toward supporting livelihoods and utilizing productive work.

For the purposes of macro-economic analysis of CSEO policies, CCS utilized the Regional Economic Models, Inc. (REMI) PI+ software. This particular REMI model is developed specifically for Minnesota, and is developed consistently with the design of models in use by state agency staff within Minnesota for a range of economic analyses. Its analytical power and accuracy made REMI a leading modeling tool in the industry used by numerous research institutions, consulting firms, non-government organizations and government agencies to analyze impacts of proposed policies on key macro-economic parameters, such as GDP, income levels and employment.

The main inputs for macro-economic analysis are microeconomic estimates of direct costs and savings expected from the implementation of individual policy options. These inputs are supplemented with additional data and assumptions necessary to complete the picture of how these costs and savings (as well as price changes, demand and supply changes, and other factors) influence Minnesota's economy. These additional data and assumptions typically regard how various actors around the state (households, businesses and governments) respond to change by changing their own economic activity. A full articulation of the general and policy-specific assumptions made by the macroeconomic analysis team is provided in the Policy Option Documents, contained as appendices to this report.

Table F-2.1 Residential, Commercial, Institutional, & Industrial Policy Options, Stand-Alone Impacts

Stand-Alone Analysis							
		GHG Reductions				Costs	
Policy Option ID	Policy Option Title	Annual CO_2e Reductions[a]		2030 Cumulative[a]	2030 Cumulative[b]	Net Costs[c] 2015-2030	Cost Effectiveness[d]
		2020 MMt	2030 MMt	$MMtCO_2e$	$MMtCO_2e$	$Million	$/tCO_2e$
RCII-1	Incentives and Resources to Promote Combined Heat and Power (CHP) for Biomass and for Natural Gas	2.2	4.9	46	50	($1,112)	($22)
RCII-2	SB2030/Zero Energy Transition/Codes	0.92	9.3	54	60	($2,050)	($34)
RCII-3	Reduce High Global Warming Potential (GWP) Greenhouse Gases	Not Applicable - Option not quantified					
RCII-4	Increase Energy Efficiency Requirement (2.5% annual electric energy savings)	1.4	4.7	36	42	($1,882)	($45)
RCII-4	Increase Energy Efficiency Requirement (2% annual electric energy savings)[e]	*1.0*	*3.2*	*25*	*29*	*($1272)*	*($44)*
RCII-5	Incentives and Resources to Promote Thermal Renewables	0.80	3.0	22	30	$872	$29
Totals		**5.3**	**22**	**157**	**182**	**($4,171)**	**($23)**

Notes:
[a] In-State (Direct) GHG Reductions
[b] Total (Direct and Indirect) GHG Reductions
[c] Net Present Value of fully implemented policy option using 2014 dollars ($2014)
[d] Cost effectiveness values include full energy-cycle GHG reductions, including those occurring out of State. Dollars expressed in 2014$.
[e] 2% annual electric energy savings scenario is an alternative scenario of RCII-4 policy evaluated for a reference, and is not included in the "**Totals**" row calculation

Table F-2.2 Residential, Commercial, Institutional, & Industrial Policy Options, Intra-Sector Interactions & Overlaps

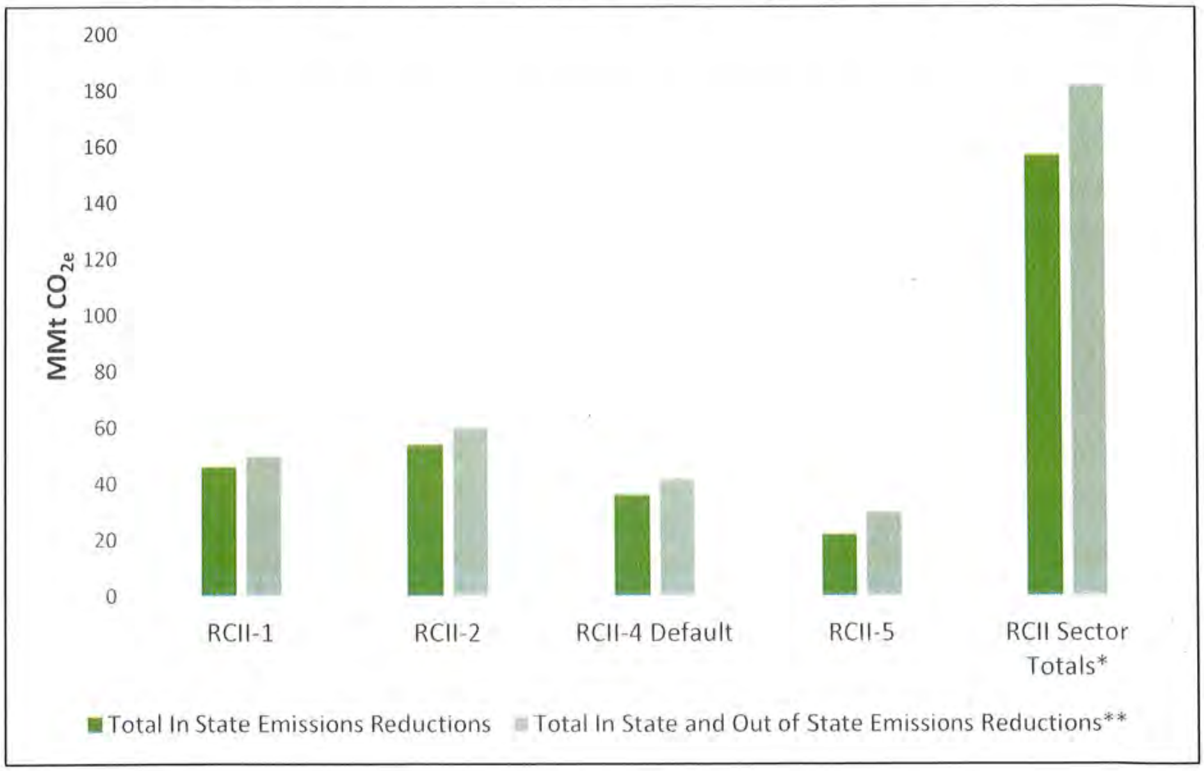
Intra-Sector Interactions & Overlaps Adjustments							
Policy Option ID	Policy Option Title	GHG Reductions				Costs	
		Annual CO_2e Reductions[a]		2030 Cumulative[a]	2030 Cumulative[b]	Net Costs[c] 2015-2030	Cost Effectiveness[d]
		2020 MMt	2030 MMt	$MMtCO_2e$	$MMtCO_2e$	$Million	$/$tCO_2e$
RCII-1[e]	Incentives and Resources to Promote Combined Heat and Power (CHP) for Biomass and for Natural Gas	2.2	4.8	46	49	($1,098)	($22)
RCII-2[f]	SB2030/Zero Energy Transition/Codes	0.92	9.3	54	60	($2,050)	($34)
RCII-3	Reduce High Global Warming Potential (GWP) Greenhouse Gases	Not Applicable - Option not quantified					
RCII-4[g]	Increase Energy Efficiency Requirement (2.5% annual electric energy savings)	1.3	4.4	34	40	($1,744)	($43)
RCII-4	Increase Energy Efficiency Requirement (2% annual electric energy savings)[i]	*1.0*	*3.0*	*23*	*28*	*($1180)*	*($42)*
RCII-5[h]	Incentives and Resources to Promote Thermal Renewables	0.82	3.0	22	30	$844	$28
Total After Intra-Sector Interactions /Overlap		**5.3**	**22**	**156**	**180**	**($4,049)**	**($23)**

Notes:
[a] In-State (Direct) GHG Reductions
[b] Total (Direct and Indirect) GHG Reductions
[c] Net Present Value of fully implemented policy option using 2014 dollars ($2014)
[d] Cost effectiveness values include full energy-cycle GHG reductions, including those occurring out of State. Dollars expressed in 2014$.
[e] RCII-1 overlaps with RCII-2 in its use of gas-fired CHP in the C/I sector. Approximate overlaps are calculated on that basis.
[f] This option is used as the basis on which overlaps from other options are calculated
[g] Overlaps with RCII-1 are already removed from RCII-4 results. As RCII-4 applies to all homes and businesses, and RCII-2 only applies to new and renovated buildings, the RCII-4 overlap with RCII-2 is estimated based on an estimate of the fraction of total Minnesota building floor area that participates in RCII-2 relative to a rough estimate of the total Minnesota building floor area.

[h] This option does not overlap with RCII-1. RCII-5 overlaps with the gas savings in RCII-2 from renewable energy use that apply to new homes, and to the fraction of gas savings in RCII-4 that comes about as a result of the application of renewable energy systems included in RCII-4. The latter are not explicitly included in the RCII-4 Policy Option Document, or explicitly calculated in the estimate of the costs and impacts of RCII-4. We therefore roughly estimate the overlap between RCII-5 and RCII-4 at 10% of the natural gas impacts of RCII-4 and a corresponding share of the gas-related costs of RCII-5.

[i] 2% annual electric energy savings scenario is an alternative scenario of RCII-4 policy evaluated for a reference, and is not included in the "**Total**" row calculation.

Figure F-2.1 RCII Policies GHG Emissions Abatement, Cumulative 2015-2030



Notes:

All Policies Total's comprise emissions reductions achieved by RCII default policies combined.

Total in and out-of-state emissions reduction are the reductions associated with the full energy cycle (fuel extraction, processing, distribution and consumption). Therefore, the emissions reductions that occur both inside and outside of the state borders as a result of a policy implementation are captured under this value.

Table F-2.3 Macroeconomic (Indirect) Impacts of RCII Policies

Macroeconomic (Indirect) Impacts Results			
Policy	Gross State Product (GSP, $2015 Millions)	Employment (Full & Part-Time Jobs)	Income Earned ($2015 Millions)

	Year 2030	Average	Cumulative (2015-2030)	Year 2030	Average	Cumulative (2015-2030)	Year 2030	Average	Cumulative (2015-2030)
RCII-1	$508	$202	$3,026	3,840	2,330	35,020	$434	$213	$3,191
RCII-2	-$69	-$6	-$91	6,020	2,750	41,190	$336	$134	$2,011
RCII-4	$137	$141	$2,111	1,430	1,560	23,340	$163	$143	$2,140
RCII-5	-$345	-$149	-$2,081	-1,680	-690	-9,610	-$154	-$58	-$809
RCII Sector Total	**$262**	**$210**	**$3,149**	**9,820**	**6,080**	**91,270**	**$801**	**$444**	**$6,658**

Notes:
[a] Gross State Production changes in Minnesota. Dollars expressed in $2015.
[b] Total employment changes in Minnesota.
[c] Personal Income changes in Minnesota. Dollars expressed in $2015.
[d] Single final year value. Year 2030 is the final year of analyses in this project.

Figure F-2.2 – Net Job Creation for RCII Policies and RCII Sector, 2015-2030

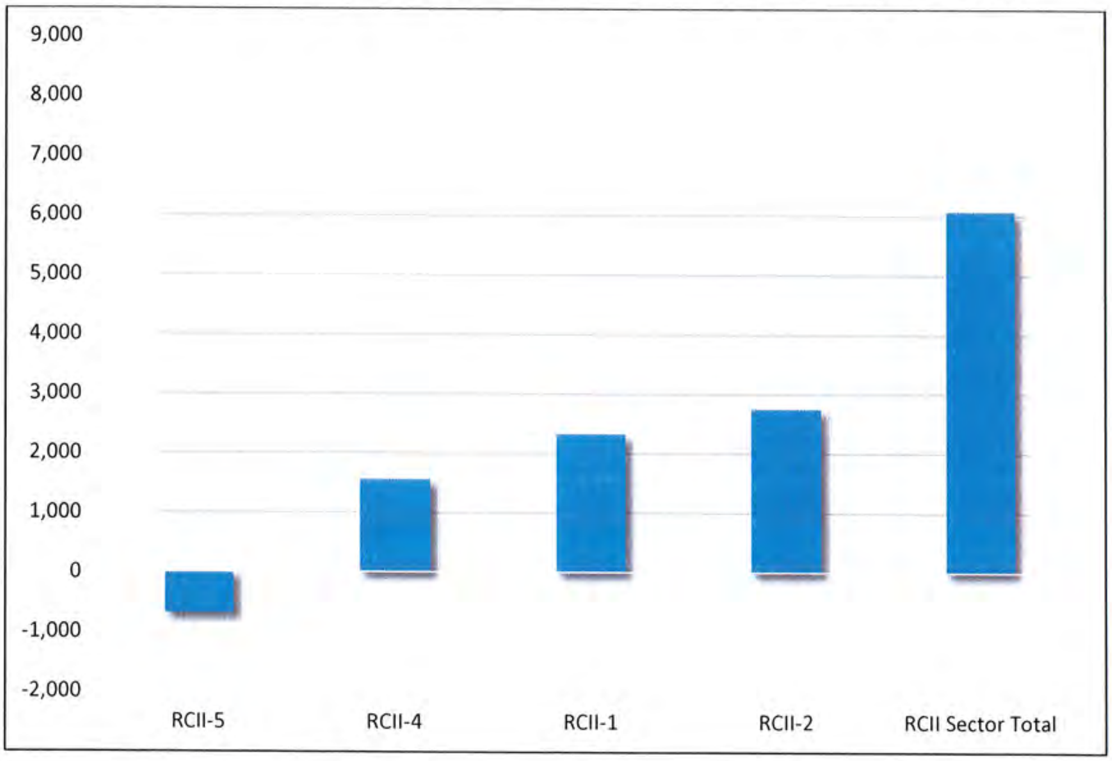
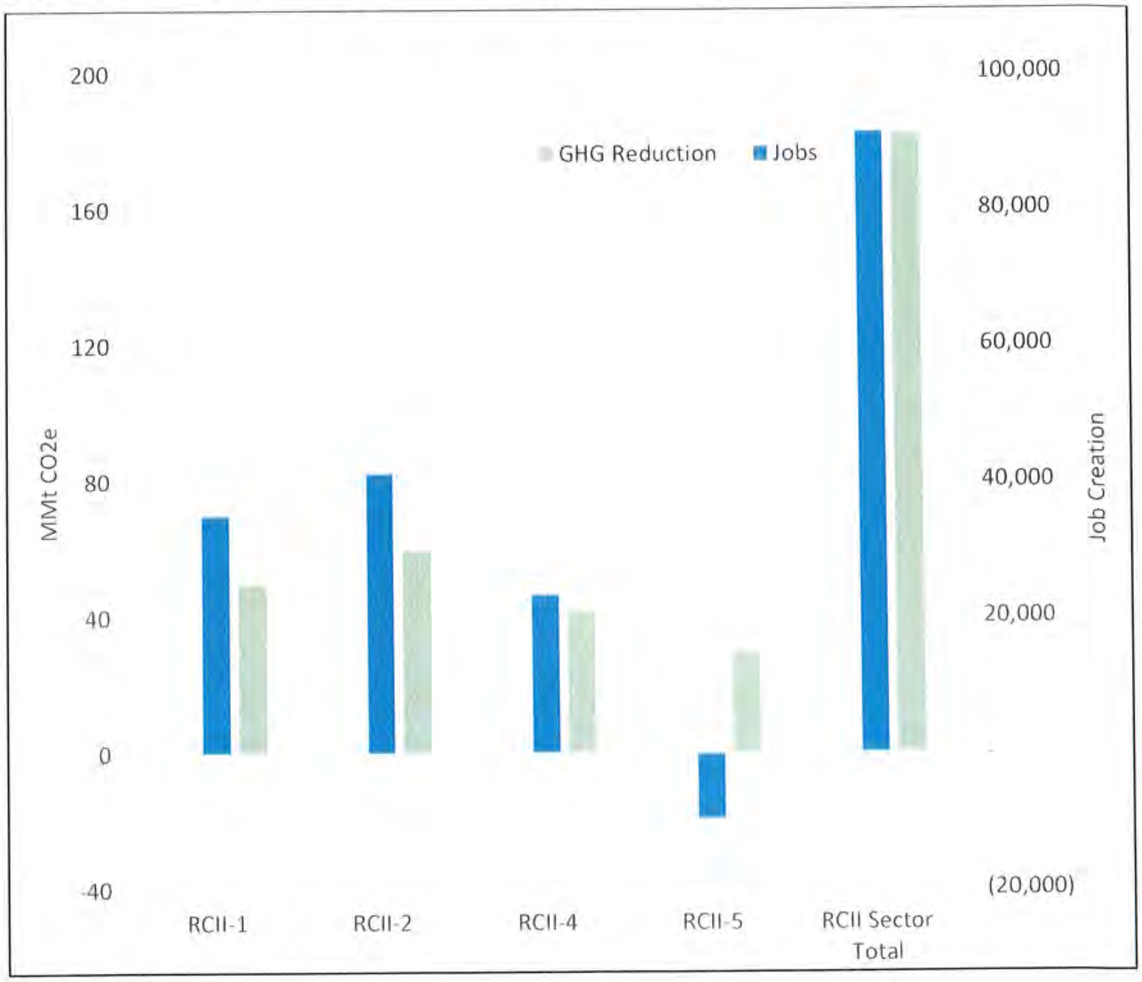


Figure F-2.3 below summarizes a potential for job creation and GHG emissions abatement of RCII sector policies on the same graph. This allows for a simultaneous assessment of performance of individual CSEO options against a crucial environmental and economic indicator.

Figure F-2.3 Cumulative Job Gains and GHG Reduction by RCII Policy Options, 2015-2030



Macroeconomic Index

The graph below expresses the overall economic impact from each scenario in a single score, and compares those scores. CCS created this single score (a Macroeconomic Impact Index) in order to encapsulate in one measurement the relative macroeconomic impacts (including jobs, GSP and incomes) of each policy. We have found in our own work and in the literature that indexed scores can be helpful to many readers when comparing options with multiple characteristics.

To produce this score, CCS set the results from the absolute best-case scenario (i.e. the implementation of all CSEO policies with all their optimal sensitivities in place) equal to 100, with that scenario's jobs, GSP and incomes impacts weighted equally at one third of the total score. Each policy's jobs, GSP and income impacts are scaled against that measure, and given a total score. The overall score indicates how significant a policy's impact is projected to be. Negative impacts are scaled the same way, except that those impacts are given negative scores and pull down the total score of the policy.

These scores are calculated separately for the final year of the study (2030), the *average* impact over the 2015-2030 period, and the *cumulative* impact of the policies over that period. While each scenario has one line, the relative importance of jobs, income and GSP remain visible as differently-shaded segments of that line.

Figure F-2.4 RCII Macroeconomic Indicators, Year 2030

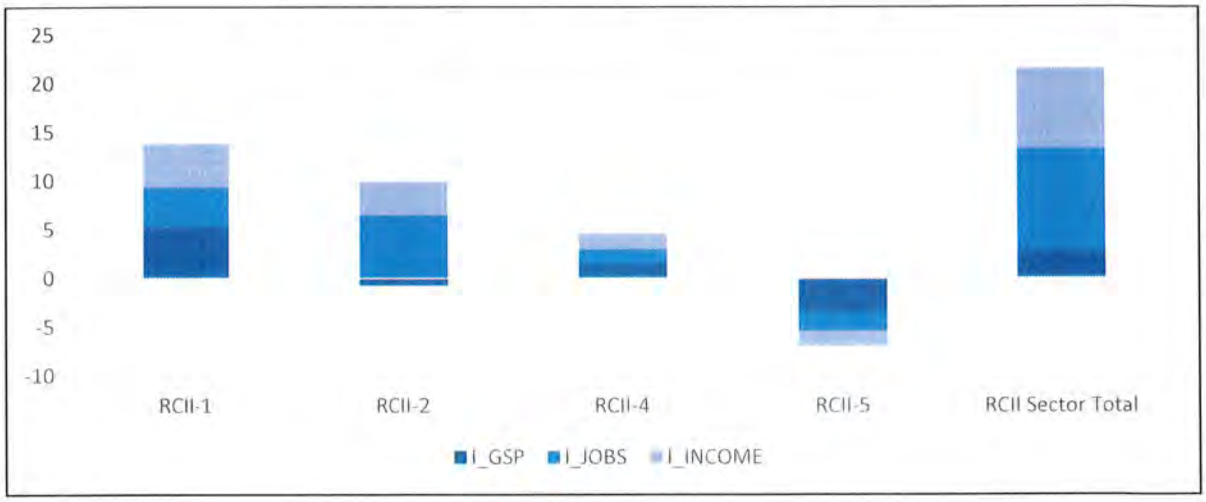


Figure F-2.5 RCII Macroeconomic Indicators, Average Annual

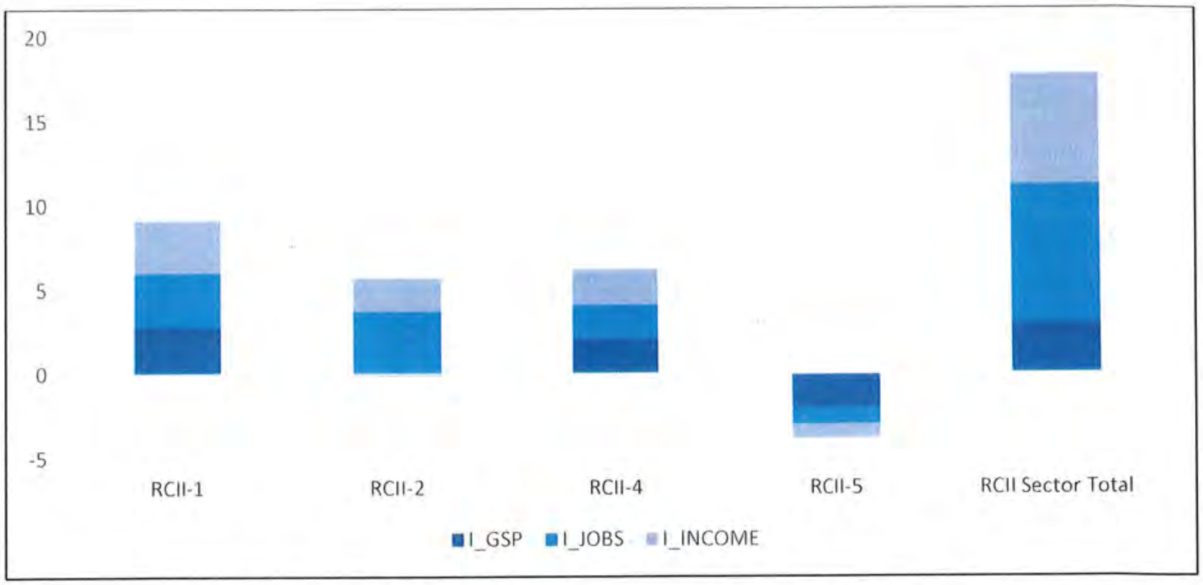
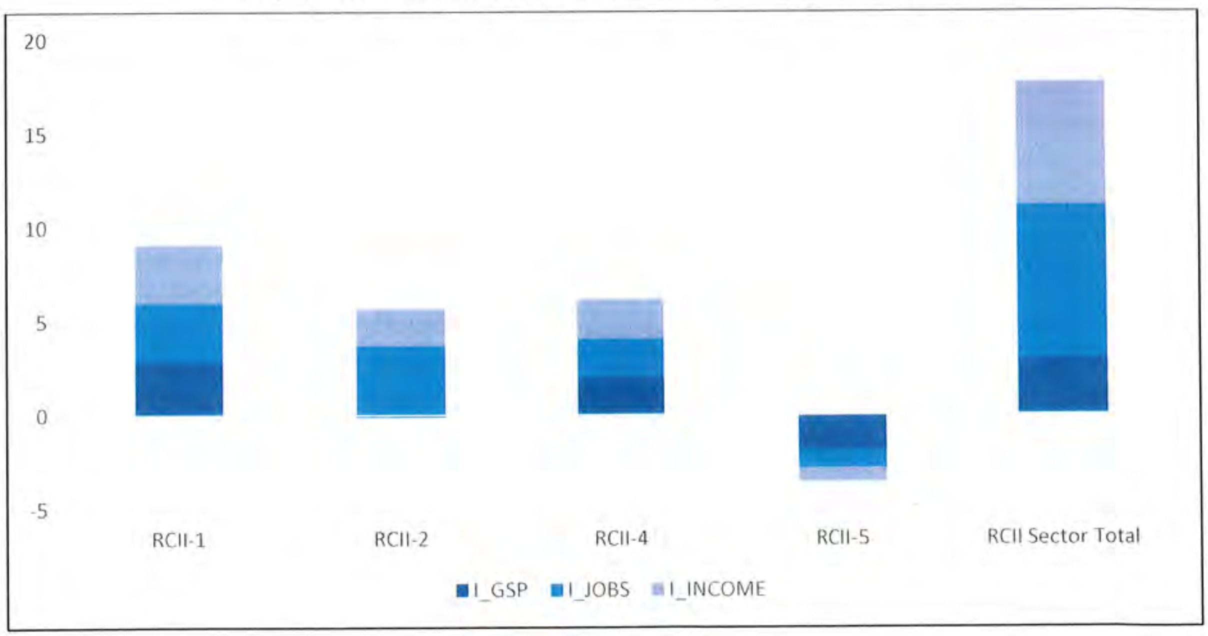


Figure F-2.6 RCII Macroeconomic Indicators, 2015-2030



The RCII Sector policies, when taken together, produce significant positive economic impacts on the Minnesota economy. As a bundle, they are projected by this analysis to drive a growth of between $180 million and $270 million per year in the state's GSP through most of the 2015-2030 period.

While GSP holds steady in that range, the jobs and income levels project actually continue to rise throughout the period. Incomes reach $800 million in gains, and the state adds approximately 10,000 new full-time and part-time positions as part of this growth. This profile, where employment metrics respond more strongly than total spending levels (GSP), is a common characteristic of efficiency measures, and much of the focus of the RCII sector policies is on achieving efficiencies.

The most positive policy is RCII-1, which focuses on the implementation of combined heat and power generation (CHP) by utilities and industries. Alone, it is projected to increase GDP by approximately a half billion dollars by 2030, nearly the same amount in incomes, and total employment by 4,000 positions. This is due to a combination of the stimulus from investing in new equipment and technology and the fundamental efficiency achieved by capturing waste heat rather than having to produce that heat separately. RCII-4, which raises the statewide energy efficiency requirement, is also positive but to a smaller scale of impact.

RCII-5, which focuses on renewable thermal energy, however, fares least well. Its overall cost burden, in terms of required investments by households and by institutions and other larger buildings, is never recovered back as savings. Because not all of the expenses incurred go into sectors that are powerful in expanding the economy of the state (either because they rely on imports or because they produce few intermediate demands for other economic activity as inputs), the economy does not benefit from the spending requires as much as it suffers from the burden imposed.

RCII-2 presents a classic efficiency profile: The impact on GSP is neutral, as spending on energy falls aggressively and balances out the spending gains in other sectors. But the efficiency effect – lower costs of living and doing business – drive large growth in incomes and jobs. This pattern is characteristic of efficiency policies, which seek to produce the same welfare benefit (what we use energy for, such as heat and light and productive work) on less input (smaller amounts of electricity or gas).

Line graphs and bar graphs that follow illustrate the above explained policy impacts and economic implications.

Figure F-2.7 RCII GSP Impacts ($2015 MM)

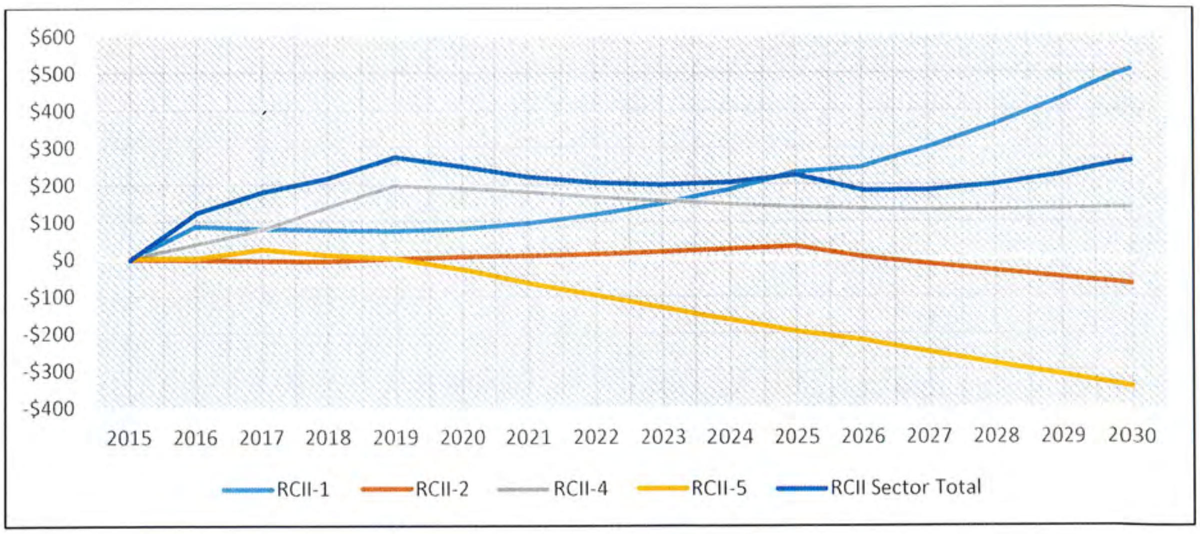

$600
$500
$400
$300
$200
$100
$0
-$100
-$200
-$300
-$400
2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030
RCII-1
RCII-2
RCII-4
RCII-5
RCII Sector Total

Figure F-2.8 RCII Employment Impacts (Individual Jobs)

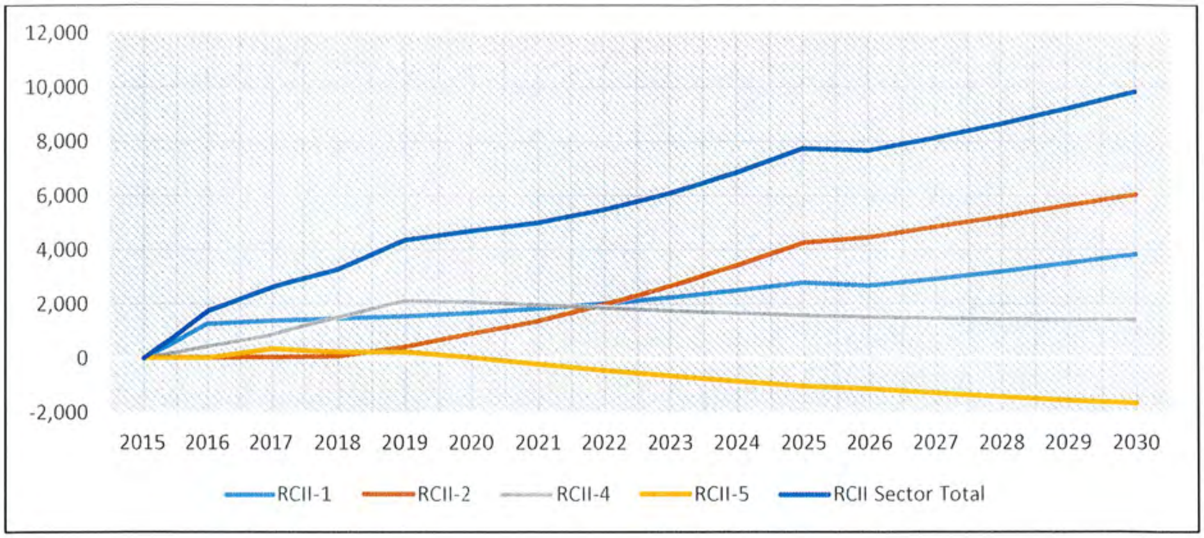
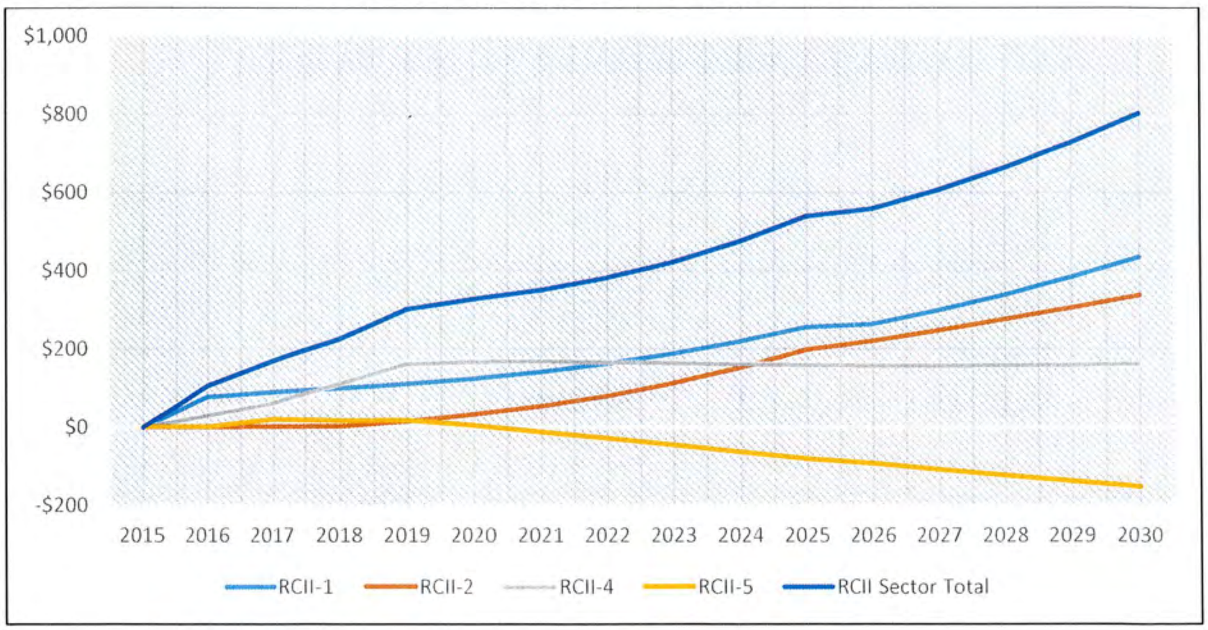


Figure F-2.9 RCII Income Impacts ($2015 MM)



Graphs below show macroeconomic impacts on GSP, personal income, and employment in the final year (2030), in average (2015-2030) and in cumulative (2015-2030).

Figure F-2.10 RCII GSP Impacts, Average Annual ($2015 MM)

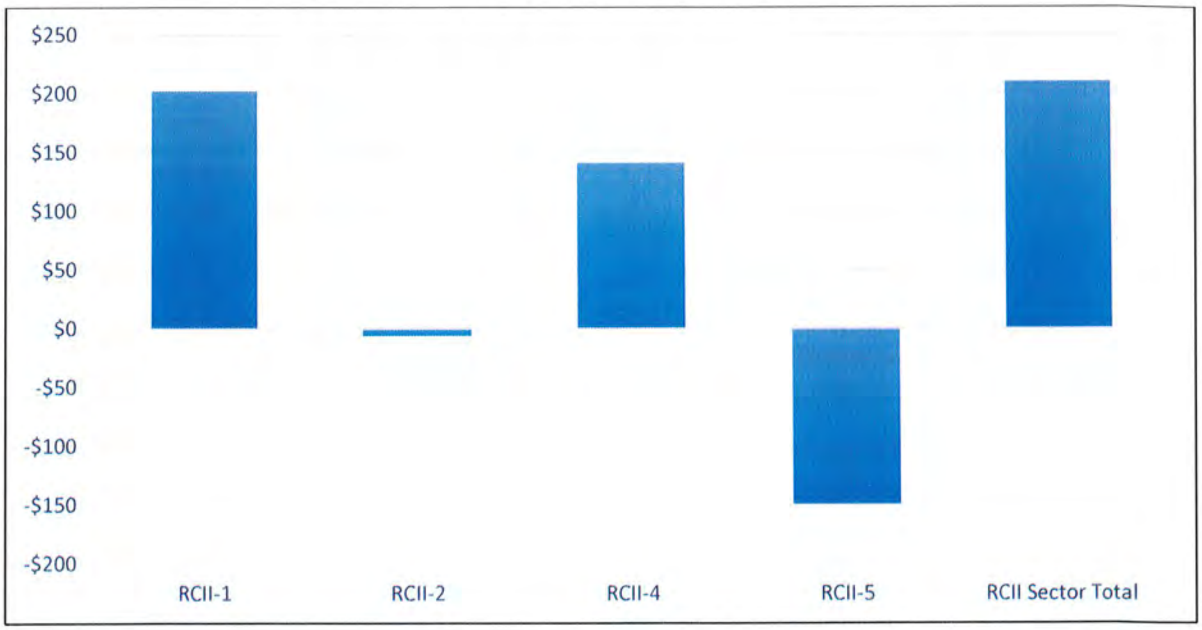


Figure F-2.11 RCII GSP Impacts, 2015-2030 ($2015 MM)

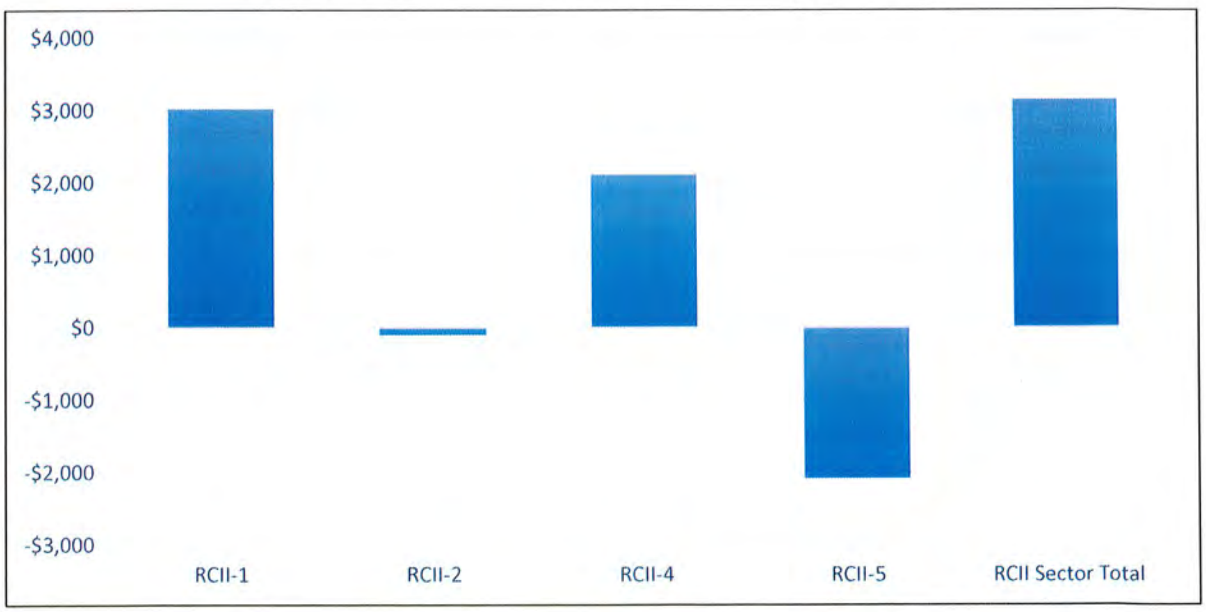


Figure F-2.12 RCII GSP Impacts, Year 2030 ($2015 MM)

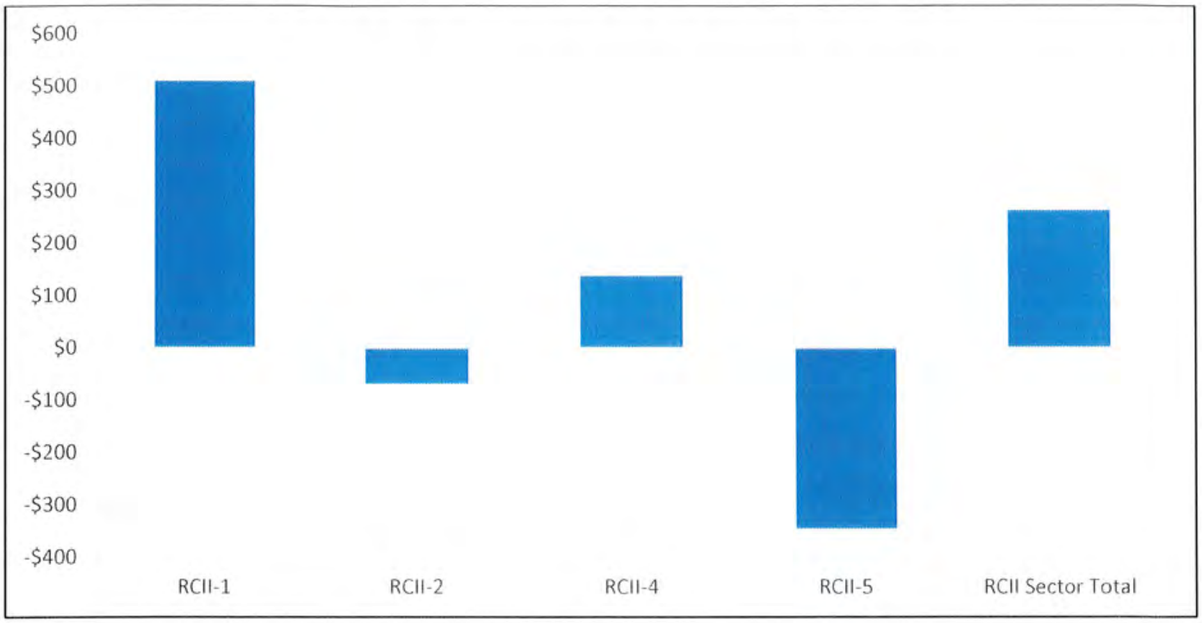


Figure F-2.13 RCII Employment Impacts, Average Annual (Jobs)

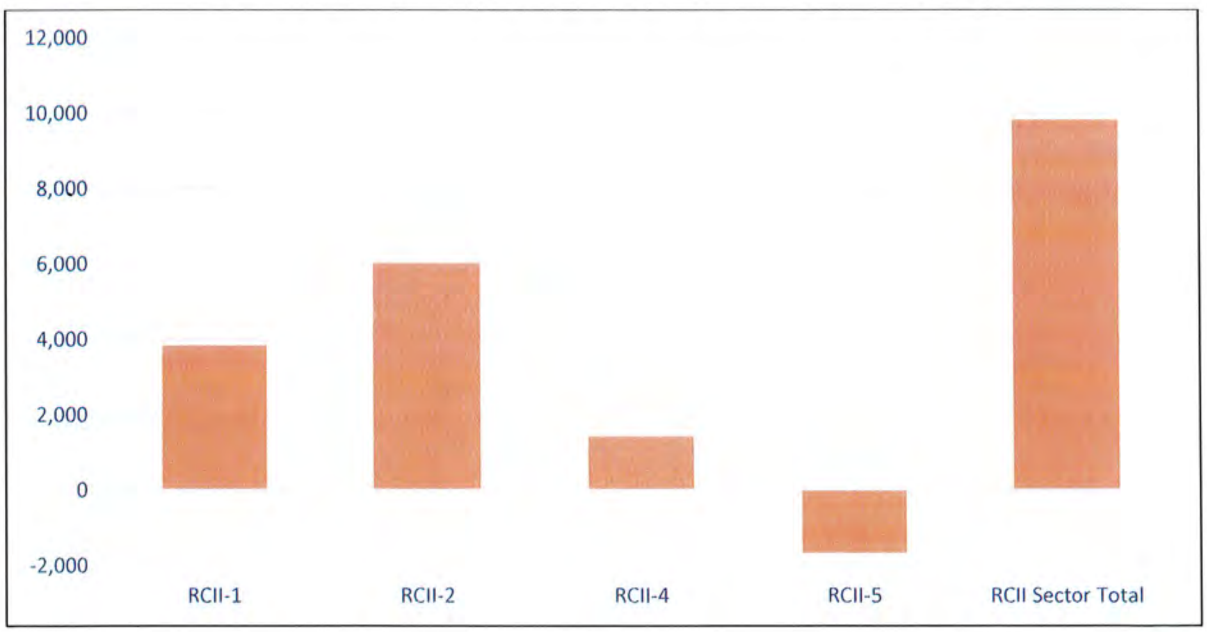


Figure F-2.14 RCII Employment Impacts, 2015-2030 Cumulative (Jobs)

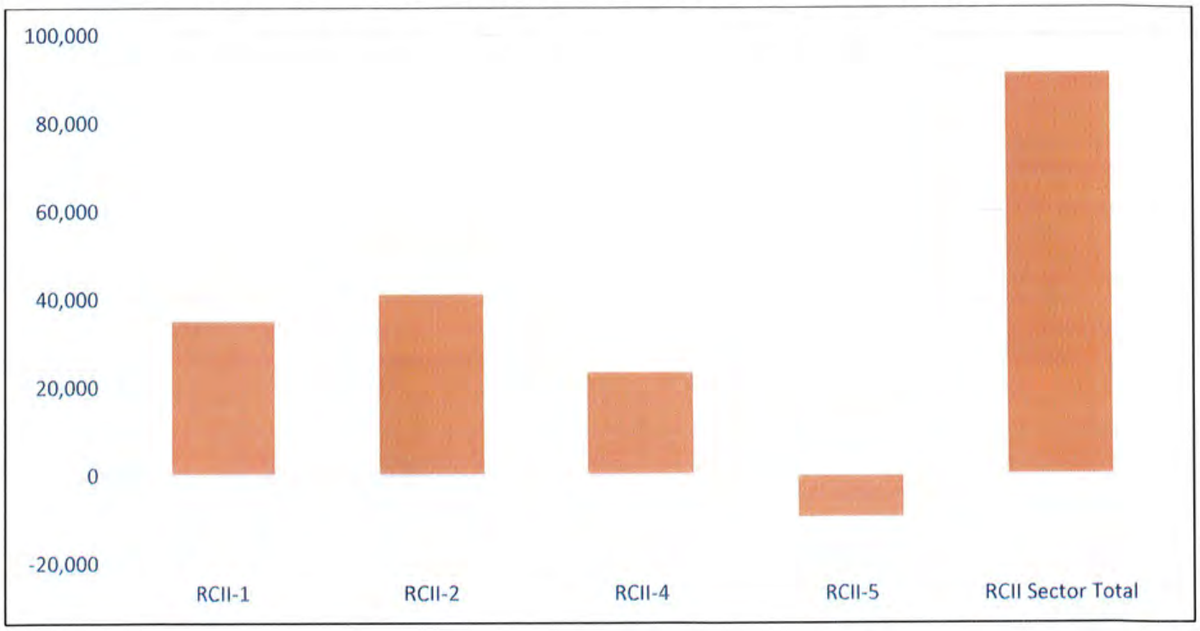


Figure F-2.15 RCII Employment Impacts, Year 2030 (Jobs)

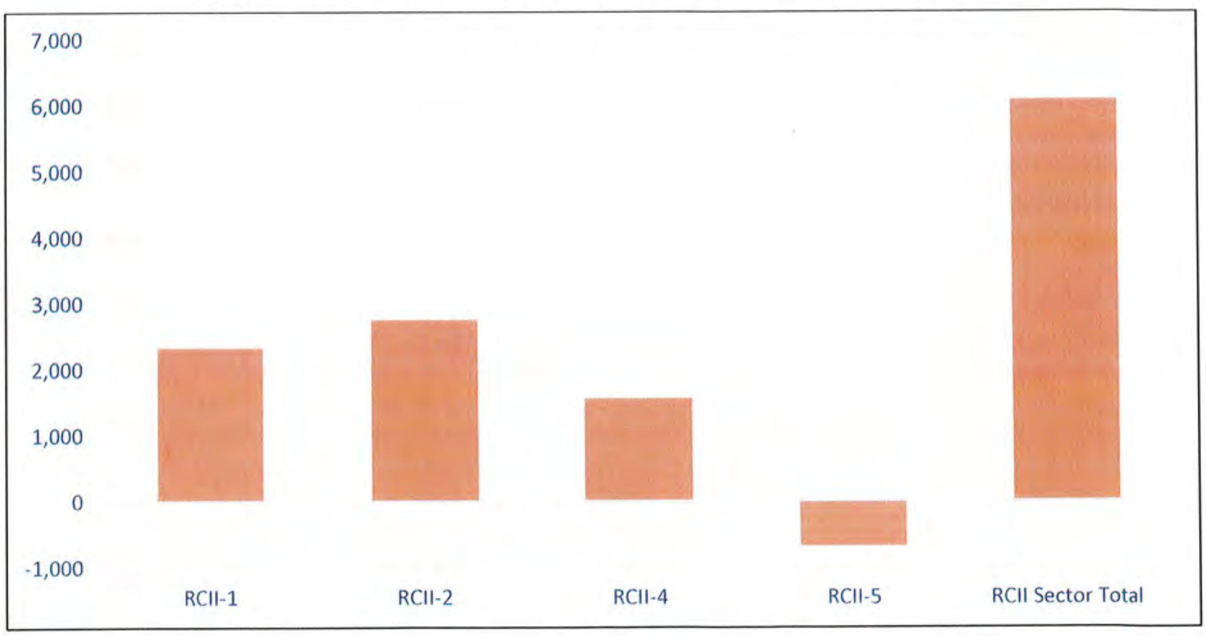


Figure F-2.16 RCII Income Impacts, Average Annual ($2015 MM)

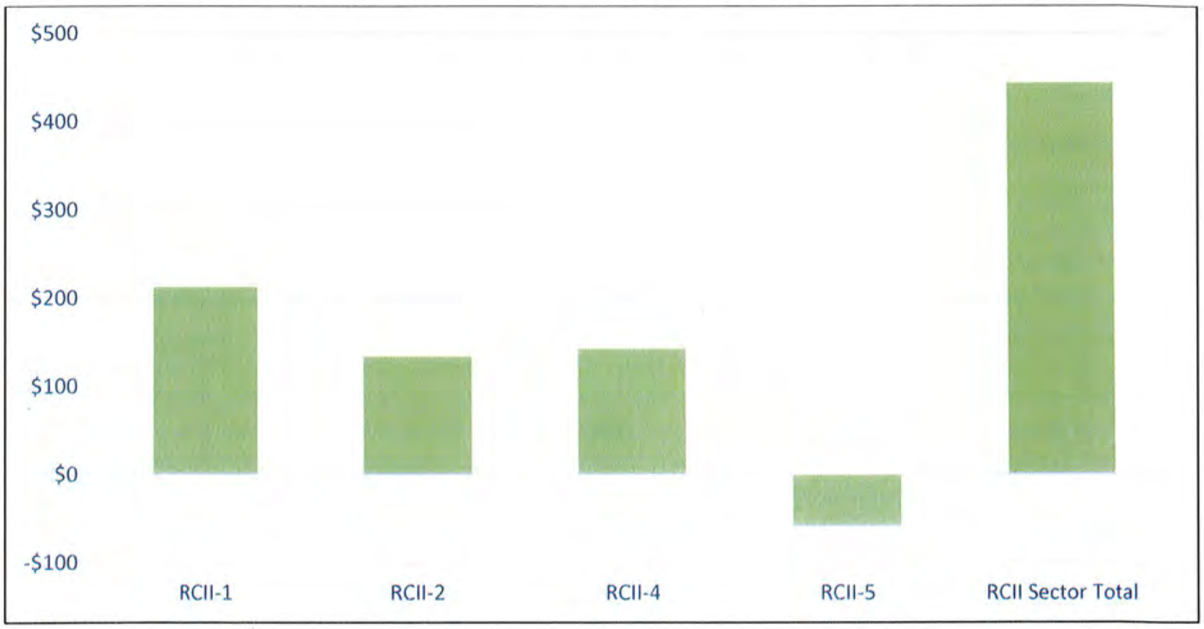


Figure F-2.17 RCII Income Impacts, 2015-2030 ($2015 MM)

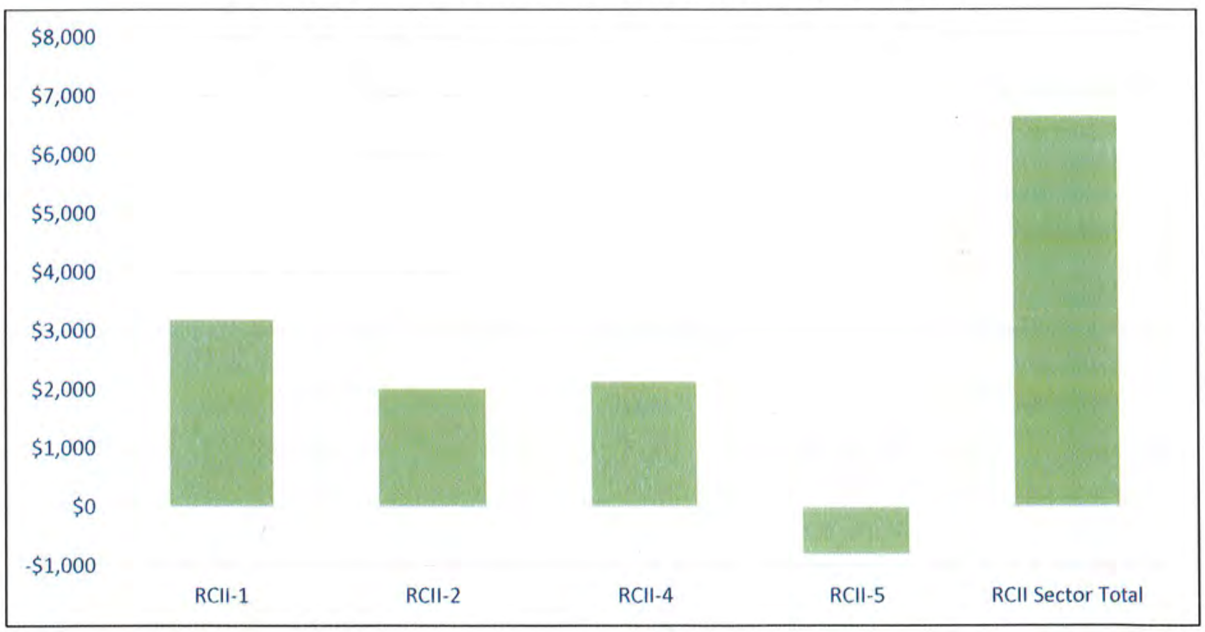
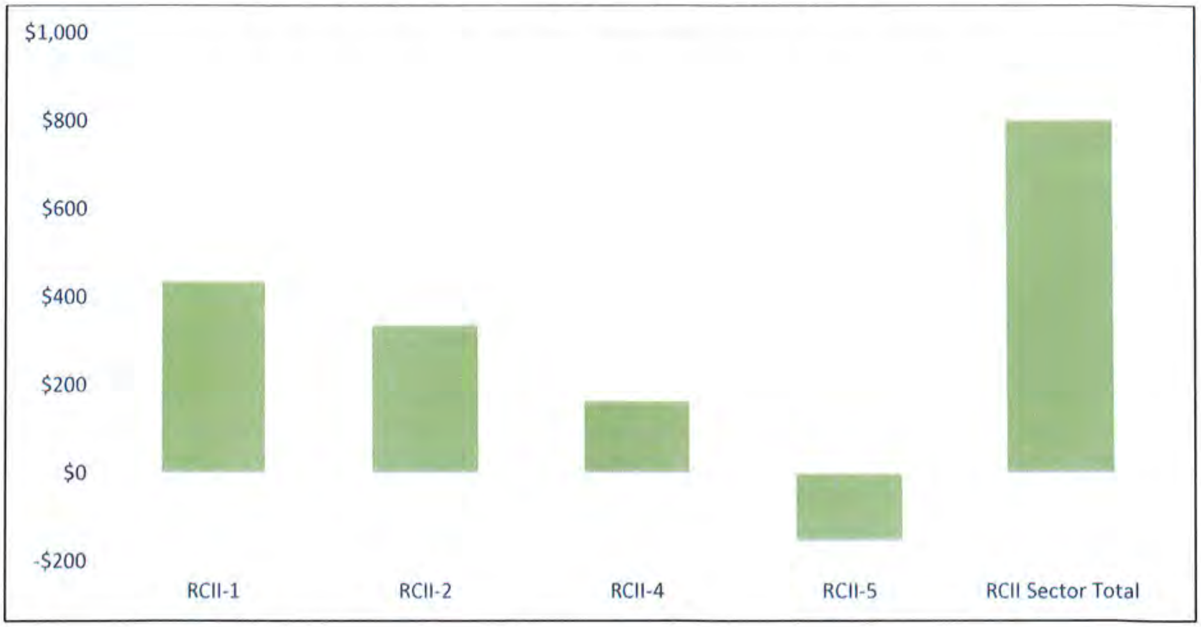


Figure F-2.18 RCII Income Impacts, Year 2030 ($2015 MM)



RCII-1. Combined Heat and Power (CHP) for Natural Gas or Biomass

Policy Option Description

Combined heat and power (CHP) systems reduce fossil fuel use and GHG emissions by recovering heat that is usually wasted as reject heat in power plants for useful purposes (heating buildings, domestic hot water, industrial process heat, or conversion to cooling energy for air conditioning or industrial cooling energy).

Additionally, reductions are achieved both through the improved efficiency of the CHP systems, relative to separate heat and power technologies, and by avoiding transmission and distribution losses associated with moving power from central power stations that are located far away from the point of electricity end use. This policy option description details Minnesota's overarching policy option for Combined Heat and Power. Within this overarching policy option, existing regulatory frameworks are leveraged and new standards developed to be included in other policy option development areas addressing greenhouse gas emissions reductions. As follows:

Conservation Improvement Program (Minnesota Statute 216B.241) – Expand the electricity and natural gas utility CIP goals to promote use of CHP systems, including encouragement of electric or natural gas utility-owned CHP as well as incentives for implementation of non-utility-owned CHP.

Renewable Energy Standard (Minnesota Statute 216B.1691) – Expand the Renewable Energy Standard (RES) to include a specific goal within the RES for currently eligible CHP technologies, and incorporate additional provisions for RES credit to encourage use of biomass for thermal energy production without power production in areas of the state without access to natural gas service.

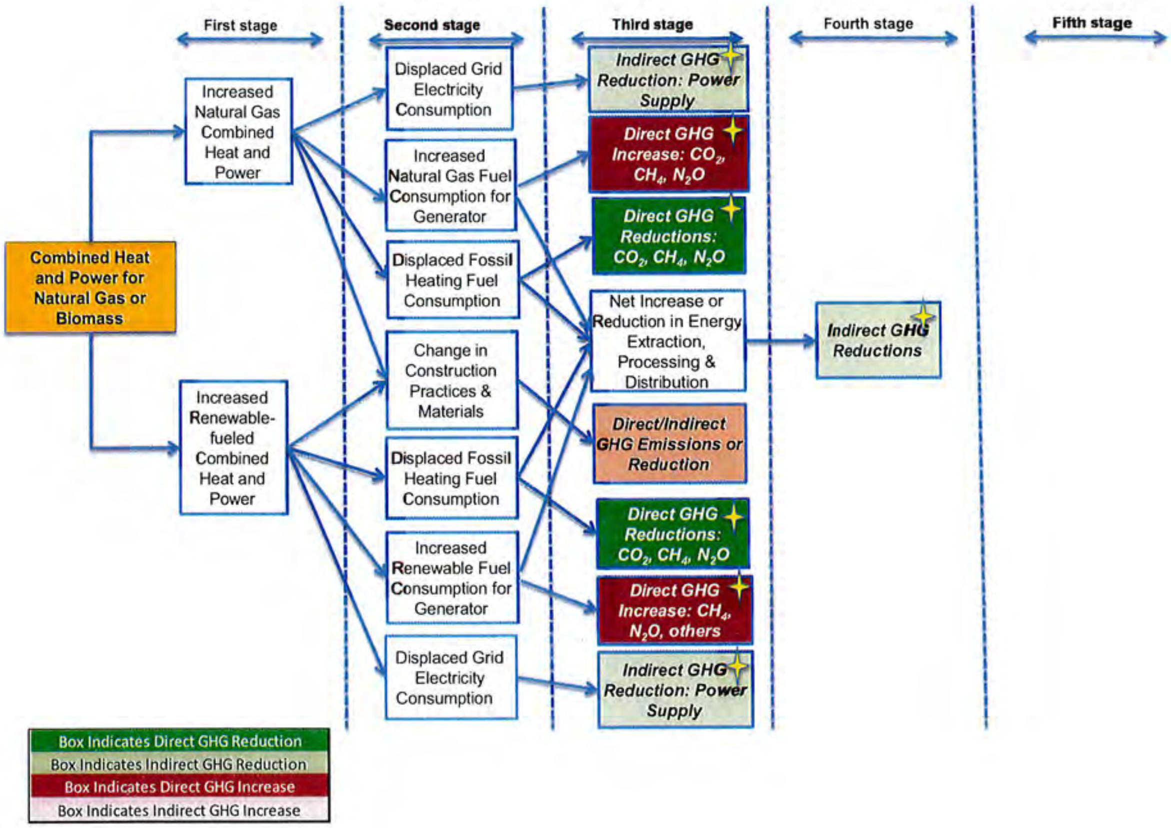
Integrated Resource Planning (Minnesota Statute 216B.2422) – Require electric utilities to demonstrate that, before power-only capacity is proposed, CHP opportunities within their service territory have been thoroughly assessed to determine the benefits of CHP (and associated technologies such as thermal energy storage) relative to existing and planned thermal loads total primary energy efficiency, GHG emissions, power grid resiliency, peak demand management and risk management.

Potential supporting measures for this policy option include technical assistance for utilities and industry to analyze feasibility and apply implementation actions to commercialize high performing CHP and other thermal recovery and advanced clean energy technologies, revision of net metering and standby rate practices, and establishment of clear and consistent interconnection standards.

Causal Chain for GHG Reductions

A schematic causal chain for this policy option is provided below. Increased capacity and use of CHP systems powered with natural gas and with renewable fuels (typically biomass of various types) displaces electricity from the central grid, and, through the use of cogenerated heat, displaces fossil fuels (natural gas, distillate oil, coal, and propane) used for space heat, water heat, and process heat produced in furnaces, boilers, and water heaters. As such, GHG emissions savings accrue through the reduction of central grid electricity supply and fossil fuels formerly used for heating, but these savings are partially offset by emissions from natural gas and renewable fuels combustion in CHP systems. In addition, reduced use of fossil fuel reduces "upstream" emissions associated with, for example, natural gas transmission and distribution, oil refining and transport, and natural gas and crude oil production. It is expected that these GHG emissions reductions and increases will be quantified. Increased use of renewable fuels will produce some increase in emissions associated with fuel processing and transport—for example, diesel-fueled equipment used for biomass harvesting and transport. These additional emissions, however, are highly variable depending on the source of the biomass fuel and the distance it must be shipped to the CHP facility. As a result, these incremental emissions may or may not be quantified, depending on data availability.

Figure F-2.19 Causal Chain for RCII-1 GHG Reductions



Policy Option Design

Table F-2.4 RCII Policy Option Design Goals

CSEO	Policy Option	Goal	Timeline	Details
RCII-1	Combined Heat and Power	CIP (RCII-4): Natural Gas 34TBtu by 2030 Electric 800 MW by 2030 RES (ES-1): 300 MW	2016 - 2030	Includes: All CHP (SEE BELOW)

CSEO	Policy Option	Goal	Timeline	Details
RCII-4	Increase EE Requirement (CIP)	Natural Gas Utility: 1.5% CIP Goal (Include 1% from Demand-side Management only) (Include 34 TBtu output of displaced fossil fuels goal by 2030) Electric Utility: 2.5% Demand-Side Management (1.5% must be DSM as defined in 216B.241) (Include an embedded 800 MW of generated electricity from CHP systems goal to be achieved by 2030)	2016 - 2030 3 Year ramp up period between 2016-2019 Minimum goal for End-Use Efficiency with an embedded CHP goal for electric and natural gas utilities.	Includes: Projects as defined in 216B.241, Subdivision 1 (e) (n) and (o); and Subdivision 10 Natural Gas CHP and distributed generation tech/fuel sources eligible under 216B.2411
ES-1	Increase RES All electric utilities subject to 216B.1691	5% Biomass CHP (300MW)	2015-2030	Includes: Tech/renewable fuel sources eligible under 216B.1691 (and 216B.2411) Minimum efficiency standard of 60%.

Goals: Establish minimum efficiency standards for non-renewable CHP in CIP, as follows:

- At least 20% of its total useful energy in the form of thermal energy which is not used to produce electrical or mechanical power (or combination thereof);
- At least 20% of its total useful energy in the form of electrical or mechanical power (or combination thereof); and
- Total useful energy equal to or greater than 60% of the input fuel energy.

CHP Potential Information

The primary sources for developing this policy option framework are from two Department of Commerce-funded studies prepared by FVB Energy. The two sources include a Regulatory Issues and Policy Evaluation study and a Technical and Economic Potential study. This work was completed in August 2014.

- The Regulatory Issues and Policy Evaluation study can be found on the Department of Commerce web site: http://mn.gov/commerce/energy/images/CHPRegulatoryIssuesandPolicyEvaluation.pdf

- The Technical and Economic Potential study can be found on the Department of Commerce web site: http://mn.gov/commerce/energy/images/CHPTechnicalandEconomicPotential.pdf

CHP Technologies

The primary source for the tables below (Table F-2.5 and Table F-2.6) is the U.S. Environmental Protection Agency Combined Heat and Power Partnership's Catalogue of CHP Technologies published in December 2008 (pages 6&7). The purpose of Table F-2.5 is to demonstrate the eligible CHP technologies and available sizes in the CHP policy option design. The purpose of Table F-2.6 is to demonstrate the different efficiencies, fuel sources, power to heat ratios, as well as other potentially useful variables for modeling the GHG emissions reductions from CHP.

Table F-2.5 Summary of CHP Technologies

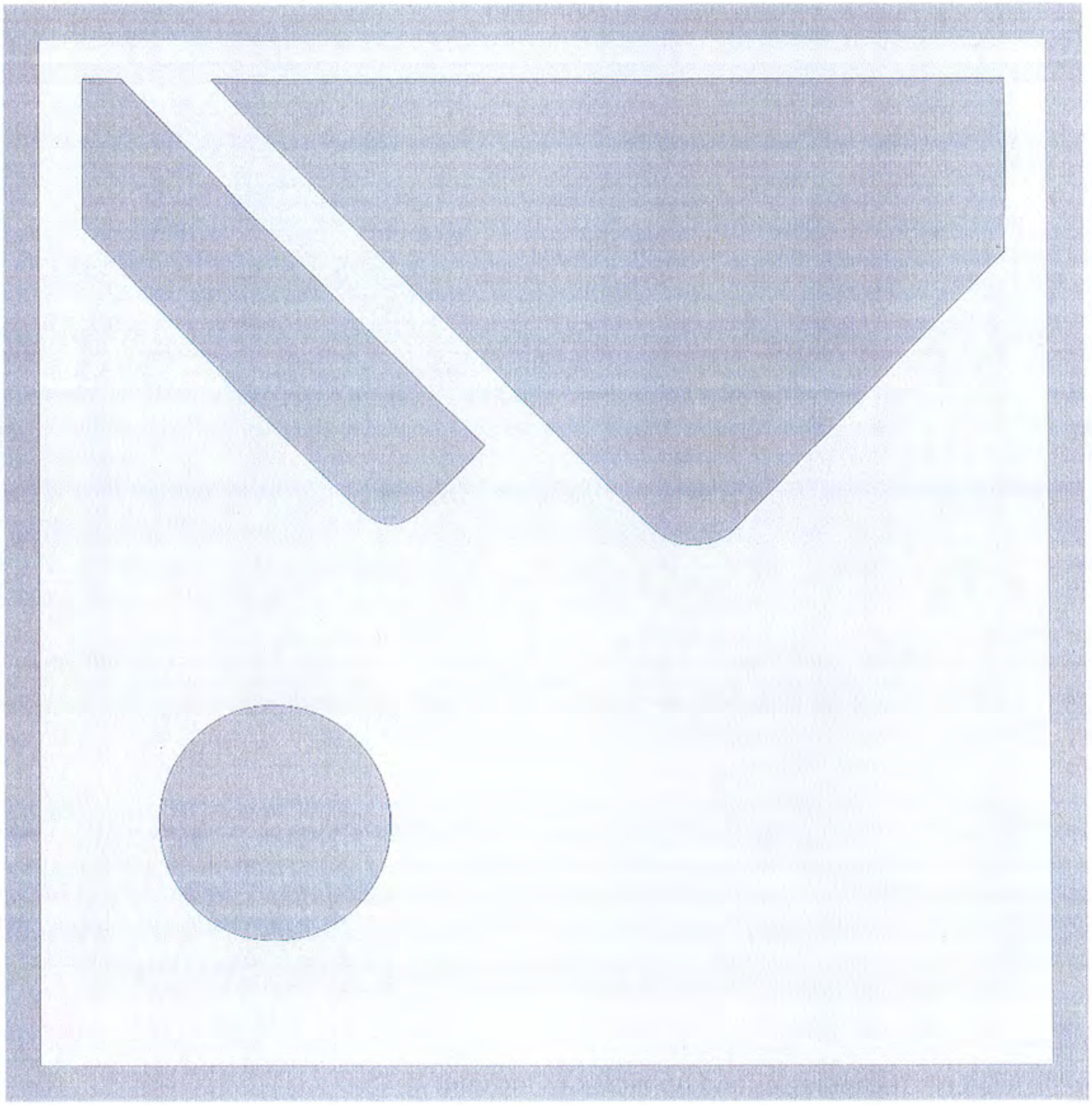
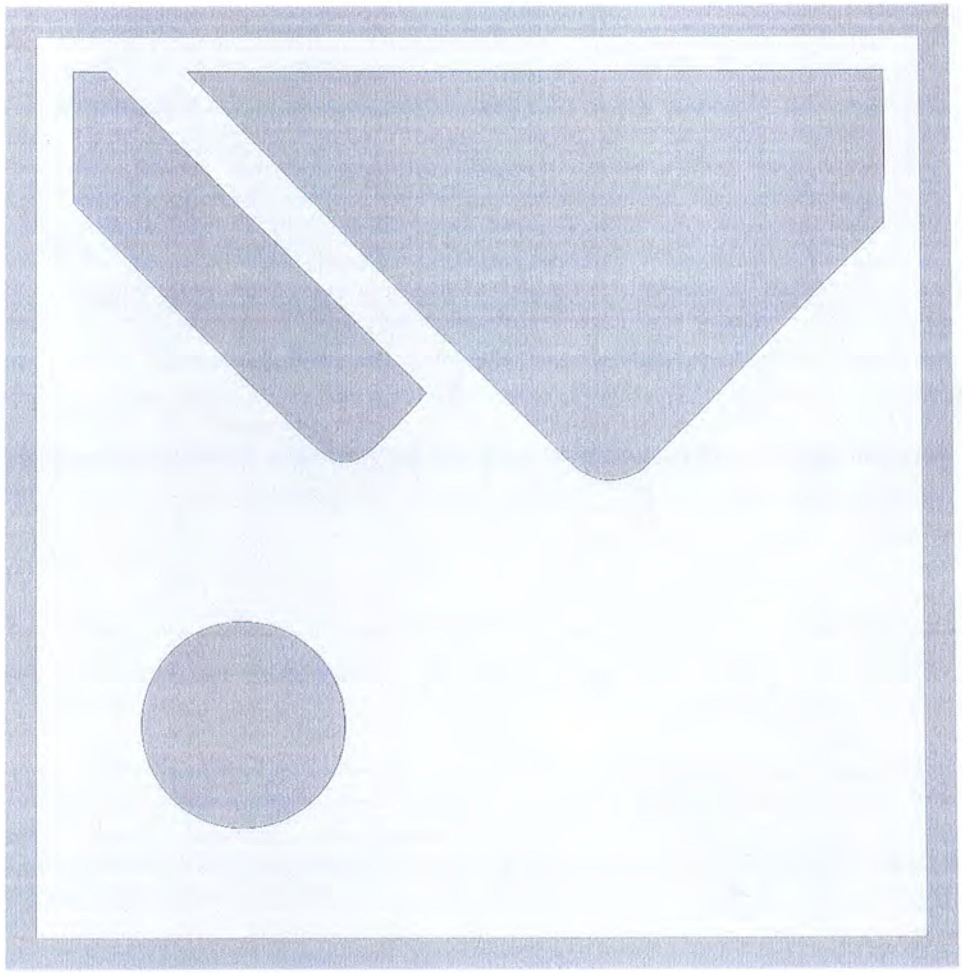


Table F-2.6 Summary Table of Typical Cost and Performance Characteristics by CHP Technology



Other Eligible CHP Technologies and Applications include:

- Waste Heat Recovery Systems
- Absorption/Adsorption Refrigeration Systems
- Thermal/Electric Energy Storage Systems for Load Management
- Emissions Control Systems

Displaced Fossil Fuel Sources: Information regarding Minnesota's energy consumption by source and by sector can be found on the U.S. Energy Information Administration's website (http://www.eia.gov/state/?sid=MN). Assumptions regarding the displaced fossil from CHP systems in different sectors can be made using this information. Below is a list of targeted fossil fuels to be displaced by implementation of the CHP technologies listed above. This list indicates the estimated amount of each fuel used in Minnesota in 2012. Most of these fuels are used to provide space, water, or process heat.[1]

- Natural Gas (Estimated consumption of 427.5 Trillion Btu)
- Coal (Estimated consumption of 257.9 Trillion Btu)
- Distillate Fuel Oil (Estimated consumption of 155.1 Trillion Btu)
- Propane (Estimated consumption of 27.9 Trillion Btu)

CHP Application and Markets: For more information regarding key existing commercial and industrial markets on a national level, and some detail on primary fuels and technologies per each application, refer to ICF International's May 2013 report prepared for the American Gas Association entitled *The Opportunity for CHP in the United States*. It is estimated that most, if not all, of the CHP potential in Minnesota will be achieved through the end uses listed below. The list below demonstrates the types of applications and markets available in Minnesota where the technologies mentioned above could be implemented.

Industrial (More information can be found in Tables 1-2 on pages 11-13 of the above mentioned report):

- Chemicals
- Petroleum Refining
- Pulp, Paper and Printing
- Food Processing
- Rubber/Plastics Manufacturing
- Transportation Equipment Manufacturing

Commercial (More information can be found in Tables 3-4 found on pages 13-16 of the ICF International report mentioned above):

- Colleges/Universities/Schools
- District Energy
- Hospitals/Health Care/Assisted Living/Nursing Care
- Government/Public Facilities
- Prisons
- Multifamily Buildings

[1] The exception here is distillate oil use. In this case, probably only 10-15 percent of total distillate oil used in Minnesota is used to provide heat, as the bulk of distillate oil is used in the form of diesel for vehicle and equipment engines. See, for example, http://www.eia.gov/dnav/pet/pet_cons_821dsta_dcu_nus_a.htm

- Office Buildings
- Hotels

Timing: Assuming any and all legislative solutions to address the policy option design goals are in place by mid-2015, the initiatives underway could begin in 2016 with related rule-making. The timing of this work would extend through 2030.

Parties Involved: Utilities (Subject to regulatory requirements):

Electric and natural gas utilities currently in CIP would be subject to the CIP CHP goals.

Electric utilities would be subject to the Biomass CHP RES.

All utilities subject to resource planning requirements would be required to consider natural gas and biomass CHP in their IRPs.

The prior list of commercial/industrial applications and market sectors may also serve as an indicator of other parties potentially involved in the achievement of the policy option design goals.

Implementation Mechanisms

Regulatory Frameworks

Conservation Improvement Program (CIP):

- Minnesota Statute 216B.241
- Using the CIP framework, establish a specific WHR/CHP goal for electric and natural gas utilities, which includes biomass and natural gas CHP, in addition to the existing conservation and end-use efficiency goal.

Renewable Energy Standard (RES):

- Minnesota Statute 216B.1691
- Using the RES framework, require electric utilities to include a certain percentage of their overall electricity generation from biomass CHP, with the option of crediting qualifying facilities producing only thermal energy.

Integrated Resource Planning:

- Minnesota Statute 216B.2422
- Minnesota Rules Chapter 7843
- Require all utilities subject to the requirements in 216B.2422 to consider both biomass-fired and natural gas CHP in its integrated resource plans.
- Require electric utilities to demonstrate in their Integrated Resource Plans that, before power-only capacity is proposed, CHP opportunities within their service territory have

been thoroughly assessed to determine the benefits of CHP (and associated technologies such as thermal energy storage) relative to total primary energy efficiency, GHG emissions, power grid resiliency, peak demand management and risk management.

Standby Rates and Net Metering:

- Create transparent, concise and easily understandable standby rates so that customers can accurately predict future standby charges and assess financial impacts of CHP.

Renewable Energy Credits:

- When combined heating and power systems use eligible energy technology to generate both electricity and thermal energy for building and/or process heating, allow both electricity and thermal energy to meet the Renewable Energy Standard. One Renewable Energy Credit shall be created for each kWh generated by an eligible energy technology and one Renewable Energy Credit shall be created for each 3,415 British Thermal Units of heat generated by eligible energy technology. Commercial combustion plants that use eligible energy technology to replace the use of fossil fuels to generate thermal energy for building and/or process heating should be eligible to receive one Renewable Energy Credit for each 3,415 British Thermal Units of heat generated.

Financing and Incentive Mechanisms:

Utility:

- Financial incentives from energy savings credit received under Minnesota Statute 216B.16 Subdivision 6c. and 216B.241 Subdivision 2c should be provided to electric and natural gas utilities required to meet CIP CHP requirements.
- A decoupling mechanism should be established for each utility subject to the applicable CHP standard requirements to separate utility revenues from sales and rate design under Minnesota Statute 216B.2412.
- CHP should be an allowable rate-base investment for electric and gas utilities:
- Allow and encourage electric and gas utilities to invest in CHP using their relatively low-cost Weighted Average Cost of Capital, with clear guidelines to avoid utility ratepayer cross-subsidization.
- Allow and encourage electric and natural gas utilities to cooperate to implement CHP projects, with the CIP credit split based on the total financial contribution made by each utility.

Industry:

- CIP incentives should be available for qualifying projects under Minnesota Statute 216B.241.
- CHP incentives should be provided for both capital costs (tied to initial capital cost) and operating costs (tied to actual CHP production).

- Use existing financing options such as St. Paul Port Authority Trillion Btu Program, Guaranteed Energy Savings Program, or others to support CHP project implementation.
- Provide patent protection, R&D tax credits, production subsidies or tax credits to firms bringing new CHP/distributed generation-related/renewable energy technologies to market, tax credits or rebates for new technology buyers, government procurement, and demonstration projects.

Technical Assistance:

Create a ratepayer-funded technical assistance program to help utilities and customers meet the requirements of this policy option design and description. A technical assistance program should offer engineering and financial expertise to help end-users determine the viability of CHP projects and provide tools/resources to help begin the implementation of CHP projects. The funding mechanism and amount should be sourced appropriately and proportionately to the standards being met.

Related Policies/Programs in Place and Recent Actions

To achieve the goals set in this policy option recommendation, existing regulatory frameworks are leveraged and new standards developed to be included in other policy option development areas addressing greenhouse gas emissions reductions. As follows:

Conservation Improvement Program (Minnesota Statute 216B.241) – Expand the electricity and natural gas utility CIP goals to promote use of CHP systems, including encouragement of electric or natural gas utility-owned CHP as well as incentives for implementation of non-utility-owned CHP.

Renewable Energy Standard (Minnesota Statute 216B.1691) – Expand the Renewable Energy Standard (RES) to include a specific goal within the RES for currently eligible CHP technologies, and incorporate additional provisions for RES credit to encourage use of biomass for thermal energy production without power production in areas of the state without access to natural gas service.

Integrated Resource Planning (Minnesota Statute 216B.2422) – Require electric utilities to demonstrate that, before power-only capacity is proposed, CHP opportunities within their service territory have been thoroughly assessed to determine the benefits of CHP (and associated technologies such as thermal energy storage) relative to existing and planned thermal loads total primary energy efficiency, GHG emissions, power grid resiliency, peak demand management and risk management.

Estimated Policy Impacts

Direct Policy Impacts

Summary in-state (direct) GHG emissions reduction and option costs results for RCII-1, "Combined Heat and Power (CHP) for Natural Gas or Biomass", are provided in the table below. These values include costs for program administration. Negative values are shown in parentheses. In the "Net present value of societal costs" column, negative values, and denote instances where the costs of the implementing option (or part of the option) are LESS than the direct economic benefits of the option in avoided energy and other costs. Negative values in the "cost effectiveness" column indicate that there is a net direct economic benefit per metric ton of carbon dioxide equivalent saved. Overall, this option results in 4.87 million metric tons (MMt in the table below) of annual CO_2e savings in 2030, with about 46 million metric tons of CO_2e savings over the analysis period. Somewhat more than half of the savings comes from implementation of natural gas CHP systems. In addition to these in-state reductions, RCII-1 produces an estimated 0.39 $MMtCO_2e$ of out-of-state (upstream) emissions reductions in 2030, and 3.26 $MMtCO_2e$ in cumulative out-of-state reductions from 2015-2030, yielding total 2030 emissions reductions of 5.26 $MMtCO_2e$ in 2030, and 49.71 $MMtCO_2e$ over 2015-2030.

Table F-2.7 RCII- 1 Estimated Net GHG Reductions and Net Costs or Savings

	2030 GHG reductions ($MMtCO_2e$)	2015 – 2030 cumulative reductions ($MMtCO_2e$)	Net present value of societal costs, 2015 – 2030 (million $2014)	Cost effectiveness ($2014/t CO_2e)
Expanded Natural Gas-fueled CHP Implementation	2.55	25.09	$(771.03)	$(31.21)
Expanded Renewable-fueled CHP Implementation	2.32	21.37	$(340.48)	$(13.62)
TOTAL	4.87	46.46	$(1,111.50)	$(22.36)

Notes: Each policy option analysis was done over a fifteen year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

Data Sources

In addition to the USEPA documents referenced above, see notes in "Key Assumptions", below.

Quantification Methods

The quantification of this option is carried out using the following step-wise process:

- Quantification begins by interpreting the goals for additional MW of gas-fired and renewable (mostly biomass)-fueled CHP to be implemented in each program year.
- Next, assumptions are made regarding the average electricity generation efficiency, useful heat production efficiency, and average capacity factors of the CHP systems implemented. Settling on these factors required identifying representative types of CHP systems (for example, steam-cycle, micro-turbine, reciprocating systems, and other) and representative types of applications in the end-use sectors in Minnesota.
- The goals and CHP technical assumptions as above are used to calculate the amount of available heat that the CHP systems will produce, along with the amount of electricity generated.
- A combination of assumptions regarding the fraction of fuels displaced, by sector (industrial, commercial, and possibly residential), based on Minnesota state consumption of fuels by sector, plus estimates of the average efficiency of heat production using those fuels (at typical furnace/boiler efficiencies) that are displaced, taking into account technologies in use in Minnesota, are used to calculate the amount of fossil fuel use displaced by fuel type. This also requires an estimate of the fraction of cogenerated heat actually used to displace heating fuel use.
- The annual amounts of electricity generated, factoring in transmission and distribution (T&D) losses avoided by using distributed generation, are multiplied by a representative statewide GHG emission factor for marginal avoided generation (a combination of emissions mostly from natural gas-fired and coal-fired units, given that nuclear energy is unlikely to be displaced by CHP output) to yield an estimate of avoided emissions from electricity generation.
- The annual amounts of heating fuel use displaced, by type of fuel, are multiplied by emission factors for each fuel type to estimate reductions in emissions of GHGs from displaced heating fuel use.
- The annual amounts of natural gas and renewable fuels used to fuel the CHP systems are multiplied by appropriate emission factors to estimate the emissions associated with the CHP systems themselves, which are netted out against GHG emission savings from the two steps above.
- A stream of future avoided costs of electricity generation is used to estimate the value of the electricity from the central grid displaced by CHP output.
- Estimates of future costs for natural gas and other fossil fuels, derived in part from United States Department of Energy (DOE) projections, are used to estimate the value/cost of inputs to gas CHP and avoided fossil fuel use from displaced heat demand.
- Estimates of the representative future costs of renewable fuels (biomass) for CHP generation are used to calculate the fuel cost of renewable CHP systems.

- Representative average capital and non-fuel operating and maintenance (O&M) costs of CHP systems are used to estimate the additional cost of buying and using CHP systems.
- Representative average capital and non-fuel operating and maintenance (O&M) costs of displaced boiler and furnace systems are used to estimate the avoided cost of buying and using these heat-only systems.
- Full energy cycle GHG emissions for new and avoided fossil-fuel consumption are calculated through the application of representative upstream emission factors. For renewable fuels, a single set of emission factors, derived as a part of the analysis of forestry and land use (FOLU) options, are used to estimate direct emissions, but these factors also incorporate Minnesota-specific studies of the GHG emissions associated with biomass fuel provision as well as combustion.

Key Assumptions

In addition to the goals described above, key assumptions used in the analysis of RCII-1, as reflected in the listing of analytical steps in the previous section of this document, include:

- Fraction of CHP deployment goals above achieved over the analysis period are assumed to be as follows: 2016-2020—37.5%, 2021-2025—37.5%, 2026-2030—25%.
- The fraction of gas-fired CHP capacity by type of technology was assumed to be as shown in the table below, based on input from FVB Energy staff. All biomass-fired CHP was assumed to use steam-cycle technology.

Table F-2.8 Fractions of Gas-Fired CHP Capacity by Type Deployed by Sector

Fractions of gas-fired CHP capacity by type deployed by sector

	Steam Turbine	Reciprocating Engine	Gas Turbine	Microturbine	Fuel Cells
Residential	0%	10%	0%	90%	0%
Commercial	5%	75%	20%	0%	0%
Industrial	30%	20%	50%	0%	0%

Average capacity factors, electricity generation efficiencies, heat generation efficiencies, and assumed fraction of CHP heat output used by type of CHP systems are as described in the tables below, based on a combination of data from the EPA documents described above, the *Minnesota Combined Heat and Power Policies and Potential: Conservation Applied Research & Development (CARD) FINAL REPORT*, dated July 2014, and the judgment of analysts and Minnesota Agency Staff.

Table F-2.9 Average Gas-fired CHP Performance Assumptions

Average Gas-fired CHP Performance Assumptions

	Steam Turbine	Reciprocating Engine	Gas Turbine	Microturbine	Fuel Cells
Electricity Generation Efficiency	28%	34.9%	33.8%	23%	45%
Heat Production Efficiency	52%	43.6%	36.6%	47%	30%
Total Fuel-to-output Efficiency	80%	78.5%	70.4%	70%	75%

Table F-2.10 Average Renewables-fired CHP Performance Assumptions

Average Renewables-fired CHP Performance Assumptions

Electricity Generation Efficiency	26%
Heat Production Efficiency	50%
Total Fuel-to-output Efficiency	76%

Table F-2.11 Average CHP Annual Capacity Factor and Heat Use Fraction Assumptions

Average CHP Annual Capacity Factor and Heat Use Fraction Assumptions

	Capacity Factor		Fraction of Heat Output Used	
	Gas-fired	Renewable-fired	Gas-fired	Renewable-fired
Residential	40%	40%	70%	70%
Commercial	70%	70%	90%	90%
Industrial	85%	85%	90%	90%

- The fractions of CHP heat displacing specific fuel types (coal, gas, propane, distillate fuel) by sector are based on the proportion of each fuel that is forecast to be used in each sector. Natural gas represents approximately 80 to 90 percent of the fuel displaced.
- Average boiler/furnace efficiencies for heat displaced by CHP heat are 86% for both the commercial/institutional and industrial sectors.[2]
- Estimated avoided marginal emission factors for electricity generation, on a delivered basis, falls from 0.936 tCO_2e per MWh in 2015 to 0.758 in 2030, with avoided costs of electricity generation (again based on delivery to consumers, that is, factoring in transmission and distribution losses) rising from $92.6 to $148.1 per MWh delivered (nominal dollars) over the same time period. Natural gas avoided (wholesale) costs rise from $4.78 to $8.97 per GJ (again nominal dollars) over the same time period.

[2] Average boiler and furnace efficiencies based on an estimate from Minnesota Agency Staff.

- Avoided costs for other fossil fuels used for heating, the use of which is displaced by CHP, are as defined in the Common Assumptions used across all sectors in the analysis of GHG Mitigation options for Minnesota.
- Wholesale costs of biomass fuels rise from $2.96/GJ in 2015 to $6.73/GJ in 2030 (nominal dollars).
- CHP capital and O&M costs by type of CHP system and by sector, are as presented in the tables below for gas-fired and biomass-fired systems, respectively. Costs are derived from several sources, including the EPA documents described above and *Minnesota Combined Heat and Power Policies and Potential: Conservation Applied Research & Development (CARD) FINAL REPORT,* dated July 2014, provided by Minnesota Agency Staff.

Table F-2.12 CHP Capital and Operating Cost Calculations

CHP CAPITAL AND OPERATING COST CALCULATIONS

Average Gas-fired CHP Cost Assumptions by System Type (cost figures assumed $2014)

	Parameter	Steam Turbine	Reciprocating Engine	Gas Turbine	Microturbine	Fuel Cells
Residential and Commercial/ Institutional Applications	Capial Cost ($/kW)	$ 1,800	$ 3,606	$ 2,334	$ 3,000	$ 5,000
	Variable Non-fuel O&M Cost ($/MWh)	$ 5.00	$ 21.81	$ 11.72	$ 20.00	$ 35.00
	Fixed O&M Costs ($/kW-yr)	$ -			$ -	$ -
	Lifetime (years)	30	15	20	20	20
	Interest Rate (%/yr)	5.0%	5.0%	5.0%	5.0%	5.0%
	Annualized Capital Payment ($/kW)	$ 117.09	$ 347.41	$ 187.30	$ 240.73	$ 401.21
Industrial Applications	Capial Cost ($/kW)	$ 1,200	$ 3,352	$ 1,792	$ 3,000	$ 5,000
	Variable Non-fuel O&M Cost ($/MWh)	$ 5.00	$ 19.56	$ 8.44	$ 20.00	$ 35.00
	Fixed O&M Costs ($/kW-yr)	$ -			$ -	$ -
	Lifetime (years)	30	15	20	20	20
	Interest Rate (%/yr)	5.0%	5.0%	5.0%	5.0%	5.0%
	Annualized Capital Payment ($/kW)	$ 78.06	$ 322.97	$ 143.82	$ 240.73	$ 401.21

Table F-2.13 Average Renewables-fired CHP Cost Assumptions (Cost Figures Assumed $2014)

Average Renewables-fired CHP Cost Assumptions (cost figures assumed $2014)

	Commercial/ Institutional	Industrial
Capial Cost ($/kW)	$ 4,551	$ 3,761.21
Variable Non-fuel O&M Cost ($/MWh)	$ 30.45	$ 23.84
Fixed O&M Costs ($/kW-yr)	$ -	$ -
Lifetime (years)	25	25
Interest Rate (%/yr)	5.0%	5.0%
Annualized Capital Payment ($/kW)	$ 322.90	$ 266.87

Boiler/furnace capital and O&M costs avoided by the application of CHP systems, by type and sector, are as follows, based on estimates from various sources.

Table F-2.14 Average Fossil-fired Heating Source Cost Assumptions (Cost Figures Assumed $2014)

Average Fossil-fired Heating Source Cost Assumption

Parameter	Residential	Commercial	Industrial
Capial Cost ($/(MMBtu/hr))	$ 25,000	$ 15,000	$ 10,000
Variable O&M Costs ($/MMBtu output)	$ 1.00	$ 1.50	$ 1.50
Lifetime (years)	20	20	20
Interest Rate (%/yr)	5.0%	5.0%	5.0%
Annualized Capital Payment ($/(MMBtu/hr))	$ 2,006.06	$ 1,203.64	$ 802.43

- GHG Emission factors for natural gas, coal, oil products, and wood, as well as upstream fuel cycle GHG emission factors for natural gas, coal, and petroleum products, and biomass fuels are as defined in the Common Assumptions used across all sectors in the analysis of GHG Mitigation options for Minnesota.
- Administrative costs are estimated based on the assumptions that a CHP program sponsor will provide incentives equal in value to 40 and 25 percent of CHP system capital costs for the commercial/institutional and industrial sectors, respectively, and that administrative costs (marketing, accounting, customer service, evaluation, etc.) will be 15 and 10 percent of incentive costs for the commercial/institutional and industrial sectors, respectively.

Macroeconomic (Indirect) Policy Impacts

Table below provides a summary of the expected impacts on jobs and economic growth during the CSEO planning period.

Table F-2.15 RCII-1 Macroeconomic Impacts on GSP, Employment and Income

Scenario	Gross State Product (GSP, $2015 Millions)			Employment (Full & Part-Time Jobs)			Income Earned ($2015 Millions)		
	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)
RCII-1	$508	$202	$3,026	3,840	2,330	35,020	$434	$213	$3,191

Following three graphs below show detail in GSP, employment and personal income impact of the RCII-1 policy.

Figure F-2.20 RCII-1 GSP Impacts ($2015 MM)

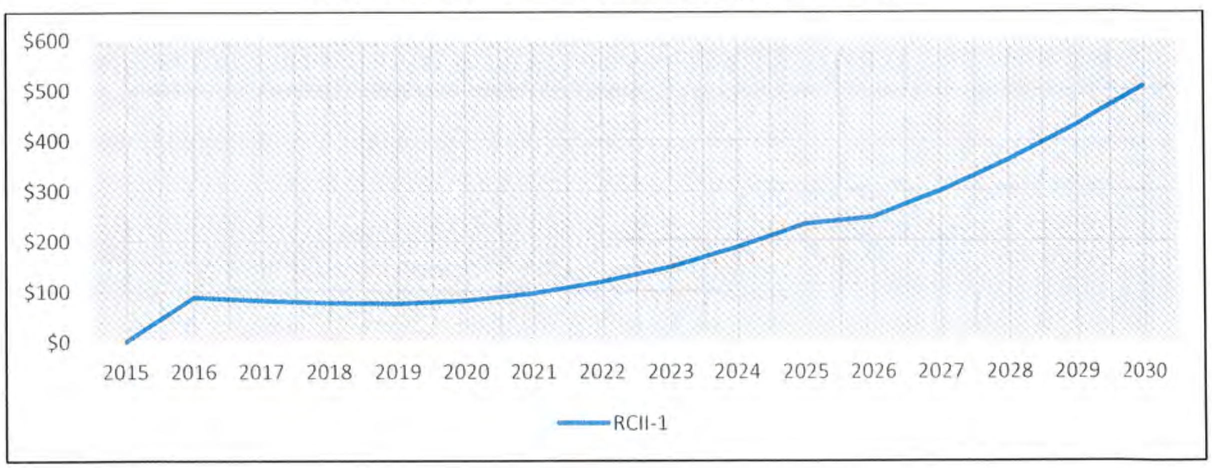


Figure F-2.21 RCII-1 Employment Impacts (Individual Jobs)

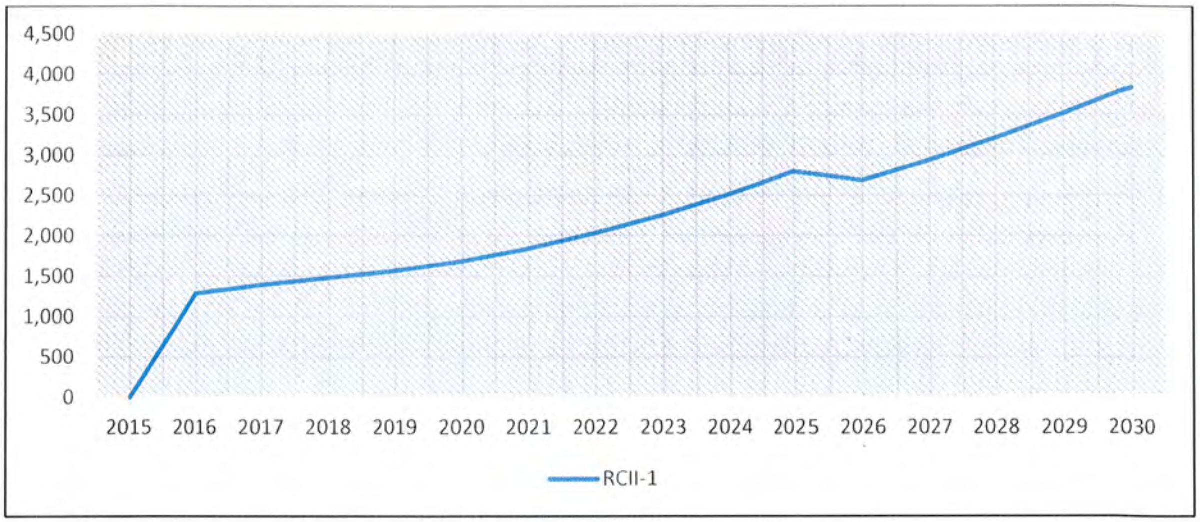
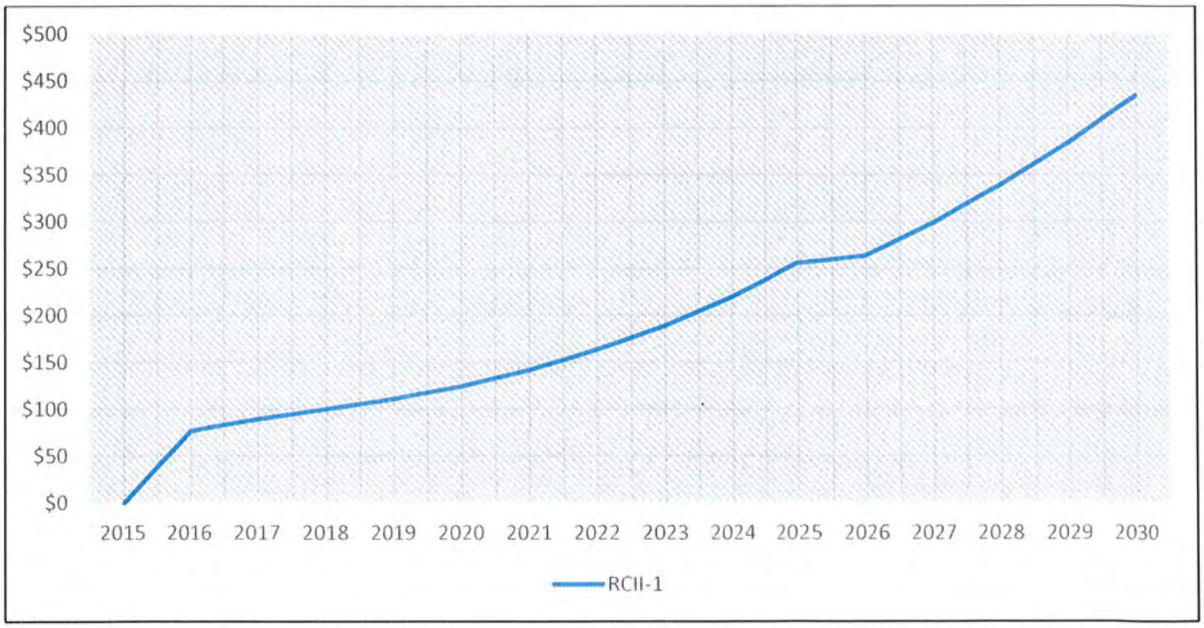
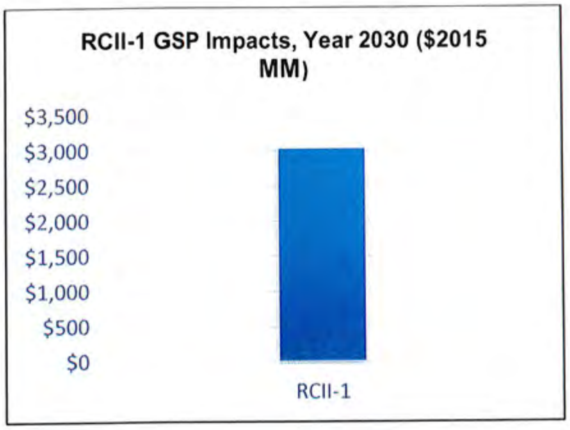
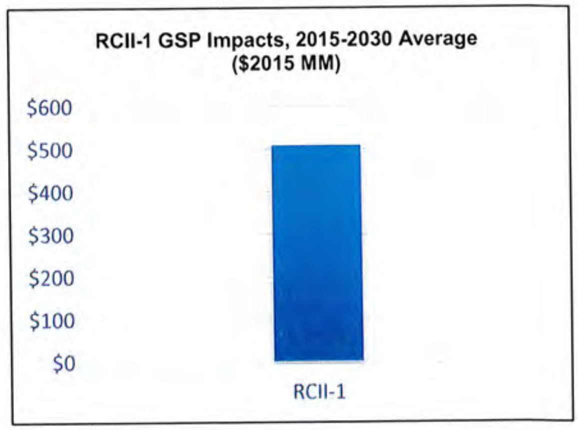


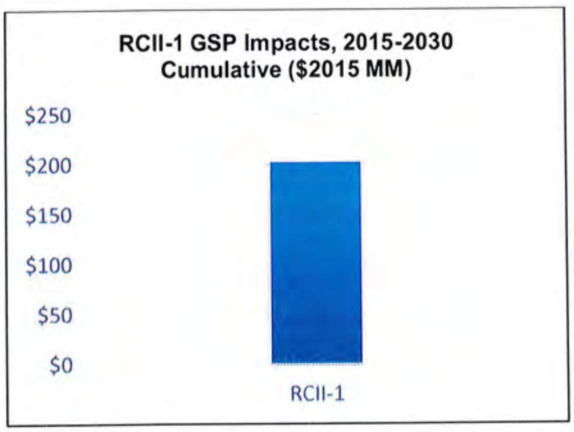
Figure F-2.22 RCII-1 Income Impacts ($2015 MM)

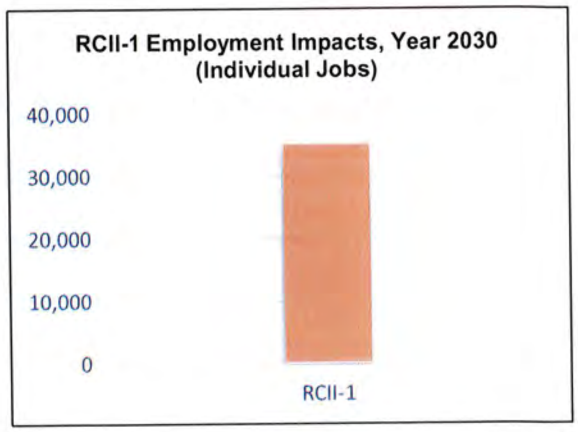


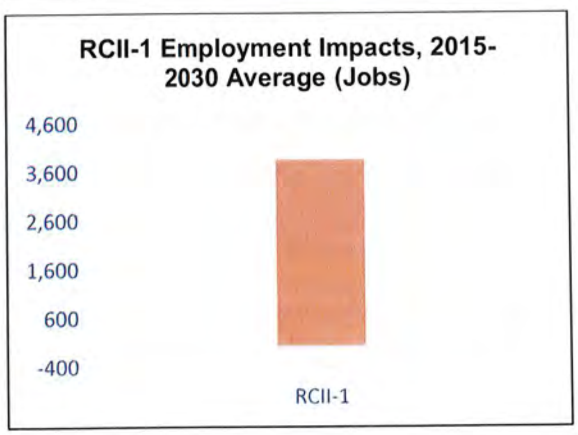
Bar charts below show macroeconomic impacts on GSP, personal income, and employment in the final year (2030), in average (2015-2030) and in cumulative (2015-2030). Light color means sensitivity scenarios.

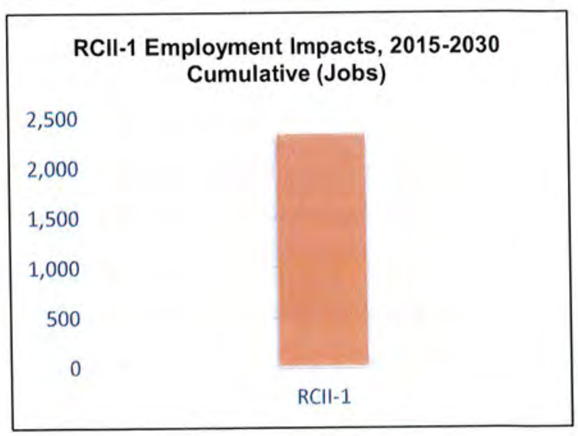

RCII-1 GSP Impacts, Year 2030 ($2015 MM)
$3,500
$3,000
$2,500
$2,000
$1,500
$1,000
$500
$0
RCII-1

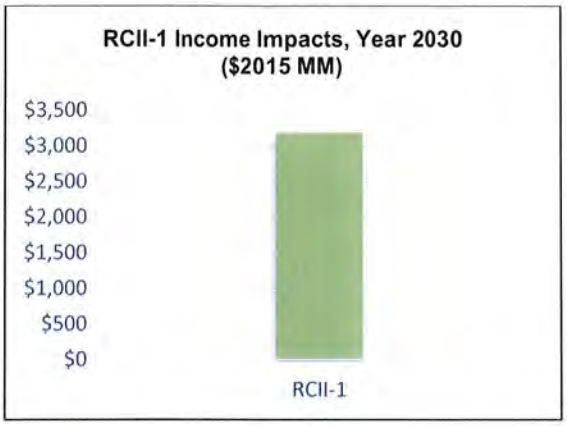

RCII-1 GSP Impacts, 2015-2030 Average ($2015 MM)
$600
$500
$400
$300
$200
$100
$0
RCII-1

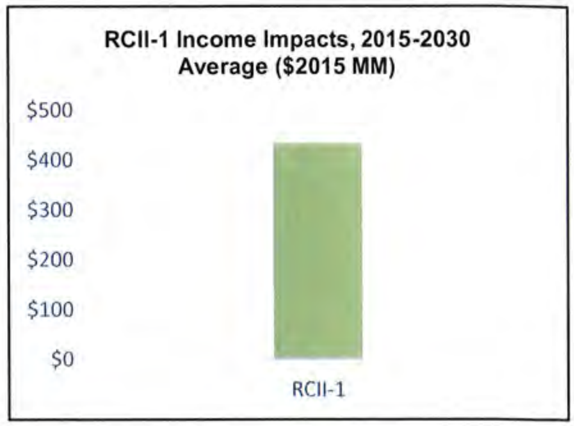

RCII-1 GSP Impacts, 2015-2030 Cumulative ($2015 MM)
$250
$200
$150
$100
$50
$0
RCII-1

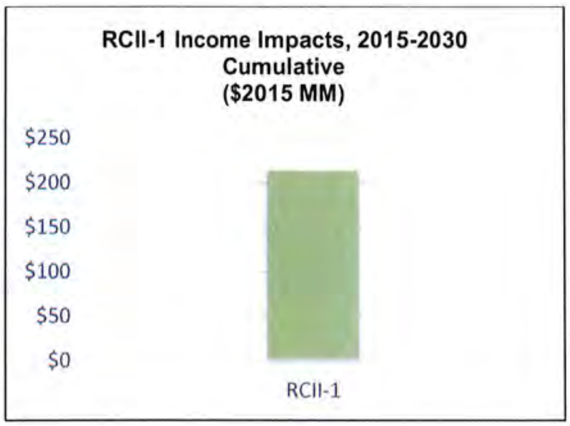

RCII-1 Employment Impacts, Year 2030 (Individual Jobs)
40,000
30,000
20,000
10,000
0
RCII-1


RCII-1 Employment Impacts, 2015-2030 Average (Jobs)
4,600
3,600
2,600
1,600
600
-400
RCII-1


RCII-1 Employment Impacts, 2015-2030 Cumulative (Jobs)
2,500
2,000
1,500
1,000
500
0
RCII-1







Principal Drivers of Macro-Economic Changes

The principal drivers of macroeconomic change are a significant savings in energy requirements by the industries and facilities that adopt CHP generation to produce both heat and power. While CHP units require large amounts of natural gas and biomass (both assumed to be utilized as fuel), the reductions in the use energy from other sources, such as conventional power and heat from coal and natural gas, or on-site power from diesel, coal or gas, far outweigh the requirements to run CHP. These savings reach hundreds of millions of dollars' worth of energy costs by 2030.

A second major driver is the spending on the construction and machinery involved in installing CHP generation. While this cost is borne over time by the entities putting them in place (a burden that applies a downward pressure on economic activity), the stimulus to the productive sectors that provide that construction and machinery drives growth. The ability of entities to finance the capital cost protects the economy from a sudden dislocation, so the spending stimulus happens quickly and the technological efficiency shift is put in place in time for the economy to benefit from both while absorbing the cost over time of the capital installation.

The state does spend money on administration of this policy as well, though it displaces other state spending. Both are similarly labor-intensive, within the assumptions of this analysis, and this is only a minor influence by comparison to those described above.

Sectors of Economy Most Affected by the Policy

Economic impacts from policies run around the economy, affecting sectors that are sometimes far from the direct target of a policy.

For RCII-1, the largest losses are direct: the utilities sector sees less demand because a more efficient economy requires less energy to generate the same level of activity and prosperity. As a result, total demand for that sector falls, and it spends less on the inputs to its production (fuel, operations and maintenance, labor and other inputs). This sector sees a drop in direct employment of about 300 positions by 2030 (against a total policy gain of around 4,000 positions in the same year).

The gains, as is common in an efficiency policy, are indirect: less spending over time on energy frees up money for other inputs, and business operating costs fall. This frees up money for other spending and applies a downward pressure to prices as well – which in turn frees up cash for purchasers and creates a positive income effect. The sectors that grow the most are consumer-oriented (apparel sales, educational services, restaurants and health care) as well as energy-related (natural gas and biomass both see increase in demand, as do associated transportation sectors). Efficiency gains also spread small boosts across nearly all the other sectors of the economy.

Data Sources

The principal data sources for the macroeconomic impacts analysis of this and all other policies in the CSEO process are the direct spending, saving, cost and price impacts developed as part of the microeconomic (direct impacts) analysis. For each policy, the cost-effectiveness analysis described above develops year-by-year estimates of the costs, savings prices, and changes demand or supply that households, businesses and government agencies are expected to encounter in a scenario where the policy is implemented as designed.

A secondary data source is the policy design. Balancing financial flows for each direct impact identified are established based on understanding the implementation mechanism, and quantitative values for these flows are developed for each direct impact identified. This balancing identifies and quantifies the responsive change that occurs as a result of the direct impact in question. For example, if a household is anticipated to save $100 per year on electricity bills as a result of a policy, the direct impact is a $100 savings to the household (which expands its spending capacity for other things) but the balancing impact is a $100 loss in revenue and demand to the utility provider (which reduces its ability and need to spend on labor, capital, profit, and other inputs). The quantitative measure of both sides of a change is of importance to a complete macroeconomic analysis. This balancing ensures that both the supply and the demand side of each economic change is fully represented in the analysis.

A third data source is direct communication with Minnesota agency staff and others involved in policy design or in a position to understand in detail the financial flows involved in the policy. These people assisted in clarifying the nature of economic changes involved so that the modeling and analysis would be accurate.

The final crucial data source is the baseline and forecast of economic activity within the REMI software. This data is compiled into a scenario that is characterized not only by the total size of the economy and its many consuming and producing sectors, but also the mechanisms by which impacts in one sector can change the broader economy – such as intermediate demands, regional purchase coefficients, and equilibria around price and quantity, labor and capital, and savings and spending, to name a few of many. REMI, Inc. maintains a full discussion of all the sources of the baseline data on its own website, www.remi.com.

In the case of the RCII-1 policy, important data included:

- The capital cost to industrial and commercial entities that install CHP generation units, and the timing over which those costs would be incurred.
- The total volumes, and total spending on those volumes, of each type of energy consumed – both those sources reduced as a result of the switch to CHP from other heat or power sources and those sources increased to fuel the CHP units.
- The operating and maintenance costs associated with the entities' adoption of and operation of the CHP units.
- The costs to state government agencies to oversee and implement this policy.

Quantification Methods

Utilizing the data developed from the microeconomic analysis, CCS analysts established for each individual change the following characteristics:

- The category of change involved (change in spending, savings, costs, prices, supply or demand)
- The party involved on both sides of each transaction
- The volume of money involved in this change in each year of the period of analysis

These values, so characterized, were then processed into inputs to the REMI PI+ software model built specifically for use by CCS and consistent with that in use by state agencies within Minnesota. These inputs were applied to the model and run. Key results were then drawn from the model and processed for consistency of units and presentation before inclusion in this report.

Key Assumptions

The macroeconomic impact analyses of this policy, as well as of the others in the CSEO process, rely on a consistent set of key assumptions:

- State and local spending is always budget-constrained. If a policy calls for the state or local government to spend money in any fashion, that spending must be either funded by a new revenue stream or offset by reductions in spending on other programs. Savings or revenues collected by the government are also expected to be returned to the economy as spending in the same year as they are collected.
- Federal spending is not budget-constrained. The capacity of the federal government to carry out deficit spending means that no CSEO policy is held responsible for driving either an increase or decrease in federal tax spending by businesses or households in the state of Minnesota.
- Consumer spending increases are sometimes financed. Small-scale purchases or purchases of consumer goods are treated as direct spending from existing household cash flows (or short-term credit). Durable goods, home improvements or vehicle purchases, however, are treated as financed. Consumers were assumed to spread out costs based on common borrowing time frames, such as five years for financing a new vehicle or 10-20 years for home improvements that might be funded by home-equity or other lending. The assumption of financing and the term of years applied was considered anew in each case.
- Business spending increases are often financed. Where spending strikes a sector which routinely utilizes financing or lines of credit to ensure steady payment of recurring costs, significant spending of nearly any type was considered a candidate for financing, thus allowing costs to spread out over time. This methodology is preferable for the modeling work, as sudden spikes or dips in business operating costs can show up as volatility when the scenario may depict a managed adoption of new equipment in an orderly fashion. The assumption of financing and the term of years applied was considered anew in each case.
- Unless otherwise stated, all changes to consumer spending or to the producers' cost of producing goods and services were treated in a standard fashion. Consumers are assumed to spend on a pre-set mix of goods, services, and basic needs, and businesses spend (based on their particular sector of the economy) on a mix of labor, capital, and intermediate demands from other sectors. Unless a policy specifically defines how a party will react to changes in cost, price, supply or demand, these standard assumptions were applied.

State and local spending gains and reductions driven by policy are assumed to apply to standard mixes of spending. Again, unless a policy specifically states that a government entity will draw from a specific source or direct savings or revenues to a specific form of spending, all gains and losses were assumed to apply to a standard profile of government spending within the economy.

Key Uncertainties

There are a few key uncertainties that should be considered in the development and implementation of this proposed policy option:

- If Minnesota stakeholders are resistant to including CHP in the EERS and RES, is there a viable alternative to create an Alternative Energy Portfolio?
- How will stand-by rates and net metering practices need to be modified to facilitate greater implementation of CHP?
- What kind of expenditures will be required of utilities and ratepayers to provide incentives and programs aimed toward achieving the CHP standard?
- What impact will changing electric and natural gas prices have on the long-term operating costs for CHP projects?
- In achievement of the CHP standard, how will ratepayer cross-subsidization of incentivizing projects be avoided or managed?
- In the absence of an existing CHP technical assistance program for potential projects, how the state and its utilities drive demand for customer on-site generation?
- How could CHP be used as resource in the future to comply with pending EPA regulations from the Clean Power Plan (111(d))?

Additional Benefits and Costs

Only 42% of the total energy consumed in Minnesota is converted to useful energy. Of the total 1,817 trillion Btu (TBtu) of energy used in Minnesota:

- 384 TBtu was lost in electricity generation, transmission and distribution, resulting in an average power sector efficiency of only 32%;
- 229 TBtu was lost the Residential, Commercial & Industrial sectors (RCI) in converting RCI primary energy or electricity to useful energy services; and
- 434 TBtu was lost in transportation, primarily due to inefficiencies in cars.

In 2008, the total 384 TBtu of wasted energy in the power sector are estimated to consist of 12 TBtu of electrical line losses[3] and 372 TBtu of waste heat. This power generation waste heat in Minnesota is nearly equal to the total requirement for heat energy in the RCI sectors (390 TBtu).[4]

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[3] Assumes 7.0 percent transmission/distribution losses.

[4] Assumes 90 percent of RCI primary energy is for heat production and is converted to useful energy at an average efficiency of 70 percent.

Given that the majority of the fuel sources in Minnesota are imported, any waste heat recovered for thermal distribution or electric generation would offset the fossil fuels that are currently imported into the state, potentially having a positive impact on Minnesota's economy.[5]

Additional Economic Benefits Could Include:

- Job creation from implementation of CHP technology
- Increased innovation in the technology sector to address market needs for cogeneration
- Development of a robust CHP supply and value chain
- Reduced facility operating costs from implementation of CHP
- Low cost supply-side resource for the purpose of utility scale electric generation

Other Potential Grid Benefits:

- Reduction in losses of power along transmission and distribution lines, especially during peak demand periods.
- Increased utility access, through CHP installations, to ancillary and capacity services that help stabilize grid voltage and balance intermittent renewable resources such as wind and solar.
- CHP can operate as a critical capacity resource, providing cost-effective system capacity in smaller increments than a single large centralized power plant.
- CHP can be incorporated into a micro-grid strategy as part of an energy assurance plan at the local level ensuring community preparedness for energy related emergencies.

Feasibility Issues

Minnesota has been perpetually challenged to implement higher levels of CHP throughout the state. The feasibility of achieving the CHP standard embedded within the EERS will be dependent on many factors, a few of which include the following:

- Alignment of utility, regulatory, environmental, and market interests regarding the value proposition of CHP and a path forward toward inclusion of a CHP standard in Minnesota.
- Creation of utility programs that significantly reduce the upfront capital costs and overall risk of moving toward customer on-site generation.
- Establishment of reasonable stand-by rates by utilities and the Public Utilities Commission to remove obstacles in a customer's ability to achieve a desired return on investment from project implementation.

[5] 2008 Data from Lawrence Livermore National Laboratory Energy Flow Diagrams – hhttps://flowcharts.llnl.gov/index.html

- Potential adjustments made to net metering and interconnection standards and practices the reduce implementation barriers.
- Air quality impacts of on-site electric generation from CHP and regulatory requirements for implementation.
- Education and training programs established and available for customers who are implementing and/or considering implementing CHP.

RCII-2. SB2030/ Zero Energy Transition/Codes

Policy Option Description

Operating, and maintaining buildings involve the consumption of large amounts of energy. In 2011, Minnesota's residential and commercial sectors consumed 39.6% of the total energy consumed in the state-- the residential sector at 21.3 % while commercial consumed 18.3%. [6]

To ensure that new or renovated buildings serve us well into the future means constructing energy efficient buildings while pairing them with clean energy. Initiatives such as the national Architecture 2030, Zero Energy Ready or Minnesota's Sustainable Building 2030 (SB2030) can provide that assurance. As defined by National Renewable Energy Laboratory (NREL), a Net Zero Energy building "produces as much as or more energy than it uses annually and exports excess RE generation to the utility (electricity grid, district hot water system, or other central energy distribution system) to offset the energy used."[7] We adopt this definition for RCII-2 policy option.

Building energy codes specify minimum requirements for new and renovated buildings. But these codes will not make buildings zero energy in time for Minnesota to accomplish its climate change goals. Stretch goals can be achieved by adopting SB2030 as an appendix to the Minnesota Building Code, which then makes it available for local jurisdictions to use.

This policy option will provide incentives for or mandate construction of buildings so that net zero energy use in buildings is achieved incrementally by 2030 (60% - 2010; 70% - 2015, etc.) or upon completion of construction with zero-energy ready buildings.

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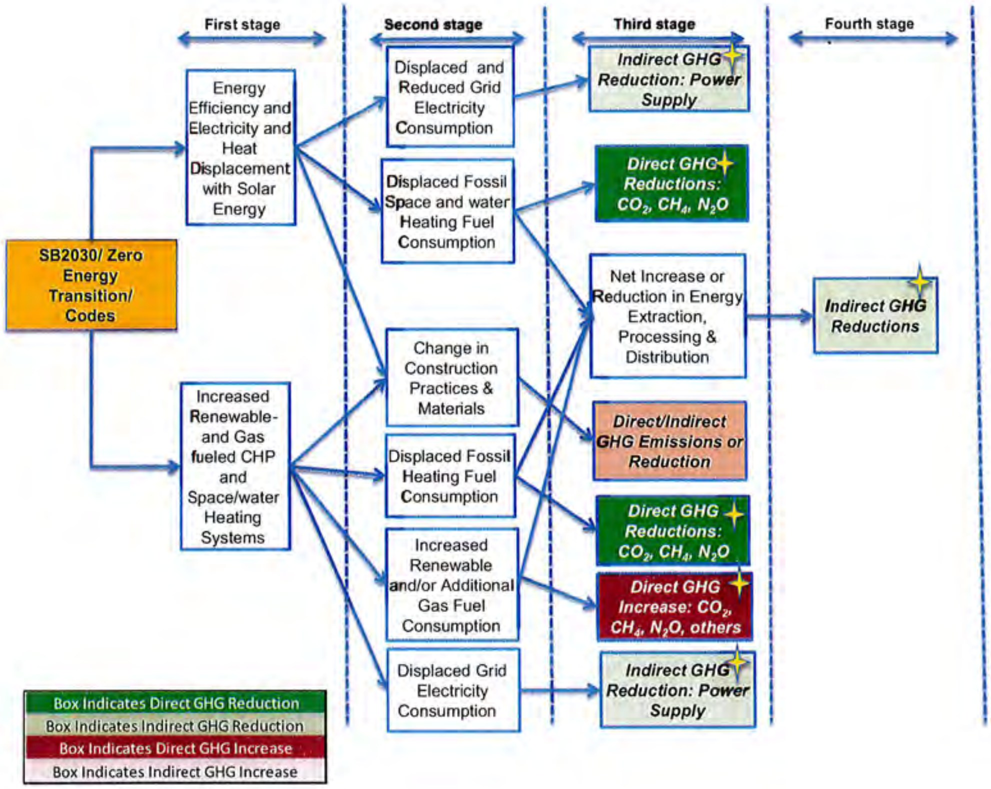
[6] Energy Information Administration, State Energy Data Systems.

[7] *Net-Zero Energy Buildings: A Classification System Based on Renewable Energy Supply Options,* Shanti Pless and Paul Torcellini , National Renewable Energy Laboratory, U.S. Department of Energy, Technical Report NREL/TP-550-44586, June 2010 .

Causal Chain for GHG Reductions

A schematic causal chain for this policy option is provided below. Increased capacity as well as use of CHP systems powered with natural gas to displace electricity from the central grid, and the use of cogenerated heat that displaces the fossil fuels (natural gas, distillate oil, coal, and propane) used for space heat and water heat that are under standard practice produced in furnaces, boilers, and water heaters. The application of solar water and space heat, and of energy efficiency, also displaces electricity and fossil fuel use. As such, GHG emissions savings accrue through the reduction of central grid electricity supply and fossil fuels formerly used for heating, but these savings are partially offset by emissions from natural gas and renewable fuels combustion. In addition, the reduced use of fossil fuel reduces "upstream" emissions associated with, for example, natural gas transmission and distribution, oil refining and transport, and natural gas and crude oil production. It is expected that these GHG emissions reductions and increases will be quantified. Increased use of renewable fuels will produce some increase in emissions associated with fuel processing and transport—for example, diesel-fueled equipment used for biomass harvesting and transport. These additional emissions, however, are highly variable depending on the source of the biomass fuel and the distance it must be shipped to the CHP facility. As a result, these incremental emissions may or may not be quantified, depending on data availability. Changes in building practices and in space and water heating equipment/appliance use in buildings may also produce changes in construction practices and materials that may have a positive or negative impact on GHG emissions. These impacts are indirect and uncertain, and will not be quantified.

Figure F-2.23 Causal Chain for RCII-2 GHG Reductions



Policy Option Design

Minnesota will develop a process for both commercial and residential buildings to reach zero energy status by 2030 through the Minnesota Sustainable Building 2030 process – a performance-based process. The current SB2030 team will continue its training program to architects and engineers. It will also need to develop a residential SB2030 program and create training elements for residential developers and builders.

The Department of Labor and Industry (DLI) will adopt SB2030 as its green stretch code and incorporate it as an appendix chapter. Jurisdictions that adopt it will then be able to require that all buildings in its jurisdiction be built to SB2030. Early adopting cities will assist in leading by example.

By stepping the requirement of voluntary use of SB2030 to mandatory use of SB2030, there will be time for appropriate training to get into place.

Goals:

- All new and renovated commercial buildings in the state, and all multi-family residential buildings four or more stories in height, will be required to use SB2030 through a stepped process, by 2020.

- All new one and two family dwellings and multi-family residential buildings three stories or less in height in the state will be required to use SB2030, through a stepped process, by 2025.
- Sufficient technical assistance and training is available to assist local units of government, architects, engineers, builders, and developers in moving toward SB2030.

Timing:

New and Renovated Commercial Buildings:

- 2015:
  - State-bonded buildings and state-licensed buildings (a new requirement) must use SB2030.
  - All public buildings may use SB2030 and receive appropriate technical assistance
  - DLI adopts SB2030 as an appendix for statewide building code for green commercial buildings.
- 2016:
  - Implement incentive program for voluntary adoption by commercial private sector.
  - Local units of government may begin adopting commercial SB2030 Appendix for use in its city.
- 2018: SB2030 mandatory for all public buildings
- 2020: SB2030 mandatory for all new and major renovated commercial buildings

Residential Buildings:

- 2016: Complete design for energy standard for residential SB2030.
- 2018:
  - Implement design assistance program
  - DLI adopts residential SB2030 as an appendix for statewide building code for green residential buildings.
  - Local units of government may begin adopting residential SB2030 Appendix for use in its city.
  - Implement incentive program for voluntary adoption by residential private sector.
- 2025: SB2030 mandatory for all new and major renovated residential buildings

Parties Involved: All parties involved in owning, operating, renovating, occupying, or other activities associated with Minnesota's new or major renovations of residential, commercial, institutional, municipal, and industrial building stock.

Implementation Mechanisms

The program should be implemented as follows:

- Pass legislation mandating that all state-licensed buildings must now use SB2030 design guidelines. Provide funding mechanisms to assist state and local governments and school districts in meeting these criteria.
- Provide tax incentives, utility design assistance and incentive programs, financing incentives or other inducements for construction of new and major renovations of residential and commercial buildings to assist with voluntary adoption of SB2030 guidelines.
- Provide funding to provide additional technical assistance to local units of government, architects, engineers, builders and developers as the move toward SB2030 guidelines starts.
- Provide funding to develop residential SB2030 guidelines.
- Provide funding to ensure that the database of ongoing building performance tracking in all sectors continues to grow.
- Establish a clearinghouse that provides information and assistance on green building guidelines and standards, the best available technologies for certain applications, a database of ongoing building performance tracking in all sectors, and access to design assistance and software tools to calculate the impacts of energy efficiency and renewable energy strategies.
- Establish education and training programs for all key decision makers, building professionals, and other participants in implementing this policy option, including design professionals, such as architects, engineers, interior designers, planners, and landscape architects; building owners; developers, contractors/builders, and building operators/facility managers; and the financing, real estate, and insurance communities.
- Mandate that state boards of licensing exams for building professionals cover knowledge of and test on SB2030 guidelines.

Related Policies/Programs in Place and Recent Actions

Guidelines that are either required or voluntary in Minnesota include Minnesota Sustainable Building Guidelines (SB2030), Leadership in Energy and Environmental Design (LEED), Green

Globes, National Association of Home Builders Guidelines, Green Star, Green Communities (Minnesota Housing Process), and ENERGY STAR.

Type(s) of GHG Reductions

Reductions in GHG emissions from avoided fossil-fuel combustion for electricity use, and from space and water heating.

Estimated Policy Impacts

Direct Policy Impacts

Summary in-state (direct) GHG emissions reduction and option costs results for RCII-2, "SB2030/ Zero Energy Transition/Codes", are provided in the table below. These values include costs for program administration. Negative values are shown in parentheses. In the "Net present value of societal costs" column, negative values, and denote instances where the costs of the implementing the option (or part of the option) are LESS than the direct economic benefits of the option in avoided energy and other costs. Negative values in the "cost effectiveness" column indicate that there is a net direct economic benefit per metric ton (t) of carbon dioxide equivalent saved. Overall, this option results in over 9 million metric tons (MMt in the table below) of annual CO_2e savings in 2030, with about 54 million metric tons of CO_2e savings over the analysis period. Somewhat more than half of the savings comes from implementation of measures in the commercial and institutional sectors. In addition to these in-state reductions, RCII-2 produces an estimated 1.23 $MMtCO_2e$ of out-of-state (upstream) emissions reductions in 2030, and 6.88 $MMtCO_2e$ in cumulative out-of-state reductions from 2015-2030, yielding total 2030 emissions reductions of 10.52 $MMtCO_2e$ in 2030, and 60.38 $MMtCO_2e$ over 2015-2030.

Table F-2.16 RCII-2 - Estimated Net GHG Reductions and Net Costs or Savings

	2030 GHG reductions ($MMtCO_2e$):	2015 – 2030 cumulative reductions ($MMtCO_2e$):	Net present value of societal costs, 2015 – 2030 (million $2014):	Cost effectiveness ($2014/ t CO_2e):
Zero Energy Building Implementation in the Residential Sector	4.73	24.61	$(823.49)	$(29.59)
Zero Energy Building Implementation in the Commercial Sector	4.56	28.89	$(1,226.73)	$(37.69)

TOTAL	**9.29**	**53.50**	**$(2,050.22)**	**$(33.95)**

Quantification Methods

The quantitative analysis of this option uses the following overall approach:

1. Estimate the total square footage of new and renovated commercial and residential buildings constructed per year in Minnesota using Minnesota-specific, national, and regional data as appropriate and available.
2. Estimate the average energy consumption per square foot of average "standard" (pre-option) commercial and residential new and renovated buildings in Minnesota, based on CBECs, USDOE EIA, and other data as available. These are estimated separately for commercial and residential buildings, by major fuel type (electricity, gas, oil products), and represent averages over the new and renovated building stock in each sector.
3. Estimate the change in energy consumption per square foot, again starting with standard (pre-option) values, for buildings built in each year that comply with SB2030. That is, for example, buildings built in 2015 will use 30% of the fossil energy and grid electricity used in (and thus save 70% relative to) buildings meeting the SB203 Energy Standard, (which is based on reductions over the average 2003 building energy consumption,) buildings built in 2020 would use 20%, and buildings built in 2030 would use 0% (on a net basis).
4. Estimate, again separately for buildings in each sector, the fractional average reductions from energy use in standard commercial and residential buildings in moving to Zero Energy Buildings that comes from the following sources: energy efficiency improvement, gas-fired CHP, solar thermal energy (space and water heating), solar PV installations, and biomass energy (space heating).
5. Calculate the net reduction (or increase) in different energy sources used per square foot of new and renovated floor area in each of the residential and commercial sectors.
6. Develop and apply projections of building area in the residential and commercial sectors, using Minnesota-specific data as available plus expert judgment regarding building trends in Minnesota.
7. Multiply the net values developed in step 5 by the new and renovated building areas developed in step 6 and, for years before 2020 in the commercial sector, and 2025 in the residential sector, by the ramp-in rates specified above for each sector to yield estimates of the net impact on use of energy sources in each sector.
8. Multiply the net impacts on fuel and electricity use in each sector by GHG emission factors appropriate for each combusted fuel and an appropriate marginal emission

factor for avoided electricity use, respectively, to yield net emissions reductions by sector, fuel/energy source, and year.

9. Adopt average cost estimates, by sector, for the net capital cost of building energy efficiency improvements needed to achieve the energy use reductions assumed, and of the other energy systems (solar thermal and PV, biomass energy, gas energy) needed to achieve ZEB as described in step 4, less the cost of standard practice.

10. Multiply the cost estimates from step 9 with the estimated energy savings by type of measure included in the option annually to provide an estimate of the net costs of the option, by sector and year.

11. Multiply the net impacts on purchased fuels as developed in Step 8 by appropriate avoided costs for electricity and fuels saved/used.

12. Estimate "upstream" emissions reduction from avoided/additional fuels and electricity use using common emission factors used in many options for fossil fuels.

13. Apply representative estimates of the fraction of the additional capital costs of technologies used in the option that might be paid by a program sponsor, plus estimates of the ratio of sponsor administrative costs to the sponsor outlays for incentives, to estimate the administrative costs of the option.

Key Assumptions

In addition to the goals described above, key assumptions used in the analysis of RCII-2, as reflected in the listing of analytical steps in the previous section of this document, include:

- Annual new and renovated square feet of commercial buildings, of multi-family buildings 4 or more stories tall, and of one and two family dwellings and multi-family residential buildings three stories or less constructed in Minnesota through the modeling period. Annual new building for these three groupings were estimated based on a combination of historical and short-term (5-year) forecast data from Reed Construction Data[8], combined with data and insights from Minnesota agency staff, and data from the Minnesota Economic Forecast (as of February 2014)[9]. The resulting forecast additions of new floor area range from 16 to 21 million square feet of commercial/institutional space, 4.1 to 4.5 million square feet of multi-family (4 stories and taller) space, and 35 to 56 million square feet of single family and small multi-family floor space annually from 2015 through 2030, with additions generally declining slowly in the later years of the analysis period. 0.6 units of renovated space were assumed to be added per unit of new commercial and institutional (CI) space. Renovated residential space was not included in the analysis of this option.

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[8] Reed Construction data was provided by The Weidt Group.

[9] "Budget and Economic Forecast." *Office of Management & Budget*, Feb. 2014. <http://www.mn.gov/mmb/images/Budget%2526Economic_Forecast_Feb2014.pdf.>.

- The fraction of new (and, for CI, renovated) floor space assumed to be covered by RCII-2 in specific years by sector is as shown in the table below. Values for other years were interpolated.

Table F-2.17 Fraction of Floor Space Assumed in RCII-2

Year	Commercial/ Institutional (Non-Residential)	Multi-family Residential as Defined In Policy Option Document	Single Family and Small Multi-family Residential
2015	12.0%	0%	0%
2016	15.0%	0%	0%
2018	20%	0.63%	0.63%
2020	75%	75%	25%
2025 and on	100%	100%	100%

- The annual target fraction of fossil energy use and off-site electricity to be reduced by year in each sector is as shown in the table that follows, based on RCII-2 targets. Again, values for other years were interpolated.

Table F-2.18 Annual Target Fraction of Fossil Energy Use and Off-Site Electricity Reductions

Year	Commercial/ Institutional (Non-Residential)	Multi-family Residential as Defined In Policy Option Document	Single Family and Small Multi-family Residential
2010/In Absence of Policy	**30%**	**30%**	**30%**
2015	70%	30%	30%
2018	70%	70%	70%
2030	100%	100%	100%

- The fractional savings above apply to the per-square-foot baseline values for energy use under SB2030 energy standard, based on estimates provided by Minnesota agency staff.

Table F-2.19 Baseline Values for Energy Use (/ft2)

	Electricity		Heating Fuels	Total
	kBtu/sq ft-yr	kWh/sq ft-yr	kBtu/sq ft-yr	kBtu/sq ft-yr
Commercial/Institutional	71.50	20.96	61.10	132.60
Multi-family Residential	41.10	12.05	83.40	124.50
Single-family Residential	25.00	7.33	85.00	110.00

- 70% of the required energy savings (or on-site generation) in each year and in each sector come from electricity savings, with the remaining 30% from savings in on-site fossil fuel use (gas, oil, and propane/LPG).
- The fractions of reduction in energy use to achieve zero energy residential and commercial buildings from different sources of reduction were assumed, based on discussions with Minnesota agency staff, to be as shown in the table below, with 2015 values used as a starting point, 2030 values uses as an end-point, and values for other years linearly interpolated.

Table F-2.20 Technologies for Electricity Savings

	Contribution as of 2015			
	Technologies for Electricity Savings			
	Energy Efficiency	Gas-fired CHP	Solar Space and Water Heating	Solar PV
Commercial/Institutional	96.0%	1.0%	2.0%	1.0%
Multi-family Residential	96.5%	0.5%	2.0%	1.0%
Single-family Residential	97.0%	0.0%	2.0%	1.0%

Table F-2.21 Technologies for Fossil Heating Fuel Savings

	Technologies for Fossil Heating Fuel Savings			
	Energy Efficiency	Gas-fired CHP (heat output)*	Solar Space and Water Heating	Biomass Heating
Commercial/Institutional	96.0%	1.0%	2.0%	1.0%
Multi-family Residential	94.1%	0.9%	3.0%	2.0%
Single-family Residential	90.0%	0.0%	5.0%	5.0%

Table F-2.22 Technologies for Electricity Savings by 2030

	Contribution by 2030			
	Technologies for Electricity Savings			
	Energy Efficiency	Gas-fired CHP	Solar Space and Water Heating	Solar PV
Commercial/Institutional	78.0%	2.0%	10.0%	10.0%
Multi-family Residential	78.5%	1.5%	10.0%	10.0%
Single-family Residential	79.5%	0.5%	10.0%	10.0%

Table F-2.23 Technologies for Heating Fuel Savings

	Technologies for Fossil Heating Fuel Savings			
	Energy Efficiency	Gas-fired CHP (heat output)*	Solar Space and Water Heating	Biomass Heating
Commercial/Institutional	90.9%	2.1%	4.0%	3.0%
Multi-family Residential	85.2%	3.8%	6.0%	5.0%
Single-family Residential	76.5%	3.5%	10.0%	10.0%

The fractions of energy savings assumed to be achieved through solar space and water heating that is ascribed to application of transpired solar heating, a relatively inexpensive form of solar space heating, were as described in the table below:

Table F-2.24 Electricity Savings Due to Solar Heating

	Electricity Savings	Gas Savings
Commercial/Institutional	50%	75%
Multi-family Residential	50%	75%
Single-family Residential	50%	50%

- Performance assumptions for biomass and fossil-fueled heating sources used to estimate required new and avoided fuel consumption, respectively, were as follows, based on Minnesota agency staff input:

Table F-2.25 Performance Assumptions for Biomass and Fossil Fuel

	Commercial/ Institutional	Multi-Family	Single Family and Small Multi-Family
Average Conventional Heating Fuel Efficiency, Fuel to Useful Heat (all	86%	86%	78%
Average Biomass Heating Fuel Efficiency, Fuel to Useful Heat	75%	75%	70%

- The net capital costs of building energy efficiency performance and on-site renewable energy systems used to meet the goals of the option were as shown in the table below. These costs were compiled from a variety of sources—see the RCII-2 worksheet for complete notes on the estimates of these parameters.

Table F-2.26 Capital Costs as of 2015 (2014$)

Capital Costs as of 2015 (2014 dollars)	Technologies for Electricity Savings				
	Energy Efficiency	Gas-fired CHP (See ***Note 4***)	Solar Space Heat with Transpired Solar Collectors	Other Solar Space and Water Heating	Solar PV (See ***Note 3***)
	$ /first-year MWh saved	$/kW	$ /first-year MWh saved	$ /first-year MWh saved	$/kW
Commercial/Institutional	$ 238.48	$ 3,606	$ 618.80	$ 1,037.52	$ 3,100
Multi-family Residential	$ 238.48	$ 3,606	$ 618.80	$ 1,037.52	$ 3,617
Single-family Residential	$ 238.48	$ 10,000	$ 558.66	$ 1,171.22	$ 4,134

Table F-2.27 Technologies for Fossil Heating Fuel Savings

	Technologies for Fossil Heating Fuel Savings			
	Energy Efficiency (as for Natural Gas in RCII-4)	Solar Space Heat with Transpired Solar Collectors*	Other Solar Space and Water Heating*	Biomass Heating*
	$ /first-year MMBtu saved	$ /first-year MMBtu saved	$ /first-year MMBtu saved	$ /(MMBtu/yr delivered)
Commercial/Institutional	$ 14.73	$ 211.04	$ 353.86	$ 31.45
Multi-family Residential	$ 14.73	$ 211.04	$ 353.86	$ 31.45
Single-family Residential	$ 14.73	$ 211.04	$ 442.45	$ 32.62

*Consistent with values used in RCII-5 analysis

Table F-2.28 Capital Costs as of 2030 (2014$)

Capital Costs as of 2030 (2014 dollars)	Technologies for Electricity Savings				
	Energy Efficiency	Gas-fired CHP (See ***Note 4***)	Solar Space Heat with Transpired Solar Collectors	Other Solar Space and Water Heating	Solar PV (See ***Note 3***)
	$ /first-year MWh saved	$/kW	$ /first-year MWh saved	$ /first-year MWh saved	$/kW
Commercial/Institutional	$ 259.49	$ 3,606	$ 618.80	$ 1,037.52	$ 1,402
Multi-family Residential	$ 259.49	$ 3,606	$ 618.80	$ 1,037.52	$ 1,636
Single-family Residential	$ 259.49	$ 5,000	$ 558.66	$ 1,171.22	$ 1,870

Table F-2.29 Technologies for Fossil Heating Fuel Savings

	Technologies for Fossil Heating Fuel Savings			
	Energy Efficiency	Solar Space Heat with Transpired Solar Collectors*	Other Solar Space and Water Heating*	Biomass Heating*
	$ /first-year MMBtu saved	$ /first-year MMBtu saved	$ /first-year MMBtu saved	$ /(MMBtu/yr delivered)
Commercial/Institutional	$ 16.03	$ 211.04	$ 353.86	$ 31.45
Multi-family Residential	$ 16.03	$ 211.04	$ 353.86	$ 31.45
Single-family Residential	$ 16.03	$ 211.04	$ 442.45	$ 32.62

*Consistent with values used in RCII-5 analysis

- Measure lifetimes, used for calculating levelized (annual) capital costs, were assumed to average 15 years for energy efficiency improvements and 20 or 25 years for renewable energy systems.

- For Energy Efficiency, operating and maintenance (O&M) costs were assumed to be 10% of levelized capital cost. In practice these costs may be zero or even negative, as in cases where changes in technology (such as switching to long-lived LED bulbs) result in reducing maintenance costs, or may be modestly greater than for standard practice, such as for building energy controllers that need to be maintained, adjusted and calibrated periodically. O&M costs for gas-fired CHP were assumed to be the same as used for gas-fired CHP in RCII-1. Solar PV O&M costs were adapted from NREL, "Distributed Generation Renewable Energy Estimate of Costs"[10] at about $20 per kW-yr. O&M costs for biomass-fueled heating systems were assumed to be as estimated in RCII-5.
- Estimated avoided marginal emission factors for electricity generation (on an electricity delivered basis[11]) falls from 0.936 tCO2e per MWh in 2015 to 0.758 in 2030, with avoided costs of electricity generation (again based on delivery to consumers, that is, factoring in transmission and distribution losses) rising from $92.6 to $148.1 per MWh delivered (nominal dollars) over the same time period. Natural gas avoided (wholesale) costs rise from $4.78 to $8.97 per GJ (again nominal dollars) over the same time period.
- Wholesale costs of biomass fuels used for renewable CHP rise from $2.96/GJ in 2015 to $6.73/GJ in 2030 (nominal dollars). Avoided costs of other fossil fuels were assumed equal to avoided wholesale costs for the various fuels, as estimated in the Common Assumptions used for all options, as were direct and, where applicable, "upstream" GHG emission factors for each fuel whose use is avoided (or, in the case of biomass, increased) by the measures in RCII-2.
- Administrative costs are estimated assuming that program sponsors will provide incentives equal to 35% (commercial/institutional sector) to 45% (single family/small multi-family) of capital costs. Administrative costs are assumed to vary from 10% (commercial/institutional) to 20% (single family/small multi-family) of incentive costs.

Macroeconomic (Indirect) Economic Impacts

Table F-2.30 below provides a summary of the expected impacts of RCII-2 policy on jobs and economic growth during the CSEO planning period.

[10] Updated August 2013, and available as http://www.nrel.gov/analysis/tech_lcoe_re_cost_est.html.

[11] That is, factoring in transmission and distribution losses, which, based on the electricity supply forecast prepared as part of this project, vary annually in the range of 5.77 to 5.86 percent over 2015 through 2030.

Table F-2.30 RCII-2 Macroeconomic Impacts on GSP, Employment and Income

Scenario	Gross State Product (GSP, $2015 Millions)			Employment (Full & Part-Time Jobs)			Income Earned ($2015 Millions)		
	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)
RCII-2	-$69	-$6	-$91	6,020	2,750	41,190	$336	$134	$2,011

Graphs below show detail in GSP, employment and personal income impact of the RCII-2 policy.

Figure F-2.24 RCII-2 GSP Impacts ($2015 MM)

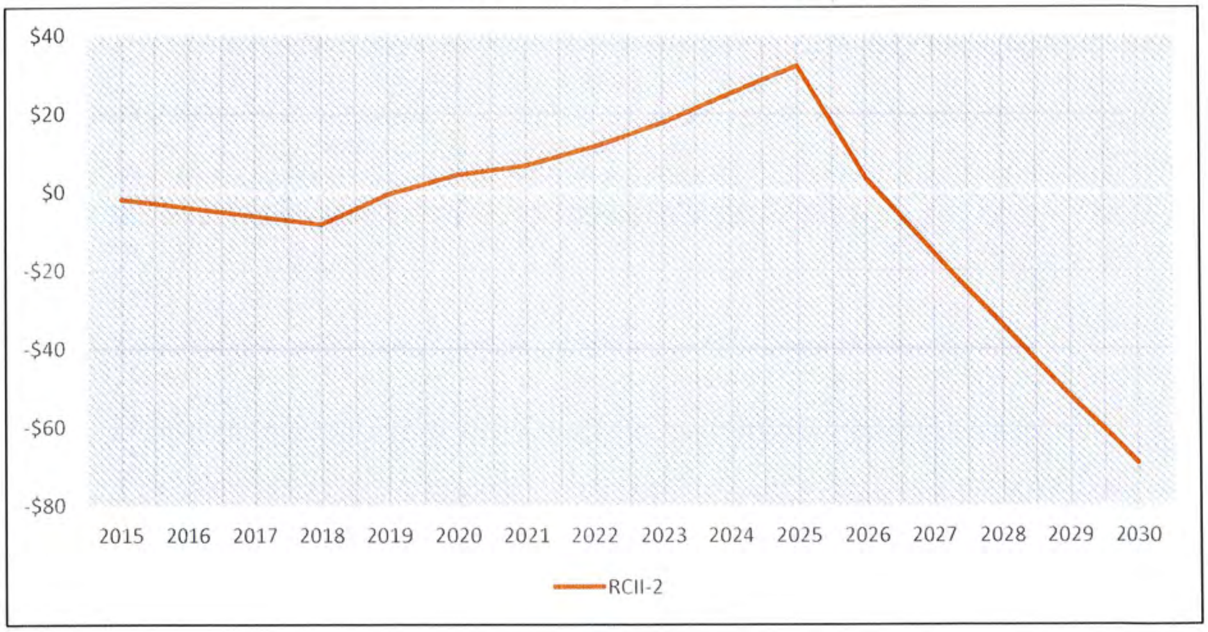


Figure F-2.25 RCII-2 Employment Impacts (Individual Jobs)

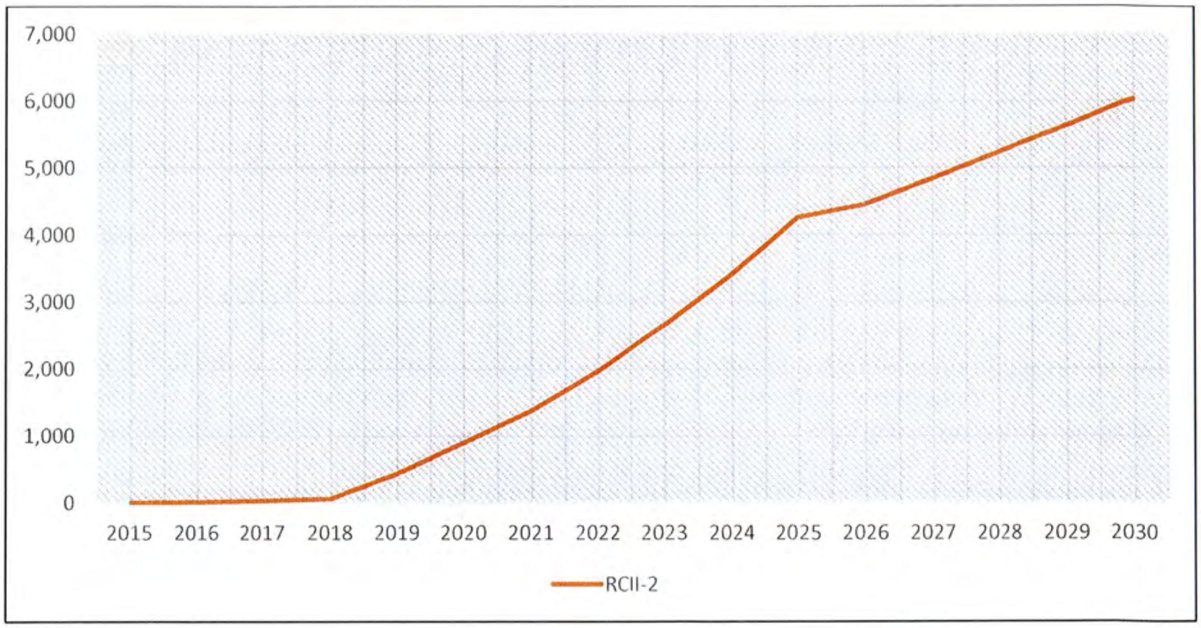
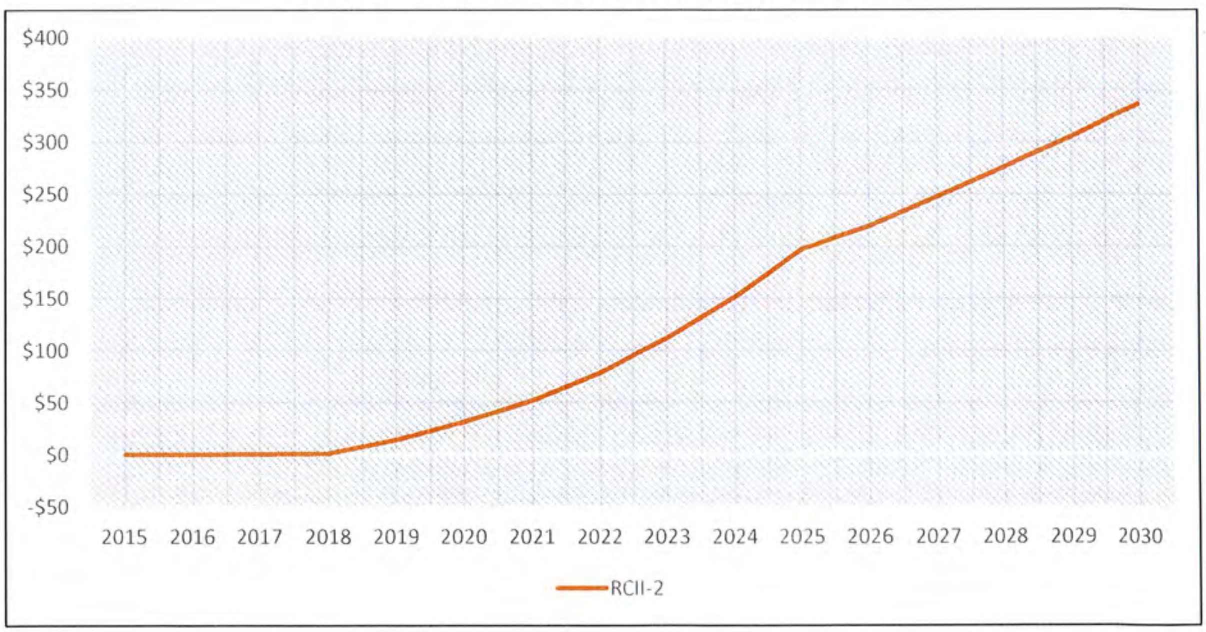
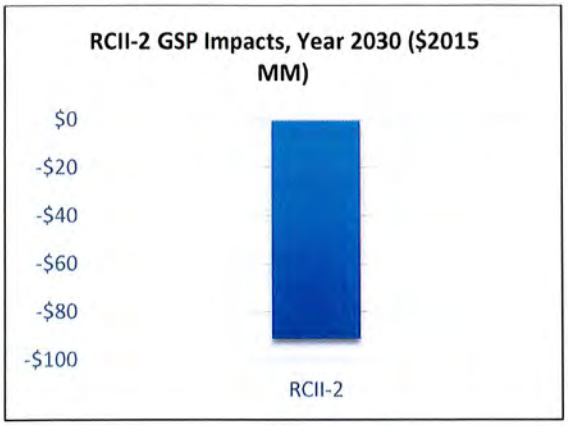
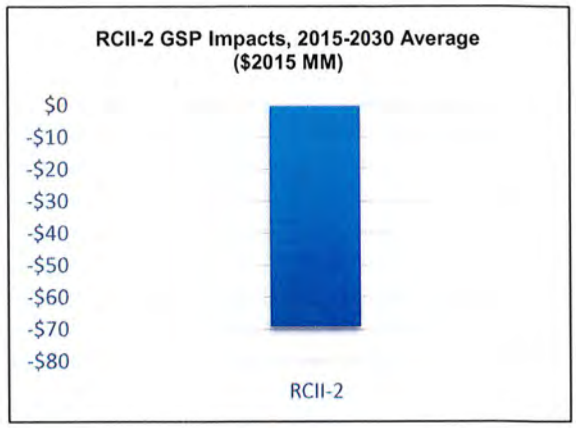


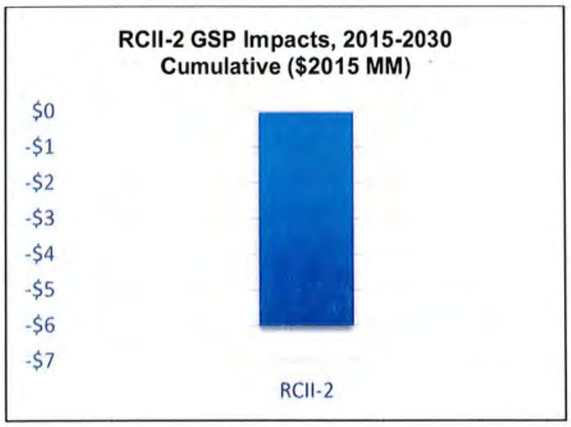
Figure F-2.26 RCII-2 Income Impacts ($2015 MM)

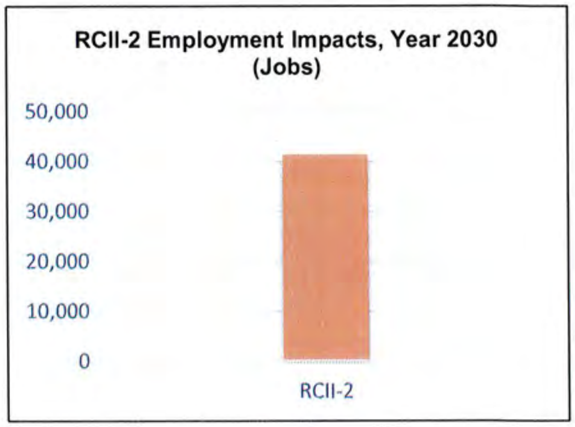


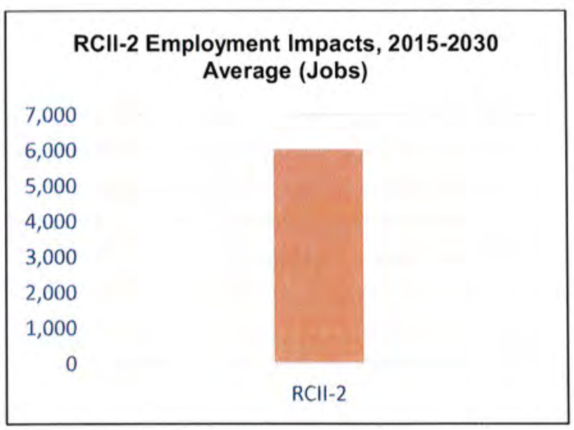
Graphs below show macroeconomic impacts on GSP, personal income, and employment in the final year (2030), in average (2015-2030) and in cumulative (2015-2030).

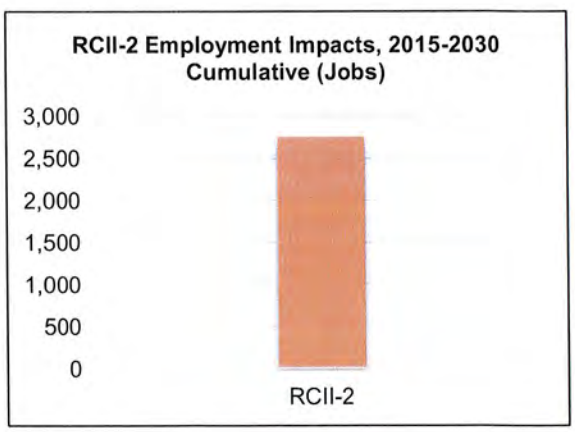

RCII-2 GSP Impacts, Year 2030 ($2015 MM)
$0
-$20
-$40
-$60
-$80
-$100
RCII-2

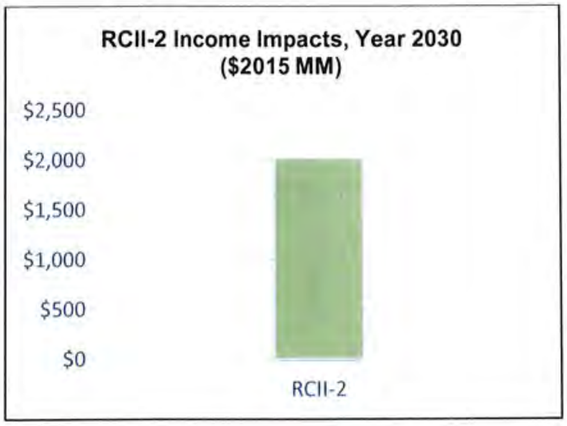

RCII-2 GSP Impacts, 2015-2030 Average ($2015 MM)
$0
-$10
-$20
-$30
-$40
-$50
-$60
-$70
-$80
RCII-2

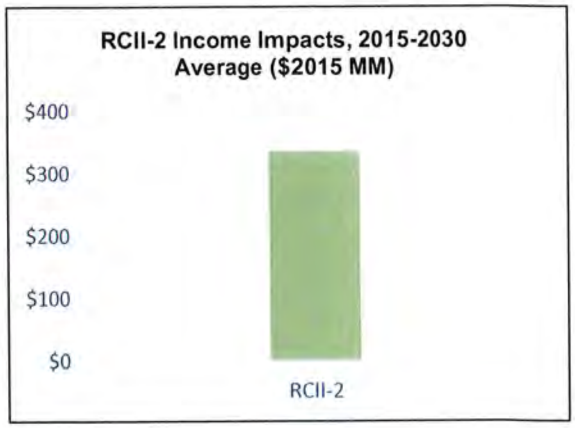

RCII-2 GSP Impacts, 2015-2030 Cumulative ($2015 MM)
$0
-$1
-$2
-$3
-$4
-$5
-$6
-$7
RCII-2

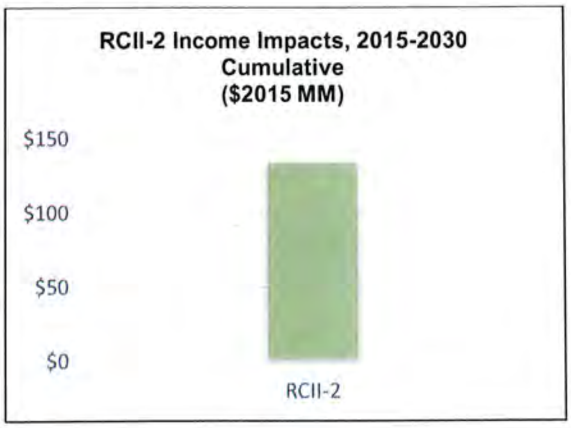

RCII-2 Employment Impacts, Year 2030 (Jobs)
50,000
40,000
30,000
20,000
10,000
0
RCII-2


RCII-2 Employment Impacts, 2015-2030 Average (Jobs)
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
RCII-2


RCII-2 Employment Impacts, 2015-2030 Cumulative (Jobs)
3,000
2,500
2,000
1,500
1,000
500
0
RCII-2







Principal Drivers of Macro-Economic Changes

RCII-2 produces an efficiency impact profile that CCS has found in other policy analyses prior to the CSEO macroeconomic modeling effort. In this profile, a policy is neutral (as in RCII-2) or even negative in its GSP impacts, meaning that the same or even less total spending is being directed to the state's products and services as a result of the policy. However, employment rises and incomes rise as well – both by significant amounts. Generally, this is because the nature of efficiency policies, if they are effective, is to seek a reduction in spending on some key input (in this case, building energy for heat, power and electricity) while not reducing the total amount of those activities. GSP, which is measured as total spending, naturally sees a downward influence from this initiative. The resulting reduction in costs means that those buying less electricity have the money available to spend elsewhere, expanding other sectors, but the losing sector (the focus of the efficiency effort) has less to spend, and its supporting sectors also see losses.

But efficiency policies typically produce income-effect impacts, meaning that buying power rises faster than actual incomes and employment rises more from the sectors that gain than it falls from the sectors that lose. RCII-2 is one of those cases – GSP falls, but employment and incomes both rise.

RCII-2 sees building-owning sectors spend significant amounts on construction, operations and maintenance to convert their facilities (or better build new ones) to comply. However, the energy savings they achieve is larger in any given year (on the order of $200 million each for the residential and the commercial sectors, by 2030) than the financed cost of compliance. This positive return on investment helps this policy succeed, while in RCII-5 (which focuses on thermal renewables), the inability of the cost of investment to produce sufficiently large returns prevents it from generating positive income and employment impacts.

Sectors of Economy Most Affected by the Policy

Economic impacts from policies run around the economy, affecting sectors that are sometimes far from the direct target of a policy.

For RCII-2, private homes see the most benefits. Statewide, though they spend significantly to implement this policy (reaching approximately $500 million by 2030), they consistently save more on energy than they spend (again, when some financing for the home improvement element is taken into account). This savings exceeds $700 million by 2030, producing a net savings of about $200 million in the final year.

The resulting additional ability to spend shows up all over the consumer economy. Homes directly hire contractors and staff as part of the economy already (landscaping, home health care, and cleaning services are common examples of this), and that spending grows significantly under this policy scenario – over 2,000 more people work in these sectors by 2030 as a result. Retail spending also rises significantly, adding about 650 positions. Nursing, health care, and real estate also grow as consumers redirect money.

Construction also gains significantly, both directly from the investment and indirectly. Utilities, the target of the efficiencies, see the largest losses – they require nearly 500 fewer people by 2030.

Data Sources

The principal data sources for the macroeconomic impacts analysis of this and all other policies in the CSEO process are the direct spending, saving, cost and price impacts developed as part of the microeconomic (direct impacts) analysis. For each policy, the cost-effectiveness analysis described above develops year-by-year estimates of the costs, savings prices, and changes demand or supply that households, businesses and government agencies are expected to encounter in a scenario where the policy is implemented as designed.

A secondary data source is the policy design. Balancing financial flows for each direct impact identified are established based on understanding the implementation mechanism, and quantitative values for these flows are developed for each direct impact identified. This balancing identifies and quantifies the responsive change that occurs as a result of the direct impact in question. For example, if a household is anticipated to save $100 per year on electricity bills as a result of a policy, the direct impact is a $100 savings to the household (which expands its spending capacity for other things) but the balancing impact is a $100 loss in revenue and demand to the utility provider (which reduces its ability and need to spend on labor, capital, profit, and other inputs). The quantitative measure of both sides of a change is of importance to a complete macroeconomic analysis. This balancing ensures that both the supply and the demand side of each economic change is fully represented in the analysis.

A third data source is direct communication with Minnesota agency staff and others involved in policy design or in a position to understand in detail the financial flows involved in the policy. These people assisted in clarifying the nature of economic changes involved so that the modeling and analysis would be accurate.

The final crucial data source is the baseline and forecast of economic activity within the REMI software. This data is compiled into a scenario that is characterized not only by the total size of the economy and its many consuming and producing sectors, but also the mechanisms by which impacts in one sector can change the broader economy – such as intermediate demands, regional purchase coefficients, and equilibria around price and quantity, labor and capital, and savings and spending, to name a few of many. REMI, Inc. maintains a full discussion of all the sources of the baseline data on its own website, www.remi.com.

In the case of the RCII-2 policy, important data included:

- The capital cost involved for commercial and residential buildings to adopt new technologies. This involves an additional cost of operation but provides a stimulus in spending to the construction and machinery production sectors.
- The cost to implement new practices and operating procedures around different equipment. These operating and maintenance costs also represent a cost to be borne by the commercial and residential sectors, but the additional labor engaged (exceeding 500 new people statewide by 2030) increases direct employment, direct incomes, and expands consumer spending – which is economically beneficial.
- The total volumes, and total spending on those volumes, of each type of energy consumed – both the sources reduced from other heat or power sources and those sources (limited in this policy to biomass) increased to fuel renewable generation.
- The costs to state government agencies to oversee and implement this policy. This is split between labor to regulate and implement, and capital spending on upgrading its own facilities. One third of this is funded through a rate surcharge to affected entities, and the remainder displaces the general treasury.

Quantification Methods

Utilizing the data developed from the microeconomic analysis, CCS analysts established for each individual change the following characteristics:

- The category of change involved (change in spending, savings, costs, prices, supply or demand)
- The party involved on both sides of each transaction

- The volume of money involved in this change in each year of the period of analysis

These values, so characterized, were then processed into inputs to the REMI PI+ software model built specifically for use by CCS and consistent with that in use by state agencies within Minnesota. These inputs were applied to the model and run. Key results were then drawn from the model and processed for consistency of units and presentation before inclusion in this report.

Key Assumptions

The macroeconomic impact analyses of this policy, as well as of the others in the CSEO process, rely on a consistent set of key assumptions:

- State and local spending is always budget-constrained. If a policy calls for the state or local government to spend money in any fashion, that spending must be either funded by a new revenue stream or offset by reductions in spending on other programs. Savings or revenues collected by the government are also expected to be returned to the economy as spending in the same year as they are collected.
- Federal spending is not budget-constrained. The capacity of the federal government to carry out deficit spending means that no CSEO policy is held responsible for driving either an increase or decrease in federal tax spending by businesses or households in the state of Minnesota.
- Consumer spending increases are sometimes financed. Small-scale purchases or purchases of consumer goods are treated as direct spending from existing household cash flows (or short-term credit). Durable goods, home improvements or vehicle purchases, however, are treated as financed. Consumers were assumed to spread out costs based on common borrowing time frames, such as five years for financing a new vehicle or 10-20 years for home improvements that might be funded by home-equity or other lending. The assumption of financing and the term of years applied was considered anew in each case.
- Business spending increases are often financed. Where spending strikes a sector which routinely utilizes financing or lines of credit to ensure steady payment of recurring costs, significant spending of nearly any type was considered a candidate for financing, thus allowing costs to spread out over time. This methodology is preferable for the modeling work, as sudden spikes or dips in business operating costs can show up as volatility when the scenario may depict a managed adoption of new equipment in an orderly fashion. The assumption of financing and the term of years applied was considered anew in each case.
- Unless otherwise stated, all changes to consumer spending or to the producers' cost of producing goods and services were treated in a standard fashion. Consumers are assumed to spend on a pre-set mix of goods, services, and basic needs, and businesses spend (based on their particular sector of the economy) on a mix of labor, capital, and intermediate demands from other sectors. Unless a policy specifically defines how a

party will react to changes in cost, price, supply or demand, these standard assumptions were applied.

- State and local spending gains and reductions driven by policy are assumed to apply to standard mixes of spending. Again, unless a policy specifically states that a government entity will draw from a specific source or direct savings or revenues to a specific form of spending, all gains and losses were assumed to apply to a standard profile of government spending within the economy.

Key Uncertainties

A few uncertainties include:

- Legislative action will be required to enact this type of statewide policy option. There are uncertainties around the support or resistance from various stakeholder groups regarding this kind of policy option change.
- Program scalability needs to be considered in the design and execution of this proposal. While there is already an infrastructure in place to meet the current SB2030 requirements written into law, considerations need to be made for the funding mechanism that will be required for expanding the existing work.
- Education and training will be needed to ensure that architects, engineers and other facility designers are able to meet the design requirements of the expanded SB3030 standard. While some training and education programs exist along with energy design assistance programs are able to meet the needs of the current requirements, some uncertainty remains as to the cost and effort of new training needs for an expanded standard.
- There are additional uncertainties regarding the interactive effects of this policy option with other policies relating to utility renewable and energy efficiency requirements. For example, as more net zero buildings are implemented, there may be upward pressure on costs to maintain the electric transmission and distribution system potentially shifting more of these costs to ratepayers still connected to the grid. This could have a negative impact to ratepayers that will have continued responsibility for these costs.

Additional Benefits and Costs

<u>Economy</u>

Increased activity within the construction industry provides an economic benefit to the state of Minnesota. Increased sales and increased innovation of technologies to meet the needs of advancing standards and goals are also a benefit.

<u>Environment</u>

Energy efficiency and renewable energy implementation directly results in reduced carbon emissions and has the potential to be one of the more cost effective solutions for reducing greenhouse gas emissions. The environmental impacts of this policy option could mitigate rising health care costs for air quality and carbon emissions related illness in Minnesota. Facilities that meet the standard also could reduce other environmental impacts to local water treatment systems and pollution control requirements as a result of more efficient and renewable operations from meeting the new standard.

Health

Per a Minnesota Department of Health analysis, increasing energy efficiency could benefit health by reducing climate change through reduced emissions. Emissions reductions may reduce the risk of cardiovascular and respiratory illness as well as cancer in communities exposed to energy-related emissions. (EPA; Kappos; Pope 2002, Pope 2000, Bernard) Building efficiency improvements could also reduce respiratory illness, reduce allergies and asthma, reduce sick building syndrome, and improve worker performance through changes in thermal environment and lighting.

Feasibility Issues

This policy option would require merging two existing policy option frameworks in Minnesota, Sustainable Buildings 2030 and Energy Codes. By adopting the SB2030 energy standard into Minnesota's Energy Code, the standard would be expanded to include new construction and major renovations for private commercial and residential facilities. Initial data indicates the costs for achieving the higher standard in the public sector remain competitive with building to a lower standard; however, the architecture, engineering and building construction industries may have concern over the cost impacts to delivering these services. If these industries believe the costs will increase exponentially, there may be feasibility issues with passing legislation. This is one example where additional collaboration with stakeholders will be required to determine specific areas of contention and/or alignment that will make this broad policy option shift feasible.

A specific example of a feasibility issue was provided above; however, below is a list of general items that need consideration to make SB2030 for private commercial and residential facilities feasible:

- Cost of building to meet standard; unintended costs
- Market acceptance of standard
- Availability of technology to meet performance requirements
- Trained network of service providers
- Incentives available for customers
- Accountability within policy option enforcement

- Measurement and verification of performance

RCII-3. Reduce High Global Warming Potential (GWP) Greenhouse Gases

This policy option was not moved forward to final CSEO recommendations due to current limitations on effective policy option design and impacts analysis.

RCII-4. Increase Energy Efficiency Requirement

Policy Option Description

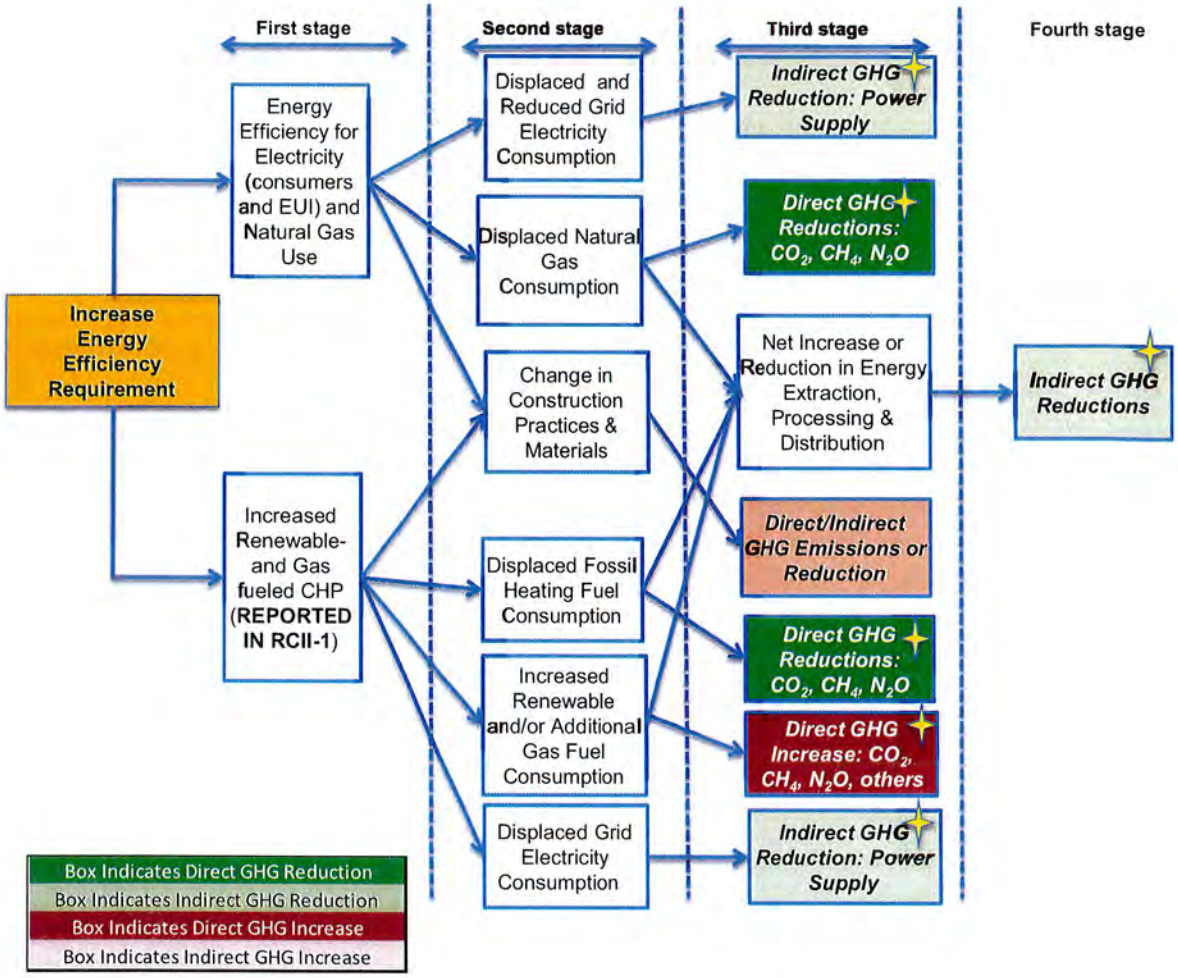
The purpose of this policy option is to increase the utility energy efficiency resource standard (EERS) requirements established in the Conservation Improvement Program (CIP) in the following manner:

- For electric utilities, increase the EERS to 2.5% with the ability to count electric energy savings from energy utility infrastructure (EUI) improvements and electricity displaced by combined heat and power projects (CHP) on top of a minimum savings goal of 1.5% from end-use efficiency.
- For gas utilities, retain the EERS of 1.5%, with a minimum savings goal of 1.0% for end-use efficiency and the addition of CHP as an eligible technology that could satisfy the remaining 0.5% requirement.
- In addition to the demand-side management requirements through the EERS, natural gas utilities and electric utilities will be required to meet a CHP standard that is embedded in the EERS. Collectively, the natural gas utilities will be required to meet a CHP goal of 34 Million MMBtu of displaced fossil fuel by 2030. Collectively, the electric utilities will be required to meet a CHP goal of 800 MW by 2030. (Details of the CHP policy option can be found in the policy option design section of RCII-1 for Combined Heat and Power.

Causal Chain for GHG Reductions

A schematic causal chain for this policy option is provided below. For energy efficiency improvements, emissions reductions occur through reduction of electricity and gas use, and their associated emissions. For CHP, as described also in RCII-1 and RCII-2, increased capacity and use of CHP systems powered with natural gas to displace electricity from the central grid, and, through the use of cogenerated heat, and displaces fossil fuels (natural gas, distillate oil, coal, and propane) used for space heat and water heat that are under standard practice produced in furnaces, boilers, and water heaters. As such, GHG emissions savings accrue through the reduction of central grid electricity supply and fossil fuels formerly used for heating, but these savings are partially offset by emissions from natural gas and renewable fuels combustion. In addition, reduced use of fossil fuel reduces "upstream" emissions associated with, for example, natural gas transmission and distribution, oil refining and transport, and natural gas and crude oil production. It is expected that these GHG emissions reductions and increases will be quantified. Increased use of renewable fuels will produce some increase in emissions associated with fuel processing and transport—for example, diesel-fueled equipment used for biomass harvesting and transport. These additional emissions, however, are highly variable depending on the source of the biomass fuel and the distance it must be shipped to the CHP facility. As a result, these incremental emissions may or may not be quantified, depending on data availability. The manufacturing and installation of energy-efficient devices and equipment, as well as CHP systems, may produce changes in construction and/or manufacturing practices and materials that may have a positive or negative impact on GHG emissions. These impacts are indirect and uncertain, and will not be quantified.

Figure F-2.27 Causal Chain for RCII-4 GHG Reductions



Policy Option Design

Goals:

- Achieve annual electric energy savings of 2.5% through customer end-use efficiency programs, electric utility infrastructure improvements, combined heat and power, energy codes and appliance standards, and other efforts.
    - A minimum of 1.5% savings will be achieved through end-use efficiency programs. The remaining 1.0% can be achieved through EUI, CHP and additional demand side management (DSM).
    - As in the current statute, there will be no minimum end-use efficiency goal for municipal and cooperative utilities.

- Electric utilities (investor-owned, municipal, and cooperative) will be required to include EUI and CHP projects in their CIP plans.

- Achieve annual gas energy savings of 1.5% through customer end-use efficiency programs, energy codes and appliance standards, combined heat and power, and other efforts.
  - A minimum of 1.0% energy savings will be achieved through end-use efficiency programs. The remaining 0.5% can be achieved through implementation of CHP and additional DSM.
  - As in current statute, there will be no minimum end-use efficiency goal for municipal gas utilities.
  - Natural gas utilities will be required to consider CHP projects in their CIP plans.
- To be eligible for CIP savings credit, combined heat and power projects must meet or exceed a minimum total efficiency[12] of 60% and a minimum thermal efficiency[13] of 20%. See RCII-1 CHP Policy Option for additional details regarding CHP electric/thermal efficiency standards.

Assumptions

- Electric utilities achieve at least 1.5% from customer end-use efficiency (DSM).
  - For a partial list of eligible DSM measures established through the Department of Commerce's Technical Reference Manual (TRM), consult the latest TRM manual version 1.0 (http://mn.gov/commerce/industries/energy/utilities/cip/technical-reference-manual/)
- Electric utilities achieve 1.0% from CHP and EUI and/or additional DSM:
  - For more information about eligible CHP technologies, efficiency requirements and other potential variables, consult RCII-1 CHP Policy Option Design.
  - For more information about potentially eligible EUI technologies, consult the following sources:
    - Minnesota Environmental Initiative *1.5% Energy Efficiency Solutions Project*, Final Report March 2011. (Pages 17-46 and 113-142) (http://mn.gov/commerce/energy/images/1_5EESolutionsFinalReport_Appendices.pdf) .
    - Franklin Energy Utility Infrastructure Improvements for Energy Efficiency: Understanding the Supply-Side Opportunity, Final Report November 2010

[12] Defined as the ratio of useful thermal energy and electric energy produced to input energy.

[13] Defined as the ratio of useful thermal energy produced to input energy.

(http://mn.gov/commerce/energy/images/CARD-Utility-EE-Improvements.pdf).

- Electric utilities (all) have a collective goal of 800MW CHP (via customer projects or utility EUI projects) by 2030.
  - For more information about eligible CHP technologies, consult RCII-1 CHP Policy Option Design.
- Natural Gas utilities achieve at least 1.0% from customer end-use efficiency (DSM).
  - For a partial list of eligible DSM measures established through the Department of Commerce's Technical Reference Manual (TRM), consult the latest TRM manual version 1.0 (http://mn.gov/commerce/energy/images/MN-TRM-2014-ver1%252E0.pdf)
- Natural Gas utilities achieve 0.5% from CHP and/or additional DSM.
- Natural Gas utilities (subject to CIP) have a collective CHP goal of 34 TBtu by 2030.
  - For more information about eligible CHP technologies, consult RCII-1 CHP Policy Option Design.

Additional Resources: Note - the 1.5% savings goal for each utility is calculated based on average weather-normalized retail energy sales, excluding sales to CIP-exempt customers, for the most recent three-year period prior to the filing year for the utility's conservation improvement plan.

Information regarding the historical performance and the baseline for CIP can be found at the following links:

- 2013 CIP CO_2 Report: http://archive.leg.state.mn.us/docs/2013/mandated/131112.pdf
- 2012 CIP CO_2 Report: http://archive.leg.state.mn.us/docs/2015/mandated/150585.pdf
- 2011 CIP CO_2 Report: http://www.leg.state.mn.us/docs/2011/mandated/110369.pdf

Timing: The new electric and gas requirements will begin in 2016 with a ramp-up to full requirements in 2019 as shown below:

Table F-2.31 Electric and Gas Ramp-up Periods

Electric Ramp-up Period

Year	Min. End-use Eff.	Total Savings Goal
2016	1.5%	1.75%

Gas Ramp-up Period

Year	Min. End-use Eff.	Total Savings Goal
2016	1.0%	1.125%

2017	1.5%	2.0%
2018	1.5%	2.25%
2019	1.5%	2.5%

2017	1.0%	1.25%
2018	1.0%	1.375
2019	1.0%	1.5%

Parties Involved:

- Minnesota utilities currently subject to Minnesota Statute 216B.241
- Minnesota households and businesses
- All parties (including utilities) involved in designing, implementing, and evaluating CIP programs including:
- HVAC, electric and mechanical contractors
- Program implementers
- Program evaluators
- Energy service companies
- Minnesota Department of Commerce, Division of Energy Resources
- Minnesota Public Utilities Commission
- Minnesota Pollution Control Agency

Other: No changes to CIP exemption laws are proposed (see Minn. Stat. §216B.241 subd. 1 (g), 1a (b) and (c), 1b (c) and 2 (d)). In 2012, sales to electric CIP-exempt customers were 13.8% of total electric sales; sales to gas CIP-exempt customers were 6.7% of total gas sales. However, for modeling purposes, it may be beneficial to model estimated displacement of fossil fuels through DSM and CHP that includes and excludes large consumer facilities that are currently exempt in CIP.

Implementation Mechanisms

The Next Generation Energy Act of 2007 established an Energy Efficiency Resource Standard (EERS) for electric and natural gas utilities in Minnesota, including investor-owned utilities, electric cooperatives, and municipal utilities (see Minn. Stat. §216B.241 subd 1c.) Under the EERS, utilities are required to develop plans to achieve energy savings equal to 1.5% of gross annual retail sales through conservation improvement programs (CIP) designed to help their customers improve end-use energy efficiency. In addition, electric utilities are allowed to count savings from electric utility infrastructure (EUI) improvements[14] approved by the Minnesota

[14] For example, installing higher than standard-efficiency transformers, low impedance distribution lines, or reconfiguring transmission system to reduce total losses.

Public Utilities Commission (MPUC) under Minn. Stat. §216B.1636[15] towards the 1.5% savings goal on top of a minimum savings goal of 1.0% from end-use efficiency measures, as long as the infrastructure improvements result in increased energy efficiency greater than that which would have occurred through normal maintenance activity.

Utilities may request a lower goal than the 1.5% standard based on a conservation potential study, historical conservation experience and other factors. However, for investor-owned utilities, the commissioner of Commerce may not approve a savings goal less than 1.0%. Natural gas utilities have used this provision to receive approval for 1.0% annual savings goals.

The ability for utilities to carry forward savings achieved in excess of the 1.5% standard under Minn. Stat. §216B.241 subd. 1c (b) will be preserved but modified to reflect the higher electric and gas standards proposed. The statute allows excess savings to be carried forward to the succeeding three calendar years, although savings from electric utility infrastructure projects may be carried forward for five years. CHP projects should be included in the five year carry forward provision.

More specific implementation mechanisms include the following:

- Increase the capacity and resources of CIP Technical Assistance administered through the Department of Commerce for the purpose of providing increased assistance to utilities, and increased capacity to implement evaluation, measurement and verification activities and anticipated regulatory compliance efforts.
- To remove the disincentive for utilities to aggressively promote conservation and efficiency, pass legislation requiring the Public Utilities Commission to approve decoupling for all investor-owned utilities by 2020. Decoupling removes the link between utility sales and revenue by allowing the utility to adjust its rates (higher or lower) without a rate case to recover its revenue requirement when conservation programs, weather, or other factors cause sales to deviate from test year sales. The Public Utilities Commission can customize the details of each utility's decoupling plan (including whether it is full or partial decoupling, and what rate classes it applies to) and adjust it over time.
- Higher energy savings achievements and/or decoupling may necessitate adjusting the demand-side management (DSM) financial incentive mechanism for investor-owned utilities to keep utility earnings at reasonable levels while still providing a strong incentive to achieve high savings. There is already a mechanism in place (Docket No. E,G999/CI-08-133) whereby the Public Utilities Commission can direct the Department of Commerce to review current incentive levels and recommend changes, with utility and other stakeholder input.

[15] Minn. Stat. §216B.1636 does not apply to municipal or cooperative utilities. However, the Department of Commerce has allowed municipal and cooperative utilities to count qualifying electric utility infrastructure (EUI) project savings towards their CIP goals even though they are not subject to Minn. Stat. §216B.1636.

- All utilities subject to the requirements of Minnesota Statute 216B.2422 should be required to consider both biomass-fired and natural gas CHP in their integrated resource plans. Electric utilities will be required to demonstrate in their Integrated Resource Plans that, before power-only capacity is proposed, CHP opportunities within their service territory have been thoroughly assessed to determine the benefits of CHP (and associated technologies such as thermal energy storage) relative to total primary energy efficiency, GHG emissions, power grid resiliency, peak demand management and risk management. Additionally, EUI (in addition to DSM) projects should be considered part of the integrated resource plan.
- Commerce will propagate rules, guidelines and standards to qualify, quantify, and report electric utility infrastructure projects, waste heat recovery converted into electricity projects, combined heat and power projects, and utility code compliance programs by end of year 2016 (efforts are currently underway.)
- Pass legislation modifying the provision in Minn. Stat. §216B.241 subd. 1c allowing utilities to carry forward savings in excess of 1.5% to subsequent years to reflect the new 2.5% goal for electric utilities and 1.5% goal for gas utilities.

Related Policies/Programs in Place and Recent Actions

Currently there are over 180 utilities subject to the CIP requirements that are administering some form of energy efficiency program. Within these 180 utilities, there are 1,250 unique programs dedicated to different types of efficiency activity. These programs address efficiency measures ranging from residential lighting programs to large industrial process efficiency to behavior change programs and energy audit services. To achieve the 2.5% standard, existing programs will need to expand and new programs will need to be developed.

Utilities file conservation improvement program plans with the Department of Commerce every three years for analysis and approval. The next anticipated filing date is in 2016 for the 2017-2019 CIP triennial period. At this time, utilities will be able to include in their new CIP plans efficiency activity that addresses the ramp up period for the increased EERS.

Other programs, such as B3 Benchmarking and the Sustainable Buildings 2030 standard, contribute toward achieving greater efficiency outside of CIP; they can also help provide efficiency savings to count toward CIP goals. These programs, along with other public sector efficiency programs such as the Guaranteed Energy Savings Program (GESP) and Local Energy Efficiency Program (LEEP), can be leveraged to help utilities meeting higher savings targets.

Estimated Policy Impacts

Direct Policy Impacts

Summary in-state (direct) GHG emissions reduction and option costs results for RCII-4, "Increase Energy Efficiency Requirement", are provided in Table F-2.32 below. These values include costs for program administration. Negative values are shown in parentheses. In the "Net present value of societal costs" column, negative values, and denote, instances where the costs of the implementing option (or part of the option) are LESS than the direct economic benefits of the option in avoided energy and other costs. Negative values in the "cost effectiveness" column indicate that there is a net direct economic benefit per metric ton (t) of carbon dioxide equivalent saved. Overall, this option results in 4.7 million metric tons (MMt in the table below) of annual CO_2e savings in 2030, with just under 36 million metric tons of CO_2e savings over the analysis period. About 20% of the savings comes from natural gas utility programs. In addition to these in-state reductions, RCII-4 produces an estimated 0.77 $MMtCO_2e$ of out-of-state (upstream) emissions reductions in 2030, and 5.59 $MMtCO_2e$ in cumulative out-of-state reductions from 2015-2030, yielding total 2030 emissions reductions of 5.46 $MMtCO_2e$ in 2030, and 41.50 $MMtCO_2e$ over 2015-2030.

Table F-2.32 RCII-4 - Estimated Net GHG Reductions and Net Costs or Savings

	2030 GHG reductions ($MMtCO_2e$):	**2015 - 2030 cumulative reductions ($MMtCO_2e$):**	**Net present value of societal costs, 2015 - 2030 (million $2014):**	**Cost effectiveness ($2014/t CO_2e):**
Electric Utility EERS: Savings from EE Programs	1.85	13.87	$(590.16)	$(38.08)
Electric Utility EERS: Savings from CHP Implementation	INCLUDED IN RCII-1			
Electric Utility EERS: Savings from EUI Investments	1.93	15.24	$(964.23)	$(56.65)
Natural Gas Utility EERS: Savings from EE Programs	0.92	6.80	$(327.16)	$(36.41)
Natural Gas Utility EERS: Savings from CHP Implementation	INCLUDED IN RCII-1			
TOTAL	4.70	35.91	$(1,881.55)	$(45.33)

Data Sources

This information has been uploaded into iMeet Central for review by CCS. Additional data may be available upon request.

Quantification Methods

1. Obtain estimates of forecast electricity and natural gas demand by sector and year through 2030 from the Inventory and Forecast (I&F) prepared to accompany the assessment of GHG Emissions Reduction options.
2. Estimate, based on historical averages and other information as available, the fraction of the electricity savings target to be provided by EUI investments and to be provided by combined heat and power (CHP, in RCII-1), as well as the fraction RCII-4 goals met by gas saved through application of CHP in RCII-1.
3. Calculate the total annual savings targets for electricity (2.5% of forecast demand, net of savings from other options) and natural gas (1.5% of forecast demand, net of savings from other options) under this option in energy units (GWh and MMBtu), by sector.
4. Calculate, for each of EE and EUI, the fraction of annual savings under each target and for each fuel that has already been included in the existing (pre-option) EERS, and thus is already included in the electricity and gas consumption forecasts, and reduce the savings targets from step 4 accordingly.
5. Calculate the annual EE savings targets by reducing the total annual savings targets by the reduction in electricity requirements and gas use from CHP implementation in each year, and, for electricity, from the implementation of EUI in each year.
6. Estimate the annual cumulative EE savings by sector for electricity and natural gas assuming that savings cease after 15 years, and thus that savings from all years of the option persist at least throughout the 15-year modeling period.
7. Estimate annual EUI savings by year based on the targets estimated above, net of EUI achieved under the existing EERS.
8. Multiply the annual impacts on electricity and natural gas use in each sector by appropriate avoided GHG emission factors to yield emissions reduction estimates. For electricity, a stream of Minnesota-specific marginal emissions-avoided factors (MEFs) was estimated for use in all RCII and other options as a part of the development of Common Assumptions for the planning effort.
9. Adopt average cost estimates, by sector If available (though likely not), for the cost of saved energy from electric and natural gas EE programs, and EUI investments, on a per-unit-energy-saved basis. Levelized costs estimated from CIP programs in Minnesota carried out in recent years, such as those reported below ("Additional Benefits and Costs") were used as a source of cost estimates. A modest escalation factor is included to provide for the increase in EE costs over time and as potential EE opportunities are taken up.

10. Multiply the cost estimates from step 9 with the annual cumulative energy savings from steps 6 and 7 to provide estimates of the net costs of the option, by sector, fuel (electricity and gas), and year.
11. Calculate the annual costs of new (not ongoing) energy savings in each year.
12. Estimate (for macroeconomic modeling) the capital and O&M components of the levelized costs estimates derived in step 8, and for the capital cost component, estimate the capital cost outlay in each year by dividing the levelized value (less the O&M fraction) by an annual payment factor that incorporates an average interest rate (probably the same as the discount rate used for the analysis) and an assumed average lifetime (assumed to be the same as that used in step 6).
13. Multiply the net impacts on purchased fuels by end-users as developed in Step 6, and purchased fuels and other costs by utilities as avoided by EUIs, by appropriate avoided costs for electricity and fuels saved/used.
14. Calculate the total net cost impact from the results of step 10 and step 13.
15. Estimate "upstream" emissions reduction from avoided/additional fuels and electricity use using common emission factors used in many options.
16. Apply representative estimates of the fraction of the additional capital costs of technologies used in the option that might be paid by a program sponsor, plus estimates of the ratio of sponsor administrative costs to the sponsor outlays for incentives, to estimate the administrative costs of the option.

Key Assumptions

Key assumptions used in the quantification methods above to produce the estimated emissions savings and cost-effectiveness results shown for RCII-4 include the following:

- Of the 2.5% annual additional savings goal for electric utilities, and 1.5% annual goal for gas utilities, 1.8% and 1.4% annually are assumed to come from energy efficiency measures, respectively by 2019.
- EUI savings by electric utilities increases to 0.3% of new savings annually by 2019. EUI efficiency options counted in this total are those implemented at existing facilities only, not for building new generation (that is, for example, switching from coal to combined-cycle natural gas generation would not count toward this goal).
- Sales by municipal and cooperative utilities are included in the calculations of emissions savings and costs, but sales to CIP-exempt industrial consumer are excluded from the analysis.

- Based on a combination of 2012 CIP spending data[16] and Xcel Energy[17] information, the levelized costs of electric energy efficiency in the Residential, Commercial/Institutional, and Industrial sectors were $15.5, $30.0, and $32.1 per lifetime MWh saved, respectively (2014 dollars), and the levelized costs of gas energy efficiency in the Residential, Commercial/Institutional, and Industrial sectors were $1.43, $1.42, and $1.51 per lifetime MMBtu saved, respectively. All of these levelized costs are escalated at an assumed 0.25%/yr (real) after 2015.
- Based on Xcel data as cited above, the average fraction of measure capital costs covered by program sponsors, in the Residential, Commercial/Institutional, and Industrial sectors were estimated at 74, 30, and 28 percent, respectively for both electric and gas utilities.
- Estimated avoided marginal emission factors for electricity generation, on a delivered basis, falls from 0.936 tCO_2e per MWh in 2015 to 0.758 in 2030, with avoided costs of electricity generation (again based on delivery to consumers, that is, factoring in transmission and distribution losses) rising from $92.6 to $148.1 per MWh delivered (nominal dollars) over the same time period. Natural gas avoided (wholesale) costs rise from $4.78 to $8.97 per GJ (again nominal dollars) over the same time period.

Macroeconomic (Indirect) Economic Impacts

Table F-2.33 below provides a summary of the expected impacts on jobs and economic growth during the CSEO planning period.

Table F-2.33 RCII-4 Macroeconomic Impacts on GSP, Employment and Income

Scenario	Gross State Product (GSP, $2015 Millions)			Employment (Full & Part-Time Jobs)			Income Earned ($2015 Millions)		
	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)
RCII-4	$137	$141	$2,111	1,430	1,560	23,340	$163	$143	$2,140

Graphs below show detail in GSP, employment and personal income impact of the RCII-4 policy.

[16] CIP Spending and Savings Information - 2012 were provided by Minnesota Agency Staff on 10/10/14.

[17] KEMA (2012), Xcel Energy Minnesota DSM Market Potential Assessment Final Report – Volume 1. Prepared for Xcel Energy, Minneapolis, Minnesota, Prepared by, KEMA, Inc., Oakland, California, dated April 20, 2012, and provided by Minnesota Agency Staff. Table 3-1 Scenario Average Spending during 2011-2020 Forecast Period ($1000s) Electric Programs ("BAU" scenario). See "Supporting Data" worksheet in

Figure F-2.28 RCII-4 GSP Impacts ($2015 MM)

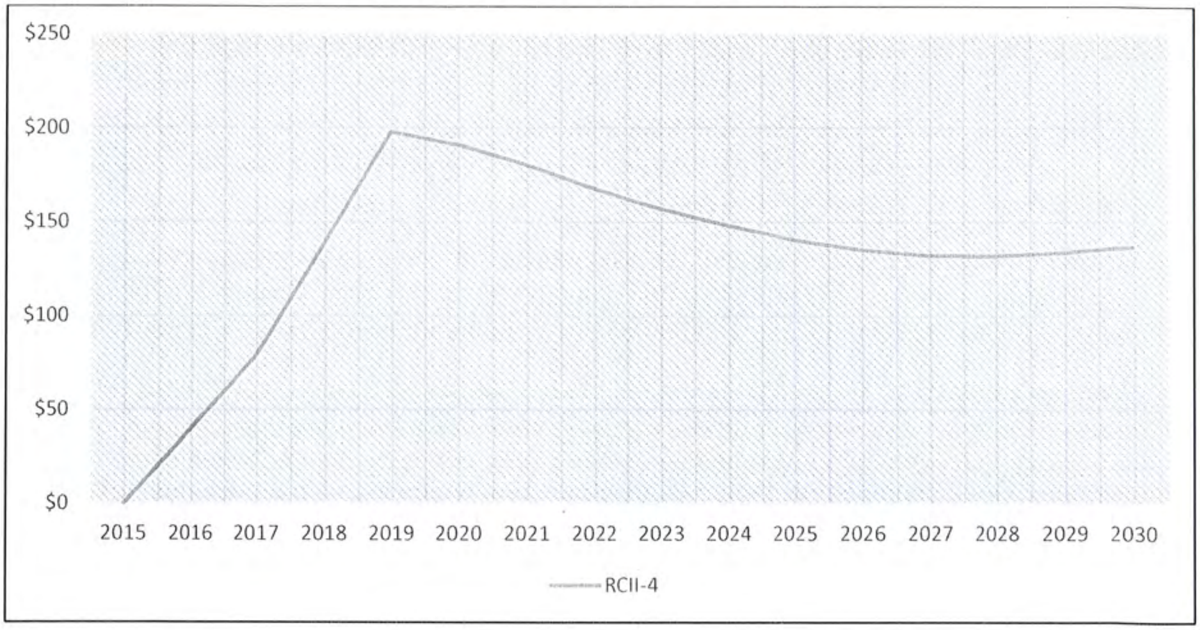


Figure F-2.29 RCII-4 Employment Impacts (Individual Jobs)

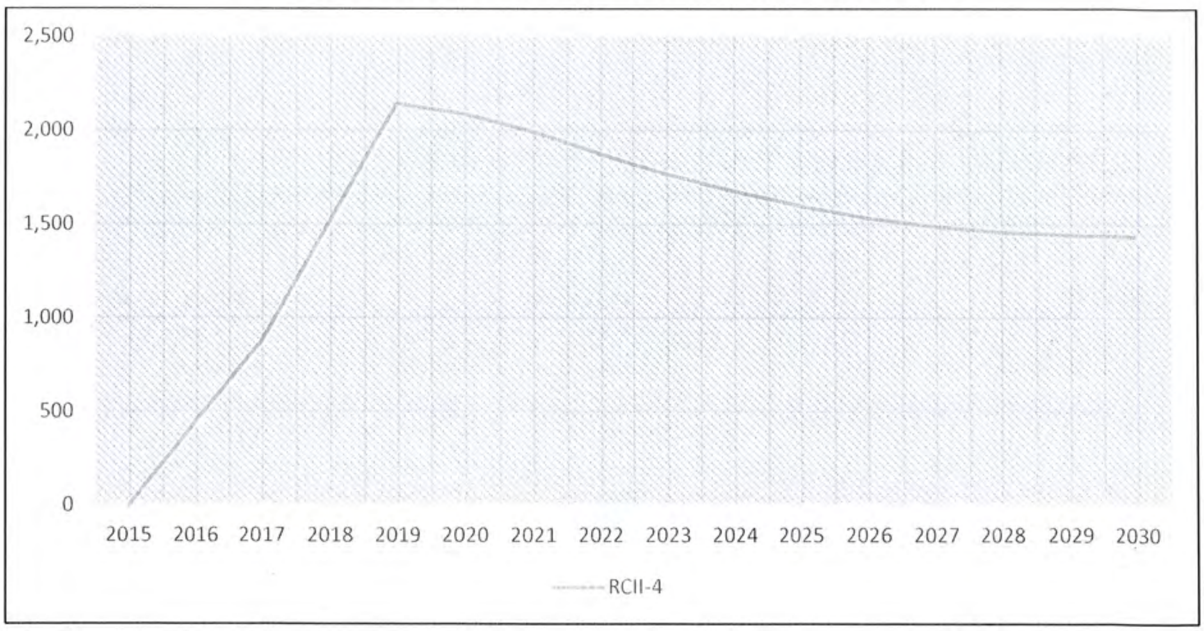
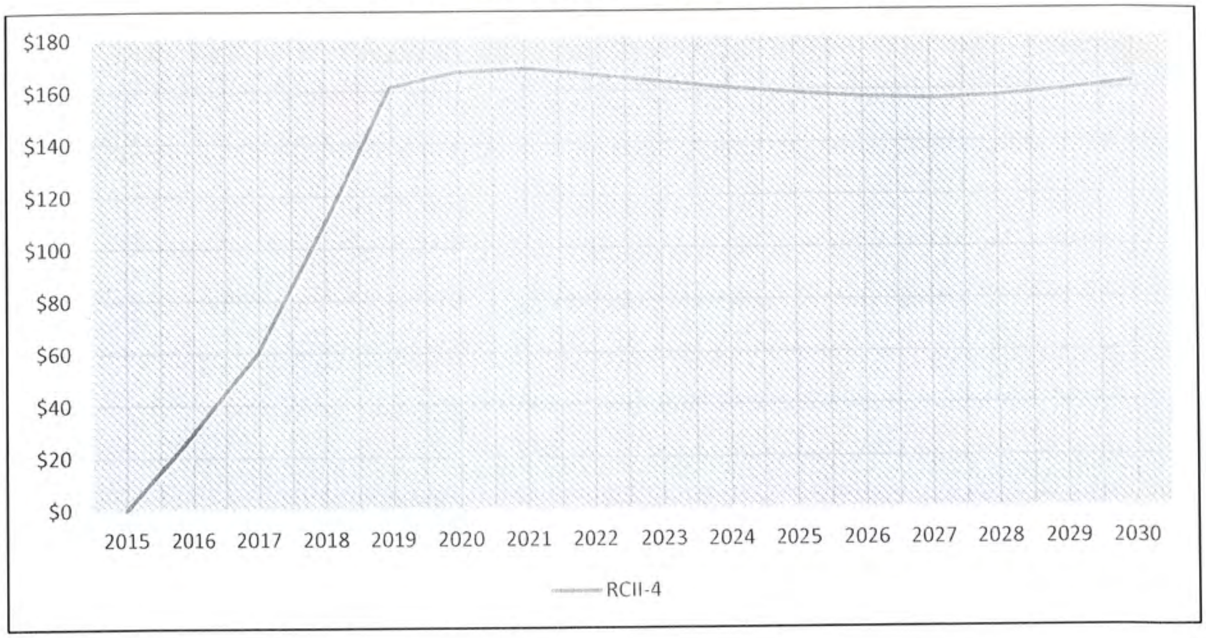
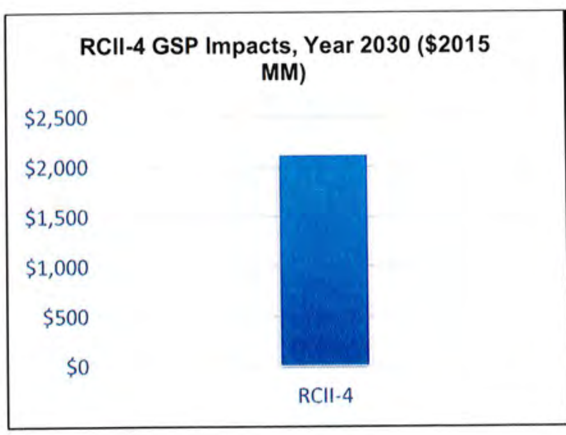
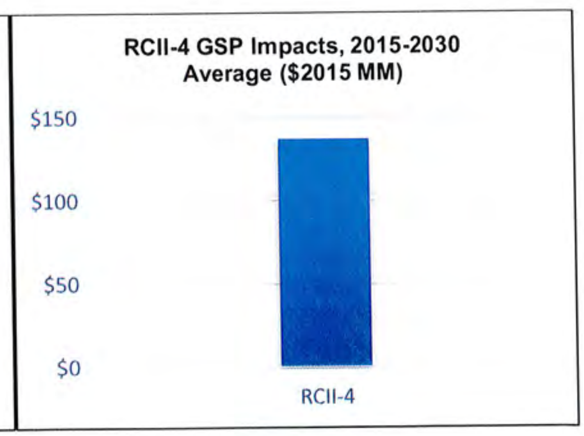


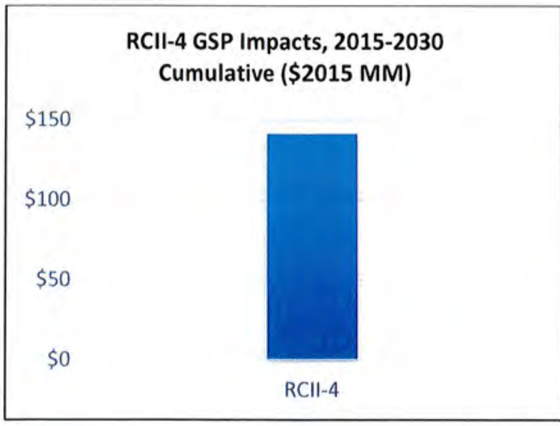
Figure F-2.30 RCII-4 Income Impacts ($2015 MM)

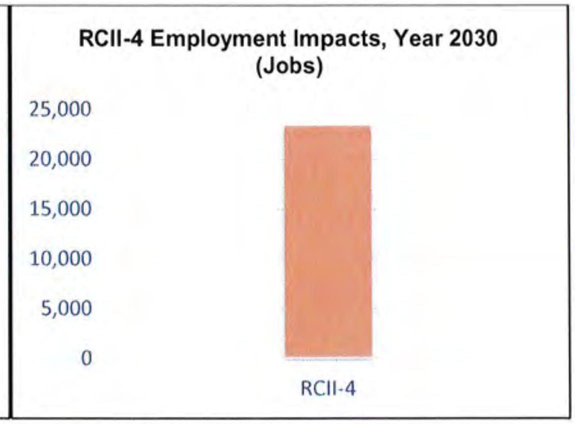


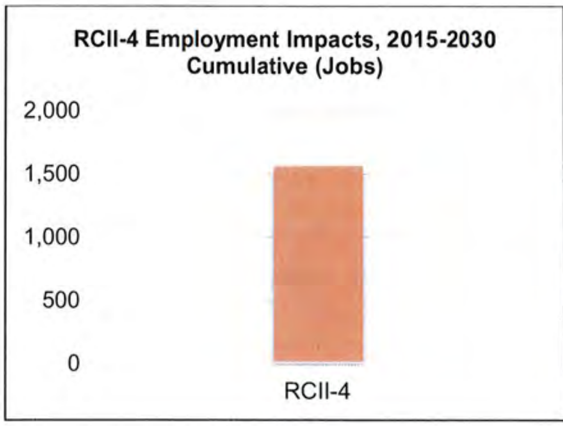
Graphs below show macroeconomic impacts on GSP, personal income, and employment in the final year (2030), in average (2015-2030) and in cumulative (2015-2030).

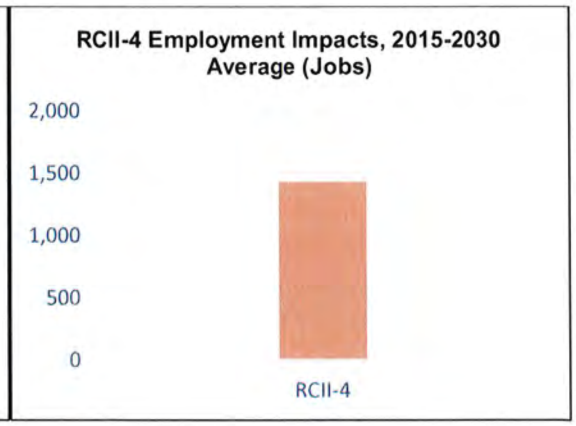


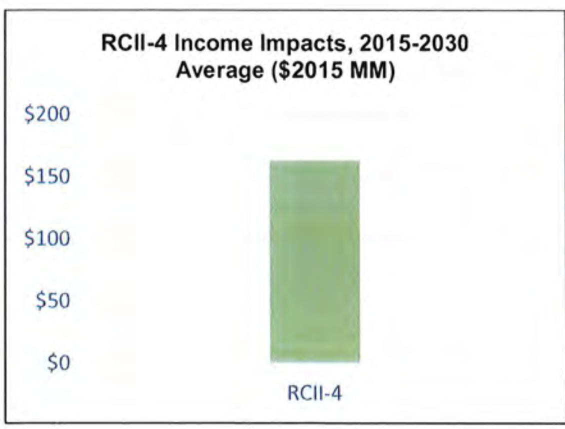


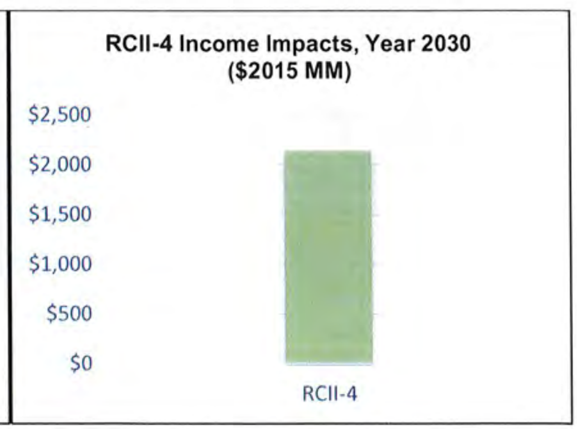

RCII-4 GSP Impacts, 2015-2030
Cumulative ($2015 MM)
$150
$100
$50
$0
RCII-4

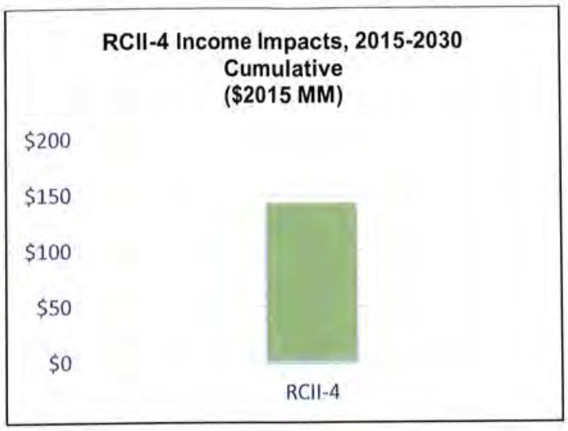

RCII-4 Employment Impacts, Year 2030
(Jobs)
25,000
20,000
15,000
10,000
5,000
0
RCII-4


RCII-4 Employment Impacts, 2015-2030
Cumulative (Jobs)
2,000
1,500
1,000
500
0
RCII-4


RCII-4 Employment Impacts, 2015-2030
Average (Jobs)
2,000
1,500
1,000
500
0
RCII-4


RCII-4 Income Impacts, 2015-2030
Average ($2015 MM)
$200
$150
$100
$50
$0
RCII-4


RCII-4 Income Impacts, Year 2030
($2015 MM)
$2,500
$2,000
$1,500
$1,000
$500
$0
RCII-4



Principal Drivers of Macroeconomic Changes

RCII-4 produces about $200 million each in annual gains in GSP and Income, with annual employment rising as a result of the policy by about 2,000 total positions statewide.

Energy savings play a big part. Statewide, various consuming sectors achieve a reduction in demand for electricity and natural gas reaching approximately $750 million by the year 2030.

The scale of those savings overwhelms the burden of program compliance, which is what produces the overall positive impacts.

The utility sector, which so often suffers under energy supply policies (and does lose volume of economic activity here as it does under other RCII policies) is somewhat helped in that it too participates in the energy-efficiency initiative and achieves large reductions in the requirements involved in its own operations, as it self-powers energy generation and provides water treatment.

Sectors of Economy Most Affected by the Policy

Economic impacts from policies run around the economy, affecting sectors that are sometimes far from the direct target of a policy.

For RCII-4, the utilities sector still sees losses in total demand, and thus reduces the amount of inputs it needs to production for a smaller total supply to produce.

The largest gains are actually in management positions, as the operating and maintenance investment that companies make to adopt this policy is large. At about 700 positions, the expansion of this labor pool is about double the size of the losses in jobs in the utilities sector.

Consumer-oriented sectors gain, as households see a net savings from this policy. Retail trade, restaurants, services, direct labor to homes, and health care all see gains. In general, the policy's net savings to affected parties frees up money for demand all around the economy, and most sectors see slight upward influence in the demand for their products and services.

Data Sources

The principal data sources for the macroeconomic impacts analysis of this and all other policies in the CSEO process are the direct spending, saving, cost and price impacts developed as part of the microeconomic (direct impacts) analysis. For each policy, the cost-effectiveness analysis described above develops year-by-year estimates of the costs, savings prices, and changes demand or supply that households, businesses and government agencies are expected to encounter in a scenario where the policy is implemented as designed.

A secondary data source is the policy design. Balancing financial flows for each direct impact identified are established based on understanding the implementation mechanism, and quantitative values for these flows are developed for each direct impact identified. This balancing identifies and quantifies the responsive change that occurs as a result of the direct impact in question. For example, if a household is anticipated to save $100 per year on electricity bills as a result of a policy, the direct impact is a $100 savings to the household (which expands its spending capacity for other things) but the balancing impact is a $100 loss in revenue and demand to the utility provider (which reduces its ability and need to spend on labor, capital, profit, and other inputs). The quantitative measure of both sides of a change is of importance to a complete macroeconomic analysis. This balancing ensures that both the supply and the demand side of each economic change is fully represented in the analysis.

A third data source is direct communication with Minnesota agency staff and others involved in policy design or in a position to understand in detail the financial flows involved in the policy. These people assisted in clarifying the nature of economic changes involved so that the modeling and analysis would be accurate.

The final crucial data source is the baseline and forecast of economic activity within the REMI software. This data is compiled into a scenario that is characterized not only by the total size of the economy and its many consuming and producing sectors, but also the mechanisms by which impacts in one sector can change the broader economy – such as intermediate demands, regional purchase coefficients, and equilibria around price and quantity, labor and capital, and savings and spending, to name a few of many. REMI, Inc. maintains a full discussion of all the sources of the baseline data on its own website, www.remi.com.

Quantification Methods

Utilizing the data developed from the microeconomic analysis, CCS analysts established for each individual change the following characteristics:

- The category of change involved (change in spending, savings, costs, prices, supply or demand)
- The party involved on both sides of each transaction
- The volume of money involved in this change in each year of the period of analysis

These values, so characterized, were then processed into inputs to the REMI PI+ software model built specifically for use by CCS and consistent with that in use by state agencies within Minnesota. These inputs were applied to the model and run. Key results were then drawn from the model and processed for consistency of units and presentation before inclusion in this report.

Key Assumptions

The macroeconomic impact analyses of this policy, as well as of the others in the CSEO process, rely on a consistent set of key assumptions:

- State and local spending is always budget-constrained. If a policy calls for the state or local government to spend money in any fashion, that spending must be either funded by a new revenue stream or offset by reductions in spending on other programs. Savings or revenues collected by the government are also expected to be returned to the economy as spending in the same year as they are collected.
- Federal spending is not budget-constrained. The capacity of the federal government to carry out deficit spending means that no CSEO policy is held responsible for driving either an increase or decrease in federal tax spending by businesses or households in the state of Minnesota.
- Consumer spending increases are sometimes financed. Small-scale purchases or purchases of consumer goods are treated as direct spending from existing household cash flows (or short-term credit). Durable goods, home improvements or vehicle purchases, however, are treated as financed. Consumers were assumed to spread out costs based on common borrowing time frames, such as five years for financing a new vehicle or 10-20 years for home improvements that might be funded by home-equity or other lending. The assumption of financing and the term of years applied was considered anew in each case.
- Business spending increases are often financed. Where spending strikes a sector which routinely utilizes financing or lines of credit to ensure steady payment of recurring costs, significant spending of nearly any type was considered a candidate for financing, thus allowing costs to spread out over time. This methodology is preferable for the modeling work, as sudden spikes or dips in business operating costs can show up as volatility when the scenario may depict a managed adoption of new equipment in an orderly fashion. The assumption of financing and the term of years applied was considered anew in each case.
- Unless otherwise stated, all changes to consumer spending or to the producers' cost of producing goods and services were treated in a standard fashion. Consumers are assumed to spend on a pre-set mix of goods, services, and basic needs, and businesses spend (based on their particular sector of the economy) on a mix of labor, capital, and intermediate demands from other sectors. Unless a policy specifically defines how a party will react to changes in cost, price, supply or demand, these standard assumptions were applied.
- State and local spending gains and reductions driven by policy are assumed to apply to standard mixes of spending. Again, unless a policy specifically states that a government entity will draw from a specific source or direct savings or revenues to a specific form of

spending, all gains and losses were assumed to apply to a standard profile of government spending within the economy.

Key Uncertainties

Key uncertainties that should be considered in the development and implementation of this proposed policy option are as follows:

- Is 2.5% for electric utilities and 1.5% for natural gas utilities feasible?

To explore the GHG and net societal cost implications for this uncertainty, an alternative scenario was modeled in which the overall requirement for savings by electric utilities rises to 2.0% of sales annually over three years (as opposed to 2.5% over four years in the base case for this option), with the annual savings requirement from energy efficiency rising from 1.5% to 1.65% in three years. As a result of this change, the overall cumulative in-state (direct) GHG emissions savings over the period 2015-2030 from the policy option declines by about one-third relative to the base case, to 24.6 million $MMtCO_2e$ (3.2 MMt in 2030), with a net cost of negative $1,270 million (about one-third less overall savings than in the base case), but with a similar cost-effectiveness (minus $51.70 per tCO_2e) as in the case where 2.5% annual savings is used as the electric utility target. The results of this alternative scenario are presented in Table F-2.34 below. In addition to these in-state reductions, when evaluated with an ultimate savings requirement of 2.0%/year for electric utilities, RCII-4 produces an estimated 0.57 $MMtCO_2e$ of out-of-state (upstream) emissions reductions in 2030, and 4.26 $MMtCO_2e$ in cumulative out-of-state reductions from 2015-2030, yielding total 2030 emissions reductions of 3.75 $MMtCO_2e$ in 2030, and 28.87 $MMtCO_2e$ over 2015-2030.

Table F-2.34 RCII-4 Alternative Scenario Results

	2030 GHG reductions ($MMtCO_2e$):	2015 - 2030 cumulative reductions ($MMtCO_2e$):	Net present value of societal costs, 2015 - 2030 (million $2014):	Cost effectiveness ($2014/t CO_2e):
Electric Utility EERS: Savings from EE Programs	0.98	7.78	$(336.11)	$(38.69)
Electric Utility EERS: Savings from CHP Implementation	INCLUDED IN RCII-1			
Electric Utility EERS: Savings from EUI Investments	1.28	10.02	$ (609.14)	$(54.41)

	2030 GHG reductions ($MMtCO_2e$):	2015 - 2030 cumulative reductions ($MMtCO_2e$):	Net present value of societal costs, 2015 - 2030 (million \$2014):	Cost effectiveness (\$2014/t CO_2e):
Natural Gas Utility EERS: Savings from EE Programs	0.92	6.80	\$(327.16)	\$(36.41)
Natural Gas Utility EERS: Savings from CHP Implementation	INCLUDED IN RCII-1			
TOTAL	3.18	24.61	\$(1,272.41)	\$(44.08)

- Is a 2.5% for electric utilities and 1.5% for natural gas utilities achievable and sustainable until 2030?
- What will the impact of changing market conditions, such as natural gas price fluctuations or decreases and advances in energy codes, be on cost-effectiveness of energy efficiency programs and energy savings?
- What is the technical and economic potential each utility has available to meet set CHP goals?
- How will the barriers that exist in Minnesota's current energy efficiency framework be addressed so they are not continued barriers in achieving the 2.5% goal?
- What will be the long-term impacts to utility rates and supply-side resources if the 2.5% EERS is achieved consistently through its effective period?
- What will be the impact on expenditures on energy efficiency and CHP efforts to achieve this higher standard?
- In achievement of the CHP standard, how will ratepayer cross-subsidization of incentivizing projects be avoided or managed?
- In the absence of an existing CHP technical assistance program for potential projects, how the state and its utilities drive demand for customer on-site generation?

Additional Benefits and Costs

Energy: Energy conservation and efficiency is the most cost-effective energy resource available in Minnesota. Increasing the 1.5% goal to a 2.5% goal will further alleviate the need to meet additional supply needs through other more costly energy resources. For example, in the most recent CO_2 Report where Commerce reports CIP performance to the legislature, a levelized cost-comparison found in 2011 energy efficiency as a result of CIP cost \$21.43/MWh whereas the average cost of generating a kWh from coal cost \$100.10/MWh.

Economy: Increased activity within CIP provides an economic benefit to the state of Minnesota in many different. Residents and businesses that participate in CIP benefit from lowered utilities bills through reduced demand and consumption. In 2013, Commerce estimated that, based on CIP historical performance, over $2.6 billion dollars has been saved by ratepayers through energy efficiency and conservation. Additional benefits include more sales for Minnesota's trade allies that implement and sell energy efficiency technology or services; dedicated low income spending required in CIP results in reduced need for Low Income Heating Assistance allowing those dollars to go further; and the financial incentives and policy option framework in CIP spur greater innovation of technologies and program design to meet the needs of advancing standards and goals.

Environment: DSM through the Conservation Improvement Program directly results in reduced carbon emissions and has the potential to be one of the more cost effective solutions for reducing greenhouse gas emissions. For example, in the most recent CO2 Report, Commerce found that in 2010-2011 (the first years of the energy savings requirement), nearly 2,000,000 tons of CO2 emissions were avoided which is roughly the equivalent of removing 371,000 cars from the road for one year.

Health: Per a Minnesota Department of Health analysis, increasing energy efficiency could benefit health by reducing climate change through reduced emissions. Emissions reductions may reduce the risk of cardiovascular and respiratory illness as well as cancer in communities exposed to energy-related emissions. (EPA; Kappos; Pope 2002, Pope 2000, Bernard) Building efficiency improvements could also reduce respiratory illness, reduce allergies and asthma, reduce sick building syndrome, and improve worker performance through changes in thermal environment and lighting.

Feasibility Issues

The Conservation Improvement Program is an existing regulatory framework that has evolved over the last three decades. Minnesota ratepayers already have contributed significant investments toward the development of energy efficiency programs and services to meet existing utility efficiency goals. Modifying the goal from 1.5% to 2.5% will increase the need for additional expenditures in CIP to achieve the more aggressive standard. While expenditures will increase, considerations need to be made to ensure efficiency activities remain cost-effective for the ratepayers. As a result of Minnesota's long standing commitment to efficiency, many opportunities to achieve greater efficiency and the ability to achieve savings cost-effectively are evolving.

While there may be some feasibility issues with a utility's ability meet a higher EERS, the inclusion of a CHP standard within the EERS will afford the utilities greater opportunity to achieve the EERS through implementation of this underutilized technology. As the opportunities exist to implement CHP, implementation of this embedded standard is not without challenge. Detailed below are a few areas of concern with regard to achieving a higher EERS and an embedded CHP standard.

Energy Efficiency Achievement Feasibility

Minnesota Energy Code: The Department of Labor and Industry is moving closer to finalizing the adoption of new residential and commercial energy codes. The new code will be based on the 2012 IECC. It is expected that the energy codes will be going into effect during the early to middle part of 2015. The new energy code will impact the incremental savings a utility can claim from projects implemented that are more efficient than code, a key criteria for project eligibility in CIP. The incremental savings, which will be reduced as a result of the code, directly impact the cost-effectiveness of CIP programs. As this change takes place, regulatory agencies and utilities will need to closely evaluate the impact the code change will have on the utility's ability to achieve a higher 2.5% goal.

Federal Standards: Similar to the issue with energy code change impacts to utility baselines, changes to federal standards for efficiency measures such as lighting or motors will also impact a utilities ability to achieve greater savings. Approximately 40% of the CIP portfolio is comprised of lighting efficiency measures. As federal standards phase out incandescent lamps from the market, compact fluorescent lighting becomes the new baseline. This will also result in reduced incremental savings that a utility can count toward its CIP goal, potentially negatively impacting the cost effectiveness of related programs. Given the size of lighting efficiency in the overall CIP portfolio, efforts will need to be made to diversify program offerings to achieve greater savings.

Sustainability of EERS Achievement: Utilities have been working with their customers to save energy since the early 1980s, but as of 2007 these efforts increased significantly with an energy savings requirement fully established by 2010. Since 2010, the utilities have collectively achieved a statewide performance of 1.5% for electric and approximately 1% for natural gas – some utilities have achieved higher savings while others have achieved less. Natural gas utilities have already successfully petitioned the Department of Commerce to approve a 1% goal based on current feasibility in meeting the standard. Additionally, lower natural gas prices are impacting the avoided cost component of cost-effective programs. If natural gas prices continue to remain low and as incremental savings decrease, utilities may have fewer programs that remain cost-effective.

Combined Heat and Power Implementation Feasibility

Minnesota has been perpetually challenged to implement higher levels of CHP throughout the state. The feasibility of achieving the CHP standard embedded within the EERS will be dependent on many factors, a few of which include the following:

- Creation of utility programs that significantly reduce the upfront capital costs and overall risk of moving toward customer on-site generation.
- Establishment of reasonable stand-by rates by utilities and the Public Utilities Commission to remove obstacles in a customer's ability to achieve a desired return on investment from project implementation.
- Potential adjustments made to net metering and interconnection standards and practices the reduce implementation barriers.

- Education and training programs established and available for customers who are implementing and/or considering implementing CHP.

RCII-5. Incentives and Resources to Promote Thermal Renewables

Policy Option Description

Establish a **renewable thermal goal** of 5% of the total forecast heating load (measured as fuel delivered for heating use) that is fueled with non-electric sources including natural gas, fuel oil, and propane in Minnesota coming from eligible renewable thermal resources by 2020 and 20% by 2030[18]. Includes a small system carve out of 5%.

Establish a statewide **Renewable Thermal Incentive Fund** that provides incentives for the installation of thermal renewable technologies and targets high-value customers including farmers, delivered fuel customers, low income housing authorities and commercial users. The fund would collect 1 cent per therm[19] of energy content on natural gas, fuel oil, and propane sold in Minnesota. A portion of the funds collected could be reserved as a loan guarantee fund for large projects while the remainder would be issued as competitive grants for large systems and prescriptive incentives for small systems. The program sunsets in 2030.

Significant opportunity exists to meet heating load with in-state renewable energy resources, resulting in reduced GHG emissions. In addition, recent propane infrastructure changes and severe shortages of propane in the winter of 2013-2014 highlight the benefits of more diversity in heating options to mitigate volatility in fuel pricing and availability throughout greater Minnesota.

A **renewable thermal goal** is a leading state policy option to promote adequate and diverse thermal energy supplies, at a reasonable cost, with minimal impact on the environment and with side benefits of increased energy security and energy access for Minnesotans. The small system carve-out ensures that a variety of end-users benefit such as residential propane customers.

A **Renewable Thermal Incentive Fund** to provide incentives for the installation of renewable thermal systems statewide and support progress toward attainment of the renewable thermal goal. A one cent per therm charge on propane, fuel oil, and natural gas use will generate a fund of approximately $40 million annually to start.

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[18] State funded building projects currently follow SB 2030 guidelines including an assessment for on-site renewable thermal technologies. Adoption of the thermal goal would support the efforts of SB 2030.

[19] One therm is 100,000 British Thermal Units (Btu) or 0.1 MMBtu.

Eligible Fuel sources:

- Biomass[20] (with emission controls and efficiency requirements)
- Biogas
- Biofuel
- Solar thermal (including solar air heat, solar water heating, industrial process heat, and transpired air heat)

Eligible technologies:

- Biogas thermal systems
- Biomass thermal systems with efficiency requirements and stringent emissions controls[21]
- Solar water and space heating systems including transpired air heat
- Solar industrial process heating and cooling systems
- Renewable combined heat and power systems[22]
- Renewable district heating and cooling systems

Causal Chain for GHG Reductions

A schematic causal chain for this policy option is provided below. Increased use of renewable heating fuels and systems displaces fossil fuel (natural gas, distillate oil, and propane) used for space heat, water heat, and process heat produced. As such, GHG emissions savings accrue through the reduction of use of fossil fuels formerly used for heating, but these savings are partially offset by emissions from renewable fuels combustion in biomass and biogas systems. In addition, reduced use of fossil fuel reduces "upstream" emissions associated with, for example, natural gas transmission and distribution, oil refining and transport, and natural gas and crude oil production. It is expected that these GHG emissions reductions and increases will

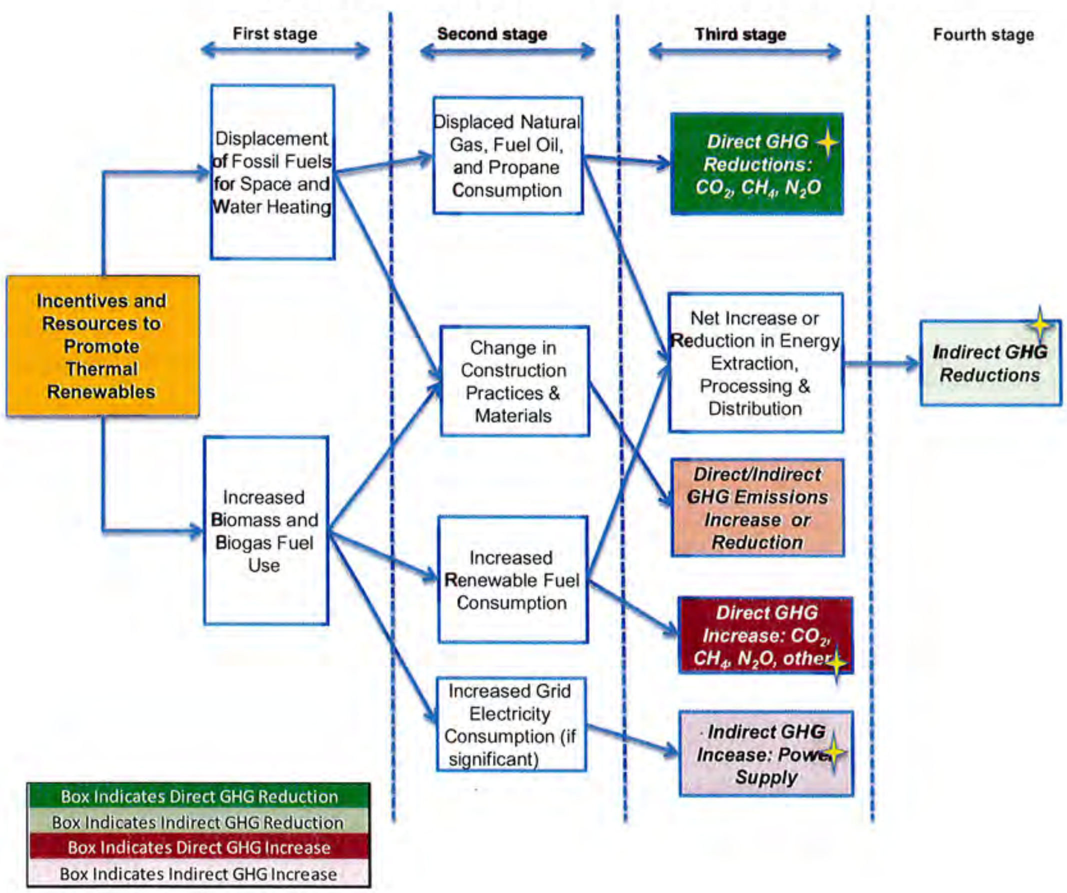
[20] The federal Biomass Thermal Utilization (BTU) Act of 2013 defines biomass as any plant-derived fuel available on a renewable or recurring basis, including agricultural crops and trees, wood and wood waste and residues, plants (including aquatic plants), grasses, residues, and fibers. This definition includes densified biomass fuels such as wood pellets.

[21] For example, the New York State Energy Research and Development Authority (NYSERDA) funds high efficiency and low emissions commercial and residential wood pellet heating equipment. The guidance documents are available by scrolling to the bottom of this link http://www.nyserda.ny.gov/Statewide-Initiatives/Cleaner-Greener-Communities/Implementing-Smart-Development-Projects/Guidance-Documents.aspx. This is not an endorsement to adopt NYSERDA's preferred equipment, but an example. The State of Maryland's emissions regulations should be considered as a model as well if this policy option is adopted.

[22] Included in the CHP policy option document RCII-1 for microeconomic and macroeconomic modeling rather than in this policy option.

be quantified. Increased use of renewable fuels will produce some increase in emissions associated with fuel processing and transport—for example, diesel-fueled equipment used for biomass harvesting and transport. These additional emissions are highly variable depending on the source of the biomass fuel and the distance it must be shipped to the users. At present, these incremental emissions are estimated using an upstream emission factor derived from a study in Ontario,[23] but Minnesota-specific average might be different. Changes in the heating equipment/appliances used that are made as a result of this option may also produce changes in construction practices and materials manufacturing that may have a positive or negative impact on GHG emissions. These impacts are indirect and uncertain, and are not quantified.

Figure F-2.31 Causal Chain for RCII-5 GHG Reductions



[23] The upstream emission factor for wood use is are based on an Ontario study of the Life Cycle Impacts of Wood vs Coal production (see Tables S-1 and S-2; http://pubs.acs.org/doi/suppl/10.1021/es902555a/suppl_file/es902555a_si_001.pdf). The value used is for pelletized wood fuel; less-processed forms of wood fuel would likely have somewhat lower emission factors.

Policy Option Design

The renewable thermal goal would apply to non-electric sources of heat including natural gas, propane, and fuel oil consumption statewide to diversify the state's use of heating fuels to include increasing amounts of renewable energy. Implementation of these policies will require enabling legislation and subsequent regulation by the Public Utilities Commission and the Department of Commerce. The Policy Option design must recognize the need to implement a renewable thermal goal that is broad enough to serve the state's various regions by matching resource preferences to regional availability with a strong emphasis on emissions impacts. The displacement of the most carbon-intensive conventional sources should be prioritized under the Renewable Thermal Incentive Fund, however, use of all fossil fuels for heating should be curbed through statewide implementation with geographic consideration.

Given Minnesota's significant heating load and the difficulty of addressing GHG reductions in the transportation sector, Minnesota cannot achieve the state energy policy option goal of 80% GHG reductions by 2050 without addressing the heating sector.

Commercial/industrial such as biomass for district energy systems, agricultural operations, institutional buildings, schools, and government buildings represents the biggest opportunity for cost effective reductions in GHG emissions and should represent most of the renewable thermal deployment. However, the 5% residential and small commercial carve out from the renewable thermal goal along with the Renewable Thermal Incentive Program will promote investment in small projects as well.

The Renewable Thermal Incentive Program would be established with fees collected by the Minnesota Department of Revenue and administered by Department of Commerce. The Department of Revenue would collect $0.01 per therm on natural gas, fuel oil and propane sold in Minnesota. Revenue currently collects $.001 per gallon of propane and fuel oil from wholesalers; a gallon of propane or fuel oil has energy contents roughly equivalent to 1 therm of heat (about 0.9 and 1.4 therms, respectively).

High-value customers include farmers, delivered fuel customers, low income housing authorities, and residential and commercials users. The program would sunset in 15 years.

Program participation would require cost-share commitments from residential, commercial, non-profit and public sector applicants. The incentive amount available to consumers should reflect the availability of other non-state incentives in order to maximize program effectiveness.

- Large and non-residential projects: Competitive grants with a suggested cost-share commitment from the applicant.
- Residential and small commercial projects: First come, first served year-round rebate with a minimum 50%cost-share commitment from the applicant.

Goals:

A. Reduce the use of fossil fuels (specifically, natural gas, fuel oil, and propane) for heating in Minnesota through the use of eligible renewable thermal resources by 5% by 2020 and 20% by 2030[24] and do so in a manner that doesn't create unacceptable exposures to air pollution from renewable-fueled heating systems.

B. Annually deploy hundreds of renewable thermal systems from various renewable technologies through the new Renewable Thermal Incentive Program. These projects should represent high-value customers and demonstrate:

  - geographically diverse locations;
  - a variety of sector end-uses including residential, commercial, agricultural, and government facilities, and;
  - projects sized for small-scale, large-scale, and utility-scale installations.

Timing--Renewable Thermal Goal (as a fraction of total use of natural gas, fuel oil, and propane for heating):

- 2017 – 1%
- 2018 – 2%
- 2020 – 5%
- 2025 – 12%
- 2030 – 20%

Timing—The Renewable Thermal Incentive Program operates through December 2030. New projects receive total funding of approximately $38,000,000 (or 95% of the funds generated) annually, net of administration and promotion costs. Reservation of funds for awardees begins no later than January 2017.

Parties Involved in Implementation

- Minnesota Department of Commerce-tracking and administration
- Minnesota Pollution Control Agency-air quality emissions criteria and outreach/education
- Minnesota Department of Natural Resources-supply chain
- Minnesota Department of Revenue-fee collection for delivered fuels

Parties Affected:

- Natural gas utilities
- Minnesota Propane Association
- Delivered fuels wholesale providers

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[24] State funded building projects currently follow SB 2030 guidelines, which for state buildings includes an assessment for on-site thermal renewable technologies. Adoption of the thermal goal would support the efforts of SB 2030.

- 3rd party gas suppliers

Other: Given the significant contribution of residential wood combustion to the direct emissions of fine particles (PM2.5) in Minnesota, several wood smoke-related recommendations were supported by the Clean Air Dialogues project. These included development of a model ordinance to assist local governments addressing air quality impacts of outdoor wood boilers (hydronic heaters), education and outreach related to residential wood smoke, and support for EPA's work to finalize a New Source Performance Standard for residential wood heaters http://www.epa.gov/residential-wood-heaters/final-new-source-performance-standards-residential-wood-heaters

Implementation Mechanisms

1. Pass legislation requiring a **renewable thermal goal** for Minnesota's heating load similar to the state's successful Renewable Electricity Standard as well as requirement for a Renewable Thermal Incentive Program.

Develop a **Renewable Thermal Incentive Program** to reduce gas, propane and fuel oil consumption and price and availability volatility. Program will be funded with fees collected by Minnesota Department of Revenue. The fund will target high-value customers for thermal technologies, including farmers, commercial users and delivered fuel customers. The program will be administered by the Department of Commerce with on-going cooperation with Revenue for fee collection and informed by Pollution Control and Natural Resources. The administrative cost must not exceed 5% of the funds collected. Include an annual report of the **Renewable Thermal Goal** and **Renewable Thermal Incentive Program** results to optimize the policy option for maximum GHG reductions.

Related Policies/Programs in Place and Recent Actions

- **Minn. Statute 216C.05 Subd. 2 (2007)** states it is the energy policy option goal of the state of Minnesota that:
    - the per capita use of fossil fuel as an energy input be reduced by 15% by the year 2015 [with a base year of 2005], through increased reliance on energy efficiency and renewable energy alternatives; and
    - 25% of the total energy used in the state be derived from renewable energy resources by the year 2025.
- **Executive Order 11-13,** ***"Strengthening State Agency Environmental, Energy and Transportation Sustainability,"*** requires that Minnesota state agencies establish a Sustainability Plan to reduce greenhouse gas emissions in its operations. A requirement for new and remodeled public buildings to incorporate on-site renewable thermal or use of renewable thermal from a district energy system is consistent with the Executive Order's goals.

- 16B.32 Energy Use.
  - Subdivision 1. **Alternative energy sources.** Plans prepared by the commissioner [of Administration] for a new building or for a renovation of 50% or more of an existing building or its energy systems must include designs which use active and passive solar energy systems, earth sheltered construction and other alternative energy sources where feasible.
  - Subd. 1a.**Onsite energy generation from renewable sources.** A state agency that prepares a predesign for a new building must consider meeting at least 2% of the energy needs of the building from renewable sources located on the building site. For purposes of this subdivision, "renewable sources" are limited to wind and the sun. The predesign must include an explicit cost and price analysis of complying with the two-percent requirement compared with the present and future costs of energy supplied by a public utility from a location away from the building site and the present and future costs of controlling carbon emissions. If the analysis concludes that the building should not meet at least 2% of its energy needs from renewable sources located on the building site, the analysis must provide explicit reasons why not. The building may not receive further state appropriations for design or construction unless at least 2% of its energy needs are designed to be met from renewable sources, unless the commissioner finds that the reasons given by the agency for not meeting the two-percent requirement were supported by evidence in the record.
- **Statute 16B.326** *Heating and Cooling Systems; State-Funded Buildings*. The commissioner [of Administration] must review project proposer's study for geothermal and solar thermal applications as possible uses for heating or cooling for all building projects subject to a predesign review under section 16B.335 that receive any state funding for replacement of heating or cooling systems. When practicable, geothermal and solar thermal heating and cooling systems must be considered when designing, planning, or letting bids for necessary replacement or initial installation of cooling or heating systems in new or existing buildings that are constructed or maintained with state funds. The predesign review must include a written plan for compliance with this section from a project proposer.

Existing Programs

- Minnesota's Renewable Energy Equipment Grant Program works with the Weatherization Assistance Program to provide eligible households with supplemental heating systems to offset conventional heating loads in weatherized, low income households through deployment of solar air heat furnaces, high efficiency-low emission wood boilers and high efficiency-low emission wood stoves.
- DNR received a $250,000 grant from the U.S. Department of Agriculture to enhance the use of renewable wood energy systems throughout the state. The primary objective is

to identify a number of commercial and institutional buildings that now use fuel oil and propane for energy and replace those systems with innovative wood energy systems.

- Business Energy Resources- IRRRB- Funding available for energy savings/renewable energy retrofits for private businesses in the Iron Range.
- Guaranteed Energy Savings Program (Commerce)
- The Made in Minnesota Solar Thermal Rebate Program provides $250,000 annually for solar air heat and solar water heating. (2014-2023)

Estimated Policy Impacts

Direct Policy Impacts

Summary in-state (direct) GHG emissions reduction and option costs results for RCII-5, "Incentives and Resources to Promote Thermal Renewables", are provided in the Table F-2.35 below. These values include costs for program administration. Overall, this option results in 3.0 million metric tons (MMt in the table below) of annual CO_2e savings in 2030, with about 22 million metric tons of CO_2e savings over the analysis period. Nearly three quarters of the overall savings come from implementation of measures in the industrial sector. This is a net positive cost option, as indicated by the positive cost per ton of CO_2e emissions avoided. In addition to these in-state reductions, RCII-5 produces an estimated 1.21 $MMtCO_2e$ of out-of-state (upstream) emissions reductions in 2030, and 8.83 $MMtCO_2e$ in cumulative out-of-state reductions from 2015-2030, yielding total 2030 emissions reductions of 4.19 $MMtCO_2e$ in 2030, and 30.46 $MMtCO_2e$ over 2015-2030.

Table F-2.35 RCII-5 Estimated Net GHG Reductions and Net Costs or Savings

	2030 GHG reductions ($MMtCO_2e$):	2015 - 2030 cumulative reductions ($MMtCO_2e$):	Net present value of societal costs, 2015 - 2030 (million $2014):	Cost effectiveness ($2014/t CO_2e):
Introduction of Thermal Renewables, Residential Sector	0.18	1.29	$114.65	$64.16
Introduction of Thermal Renewables, Commercial Sector	0.60	4.37	$250.35	$40.64
Introduction of Thermal Renewables, Industrial Sector	2.20	15.97	$507.21	$22.44

	2030 GHG reductions ($MMtCO_2e$):	2015 - 2030 cumulative reductions ($MMtCO_2e$):	Net present value of societal costs, 2015 - 2030 (million $2014):	Cost effectiveness ($2014/t CO_2e):
Total	2.98	21.63	$872.22	$28.55

Data Sources

Typical heat to fuel efficiencies for technologies commonly used in Minnesota:[25]

- Natural gas/propane water heaters – 70%
- Natural gas/propane furnaces – 80%
- Commercial natural gas steam boilers – 85%
- Natural gas hot water boilers – 88%

In 2012, Minnesota used the following amounts of propane and natural gas in the residential, commercial and industrial sectors:

- Propane[26]
  - 349,485 million Cubic feet
  - 323,688,333 Therms
- Natural Gas[27]
  - 353,191,320 Gallons
  - 4,338,459,152 Therms

Quantification Methods

1. Obtain estimates of forecast natural gas, distillate oil, and propane (or liquefied petroleum gas—LPG) demand by sector and year through 2030 from the Inventory and Forecast (I&F) prepared to accompany the assessment of GHG Emissions Reduction options.
2. Calculate the fraction of forecast use of the above fuels by sector that is used for space and water heating by applying relevant factors from the literature or the inventory and forecast.

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[25] Minnesota Department of Commerce, Mark Garofano et al.

[26] Minnesota's Supply and Demand for Propane and Anhydrous Ammonia, Minnesota Department of Agriculture April 1, 2011.

[27] U.S. Energy Information Administration, Natural gas delivered to consumers by sector, 2008-2012. http://www.eia.gov/naturalgas/annual/pdf/table_016.pdf

3. Based on the goals set out above, define a stream of annual fractional savings for the covered fuels, and apply it to estimate the reduction in fuel use of each type by year.
4. Prepare, in consultation with Minnesota Agency staff, estimates of the fraction of savings to ascribe to each sector, and use those estimates to calculate reductions in fuel use by sector and by year.
5. Calculate the annual emissions reduction from avoided fossil fuel use as estimated in step 4 by applying emission factors from the I&F.
6. Use a stream of values interpolated from those provided in Key Assumptions, below, to estimate the fraction of the reduction in fuel use calculated in step 4 that will be provided by renewable systems (biogas, biomass, and solar thermal).
7. Calculate the fuel input to biogas and biomass renewable heating systems by applying estimates to compare the heating efficiency of the biomass fuels to the fossil fuels displaced to the estimates of avoided fuel use from step 4.
8. Apply emission factors from the I&F to the biomass and biogas fuel use calculated in step 7 to estimate the new emissions of GHGs (methane and nitrous oxide, as carbon dioxide emissions from biomass/biogas will be assumed to be offset by carbon uptake, assuming sustainable use of biomass inputs).
9. Compile and convert into applicable forms representative cost estimates, by sector, if available, for renewable energy systems replacing conventional heating systems, on a per-unit-energy provided basis, and apply them to the savings in fuel use calculated in step 4 to estimate the annual costs by sector, technology, and year for the program, splitting costs into capital and O&M costs. This step will involve application of capital costs to only the new systems added in each program year.
10. Multiply the net impacts on purchased fuels as developed in Step 4 by appropriate avoided costs for the fossil fuels saved to yield avoided fuel costs by sector.
11. Multiply the new biomass fuels use by appropriate estimated costs for those fuels to yield renewable fuel costs by sector and technology.
12. Calculate the total net cost impact from the results of steps 9 through 11.
13. Estimate "upstream" emissions reduction from avoided fossil fuels use using common emission factors used in many options.
14. Apply representative estimates of the fraction of the additional capital costs of technologies used in the option that might be paid by a program sponsor, plus estimates of the ratio of sponsor administrative costs to the sponsor outlays for incentives, to estimate the administrative costs of the option.

<u>Key Assumptions</u>

- The overall goal of 20% displacement of fossil heating fuels by renewable energy sources is achieved incrementally based on the following milestones: 1% in 2017, 2% in 2018, 5% in 2020, and 12% in 2025.
- The overall savings target is divided into small and larger systems, and by sector, as shown below:

Table F-2.36 Overall Savings Target by Sector

	Fractions of savings by all systems by sector	Fractions of small system set-aside by sector	larger system system total by sector
Residential	5%	100.0%	0%
Commercial	20%	0.0%	21.1%
Industrial*	75%	0.0%	78.9%

*Industrial includes agricultural users

- 85 to 100 percent of the fossil fuels used in each sector is assumed to be used for heating, and thus can be avoided by the measures included in this option. The exception is distillate oil use in the industrial sector, where only 8% is assumed to be used for heating (the rest being for internal combustion engines in equipment, including in agriculture).
- Heating fuels are displaced in proportion to their use for heating, as derived based on forecast values and the assumptions as to fraction of fuel use for heating shown above.
- The fractions of the overall savings targets achieved by the use of different measures are as shown in the Table F-2.37 below.

Table F-2.37 Fractions of Overall Savings Target

Fractions of Thermal Fuels Use Displaced by Systems of Different Types, by Sector

	Biogas	Biomass	Solar Water and Space Heating	Solar Industrial Process Heating and Cooling	Renewable District Heating and Cooling (Biomass-fired)	Combined Heat and Power
Residential	0%	65%	25%	0%	10%	0%
Commercial	5%	50%	20%	0%	10%	15%
Industrial*	5%	50%	15%	15%	0%	15%
Small Systems	5%	60%	35%	0%	0%	0%

*Industrial includes agricultural users

- The capital cost, operating and maintenance cost, and capacity factor assumptions assumed for each type of measure included in RCII-5 are as presented in Table F-2.38 below. Solar transpired heat was assumed to produce 75% of the total savings by the solar measures above in the commercial/institutional and industrial sectors. A variety of sources were used to derive the cost estimates shown. References to "Notes" in the column headers of the table below are to notes included in the RCII-5 analysis worksheet.

Table F-2.38 Costs by Parameter

Parameter	Biogas (see ***Note 8***)	Biomass, Residential (see ***Note 3***)	Biomass, Commercial and Industrial (see ***Note 5***)	Solar Water Heat, Residential (for O&M, see ***Note 11***)	Solar Water Heat, Commercial and Industrial (for O&M, see ***Note 11***)
Capial Cost ($/(MMBtu/yr))	$ 124.16	$ 32.62	$ 31.45	$ 465.10	$ 380.54
Variable Non-fuel O&M Cost ($/MMBtu)	$ -	$ -	$ 1.63	$ -	
Fixed O&M Costs ($/MMBtu-yr)	$ -	$ 0.24	$ -	$ 4.65	$ 3.81
Lifetime (years)	25	20	25	25	25
Interest Rate (%/yr)	5.0%	5.0%	5.0%	5.0%	5.0%
Annualized Capital Payment ($/(MMBtu/yr))	$ 8.81	$ 2.62	$ 2.23	$33	$27
Average Capacity Factors by Sector (see ***Note 7***)					
Residential	35%	35%	35%	100%	100%
Commercial	45%	45%	45%	100%	100%
Industrial	80%	80%	80%	100%	100%
Fraction of Solar Water and Space Heating by Technology					
Residential*	N/A		N/A	19.7%	N/A
Commercial**	N/A		N/A	N/A	12.7%
Industrial***	N/A		N/A	N/A	1.4%

Table F-2.39 Costs by Parameter (continued)

Parameter	Solar Space Heating, Residential (for O&M, see ***Note 11***)	Solar Commercial and Industrial Transpired Air Heating (see ***Note 6***)	Solar Commercial and Industrial Space and Process Heating and Cooling (for O&M, see ***Note 11***)	Renewable District Heating and Cooling (See ***Note 4***)
Capial Cost ($/(MMBtu/yr))	$ 436.91	$ 219.92	$ 352.35	$ 101.45
Variable Non-fuel O&M Cost ($/MMBtu)	$ -	$ -	$ -	$ 0.51
Fixed O&M Costs ($/MMBtu-yr)	$ 4.37	$ -	$ 3.52	$ 5.98
Lifetime (years)	25	25	25	30
Interest Rate (%/yr)	5.0%	5.0%	5.0%	5.0%
Annualized Capital Payment ($/(MMBtu/yr)	$31	$ 15.60	$ 25.00	$ 6.60
Average Capacity Factors by Sector (see ***Note 7***)				
Residential	100%	100%	100%	35%
Commercial	100%	100%	100%	35%
Industrial	100%	100%	100%	60%
Fraction of Solar Water and Space Heating by Technology				
Residential*	80.3%	N/A	N/A	N/A
Commercial**	N/A	65.4%	21.8%	N/A
Industrial***	N/A	74.0%	24.7%	N/A

Notes:
Blue shaded values in table above provided by Stacy Miller, 9/22/14 and 11/10/14.
Fractions derived from averages of 2015-2030 residential forecasts by end-use prepared for this project. See "Supporting Data" worksheet in this workbook.
Relative shares of commercial water heat and space heat estimated based on US DOE EIA CBECS data for natural gas use by end use in the West North Central Region. See worksheet http://www.eia.gov/consumption/commercial/data/2003/xls/e07a.xls.
Relative shares of industrial water heat and space/process heat estimated based on US DOE EIA MECS data for natural gas use by end use in the Midwest Region. See worksheet http://www.eia.gov/consumption/manufacturing/data/2010/xls/Table5_6.xls. Note that the MECS category "Other Facility Support" is assumed to be mostly water heating.

- Renewable energy systems were assumed to displace the capital costs of fossil-fueled boilers, water heater, and furnaces except for solar technologies, which were assumed to require a fossil-fueled back-up. The assumed average capacity factors for the fossil-fueled heating technologies displaced by renewable systems in the residential, commercial/institutional, and industrial sectors were 35%, 45%, and 80%, respectively. The capital costs for the avoided fossil heating systems are based on the same sources as used to derive similar assumptions in RCII-1, and are as shown below.

Table F-2.40 Average Fossil-fired Heating Source Cost Assumptions

Average Fossil-fired Heating Source Cost Assumptions (cost figures assumed $2014)

Parameter	Residential	Commercial	Industrial/ Agricultural
Capial Cost ($/(MMBtu/yr))	$ 4.48	$ 2.57	$ 1.71
Variable O&M Costs ($/MMBtu output)	$ 0.25	$ 1.00	$ 1.00
Lifetime (years)	20	20	20
Interest Rate (%/yr)	5.0%	5.0%	5.0%
Annualized Capital Payment ($/(MMBtu/yr))	$ 0.36	$ 0.21	$ 0.14

- To calculate administrative costs, program sponsors were assumed to offer incentives averaging 30% of total capital costs (all sectors). Administrative costs were set equal to 5% of incentive costs in each sector, based on the assumption that significant economies of scale in program administration could be captured in a program of the size envisioned in this option.
- Wholesale costs of biomass fuels rise from $2.96/GJ in 2015 to $6.73/GJ in 2030 (nominal dollars). Avoided costs of other fossil fuels were assumed equal to avoided wholesale costs for the various fuels, as estimated in the Common Assumptions used for all options, as were direct and, as applicable, "upstream" GHG emission factors for each fuel whose use is avoided (or, in the case of biomass, increased) by the measures in RCII-5.

Macroeconomic (Indirect) Economic Impacts of RCII Policies

Table below provides a summary of the expected impacts on jobs and economic growth during the CSEO planning period.

Table F-2.41 RCII-5 Macroeconomic Impacts on GSP, Employment and Income

Scenario	Gross State Product (GSP, $2015 Millions)			Employment (Full & Part-Time Jobs)			Income Earned ($2015 Millions)		
	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)
RCII-5	-$345	-$149	-$2,081	-1,680	-690	-9,610	-$154	-$58	-$809

Graphs below show detail in GSP, employment and personal income impact of the RCII-5 policy.

Figure F-2.32 RCII-5 GSP Impacts ($2015 MM)

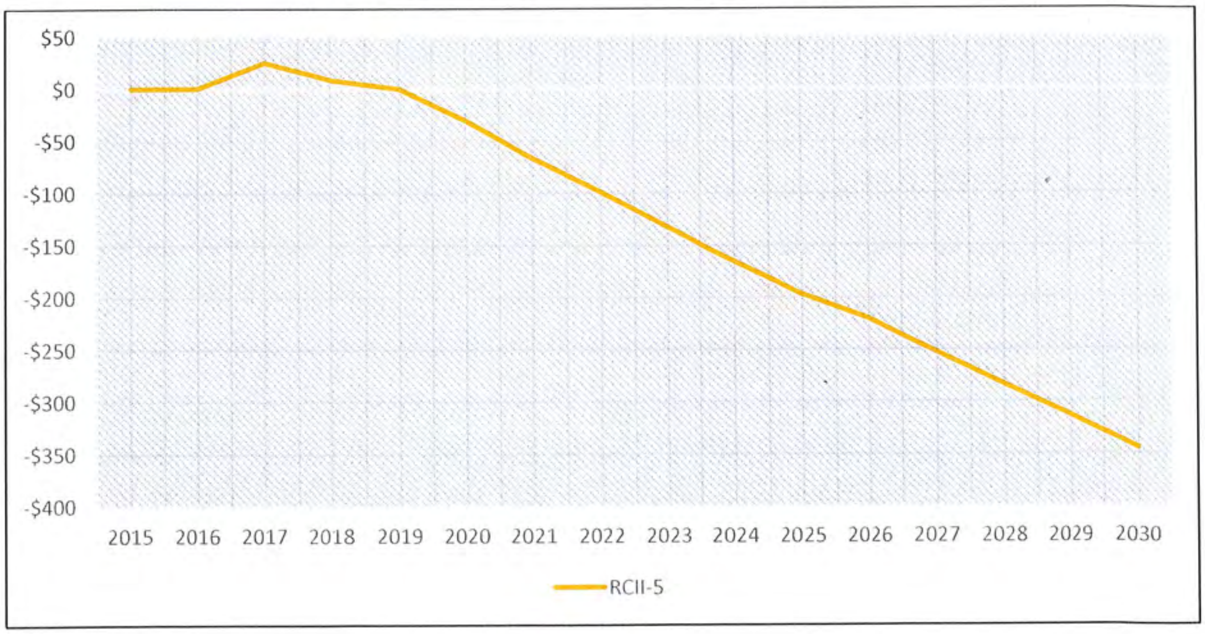


Figure F-2.33 RCII-5 Employment Impacts (Individual Jobs)

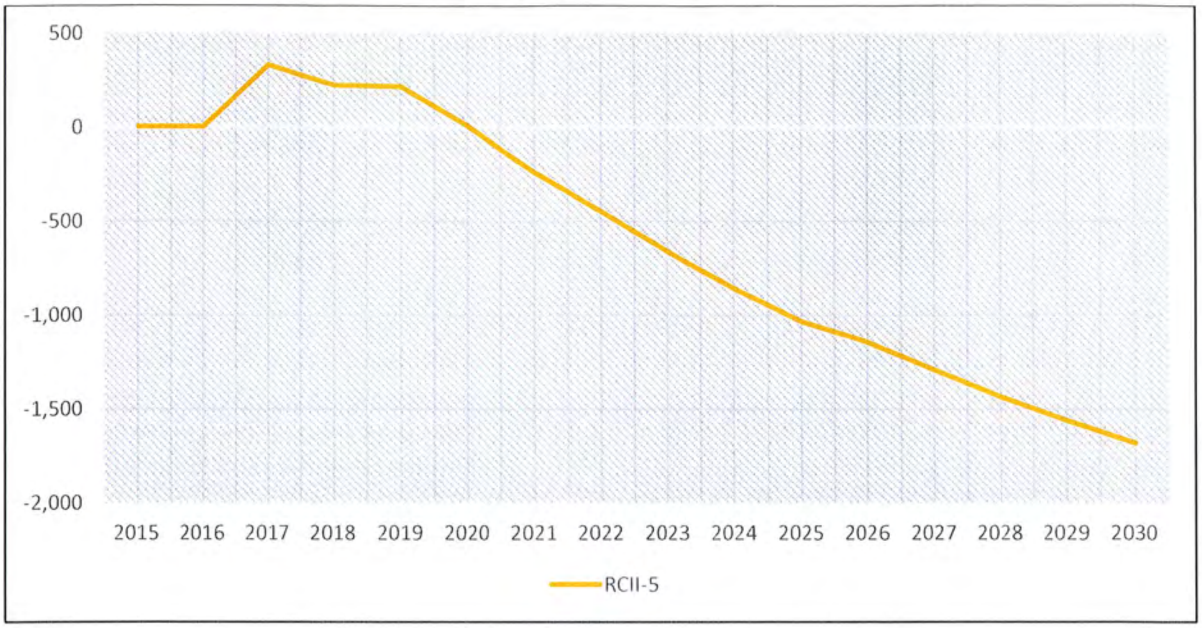
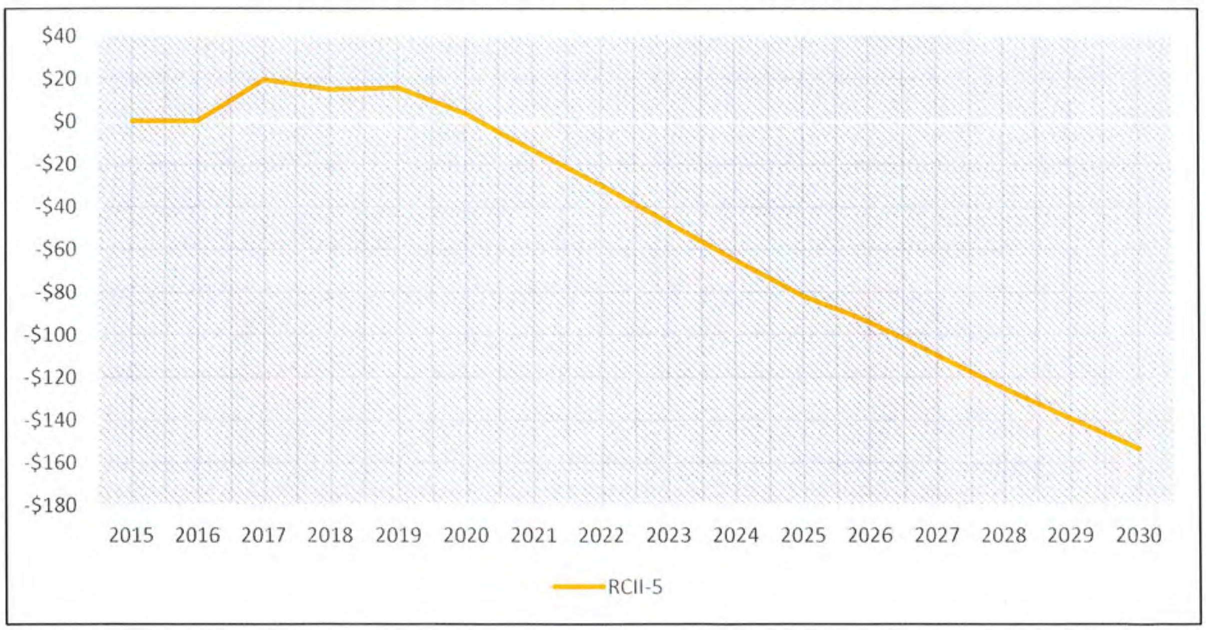
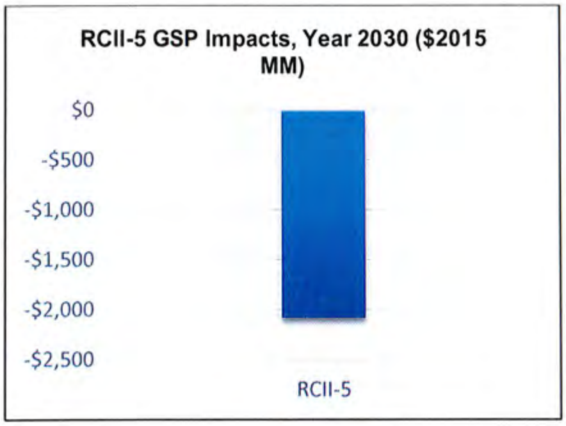
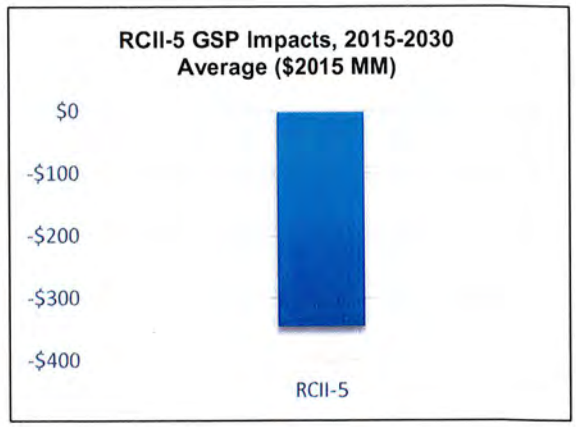


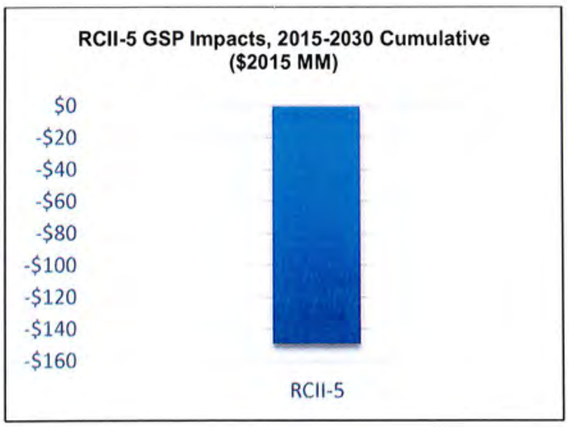
Figure F-2.34 RCII-5 Income Impacts ($2015 MM)

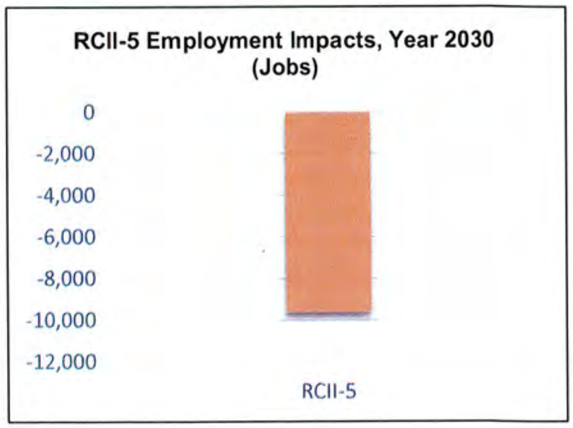


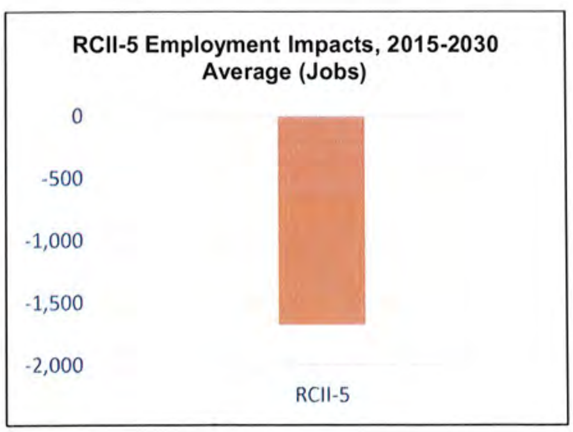
Graphs below show macroeconomic impacts on GSP, personal income, and employment in the final year (2030), in average (2015-2030) and in cumulative (2015-2030).

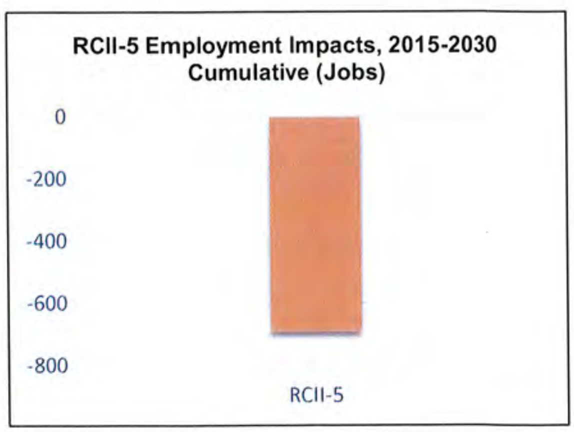

RCII-5 GSP Impacts, Year 2030 ($2015 MM)
$0
-$500
-$1,000
-$1,500
-$2,000
-$2,500
RCII-5

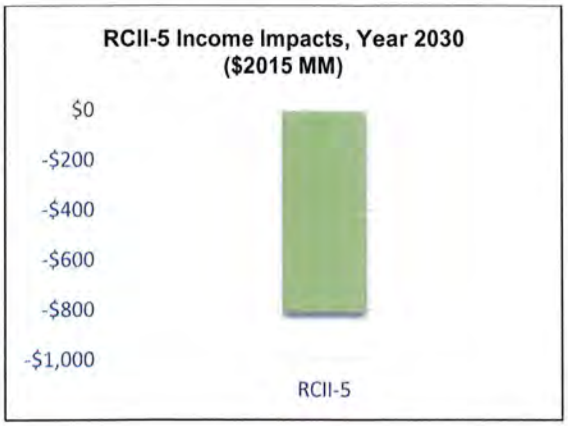

RCII-5 GSP Impacts, 2015-2030 Average ($2015 MM)
$0
-$100
-$200
-$300
-$400
RCII-5

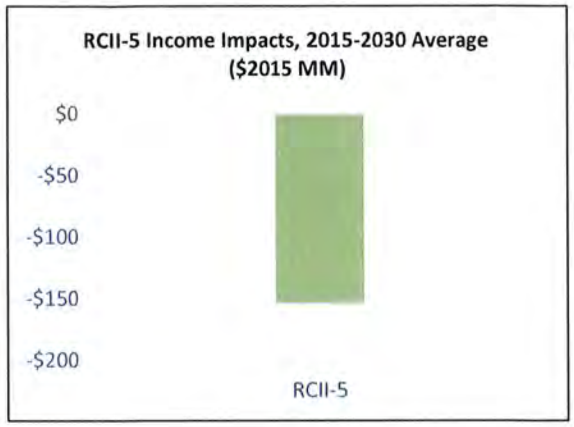

RCII-5 GSP Impacts, 2015-2030 Cumulative ($2015 MM)
$0
-$20
-$40
-$60
-$80
-$100
-$120
-$140
-$160
RCII-5

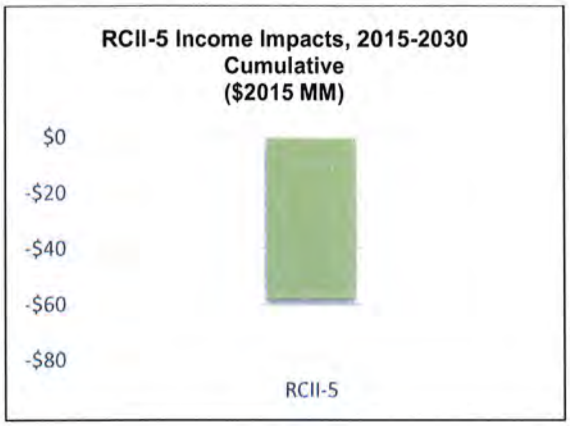

RCII-5 Employment Impacts, Year 2030 (Jobs)
0
-2,000
-4,000
-6,000
-8,000
-10,000
-12,000
RCII-5


RCII-5 Employment Impacts, 2015-2030 Average (Jobs)
0
-500
-1,000
-1,500
-2,000
RCII-5


RCII-5 Employment Impacts, 2015-2030 Cumulative (Jobs)
0
-200
-400
-600
-800
RCII-5







Principal Drivers of Macroeconomic Changes

RCII-5 ends up producing negative impacts statewide, in terms of all three major indicators. This is driven, fundamentally, by the fact that the costs borne to adopt the new energy source outweigh the savings and reductions in conventional fuel use that the policy produces.

Unlike many other of the RCII policies, this policy does not seek to create a large efficiency gain, but rather to switch from one set of energy sources to another. As a result, the expansion in available spending power for other productive sectors, as well as the lowered production costs with their inducement to economic growth and lower prices, are not generated by this policy. As a result, while the investment in renewable thermal technology does generate a spending stimulus and the operating and maintenance spending does boost direct hiring, the overall higher cost of operation under this policy pulls down total economic activity across all markers.

Sectors of Economy Most Affected by the Policy

Economic impacts from policies run around the economy, affecting sectors that are sometimes far from the direct target of a policy.

For RCII-5, the construction and biomass producing sectors see direct gains from the policy-driven investments. Households also hire more on a direct basis, as they adapt to the operation and maintenance of these new energy sources.

But the sectors that do so well as jobs and incomes rise (restaurants, retail, health care, etc.) all see losses as consumers and businesses have less in pocket with this policy than without.

Data Sources

The principal data sources for the macroeconomic impacts analysis of this and all other policies in the CSEO process are the direct spending, saving, cost and price impacts developed as part of the microeconomic (direct impacts) analysis. For each policy, the cost-effectiveness analysis described above develops year-by-year estimates of the costs, savings prices, and changes demand or supply that households, businesses and government agencies are expected to encounter in a scenario where the policy is implemented as designed.

A secondary data source is the policy design. Balancing financial flows for each direct impact identified are established based on understanding the implementation mechanism, and quantitative values for these flows are developed for each direct impact identified. This balancing identifies and quantifies the responsive change that occurs as a result of the direct impact in question. For example, if a household is anticipated to save $100 per year on electricity bills as a result of a policy, the direct impact is a $100 savings to the household (which expands its spending capacity for other things) but the balancing impact is a $100 loss in revenue and demand to the utility provider (which reduces its ability and need to spend on labor, capital, profit, and other inputs). The quantitative measure of both sides of a change is of importance to a complete macroeconomic analysis. This balancing ensures that both the supply and the demand side of each economic change is fully represented in the analysis.

A third data source is direct communication with Minnesota agency staff and others involved in policy design or in a position to understand in detail the financial flows involved in the policy. These people assisted in clarifying the nature of economic changes involved so that the modeling and analysis would be accurate.

The final crucial data source is the baseline and forecast of economic activity within the REMI software. This data is compiled into a scenario that is characterized not only by the total size of the economy and its many consuming and producing sectors, but also the mechanisms by which impacts in one sector can change the broader economy – such as intermediate demands, regional purchase coefficients, and equilibria around price and quantity, labor and capital, and savings and spending, to name a few of many. REMI, Inc. maintains a full discussion of all the sources of the baseline data on its own website, www.remi.com.

In the case of the RCII-5 policy, important data included:

- The capital cost involved for buildings to adopt new heat energy sources (in this case, biomass). This involves an additional cost of operation but provides a stimulus in spending to the construction and machinery production sectors. For residential investments, the stimulus is to home improvement and construction.

- The cost to implement new practices and operating procedures around different equipment. These operating and maintenance costs also represent a cost to be borne by the commercial and residential sectors, but the additional labor engaged drives employment, direct incomes, and expands consumer spending – which is economically beneficial.
- The total volumes, and total spending on those volumes, of each type of energy consumed – in this case, all sources are reduced except the biomass which is replacing conventional fuels.
- The costs to state government agencies to oversee and implement this policy. This is split between labor to regulate and implement, and capital spending on upgrading its own facilities.
- All the capital costs, operating and maintenance costs, and energy spending figures were developed individually for the industrial, commercial, residential and utility sectors.

Quantification Methods

Utilizing the data developed from the microeconomic analysis, CCS analysts established for each individual change the following characteristics:

- The category of change involved (change in spending, savings, costs, prices, supply or demand)
- The party involved on both sides of each transaction
- The volume of money involved in this change in each year of the period of analysis

These values, so characterized, were then processed into inputs to the REMI PI+ software model built specifically for use by CCS and consistent with that in use by state agencies within Minnesota. These inputs were applied to the model and run. Key results were then drawn from the model and processed for consistency of units and presentation before inclusion in this report.

Key Assumptions

The macroeconomic impact analyses of this policy, as well as of the others in the CSEO process, rely on a consistent set of key assumptions:

- State and local spending is always budget-constrained. If a policy calls for the state or local government to spend money in any fashion, that spending must be either funded by a new revenue stream or offset by reductions in spending on other programs. Savings or revenues collected by the government are also expected to be returned to the economy as spending in the same year as they are collected.
- Federal spending is not budget-constrained. The capacity of the federal government to carry out deficit spending means that no CSEO policy is held responsible for driving

either an increase or decrease in federal tax spending by businesses or households in the state of Minnesota.

- Consumer spending increases are sometimes financed. Small-scale purchases or purchases of consumer goods are treated as direct spending from existing household cash flows (or short-term credit). Durable goods, home improvements or vehicle purchases, however, are treated as financed. Consumers were assumed to spread out costs based on common borrowing time frames, such as five years for financing a new vehicle or 10-20 years for home improvements that might be funded by home-equity or other lending. The assumption of financing and the term of years applied was considered anew in each case.
- Business spending increases are often financed. Where spending strikes a sector which routinely utilizes financing or lines of credit to ensure steady payment of recurring costs, significant spending of nearly any type was considered a candidate for financing, thus allowing costs to spread out over time. This methodology is preferable for the modeling work, as sudden spikes or dips in business operating costs can show up as volatility when the scenario may depict a managed adoption of new equipment in an orderly fashion. The assumption of financing and the term of years applied was considered anew in each case.
- Unless otherwise stated, all changes to consumer spending or to the producers' cost of producing goods and services were treated in a standard fashion. Consumers are assumed to spend on a pre-set mix of goods, services, and basic needs, and businesses spend (based on their particular sector of the economy) on a mix of labor, capital, and intermediate demands from other sectors. Unless a policy specifically defines how a party will react to changes in cost, price, supply or demand, these standard assumptions were applied.

State and local spending gains and reductions driven by policy are assumed to apply to standard mixes of spending. Again, unless a policy specifically states that a government entity will draw from a specific source or direct savings or revenues to a specific form of spending, all gains and losses were assumed to apply to a standard profile of government spending within the economy.

Key Uncertainties

There is uncertainty surrounding the percentages of various eligible renewable thermal technologies that would be implemented. For example, the share of solar thermal deployment versus biomass and the adoption rate within commercial versus industrial applications. The future cost of conventional fuels and biomass feedstocks is also uncertain.

To explore the GHG and net societal cost implications of targeting the residential sector portion of this option towards users of propane for heating and water heating, an alternative scenario was modeled in which the heating fuel displaced by renewable energy use in the residential sector was assumed to be 75% propane/LPG, reflecting the higher fuel costs paid by propane/LPG consumers. As a result of this change, the overall cumulative in-state (direct) GHG emission savings over the period 2015-2030 from the policy option increases very slightly, by about 0.5% relative to the base case, to 21.74 million $MMtCO_2e$ (3.0 MMt in 2030), with a net cost of $804 million (about 8% less than in the base case—the result of more costly propane being displaced rather than natural gas), and with similarly-reduced cost per t CO_2e ($37.00), also about 8% less than for the overall base case. Focusing only on the residential sector, the impact of the alternative scenario is more striking, reducing net residential sector costs and costs per t CO_2e of GHG emissions reduction by about 60% (to $47 million and $33.39, respectively) relative to the base case. The results of this alternative scenario are shown in the table below. In addition to these in-state reductions, when evaluated with the assumption of targeted displacement of propane fuel as above, RCII-5 produces an estimated 1.21 $MMtCO_2e$ of out-of-state (upstream) emissions reductions in 2030, and 8.82 $MMtCO_2e$ in cumulative out-of-state reductions from 2015-2030, yielding total 2030 emissions reductions of 4.21 $MMtCO_2e$ in 2030, and 30.56 $MMtCO_2e$ over 2015-2030.

Table F-2.42 RCII-5 Alternative Scenario Results

	2030 GHG reductions ($MMtCO_2e$):	2015 - 2030 cumulative reductions ($MMtCO_2e$):	Net present value of societal costs, 2015 - 2030 (million $2014):	Cost effectiveness ($2014/t CO_2e):
Introduction of Thermal Renewables, Residential Sector	0.19	1.40	$46.84	$24.78
Introduction of Thermal Renewables, Commercial Sector	0.60	4.37	$250.35	$40.64
Introduction of Thermal Renewables, Industrial Sector	2.20	15.97	$507.21	$22.44
Total	3.00	21.74	$804.40	$26.24

Note: Each policy option analysis was done over a fifteen year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

Additional Benefits and Costs

- Cost benefit study of renewable thermal policy option in Massachusetts showed between 2:1 and 3:1 benefits (mostly in fuel savings) + GHG emissions savings + higher tax revenue in state from sales + employment drivers for biomass fuel.
- Renewable thermal policies will provide new business opportunities to renewable fuel suppliers, developers and other energy service providers.
- A renewable thermal policy option will increase the local forestry market for biomass including the expansion of cord wood in Northwest Minnesota per DNR and can be achieved in a sustainable manner.
- A renewable thermal policy option will diversify resources and increase energy security resulting in less volatility in heating fuel availability.
- A renewable thermal policy option will mitigate fluctuations in the price of fossil fuels for heating by diversifying supply and reducing demand pressures.

Health Benefits: Establishment of a renewable fuel goal and incentive program may reduce emissions of air toxics and reduce associated health risks. Additionally, diversifying thermal energy may help to mitigate fuel price volatility. Volatility of fuel prices in recent years, especially in the Midwest and Northeast United States, has raised concerns that large numbers of people may be unable to access and pay for the cost of heating their homes in the winter. Mitigation of volatility in fuel pricing and availability throughout greater Minnesota will reduce risk among vulnerable communities in the future.

Figure F-2.35 Potential Health Benefits RCII-5

*Reducing energy-related emissions is likely to reduce the risk for respiratory and cardiovascular illness, and cancer in exposed populations.

Feasibility Issues

This policy option is framed as a goal with the analysis completed as though the goal will be achieved (as a standard would) according to the schedule included herein despite a lack of an existing enforcement mechanism within delivered fuels. However, the Renewable Thermal Incentive Program is the primary mechanism to advance the state's progress toward the goal and acts as the primary driver of voluntary renewable thermal deployment in practice.

The Renewable Thermal Incentive Program would be funded through a fee on each unit of thermal energy sold in the state, suggested at $.01 per therm for gas, propane, and fuel oil. For natural gas for thermal use, gas utilities will collect fees from customers to support the program. Since delivered fuel is currently taxed at the wholesale level by the Minnesota Department of Revenue, the Renewable Thermal Incentive Program will rely on assessments on wholesale transactions of propane and fuel oil [instead of retail sales.]

Eligible biomass technologies should be subject to best practices for reduction of particulate matter and other emissions. Best practice policy option may be more stringent than current EPA standards for biomass.

Northwest Minnesota has a plethora of excess biomass while in Northeast Minnesota (excepting the North Shore) there is competition for round wood. There will be wider inter-agency support for a policy option sensitive to the regional biomass market availability within the state (DNR, DEED).

Chapter XV. Appendix F-3. Transportation and Land Use Policy Option Recommendations

Overview

This appendix provides greater detail regarding the policy analysis in the Transportation and Land Use area.

Direct Impacts

The stand-alone results provide the annual GHG reductions for 2020 and 2030 in million metric tons (MMt) of carbon dioxide equivalent reductions (CO_2e), as well as the cumulative reductions through 2030. The reductions shown are just those that have been estimated to occur within the state. Additional GHG reductions, typically those associated with upstream emissions in the supply of fuels or materials, have also been estimated and are reported within each of the analyses in each POD.

Also reported in the stand-alone results is the net present value (NPV) of societal costs/savings for each policy option. These are the net costs of implementing each policy option reported in 2014 dollars. The cost effectiveness (CE) estimated for each policy option is also provided. Cost effectiveness is a common metric that denotes the cost/savings for reducing each metric ton (t) of emissions. Note that the CE estimates use the total emission reductions for the policy option (i.e. those occurring both within and outside of the state).

Results for individual parts of TLU-2 (PAYD insurance, carbon tax, and fuel tax) and TLU-3 (reduced home energy needs, reduced vehicle miles traveled [VMT]) are described within the POD for each policy option.

Integrative Adjustments & Overlaps

This appendix also provides the same values described above after an assessment was made of any policy option interactions or overlaps. The TLU-1, -2, and -3 policies all rely on a reduction of VMT. TLU-2 and TLU-3 were considered together, as described in the PODs for these policies; therefore the estimates already account for any overlap. TLU-1 was adjusted based on the reduction in VMT from TLU-2 and TLU-3. TLU-4 was considered last, with benefits adjusted downward to account for the savings in TLU-1, TLU-2 and TLU-3.

Macroeconomic (Indirect) Impacts

Tables below provide a summary of the expected impacts of TLU policies on jobs and economic growth during the CSEO planning period. These focus on the impact of policies on Gross State Product (the total amount spent on goods and services produced within the state), Employment (the total number of full-time and part-time positions), and Incomes (the total amount earned by households from all possible sources). These metrics represent three valuable indicators of both the overall size of the economy and that economy's structural orientation toward supporting livelihoods and utilizing productive work.

For the purposes of macro-economic analysis of CSEO policies, CCS utilized the Regional Economic Models, Inc. (REMI) PI+ software. This particular REMI model is developed specifically for Minnesota, and is developed consistently with the design of models in use by state agency staff within Minnesota for a range of economic analyses. Its analytical power and accuracy made REMI a leading modeling tool in the industry used by numerous research institutions, consulting firms, non-government organizations and government agencies to analyze impacts of proposed policies on key macro-economic parameters, such as GDP, income levels and employment.

The main inputs for macro-economic analysis are microeconomic estimates of direct costs and savings expected from the implementation of individual policy options. These inputs are supplemented with additional data and assumptions necessary to complete the picture of how these costs and savings (as well as price changes, demand and supply changes, and other factors) influence Minnesota's economy. These additional data and assumptions typically regard how various actors around the state (households, businesses and governments) respond to change by changing their own economic activity. A full articulation of the general and policy-specific assumptions made by the macroeconomic analysis team is provided in the Policy Option Documents, contained as appendices to this report.

Table F-3.1 Transportation & Land Use Policy Options, Direct Stand-Alone Impacts

Stand-Alone Analysis							
		GHG Reductions				Costs	
Policy Option ID	Policy Option Title	Annual CO_2e Reductions[a]		2030 Cumulative[a]	2030 Cumulative[b]	Net Costs[c] 2015-2030	Cost Effectiveness[d]
		2020 MMt	2030 MMt	$MMtCO_2e$	$MMtCO_2e$	$Million	$/tCO_2e$
TLU-1	Transportation Pricing - Total	1.50	2.03	22	28	$2,718	$96
	- PAYD Insurance Component	0.46	1.0	8.8	11	($2,160)	($189)
	- Carbon Tax Component	0.58	0.57	7.1	9.2	$1,898	$205
	- Fuel Tax Component	0.45	0.42	5.8	7.6	$2,980	$394
TLU-2	Improve Land Development and Urban Form - Total	0.31	0.82	6.96	8.17	($425)	($52)
	- Reduced Home Energy Needs Component	0.31	0.82	6.9	8.1	($351)	($43)
	- Reduced VMT Component	0.0027	0.0080	0.064	0.064	($74)	($1,155)
TLU-3	Metropolitan Council Transportation Policy Plan	0.083	0.25	2.0	2.6	($330)	($126)
TLU-4	Zero Emission Vehicle Standard (100%) renewable electricity	0.09	1.25	6.4	7.9	$3,278	$417
TLU-4	*Zero Emission Vehicle Standard (0%) renewable electricity*[e]	*(0.02)*	*(0.42)*	*(2.1)*	*(1.1)*	*$3,237*	*N/A*

Totals	**2.0**	**4.4**	**37**	**47**	**$5,241**	$112

Notes:
[a] In-state (Direct) GHG Reductions.
[b] Total (Direct and Indirect) GHG Reductions.
[c] Net Present Value of fully implemented policy option using 2014 dollars ($2014).
[d] Cost effectiveness values include full energy-cycle GHG reductions, including those occurring out of state. Dollars expressed in $2014.
[e] TLU-4 0% renewable electricity is a sensitivity scenario not included in "**Totals**" row calculation. This sensitivity scenario increases net GHG emissions above the baseline, thus **cost effectiveness** calculation is not applicable.

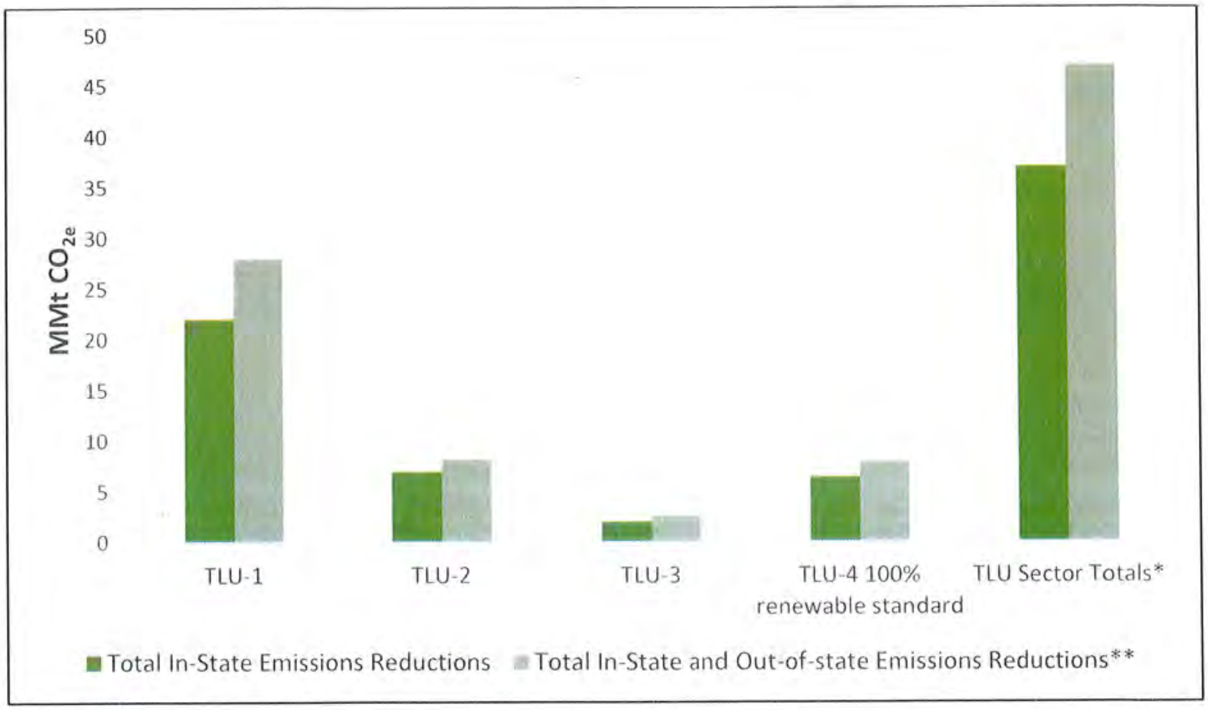
Table F-3.2 Transportation and Land Use Policy Options, Intra-Sector Interactions & Overlaps

Intra-Sector Interactions & Overlaps Adjustments							
Policy Option ID	**Policy Option Title**	**GHG Reductions**				**Costs**	
		Annual CO_2e Reductions[a]		**2030 Cumulative[a]**	**2030 Cumulative[b]**	**Net Costs[c] 2015-2030**	**Cost Effectiveness[d]**
		2020 MMt	**2030 MMt**	**$MMtCO_2e$**	**$MMtCO_2e$**	**$Million**	**$/tCO_2e$**
TLU-1	Transportation Pricing - Total	1.5	2.0	21	28	$2,718	$97.30
	- PAYD Insurance	0.46	1.02	8.67	11.30	($2,160)	($191)
	- Carbon Tax	0.58	0.56	7.01	9.14	$1,898	$208
	- Fuel Tax	0.45	0.41	5.75	7.49	$2,980	$398
TLU-2	Improve Land Development and Urban Form - Total	0.31	0.82	6.96	8.2	($425)	($52)
	- Reduced Home Energy Needs Component	0.31	0.82	6.9	8.11	(351)	($43)
	- Reduced VMT Component	0.0027	0.0080	0.064	0.064	(74)	($1,155)
TLU-3	Metropolitan Council Transportation Policy Plan	0.083	0.25	2.00	2.61	($330)	($126)
TLU-4	Zero Emission Vehicle Standard (100%) renewable electricity	0.08	1.05	5.5	6.8	$3,278	$484
TLU-4	*Zero Emission Vehicle Standard (0%) renewable electricity[e]*	*(0.02)*	*(0.35)*	*(1.8)*	*(1.0)*	*$3,237*	*N/A*
	Total After Intra-Sector Interactions /Overlap	**2.0**	**4.1**	**36**	**45**	**$5,241**	$115

Notes:
[a] In-state (Direct) GHG Reductions.
[b] Total (Direct and Indirect) GHG Reductions.
[c] Net Present Value of fully implemented policy option using 2014 dollars ($2014).
[d] Cost effectiveness values include full energy-cycle GHG reductions, including those occurring out of state. Dollars expressed in $2014.

[e] TLU-4 0% renewable electricity is a sensitivity scenario not included in "**Totals**" row calculation. This sensitivity scenario increases net GHG emissions above the baseline, thus **cost effectiveness** calculation is not applicable.
Note: Intra-Sector overlap was estimated for all TLU options. TLU-1, 2 and 3 are all options that rely on reducing VMT. The Overlaps analysis looks at TLU-2 and 3 first. These were considered together, because the SmartGAP run indicated that the impacts of these policies are additive. Therefore, no adjustments were made to TLU-2 or TLU-3. TLU-1 is adjusted based on the reduction in VMT from TLU-2 and TLU-3. The benefits of TLU-4 were then adjusted downward to account for the expected VMT reductions from BAU due to implementation of TLU-1, 2 and 3. There is also an inter-sector overlap of results between the TLU policies and the "Biofuels Package" (Policies A-4 and A-5). Those policies will introduce additional advanced biofuels into the Minnesota market which will reduce the overall GHG reduction potential of each TLU policy. The adjustments for that interaction are addressed in the Inter-Sector Integration results.

Figure F-3.1 TLU Policies GHG Emissions Abatement, 2015-2030



Notes:
All Policies Total's comprise emissions reductions achieved by TLU policies combined.
Total in and out-of-state emissions reduction are the reductions associated with the full energy cycle (fuel extraction, processing, distribution and consumption). Therefore, the emissions reductions that occur both inside and outside of the state borders as a result of a policy implementation are captured under this value.

Table F-3.3 Macroeconomic (Indirect) Impacts of TLU Policies

Macroeconomic (Indirect) Impacts Results									
Scenario	Gross State Product GSP ($2015 Millions)			Employment (Full and Part-Time Jobs)			Income Earned ($2015 Millions)		
	Year 2030[d]	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)

TLU-1	$711	$688	$10,319	8,140	8,230	123,400	$781	$659	$9,885
TLU-2	$4	-$2	-$31	500	220	3,290	$29	$10	$151
TLU-3 Low Transit Cost	$90	$41	$608	830	450	6,740	$43	$20	$302
TLU-3 High Transit Cost	$125	$165	$2,477	1,330	1,720	25,860	$78	$138	$2,068
TLU-4 Falling EV Price	$140	-$65	-$969	-810	-1,220	-18,300	-$56	-$108	-$1,622
TLU-4 High EV Price	-$711	-$354	-$5,315	-7,910	-3,750	-56,240	-$862	-$370	-$5,551
TLU Sector–Low Transit Cost	**$95**	**$372**	**$5,586**	**1,580**	**4,560**	**68,360**	**-$7**	**$319**	**$4,792**
TLU Sector–High Transit Cost	**$130**	**$497**	**$7,452**	**2,080**	**6,420**	**96,350**	**$27**	**$437**	**$6,555**
TLU Sector–Falling EV Price	**$946**	**$620**	**$9,293**	**8,670**	**7,680**	**115,170**	**$798**	**$581**	**$8,722**
TLU Sector–High Transit Cost & Low EV Price	**$981**	**$787**	**$11,799**	**9,170**	**8,950**	**134,270**	**$833**	**$699**	**$10,485**

Notes:

TLU-3's two different cost scenarios represent two different modeling approaches to the capital spending required to build out the transit lines described in the plan. The first is the use of a national model, SmartGAP, that estimates capital costs based on a blend of project types. This was used for the direct-impacts analysis. The high-cost estimate was developed with Met Council, using its line-by-line capital cost estimates. The macro work was run with both options.

As the table above shows, the macroeconomic impacts analysis of this sector comprises 5 scenarios including the sector wide analysis:

- TLU-1
- TLU-2
- TLU-3 Low Transit $: TLU-3 default scenario
- TLU-3 High Transit $: TLU-3 sensitivity scenario with high transit capital cost
- TLU-4 High EV $: TLU-4 default scenario
- TLU-4 Low EV $: TLU-4 sensitivity scenario with falling price of EV
- TLU Sector Total Low Transit $: TLU sector-wide default scenario

- TLU Sector Total High Transit $: TLU sector-wide with high transit capital cost scenario
- TLU Sector Total Low EV $: TLU sector-wide with falling price of EV scenario

TLU Sector Total Both Sensitivities: TLU sector-wide with both high transit capital cost and falling price of EV scenarios

The TLU sector has four policies. Two of them (TLU-1 and TLU-4) deal directly with the kinds of vehicles people drive and the incentives they face to drive less. Two deal with urban form and transit access (TLU-2 and TLU-3).

The vehicles policies generate large impacts on the Minnesota economy, with TLU-1 (focusing on fuel taxes, carbon taxes and pay-as-you-go insurance) producing very significant positive gains, and TLU-4 (focusing on driving adoption of electric vehicles) being weighed down in early years by electric vehicle prices. Once the vehicle prices recede (particularly after 2025), the policy trends upward and is positive in its impacts.

The urban form and transit policies, by comparison, produce relatively small impacts, outside of a short positive spike in construction spending driven by the investment by state and federal entities in new transit infrastructure.

Overall, the sector does very well as a result of TLU-1, 2 and 3, and as electric vehicle prices in TLU-4 fall gradually to parity with other vehicles (a point they reach in 2030, in this forecast), the sector's impacts trend positive again and appear to indicate further growth past 2030.

Line graphs and bar charts that follow illustrate the above explained broader economic impacts of the TLU policies.

Figure F-3.2 Average Annual Net Job Creation for TLU Polices and TLU Sector, 2015-2030

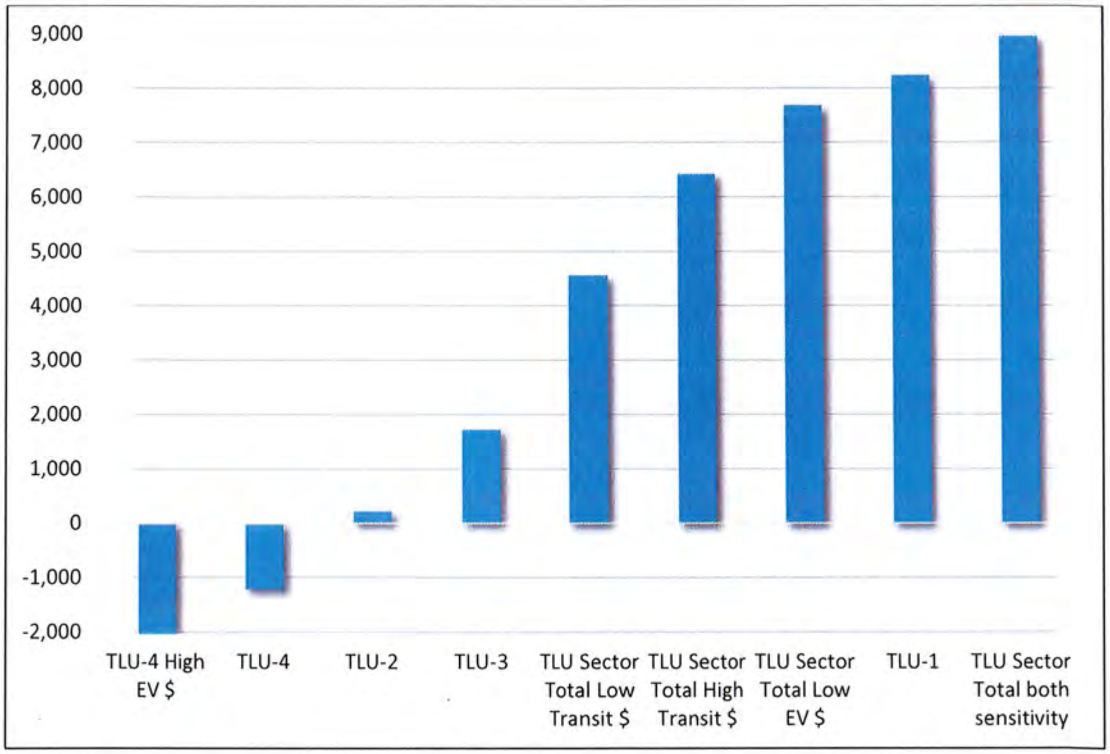
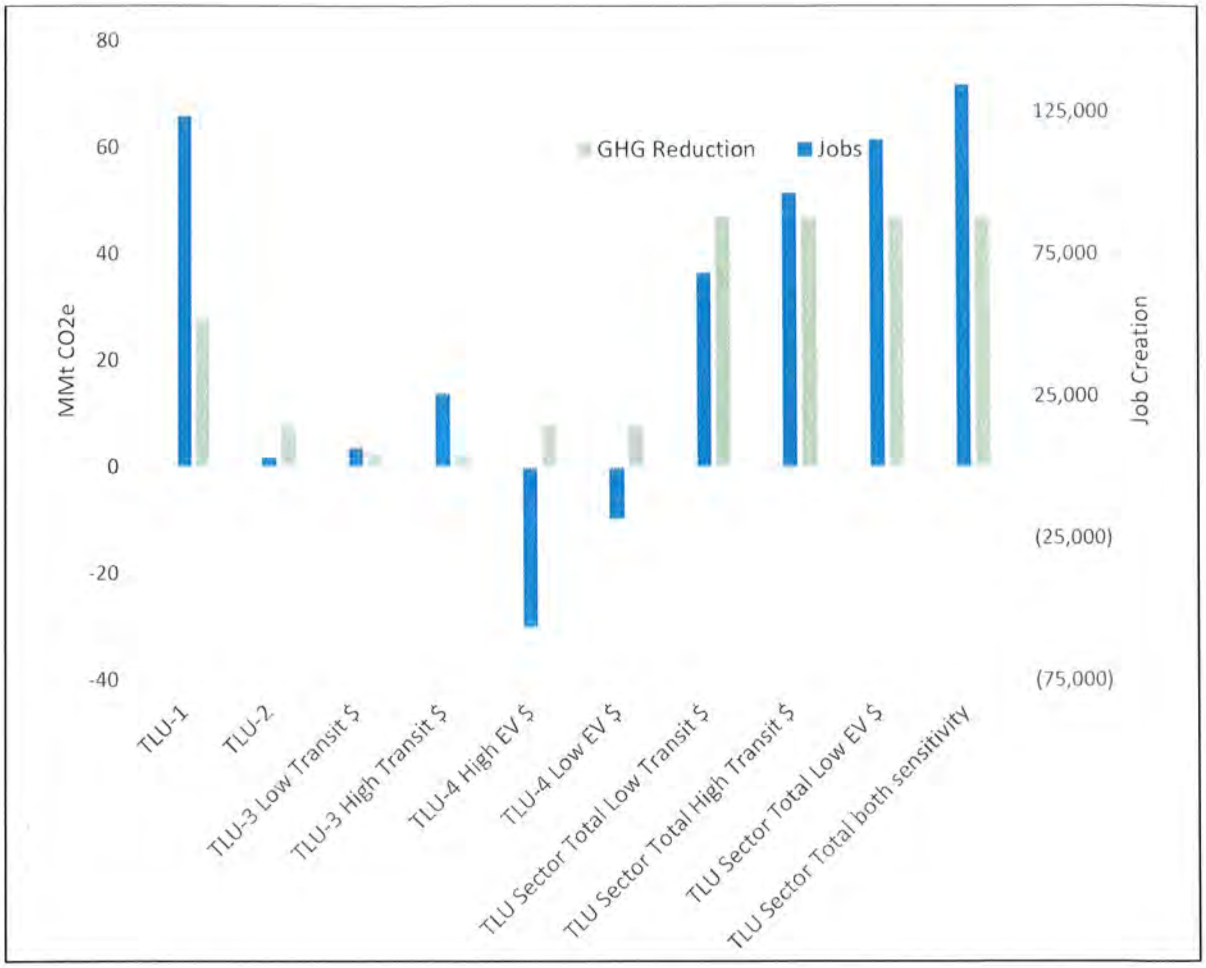


Figure F-3.3 below summarizes a potential for job creation and GHG emissions abatement of TLU sector policies on the same graph. This allows for a simultaneous assessment of performance of individual CSEO options against two crucial environmental and economic indicators.

Figure F-3.3 – Cumulative Jobs and Emissions Impacts of TLU Policies



Sector Level Index

The graphs below express the overall economic impact from each scenario in a single score, and compares those scores. CCS created this single score (a Macroeconomic Impact Index) in order to encapsulate in one measurement the relative macroeconomic impacts (including jobs, GSP and incomes) of each policy. We have found in our own work and in the literature that indexed scores can be helpful to many readers when comparing options with multiple characteristics.

To produce this score, CCS set the results from the absolute best-case scenario (i.e. the implementation of all CSEO policies with all their optimal sensitivities in place) equal to 100, with that scenario's jobs, GSP and incomes impacts weighted equally at one third of the total score. Each policy's jobs, GSP and income impacts are scaled against that measure, and given a total score. The overall score indicates how significant a policy's impact is projected to be. Negative impacts are scaled the same way, except that those impacts are given negative scores and pull down the total score of the policy.

These scores are calculated separately for the final year of the study (2030), the *average* impact over the 2015-2030 period, and the *cumulative* impact of the policies over that period. While each scenario has one line, the relative importance of jobs, income and GSP remain visible as differently-shaded segments of that line.

Figure F-3.4 TLU Macroeconomic Indicators, 2030

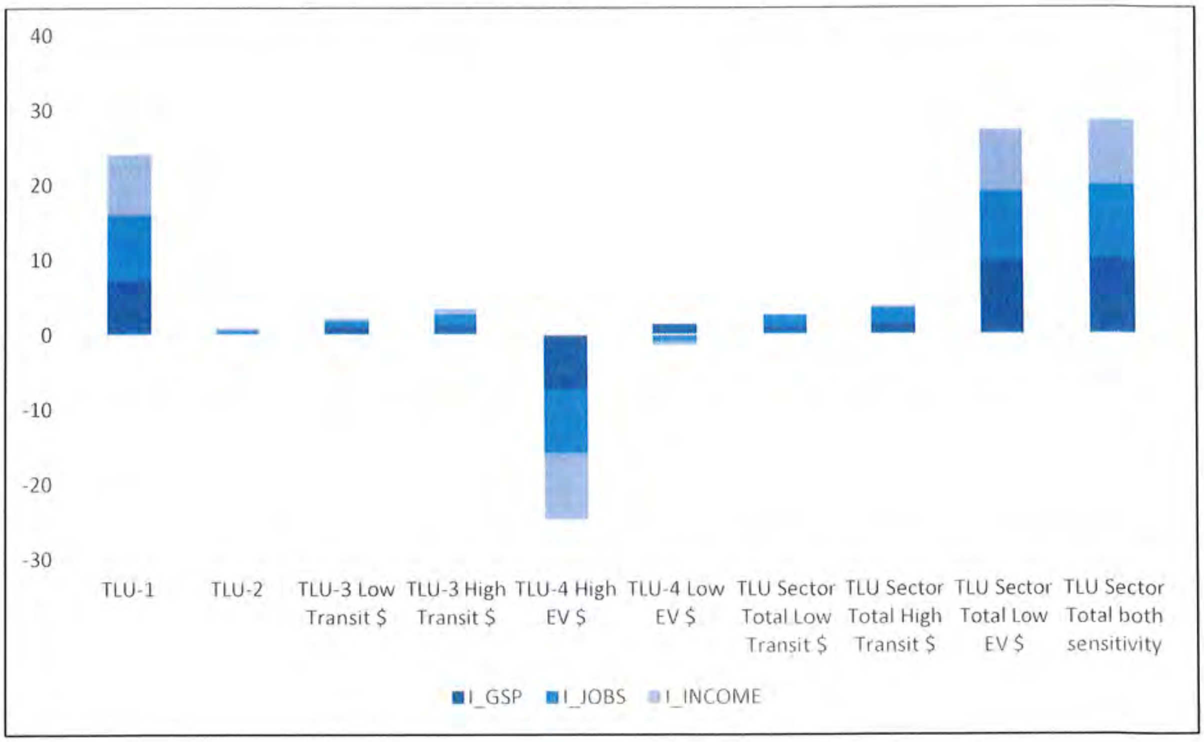


Figure F-3.5 TLU Macroeconomic Indicators, 2015-2030 Average Annual

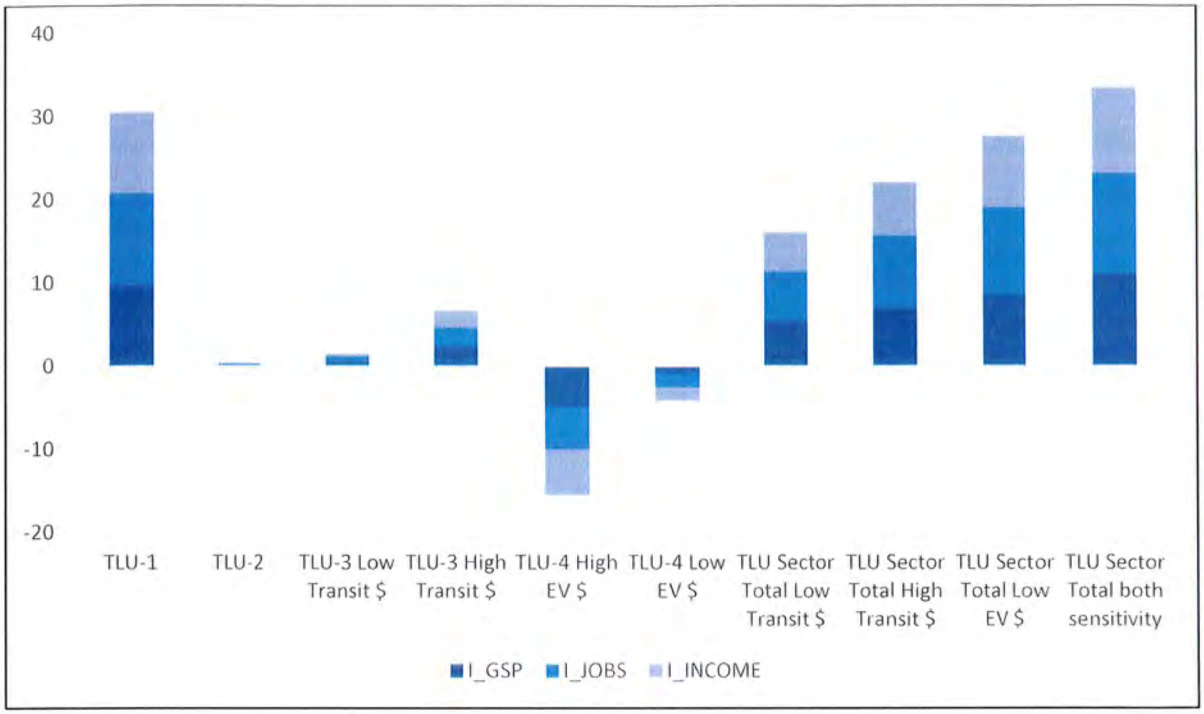
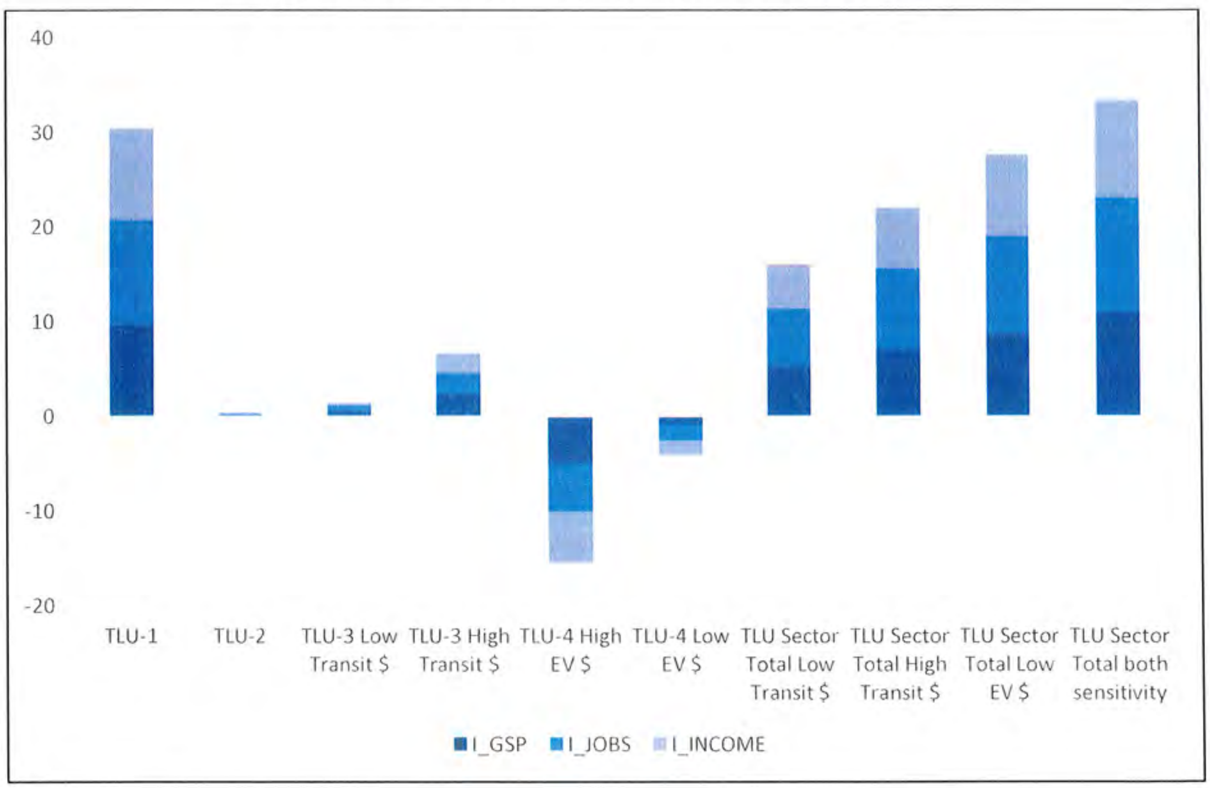


Figure F-3.6 TLU Macroeconomic Indicators, 2015-2030



Graphs F-3.7 – 3.9 below show the trend of TLU policy macroeconomic impacts during the year 2015 to the year 2030.

Figure F-3.7 TLU GSP Impacts (2015 $MM)

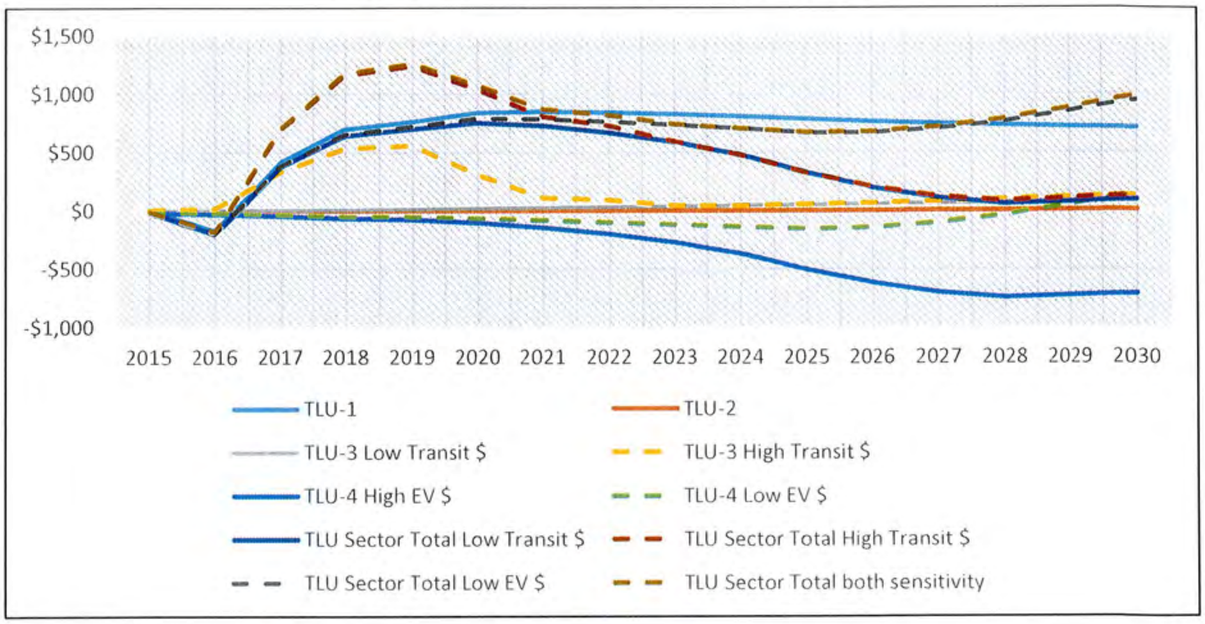


Figure F-3.8 TLU Income Impacts (2015 $MM)

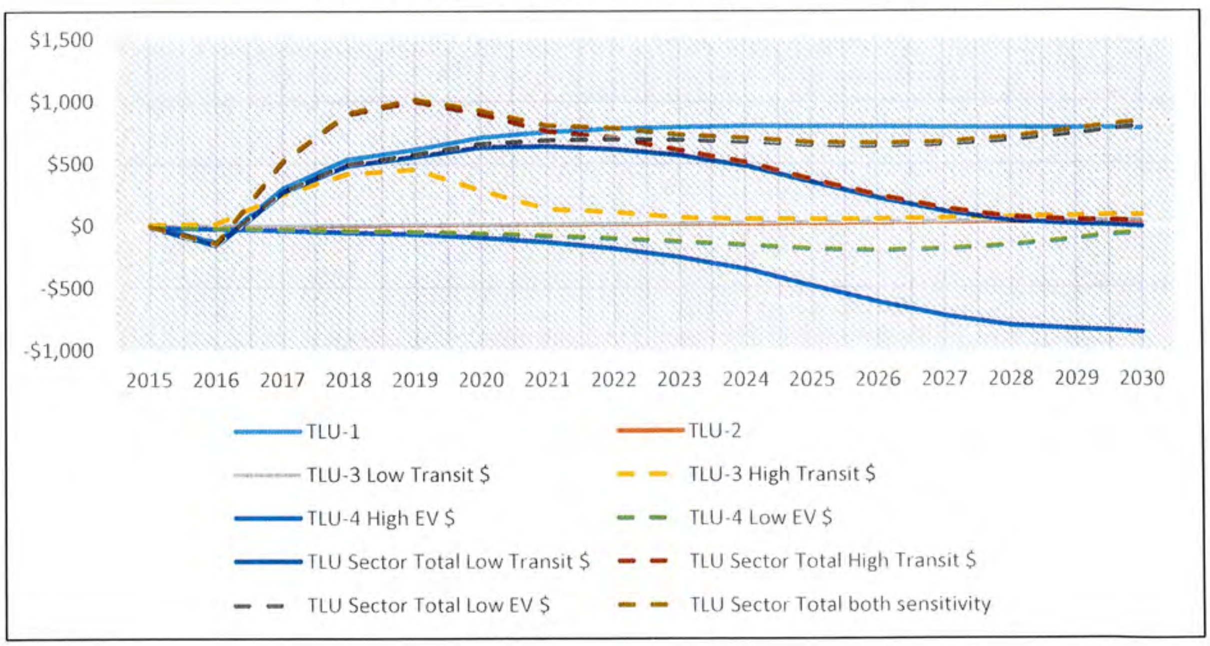
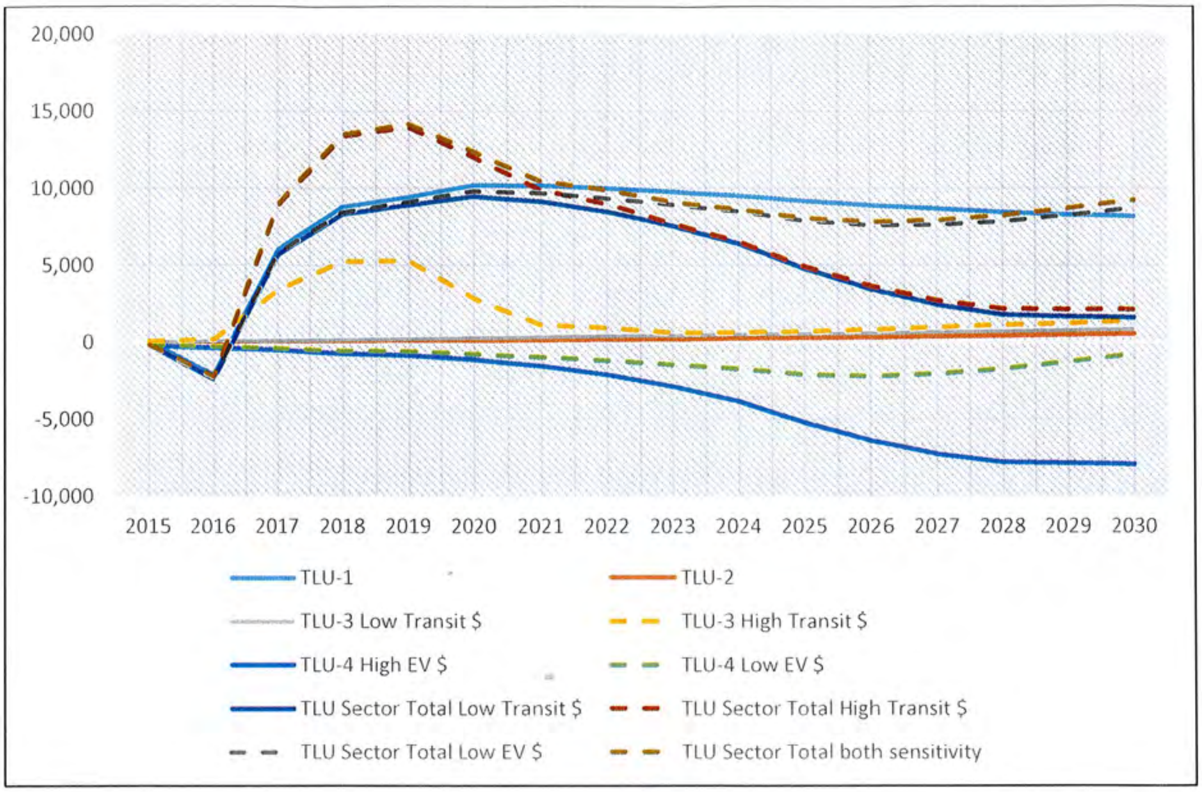


Figure F-3.9 TLU Employment Impacts (2015 $MM)



Graphs F-3.11 – 3.16 below show macroeconomic impacts on GSP, personal income, and employment in the final year (2030), in average (2015-2030) and in cumulative (2015-2030). Light color means sensitivity scenarios.

Figure F-3.10 TLU GSP Impacts, Average Annual (2015 $MM)

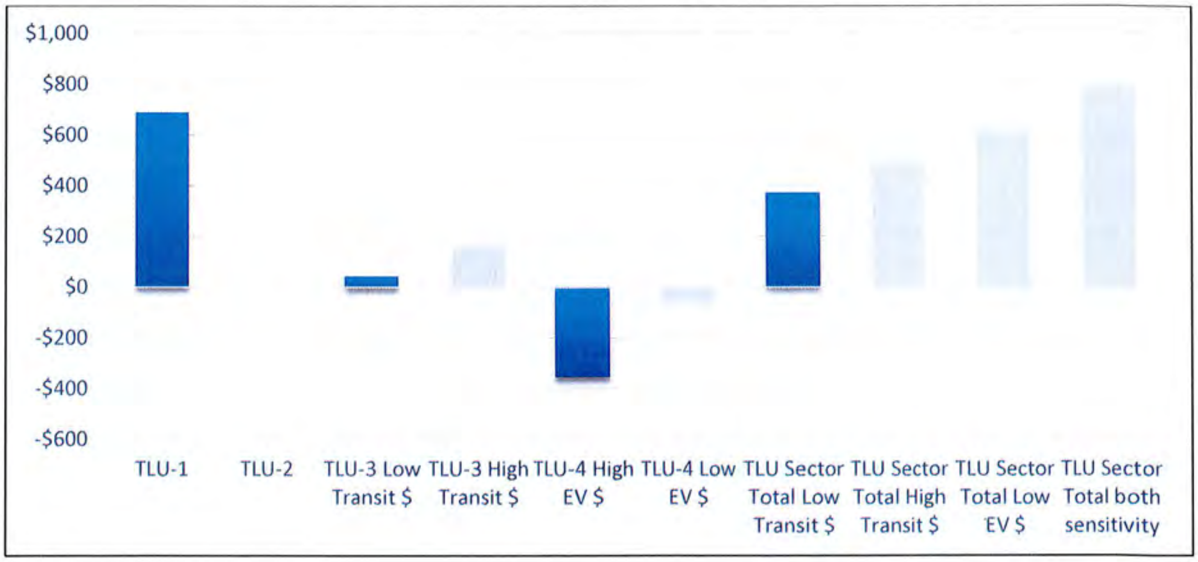


Figure F-3.11 TLU GSP Impacts, 2015-2030 (2015 $MM)

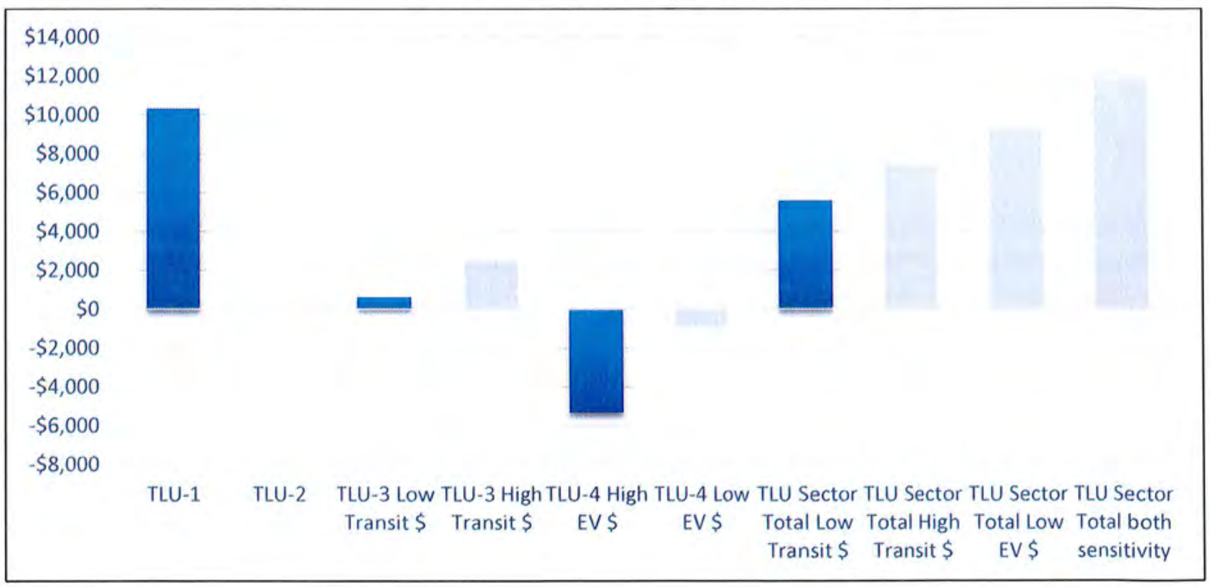


Figure F-3.12 TLU GSP Impacts, Year 2030 (2015 $MM)

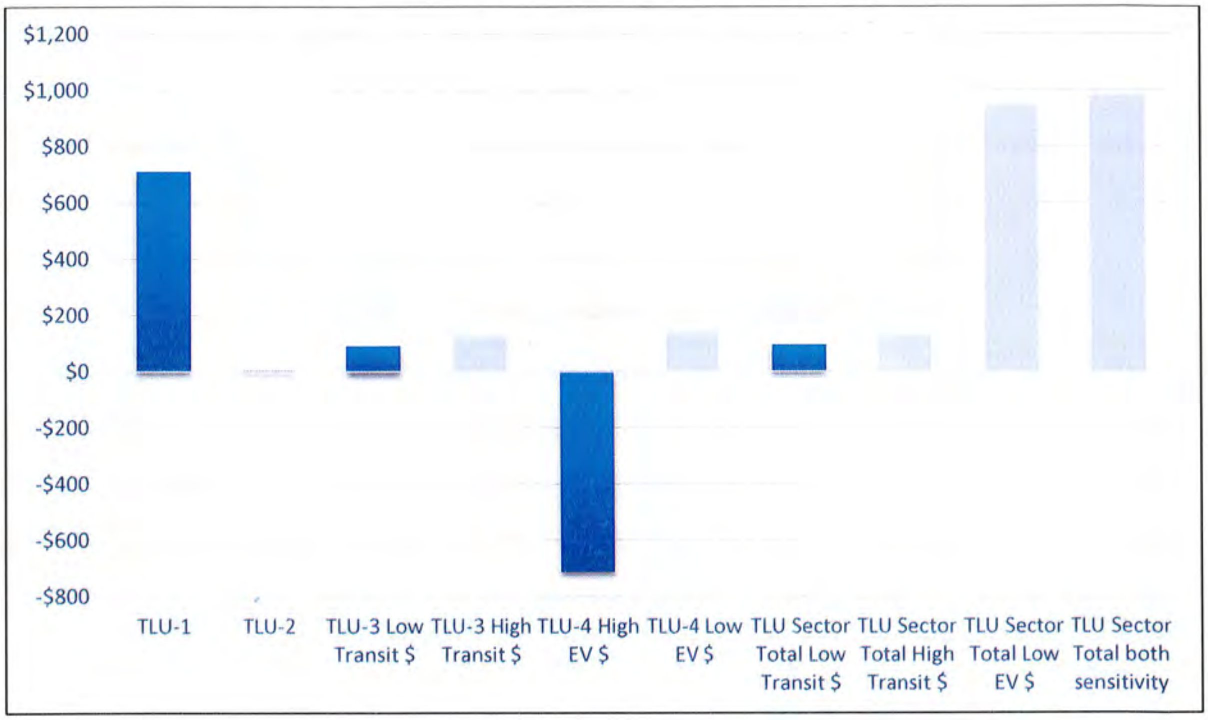


Figure F-3.13 TLU Employment Impacts, 2015-2030 Average Annual (Jobs)

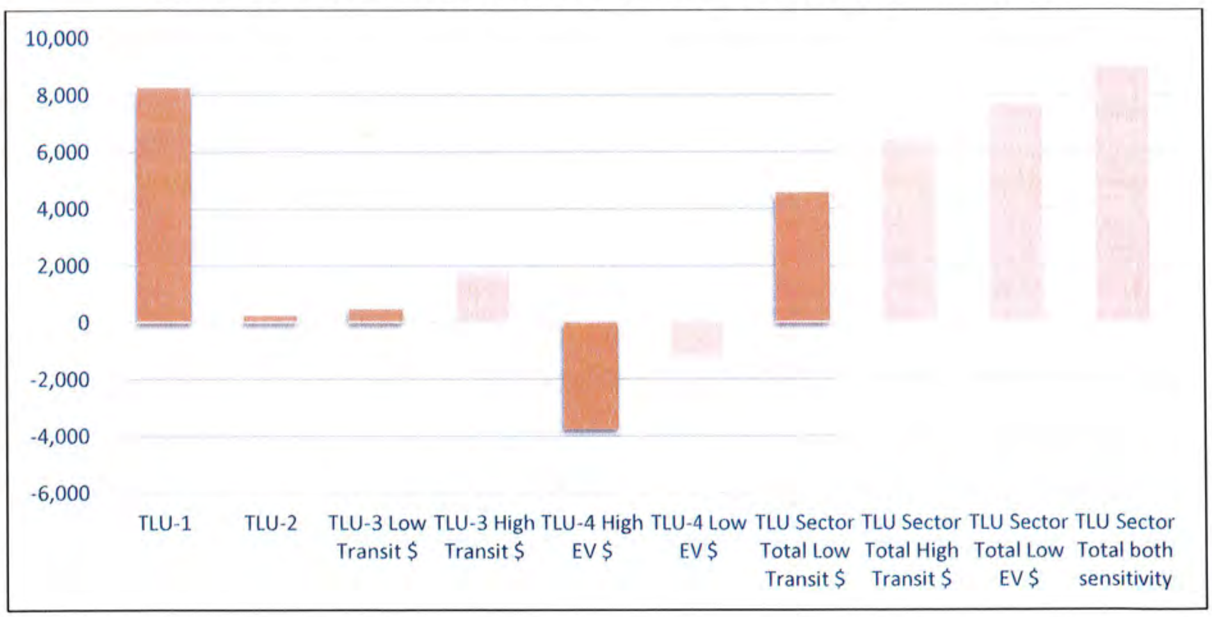


Figure F-3.14 TLU Employment Impacts, 2015-2030 (Jobs)

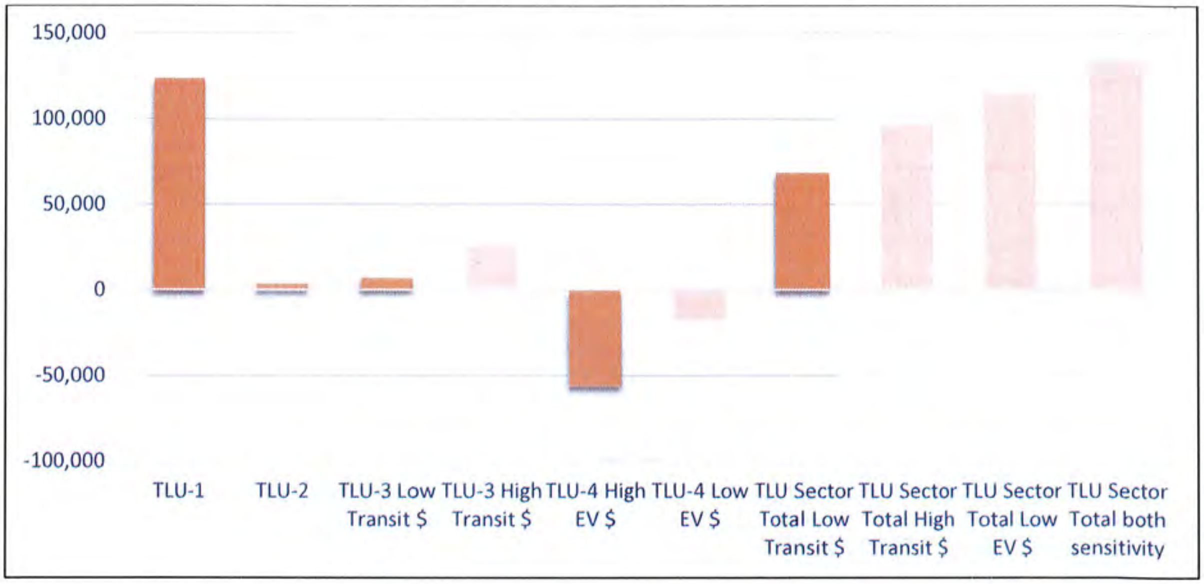


Figure F-3.15 TLU Employment Impacts, Year 2030 (Jobs)

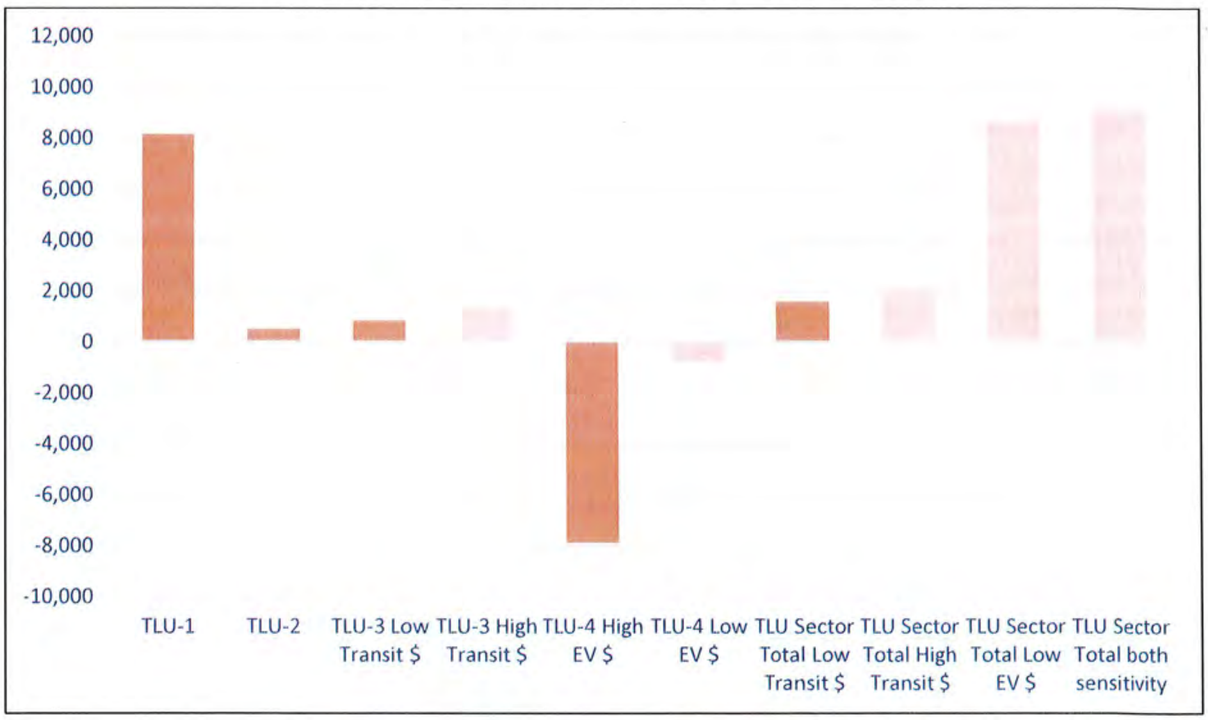


Figure F-3.16 TLU Income Impacts, 2015-2030 Average Annual (2015 $MM)

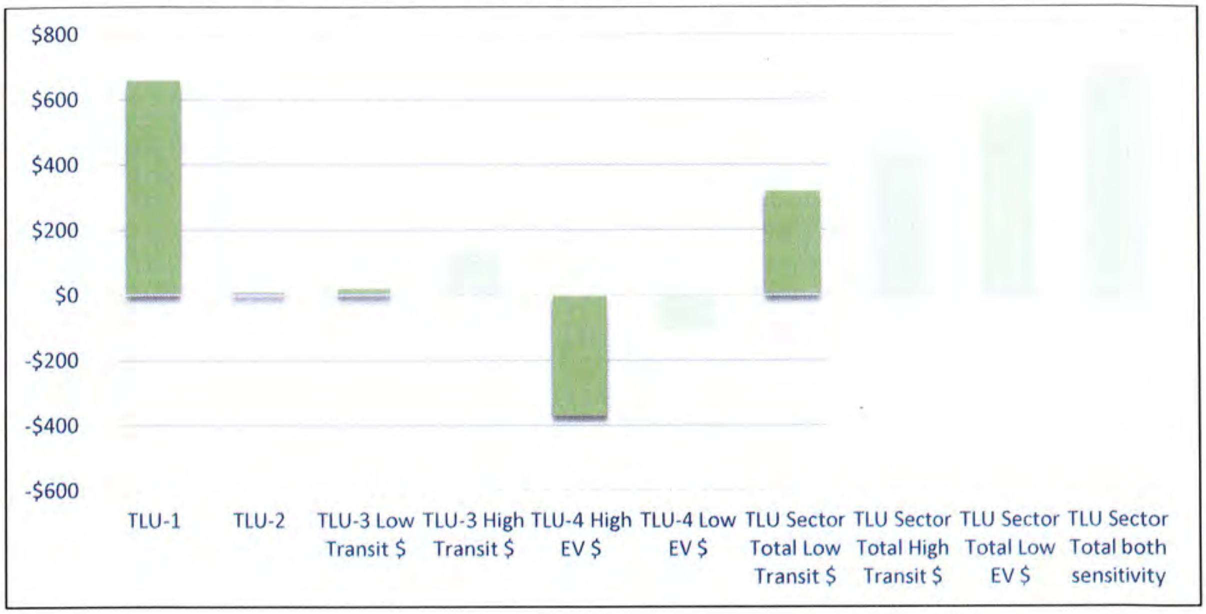


Figure F-3.17 TLU Income Impacts, 2015-2030 ($2015 MM)

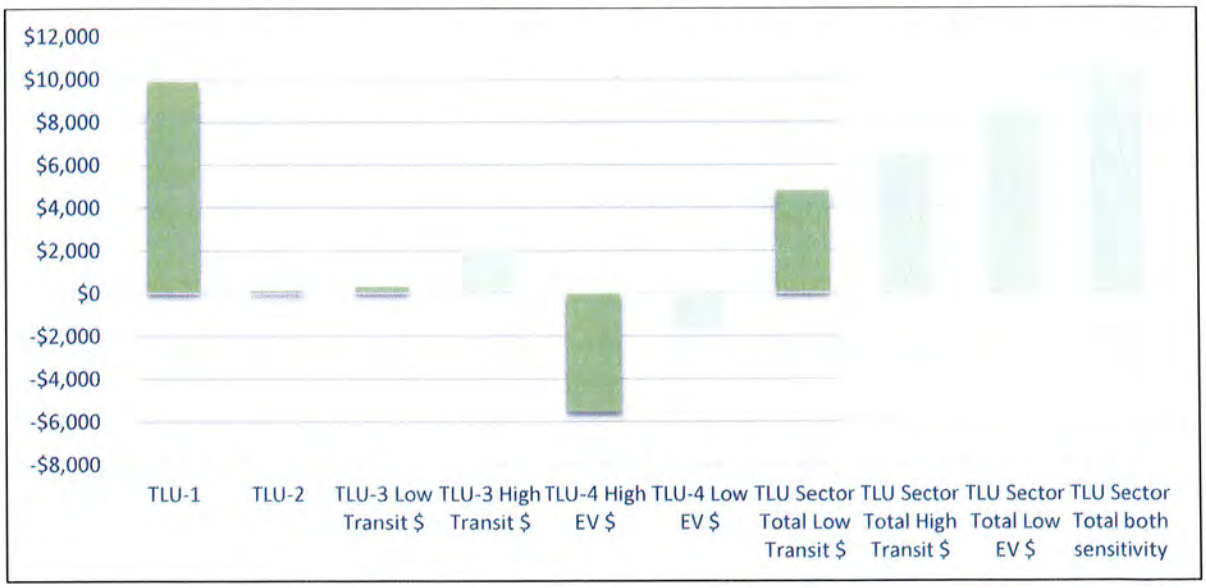
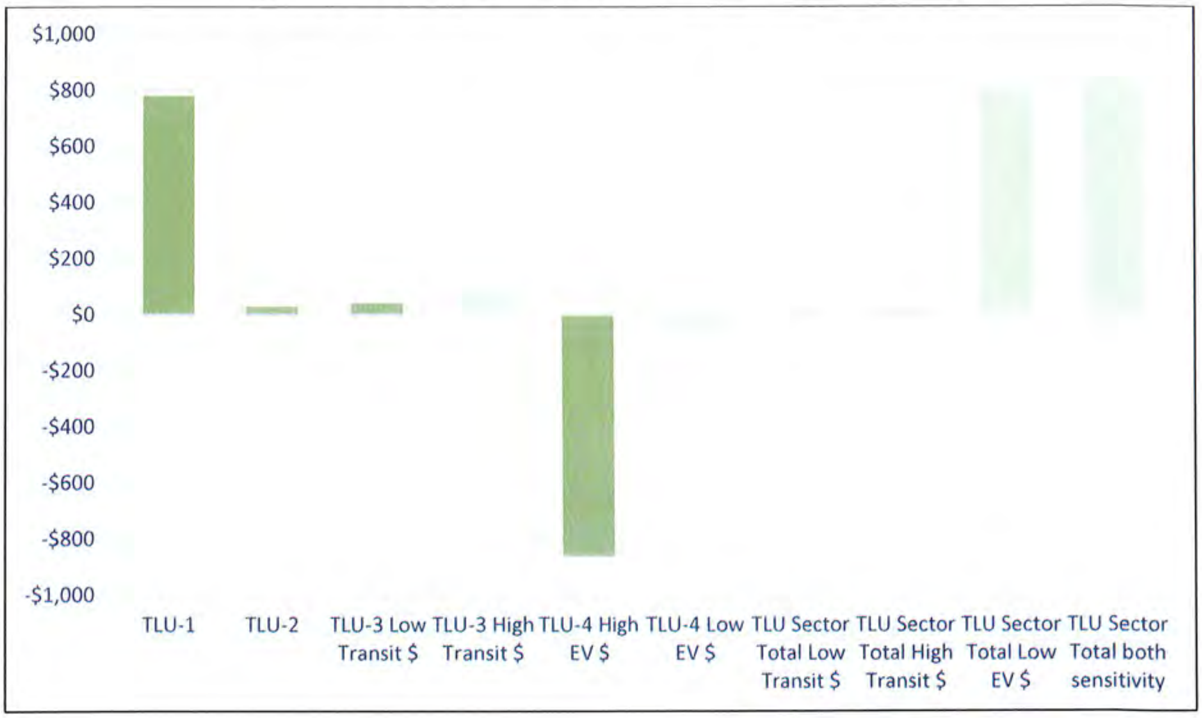


Figure F-3.18 TLU Income Impacts, Year 2030 (2015 $MM)



TLU-1. Transportation Pricing

Policy Option Description

Transportation pricing can reduce greenhouse gas emissions by increasing the marginal and/or total cost of driving and thereby encourage behavior changes that reduce the total vehicle trips or encouraging the purchase of more fuel-efficient vehicles. This policy option is really three policies that can be independently implemented or combined.

The first two policies are specifically designed to reduce greenhouse gas emissions:

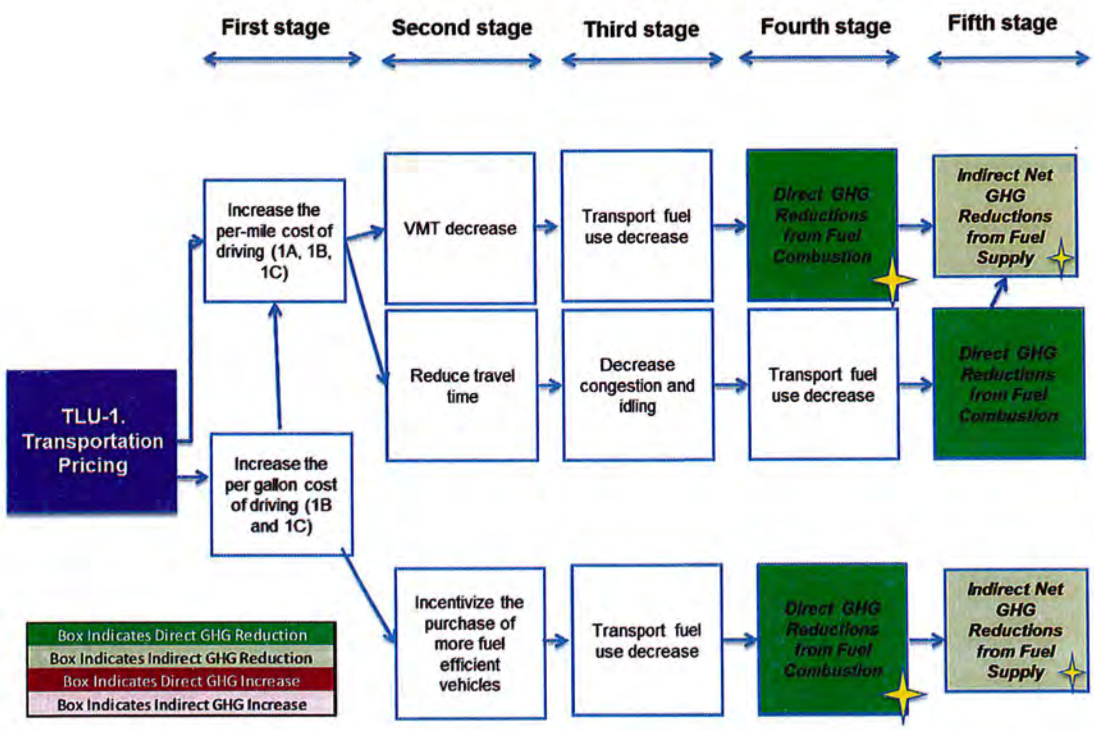
- TLU-1A: Provide incentives for automotive insurance companies to institute pay as you go insurance pricing.
- TLU-1B: Carbon tax on transportation fuels with rebates to low income households and to address other needs.

The third strategy is designed to provide more reliable funding for roads and bridges in Minnesota. It is included as part of this analysis to assess its potential to reduce greenhouse gas emissions.

- TLU-1C: Enact a 6.5% statewide wholesale fuel sales tax on gross gasoline and special fuel (including diesel) purchases.

Causal Chain for Greenhouse Gas Reductions

Figure F-3.19 Causal Chain for TLU-1 GHG Reductions



Policy Option Design

Goals:

- TLU-1A: Achieve 30%, 50% and 80% market penetration of pay-as-you-drive insurance policies by 2020, 2025, 2030, starting in 2017.
- TLU-1B: Cost of operating a motored vehicle in Minnesota includes the social cost of greenhouse gas emissions (using US government data) starting in 2017 and in effect through 2030.
- TLU-1C: Generate sufficient revenue to achieve Minnesota Department of Transportation's (MnDOT) performance targets for pavement condition and bridge condition as well as have funding to complete the envisioned MnPASS system and complete several major highway capacity expansions throughout the state by 2030. Provide a revenue source less vulnerable to inflation.

Timing:

- TLU-1A: Assume some action by the Legislature in 2015 to encourage or otherwise incentivize greater market penetration of PAYD insurance policies
- TLU-1B: Passage of a carbon tax as part of a comprehensive transportation funding bill in 2015. Assume phase in over three years and then annual rate adjustments for inflation. Use of funds could begin in 2017.
- TLU-1C: The new wholesale fuel sales tax would be 6.5%, with no phase-in period. Up to a year of lead time should be expected following passage of the tax to institute collection procedures before the start of revenue generation (and fuel price effects).

Parties Involved:

Legislature, Department of Revenue, state licensed distributors of petroleum products, special fuel dealers, and bulk purchasers of fuel, Minnesota Management and Budget, and the Minnesota Department of Transportation, insurance companies, state Insurance Commission, Department of Commerce, and all vehicle owners.

Implementation Mechanisms

TLU-1A: PAYD Insurance

This policy option was analyzed in the Minnesota Climate Change Advisory Group work in 2008. From MCCAG: The state would encourage and support the provision of PAYD auto insurance, possibly including state support for additional pilot programs. This would also require the state Insurance Commission to conduct an active review of possibilities.

TLU-1B: Carbon Tax

Impose carbon tax on fuel approximately $0.24 per gallon for gasoline and diesel assuming E10 and B20 and $30 per ton social cost of Carbon. The carbon tax would be collected at the same time as the motor fuel excise tax from the state's licensed distributors of petroleum products, special fuel dealers, and bulk purchasers—fewer than 600 in number. Cost would be passed on to consumers.

Use of funds would be split between maintaining/adapting highway infrastructure to climate change, rebating to low-income households to address equity concerns (estimated to be 30% of revenue raised), and funding other climate change mitigation strategies.

To ensure the tax appropriately levies the current social cost of carbon, a preferred mechanism would be to index the rate to inflation. However, an alternative could be a periodic commission review (every other year or every third year) of the current research and review of existing carbon markets for price signals. A third alternative would be to benchmark against some other national source and update annually.

TLU-1C: Wholesale Fuel Sales Tax

For state fiscal years 2010-2015, the national ratio of retail to wholesale gasoline prices averages 1.27 (in a narrow range of 1.25 to 1.31), according to Energy Information Administration data and projections. Retail (as posted at the pump) and wholesale ("rack") fuel prices will intuitively be highly correlated, and lagged wholesale prices have been shown historically to predict retail prices at the national level. For this reason, a driver demand elasticity analysis that assumes complete pass-through to the retail setting in the amount of the wholesale tax may be appropriate. To summarize, it is likely that the full cost of such a tax would be passed onto consumers.

The state's licensed distributors of petroleum products, special fuel dealers, and bulk purchasers, who are already the remitting entities for prevailing excise taxes levied on a volumetric basis, would also be the collection points for the new price-sensitive wholesale tax. Demonstrating the precedent for a variable-rate fuel tax, the Institute on Taxation and Economic Policy calculates that a majority (55%) of Americans now live in a state with such a tax provision, a claim reinforcing the measure's feasibility.

Revenue would be deposited into the Highway User Tax Distribution Fund and then constitutionally distributed to state, county, and municipal road jurisdictions for capital, operations, and maintenance expenditures.

Related Policies/Programs in Place and Recent Actions

GMAC and On Star Low-Mileage Discount Rates

(From original MCCAG appendix regarding TLU-1A)

Since mid-2004, the General Motors Acceptance Corporation Insurance has offered mileage-based discounts to OnStar[1] subscribers located in certain states. The system automatically reports vehicle odometer readings at the beginning and end of the policy term to verify vehicle mileage.

Motorist who drive less than the specified annual mileage receive insurance premium discounts of up to 40%:

- 1–2,500 miles: 40% discount
- 2,501–5,000 miles: 33% discount
- 5,001–7,500 miles: 28% discount
- 7,501–10,000 miles: 20% discount
- 10,001–12,500 miles: 11% discount
- 12,501–15,000 miles: 5% discount

[1] http://www.onstar.com/us_english/jsp/low_mileage_discount.jsp.

- 15,001–99,999 miles: 0% discount

The Federal Highway Administration's Value Pricing Pilot Program is now providing funding for PAYD insurance simulation projects in Georgia and Massachusetts.[2]

Distance-Based Program - Progressive Insurance offers distance-based insurance in Oregon, Michigan, and Minnesota. The program uses Global Positioning System technology to track vehicle location and use.

TripSense(SM) - In August 2004, the Progressive Direct Group of Insurance Companies introduced TripSense, a usage-based auto insurance discount. The group notes:

"Safer drivers and people who drive less than average should pay less for auto insurance. That's why we created the revolutionary TripSense (SM) discount program, which measures your actual driving habits and allows you to earn discounts on your insurance by showing us how much, how fast and what times of day you drive. TripSense gives you more control over what you pay for insurance, as your driving habits determine your discount." [3]

In 2012, Minnesota Governor Dayton established the Minnesota Transportation Finance Advisory Committee, which recommended increasing fuel taxes to help close the funding gap for road and bridge needs in the state.[4]

Estimated Policy Impacts

Direct Policy Impacts

Table F-3.4 TLU-1a-c combined - Estimated Net GHG Reductions and Net Costs or Savings

Policy Option Component	2030 In-State GHG Reductions ($MMtCO_2e$):	2015 – 2030 Total Cumulative Reductions ($MMtCO_2e$):	Net Present Value of Societal Costs, 2015 – 2030 ($MM2014):	Cost Effectiveness ($2014/ ton CO_2e):
TLU-1A	1.0	11	-$2,160	-$189
TLU-1B	0.57	9.2	$1,898	$205
TLU-1C	0.42	7.6	$2,980	$394
TLU-1 Total	**2.0**	**28**	**$2,718**	**$96**

Notes:
Total cumulative reductions and cost effectiveness include reductions that occur both within and outside of the State.

[2] http://www.fhwa.dot.gov/policy/13-hmpg.htm
[3] http://newsroom.progressive.com/press-kit/tripsense-images.aspx
[4] http://www.dot.state.mn.us/tfac/

Data Sources

- Joseph Ferreira Jr. and Eric Minikel (2010), Pay-As-You-Drive Auto Insurance In Massachusetts: A Risk Assessment And Report On Consumer, Industry And Environmental Benefits, by the Department of Urban Studies and Planning, Massachusetts Institute of Technology (http://dusp.mit.edu) for the Conservation Law Foundation (www.clf.org).[5]
- Dan Brand (2009), Impacts of Higher Fuel Costs, Federal Highway Administration.[6]
- Phil Goodwin, Joyce Dargay and Mark Hanly (2004), "Elasticities of Road Traffic and Fuel Consumption With Respect to Price and Income: A Review," *Transport Reviews*
- Litman, Todd (2012). "Changing Vehicle Travel Price Sensitivities". 10 September 2012. Victoria Transportation Policy Institute.[7]
- Gar W. Lipow (2008), Price-Elasticity of Energy Demand: A Bibliography, Carbon Tax Center

Quantification Methods

For TLU-1A, the primary study used to estimate the VMT reductions and fuel savings that can be achieved with a PAYD insurance program came from Ferreira and Minikel (2010). This study indicated that a revenue neutral PAYD program, in which all insurance costs are converted into a per-mile fee, would achieve a reduction in VMT of 9.5% and a reduction in fuel consumption of 9.3% per driver. The fuel savings were estimated by multiplying the Minnesota highway fuel consumption per year (from the Minnesota Transportation Inventory) by the 9.3% reduction per driver by the implementation path (the percentage of Minnesota drivers in a PAYD program). The implementation path starts at 8% in 2017 and increases to 80% in 2030. This reduction in fuel consumption is then used to estimate total greenhouse gas reductions and overall fuel savings. There were no implementation costs included in the estimate at this time, because the switch from conventional to PAYD insurance is expected to have very few associated costs. The quantification results can be seen in tables below.

Table F-3.5 TLU-1A Pay-As-You-Go Insurance Greenhouse Gas Savings and Costs

Year	Change in Fuel Consumption (000 gallons)	tCO_2e Change	Change in Fuel Cost ($2014 Million)
2015	0	0	$0
2016	0	0	$0
2017	-13,897	-121,351	-$42
2018	-27,330	-238,650	-$79

[5] http://www.clf.org/our-work/healthy-communities/modernizing-transportation/pay-as-you-drive-auto-insurance-payd
[6] http://www.fhwa.dot.gov/policy/otps/innovation/issue1/impacts.htm
[7] http://www.vtpi.org/VMT_Elasticities.pdf

Year	Change in Fuel Consumption (000 gallons)	tCO_2e Change	Change in Fuel Cost ($2014 Million)
2019	-40,289	-351,817	-$111
2020	-52,816	-461,205	-$140
2021	-58,818	-513,612	-$149
2022	-64,550	-563,662	-$157
2023	-70,139	-612,472	-$164
2024	-75,484	-659,144	-$169
2025	-80,618	-703,977	-$173
2026	-88,763	-775,099	-$182
2027	-96,653	-843,998	-$190
2028	-104,312	-910,878	-$197
2029	-111,752	-975,840	-$202
2030	-118,991	-1,039,056	-$206
Total		**-8,770,761**	**-$2,160**

TLU-1B and -1C both focus on the affect that changing the cost of driving has on driver behavior. Where pay-as-you-go insurance is simply converting an existing cost (car insurance) into a per-mile cost, 1B and 1C are examining the effects of increasing the cost of driving.

The quantification for the carbon tax policy (1B) looked at the impacts of assessing a $30 per ton societal cost for each ton of carbon. According to Environmental Protection Agency's (EPA) emissions factors, each gallon of gasoline has an emissions factor of 8.59 kg per gallon, which averages to a tax of $0.24 per gallon of E10 gasoline. This is then indexed to inflation for 2015-2030, based on Minnesota's GDP price index. This would likely be implemented in the same manner as a fuel tax, and therefore TLU-1B was quantified in the same way as TLU-1C.

The impact of this increase in cost depends on the VMT elasticity that is selected. Goodwin, Dargay and Hanly (2004) found that as fuel and carbon taxes increase the per mile costs of travel, fuel consumption declines faster than vehicle travel. This is because fuel/carbon taxes provide an incentive to use a more fuel efficient vehicle as well as to drive less. Consumers have greater ability to reduce fuel consumption when they can adjust over a long period of time. Goodwin, Dargay and Hanly (2004) found that in the long run, 43% of the decline in fuel consumption is the result of VMT reduction, whereas 57% is the result of improved fuel efficiency. A study by the FHWA found VMT elasticity in the short term (four years or less) of -0.17, and of -0.40 in the longer term (Litman, 2012 and Lipow, 2008). Therefore, a 10% increase in the per mile cost of driving would result in a 1.7% decrease in fuel consumption in the short term, and a 4% decrease over a longer term (Litman, 2012 and Lipow, 2008). This estimate is used to estimate the change in VMT and fuel consumption as a result of TLU-1B and -1C. The cost of collection in TLU-1B is assumed to be near zero, but a rebate program to address equity issues would take resources. For the purposes of this analysis, we assume one percent of collected revenues to administer the rebate program, which are included in the total costs of

TLU-1B. The rebate program immediately reinvests 30% of the revenue raised in TLU-1B back into the economy.

The implementation costs, fuel consumption and greenhouse gas changes of TLU-1B are laid out in tables below. The fuel savings achieved decline over the 2019-2030 analysis period because vehicles are becoming more efficient, and therefore will be less affected by the carbon tax. These tables also present the revenue raised, fuel cost savings, and discounted total costs of TLU-1B.

Table F-3.6 Fuel and Greenhouse Gas Impacts of TLU-1B – Carbon Tax

Year	Fuel Tax (Gasoline and Diesel) ($/gal)	Total Fuel Savings (million gallons)	$MtCO_2e$ Change
2015	$0.00	0.0	0
2016	$0.00	0.0	0
2017	$0.25	-28.6	-250,113
2018	$0.25	-28.6	-250,034
2019	$0.26	-28.6	-249,446
2020	$0.26	-66.9	-583,959
2021	$0.27	-66.7	-582,704
2022	$0.27	-66.5	-581,114
2023	$0.28	-66.4	-579,390
2024	$0.28	-66.2	-577,718
2025	$0.29	-65.9	-575,811
2026	$0.29	-65.7	-574,048
2027	$0.30	-65.6	-572,590
2028	$0.30	-65.5	-571,595
2029	$0.31	-65.4	-571,067
2030	$0.31	-65.4	-571,306
Total		-812	-7,090,895

Note: Each policy option analysis was done over a fifteen-year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

Table F-3.7 Costs of TLU-1B – Carbon Tax

Year	Revenue Raised (Million $)	Fuel Savings (Million $)	Rebate Program Costs	Rebate Program Reinvestment	TLU 1B Total Costs ($2014 Million)
2015	$0	$0.0	$0.00	$0	$0
2016	$0	$0.0	$0.00	$0	$0
2017	$589	-$100.1	$5.89	$177	$265
2018	$591	-$100.4	$5.91	$177	$253

Year	Revenue Raised (Million $)	Fuel Savings (Million $)	Rebate Program Costs	Rebate Program Reinvestment	TLU 1B Total Costs ($2014 Million)
2019	$592	-$100.7	$5.92	$178	$241
2020	$594	-$237.6	$5.94	$178	$129
2021	$596	-$238.4	$5.96	$179	$123
2022	$598	-$239.2	$5.98	$179	$117
2023	$600	-$240.1	$6.00	$180	$112
2024	$602	-$240.8	$6.02	$181	$107
2025	$604	-$241.5	$6.04	$181	$102
2026	$606	-$242.3	$6.06	$182	$98
2027	$608	-$243.2	$6.08	$182	$94
2028	$611	-$244.3	$6.11	$183	$89
2029	$614	-$245.6	$6.14	$184	$86
2030	$618	-$247.3	$6.18	$185	$82
Total					$1,898

TLU-1C, a 6.5% wholesale fuel tax, is quantified in a similar manner as TLU-1B. The reductions in fuel consumption and VMT that occur were also estimated based on the results in Litman, (2012), Lipow (2008) and Goodwin, Dargay and Hanly (2004). The fuel tax increases the per mile cost of driving, and incentivizes both driving a more efficient vehicle and reducing VMT. The implementation, fuel consumption and greenhouse gas changes of TLU-1C are shown in Table F-3.8. Note that as vehicle efficiency (fuel economy) is projected to improve, the fuel savings as a result of the fuel tax are estimated to decrease. The next table shows the revenue raised, fuel cost savings, and discounted total costs of TLU-1C.

Table F-3.8 Fuel and Greenhouse Gas Impacts of TLU-1C – Fuel Tax

Year	Fuel Tax (Gasoline and Diesel) ($/gal)	Total Fuel Savings (million gallons)	MtCO_2e Change
2015	$0.000	0.0	0
2016	$0.193	-22.7	-197,905
2017	$0.195	-22.3	-194,677
2018	$0.198	-22.2	-194,051
2019	$0.200	-52.0	-454,001
2020	$0.203	-51.5	-450,001
2021	$0.205	-51.2	-447,200
2022	$0.208	-50.8	-444,018
2023	$0.210	-50.5	-440,660
2024	$0.213	-50.1	-437,401

Year	Fuel Tax (Gasoline and Diesel) ($/gal)	Total Fuel Savings (million gallons)	$MtCO_2e$ Change
2025	$0.216	-49.7	-433,929
2026	$0.218	-49.3	-430,501
2027	$0.221	-48.9	-427,227
2028	$0.224	-48.6	-424,092
2029	$0.227	-48.2	-421,128
2030	$0.230	-47.9	-418,315
Total		-665.9	-5,815,105

Table F-3.9 Costs of TLU-1C – Fuel Tax

Year	Revenue Raised (Million $)	Fuel Savings (Million $)	TLU-1C Total Costs ($2014 Million)
2015	$0	$0.0	$0
2016	$458	-$77.9	$345
2017	$458	-$77.9	$329
2018	$458	-$77.9	$313
2019	$458	-$183.2	$215
2020	$458	-$183.1	$205
2021	$457	-$182.9	$195
2022	$457	-$182.8	$186
2023	$456	-$182.6	$177
2024	$456	-$182.3	$168
2025	$455	-$182.0	$160
2026	$454	-$181.7	$152
2027	$454	-$181.5	$144
2028	$453	-$181.3	$137
2029	$453	-$181.1	$131
2030	$453	-$181.1	$124
Total			**$2,980**

The total greenhouse gas impacts of the TLU-1 policies are displayed in the following table, while the table immediately next shows the additional upstream savings from reduced fuel consumption of TLU-1. The next table yet (Table F-3.12) shows the total costs of TLU-1. For all three tables, the total column shows the combined effects of all three policies, assuming they produce additive effects.

Table F-3.10 Total In-State Greenhouse Gas Impacts of TLU-1 Policies ($MtCO_2e$)

	TLU-1A – PAYD	TLU-1B – Carbon Tax	TLU-1C – Fuel Tax	TLU-1 Total
2015	0	0	0	0
2016	0	0	-197,905	-197,905
2017	-121,351	-250,113	-194,677	-566,140
2018	-238,650	-250,034	-194,051	-682,735
2019	-351,817	-249,446	-454,001	-1,055,263
2020	-461,205	-583,959	-450,001	-1,495,166
2021	-513,612	-582,704	-447,200	-1,543,516
2022	-563,662	-581,114	-444,018	-1,588,793
2023	-612,472	-579,390	-440,660	-1,632,522
2024	-659,144	-577,718	-437,401	-1,674,262
2025	-703,977	-575,811	-433,929	-1,713,717
2026	-775,099	-574,048	-430,501	-1,779,649
2027	-843,998	-572,590	-427,227	-1,843,815
2028	-910,878	-571,595	-424,092	-1,906,566
2029	-975,840	-571,067	-421,128	-1,968,035
2030	-1,039,056	-571,306	-418,315	-2,028,677
Total	**-8,770,761**	**-7,090,895**	**-5,815,105**	**-21,676,762**

Table F-3.11 Total Upstream Greenhouse Gas Impacts of TLU-1 Policies (MtCO₂e)

	TLU-1A – PAYD	TLU-1B – Carbon Tax	TLU-1C – Fuel Tax	TLU-1 Upstream Total	TLU-1 Upstream plus Instate
2015	0	0	0	0	0
2016	0	0	-58,514	-58,514	-256,420
2017	-36,051	-74,304	-57,835	-168,191	-734,331
2018	-71,231	-74,629	-57,919	-203,779	-886,514
2019	-105,490	-74,795	-136,130	-316,416	-1,371,679
2020	-138,912	-175,885	-135,537	-450,334	-1,945,500
2021	-154,898	-175,736	-134,869	-465,503	-2,009,019
2022	-170,215	-175,485	-134,085	-479,784	-2,068,577
2023	-185,196	-175,193	-133,244	-493,632	-2,126,154
2024	-199,568	-174,915	-132,431	-506,915	-2,181,177
2025	-213,421	-174,565	-131,552	-519,537	-2,233,255
2026	-235,289	-174,258	-130,683	-540,230	-2,319,879
2027	-256,538	-174,042	-129,858	-560,438	-2,404,253
2028	-277,228	-173,966	-129,074	-580,268	-2,486,834
2029	-297,387	-174,033	-128,339	-599,758	-2,567,793
2030	-317,065	-174,333	-127,648	-619,046	-2,647,723
Total				-6,562,346	-28,239,107

Table F-3.12 Total Costs of TLU-1 Policies ($2014 MM)

	TLU-1A – PAYD	TLU-1B – Carbon Tax	TLU-1C – Fuel Tax	TLU-1 Total
2015	$0	$0	$0	$0
2016	$0	$0	$345	$345
2017	-$42	$265	$329	$551
2018	-$79	$253	$313	$487
2019	-$111	$241	$215	$345
2020	-$140	$129	$205	$193
2021	-$149	$123	$195	$169
2022	-$157	$117	$186	$146
2023	-$164	$112	$177	$125
2024	-$169	$107	$168	$106
2025	-$173	$102	$160	$89
2026	-$182	$98	$152	$67
2027	-$190	$94	$144	$48
2028	-$197	$89	$137	$30
2029	-$202	$86	$131	$14
2030	-$206	$82	$124	$1

	TLU-1A – PAYD	TLU-1B – Carbon Tax	TLU-1C – Fuel Tax	TLU-1 Total
Total	-$2,160	$1,898	$2,980	$2,718

TLU-1B and -1C both serve to increase the cost of driving. To better understand the price impact of these polices, it can be useful to express this cost change in terms of change in price per gallon. Table F-3.13 shows the increase in $/gallon for both policies. TLU-1A cannot be expressed as a $/gallon impact, because it does not directly affect the price of gas; instead 1A converts an existing fixed cost (car insurance) to a variable cost.

Table F-3.13 $/Gallon Increase of TLU-1B and 1C

	TLU-1B	TLU-1C	Total Increase in $/Gallon of All TLU-1 Policies
2015	$0.00	$0.00	$0.00
2016	$0.00	$0.19	$0.19
2017	$0.25	$0.20	$0.45
2018	$0.25	$0.20	$0.45
2019	$0.26	$0.20	$0.46
2020	$0.26	$0.20	$0.47
2021	$0.27	$0.21	$0.47
2022	$0.27	$0.21	$0.48
2023	$0.28	$0.21	$0.49
2024	$0.28	$0.21	$0.49
2025	$0.29	$0.22	$0.50
2026	$0.29	$0.22	$0.51
2027	$0.30	$0.22	$0.52
2028	$0.30	$0.22	$0.53
2029	$0.31	$0.23	$0.53
2030	$0.31	$0.23	$0.54

Key Assumptions

This analysis assumes no interaction or overlap within this policy option.

The baseline forecast assumes vehicle miles traveled in Minnesota increase annually at a rate of 0.8%.

The baseline fuel economy forecast is from the Energy Information Administration (EIA) which projects average efficiency of vehicles travelling in Minnesota to increase from 24.1 miles per gallon in 2015 to 33.4 miles per gallon in 2030.

The impacts of this policy option are based on gasoline powered light duty vehicles only, even though TLU-1B and -1C would provide an incentive to reduce emissions other than just in gasoline highway vehicles. In particular, the policy option options would reduce emissions from medium duty and heavy commercial vehicles albeit to a lesser degree than for light duty vehicles. Therefore, this analysis likely underestimates the total effect of TLU-1B and -1C.

Administrative costs of TLU-1 policies are assumed to be low, with only 1B including a specific administrative cost of one percent for a rebate program to address equity issues. The actual cost of administering the rebate programs envisioned for 1B could be substantially different. It is likely that TLU-1C would also need to address equity issues to avoid having an adverse impact on poorer communities.

The Pay-as-you-drive policy option in TLU-1A assumes that such a policy option can be implemented on a wide scale and will be widely adopted in Minnesota.

Macroeconomic (Indirect) Policy Impacts

Table F-3.14 TLU-1 Macroeconomic Impacts on GSP, Employment and Income

Scenario	GSP ($2015 MM)			Employment (Individual)			Personal Income ($2015 MM)		
	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)
TLU-1	$711	$688	$10,319	8,140	8,230	123,400	$781	$659	$9,885

Graphs F-20 – 22 below show detail in GSP, employment and personal income impacts of the TLU-1 policy.

Figure F-3.20 TLU-1 Impacts on Gross State Product ($2015 MM)

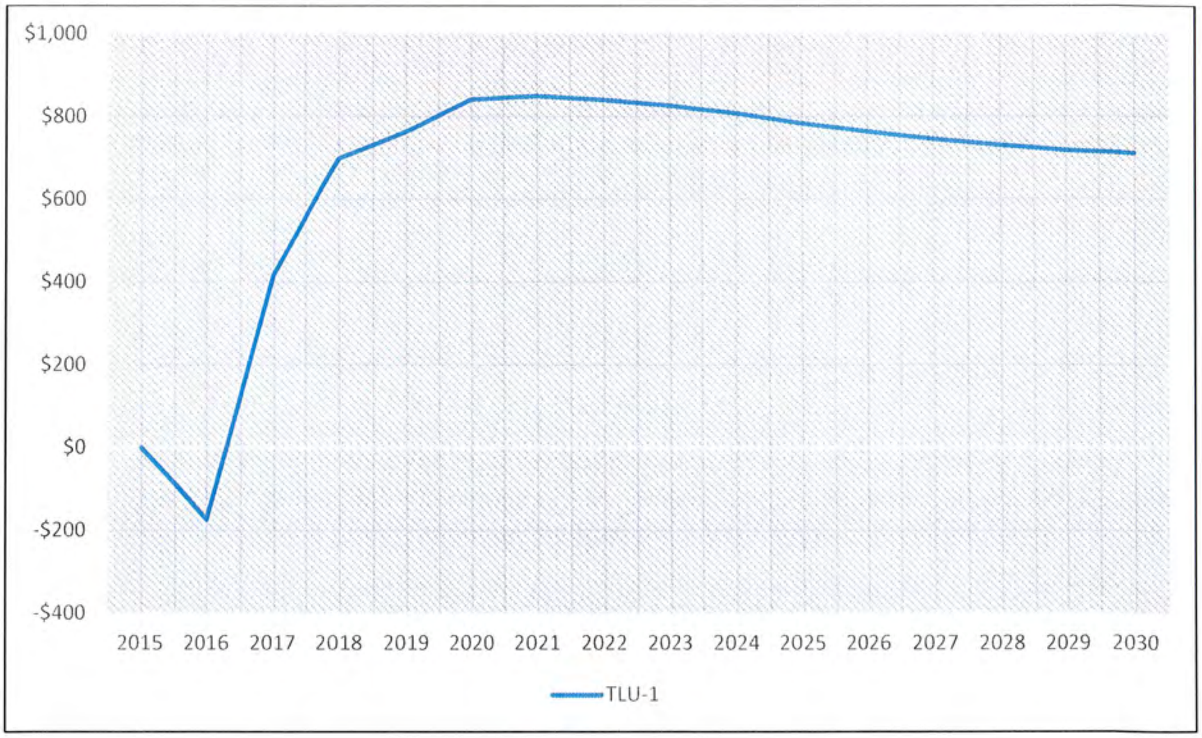


Figure F-3.21 TLU-1 Impacts on Incomes ($2015 MM)

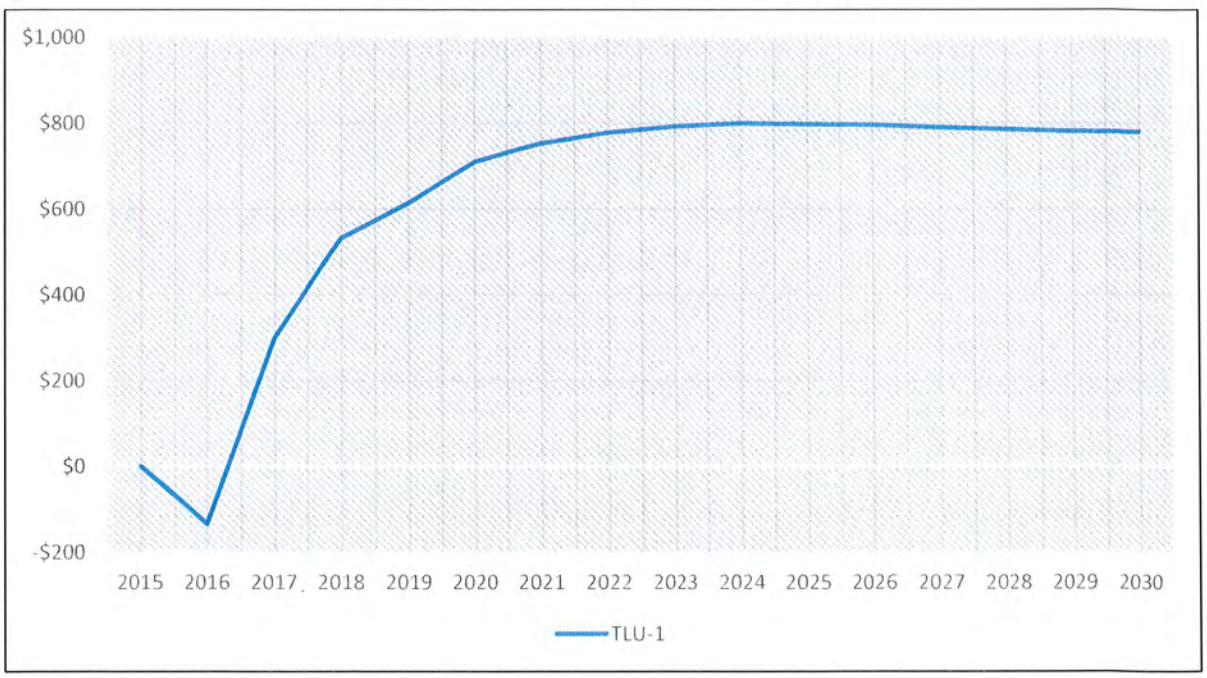
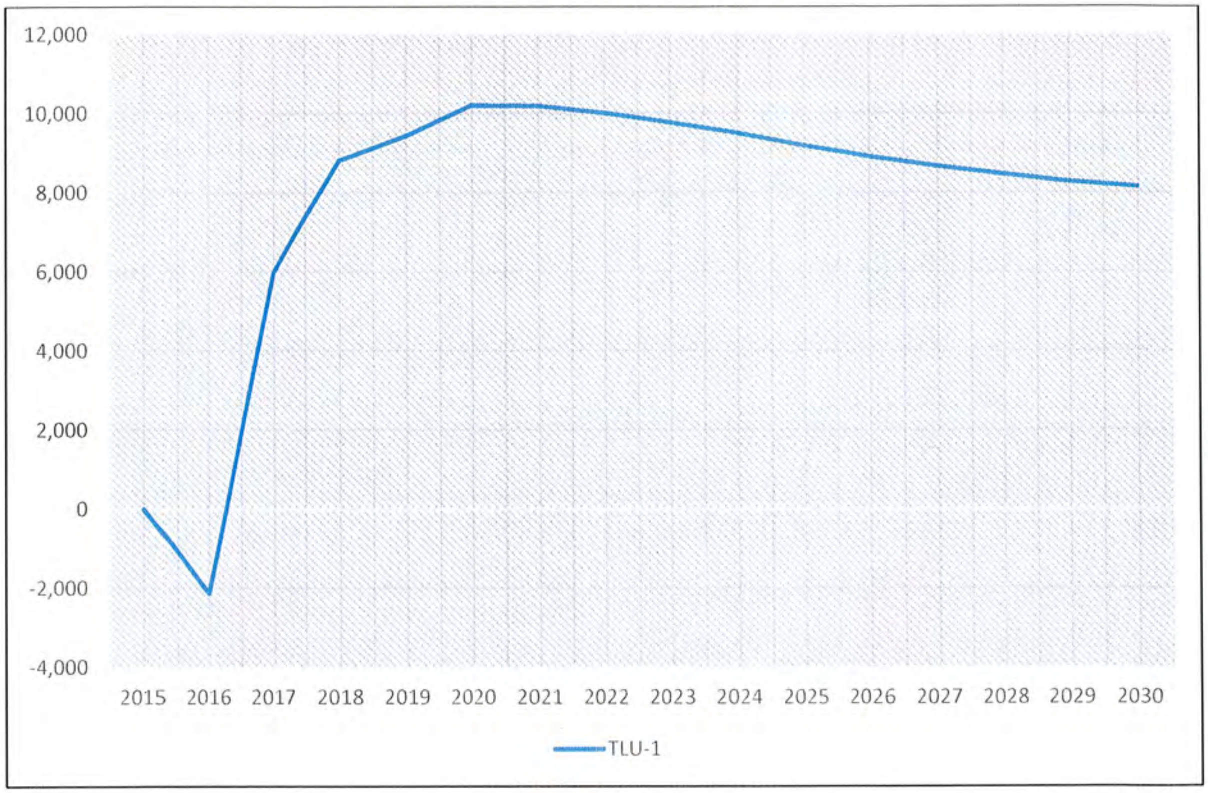
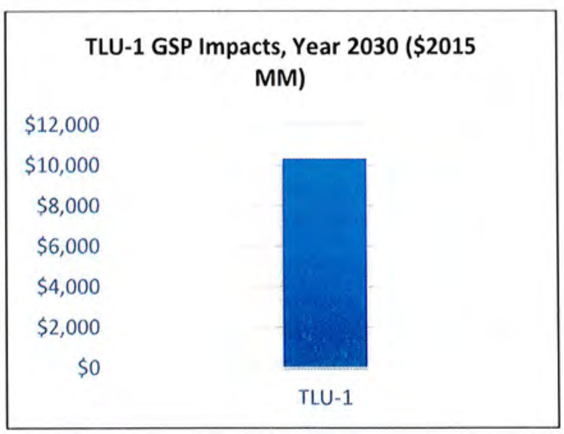
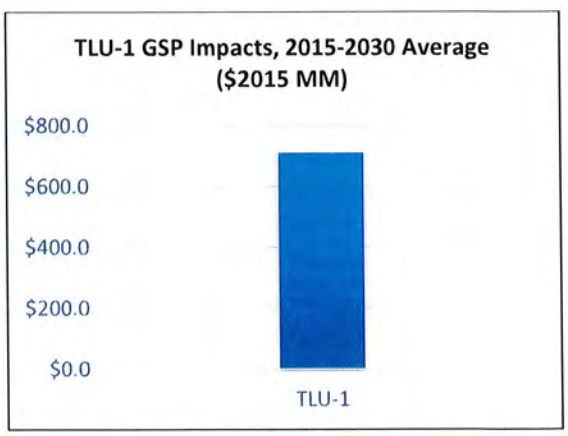


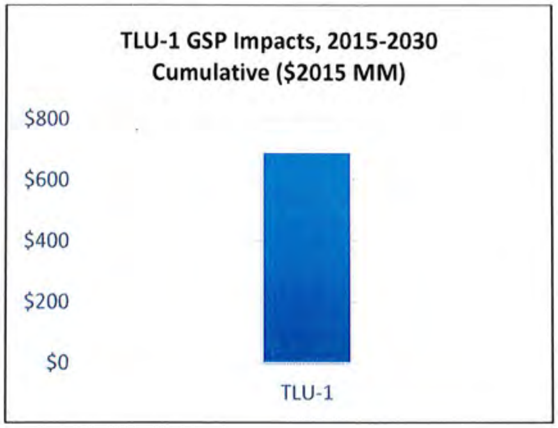
Figure F-3.22 TLU-1 Impacts on Employment (Individual Jobs)

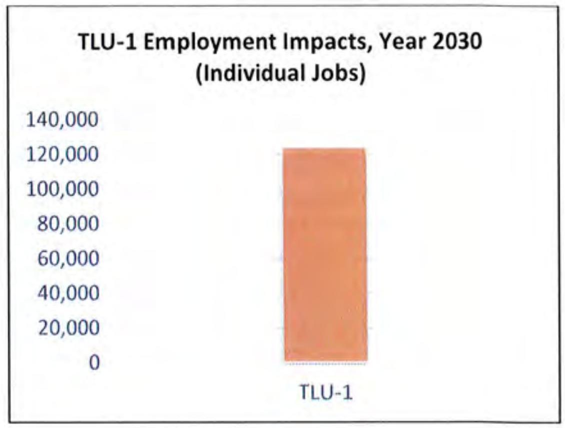


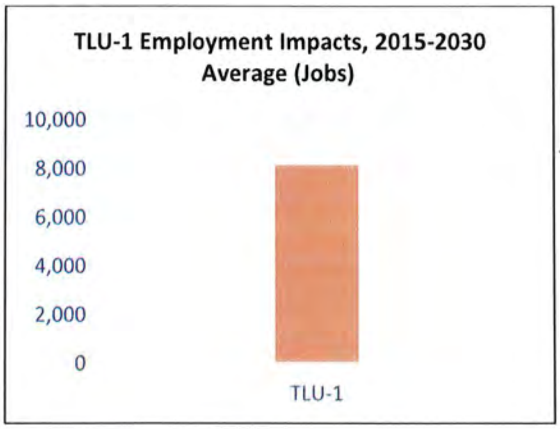
Graphs below show macroeconomic impacts on GSP, personal income, and employment in the final year (2030), in average (2015-2030) and in cumulative (2015-2030).

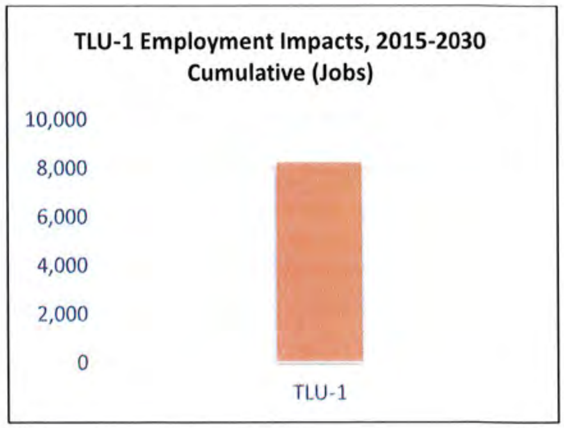


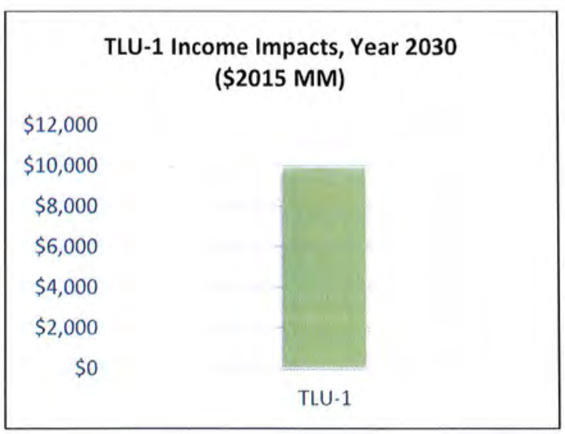


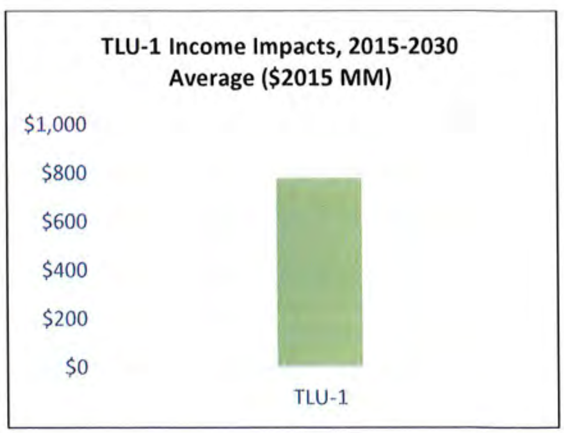

TLU-1 GSP Impacts, 2015-2030
Cumulative ($2015 MM)
$800
$600
$400
$200
$0
TLU-1

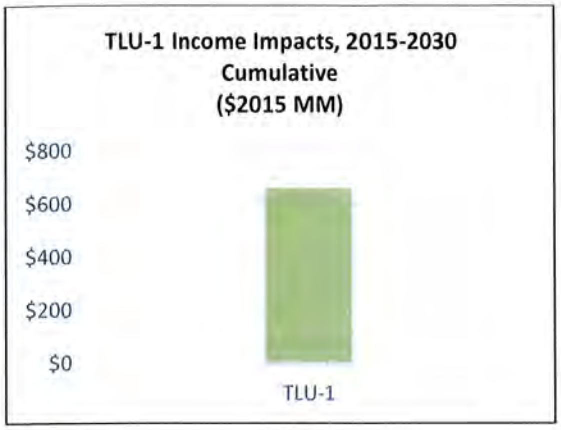

TLU-1 Employment Impacts, Year 2030
(Individual Jobs)
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
TLU-1


TLU-1 Employment Impacts, 2015-2030
Average (Jobs)
10,000
8,000
6,000
4,000
2,000
0
TLU-1


TLU-1 Employment Impacts, 2015-2030
Cumulative (Jobs)
10,000
8,000
6,000
4,000
2,000
0
TLU-1


TLU-1 Income Impacts, Year 2030
($2015 MM)
$12,000
$10,000
$8,000
$6,000
$4,000
$2,000
$0
TLU-1


TLU-1 Income Impacts, 2015-2030
Average ($2015 MM)
$1,000
$800
$600
$400
$200
$0
TLU-1



Principal Drivers of Macroeconomic Changes

TLU-1 presents a set of offsetting impacts to consumer spending, with the Pay-As-You-Go insurance policy producing a savings to consumers of nearly $450 million by 2030. However, In the other direction, the fuel tax and carbon tax elements produce costs to consumers of very similar amounts. As a result, consumers see little overall change in their total cost of transportation.

While consumers do not end up having lost very much money after balancing out the effects of these three initiatives, the government does have significant new revenue (all the funds collected from the carbon and gas taxes) as a result of those policies. This expands government budgets, and increases spending on programs and services – both of which are a component of GDP and are typically labor-intensive.

The result of this policy is highly positive. The policy generates about $800 million in new GDP annually, and a similar amount in incomes through the creation of nearly 10,000 new jobs.

The combination of the pay-as-you-go insurance with the taxes is crucial to this. The savings out of the former policy substantially offsets the burden imposed by the latter two. In the absence of this balancing force, while the government spending expansion would still be present and a positive force, the burden of the taxes would be significant as a driver of negative economic impacts. In that case, the impacts would tend much closer to neutral.

Data Sources

The principal data sources for the macroeconomic impacts analysis of this and all other policies in the CSEO process are the direct spending, saving, cost and price impacts developed as part of the microeconomic (direct impacts) analysis. For each policy, the cost-effectiveness analysis described above develops year-by-year estimates of the costs, savings prices, and changes demand or supply that households, businesses and government agencies are expected to encounter in a scenario where the policy is implemented as designed.

A secondary data source is the policy design. Balancing financial flows for each direct impact identified are established based on understanding the implementation mechanism, and quantitative values for these flows are developed for each direct impact identified. This balancing identifies and quantifies the responsive change that occurs as a result of the direct impact in question. For example, if a household is anticipated to save $100 per year on electricity bills as a result of a policy, the direct impact is a $100 savings to the household (which expands its spending capacity for other things) but the balancing impact is a $100 loss in revenue and demand to the utility provider (which reduces its ability and need to spend on labor, capital, profit, and other inputs). The quantitative measure of both sides of a change is of importance to a complete macroeconomic analysis. This balancing ensures that both the supply and the demand side of each economic change is fully represented in the analysis.

A third data source is direct communication with Minnesota agency staff and others involved in policy design or in a position to understand in detail the financial flows involved in the policy. These people assisted in clarifying the nature of economic changes involved so that the modeling and analysis would be accurate.

The final crucial data source is the baseline and forecast of economic activity within the REMI software. This data is compiled into a scenario that is characterized not only by the total size of the economy and its many consuming and producing sectors, but also the mechanisms by which impacts in one sector can change the broader economy – such as intermediate demands, regional purchase coefficients, and equilibria around price and quantity, labor and capital, and savings and spending, to name a few of many. REMI, Inc. maintains a full discussion of all the sources of the baseline data on its own website, www.remi.com.

In the case of the TLU-1 policy, important data included:

- Fuel savings that result from the incentive of spending less on auto insurance by driving less
- Spending on the carbon tax on fuel by consumers and businesses, which reduces money to be spent on other goods and services.
- Spending on the gasoline tax, which reduces money to be spent on other goods and services.
- Government spending expansion as it utilizes the revenue from the carbon tax and gas tax.

Quantification Methods

Utilizing the data developed from the microeconomic analysis, CCS analysts established for each individual change the following characteristics:

- The category of change involved (change in spending, savings, costs, prices, supply or demand)
- The party involved on both sides of each transaction
- The volume of money involved in this change in each year of the period of analysis

These values, so characterized, were then processed into inputs to the REMI PI+ software model built specifically for use by CCS and consistent with that in use by state agencies within Minnesota. These inputs were applied to the model and run. Key results were then drawn from the model and processed for consistency of units and presentation before inclusion in this report.

Key Assumptions

The macroeconomic impact analyses of this policy, as well as of the others in the CSEO process, rely on a consistent set of key assumptions:

- State and local spending is always budget-constrained. If a policy calls for the state or local government to spend money in any fashion, that spending must be either funded by a new revenue stream or offset by reductions in spending on other programs. Savings or revenues collected by the government are also expected to be returned to the economy as spending in the same year as they are collected.
- Federal spending is not budget-constrained. The capacity of the federal government to carry out deficit spending means that no CSEO policy is held responsible for driving either an increase or decrease in federal tax spending by businesses or households in the state of Minnesota.
- Consumer spending increases are sometimes financed. Small-scale purchases or purchases of consumer goods are treated as direct spending from existing household cash flows (or short-term credit). Durable goods, home improvements or vehicle purchases, however, are treated as financed. Consumers were assumed to spread out costs based on common borrowing time frames, such as five years for financing a new vehicle or 10-20 years for home improvements that might be funded by home-equity or other lending. The assumption of financing and the term of years applied was considered anew in each case.
- Business spending increases are often financed. Where spending strikes a sector which routinely utilizes financing or lines of credit to ensure steady payment of recurring costs, significant spending of nearly any type was considered a candidate for financing, thus allowing costs to spread out over time. This methodology is preferable for the modeling work, as sudden spikes or dips in business operating costs can show up as volatility when the scenario may depict a managed adoption of new equipment in an orderly fashion. The assumption of financing and the term of years applied was considered anew in each case.
- Unless otherwise stated, all changes to consumer spending or to the producers' cost of producing goods and services were treated in a standard fashion. Consumers are assumed to spend on a pre-set mix of goods, services, and basic needs, and businesses spend (based on their particular sector of the economy) on a mix of labor, capital, and intermediate demands from other sectors. Unless a policy specifically defines how a party will react to changes in cost, price, supply or demand, these standard assumptions were applied.
- State and local spending gains and reductions driven by policy are assumed to apply to standard mixes of spending. Again, unless a policy specifically states that a government entity will draw from a specific source or direct savings or revenues to a specific form of

spending, all gains and losses were assumed to apply to a standard profile of government spending within the economy.

Key Uncertainties

A key uncertainty in the analysis is how Minnesotans will adjust their travel and vehicle purchases in response to these policies. The response is likely to vary over time particularly as more fuel efficient vehicles will offset the marginal increase in driving costs from these policies.

The effectiveness and impacts of TLU-1B and -1C are greatly affected by the price of gasoline. If the price of gasoline is higher than is currently projected, then the cost savings of this policy option would increase. Additionally, the baseline assumed price of gasoline does not include significant price variability. Increase price volatility could affect the magnitude of TLU-1B and -1C emissions reductions.

Additional Benefits and Costs

All TLU-1 sub options reduce non-greenhouse gas transportation-related emissions (i.e. volatile organic compounds and particulate matter) and are therefore likely to reduce the risk for respiratory and cardiovascular illness, cancer, stress, premature birth weight, and premature death in exposed populations. As individuals reduce the amount that they drive, these policies may additionally generate health benefits from increased physical activity.

Figure F-3.23 Potential Health Benefits of TLU-1

Both TLU-1B and -1C generate revenues, which could support a range of other benefits.

The revenues generated by TLU-1B would help to upgrade Minnesota's transportation infrastructure to be less vulnerable to the effects of a changing climate. This would create direct construction jobs, but also reduce travel delays and property damage to households and businesses from future floods and other climate-related damage. Additional TLU-1B revenue could help fund other CSEO strategies and their related benefits. A portion of TLU-1B revenue would be rebated to low-income households to help mitigate equity concerns.

Revenue from TLU-1C would be dedicated to highway and road infrastructure, which would create construction jobs. The funded projects would help to ensure a state of good repair for the state's roads and bridges, and would make improvements to travel time reliability and traveler safety. Some projects may include improvements for non-motorized travel, which would support improved health outcomes from increased physical activity.

Feasibility Issues

Both TLU-1B and -1C are technically feasible with established or easy to establish collection mechanisms. However, imposing or raising taxes on transportation fuels has historically been politically unpopular.

Establishing the rebate mechanisms for low-income households envisioned in TLU-1B would require substantial additional work and ongoing effort.

TLU-2. Improve Land Use and Urban Form

Policy Option Description

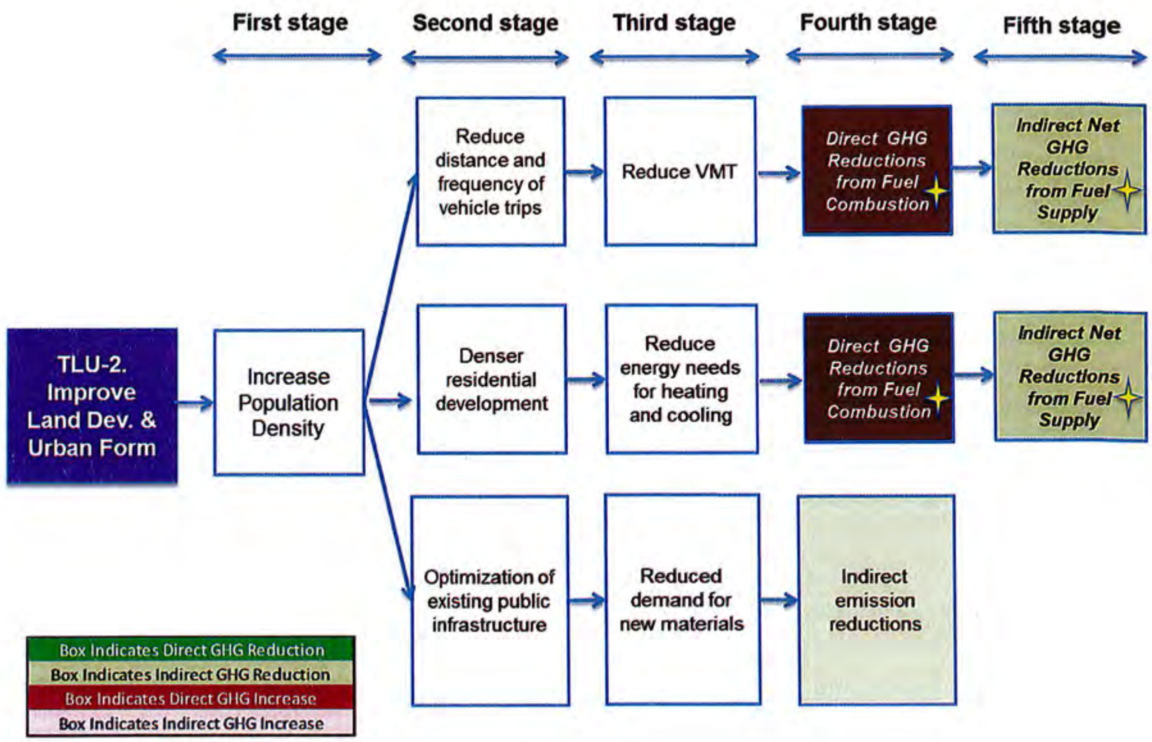
Implement urban planning and development practices in the seven-county metropolitan area that result in greater concentration of development, more compact urban form, more locally diverse uses, and shorter trip distances, thus mitigating Vehicle Miles Traveled (VMT) and greenhouse gas emissions (GHG) from transportation.

Compact urban form, which features increased shares of households in multi-unit buildings and commercial activity in multi-tenant buildings, can also reduce heating and cooling loads, thus mitigating GHG from buildings. Also, greater concentration and more compact urban form can economize on infrastructure expansion, reducing the associated GHG emissions.

Since urban form and travel behavior are mutually reinforcing factors, limiting growth of VMT will require a suite of coordinated land use and transportation actions. These actions are organized in four tiers of urban form: low-density urban development; compact centers; transit-supportive areas; and transit-oriented areas. Each bundle of actions is intended to optimize the performance of their urban form.

Causal Chain for GHG Reductions

Figure F-3.24 Causal Chain for TLU-2 GHG Reductions



The causal chain above identifies the main policy option effects and the subsequent GHG impacts. The star symbol identifies significant GHG effects that will be quantified.

Policy Option Design

Goals: Starting in 2015 and continuing annually through 2040:

- Zero net growth of housing units in exurban areas (with density averaging one unit/acre) and rural areas of the seven metropolitan counties.
- Decrease household growth located in low-density suburban areas (with density averaging three units/acre) of the seven metropolitan counties. Goal is less than 25% of net housing growth locating in low-density suburban areas.
- Increase household growth located in compact centers, transit-supportive areas, transit-oriented areas (with density averaging eight or more units/acre) of the seven metropolitan counties. Goal is greater than 75% of net housing growth locating in such areas.

- Increase share of housing stock in multi-unit buildings and increase share of commercial space in multi-tenant commercial buildings.

These targets effect reduced VMT by situating people closer to their destinations, and by increasing compactness of development. At least two approaches are available for estimating VMT response; *see Data sources and Quantification section below*.

Compact urban form featuring increased share of households and commercial activity in compact buildings (multi-unit residential and multi-tenant commercial buildings) can also effect economies-of-scale in building heating and cooling, thus mitigating GHG from buildings.

Timing: Total forecasted growth is distributed equally in each year throughout the 2015-2030 period. In the metro area, 75% of household growth located in compact centers, transit-supportive areas, transit-oriented areas; 25% in low-density suburban areas; 0% in rural and exurban areas.

Parties Involved: Implementation: cities, townships, counties, and the Metropolitan Council create and implement land use policy option in the seven-county metropolitan region. Outside the metro, cities, counties, and townships have a comparable role.

Implementation Mechanisms

TLU-2 public policy option mechanisms asserted for analysis are centered on comprehensive land use planning. Land use and urban form respond to public policy option mechanisms, but they also rely heavily on economic trends, market forces, and private sector decisions that are beyond public control.

Additional mechanisms are also listed below, which are intended to encourage actions in the private arena. These mechanisms are not quantified in the analysis but would likely speed the implementation of TLU-2. They are provided here as a reference for discussion.

Comprehensive land use planning

TLU-2 is limited to the seven-county metropolitan area because much of the growth state is projected to occur there, and the policy option base and comprehensive planning process is already in place by statute.

- Plan for density of new development appropriate for the variety of geographic areas in the seven-county Metropolitan area.
- Coordinate land use and development patterns with transit modes and locations to increase transit ridership, especially on frequent, all day transit service and transit ways.

Actions to encourage transit-oriented, transit supportive and compact development patterns

- Align resources to support transit-oriented development in areas with density suitable for transit to create vibrant, mixed-income, walkable places where people can live without an automobile.

- Partner with local communities to improve land patterns to reduce vehicle miles traveled and generation of carbon emissions.
- Adopt land use regulations and government policies that support the growing market for compact development in order for it to function effectively as a climate change strategy.
- Encourage redevelopment and infill development in urban core areas across the region which can reduce trip length, and increase use of transit and non-motorized modes.
- Collaborate with metropolitan planning organization (MPOs) and local governments on technical analysis, including improved data, models, and scenario planning tools to help in developing and implementing high density and compact development
- Provide/increase funding for Main Streets programs and revitalization of downtowns.
- Incentivize employment density to encourage transit ridership.
- Promote development patterns that protect natural resources, the quality and quantity of our water resources and water supply.
- Provide/Increase Brownfield funding (cleanup and redevelopment).

Statutory regulatory actions to effect statewide implementation

- Adopt a statewide land use control legislation / State Planning and Zoning Law that requires each city, county, or city and county to prepare and adopt a comprehensive plan.
- Implement land use code changes that support GHG emissions reductions.
- Require that regions adopt a Sustainable Communities Strategy – designed to achieve certain goals for the reduction of greenhouse gas emissions (See California SB 375).

Funding possibilities

- Create state and metropolitan funding formulas with incentives for reducing transportation demand instead of rewarding increased driving, as current legislation does.
- Use funding from carbon tax to fund incentivizing programs (e.g., statewide version of LCDA, or any of the items listed above).
- Link funding for public infrastructure and other public investments to criteria for population density or location (e.g., adjacent to existing development), as a requirement or as an incentive.

Streamlining

- Ease environmental review requirements: (See California SB 375).

Implementation Mechanisms That Strongly Support TLU-2

Increase transportation options:

- Prioritize transit investments in areas where infrastructure and development patterns can support successful transit system.
- Identify transit-supportive land use and development patterns for coordination with cities, especially around high-investment projects such as frequent, all day transit service and transit-ways to increase transit ridership.
- Provide and promote alternatives to single-occupancy vehicle travel, including transit, carpooling, bicycling and walking.
- Provide bicycle facilities to promote bicycling for transportation, recreation and healthy lifestyles (including state trails, Regional Bicycle Transportation Network, regional trails, and local bicycle networks).
- Encourage local communities to include bicycle and pedestrian plans in their comprehensive plan.
- Expand safe routes to school programs.
- Fund sidewalk improvements (criteria for population served/density and/or mix of land uses).
- Provide/Increase Bike-share program funding/coordination.
- Implement travel demand management policies and ordinances that encourage use of travel options and decrease reliance on single-occupancy vehicle travel.

Related mechanisms

- Increase funding for statewide "Complete Streets" Policy Option and funding program that improve safety and mobility for all users.
- Adopt and sub-allocate VMT reduction targets. (These could be linked to GHG reduction goals. These goals could be translated into VMT reduction targets. The targets could be proportionally allocated to the Twin cities region, and each MPO could be charged with developing a plan for meeting its respective target. VMT targets could even be sub-allocated to localities).
- Enable lower-carbon freight movement.
- Manage/price parking.
- Teleworking programs, which give employees the choice to work from home or choose alternative travel schedule.

Related Policies/Programs in Place and Recent Actions

Met Council growth forecasts to 2040 have predicted market behavior of metro-area households, taking into account the existing policies and land availability. New policies and actions that affect this behavior should result in household location choices that are more favorable for compact development.

Estimated Policy Impacts

Direct Policy Impacts

Table F-3.15 TLU-2 Estimated Net GHG Reductions and Net Costs or Savings

2030 In-State GHG reductions ($MMtCO_2e$):	2015 – 2030 Total cumulative reductions (metric tons CO_2e):	Net present value of societal costs, 2015 – 2030 ($MM2014):	Cost effectiveness ($2014/ ton CO_2e):
0.82	8.2	-$425	-$52

Note: Each policy option analysis was done over a fifteen year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

Data Sources

- Strategic Highway Research Program, 2013. "The Effect of Smart Growth Policies on Travel Demand".[8]
- FHWA, 2014. Smart Growth Area Planning Tool (SmartGAP) Model.[9]
- EIA, 2012. Energy Information Administration. "2009 Residential Energy Consumption Survey". Released December 2012.[10]
- Texas Transportation Institute, "Urban Mobility Report", latest version is currently from 2012.[11]

Quantification Methods

This policy option examines the VMT, fuel consumption and cost impacts of denser development within the seven-county Metropolitan area. The TLU workgroup determined that this type of denser development policy option is not practical for the rest of the state.

Scenario TLU-2 models the economic and environmental impacts of a more compact, centralized urban form in the metro region and a changed housing mix. The Federal Highway

[8] http://onlinepubs.trb.org/onlinepubs/shrp2/SHRP2prepubC16.pdf
[9] https://www.fhwa.dot.gov/planning/tmip/publications/other_reports/smartgap/index.cfm
[10] http://www.eia.gov/consumption/residential/data/2009/index.cfm?view=consumption#summary
[11] http://mobility.tamu.edu/ums/

Association's SmartGAP model was used to perform this modeling. The SmartGAP model was created as part of the second Strategic Highway Research Program (SHRP 2) Capacity Project. That project culminated in the report "The Effect of Smart Growth Policies on Travel Demand" that explores the underlying relationships between households, firms, and travel demand. The SmartGAP model is a macroscopic scenario planning tool that can be used to evaluate the impacts of various smart growth policies. The SmartGAP model synthesizes households and firms in a region and determines their travel demand characteristics based on their built environment and transportation policies. In this case, we have used the SmartGAP model to estimate the impacts of a denser development policy on the 7 county Metro area (Anoka, Carver, Dakota, Hennepin, Ramsey, Scott, and Washington counties), based on the results of the SHRP2 analysis.

SmartGAP provides an estimate of GHG and VMT impacts, as well as overall cost in the forecast year. In order to estimate the impacts of various policies, a business-as-usual scenario is compared against a policy option scenario, and the overall costs and GHG impacts are estimated based on the difference between these two scenarios. This output is provided only for the final year of the analysis, in this case 2030. For this analysis, a linear growth from 2015 (0% implementation) to 2030 (100%) is assumed.

In TLU-2, the business-as-usual case comes from Met Council's Thrive MSP 2040 forecast; the alternative scenario changes the geographic distribution of future growth and the housing products mix: 38% of new development is attached and multifamily in the BAU case; 75% attached and multifamily in the alternative scenario case.

Met Council provided regional population growth and employment growth forecasts, distributions of that growth by community type, auto trip rates, transit trip rates, daily VMT total, the highway share of that daily VMT, households growth, and distributions by housing type. This data was then input into the SmartGAP model for this analysis. In many cases (for example, trip rates and VMT distribution), this information is the same for both the BAU and scenario analysis. However, this data is nonetheless important to make the analysis more relevant for Minnesota, and because many of these variables are interdependent and systematically related to one another. Here are some additional details about the data sources and scenario assumptions which were used to differentiate between the BAU and policy option scenario in the SmartGAP model:

Spatial distributions of the growth using community types:

- **Spatial distributions** come from Met Council's *Thrive MSP2040* forecast, which used a real estate market and land use simulation model built with Citilabs CubeLand software. Met Council methodology is documented here: http://www.metrocouncil.org/Data-and-Maps/Data/Census,-Forecasts-Estimates/Forecast-Methodology-report,-2014.aspx
- For these scenarios, local Traffic Analysis Zone (TAZ) data was summarized to community type bins defined by the FHWA SmartGAP model; TAZs were assigned types based on regional geographic position, residential density and employment/population mix.

- For TLU2 and TLU3, the BAU baseline is: 21.5% of population growth in urban core; 14.4% in urbanized "close in" communities; 51.0% in low-density suburbs; 13.2% in rural and exurban areas.
- For TLU2, the analysis asserts an alternative in which many suburban areas evolve to be more urban, and are re-categorized accordingly: 29.4% of population growth in urban core; 44.6% in urbanized "close in" communities; 19.4% in low-density suburbs; 6.6% in rural and exurban areas.

Distributions of growth by housing type:

- **Distributions of new housing** come from Met Council's *Thrive MSP 2040* forecast.
- For the BAU baseline is: 38% of net housing additions are attached and multi-family; 62% are single-family-detached. The attached and multi-family can be broken down into subcategories.
- For the policy option alternative, there is a substantial shift toward attached and multi-family housing: 75% of net housing additions are attached and multi-family; 25% are single-family-detached. These distributions are asserted to be the result of an ambitious set of local and regional policies and restrictions.

The SmartGAP model estimates the GHG savings and economic impacts by comparing the BAU scenario against the denser growth policy option scenario. The net change between these two runs is displayed in Table F-3.16 below. This analysis assumes a linear implementation path as the policy option has gradually increasing effects between 2015 and 2030. The impacts from 2031 onward are not estimated in this analysis, but would likely be higher as analyses focusing on increasing population density typically realize results over a long time frame.

Table F-3.16 SmartGAP Estimated GHG and VMT Impacts of TLU-2

	Implementation Path	GHG Savings, Denser Growth (tCO_2e)	TLU-2 Annual VMT Change (Million Miles)
2015	0%	0	0
2016	7%	-534	26
2017	13%	-1,068	52
2018	20%	-1,602	79
2019	27%	-2,137	105
2020	33%	-2,671	131
2021	40%	-3,205	157
2022	47%	-3,739	184
2023	53%	-4,273	210
2024	60%	-4,807	236
2025	67%	-5,342	262
2026	73%	-5,876	289

	Implementation Path	GHG Savings, Denser Growth (tCO_2e)	TLU-2 Annual VMT Change (Million Miles)
2027	80%	-6,410	315
2028	87%	-6,944	341
2029	93%	-7,478	367
2030	100%	-8,012	393
Total		-64,100	3,148

The transportation-sector VMT results of TLU-2 amount to a -1.4% reduction from the projected business-as-usual scenario for the metro region. However, the changed spatial distribution in the scenario appears to cause elevated traffic congestion in the urban core and close-in, first-ring suburbs, such that fuel economy deteriorates by -1.3%. As a result, the transportation-sector GHG results are minimal – approximately -0.1%.

Table F-3.17 shows the estimated costs of the TLU-2 policy option. The model estimates that there will be some additional government costs in terms of transit infrastructure and operations, but that these are much smaller than the overall societal cost savings of the policy option as a whole (which includes fuel and vehicles savings from reduced VMT). The cost savings from the SmartGAP run are the result of reduced vehicle use, which includes reduced fuel costs, fuel taxes, vehicle purchase costs, vehicle maintenance, insurance costs, and a monetized value of travel time. Travel time value comes from the Texas Transportation Institute's Urban Mobility Report.

Table F-3.17 SmartGAP Estimated Costs of TLU-2

	Implementation Path	TLU-2 Additional Govt. Spending ($ Millions)	TLU-2 Net Societal Spending ($ Millions)	TLU-2 Discounted Net Societal Spending ($2014 millions)
2015	0%	$0.0	$0.0	$0.0
2016	7%	$0.5	-$1.1	-$1.0
2017	13%	$0.9	-$2.1	-$1.8
2018	20%	$1.4	-$3.2	-$2.6
2019	27%	$1.8	-$4.2	-$3.3
2020	33%	$2.3	-$5.3	-$3.9
2021	40%	$2.7	-$6.3	-$4.5
2022	47%	$3.2	-$7.4	-$5.0
2023	53%	$3.6	-$8.4	-$5.4
2024	60%	$4.1	-$9.5	-$5.8
2025	67%	$4.5	-$10.6	-$6.2
2026	73%	$5.0	-$11.6	-$6.5
2027	80%	$5.4	-$12.7	-$6.7

	Implementation Path	TLU-2 Additional Govt. Spending ($ Millions)	TLU-2 Net Societal Spending ($ Millions)	TLU-2 Discounted Net Societal Spending ($2014 millions)
2028	87%	$5.9	-$13.7	-$6.9
2029	93%	$6.3	-$14.8	-$7.1
2030	100%	$6.8	-$15.8	-$7.2
Total		**$54.3**	**-$126.6**	**-$74.0**

There were also GHG impacts and fuel savings from buildings. Denser development means fewer single family homes in favor of multi-family residential units, and these have significantly lower heating and cooling energy requirements. The US Energy Information Administration performed the 2009 Residential Energy Consumption Survey (RECS), which outlined the residential energy needs per household by region and by housing type (EIA, 2012). The average energy use per household in the Midwest (which includes Minnesota) was used for this analysis. Table F-3.18 below shows how RECS data on energy use per household varies in the Midwest region depending on the type of housing.

Table F-3.18 Annual Energy Use per Household by Housing Type

Metro Households (Occupied Units)	Million BTU per Household
Single Family Detached	128.0
Single Family Attached	98.6
Multi-Family 2-4 units	102.6
Multi-Family 5+ units	51.9
Mobile Homes	93.2

This information was then multiplied by the expected change in housing patterns between the BAU and the denser growth scenarios. Using this data, by 2030 the number of detached single family households is estimated to be 12% lower in the denser growth scenario, whereas the number of 5+ multifamily units increases 28%. Based on Met Council household distribution data, we estimate that overall household energy costs will be 5.0% lower in the denser growth scenario than the BAU. This reduced energy demand is assumed to come from natural gas (65%) and electricity (35%), based on information in the 2009 RECS. The energy and GHG savings for the Metro region are displayed in Table F-3.19 below. The reduced cost savings are displayed in Table F-3.20.

Table F-3.19 Energy and GHG Savings from Reduced Household Energy Needs in TLU-2

	Implementation Path	Natural Gas Savings (TJ)	Electricity Savings (MWh)	GHG Savings From Lowered Heating Needs (tCO_2e)
2015	0%	0	0	0
2016	7%	333	49,690	62,611
2017	13%	665	99,381	124,397
2018	20%	998	149,071	185,603
2019	27%	1,331	198,761	246,184
2020	33%	1,664	248,452	306,047
2021	40%	1,996	298,142	361,099
2022	47%	2,329	347,832	417,258
2023	53%	2,662	397,523	473,949
2024	60%	2,994	447,213	527,962
2025	67%	3,327	496,903	577,367
2026	73%	3,660	546,594	628,576
2027	80%	3,992	596,284	677,596
2028	87%	4,325	645,974	724,814
2029	93%	4,658	695,665	770,887
2030	100%	4,991	745,355	815,022
Total				**6,899,372**

Table F-3.20 Energy Cost Savings from Reduced Household Energy Needs in TLU-2

	Implementation Path	Fuel Savings From Reduced Natural Gas ($ Million)	Fuel Savings From Reduced Electricity ($ Million)	Total Fuel Savings ($ Million)
2015	0%	$0	$0	$0
2016	7%	$4	$6	$10
2017	13%	$9	$11	$20
2018	20%	$13	$17	$31
2019	27%	$18	$23	$41
2020	33%	$23	$29	$52
2021	40%	$28	$35	$63
2022	47%	$33	$41	$74
2023	53%	$39	$46	$85
2024	60%	$44	$53	$97
2025	67%	$50	$59	$108
2026	73%	$56	$65	$120
2027	80%	$62	$71	$133

	Implementation Path	Fuel Savings From Reduced Natural Gas ($ Million)	Fuel Savings From Reduced Electricity ($ Million)	Total Fuel Savings ($ Million)
2028	87%	$68	$77	$145
2029	93%	$74	$83	$158
2030	100%	$81	$90	$171
Total				**$1,307**

The total GHG Savings and Discounted Net Costs of the TLU-2 policy option are displayed in Table F-3.21 below. Upstream GHG savings from reduced transportation fuel and heating needs are also displayed.

Table F-3.21 Total GHG Impacts and Costs of TLU-2

	GHG Savings (tCO_2e)	Upstream Emissions Savings (tCO_2e)	Total Costs ($ Million)	Total Discounted Costs ($ Million)
2015	0	0	$0	$0
2016	63,145	9,834	-$5	-$5
2017	125,465	19,820	-$11	-$9
2018	187,206	29,920	-$17	-$14
2019	248,321	40,437	-$22	-$18
2020	308,718	50,885	-$28	-$21
2021	364,304	60,723	-$35	-$25
2022	420,997	71,066	-$41	-$28
2023	478,223	81,729	-$47	-$30
2024	532,769	91,924	-$54	-$33
2025	582,709	100,921	-$61	-$35
2026	634,451	111,175	-$68	-$38
2027	684,006	121,129	-$75	-$40
2028	731,759	130,860	-$82	-$41
2029	778,365	140,541	-$90	-$43
2030	823,034	150,105	-$97	-$45
Total	**6,963,472**	**1,211,069**	**-733**	**-425**

Integration Analysis Between TLU-2 and TLU-3

Both TLU-2 and TLU-3 were analyzed using the SmartGAP model to estimate GHG savings and total costs in year 2030. A combined run based on the inputs of both TLU-2 (denser development) and TLU-3 (increased transit infrastructure) was also completed, to estimate the combined impacts of these two policies in a single run.

Results from the combined run strongly indicated that, for this situation, the SmartGAP model did not immediately capture the full range of mutually reinforcing relationships between land use and transportation that the SHRP 2 report discusses (see Data Sources section). Time constraints prevented further investigation. Because of this uncertainty, results from the combined run are reported in the TLU-3 write-up, but not in the overall project summaries.

Key Assumptions

The policy option context and completeness of the Met Council data make it the best data source for the purposes of this analysis.

- Population forecasts from the Metropolitan Council were used for TLU-2 (and TLU-3) analysis. Met Council forecasts were used because they were integral to the development of the business as usual policies, and because of the additional specificity and effort invested in them previously. These forecasts include an additional 826,000 residents, 392,000 households, and 558,000 jobs between 2010 to 2040. Other policies in the overall CSEO project used statewide forecasts developed by others.
- Shifts in household characteristics – a growing senior population, more single-person households and an increasingly diverse population are likely to increase demand for a wider variety of housing options.
- Constrained funding for transportation, combined with population growth, will likely decrease unimpeded mobility, and increase the focus on alternate ways for people to access work, goods and recreation. This dynamic supports the notion of increasingly compact development patterns where more people can make short trips by car, bike, foot or transit.

Macroeconomic (Indirect) Policy Impacts

Table F-3.22 TLU-2 Macroeconomic Impacts on GSP, Employment and Income

Scenario	GSP ($2015 MM)			Employment (Individual)			Personal Income ($2015 MM)		
	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)
TLU-2	$4	-$2	-$31	500	220	3,290	$29	$10	$151

Graphs F-25 – 27 below show detail in GSP, employment and personal income impact of the TLU-2 policy.

Figure F-3.25 TLU-2 Impacts on Gross State Product ($2015 MM)

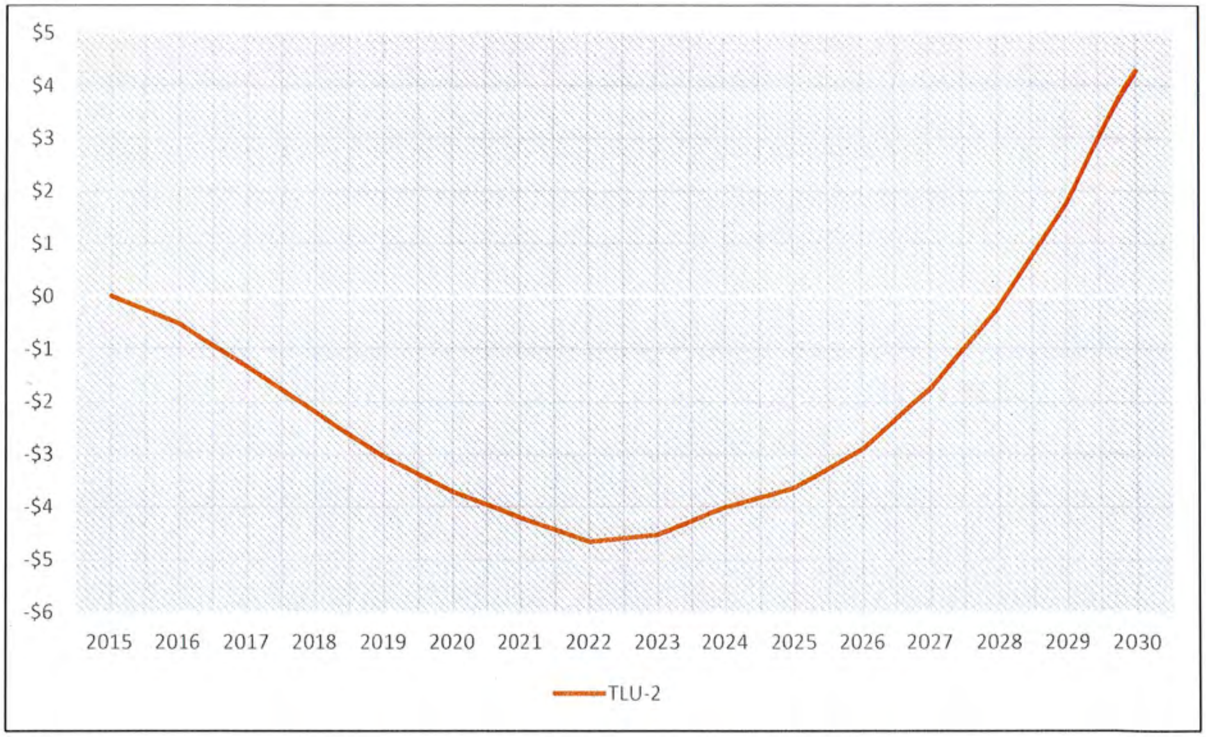


Figure F-3.26 TLU-2 Impacts on Incomes ($2015 MM)

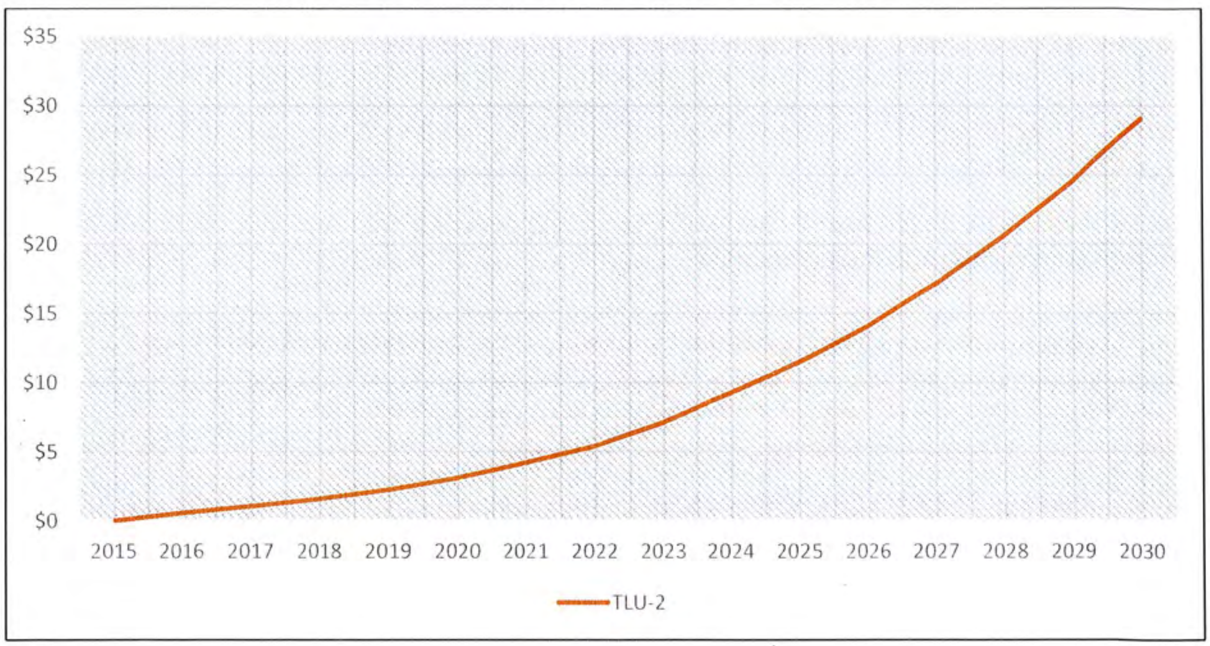
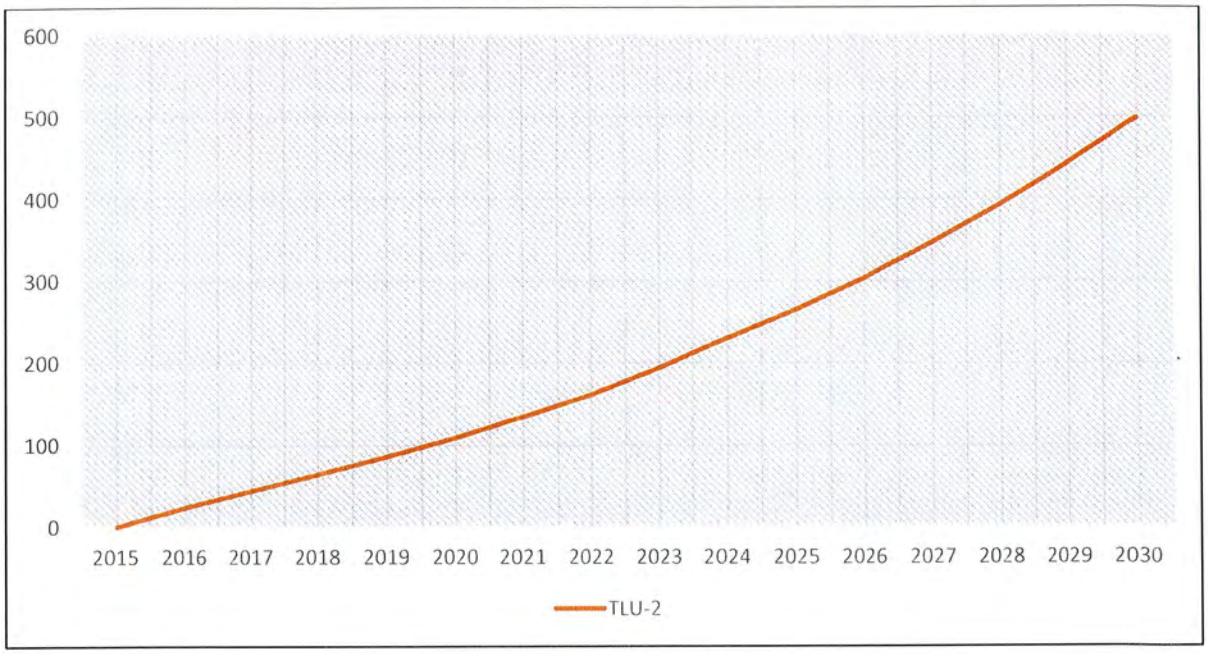
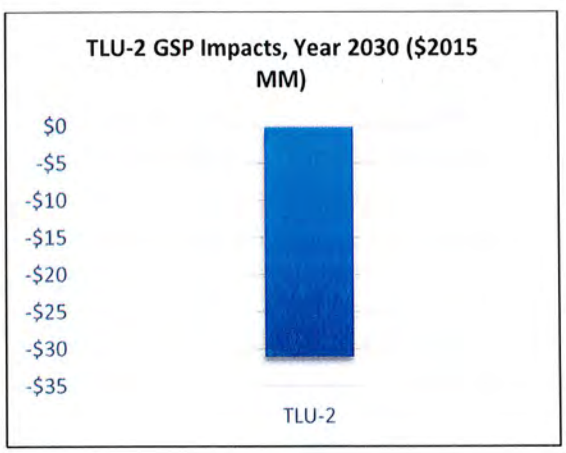
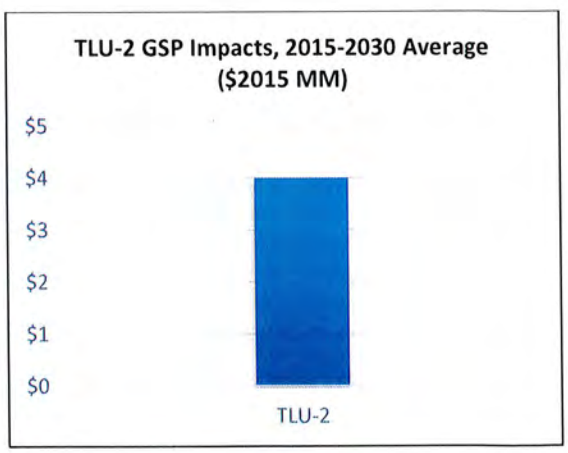


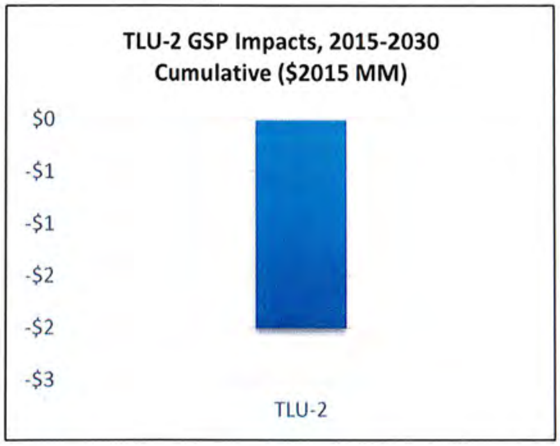
Figure F-3.27 TLU-2 Impacts on Employment (Individual Jobs)

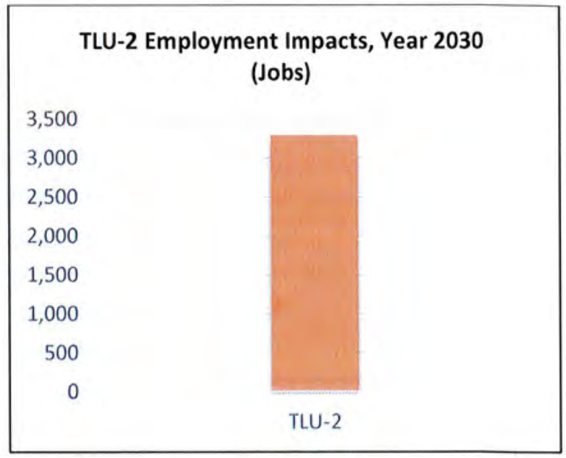


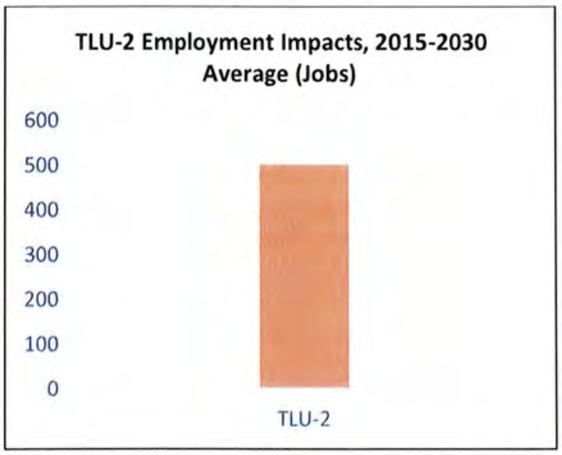
Graphs below show macroeconomic impacts on GSP, personal income, and employment in the final year (2030), in average (2015-2030) and in cumulative (2015-2030).

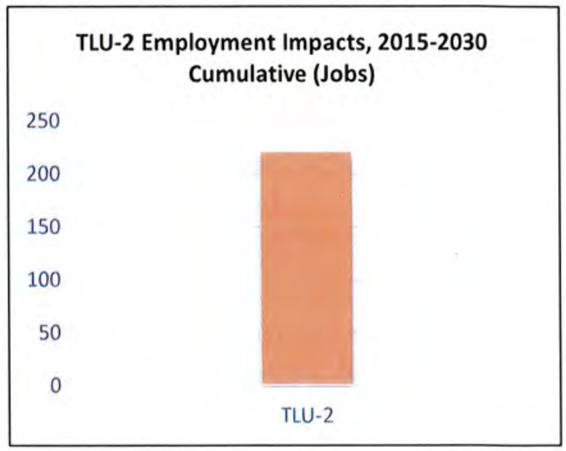


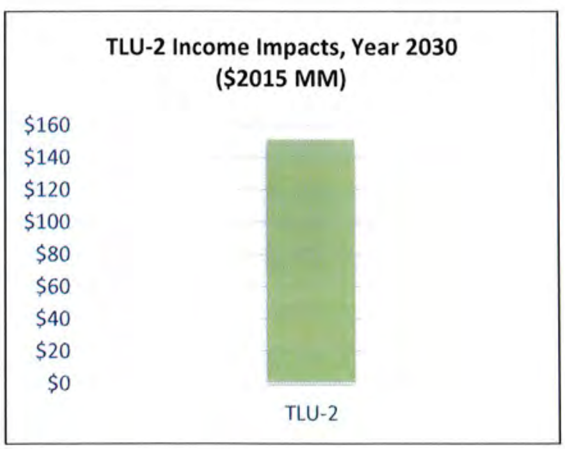


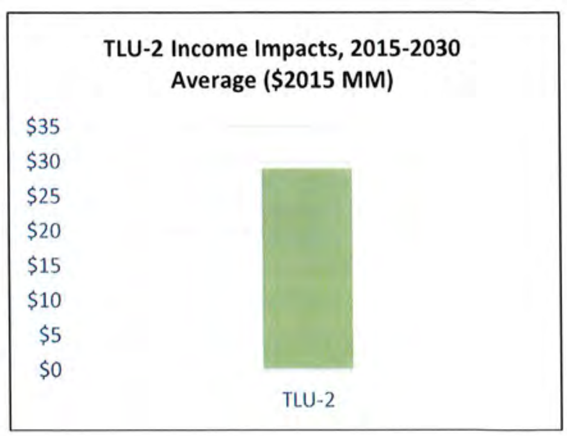

TLU-2 GSP Impacts, 2015-2030
Cumulative ($2015 MM)
$0
-$1
-$1
-$2
-$2
-$3
TLU-2

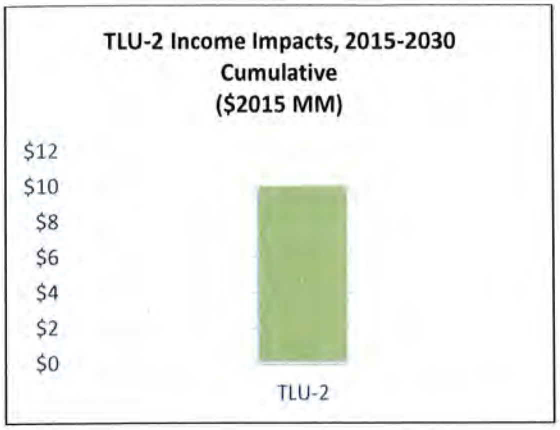

TLU-2 Employment Impacts, Year 2030
(Jobs)
3,500
3,000
2,500
2,000
1,500
1,000
500
0
TLU-2


TLU-2 Employment Impacts, 2015-2030
Average (Jobs)
600
500
400
300
200
100
0
TLU-2


TLU-2 Employment Impacts, 2015-2030
Cumulative (Jobs)
250
200
150
100
50
0
TLU-2


TLU-2 Income Impacts, Year 2030
($2015 MM)
$160
$140
$120
$100
$80
$60
$40
$20
$0
TLU-2


TLU-2 Income Impacts, 2015-2030
Average ($2015 MM)
$35
$30
$25
$20
$15
$10
$5
$0
TLU-2



Principal Drivers of Policy Impact on the Broader Economy

From TLU-2, the policy's drivers are very positive, as the total program costs to government are very small (less than $10 million per year even in the highest year) while savings to households on energy costs reach and even exceed $100 million in the final years. The policy anticipates significant reductions in the need for transportation energy and for heating energy from a more efficient urban form.

This follows the efficiency profile discussed in more detail in the RCII sector discussion. The reduction in spending from efficiencies pushes down total spending (and thus total GSP, which is measured by total spending). However, the money available as a result is now redirected to other spending, typically bringing the GSP impact back fairly close to neutral. The real benefits of efficiency are seen in the incomes and jobs gains, as commodity spending is replaced with value-added spending, which is more labor-intensive and requires more intermediate demands from other sectors of the economy.

Key Uncertainties

Major changes in urban form and development pattern can be expected to result in fiscal costs impacts, for costs (or savings) associated with infrastructure and services. These costs have only partially been identified and quantified.

This analysis relies on the SmartGAP model to estimate costs and GHG savings. This model is based on the results of the SHRP2 analysis, which are summarized in "The Effect of Smart Growth Policies on Travel Demand". However, with all modeling forecasts there is significant uncertainty with the results.

Additional Benefits and Costs

It is possible that reduced VMT as a result of denser development would result in reduced traffic injuries and fatalities.

TLU-3. Metropolitan Council Draft 2040 Transportation Policy Plan

Policy Option Description

The Metropolitan Council is currently updating the region's long range transportation plan known as the 2040 Transportation Policy Plan (2040 TPP). This plan is multimodal in character, addressing highway, transit, transitways, pedestrian facilities, bicycle facilities, freight, and aviation. Relevant objectives include reduced transportation-related air emissions; additional MnPASS managed lanes; additional transitways and arterial bus rapid transit lines; increased the use of transit, bicycling, and walking; increased availability of multimodal travel options.

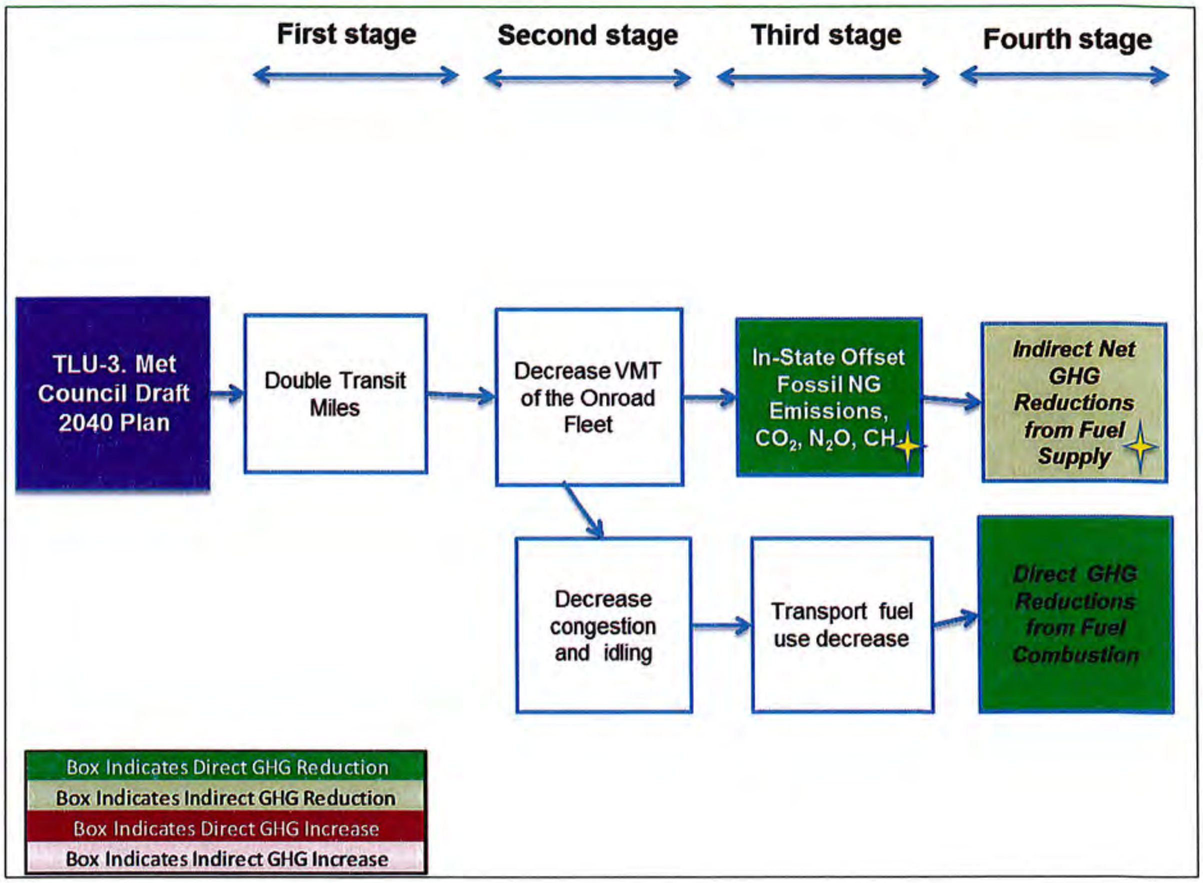
The 2040 TPP includes two investment scenarios: the Current Revenue Scenario (assumes revenues that can reasonably be expected to be available based on past experience and current laws and allocation formulas) and the Increased Revenue Scenario (assumes revenues that the region might reasonably be able to attain through policy changes, laws or decisions that increase local, state or federal funding sources. If additional revenues were provided, the projects in the Current Revenue Scenario could be implemented sooner, and the projects in the Increased Revenue Scenario also implemented by 2040.

For this policy option, the three focus areas from the 2040 TPP are:

- Expansion and operation of the MnPASS System
- Expansion and operation of the Transit System
- Expansion and operation of the Bicycle/Pedestrian System

Causal Chain for GHG Reductions

Figure F-3.28 Causal Chain for TLU-3 GHG Reductions



The causal chain above identifies the main policy option effects and the subsequent GHG impacts. The star symbol identifies significant GHG effects that will be quantified.

Policy Option Design

Goals:

- Double transit ridership by 2030.

Timing:

As indicated above; assume implementation begins in 2015 with a linear progression toward the policy option goals.

Parties Involved:

State legislature, Minnesota Department of Transportation, Metropolitan Council, County Transit Improvement Board (CTIB), regional rail authorities.

Transit: Primarily operate and manage the existing bus network, continue operating Metro Mobility including anticipated growth to meet statutory requirements, continue operating Transit Link, continue providing Metro Vanpool subsidies, operate and maintain support systems, maintain and replace vehicles and existing facilities as needed, minimal expansion of vehicles and service to new markets or to improve experience of existing customers, and modernization of existing facilities.

Transitways: Continue to operate and maintain existing transit ways, implement METRO Orange Line (I-35W South BRT), implement METRO Green Line Extension (Southwest LRT), Implement METRO Blue Line Extension (Bottineau LRT), implement 4 arterial BRT projects.

Bicycle/Pedestrian: The 2040 TPP includes a proposed Regional Bicycle Transportation Network. Implementation of this network would come through TAP projects selected by TAB or local (state, county, city) street design and funding and rely on:

- Local planning
- Placement on highways
- Bicycle facility types that meet functionality
- Wide paved shoulders
- Bicycle boulevards
- Conventional bicycle lanes
- Buffered bicycle lanes
- Cycle tracks

Implementation Mechanisms

The relevant state and regional agencies work with the state legislature to identify and commit sufficient financial resources to fund the Increased Revenue Scenario as outlined in the 2040 TPP.

Implement two additional LRT lines, one highway BRT line and 4 arterial BRT lines by 2040.

Related Policies/Programs in Place and Recent Actions

In January 2012, Governor Dayton established the Transportation Finance Advisory Committee with a charge to develop recommendations for the next 20 years to fund and finance the state's highways, roads, bridges, and public transport systems. That committee developed recommendations for increased funding from a variety of sources, such as increased motor vehicle registration fees, increased per-gallon excise tax rate on motor fuels, transit oriented sales tax, expand the option of local wheelage tax, enable formation of Transportation Improvement Districts, enable local sales taxes for transportation without need of a referendum, expand regional transit capital levy, expand MnPASS system, employ value capture concepts around transportation improvements. Several additional areas were recommended for further study as well.

Estimated Policy Impacts

Direct Policy Impacts

Table F-3.23 TLU-3 Estimated Net GHG Reductions and Net Costs or Savings

2030 In-State GHG reductions (MMtCO_2e):	2015 – 2030 Total cumulative reductions (tCO_2e):	Net present value of societal costs, 2015 – 2030 ($MM2014):	Cost effectiveness ($2014/t$CO_2$e):
0.25	2.6	-$330	-$126

The table below provides a summary of the expected impacts on jobs and economic growth during the CSEO planning period [*insert the results of macro-economic analysis*]

Table F-3.24 TLU-3 Indirect Economic Impacts

Macroeconomic (Indirect) Impacts Results									
Scenario	GSP[a] ($2015 MM)			Employment[b] (Individual)			Personal Income[c] ($2015 MM)		
	Year 2030[d]	Average (2015-2030)[e]	Cumulative (2015-2030)[f]	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)
TLU-3 Low Transit $	$90	$41	$608	830	450	6,740	$43	$20	$302
TLU-3 High Transit $	$125	$165	$2,477	1,330	1,720	25,860	$78	$138	$2,068

Data Sources

Strategic Highway Research Program, 2013. "The Effect of Smart Growth Policies on Travel Demand". Can be found online at:
http://onlinepubs.trb.org/onlinepubs/shrp2/SHRP2prepubC16.pdf

FHWA, 2014. Smart Growth Area Planning Tool (SmartGAP) Model. Information and User's Guide can be found here:
https://www.fhwa.dot.gov/planning/tmip/publications/other_reports/smartgap/index.cfm

Texas Transportation Institute, "Urban Mobility Report", latest version is currently from 2012. Located online at: http://mobility.tamu.edu/ums/

Quantification Methods

This policy option examines the VMT, fuel consumption and cost impacts of expanded transit use within the 7 county Metro area. The TLU workgroup determined that this type of expanded transit policy option is not practical for the rest of the state. Any analysis outside of the Metro area should be modeled separately.

Scenario TLU-3 models the economic and environmental impacts of doubling transit ridership by 2030 The Federal Highway Association's SmartGAP model was used to perform this modeling. The SmartGAP model was created as part of the second Strategic Highway Research Program (SHRP 2) Capacity Project. The SmartGAP model is a macroscopic scenario planning tool that can be used to evaluate the impacts of various smart growth policies. The SmartGAP model synthesizes households and firms in a region and determines their travel demand characteristics based on their built environment and transportation policies. The model also allows spatial distributions of population and employment to shift, in response to the future accessibility terrain. For the present analysis, we have used the SmartGAP model to estimate the impacts of doubling transit usage on the seven-county Metropolitan area (Anoka, Carver, Dakota, Hennepin, Ramsey, Scott, and Washington counties).

SmartGAP provides an estimate of GHG and VMT impacts, as well as overall cost in the forecast year. In order to estimate the impacts of various policies, a business-as-usual scenario is compared against a policy option scenario, and the overall costs and GHG impacts are estimated based on the difference between these two scenarios. This output is provided only for the final year of the analysis, in this case 2030. For this analysis, a linear growth from 2015 (0% implementation) to 2030 (100%) is assumed.

TLU-3 estimates the GHG and economic impacts of the Met Council-proposed 2030/40 transportation system investments in the metro region. The business-as-usual case is the fiscal-constrained highway investment program, with no new transit ways. The alternative scenario includes Met Council-proposed system investments. Both scenarios are discussed and documented in Met Council's regional transportation plan. It is worth remarking, the BAU vs. alternative difference in transport network measures (VMT, trips, etc.) is slight when spatial distributions of population and employment are held constant.

Met Council staff provided regional population growth and employment growth forecasts, distributions of that growth by community type, auto trip rates, transit trip rates, daily VMT totals, the highway share of that daily VMT, households growth, and distributions by housing type. This data was input into the SmartGAP model for this analysis. In many cases (for example, housing distribution), this information is the same or similar for both the BAU and scenario analysis. The significant difference between the BAU and the policy option scenario is that within the model, the policy option scenario doubles transit (Bus and Rail) demand in the forecast year.

The SmartGAP model estimates the GHG savings and economic impacts of TLU-3 by comparing the BAU scenario against the expanded transit policy option scenario. The net change between these two runs is displayed in table below. This analysis assumes a linear implementation path as the policy option has gradually increasing effects between 2015 and 2030. The impacts from 2031 onward are not estimated in this analysis, but would likely be higher as analyses focusing on increasing transit infrastructure and use typically realize results over a long time frame.

Table F-3.25 SmartGAP Estimated GHG and VMT Impacts of TLU-3

	Implementation Path	GHG Savings, Expanded Transit (tCO_2e)	TLU-3 Annual VMT Reduced (Million Miles)
2015	0%	0	0
2016	7%	16,659	62
2017	13%	33,318	123
2018	20%	49,977	185
2019	27%	66,636	247
2020	33%	83,295	309
2021	40%	99,953	370
2022	47%	116,612	432
2023	53%	133,271	494
2024	60%	149,930	556
2025	67%	166,589	617
2026	73%	183,248	679
2027	80%	199,907	741
2028	87%	216,566	803
2029	93%	233,225	864
2030	100%	249,884	926
Total		**1,999,070**	**7,408**

The SmartGap model segments the metro region into community types and neighborhood types. In the TLU-3 scenario, VMT is reduced in all parts of the region. Specifically, in the urban core and close-in, first-ring suburbs, total VMT and VMT per capita is substantially reduced as the future population makes use of enhanced and expanded transit services. Concurrently, total VMT in lower-density suburbs and rural areas is also reduced as result of a small marginal reduction (-3.5%) in suburban and rural populations; the population reduction is balanced by an equivalent population increase in the urban core and close-in, first-ring suburbs.

Table 3-26 shows the estimated costs of the TLU-3 policy option. The government expenditures estimated through the SmartGAP model are estimated to be significant for the 2015-2030 period. However, these costs are more than made up for at the consumer level, where reduced trips and reduced fuel and vehicle costs more than make up for the increase in transit infrastructure expenditures. Note that the societal spending includes both the government spending and private spending.

The additional government spending within the SmartGAP model includes additional capital costs in transit/transportation infrastructure, the operating and maintenance costs of the transit system and the additional costs to the user of transit fares. The cost savings from the SmartGAP run are the result of reduced vehicle use, which includes reduced fuel costs, fuel taxes, vehicle purchase costs, vehicle maintenance, insurance costs, and a monetized value of travel time. Travel time value comes from the Texas Transportation Institute's Urban Mobility Report. The SmartGAP model estimates transit infrastructure and operating costs based on the costs in the National Transit Database, which are from 2009. The model assumes that some users will forego vehicle ownership entirely when additional transit options are available.

Table F-3.26 SmartGAP Estimated Costs of TLU-3

	Implementation Path	TLU-3 Additional Govt. Spending ($ Millions)	TLU-3 Net Societal Spending ($ Millions)	TLU-3 Discounted Net Societal Spending ($2014 millions)
2015	0%	$0.0	$0.0	$0.0
2016	7%	$4.5	-$4.7	-$4.3
2017	13%	$9.0	-$9.4	-$8.1
2018	20%	$13.5	-$14.1	-$11.6
2019	27%	$18.0	-$18.8	-$14.7
2020	33%	$22.5	-$23.5	-$17.5
2021	40%	$27.0	-$28.2	-$20.1
2022	47%	$31.5	-$32.9	-$22.3
2023	53%	$36.0	-$37.6	-$24.2
2024	60%	$40.5	-$42.3	-$26.0
2025	67%	$45.0	-$47.0	-$27.5
2026	73%	$49.5	-$51.7	-$28.8
2027	80%	$54.0	-$56.4	-$29.9
2028	87%	$58.5	-$61.1	-$30.9
2029	93%	$63.0	-$65.8	-$31.7
2030	100%	$67.5	-$70.5	-$32.3
Total		**$540.0**	**-$564.3**	**-$329.9**

Integration Analysis for TLU-2 and TLU-3

Both TLU-2 and TLU-3 were analyzed using the SmartGAP model to estimate GHG savings and total costs in year 2030. A combined run based on the inputs of both TLU-2 (compact development) and TLU-3 (increased transit infrastructure) was also provided to estimate the combined impacts of these two policies in a single run. This ideally should provide an estimate of whether the combined benefits of the two policies would overlapping (as in, the benefits of the two combined policies is less than the two separately), additive or synergistic (the benefits are greater than the sum of the two policies separately).

Results from the combined run strongly indicated that, for this situation, the SmartGAP model did not immediately capture the full range of mutually reinforcing relationships between land use and transportation that the SHRP 2 report discusses (see Data Sources section). Time constraints prevented further investigation. Because of this uncertainty, results from the combined run are reported below and also mentioned in the TLU-2 write-up, but not in the overall project summaries.

This run was performed by evaluating both the compact development elements of TLU-2 and the increased transit availability and costs of TLU-3. The GHG impacts of the combined run is displayed in Table 3-27 below.

Table F-3.27 SmartGAP Estimated GHG and VMT Impacts of Combined TLU-2 and TLU-3 Policy Option

	Implementation Path	GHG Savings, Expanded Transit (tCO_2e)	Annual VMT Reduced (Million Miles)
2015	0%	0	0
2016	7%	17,228	88
2017	13%	34,455	175
2018	20%	51,683	263
2019	27%	68,910	351
2020	33%	86,138	439
2021	40%	103,365	526
2022	47%	120,593	614
2023	53%	137,820	702
2024	60%	155,048	790
2025	67%	172,275	877
2026	73%	189,503	965
2027	80%	206,731	1,053
2028	87%	223,958	1,140
2029	93%	241,186	1,228
2030	100%	258,413	1,316

Total		**2,067,305**	**10,527**

Both the GHG Savings and the VMT reductions are similar to the sum of the results of the TLU-2 and TLU-3 policies considered separately. GHG Savings are slightly higher in the combined run, and the VMT reduction is slightly lower, but in both cases this difference is very small (less than 0.5% of the total).

Total costs of the combined run are displayed in Table F.3-28 below. Costs have increased in the combined run, as compared to the additive impacts of TLU-2 and TLU-3. For example, the additional government spending of TLU-2 for 2015-2030 is $54 million, and for TLU-3 is $540 million, for a combined total of $594 million. In comparison, the combined SmartGAP run indicated costs of $680 million for the 2015-2030 period. The cost savings within the combined run are more or less comparable, once those additional costs are taken into account. Costs are estimated to be $86 million higher in the combined scenario, and overall cost savings are $86 million lower. There could be a variety of factors that could lead to this change in costs, but it is most likely the result of increased transit costs in a more densely developed area.

Table F-3.28 SmartGAP Estimated Costs of Combined TLU-2 and TLU-3 Policy Option

	Implementation Path	Additional Govt. Spending ($ Millions)	Net Societal Spending ($ Millions)	Discounted Net Societal Spending ($ millions)
2015	0%	$0.0	$0.0	$0.0
2016	7%	$5.7	-$5.0	-$4.6
2017	13%	$11.3	-$10.1	-$8.7
2018	20%	$17.0	-$15.1	-$12.4
2019	27%	$22.7	-$20.2	-$15.8
2020	33%	$28.3	-$25.2	-$18.8
2021	40%	$34.0	-$30.2	-$21.5
2022	47%	$39.7	-$35.3	-$23.9
2023	53%	$45.3	-$40.3	-$26.0
2024	60%	$51.0	-$45.4	-$27.8
2025	67%	$56.7	-$50.4	-$29.5
2026	73%	$62.3	-$55.4	-$30.9
2027	80%	$68.0	-$60.5	-$32.1
2028	87%	$73.7	-$65.5	-$33.1
2029	93%	$79.4	-$70.6	-$33.9
2030	100%	$85.0	-$75.6	-$34.6
Total		**$680**	**-$605**	**-$354**

Key Assumptions

- Ideally, models are conceived and structured to represent the systems at issue, apply appropriate methods, and use reliable data. Still this does not eliminate the uncertainties inherent in modeling: The dynamics of represented systems change over time.
- There may be other, unknown limitations or issues associated with FHWA's SmartGap model.
- This analysis assumes the year 2030 employment and population levels forecasted by Metropolitan Council. Policy context and completeness of the Met Council data make it the best data source for the purposes of this analysis. However, over the course of three decades actual economic and population growth of the metro area could be higher or lower than Metropolitan Council forecasts.

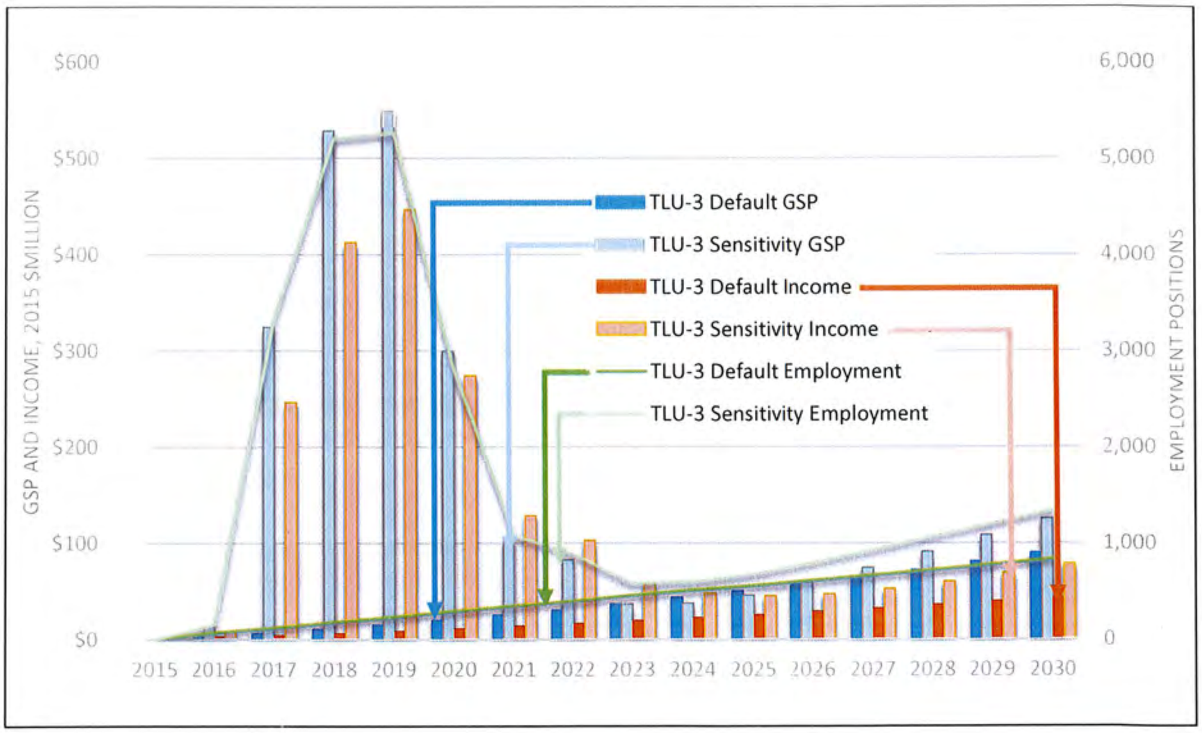
Macroeconomic (Indirect) Policy Impacts

Table F-3.29 TLU-3 Macroeconomic Impacts on GSP, Employment and Income

Scenario	GSP ($2015 MM)			Employment (Individual)			Personal Income ($2015 MM)		
	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)
TLU-3 Low Transit $	$90	$41	$608	830	450	6,740	$43	$20	$302
TLU-3 High Transit $	$125	$165	$2,477	1,330	1,720	25,860	$78	$138	$2,068

In TLU-3 policy analysis, a sensitivity scenario is also used for analyzing the macroeconomic impacts of the policy. The sensitivity scenario assumes higher capital cost of transit (the values are provided by MAT Council) than the capital costs assumed in the default scenario. The comparison of indirect macroeconomic results is shown in the graph below.

Figure F-3.29 TLU Policy Impacts of Different Capital Cost Assumptions



Graphs F-30 – 32 below show annual changes in GSP, employment and personal income impact of the TLU-3 policy, both in the default and the sensitivity scenario.

Figure F-3.30 TLU-3 Impacts on Gross State Product ($2015 MM)

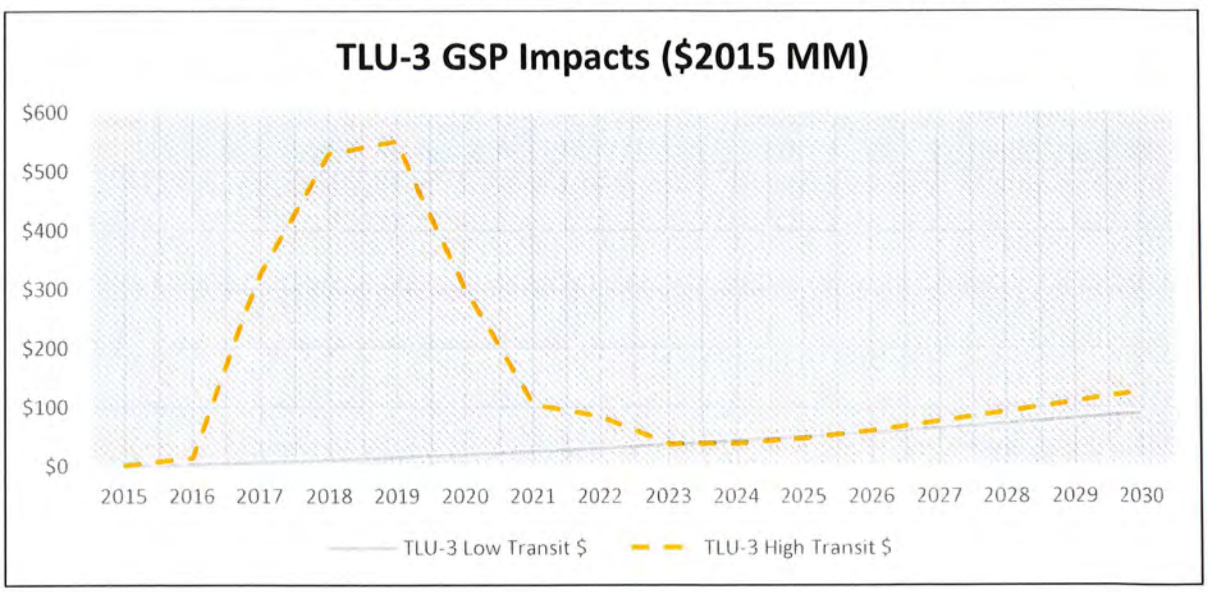


Figure F-3.31 TLU-2 Impacts on Income ($2015 MM)

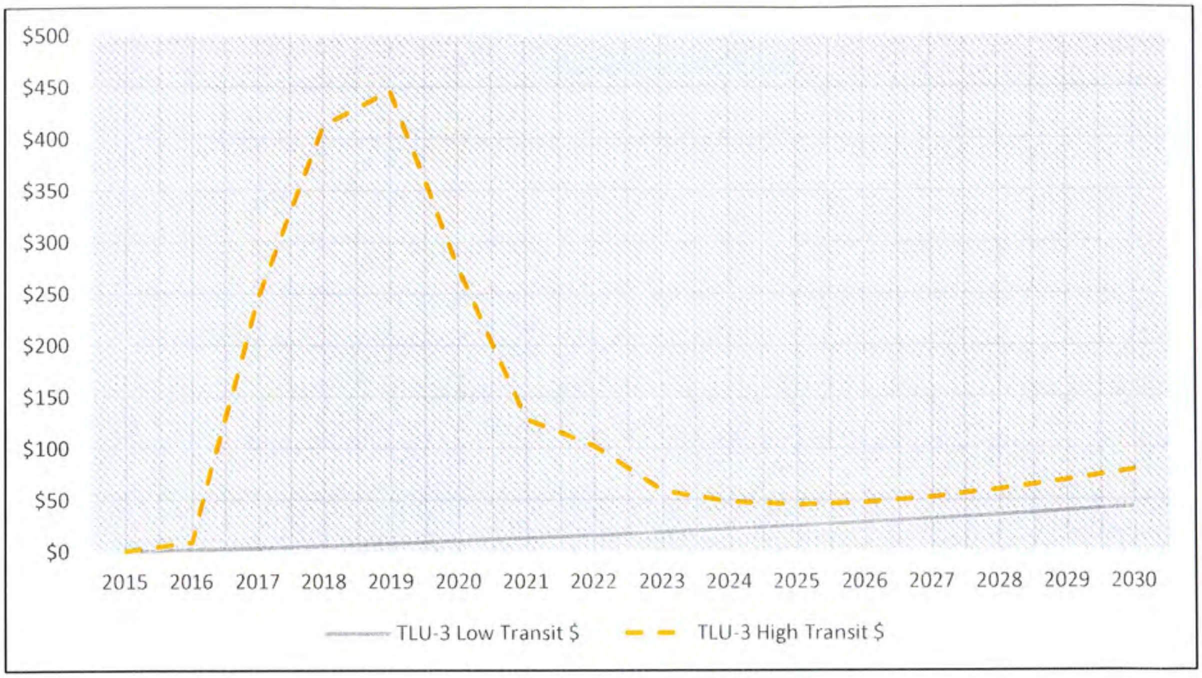
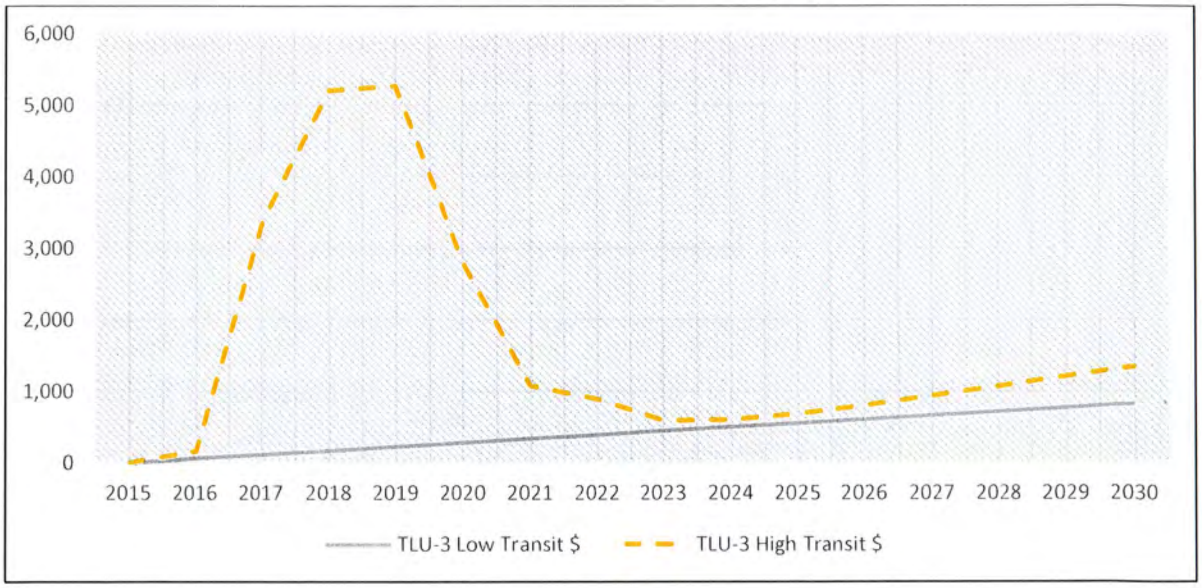
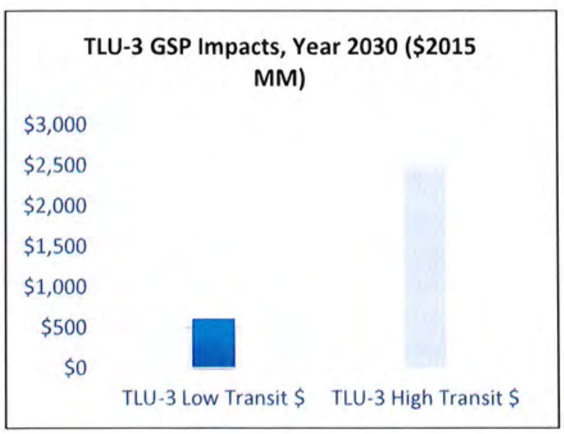
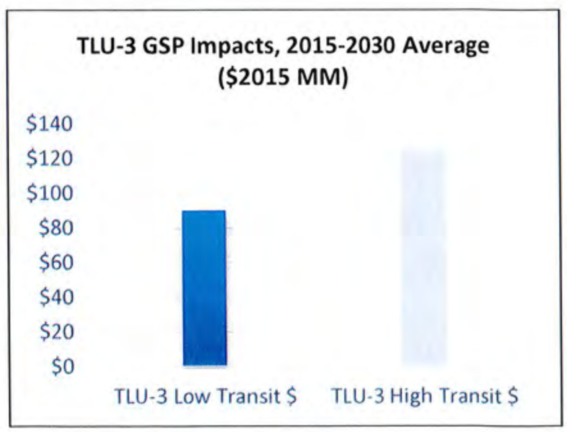


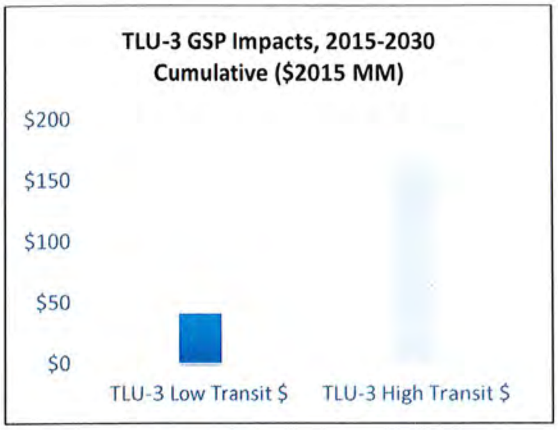
Figure F-3.32 TLU-2 Impacts on Employment (Individual Jobs)

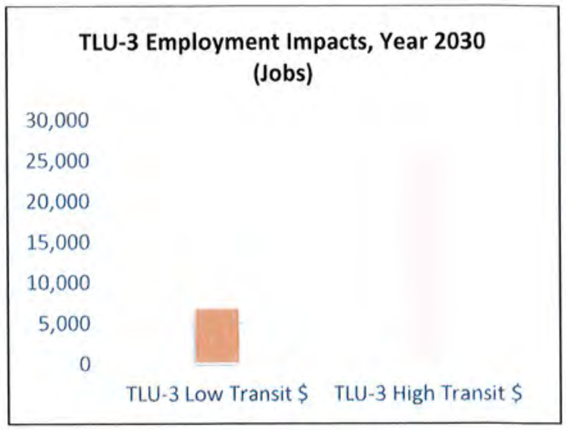


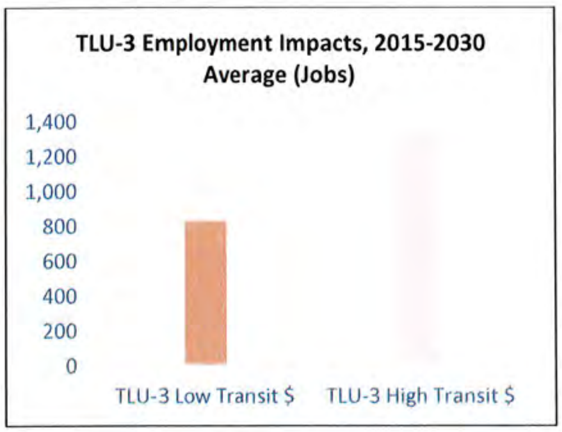
Graphs below show macroeconomic impacts on GSP, personal income, and employment in the final year (2030), average (2015-2030) and cumulative (2015-2030). Lighter color indicates the sensitivity scenarios.

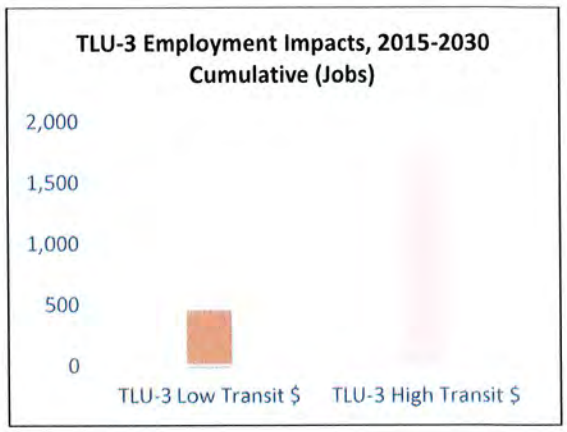


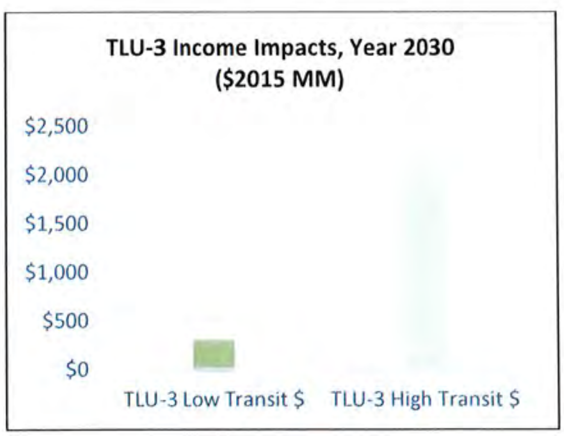


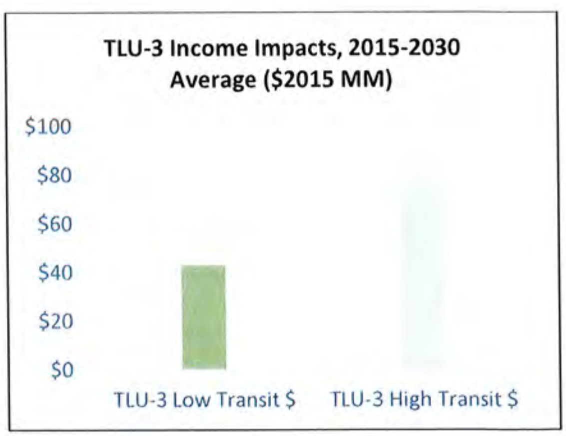

TLU-3 GSP Impacts, 2015-2030 Cumulative ($2015 MM)
$200
$150
$100
$50
$0
TLU-3 Low Transit $
TLU-3 High Transit $

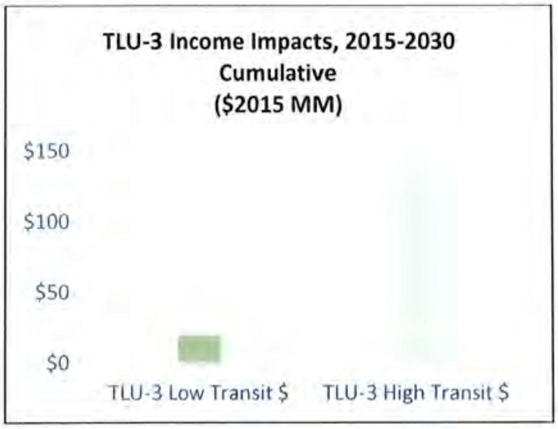

TLU-3 Employment Impacts, Year 2030 (Jobs)
30,000
25,000
20,000
15,000
10,000
5,000
0
TLU-3 Low Transit $
TLU-3 High Transit $


TLU-3 Employment Impacts, 2015-2030 Average (Jobs)
1,400
1,200
1,000
800
600
400
200
0
TLU-3 Low Transit $
TLU-3 High Transit $


TLU-3 Employment Impacts, 2015-2030 Cumulative (Jobs)
2,000
1,500
1,000
500
0
TLU-3 Low Transit $
TLU-3 High Transit $


TLU-3 Income Impacts, Year 2030 ($2015 MM)
$2,500
$2,000
$1,500
$1,000
$500
$0
TLU-3 Low Transit $
TLU-3 High Transit $


TLU-3 Income Impacts, 2015-2030 Average ($2015 MM)
$100
$80
$60
$40
$20
$0
TLU-3 Low Transit $
TLU-3 High Transit $



Principal Drivers of Macroeconomic Changes

The first major driver of positive impacts of this policy is the significant savings that travelers in the Minneapolis-St. Paul metro area encounter by switching to transit.

- The additional transit costs paid by the new riders was estimated as part of the macroeconomic analysis to represent one third of the transit system's operating costs. This cost came out to a value beginning at approximately $1 million, and rising to $16 million by 2030.
- By comparison, the fuel savings avoided by reductions in the volume of driving (below a business-as-usual scenario) are nearly ten times that scale, rising from $9 million saved to approximately $138 million saved by 2030.
- The resulting savings is redirected from petroleum spending, which largely purchases imports and is very poor in terms of jobs creation, to other consumer spending, which directs money far more to domestically produced goods and services and is better in terms of jobs creation.

A second driver, though smaller, is an improvement in the labor access index. Improved transit systems expand access between labor and employers, improving the allocation of labor through better choice and improving productivity through shorter commute times. In macroeconomic models, this represents an increase in productivity. In this policy, the improvement is slight – 0.03% - but this will improve the output of the metro area's economy as a result.

Government spending on transit capital and operations expands to cover all the costs that the farebox revenue does not, but these costs must be offset with reductions in other government spending. Using the Federal Highway Administration model, this expenditure and its offset are less clearly a driver of the positive impacts shown in the results. However, using the Met Council estimates of capital spending required to build out this transit infrastructure, the investment is a far greater stimulus to the economy. The presence of an assumed 50% federal match to state and local funds to cover this cost means that this higher-cost scenario is actually far more positive for the economy, as the larger flow of federal dollars creates more stimulus. The resulting transit network is the same, and after the larger spike of investment ends, the economy shows the same minor (though still positive) gains as a result of lower transportation costs and a slightly higher labor access index.

Key Uncertainties

In recent years, two other studies have evaluated the impacts of building out the planned transit system. These studies were:

- Itasca Group: Regional Transit System Return on Investment Assessment
- 2040 Transportation Policy Plan

These two previous studies, along with the analysis conducted by this effort provide a range of VMT reduction estimates and resulting CO_2e reductions. Each of the set of estimates were based in sound practice. However, there are differences, highlighted below, which result in differing impact estimates.

The present analysis relies on the SmartGAP model to estimate costs and GHG savings. This model is based on the results of the SHRP2 analysis, which are summarized in "The Effect of Smart Growth Policies on Travel Demand". However, SmartGAP appears to adjust the spatial distributions of population, households and employment based on the transportation investments.

The Itasca Group: Regional Transit System Return on Investment Assessment was conducted in 2011 predating the development of Thrive MSP 2040 population, household and employment data. As such, the ROI work was based on forecast 2030 socio-economic data. A comparison of the data between that used for the ROI work and that developed for Thrive MSP 2040 shows slower growth during 2010 to 2040 than was previously projected for 2030 in the earlier data set. Additionally, the ROI model network included one more LRT line than does the 2040 TPP, two more highway BRT lines, and five more arterial BRT lines. In the ROI study scenario, all of these transit system improvements were assumed to be complete and operational by 2023 – a highly aggressive assumption.

The modeling for the 2040 Transportation Policy Plan (TPP) was conducted using the region's standard four-step regional travel demand model. Population, household and employment allocations were held constant as to their location between the build and no-build scenarios. CO_2 equivalents were estimated using the EPA emissions model MOVES2010b.

Additional Benefits and Costs

Reduced emissions and increased use of transit, bicycling and walking may confer significant health benefits. (Younger) In particular, switching from driving to bicycling can not only reduce emissions but increase physical activity and reduce chronic diseases and deaths due to a sedentary lifestyle. (Rojas-Rueda) A study of the Midwest region found that eliminating short car trips and completing 50% of them by bicycle would result in fewer deaths due to improved air quality and fewer deaths due to increased physical activity. (Grabow et al.).

Ensuring the safety of pedestrians and cyclists as this plan is implemented will be critically important to reduce transit injuries. As with TLU-2, implementation of this plan may also provide communities with increased access to beneficial health services and nutrition.

Figure F-3.33 Potential Health Benefits of TLU-3

*Reducing transit-related emissions is likely to reduce the risk for respiratory and cardiovascular illness, cancer, stress, premature birth weight, and premature death in exposed populations.

TLU-4. Zero Emission Vehicle Standard

Policy Option Options

The Zero Emission Vehicle (ZEV) Standard policy option would require automobile manufacturers, through their dealerships, to have a percentage of the total light and medium duty vehicle sales in Minnesota, designated as electric vehicle sales. This regulatory approach for states to increase use of electric in place of gasoline-powered vehicles through use of sales quotas, is allowed under the federal Clean Air Act, Section177, by the U.S. Environmental Protection Agency.

Electric vehicles are designated as ZEVs because these vehicles have zero emissions from the tailpipe when operating on battery power. ZEVs are four times more efficient than gasoline powered vehicles and have the unique capability of directly using renewable solar or wind-generated electricity for power. These electric vehicles can be plugged-in and charged at night, taking advantage of off-peak electricity production, to help balance utility production load. Transitioning vehicles from use of petroleum-based fuels to electricity reduces the state GHG emissions due to:

- An increase in energy efficiency from use of electric vehicles in place of gasoline-powered vehicles;
- Existing policies designed to incrementally deploy cleaner generation in the state's electricity grid.

- In 2010, 24% of GHG emissions in Minnesota were from the transportation sector, second only to electric utility GHG emissions. Addressing both sectors at the same time, leveraging the synergies between cleaner electricity production and electricity use, will result in bold GHG emissions reduction. California and nine other states view the ZEV regulatory program as a primary means of meeting their respective GHG reduction goals.

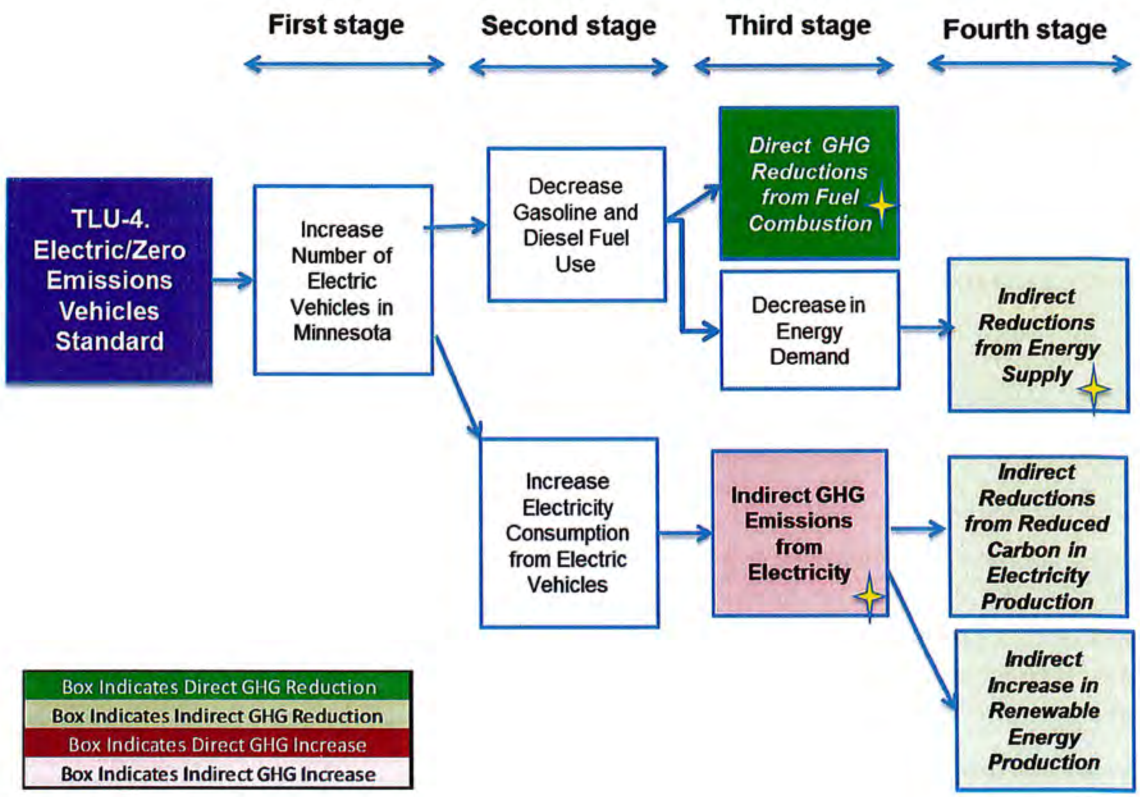
Modeling limits: EVs are an emerging technology with great potential and a lot of unknowns for the role they might play in society. The potential of EVs to reduce GHG emissions is determined by the power generation of the electricity. For instance, electricity generated from coal has much higher emissions than electricity generated from a solar or wind. Integration of EVs into the electric grid represents new demand on the system, how clean the energy is to meet that demand will determine how clean EVs are for the system. Depending on time of day for charging, EVs could even out load demand or increase the intensity of demand peaks. Minnesota and several states are already beginning to design programs around time of day pricing structures to even out demand. At high penetration levels, EVs could be used as storage for the electric grid, where at peak times the system could pull electricity from plugged in vehicles.

As adoption of EVs increases in Minnesota and other parts of the country we will have better information about their integration on systems and we will see what innovations evolve. For this study, much of these considerations were beyond the scope of the modeling work. To capture the full potential of EVs and illustrate the uncertainty that hinges on the power source of generation, we model bookend numbers. We model:

- EVs as new demand that are met with the electricity at the margin, this is 80/20 coal/natural gas in 2015 and going to 50/50 in 2030.
- EVs with 100% renewable energy.

Causal Chain for GHG Reductions

Figure F-3.34. Causal Chain for TLU-4 GHG Reductions



The causal chain above identifies the main policy option effects and the subsequent GHG impacts. The star symbol identifies significant GHG effects that will be quantified.

Policy Option Design

Adoption of the ZEV Standard would significantly advance the use of electric vehicles, along with an anticipated growth of the charging infrastructure to allow for ease of travel in urban and along high-traffic destination corridors such as tourism routes, while leveraging use of renewable sources of energy, by 2030.

Goals (starting in 2017 and continuing through 2030):

- Achieve 10% or 450,000 registered cumulative penetration of ZEVs registered in Minnesota.
- Installation of Level 2 (240 volt, full charge in 2 to 4 hours) or DC Fast Charger (480 volt, full charge in 15 t0 25 minutes) plug-in public charging stations at increments no greater

than every 50 miles in high population density and high-traffic corridors throughout the state.

- Education and outreach goal to result in powering 50% of the charging stations with renewable electricity production.

Timing: During the 2015 Minnesota Legislative session advance and support either the regulatory Zero Emissions Vehicle Standard.

Parties Involved:

Implementation: State Legislature, Governor's Office, Minnesota Departments of Environmental Quality, Natural Resources, Commerce, MPCA, Department of Public Safety, and electric utilities.

Affected parties: fuel retailers, electric utilities, auto manufacturers, auto dealerships, and consumers.

Other:

This analysis looks at the impact of Minnesota adopting the ZEV portion of the California vehicle emission standards. Adopting only the ZEV requirements is possible because Minnesota has a State Implementation Plan due to two carbon monoxide (CO) maintenance areas. 4.2% is the percentage of ZEV Memorandum of Understanding (MOU) state residents who would have a ZEV under the MOU's 3.3 million goal. The collective target for the ZEV states is to have 3 million ZEVs on the road by 2025. Based upon Minnesota's population in comparison to the other ZEV states – should Minnesota join, it would need 220,000 ZEVs on the road by 2025. This is used as a target for this analysis. For 2026-2030, the number of new vehicles is held at the same number as 2025. Vehicles are also being replaced after ten years, so 2015 vehicles will be replaced in 2026, etc. The total number of EVs and the number of new EVs sold per year are shown in Table F-3.30 below.

Table F-3.30 EVs Needed in the TLU-4 Analysis

Year	Total # EVs	New EVs Sold Per Year
2015	5,000	5,000
2016	7,300	2,300
2017	10,658	3,358
2018	15,561	4,903
2019	22,719	7,158
2020	33,169	10,451
2021	48,427	15,258
2022	70,703	22,276
2023	103,227	32,524
2024	150,711	47,484
2025	220,038	74,327
2026	291,666	71,627

Year	Total # EVs	New EVs Sold Per Year
2027	362,051	72,685
2028	432,923	74,230
2029	504,505	76,485
2030	577,125	79,778

Implementation Mechanisms

Adoption of the ZEV Standard involves:

- Potential legislative action (subject to state legal counsel review and decisions);
- An optional Governor's Executive Order outlining the program and expectations;
- Adoption of the ZEV states' Memorandum of Understanding.
- The standards approved the U.S. Environmental Protection Agency are already in place. Related rulemaking, organizational support design, and staff assignments would subsequently be undertaken by the MPCA.

Related Policies/Programs in Place and Recent Actions

The following ZEV related policy initiatives were enacted by the 2014 Minnesota State Legislature:

- **Public Fleet Procurement Section:** 1. Minnesota Statutes 2012, section 16C.135, subdivision 3, is amended to read:1.8 Subd. 3. **Vehicle purchases.** Consistent with section 16C.137, subdivision 1, 1.9when purchasing a motor vehicle for the central motor pool or for use by an agency the commissioner or the agency shall purchase a motor vehicle that is capable of being powered by cleaner fuels, or a motor vehicle powered by electricity or by a combination of electricity and liquid fuel if the total life-cycle cost of ownership is less than or comparable that of other vehicles, and if the vehicle is capable of carrying out the purpose for which it is purchased.

  Reporting: the Commissioner of Administration, in collaboration with the Commissioners of the Pollution Control Agency, the Departments of Agriculture, Commerce, Natural Resources, and Transportation, and other state departments must evaluate the goals and directives established in this section, and report their findings to the governor and the appropriate committees of the legislature February 1 of each odd-numbered year. In the report, the committee must make recommendations for new or adjusted goals, directives, or legislative initiatives; in light of the progress the state has made implementing this section and the availability of new or improved technologies.

- **Electric Vehicle Charging Tariff** Sec. 10. [216B.1614] ELECTRIC VEHICLE CHARGING TARIFF. 6.10 Subd. 2. Required tariff. (a) By February 1, 2015, each public utility selling electricity at retail must file with the commission a tariff that allows a customer to purchase electricity solely for the purpose of recharging an electric vehicle. The tariff must: contain either a time-of-day or off-peak rate, as elected by the public utility; offer a customer the option to purchase electricity: from the utility's current mix of energy supply sources; or entirely from renewable energy sources, subject to the conditions established and be made available to the residential customer class.

  Reporting: Each public utility providing a tariff under this section shall periodically report to the commission, as established by the commission and on a form prescribed by the commission, the following information, organized on a per-quarter basis: the number of customers who have arranged to purchase electricity under the tariff; the total amount of electricity sold under the tariff; and other data required by the commission.

- **Energy Policy Goals.** [216C.05 Subd. 2 (2007)] states it is the energy policy goal of the state of Minnesota that the per capita use of fossil fuel as an energy input be reduced by 15 percent by the year 2015, through increased reliance on energy efficiency and renewable energy alternatives.
- **Renewable Electricity Standard. [** 216B.1691 **]** requires the state's electric utilities to obtain the RPS schedule for Xcel Energy is as follows:
  - 15% by 12/31/2010
  - 18% by 12/31/2012
  - 25% by 12/31/2016
  - 31.5% by 12/31/2020 (including 1.5% solar)
- **Standard for Non-Xcel Public Utilities**: The standard for other public utilities requires that eligible renewable electricity account for 26.5% of retail electricity sales to retail customers in Minnesota by 2025. Of this electricity, 1.5% must be solar photovoltaics by 2020, and 10% of the solar standard must be met with systems of 20 kW or less.
  - 12% by 12/31/2012
  - 17% by 12/31/2016
  - 21.5% by 12/31/2020 (including 1.5% solar)
  - 26.5% by 12/31/2025 (including 1.5% solar)
- **Standard for Non-Public Utilities:** The standard for other Minnesota utilities requires that eligible renewable electricity account for 25% of retail electricity sales to retail customers (and to retail customers of a distribution utility to which the one or more of the utilities provides wholesale service) in Minnesota by 2025. The RPS schedule for other Minnesota utilities is as follows:

  - 12% by 12/31/2012
  - 17% by 12/31/2016
  - 20% by 12/31/2020
  - 25% by 12/31/2025

- **Solar Electricity Goal.** H.F. 729 (2013) created a statewide solar goal of 10% of retail electric sales from solar by 2030.
- The Zero Emissions Charging Challenge participants that have **public charging stations powered by solar or wind** include: City of Minneapolis, City of Saint Paul, Hennepin County, Macalester College, Metropolitan Airports Commission (MSP), Ramsey County, Ramsey County Regional Rail Authority, University of Minnesota, Minneapolis Public School (Davis Center), State Capital complex station (corner of Rice and University), Riverside Community College (Albert Lea), City of Austin. As this program expands this list continues to grow.
- Utilities also have programs designed for encouraging **renewables and residential electric vehicle charging** (wind and community solar). Electric vehicles owners report more awareness about sources of electricity and renewable energy use.

Estimated Policy Impacts

Direct Policy Impacts

Table F-3.31 TLU-4 Estimated Net GHG Reductions and Net Costs or Savings

Scenario	2030 In-State GHG reductions ($MMtCO_2e$):	2015 – 2030 Total cumulative reductions ($MMtCO_2e$):	Net present value of societal costs, 2015 – 2030 ($MM2014):	Cost effectiveness ($2014/$tCO_2e$):
Grid Electricity (0% Renewables) Case	-0.42	-2.0	$3,237	N/A
100% Renewables Case	1.3	6.4	$3,278	$417

Data Sources

- US Department of Energy, Annual Energy Outlook 2014. Can be located online at: http://www.eia.gov/forecasts/aeo/
- Department of Energy, FuelEconomy.gov website. Accessed September 2, 2014. Located online at: http://www.fueleconomy.gov/
- Tessum, Christopher, et al, 2014. "Life cycle air quality impacts of conventional and alternative light-duty transportation in the United States". Proceedings of the National

Academy of Science, December 2014. http://www.pnas.org/content/111/52/18490.full.pdf+html

- *McNeill, Karin, 2014. "Electric Vehicles Cost Less". Drive Electric Vermont, posted January 15, 2014. Located online at:* http://driveelectricvt.com/blog/post/drive-electric-blog/2014/01/15/electric-vehicles-cost-less

Quantification Methods

This analysis focuses on increasing the number of electric vehicles (EVs) in Minnesota, as outlined in Table F-3.31 above. This target matches Minnesota's portion of the Zero Emissions Vehicles (ZEV) target through 2025. This analysis is focusing exclusively on fully electric vehicles, and does not include any hybrid-electric or plug-in hybrid vehicles. The electric vehicles are assumed to be between mid-sized sedans (for example, the Nissan Leaf) and small SUVs (for example, the Toyota RAV4 EV). The split used in this analysis is 90% electric cars and 10% electric SUVs, based on the breakdown between light cars and trucks in the Annual Energy Outlook 2014 (AEO 2014)'s projected electric vehicle sales for 2015-2030.

While EVs would come in a greater number of vehicle categories, these are the categories which have historically been the most popular for EVs. The analysis estimates the fuel savings based on the typical Vehicle Miles Traveled (VMT) of a light duty vehicle (from the Minnesota I&F). This annual mileage number is divided by the miles per gallon of a sedan and small SUV for the forecast years, which is also estimated in the AEO 2014. The vehicles being displaced are assumed to be entirely gasoline vehicles. This is multiplied by the total number of EVs per year (from Table F-3.30) to estimate total gasoline savings of these electric vehicles, and these gallons of gasoline are used to estimate metric tons of CO_2e avoided.

Table F-3.32 VMT, MPG, and Gasoline Saved from Electric Vehicles

Year	VMT Per Vehicle	New Mid-Sized Sedans (mpg)	New Small Utility Vehicles (mpg)	Million Gallons of Gasoline Saved	$MtCO_2e$ Saved from Reduced Gasoline
2015	11,788	37.0	30.9	1.6	14,182
2016	11,836	37.2	31.6	2.4	20,741
2017	11,880	39.0	32.1	3.4	29,951
2018	11,939	39.7	32.8	5.0	43,239
2019	12,005	41.1	36.2	7.1	61,966
2020	12,069	42.9	36.8	10.1	88,368
2021	12,126	44.9	37.8	14.4	125,459
2022	12,188	47.4	38.7	20.3	177,274
2023	12,253	49.7	39.7	28.6	249,946
2024	12,314	50.9	41.6	40.5	353,747
2025	12,380	53.3	43.4	58.4	509,847

Year	VMT Per Vehicle	New Mid-Sized Sedans (mpg)	New Small Utility Vehicles (mpg)	Million Gallons of Gasoline Saved	$MtCO_2e$ Saved from Reduced Gasoline
2026	12,449	53.3	43.5	74.1	647,104
2027	12,515	53.3	43.6	91.2	796,007
2028	12,578	53.3	43.7	108.4	946,767
2029	12,636	53.3	43.7	125.9	1,099,169
2030	12,694	53.2	43.7	143.7	1,254,402

GHG emissions from electric vehicles are also calculated in this analysis. The Department of Energy's FuelEconomy.gov website was used to estimate the electricity needed per mile for an EV. The Nissan Leaf was used to estimate the electricity required to power a mid-sized sedan EV (30 kWh per 100 miles). The Toyota RAV4 was used as a stand-in for the small SUV category (44 kWh per 100 miles). These efficiency estimates were then forecast into the future using the Annual Energy Outlook's estimate of Electric Vehicle Efficiency. This models the expected efficiency improvement of EVs between 2015 and 2030 – for example, mid-sized sedans are expected to increase their efficiency to an energy demand of only 25.7 kWh per 100 miles by 2030. These efficiency figures were applied to VMT forecasts to estimate total energy (in MWh) needed to power Minnesota's EV fleet. The MWh required is then increased by an assumption that it is 10% higher than the MWh used, to account for electricity inefficiencies in vehicle charging, based on information from EPA's Fuel Economy.gov website.

The CO_2 emissions from EVs are estimated based on the MWh of electricity needed multiplied by the percentage of electricity that is assumed to be coming from conventional sources, multiplied by the business as usual emissions factor (tons of CO_2e per MWh). This analysis looks at two scenarios, one in which grid electricity is used with 0% renewables set aside for EVS. The second scenario assumes that 100% of electricity that is going towards EVs will be coming from separate generation specifically set aside for EVs from 50% wind and 50% solar PV generation. This can be done a variety of ways, such as through solar charging stations or distributed PV on houses or at the workplace. This analysis assumes that any policy push towards EVs will need to have a component to encourage the use of renewables such as solar PV to power these vehicles.

The difference between the (replaced) gasoline vehicle emissions and the electricity emissions from EVs is the total GHG savings from TLU-4. For the grid electricity (0% renewables) scenario, these calculations are displayed in Table F-3.33 below. This table also shows upstream emissions savings, which estimate the GHG impact that is occurring outside of Minnesota. This includes the GHG impact of gasoline extraction and refining minus the impact of coal/natural gas extraction for electricity production. In this analysis, the upstream impacts from gasoline are greater than those for electricity, and thus the upstream GHG savings are significant. While Minnesota has significant renewable energy in its electricity mix, the electricity that would need to come online for EV power is expected to be primarily coal. When electricity from coal generation is used to power EVs, the GHG impact is actually negative, which matches what was found in a recent study of EVs for the University of Minnesota (Tessum, 2014).

These same factors are displayed for the 100% renewable scenario in Table F-3.31, where GHG savings are significant, because all the electricity going towards EVs is coming from wind/solar PV, which are assumed to have zero emissions in this analysis.

Table F-3.33 Electricity GHG Emissions from EVs and Net GHG Savings from TLU-4 in Grid Electricity (0% Renewables) Case

Year	Mid-Sized Sedans (miles per kWh)	Small Utility (miles per kWh)	MWh Required	MWh from Renewables Required	GHG Emissions from Grid Electricity (tCO_2e)	Net GHG Savings from Gasoline minus Electricity (tCO_2e)	Upstream GHG Savings (tCO_2e)
2015	3.7	3.1	17,901	0	16,760	-2,578	2,641
2016	3.7	3.2	26,221	0	24,231	-3,490	3,867
2017	3.7	3.2	38,363	0	35,133	-5,182	5,512
2018	3.8	3.2	56,149	0	51,047	-7,808	7,858
2019	3.8	3.3	82,121	0	74,128	-12,161	10,944
2020	3.8	3.3	119,952	0	107,464	-19,096	15,257
2021	3.8	3.4	175,013	0	153,178	-27,719	21,389
2022	3.9	3.4	255,098	0	220,320	-43,047	29,287
2023	3.9	3.5	372,120	0	318,658	-68,712	39,573
2024	3.9	3.5	543,302	0	458,892	-105,145	54,335
2025	3.9	3.6	812,239	0	670,914	-161,067	77,327
2026	3.9	3.6	1,074,473	0	874,687	-227,583	93,490
2027	3.9	3.6	1,343,040	0	1,075,022	-279,015	113,062
2028	3.9	3.6	1,619,638	0	1,273,234	-326,468	132,957
2029	3.9	3.6	1,906,365	0	1,472,104	-372,934	152,571
2030	3.9	3.6	2,207,734	0	1,672,452	-418,049	172,041
Total						**-2,080,054**	**932,109**

Table F-3.34 Electricity GHG Emissions from EVs and Net GHG Savings from TLU-4 in 100% Renewables Case

Year	Mid-Sized Sedans (miles per kWh)	Small Utility (miles per kWh)	MWh Required	MWh from Renewables Required	GHG Emissions from Grid Electricity (tCO_2e)	Net GHG Savings from Gasoline minus Electricity (tCO_2e)	Upstream GHG Savings (tCO_2e)
2015	3.7	3.1	17,901	17,901	0	14,182	3,407
2016	3.7	3.2	26,221	26,221	0	20,741	5,000

Year	Mid-Sized Sedans (miles per kWh)	Small Utility (miles per kWh)	MWh Required	MWh from Renewables Required	GHG Emissions from Grid Electricity (tCO_2e)	Net GHG Savings from Gasoline minus Electricity (tCO_2e)	Upstream GHG Savings (tCO_2e)
2017	3.7	3.2	38,363	38,363	0	29,951	7,205
2018	3.8	3.2	56,149	56,149	0	43,239	10,382
2019	3.8	3.3	82,121	82,121	0	61,966	14,762
2020	3.8	3.3	119,952	119,952	0	88,368	20,937
2021	3.8	3.4	175,013	175,013	0	125,459	29,613
2022	3.9	3.4	255,098	255,098	0	177,274	41,410
2023	3.9	3.5	372,120	372,120	0	249,946	57,575
2024	3.9	3.5	543,302	543,302	0	353,747	80,719
2025	3.9	3.6	812,239	812,239	0	509,847	115,947
2026	3.9	3.6	1,074,473	1,074,473	0	647,104	144,962
2027	3.9	3.6	1,343,040	1,343,040	0	796,007	177,506
2028	3.9	3.6	1,619,638	1,619,638	0	946,767	210,554
2029	3.9	3.6	1,906,365	1,906,365	0	1,099,169	243,771
2030	3.9	3.6	2,207,734	2,207,734	0	1,254,402	277,410
Total						**6,418,171**	**1,441,159**

The 100% renewables scenario has different costs and GHG impacts associated with it. The scenario assumes 50% wind and 50% solar PV, which requires investment into renewable infrastructure in Minnesota. The costs of PV investment come from the RCII-2 analysis of distributed renewables, and the wind costs come from similar RCII methodologies (although wind was not explicitly included in RCII-2). PV systems are assumed to have a lifetime of 25 years, and the PV costs are estimated to be $3,100 per installed KW, and that PV arrays generate 1,348 kWh of electricity per year for each installed KW of capacity. In contrast, wind systems are assumed to have a lifetime of 20 years, with costs estimated to be $1,600 per installed KW, and that generate 2,367 kWh of electricity per year for each installed KW of capacity. The additional renewables required, and the costs of installing those renewables, is displayed in Table F-3.35 for Solar PV and Table F-3.36 for Wind. The grid electricity scenario does not have any of these costs.

Table F-3.35 Cost of Additional PV Installations Required, 100% Renewables Case

Year	MWh from PV Required	Additional PV Capacity Required (MW)	Capital Cost of Installed PV Capacity ($ Million)	O&M Cost of PV Installations ($ Million)
2015	8,950	6.6	$1.5	$0.1
2016	13,111	9.7	$2.1	$0.2
2017	19,182	14.2	$3.1	$0.3

Year	MWh from PV Required	Additional PV Capacity Required (MW)	Capital Cost of Installed PV Capacity ($ Million)	O&M Cost of PV Installations ($ Million)
2018	28,075	20.8	$4.6	$0.4
2019	41,061	30.5	$6.7	$0.6
2020	59,976	44.5	$9.8	$0.9
2021	87,506	64.9	$14.3	$1.3
2022	127,549	94.6	$20.8	$1.8
2023	186,060	138.0	$30.4	$2.7
2024	271,651	201.5	$44.3	$3.9
2025	406,120	301.3	$66.3	$5.8
2026	537,236	398.5	$87.7	$7.7
2027	671,520	498.2	$109.6	$9.6
2028	809,819	600.8	$132.1	$11.6
2029	953,182	707.1	$155.5	$13.7
2030	1,103,867	818.9	$180.1	$15.8

Table F-3.36 Cost of Additional Wind Installations Required, 100% Renewables Case

Year	MWh from Wind Required	Additional Wind Capacity Required (MW)	Capital Cost of Installed Wind Capacity ($ Million)	O&M Cost of Wind Installations ($ Million)
2015	8,950	4.02	$0.52	$0.2
2016	13,111	5.88	$0.76	$0.2
2017	19,182	8.61	$1.10	$0.3
2018	28,075	12.60	$1.62	$0.5
2019	41,061	18.42	$2.36	$0.7
2020	59,976	26.90	$3.45	$1.0
2021	87,506	39.27	$5.04	$1.5
2022	127,549	57.24	$7.35	$2.1
2023	186,060	83.50	$10.72	$3.1
2024	271,651	121.90	$15.65	$4.6
2025	406,120	182.15	$23.39	$6.8
2026	537,236	240.91	$30.93	$9.0
2027	671,520	301.40	$38.70	$11.3
2028	809,819	363.22	$46.63	$13.6
2029	953,182	427.52	$54.89	$16.0
2030	1,103,867	495.00	$63.55	$18.6

The costs of TLU-4 are estimated based on the cost differential between a conventional and an electric vehicle, the cost differential between gasoline and electricity needed to power those vehicles and any additional charging infrastructure that will be needed to support EVs. The difference in price between a gasoline powered vehicle and an EV came from AEO 2014. This cost delta is then multiplied by the number of vehicles purchased in each year. The cost differences used are displayed in Table F-3.37 below. The cost difference between an EV and a gasoline vehicle declines from ~18 thousand dollars in 2015 to ~9 thousand by 2030 based on EIA data.

It is worth noting however, that EIA publishes the Annual Energy Outlook as a BAU trend estimate. In developing this forecast:

- EIA does not assume substantial EV technology improvements.
- EIA assumes that current laws and regulations will be unchanged for the life of the forecast.[12]
- EPA's estimated cost of compliance with increased 2025 fuel economy standards aren't included in EIA's analysis. http://www3.epa.gov/otaq/climate/regs-light-duty.htm
- EIA's estimation of future increases in gasoline cost assumes a conservative rate of change.

Meanwhile, the Obama Administration established the EVs Everywhere Grand Challenge in 2012 with the goal for the U.S. to be the first nation "*to produce plug-in electric vehicles that are as affordable for the average American family as today's gasoline-powered vehicles within the next 10 years.*"[13]

EVs Everywhere was adopted as an aggressive but achievable R&D goal and was developed with significant stakeholder input from OEMs (Chrysler, Nissan, Ford, and others), industry, and R&D partnerships. The goal includes ambitious cost reduction targets in four areas: battery R&D; electric drive system R&D; vehicle lightweighting; and advanced climate control technologies. Some specific cost reduction goals include:

- Cutting battery costs from their current $500/kWh to $125/kWh
- Eliminating almost 30% of vehicle weight through lightweighting
- Reducing the cost of electric drive systems from $30/kW to $8/kW

The U.S. is meeting EVs Everywhere Grand Challenge interim targets to date.[14] In order to obtain a more accurate analysis of the TLU-4 option, it is both reasonable and necessary to include the EVs Everywhere goals for cost reductions as adopted by the Department of Energy in the analysis of a ZEV standard as representing not only a possible scenario but a more likely one. The results of the analysis are tabulated alongside the EIA-based findings.

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[12] Department of Energy . (2014, April). *Annual Energy Outlook 2014.* U.S. Energy Information Administration (EIA). iii. Retrieved from http://www.eia.gov/forecasts/aeo/pdf/0383%282014%29.pdf

[13] Department of Energy. (2016). *EV Everywhere About*. Retrieved from Office of Energy Efficiency & Renewable Energy: http://energy.gov/eere/eveverywhere/about-ev-everywhere

[14] U.S. Department of Energy. (2014, January). *EV Everywhere Grand Challenge* . Office of Energy Efficiency & Renewable Energy. 5-7, Retrieved from http://energy.gov/eere/eveverywhere/about-ev-everywhere

Table F-3.37 Initial Per Vehicle Cost Difference Between a New Conventional Gasoline and Electric Vehicle

	Mid-Sized Sedan ($ Thousands)			Small Utility Vehicle ($ Thousands)		
Year	New EV Cost	New Conventional Cost	Cost Differential	New EV Cost	New Conventional Cost	Cost Differential
2015	43.0	24.9	18.2	45.0	26.2	18.8
2016	42.8	24.9	18.0	44.7	26.3	18.3
2017	42.6	25.1	17.5	44.4	26.4	18.0
2018	42.3	25.2	17.1	44.0	26.5	17.5
2019	42.0	25.4	16.6	43.1	27.0	16.1
2020	41.5	25.7	15.8	42.6	27.1	15.5
2021	41.0	25.9	15.1	42.0	27.2	14.8
2022	40.4	26.3	14.1	41.4	27.3	14.0
2023	39.9	26.7	13.2	40.7	27.5	13.2
2024	39.3	26.8	12.5	39.9	27.8	12.1
2025	38.7	27.2	11.5	39.2	28.1	11.1
2026	38.2	27.2	11.0	38.7	28.1	10.6
2027	37.7	27.2	10.5	38.3	28.2	10.1
2028	37.3	27.2	10.0	37.9	28.2	9.7
2029	37.0	27.3	9.7	37.6	28.2	9.4
2030	36.7	27.3	9.4	37.3	28.2	9.1

The total vehicle costs are calculated by multiplying the total number of new EVs with the cost differential for each of the two vehicle types. In addition, there is also evidence that a new electric vehicle costs less to maintain than a conventional vehicle. Based on the costs of three conventional and three electric vehicles, we estimate an average savings of $123 per vehicle per year compared for EVs. Vehicle purchase and vehicle maintenance costs are summarized in Table F-3.38.

Table F-3.38 Additional Vehicle Purchase and Vehicle Maintenance Costs from TLU-4 (Costs Same for Both Scenarios)

		Additional Vehicle Costs ($ Million)			Annual Maintenance Savings from EVs ($ million)
Year	New EVs Sold Per Year	Mid-Sized Sedans	Small Utility	Total	
2015	5,000	$82	$9	$91	$0.6
2016	2,300	$37	$4	$41	$0.9
2017	3,358	$53	$6	$59	$1.3
2018	4,903	$75	$9	$84	$1.9
2019	7,158	$107	$12	$118	$2.8

		Additional Vehicle Costs ($ Million)			Annual Maintenance Savings from EVs ($ million)
Year	New EVs Sold Per Year	Mid-Sized Sedans	Small Utility	Total	
2020	10,451	$149	$16	$165	$4.1
2021	15,258	$207	$23	$230	$5.9
2022	22,276	$283	$31	$314	$8.7
2023	32,524	$387	$43	$430	$12.7
2024	47,484	$533	$57	$591	$18.5
2025	74,327	$770	$82	$853	$27.0
2026	71,627	$707	$76	$783	$35.8
2027	72,685	$685	$73	$758	$44.4
2028	74,230	$671	$72	$743	$53.1
2029	76,485	$668	$72	$739	$61.9
2030	79,778	$678	$73	$750	$70.8

The fuel costs are estimated based on the avoided gasoline costs minus the additional electricity costs. Gasoline cost savings are estimated by multiplying the total gallons of gasoline saved by the $/gallon. Additional electricity costs are estimated from the total MWh needed (beyond that created specifically for this policy option under the renewable energy production) multiplied by the $/MWh.

Tables F-3.39 and F-3.40 also include the additional infrastructure costs of TLU-4. These costs come in two parts: home charging stations and public charging stations. Home charging stations are where people can plug in their EV while not using it, and typically cost ~ $1,000. Public charging stations are assumed to be add-ons to existing gasoline stations. These are expected to be located along 3 400 mile corridors to northern Minnesota (west, central, and east) and along 9 200 mile corridors south of the metro area and east to west in northern Minnesota, thus requiring 60 stations in all. These level 3 charging stations are phased in on a linear basis between 2015 and 2030, and based on information from ZEF Energy are estimated to cost $70,000 per station ($40,000 for station and $30,000 for installation and service upgrades).

Table F-3.39 Fuel and Infrastructure Costs of TLU-4 Grid Electricity (0% Renewables Case)

Year	Fuel Savings ($ Million)	Electricity Costs ($ Million)	Number of Home Charging Stations Required	Total Costs for Home Charging Stations ($ Million)	Number of Public Charging Stations Required	Total Capital Costs for Charging Stations ($ Million)
2015	$5.6	$2.0	5,000	$5.0	0	$0.0
2016	$8.2	$3.0	2,300	$2.3	4	$0.3
2017	$12.0	$4.4	3,358	$3.4	8	$0.3

Year	Fuel Savings ($ Million)	Electricity Costs ($ Million)	Number of Home Charging Stations Required	Total Costs for Home Charging Stations ($ Million)	Number of Public Charging Stations Required	Total Capital Costs for Charging Stations ($ Million)
2018	$17.4	$6.4	4,903	$4.9	12	$0.3
2019	$25.0	$9.5	7,158	$7.2	16	$0.3
2020	$36.0	$13.9	10,450	$10.5	20	$0.3
2021	$51.3	$20.3	15,258	$15.3	24	$0.3
2022	$73.0	$29.7	22,276	$22.3	28	$0.3
2023	$103.6	$43.5	32,524	$32.5	32	$0.3
2024	$147.5	$63.8	47,484	$47.5	36	$0.3
2025	$213.9	$95.8	69,327	$69.3	40	$0.3
2026	$273.2	$127.2	71,628	$71.6	44	$0.3
2027	$338.1	$159.6	70,385	$70.4	48	$0.3
2028	$404.7	$193.2	70,872	$70.9	52	$0.3
2029	$472.8	$228.3	71,582	$71.6	56	$0.3
2030	$542.9	$265.5	72,620	$72.6	60	$0.3

Table F-3.40 Fuel and Infrastructure Costs of TLU-4 (100% Renewables Case)

Year	Fuel Savings ($ Million)	Electricity Costs ($ Million)	Number of Home Charging Stations Required	Total Costs for Home Charging Stations ($ Million)	Number of Public Charging Stations Required	Total Capital Costs for Charging Stations ($ Million)
2015	$5.6	$0.0	5,000	$5.0	0	$0.0
2016	$8.2	$0.0	2,300	$2.3	4	$0.3
2017	$12.0	$0.0	3,358	$3.4	8	$0.3
2018	$17.4	$0.0	4,903	$4.9	12	$0.3
2019	$25.0	$0.0	7,158	$7.2	16	$0.3
2020	$36.0	$0.0	10,450	$10.5	20	$0.3
2021	$51.3	$0.0	15,258	$15.3	24	$0.3
2022	$73.0	$0.0	22,276	$22.3	28	$0.3
2023	$103.6	$0.0	32,524	$32.5	32	$0.3
2024	$147.5	$0.0	47,484	$47.5	36	$0.3
2025	$213.9	$0.0	69,327	$69.3	40	$0.3
2026	$273.2	$0.0	71,628	$71.6	44	$0.3
2027	$338.1	$0.0	70,385	$70.4	48	$0.3
2028	$404.7	$0.0	70,872	$70.9	52	$0.3
2029	$472.8	$0.0	71,582	$71.6	56	$0.3
2030	$542.9	$0.0	72,620	$72.6	60	$0.3

Total costs (additional vehicle costs – gasoline savings + electricity costs + EV infrastructure costs + renewable energy infrastructure costs) are displayed in Table F-3.41 and Table F-3.42 below. These costs are then discounted to 2014 dollars.

Table F-3.41 Total Costs of TLU-4 Grid Electricity 0% Renewable Case ($ Million Dollars)

Year	Net Costs of EV program	Discounted Costs of TLU-4 ($MM2014)
2015	$92.0	$87.7
2016	$37.9	$34.4
2017	$53.6	$46.3
2018	$76.3	$62.8
2019	$107.3	$84.1
2020	$149.7	$111.7
2021	$208.2	$148.0
2022	$284.8	$192.8
2023	$389.8	$251.3
2024	$536.4	$329.3
2025	$777.1	$454.4
2026	$672.9	$374.7
2027	$606.0	$321.4
2028	$549.6	$277.6
2029	$505.0	$242.9
2030	$475.0	$217.6
Total		**$3,237**

Table F-3.42 Total Costs of TLU-4 100% Renewable Case ($ Million Dollars)

Year	Net Costs of EV program	Discounted Costs of TLU-4 ($MM2014)
2015	$92.3	$87.9
2016	$38.2	$34.7
2017	$54.1	$46.7
2018	$76.9	$63.3
2019	$108.2	$84.8
2020	$151.0	$112.6
2021	$210.0	$149.2
2022	$287.3	$194.4
2023	$393.2	$253.5
2024	$541.1	$332.2
2025	$783.7	$458.2
2026	$681.1	$379.2
2027	$615.6	$326.5

Year	Net Costs of EV program	Discounted Costs of TLU-4 ($MM2014)
2028	$560.3	$283.0
2029	$516.8	$248.6
2030	$487.6	$223.4

The total costs are higher in the 100% renewable case than they are in the grid electricity case. However, the vehicle costs are the major driver of costs in this policy option, and the total increase in cost of increasing the dedicated PV to 100% is only a small portion of the total (an increase from $3.23 billion in cumulative costs to $3.28 billion over the entire policy option period). However, the GHG impact is significant. Because electricity is now coming entirely from dedicated PV and wind, the total GHG savings increase to more than 6 million tons of CO_2e, whereas in the grid electricity scenario the use of EVs actually increases GHG emissions (which matches what was found in a recent study of EVs for the University of Minnesota (Tessum, 2014). The upstream GHG savings have also increased, because there are no longer any upstream GHG emissions from electricity production.

Key Assumptions

- This analysis assumes that all of the ZEV requirements will be met with entirely electric vehicles, rather than a mix of EVs and PHEVs. If PHEV sales are substituted for some EV sales, then the program emission reductions will be less than estimated here.
- The analysis takes into account the following costs and cost savings:
- Costs – Additional vehicle costs for EVs, capital costs for EV charging stations, additional capital and O&M costs for installing dedicated wind/solar generation for EVs (in the renewable energy scenario) OR additional electricity costs (in the grid electricity scenario).
- Cost Savings – Reduced gasoline costs from EVs, reduced maintenance costs from EVs compared to conventional vehicles
- Electric vehicles are assumed to be driven the same amount annually as gasoline powered vehicles.
- The analysis assumes that vehicles will last on average 10 years.
- Potential overestimate of fuel efficiency in gasoline cars, which would underestimate greenhouse gas reductions and financial savings from EVs. The fuel economy of gasoline powered vehicles comes from the Annual Energy Outlook 2014, which provides new vehicle fuel economy ratings from EPA. These ratings have often been found to be only achievable under ideal conditions (flat road, constant speed, no heat or air conditioning use). Real world driving conditions often experience efficiencies as much as 20% lower than EPA efficiency listings. No adjustment was included in this analysis to ensure that

the EV estimate is a conservative one (actual fuel savings would likely be higher), and because it is unknown if efficiency ratings for EVs are similarly optimistic.

- This analysis does not consider time of day for charging.

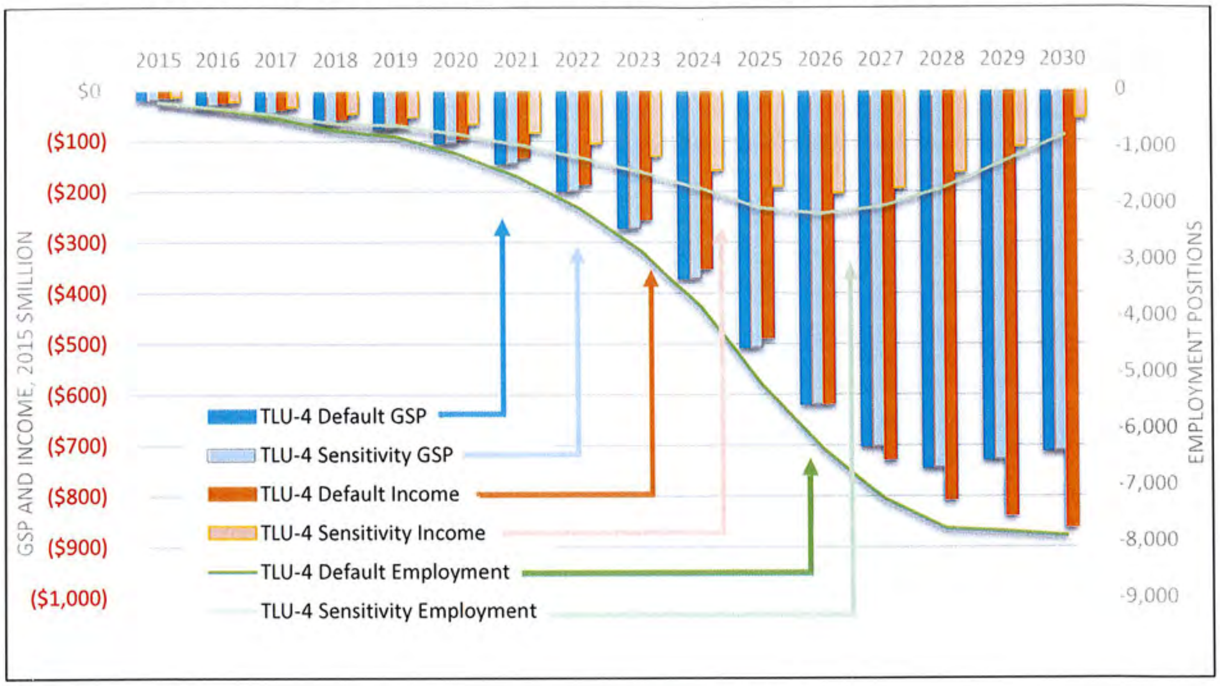
Macroeconomic (Indirect) Policy Impacts

Table F-3.43 TLU-4 Macroeconomic Impacts on GSP, Employment and Income

Scenario	GSP ($2015 MM)			Employment (Individual)			Personal Income ($2015 MM)		
	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)
TLU-4 High EV $	-$711	-$354	-$5,315	-7,910	-3,750	-56,240	-$862	-$370	-$5,551
TLU-4 Low EV $	$140	-$65	-$969	-810	-1,220	-18,300	-$56	-$108	-$1,622

In TLU-4 policy analysis, a sensitivity scenario is also used for analyzing the macroeconomic impacts of the policy. The sensitivity scenario assumes that the EV price will decline during the implementation period, eventually achieving price parity with conventional vehicles, as oppose to relatively higher price of EVs in comparison to conventional vehicles assumed in the default scenario. The comparison of indirect macroeconomic results between these two scenarios is shown in the graph below. The expected negative macroeconomic impacts of this policy are significantly alleviated under the sensitivity (low EV price) scenario.

Figure F-3.35 TLU Policy Impacts of Different Electric-Vehicle Price Assumptions



Notes:
"Default" refers to a case where EV prices remain 40-60% higher than conventional vehicles, imposing a large price burden on consumers. "Sensitivity" refers to a case where EV prices start out at 40-60% higher but fall in a linear fashion to no price premium at all in the year 2030.

Graphs below show detail in GSP, employment and personal income impact of the TLU-4 policy.

Figure F-3.36 TLU-4 Impacts on Gross State Product ($2015 MM)

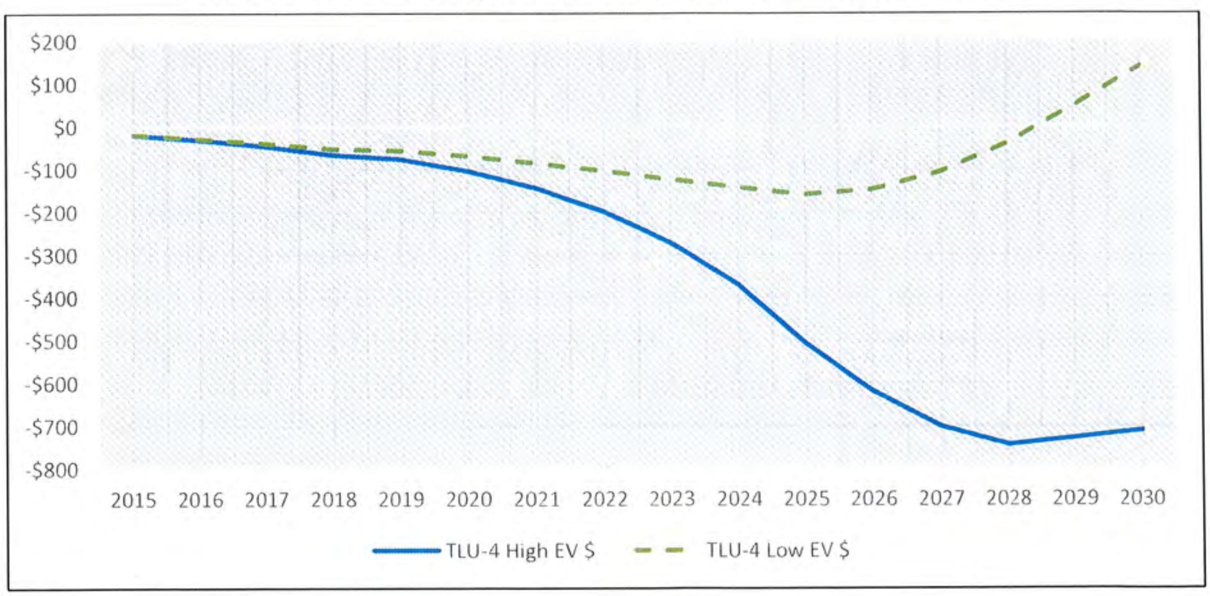


Figure F-3.37 TLU-4 Impacts on Incomes ($2015 MM)

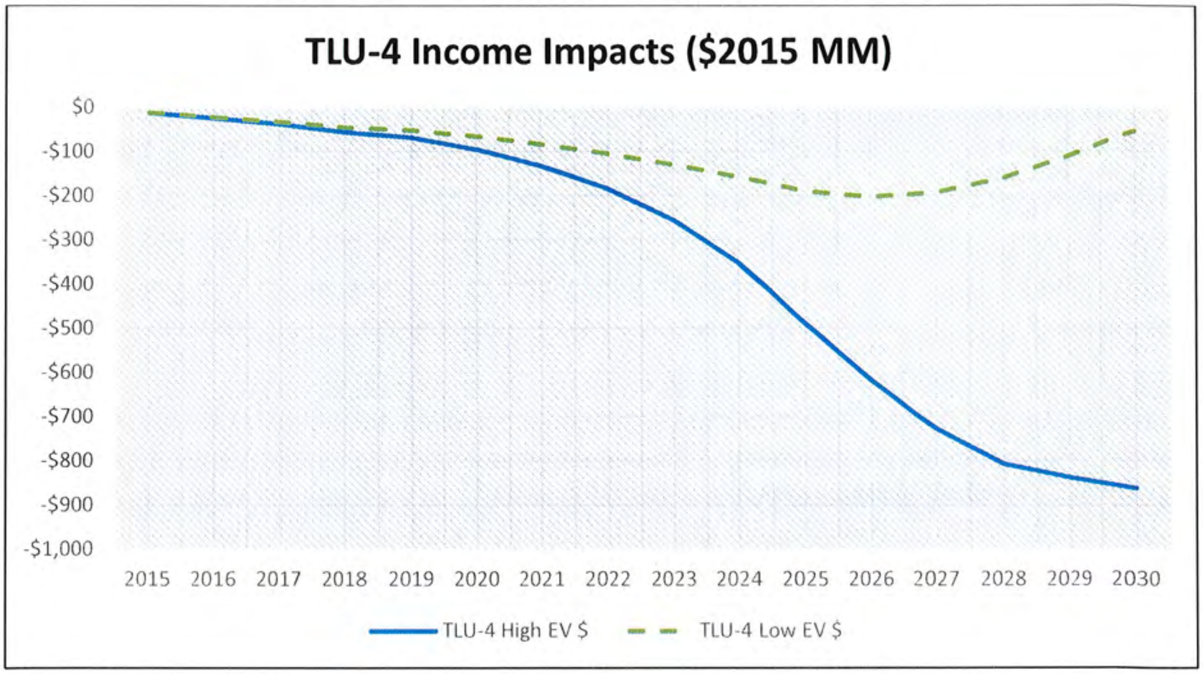
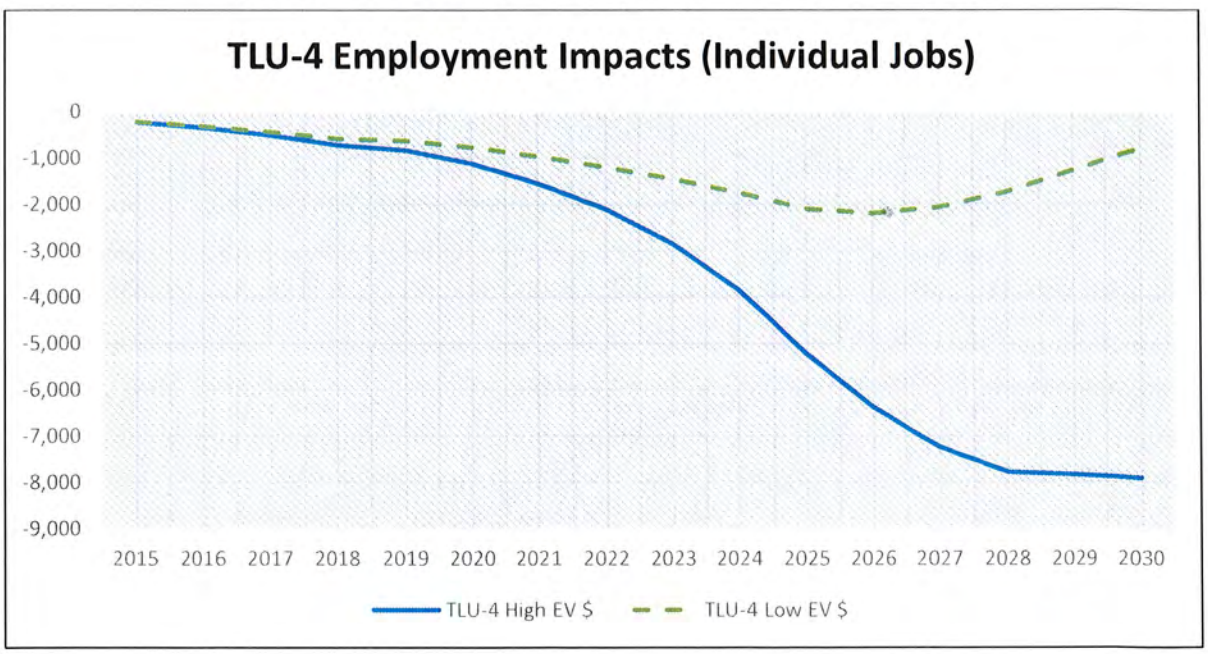
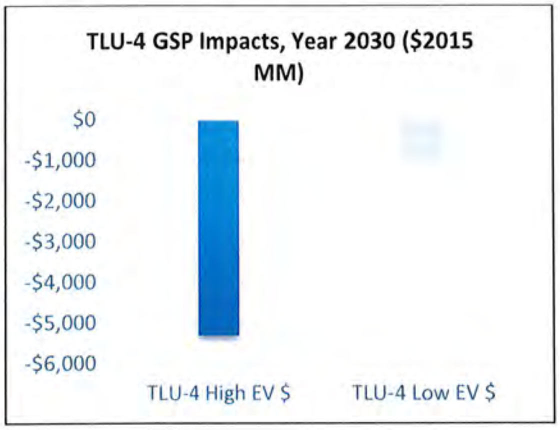
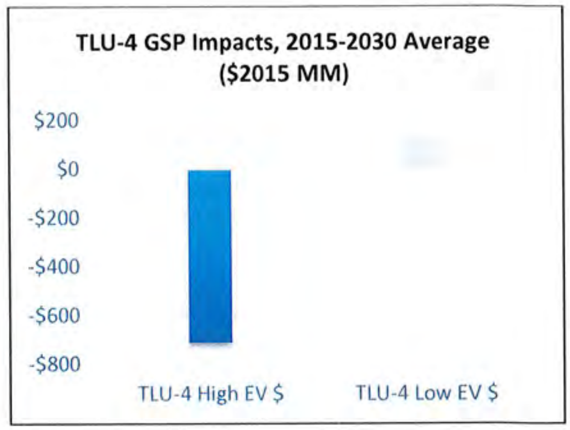


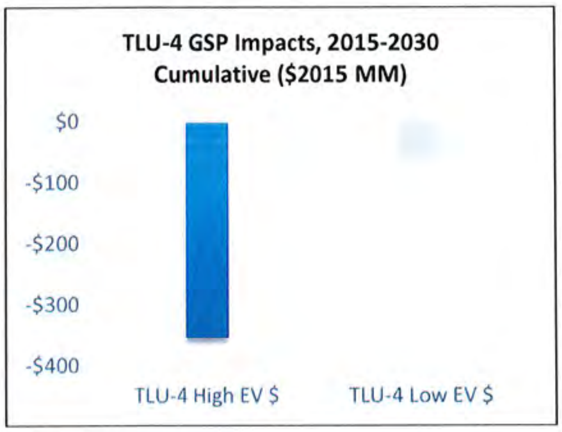
Figure F-3.38 TLU-4 Impacts on Employment (Individual Jobs)

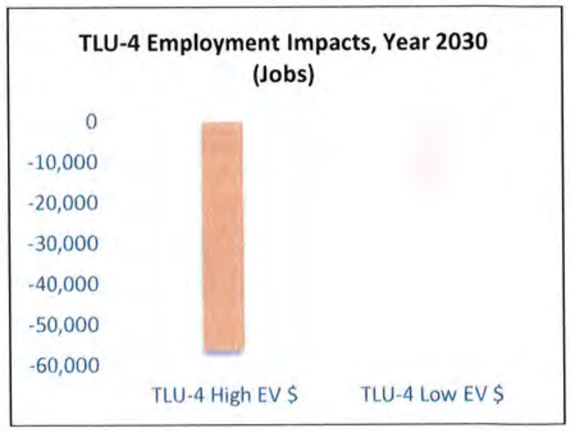


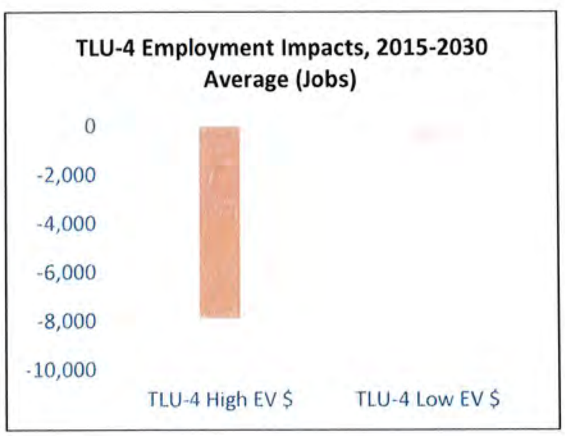
Graphs below show macroeconomic impacts on GSP, personal income, and employment in the final year (2030), in average (2015-2030) and in cumulative (2015-2030). Lighter color indicates the sensitivity scenario.

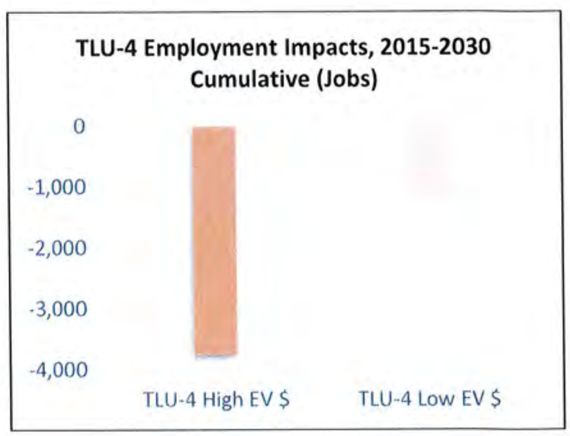

TLU-4 GSP Impacts, Year 2030 ($2015 MM)
$0
-$1,000
-$2,000
-$3,000
-$4,000
-$5,000
-$6,000
TLU-4 High EV $
TLU-4 Low EV $

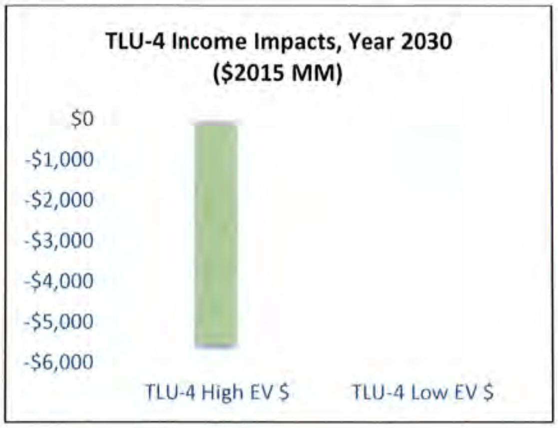

TLU-4 GSP Impacts, 2015-2030 Average ($2015 MM)
$200
$0
-$200
-$400
-$600
-$800
TLU-4 High EV $
TLU-4 Low EV $

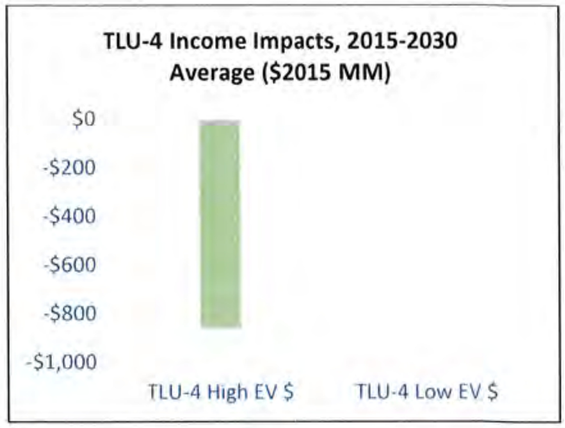

TLU-4 GSP Impacts, 2015-2030 Cumulative ($2015 MM)
$0
-$100
-$200
-$300
-$400
TLU-4 High EV $
TLU-4 Low EV $

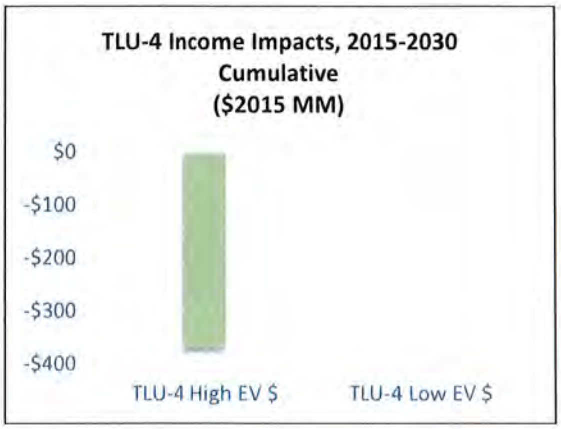

TLU-4 Employment Impacts, Year 2030 (Jobs)
0
-10,000
-20,000
-30,000
-40,000
-50,000
-60,000
TLU-4 High EV $
TLU-4 Low EV $


TLU-4 Employment Impacts, 2015-2030 Average (Jobs)
0
-2,000
-4,000
-6,000
-8,000
-10,000
TLU-4 High EV $
TLU-4 Low EV $


TLU-4 Employment Impacts, 2015-2030 Cumulative (Jobs)
0
-1,000
-2,000
-3,000
-4,000
TLU-4 High EV $
TLU-4 Low EV $







Principal Drivers of Macroeconomic Changes

The overall sector has many drivers, but a dominant driver comes from the electric-vehicles policy (TLU-4). In that policy, the scenario calls for consumers to shift a substantial number of vehicle purchases from conventional to electric vehicles. Electric vehicles come at a substantial price premium, and this change represents a significant price increase encountered by consumers (which reaches over $700 million by the year 2025).

This vehicle-price increase impact is a crucial driver of economic impacts. CCS conducted sensitivity analyses in which the price premium of electric vehicles was modulated while holding all other inputs constant in order to test its importance. When EV prices fall to parity over time (meaning there is no price premium by 2030), the policy has somewhat positive GSP impacts (reaching $140 million additional GSP per year by 2030, though it is still negative in early years), though it still falls below the baseline on employment and jobs (the prices, while falling, are still higher, and those higher prices reduce spending power around the rest of the economy). When EV prices stay high, however, the policy (and the high prices) pull GSP down by as much as $750 million per year. However, at this price, the policy is unlikely to be effective at driving a change in vehicle choice anyway, and these results should be understood in that context.

Key Uncertainties

Where does the funding come from to support development for infrastructure? Electric utilities, general fund, tax on vehicle registration or exemptions for EV owners, gas tax, Conservation Improvement Program. Under California program adoption, there may be incentives for auto manufacturers to invest in public charging stations.

Additional Benefits and Costs

In addition to GHG reductions, there is economic, energy security, and public health benefits associated with Zero Emission Fleets (ZEV) fleets, for instance:

- Electrification of the vehicle fleet creates new opportunities for electric utilities to employ load management strategies and to improve grid reliability while also resulting in increased electricity sales. While these strategies will take years to implement, there is potential to realize near-term benefits to utilities, consumers, and society.
- Zero emission vehicles, which may generate significantly fewer emissions than gasoline powered vehicles, could significantly reduce emissions if broadly adopted. However, it is critical that the electricity source for these vehicles be considered, as coal-fired power plants that generate electricity do produce significant emissions that can negatively impact health.

Figure F-3.39. Potential Health Benefits of TLU-4

Reducing transit-related emissions is likely to reduce the risk for respiratory and cardiovascular illness, cancer, stress, premature birth weight, and premature death in exposed populations.

Feasibility Issues

These policies are technically feasible, and could expect broad and growing consumer support. Electric utilities are primary stakeholders and likely supporters.

Adoption of the regulatory Zero Emissions Vehicle Standard would likely result in resistance from automobile manufacturers and the Minnesota Auto Dealers Association due to the ZEV sales quota and reporting requirements. The implementation and oversight costs to the state would need to be considered.

Chapter XVI. Appendix F-4. Agriculture Policy Option Recommendations

Overview

The tables below provide a summary of the microeconomic analysis of Climate Solutions & Economic Opportunities (CSEO) policies in the Agriculture sector. The first table, Table F-4.1 provides a summary of results on a stand-alone basis, meaning that each policy option was analyzed separately against baseline (business as usual or BAU) conditions. Details on the analysis of each policy option are provided in each of the Policy Option Documents (PODs) that follow within this appendix.

Direct Impacts

The stand-alone results provide the annual greenhouse gas (GHG) reductions for 2020 and 2030 in million metric tons (MMt) of carbon dioxide equivalent reductions (CO_2e), as well as the cumulative reductions through 2030. The reductions shown are just those that have been estimated to occur within the State. Additional GHG reductions, typically those associated with upstream emissions in the supply of fuels or materials, have also been estimated and are reported within each of the analyses in each POD.

Also reported in the stand-alone results is the net present value (NPV) of societal costs/savings for each policy option. These are the net costs of implementing each policy option reported in 2014 dollars. The cost effectiveness (CE) estimated for each policy option is also provided. Cost effectiveness is a common metric that denotes the cost/savings for reducing each metric ton (t) of emissions. Note that the CE estimates use the total emission reductions for the policy option (i.e. those occurring both within and outside of the State).

As indicated in Table F-4.1 the combined impacts of Policy AG-4 (Advanced Biofuels Production) and Policy AG-5 addressing biofuel consumption (Existing Biofuel Statute) are provided in the overall results shown for Policy AG-5. In other portions of this appendix and the final CSEO report, these two policies are referred to as the "Biofuels Package". In order to estimate net energy and GHG impacts, the analysis of biofuels production needs to be taken all of the way through consumption of those fuels; so separate reporting of overall policy option impacts is not done (if GHG estimates of biofuel production were provided, these would only indicate an increase in emissions, which would be misleading or confusing to most readers). Implementation of the Biofuels Package will have some overlap with on-road vehicle policies in the Transportation and Land Use (TLU) sector; these will be addressed in the *inter*-sector integration analysis and documented in the final report for the project.

Integrative Adjustments & Overlaps

The second summary table, Table F-4.2, provides the same values described above after an assessment was made of any policy option interactions or overlaps. In the Agriculture sector, overlaps were identified between the AG-1 policy option addressing nutrient management and policies AG-3 and AG-4. Essentially, implementation of the AG-3 and AG-4 policies will result in

conversion of some corn to either perennial cover (AG-3) or other energy crops (AG-4). So the stand-alone reductions and costs estimated for Policy Option AG-1 were adjusted downward to account for a smaller corn production base than is currently expected in the baseline forecast.

As indicated in the Table F-4.2 there could also be some interaction of Policy Option AG-2 with Policy Option AG-1 (i.e. lower nitrogen [N] fertilization requirements achieved via cover cropping); however, the net nitrous oxide (N_2O) emissions impacts related to cover cropping are currently uncertain. Therefore, no adjustments were made relative to this interaction.

Macroeconomic (Indirect) Impacts of Agriculture Policies

Table F-4.3 below provides a summary of the expected impacts of Ag policies on jobs and economic growth during the CSEO planning period. This table focuses on the impact of policies on Gross State Product (the total amount spent on goods and services produced within the state), Employment (the total number of full-time and part-time positions), and Incomes (the total amount earned by households from all possible sources). These metrics represent three valuable indicators of both the overall size of the economy and that economy's structural orientation toward supporting livelihoods and utilizing productive work.

For the purposes of macro-economic analysis of CSEO policies, CCS utilized the Regional Economic Models, Inc. (REMI) PI+ software. This particular REMI model is developed specifically for Minnesota, and is developed consistently with the design of models in use by state agency staff within Minnesota for a range of economic analyses. Its analytical power and accuracy made REMI a leading modeling tool in the industry used by numerous research institutions, consulting firms, non-government organizations and government agencies to analyze impacts of proposed policies on key macro-economic parameters, such as GDP, income levels and employment.

The main inputs for macro-economic analysis are microeconomic estimates of direct costs and savings expected from the implementation of individual policy options. These inputs are supplemented with additional data and assumptions necessary to complete the picture of how these costs and savings (as well as price changes, demand and supply changes, and other factors) influence Minnesota's economy. These additional data and assumptions typically regard how various actors around the state (households, businesses and governments) respond to change by changing their own economic activity. A full articulation of the general and policy-specific assumptions made by the macroeconomic analysis team is provided in the Policy Option Documents, contained as appendices to this report.

Table F-4.1 Agriculture Policy Options, Direct Stand-Alone Impacts

Stand-Alone Analysis						
		GHG Reductions			Costs	
Policy Option ID	Policy Option Title	Annual CO_2e Reductions[a]	2030 Cumulative[a]	2030 Cumulative[b]	Net Costs[c] 2015-2030	Cost Effectiveness[d]

		2020 MMt	2030 MMt	MMtCO_2e	MMtCO_2e	$Million	$/t$CO_2$e
AG-1	Nutrient Management in Agriculture	0.036	0.14	1.1	2.8	($131)	($46)
AG-2	Soil Carbon Management: Increased Use of Cover Crops	0.059	0.49	3.1	3.6	($1,346)	($377)
AG-3	Soil Carbon Management: Increased Conversion of Row Crops to Perennial Crops	0.62	1.6	14	14	($2,104)	($153)
AG-4	Advanced Biofuels Production	*Not Applicable - Results of this supply-side policy option are combined with those from AG-5 (demand-side policy option)*					
AG-5[e]	Existing Biofuel Statute	0.12	0.17	1.8	3.5	$462	$133
Totals		**0.83**	**2.4**	**19**	**24**	**($3,119)**	**($132)**

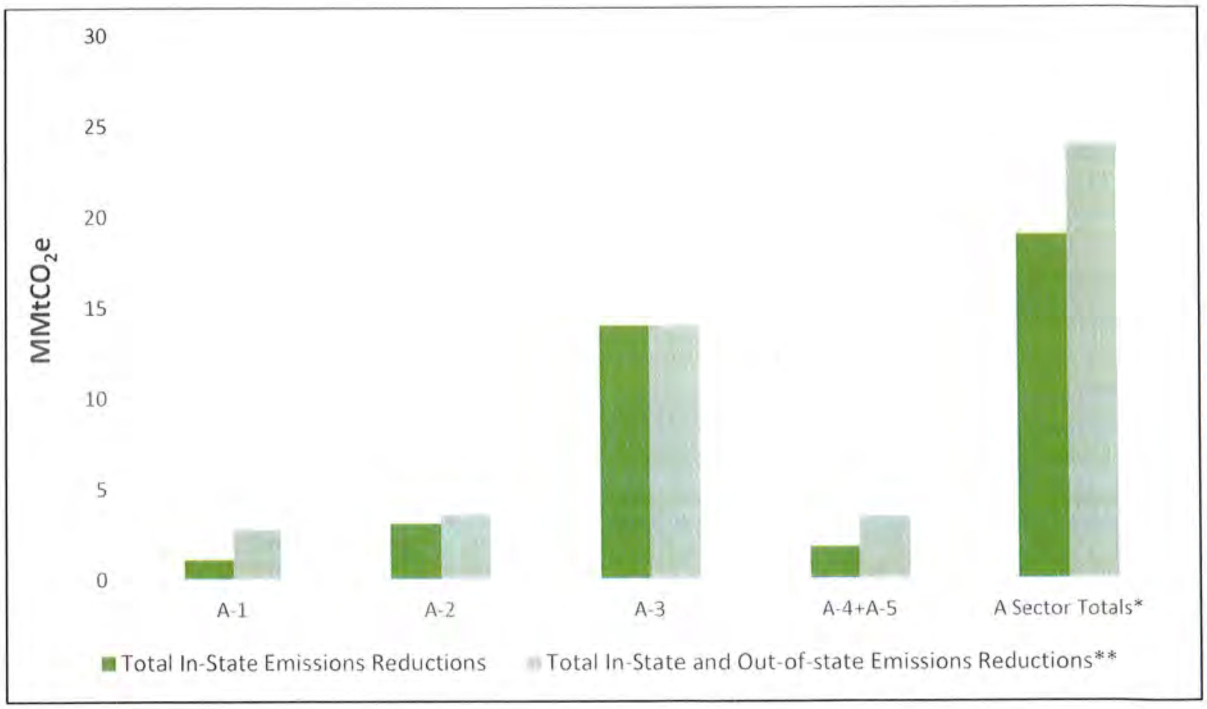
Notes:
[a] In-state (Direct) GHG Reductions.
[b] Total (Direct and Indirect) GHG Reductions.
[c] Net Present Value of fully implemented policy option using 2014 dollars ($2014).
[d] Cost effectiveness values include full energy-cycle GHG reductions, including those occurring out of state. Dollars expressed in $2014.
[e] Contains the total net impacts of the AG-4/AG-5 Biofuels Package.

Table F-4.2 Agriculture Policy Options, Intra-Sector Interactions & Overlaps

Intra-Sector Interactions & Overlaps Adjusted Results							
Policy Option ID	**Policy Option Title**	**GHG Reductions**				**Costs**	
		Annual[a]		**2030 Cumulative[a]**	**2030 Cumulative[b]**	**Net Cost[c] 2015-2030**	**Cost Effectiveness[d]**
		2020 MMt	**2030 MMt**	**MMtCO_2e**	**MMtCO_2e**	**$Million**	**$/t$CO_2$e**
AG-1[e]	Nutrient Management in Agriculture	0.035	0.13	1.0	2.7	($127)	($47)
AG-2[f]	Soil Carbon Management: Increased Use of Cover Crops	0.059	0.49	3.1	3.6	($1,346)	($377)
AG-3[g]	Soil Carbon Management: Increased Conversion of Row Crops to Perennial Crops	0.62	1.6	14	14	($2,104)	($153)
AG-4[h]	Advanced Biofuels Production	*Not Applicable*					
AG-5	Existing Biofuel Statute	0.12	0.17	1.8	3.5	$462	$133
Total After Intra-Sector Interactions/ Overlap		**0.83**	**2.4**	**19**	**23**	**($3,115)**	**($133)**

Notes:
[a] In-state (Direct) GHG Reductions.
[b] Total (Direct and Indirect) GHG Reductions.
[c] Net Present Value of fully implemented policy option using 2014 dollars ($2014).
[d] Cost effectiveness values include full energy-cycle GHG reductions, including those occurring out of State. Dollars expressed in $2014.
[e] See AG-2, AG-3, and AG-4 below.
[f] Use of cover crops on 2.25 MMacres of corn by 2030 could reduce N requirements addressed under AG-1. However, net N_2O emissions impacts from cover cropping are uncertain; so no changes were made to AG-1 as a result of implementation of AG-2.
[g] Conversion of 500,000 acres of corn to perennial crops reduces impacts and costs of AG-1.
[h] Diverted corn production to energy beets reduces the impacts and costs of AG-1.

Figure F-4.1 AG Policies GHG Emissions Abatement, 2015-2030



Notes:
Total in and out-of-state emissions reduction are the reductions associated with the full energy cycle (fuel extraction, processing, distribution and consumption). Therefore, the emissions reductions that occur both inside and outside of the state borders as a result of a policy implementation are captured under this value.

Table F-4.3 Macroeconomic (Indirect) Impacts of Agriculture Policies

Macroeconomic (Indirect) Impacts Results									
Scenario	Gross State Product GSP ($2015 Millions)			Employment (Full and Part-Time Jobs)			Income Earned ($2015 Millions)		
	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)

AG-1	-$9	-$5	-$73	-360	-200	-2,960	-$22	-$8	-$125
AG-2	-$2	$8	$113	70	230	3,380	$21	$20	$299
AG-3	$23	-$35	-$529	1,170	-490	-7,420	$56	-$32	-$486
AG-4+AG-5	$1,132	$819	$11,469	3,610	3,420	47,820	$539	$398	$5,576
AG Sector Total	**$980**	**$680**	**$10,203**	**810**	**1,490**	**22,300**	**$349**	**$277**	**$4,148**

Notes:
[a] Gross State Production changes in Minnesota. Dollars expressed in $2015.
[b] Total employment changes in Minnesota.
[c] Personal Income changes in Minnesota. Dollars expressed in $2015.
[d] Single final year value. Year 2030 is the final year of analyses in this project.
[e] Average value from the year 2016 to the year 2030. The average value is calculated from the first year of the policy implementation through the year 2030 if implementation of the policy starts after year 2016.
[f] Cumulative value from 2015-2030 time period.

Figure F-4.2 – Average Annual Jobs Impact of Ag Policies, Individually and in Concert

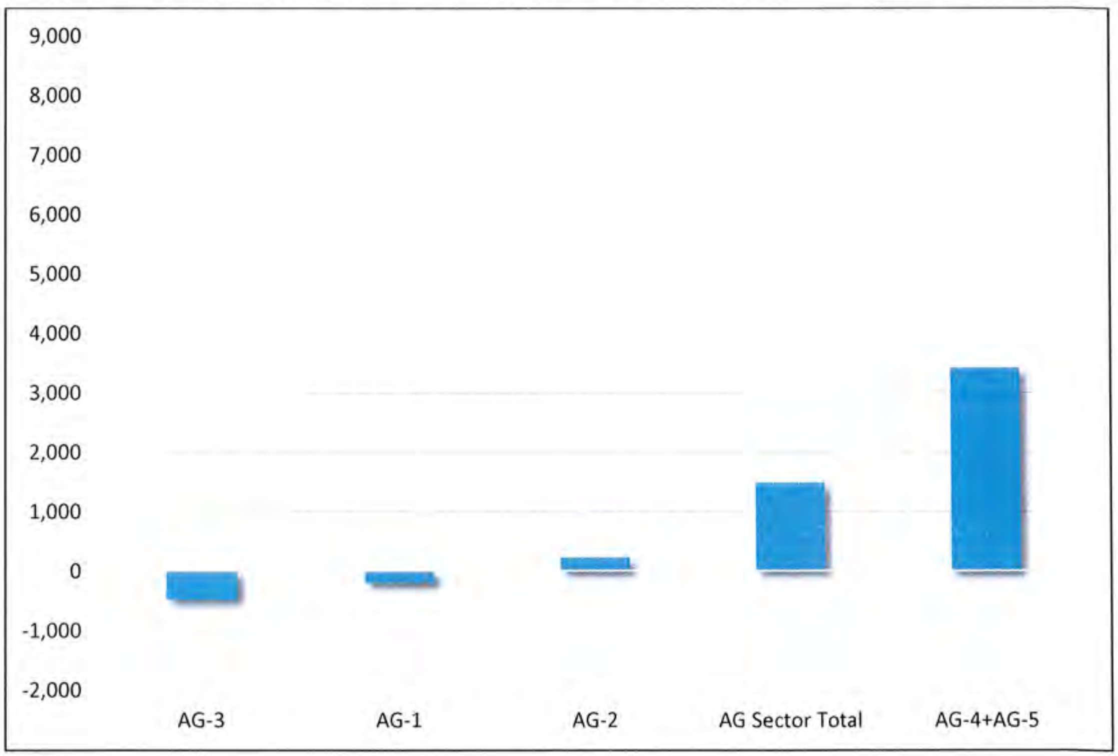
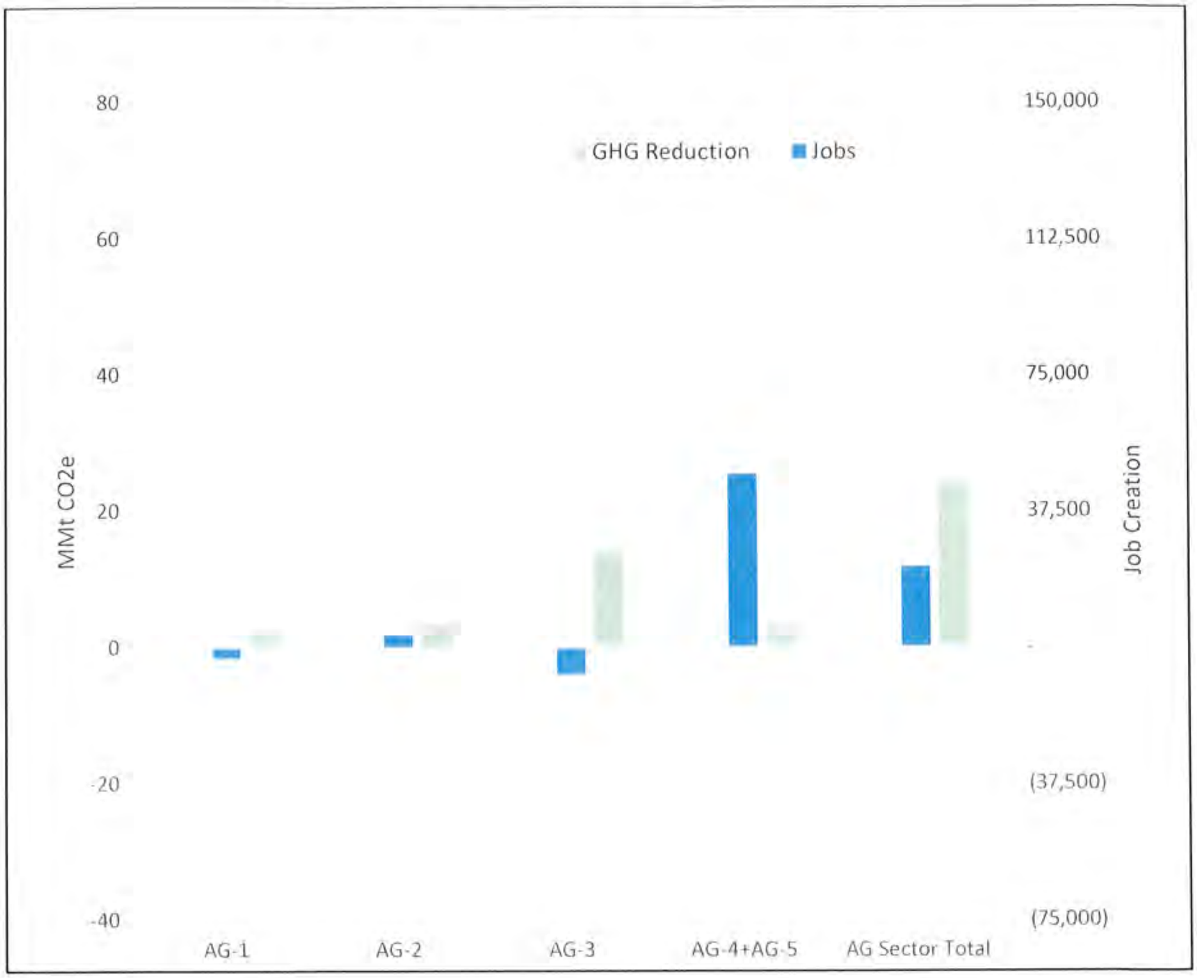


Figure F-4.3 below summarizes a potential for job creation and GHG emissions abatement of Agriculture sector policies on the same graph. This allows for a simultaneous assessment of performance of individual CSEO options against two crucial environmental and economic indicators.

Figure F-4.3 Ag Jobs and GHG Reduction, 2015-2030



Sector Level Index

The graphs below express the overall economic impact from each scenario in a single score, and compares those scores. CCS created this single score (a Macroeconomic Impact Index) in order to encapsulate in one measurement the relative macroeconomic impacts (including jobs, GSP and incomes) of each policy. We have found in our own work and in the literature that indexed scores can be helpful to many readers when comparing options with multiple characteristics.

To produce this score, CCS set the results from the absolute best-case scenario (i.e. the implementation of all CSEO policies with all their optimal sensitivities in place) equal to 100, with that scenario's jobs, GSP and incomes impacts weighted equally at one third of the total score. Each policy's jobs, GSP and income impacts are scaled against that measure, and given a total score. The overall score indicates how significant a policy's impact is projected to be.

Negative impacts are scaled the same way, except that those impacts are given negative scores and pull down the total score of the policy.

These scores are calculated separately for the final year of the study (2030), the *average* impact over the 2015-2030 period, and the *cumulative* impact of the policies over that period. While each scenario has one line, the relative importance of jobs, income and GSP remain visible as differently-shaded segments of that line.

Figure F-4.4 AG Macroeconomic Indicators, 2030

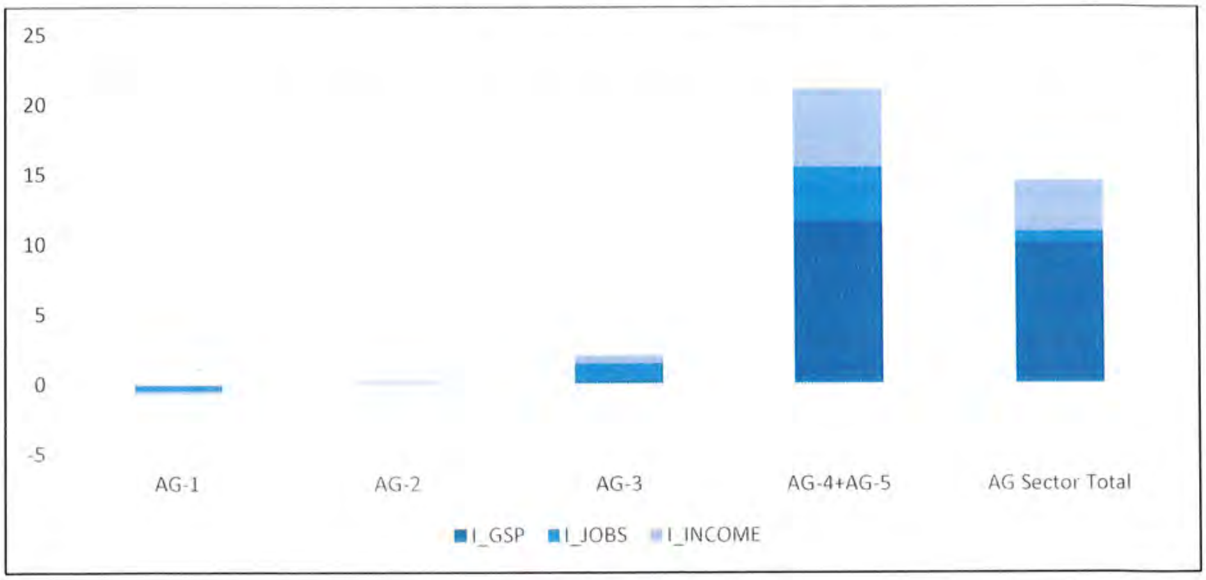


Figure F-4.5 AG Macroeconomic Indicators, Average Annual

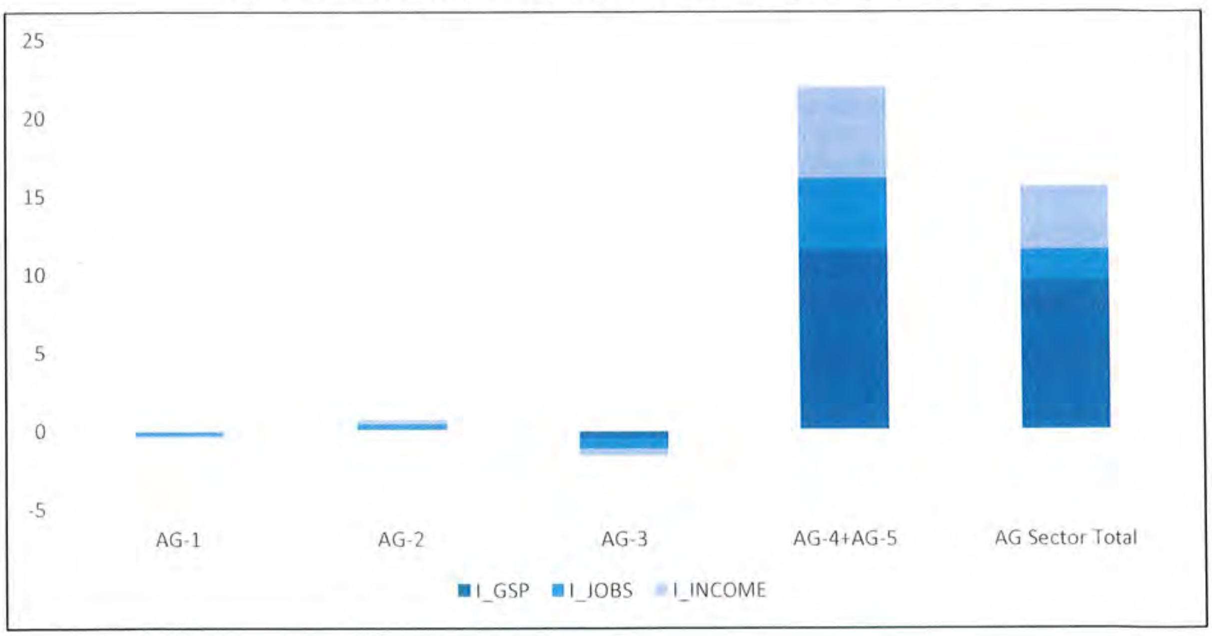
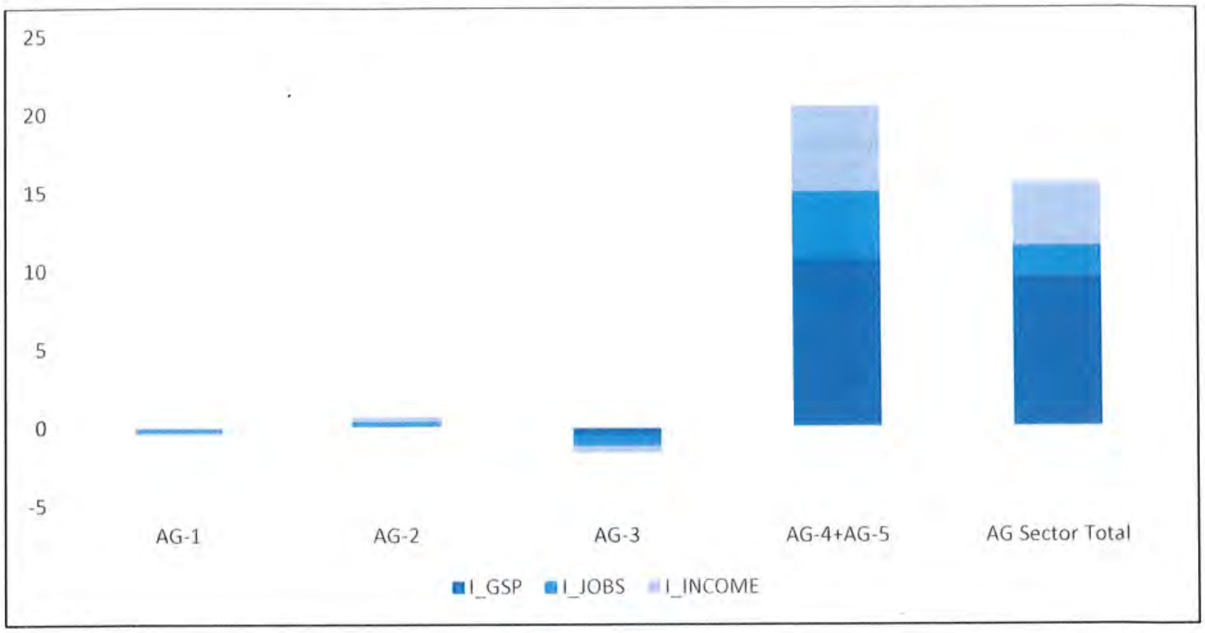


Figure F-4.6 AG Macroeconomic Indicators, 2015-2030



The Agriculture sector generates significant positive impacts – around $1 billion in GSP and nearly two and half times that in income, with a few thousand jobs more than would exist in the state than if these policies were not implemented.

The Agriculture sector impact on Minnesota's economy, according to this analysis, is really the story of the biofuels policy (the combined supply and demand of biofuels from AG-4 and AG-5). While the other policies are effectively neutral in their impacts, driving very small positive or negative shifts over time, the biofuels policies together are responsible for effectively all of the GSP and income gains. They also drive all the employment gains – indeed, the other policies pull the totals slightly down. Graphs and bar charts that follow illustrate the above explained policy effects.

Figure F-4.7 AG GSP Impacts ($2015 MM)

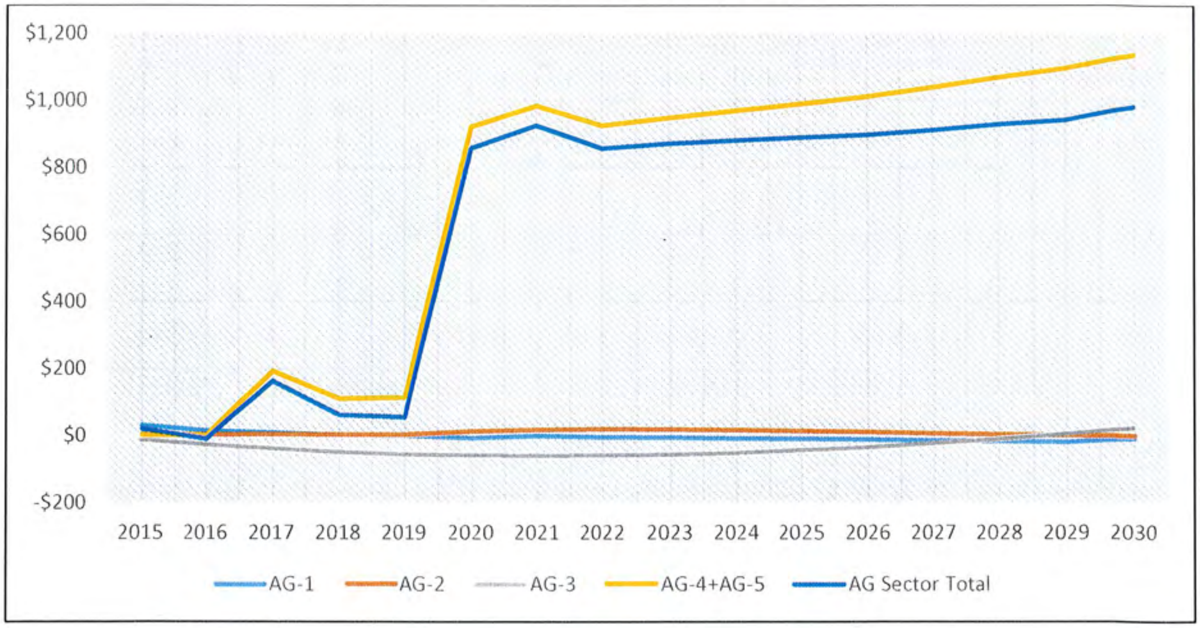


Figure F-4.8 AG Employment Impacts (Jobs)

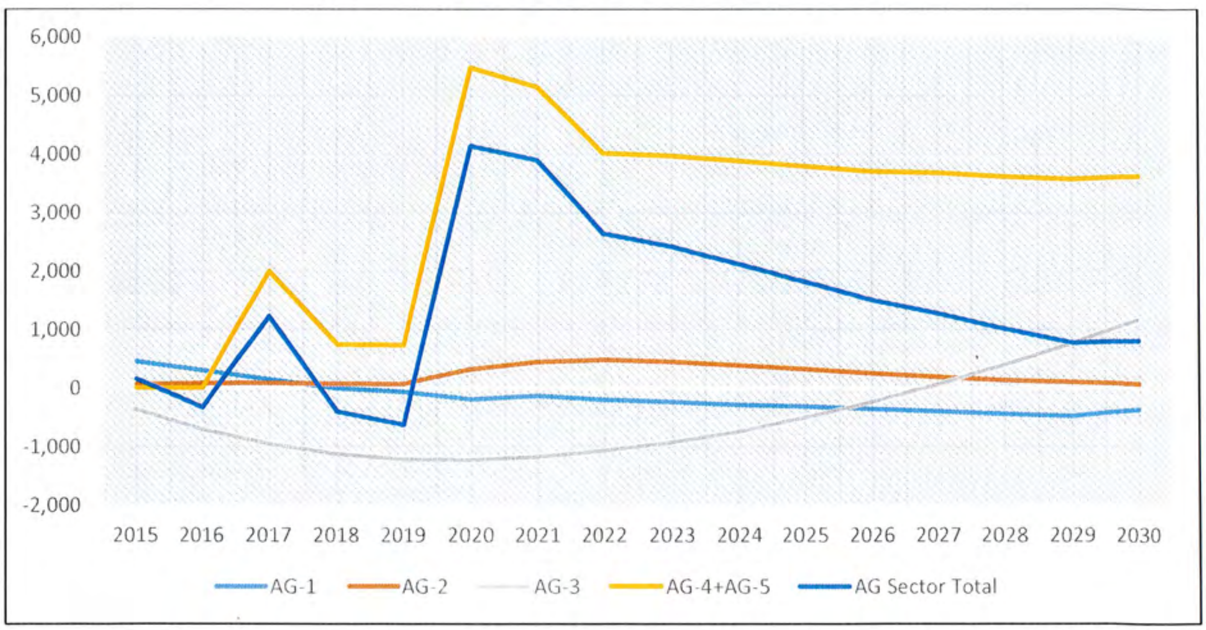
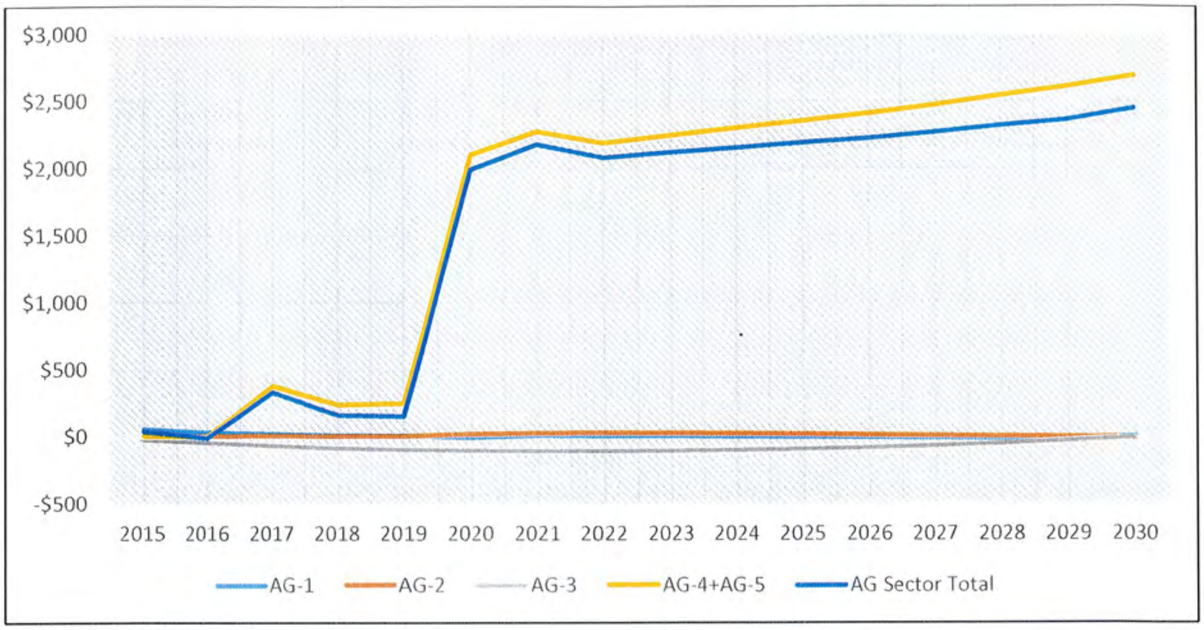


Figure F-4.9 AG Income Impacts ($2015 MM)



Graphs below show macroeconomic impacts on GSP, personal income, and employment in the final year (2030), in average (2015-2030) and cumulative (2015-2030).

Figure F-4.10 AG GSP Impacts, 2015-2030 Average Annual ($2015 MM)

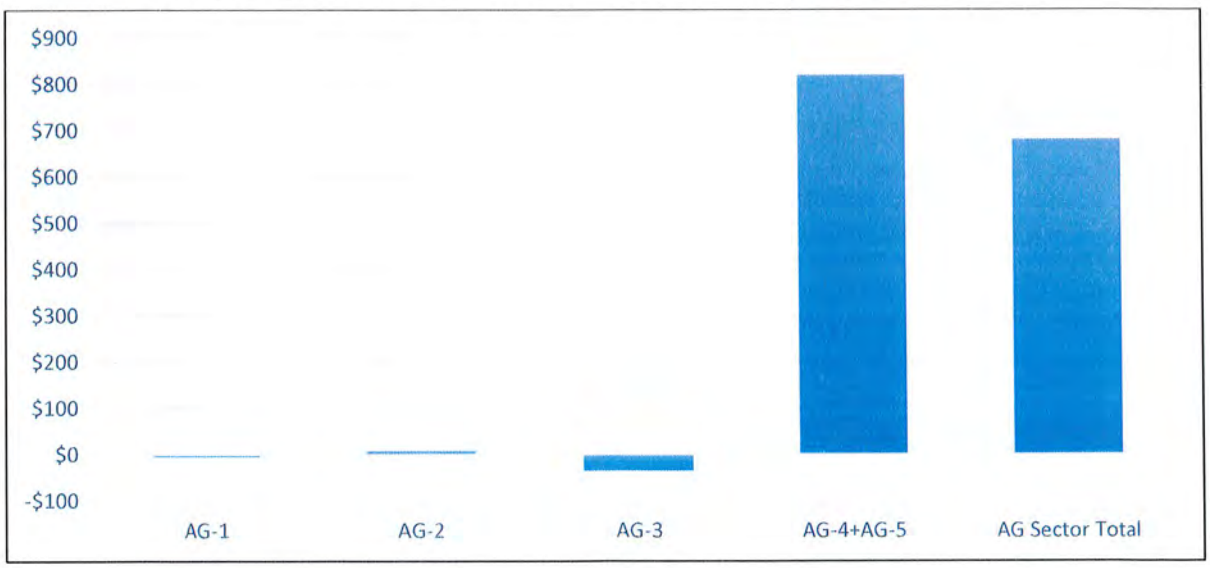


Figure F-4.11 AG GSP Impacts, 2015-2030 ($2015 MM)

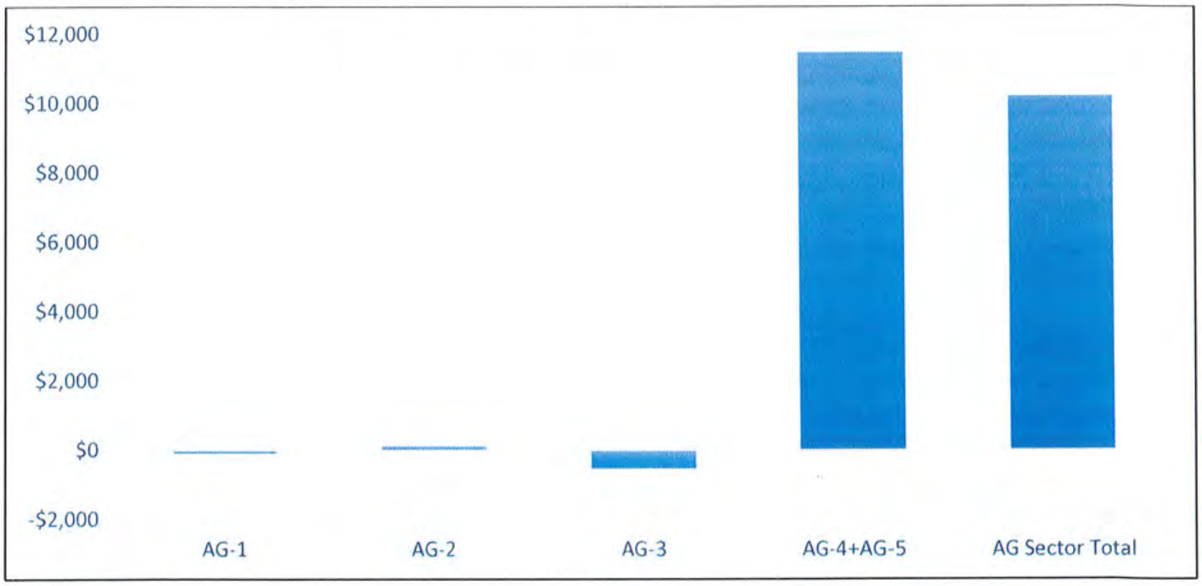


Figure F-4.12 AG GSP Impacts, Year 2030 ($2015 MM)

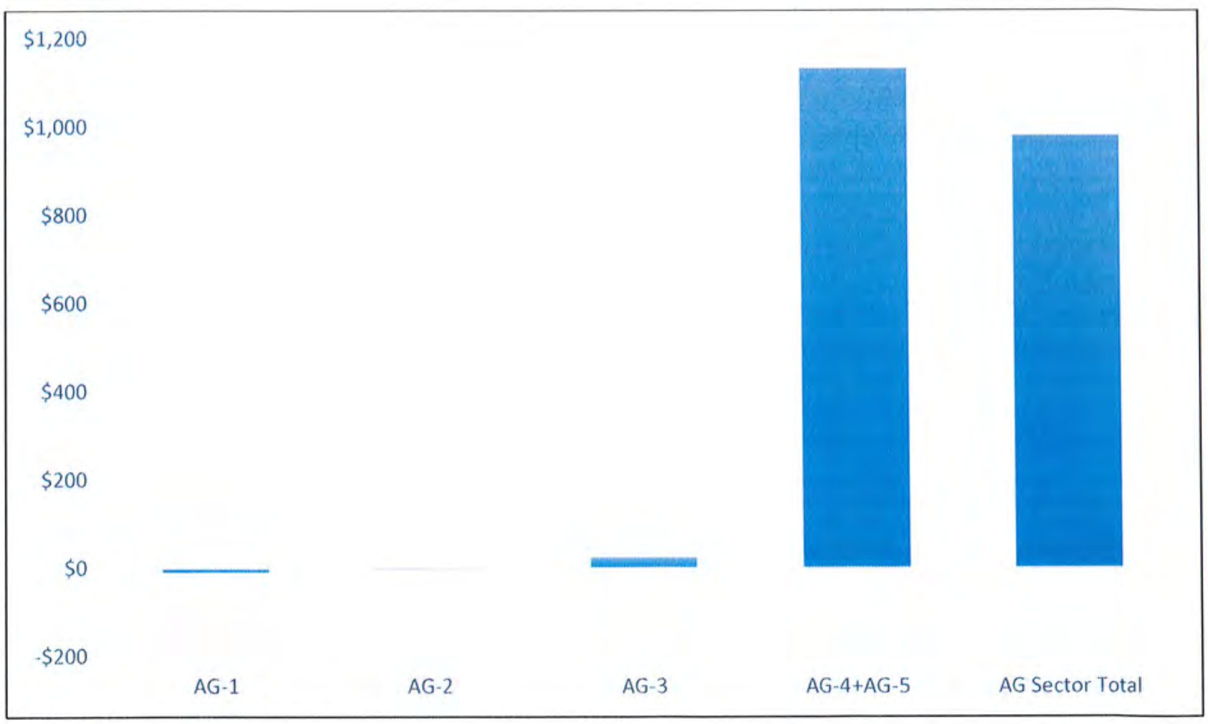


Figure F-4.13 AG Employment Impacts, Average Annual (Jobs)

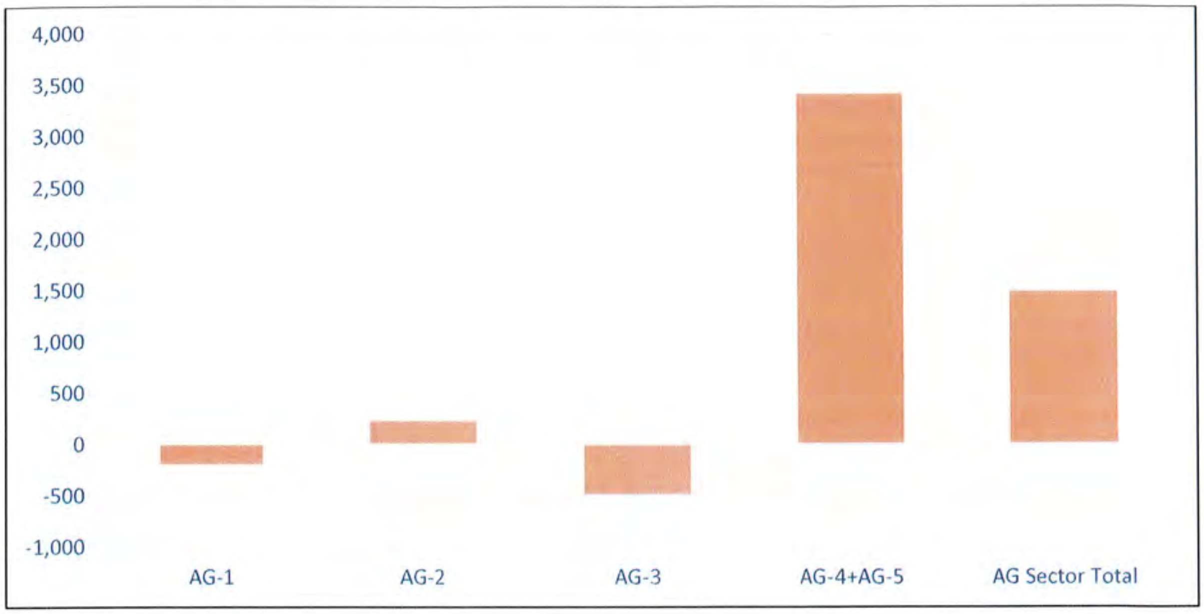


Figure F-4.14 AG Employment Impacts, 2015-2030 (Job Years)

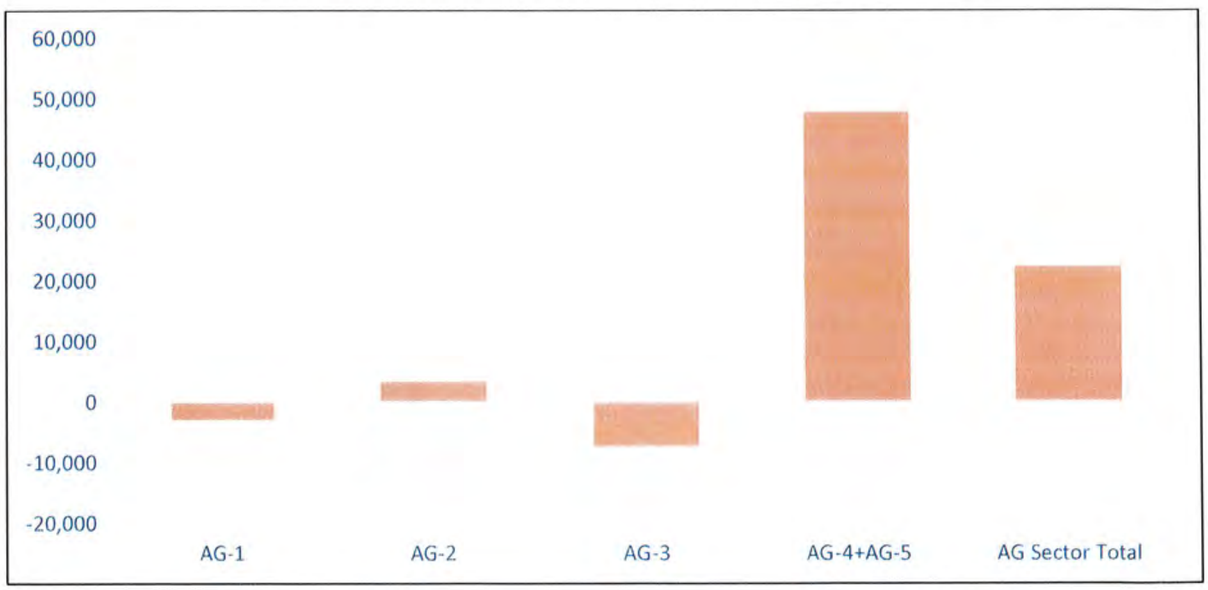


Figure F-4.15 AG Employment Impacts, Year 2030 (Jobs)

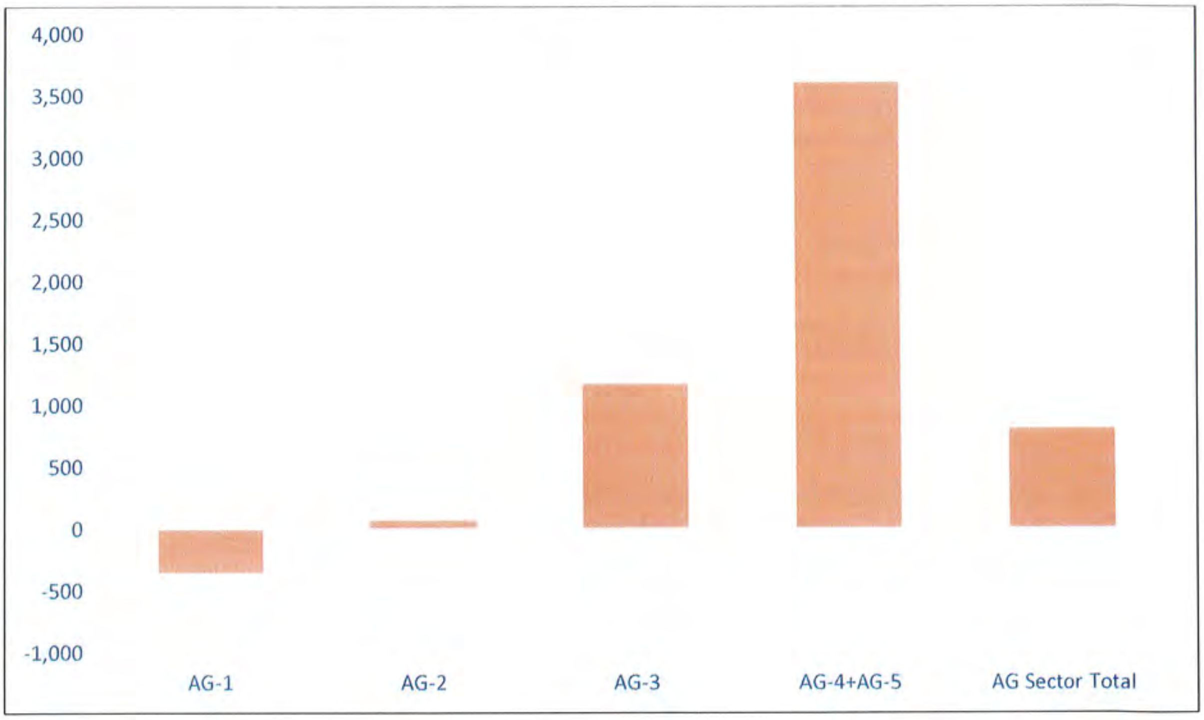


Figure F-4.16 AG Income Impacts, Average Annual ($2015 MM)

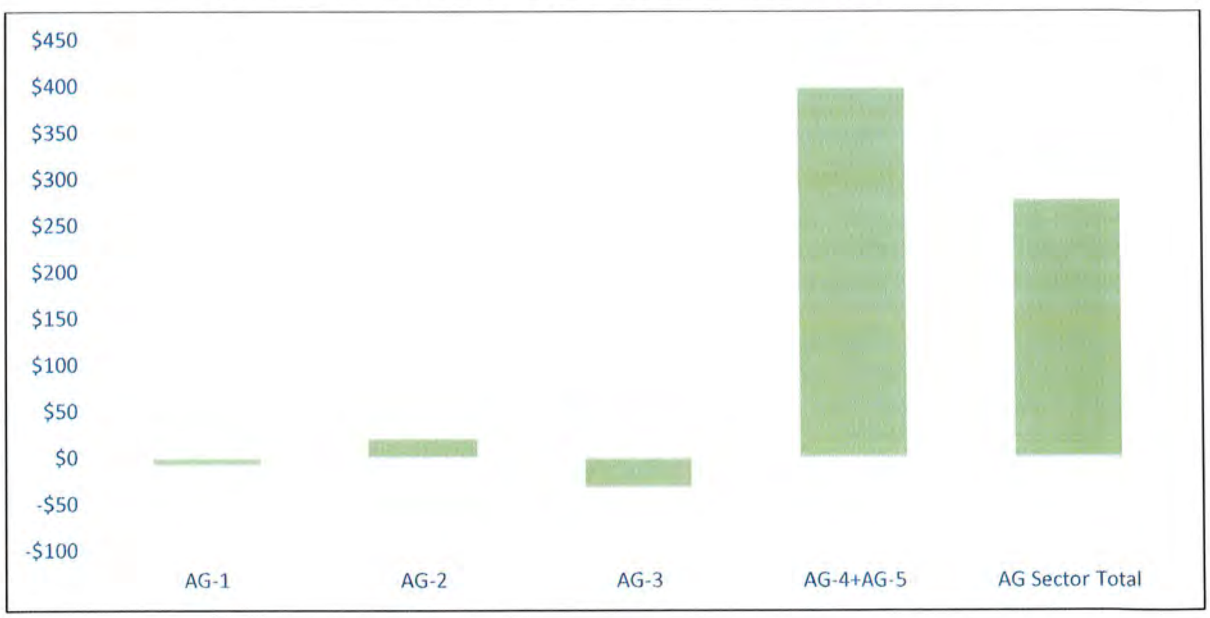


Figure F-4.17 AG Income Impacts, 2015-2030 ($2015 MM)

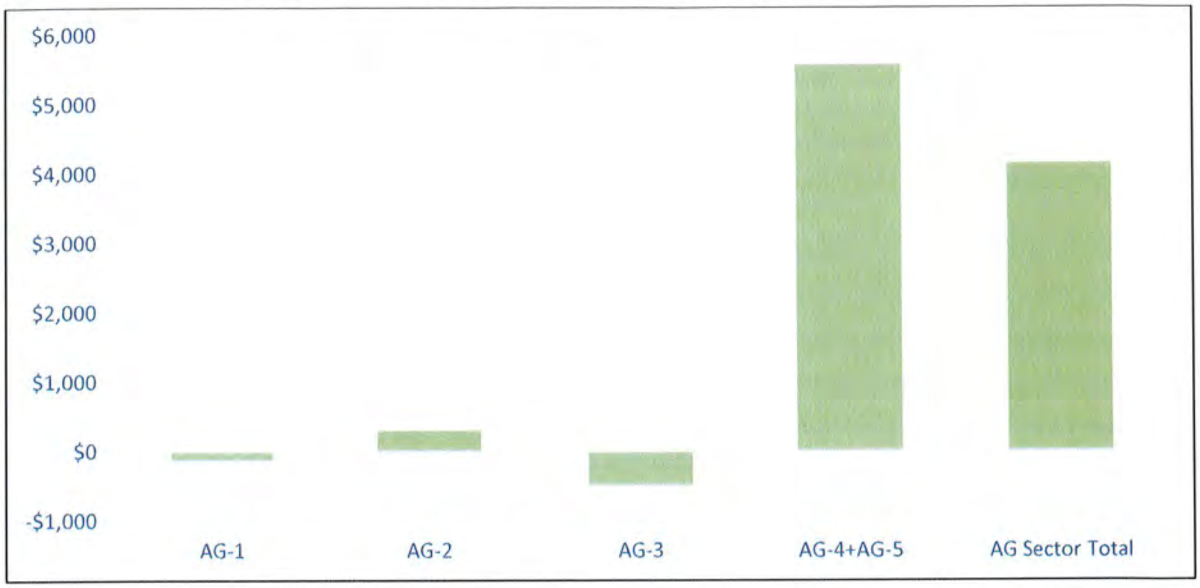
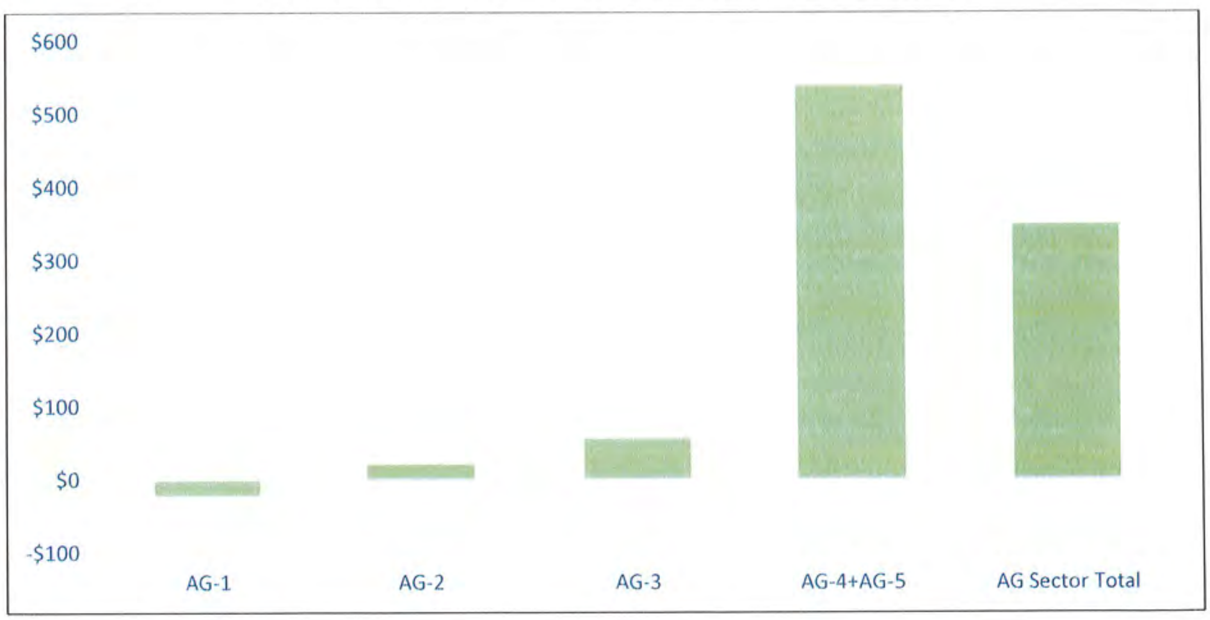


Figure F-4.18 AG Income Impacts, Year 2030 ($2015 MM)



AG-1. Nutrient Management in Agriculture

Policy Option Description

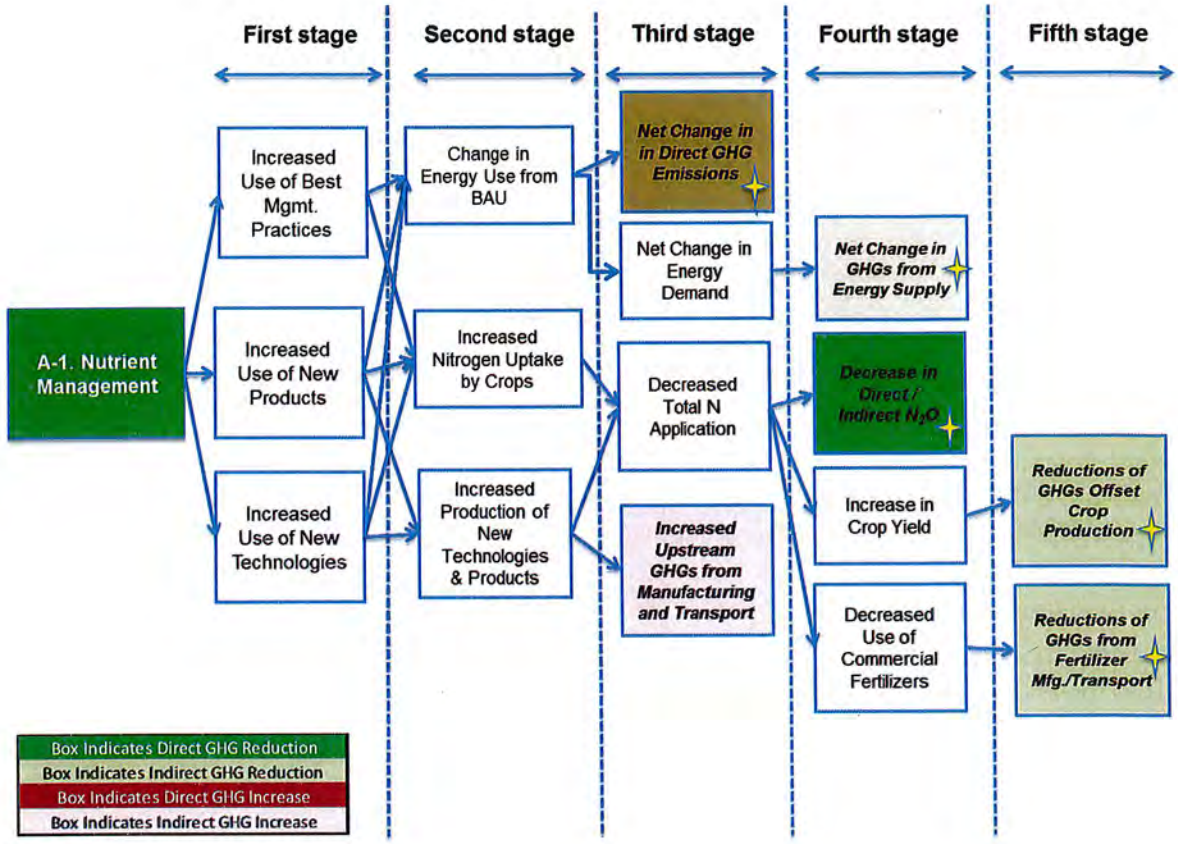
The nitrogen in inorganic and organic fertilizer (manure and plant-based) is the main GHG contributor to nitrous oxide (N_2O) emissions during crop production (N_2O has about 300 times the GHG potential as CO_2). When vegetation does not fully use nitrogen fertilizer, nitrogen can (among other things) leach into groundwater, and/or be emitted into the atmosphere as N_2O. Nitrogen management practices increase efficiency of nitrogen use, reducing nitrate leaching into groundwater and surface water and N_2O emissions. This policy option includes further development, refinement and implementation of nitrogen fertilizer Best Management Practices (BMPs), but also development and use of new technologies. This includes: improved nitrogen fertilizer products and techniques such as the "4Rs": (Right fertilizer source at the Right rate, at the Right time and in the Right place), as well as precision agriculture materials and methodology (e.g., variable fertilizer rate application, drone use, plant tissue sensors, etc.). The result of changes in the above management practices, products and techniques can be measured using Nitrogen Use Efficiency (NUE). Therefore NUE can be used as a measure of GHG reduction progress.

The reduction in leaching of nitrates to water is a co-benefit of this policy option. Upstream emission reductions associated with nitrogen fertilizer manufacturing and transport are also reduced. While commercial nitrogen fertilizers are not manufactured in Minnesota, the reduced demand will lead to reductions outside of the State's boundaries.

Causal Chain for GHG Reductions

The GHG causal chain below identifies the main policy option effects and the subsequent GHG impacts. The star symbol identifies significant GHG effects that will be analyzed. Assumptions: the overall amount of organic nitrogen (N) applied to crop fields is not affected by the overall reductions in commercial N application; N application rates will be maintained/optimized to achieve the same yields as expected under BAU conditions; except for use of new products, where an increase in yields are supported by studies in the literature. As discussed in the Estimated GHG Reductions and Net Societal Costs section below, there is still a need to gain an understanding of whether there are significant energy impacts (e.g. diesel fuel consumption) associated with the implementation each BMP (reason why the boxes are currently colored tan).

Figure F-4.19 Causal Chain for AG-1 GHG Reductions



Policy Option Design

Goals: By 2030, increase Nitrogen Use Efficiency (NUE) of Corn by 30% from projected baseline levels. In Minnesota, NUE for corn is used by Minnesota Department of Agriculture (MDA) in the Nitrogen Fertilizer Management Plan.[1]

Timing: Technological progress assumes market availability and adoption by agri-business and farmers. NUE assumes linear progression toward the 2030 goal and will be based on National Agricultural Statistics Service (NASS) production and fertilizer application data.

Parties Involved: Agricultural organizations & individual farmers, agri-business, and the agricultural community; Minnesota Association of Soil and Water Conservation Districts (SWCD), U.S. Department of Agriculture's (USDA's) Natural Resources Conservation Service (NRCS), Minnesota Department of Agriculture (MDA), Board of Water and Soil Resources

[1] Nitrogen Fertilizer Management Plan; See draft NFMP, pg 39, since it represents the major nitrogen use crop grown in MN (slightly over 8 mil. acres versus under 3 million for all other nitrogen using crops grown combined – 2013 NASS data).

(BWSR), Department of Natural Resources (DNR), University of Minnesota, USDA's Farm Service Agency (FSA), and conservation organizations.

Other: NUE is a measure of how much of the nitrogen applied is used by the crop. Since corn is the major nitrogen-using crop this is used as the representative crop for this measure. Varying definitions for NUE exist. MDA uses bushel corn per pound of N applied to calculate NUE. This has been done by using N fertilizer sales data (MDA data) & total corn yield (NASS data). Note that this method does not account for soil mineralization, or legume or manure contributions.

In general, any nitrogen management practice that increases NUE should reduce N_2O emissions on a per-acre basis, since less nitrogen is applied to the soil and available to take part in soil denitrification processes. NUE is affected by many factors including adoption of nitrogen fertilizer BMPs, new fertilizer products and technologies, use of the "4Rs", and adoption of precision agriculture.

This policy option design is based upon increasing NUE, but N_2O emissions can also be reduced by reducing the acreage of crops requiring application of nitrogen fertilizer. Policy Option designs AG-2 (Soil Carbon Management) and FOLU-5 (Conservation on Private Lands) contain goals for reducing row-crop acreage. Corn is the largest sink for N fertilizer used in Minnesota (~70% of N fertilizer used in Minnesota based on MDA personnel conversations). The CSEO crop production baseline assumes growth from around 7.4 million acres of grain corn planted in 2010 to over 7.8 million acres planted in 2030. Conversion of corn acres to low/no nitrogen fertilizer input perennial vegetative cover would most significantly reduce the amount of N fertilizer applied. Each acre of corn taken out of production and converted to grassland would provide a reduction of N input of about 140 lbs/acre (statewide average, N fertilizer applied to corn).[2]

Cover crops are another strategy to reduce N_2O emissions. Cover crops take up, or "scavenge," nitrogen. Cover crops are included in the AG-2 policy option design.

Implementation Mechanisms

MDA developed the following Implementation Mechanisms with applicable acres for modeling consideration. The modeling of GHG reductions and costs documented in a separate subsection below was conducted just for the nitrification inhibitors and precision agriculture components. That assessment indicated that additional implementation measures would be needed in order to reach the goals of the policy option. MDA believes that carrying out the implementation measures below would achieve the 2030 goal of 30% increase in corn NUE and a corresponding reduction in N_2O.

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[2] (See - MDA 2009 survey data; MDA -2010 survey data –these surveys provide information of N fertilizer type use and timing as well). This policy overlaps with policies AG-2 & FOLU-5 vegetative cover and cover crop factors. Perennial vegetative cover (hay, grazing land, working grasslands, biofuel crops, set-aside, and others that would be low N use vegetation would fit in this category) that replaces corn will in many cases eliminate N fertilizer use on those acres. Cover crops also have the potential to increase NUE through mechanisms such as increased soil storage and change in mineralization, although this will not be quantified in this policy design.

Implementation Measures

Reduced N fertilizer rate on corn following manure and legume

- MDA survey data has shown that there is an opportunity to reduce N fertilizer application to corn BMP recommendations for years following a legume or manure application.
- It is assumed that this mechanism applies to about 25% of corn acres. (Based on NASS & MDA Surveys – percentage of corn acres with manure applied.)

Potential that commercial N fertilizer use can be reduced by 40 lbs N/ac on 1.5 million acres

- Use of nitrification inhibitors (NI) and urease inhibitors and other N enhancement products - This has limited application; in Minnesota. A large portion of farmers incorporate N fertilizer, and spring apply. NI/urease use would mostly apply to south-central Minnesota, and use on course textured soils. It is estimated (based on MDA records of sales data) that 1.2 M acres of corn currently use Nitrapyrin (N-serve, Instinct). MDA only tracks 2 of these products, so use for all products will be higher. This mechanism could include use of all N enhancement products. Ex: (all nitrapyrin= N-serve, Instinct, DCD=AgrotainPlus, SuperU, Guardian), Urease inhibitors (Agrotain, Nutrisphere etc.) or both, and coated products (ESN).
- Note: Use of inhibitor and microbial products will likely result in decreased N fertilizer rate as well however this is not quantified. (A farmer has a fixed cost for N product, and will balance of cost of N fertilizer≥ cost of inhibitor/microbial product.)
- Note: Also it appears that there is significant industry effort around soil amendment products for microbials. However, this is not included since the efficacy and impact of these new technologies are unknown.

Potential for use of NI/urease products is applicable to 1 million acres.

- Precision agriculture: For this project, this is defined to include in field geographic positioning systems (GPS)/ geographic information system (GIS) technology (Ex. auto-steer) and variable rate fertilizer nitrogen (N) application.
- This mechanism is additive; it will increase incrementally as well as overlap (Ex. GPS and variable rate technology [VRT] is used)
- Increased Use of GPS: Automatic steering to prevent row overlap, and other variability based on site conditions (Hedley, 2014). Research has shown that the use of GPS alone can increase efficiency by five to ten percent. Combine the GPS technology with GIS prescription maps and the efficiency can increase an additional 10 – 20%. Various sources indicate that GPS technology is used by 30-50% of farmers; 50% is assumed.

Potential for N fertilizer reduction of 10% (15lbs/acre using average N application rate of 145lbs/ac.) applies to 3.5 million acres.

- VRT fertilizer application –This can include N fertilizer application based on; soil mapping unit, field conditions (Ex. wetness), fertigation (soil grid sampling in Minnesota), corn variety or other criteria. Agvise Laboratories information indicates 80% of farmers they worked with used soil grid sampling in Minnesota. Fertilizer and Manure Selection and Management Practices Associated with Minnesota's 2010 Corn and Wheat Production publication notes variable rate N application use of 24% use statewide. MDA 2011 Corn Production survey indicates 20-25% may variable rate apply N fertilizer. Assume currently a 50% adoption rate.

Assumed VRT is applied to 4 million corn acres.

- Change from fall to spring application of N: Some research indicates switch for fall to spring N application will reduce N_2O.[34] This will apply in limited areas where N fertilizer BMPs do not recommend fall application. Fertilizer and Manure Selection and Management Practices Associated with Minnesota's 2010 Corn and Wheat Production document notes 32% application of some N in fall statewide (mostly MAP & DAP), while ~ 10% fall apply urea.; 18% fall apply AA. The Survey of Nitrogen Fertilizer Use on Corn in Minnesota, by Bierman etal indicates about 32.5% of main N application in fall)

Potential for change from fall to spring application of N applicable to one million acres:

- Tissue/meters & soil N testing: Tissue testing for crop N needs and a reliable soil N test are emerging technologies that may lead to an increase in NUE (In western Minnesota, soil N testing is used). Currently, it is not known if these will prove effective statewide. Assume that one of these technologies (or a combination thereof) will be applied to corn acres (use 7 M). Assume that this will lead to a reduction of N fertilizer application amount. (This could mean an overall reduction in N applied, or increased NUE due to increased plant uptake.)
- This will lead in direct reductions in N applied as well as increase N uptake based on resulting crop needs (better timing –when the crop needs; better placement – at corn roots).
- MDA 2011 Corn Production document notes about 10% of acres use tissue or basal testing, and about 10% use deep N soil test.

Potential for application of tissue/meters & soil N testing on seven million acres:

MDA chose for consideration the implementation mechanisms discussed above because they have the greatest likelihood of increasing NUE, and are actions that can be taken by the state. NUE may also be increased through other means that were not included in this policy option

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[3] *Influence of fertilizer nitrogen source and management practice on N_2O emissions from two Black Chernozemic soils* D L Burton, Xinhui Li, C A Grant

[4] *Nitrous oxide emissions from an irrigated soil as affected by fertilizer and straw management* X. Hao, C. Chang, J.M. Carefoot, H.H. Janzen, B.H. Ellert)

design either because they were deemed less effective than the above mechanisms, or they were actions that would likely be taken by the private sector (e.g., improved plant genetics).

Related Policies/Programs in Place and Recent Actions

Existing Programs and funding that address NUE and reducing N_2O emissions.

- Note: None of these programs has reducing N_2O emissions as a stated goal, and may not specify increasing NUE either. These programs goals are to increase water quality, increase nitrogen fertilizer management, increase "conservation cover," etc.; which implicitly provide N_2O reduction as well (though results may vary).
- Note: programs and associated cost related to perennial cover will be done with the AG-2 and FOLU-5 policies.

The Nutrient Management Initiative (NMI) and BMP Challenge work directly with farms to try variable N fertilizer rates and methodologies that will result in an increase in NUE.

Assumed annual Cost $100,000/year (from 2012 budget information – includes federal dollars).

Agriculture Fertilizer Research and Education Council
AFREC[5] funds a broad range of research activities including nitrogen fertilizer related. An annual expenditure of ~$800,000 has been allocated recently. *Assumed $200,000 annually for N related research*

Clean Water Funded research and technical assistance – funds various research activities and on-the-ground studies that promote clean water. Some research/technical assistance nutrient management activities will benefit N_2O as well. Approximately $5 million is available annually ($3M TA, $2.1M research). *Assumed $1 million annually will have a direct relationship to N_2O GHG emissions.*

N Management Education - MDA, University of Minnesota and others annually host and collaborate with; nutrient management related field days, conferences, presentations, and/or provide information (booths, handouts, etc.) to educate farmers and agriculture industry representatives about N management. *Assumed estimated annual cost: $100,000*

Annual N Surveys - MDA conducts surveys of Minnesota farmers' N use and management practices. This is important to track current conditions and progress in increasing NUE. *Assumed estimated annual cost: $100,000*

Others Considered:

The above are programs most likely to indirectly address N_2O emissions. Other public investment not quantified includes:

- MDA Clean Water Fund Activities,

[5] http://www.mda.state.mn.us/chemicals/fertilizers/afrec/researchprojects.aspx

- Significant research and demonstrations are already occurring related to nitrogen fertilizer management, including University of Minnesota research stations, MDA demonstration sites, and information and education activities,
- N fertilizer BMP research and field trials by University of Minnesota & other academic institutions,
- Other technical and financial assistance for nutrient management practices through programs such as USDA Conservation Programs; - (EQIP, CSP, RCPP, CRP, CREP, ACEP) BWSR Grant and Easement Programs, state cost share, and RIM,
- Minnesota Agricultural Water Quality Certification Program (MAWQCP),
- Nitrogen Fertilizer Management Plan,
- Minnesota Nutrient Reduction Strategy,
- MDA cover crop initiatives and research grants (including Clean Water Fund-supported research),
- University of Minnesota Nitrogen Fertilizer BMPs,
- Natural Resources Conservation Service (NRCS) nutrient management programs – technical assistance and cost share,
- Watershed Restoration and Protection Strategy (WRAPS)[6] & Total Maximum Daily Loads (TMDLs), and
- Local initiatives for cover crop adoption, alternative crop development, and nutrient management (e.g., 'Third Crop Initiative" of Blue Earth River Basin Initiative).

Estimated Policy Impacts

Direct Policy Impacts

Table F-4.4 Estimated Net GHG Reductions and Net Costs or Savings

2030 GHG Reductions (MMt CO_2e)	2015 – 2030 Cumulative Reductions (MMt CO_2e)	Net Present Value of Societal Costs, 2015 – 2030 ($2014)	Cost Effectiveness ($2014/ tCO_2e)
0.37	2.8	-$131	-$46

Note: Each policy option analysis was done over a fifteen-year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

The GHG reductions summarized above represent full energy-cycle reductions for the policy option, which include reductions of upstream emissions that may occur outside of Minnesota.

[6] http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/watershed-approach/index.html

For comparison, emission reductions that can be specifically allocated to occur within the State are 0.14 MMt CO_2e in 2030 and 1.1 MMt CO_2e cumulatively from 2015 to 2030.

Data Sources

Key data sources are referenced within the discussion of Quantification Methods below and include:

- N application reductions for a variety of precision agriculture (PA) approaches: *Greenhouse Gas Mitigation Potential of Agricultural Land Management in the United States, A Synthesis of the Literature*, Technical Working Group on Agricultural Greenhouse Gases (T-AGG) Report, Nicolas Institute for Environmental Policy Solutions, Duke University, January 2012[7].

Quantification Methods

There is not one major item that contributes to NUE, but rather several additive components that result in the NUE metric. There are many factors that contribute to NUE. The research on these various NUE components is variable as to N_2O reductions provided. The approach used in this policy option design was to determine BAU and future conditions in aggregate. The analysis documented here corresponds to an earlier analysis that used only two of the implementation mechanisms described above: precision agriculture (PA) defined as a combination of two technologies, GPS and VRT N application; and the use of NI.

- BMPs that are most applicable to Minnesota, and approximate applicable acres are described under the Implementation Mechanisms section. The first of these is continued State outreach programs aimed at reducing N application following manure application or legumes. MDA estimates that 40 lb. N/acre of synthetic fertilizer can be reduced via this mechanism on 1.5 Minnesota acres. Timing of this mechanism was assumed to be linear beginning in 2015 and reaching its full potential by 2024.
- To estimate GHG reductions of the full suite of implementation mechanisms, the approach used here was to first estimate the amount of N reduction required to meet the requirements of the policy option design (30% NUE increase by 2030). Then, based on these expected N application reductions, the quantity of N_2O reductions was determined using emission factors from the baseline. Literature sources were used to determine the upstream reductions associated with reduced commercial fertilizer demand (e.g. from the T-AGG study). Information from the literature was not clear on the potential net change in diesel consumption associated with application the BMPs analyzed, so it was assumed that no change in diesel consumption was expected between BAU and the Policy Option Scenario.
- New Products: for NI, one literature source suggests an N application reduction of 20%[8]; this fraction was be used along with BAU emission factors to determine N_2O reductions

[7] http://nicholasinstitute.duke.edu/sites/default/files/publications/ni_r_10-04_3rd_edition.pdf.

[8] Laboski (2006) economic analysis of NI on corn; http://www.soils.wisc.edu/extension/wcmc/2006/pap/Laboski1.pdf.

and upstream commercial fertilizer manufacturing/transport reductions. Literature sources (Laboski, 2006) suggest a yield increase of 4-6% using NI. The increase in yield was included within the estimation of net societal costs (described below) for the Policy Option Scenario.

- New Technologies: referred to as Precision Agriculture (PA); assumes some combination of yield monitors (including tractor-mounted geographical information system), soil sampling, and variable rate N application; previous studies (T-AGG) suggest a N application reduction of ~15%. This value was applied to the acres specified for PA and the same baseline N_2O emission factors applied.

Table F-4.5 below provides a summary of the Policy Option Scenario results for N application reductions and the associated N_2O reductions for the policy option.

Net Societal Costs:

The cost elements of the policy option are summarized below:

- BAU avoided costs: through application of policy option mechanisms (e.g. NI application or PA), there can be cases where the change in practice will remove some production cost that would have occurred otherwise. No avoided costs (other than reduced N fertilizer costs) were identified for this analysis.
- All Policy Option Scenario costs are presumed to be incremental to BAU and are some combination of capital, non-fuel operations/maintenance costs, fuel costs, and material costs. Cost reductions for all expected commercial N reductions are based on USDA ERS fertilizer cost data[9]. Fertilizer prices are escalated based on the historical growth in N fertilizer pricing from 2008 to 2012 (0.4%). Note that going back one year to 2007 would have resulted in a much higher growth rate of over nine percent. Based on recent and expected pricing on natural gas (the major feedstock for N fertilizer), the much smaller growth rate appears to be much more in line with expectations.
- Incremental costs of new products (e.g., a cost for the nitrification inhibitor, Nserve) at \$7.75/acre (Laboski, 2006) is used, and the corresponding reduction (offset) of commercial fertilizer costs is also calculated.
- Incremental costs of new technologies: studies suggest PA costs of \$8-12/acre with about half of these costs associated with enhanced soil sampling.[10] Currently, it is unclear to what extent these new technologies change BAU energy use (so no change in fuel costs is factored into the analysis).

Table F-4.7 provides a summary of the net societal cost results. The estimated cost effectiveness is -\$46/tCO_2e, indicating a net societal cost savings. A key assumption here is that implementation mechanism #1 (Minnesota technical outreach programs) to farmers is

[9] http://www.ers.usda.gov/Data/FertilizerUse/s/Table8.xls.

[10] http://www.cnie.org/NLE/CRSreports/Agriculture/ag-97.cfm;
http://www.plantmanagementnetwork.org/pub/cm/research/2005/precision/;
http://www.cdfa.ca.gov/is/docs/01-0507Plant%2007.pdf.

successfully applied and reaches its objectives of N reductions on 1.5 MM acres of corn. Another key assumption is that the estimated program costs (which address all state support for the policy option) are sufficient to successfully achieve the overall policy option goals.

Table F-4.5 GHG Impacts Summary - BAU Energy & Emissions

Year	Grain Corn N Use Efficiency (NUE) bu/lb N	MN Grain Corn Production bu	Comm. N Applied lb N	N_2O Emissions tCO_2e	Targeted PA/NI Cropland Harvested Acres	Diesel Fuel Use TJ	Diesel Fuel Use tCO_2e
2015	1.37	1,297,029,358	946,736,758	702,060	7,899,083	12,236	853,158
2016	1.41	1,275,475,229	904,592,361	670,607	7,669,725	11,903	829,947
2017	1.45	1,260,682,569	869,436,254	643,760	7,486,239	11,640	811,616
2018	1.50	1,260,761,468	840,507,645	625,200	7,394,495	11,519	803,175
2019	1.54	1,276,289,908	828,759,681	614,529	7,394,495	11,530	803,928
2020	1.59	1,291,818,349	812,464,370	603,858	7,394,495	11,552	805,433
2021	1.61	1,315,456,881	817,053,963	607,604	7,440,367	11,645	811,944
2022	1.63	1,331,081,651	816,614,510	607,604	7,440,367	11,656	812,702
2023	1.65	1,346,706,422	816,185,710	607,604	7,440,367	11,678	814,217
2024	1.67	1,366,051,376	817,994,836	607,604	7,440,367	11,699	815,732
2025	1.68	1,375,528,702	818,767,085	606,534	7,427,261	11,700	815,807
2026	1.70	1,391,125,950	818,309,382	606,534	7,427,261	11,711	816,563
2027	1.72	1,406,723,198	817,862,324	606,534	7,427,261	11,733	818,075
2028	1.74	1,422,320,446	817,425,544	606,534	7,427,261	11,755	819,587
2029	1.76	1,437,917,693	816,998,689	606,534	7,427,261	11,766	820,343
2030	1.78	1,453,514,941	816,581,428	606,534	7,427,261	11,787	821,855
Sum		**21,508,484,141**	**13,376,290,541**	**9,929,635**		**187,511**	**13,074,081**

Table F-4.6 GHG Impacts Summary - Policy Option Scenario Energy & Emissions

	Policy Option Scenario Energy & Emissions				Net Change			
Year	Grain Corn N Use Efficiency (NUE) bu/lb N	Increased Grain Corn NUE Over BAU %	Commercial N Applied lbs N	N_2O Emissions tCO_2e	Change in Commercial N Applied lbs N	N_2O Emissions tCO_2e	Net In-State GHG Reductions MMt CO_2e	Out-of-State GHG Reductions MMt CO_2e
2015	1.42	3.9%	911,219,164	676,830	(35,517,594)	(25,230)	(0.025)	(0.043)
2016	1.48	4.7%	863,674,993	641,516	(40,917,368)	(29,091)	(0.029)	(0.049)
2017	1.53	5.5%	823,867,840	611,948	(45,568,414)	(31,812)	(0.032)	(0.055)
2018	1.58	5.6%	796,136,315	591,350	(44,371,331)	(33,850)	(0.034)	(0.054)
2019	1.64	6.3%	779,651,746	579,105	(49,107,935)	(35,424)	(0.035)	(0.059)
2020	1.69	6.3%	764,208,678	567,635	(48,255,693)	(36,223)	(0.036)	(0.058)
2021	1.74	8.3%	754,362,244	560,321	(62,691,719)	(47,283)	(0.047)	(0.076)
2022	1.80	10.3%	740,641,916	550,130	(75,972,594)	(57,474)	(0.06)	(0.092)
2023	1.85	12.2%	727,713,402	540,527	(88,472,308)	(67,077)	(0.07)	(0.11)
2024	1.90	14.0%	717,463,958	532,914	(100,530,878)	(74,690)	(0.07)	(0.12)
2025	1.96	16.5%	702,732,554	521,972	(116,034,530)	(84,562)	(0.08)	(0.14)
2026	2.01	18.3%	691,827,109	513,872	(126,482,274)	(92,662)	(0.09)	(0.15)
2027	2.06	20.0%	681,485,902	506,190	(136,376,423)	(100,343)	(0.10)	(0.16)
2028	2.12	21.7%	671,666,248	498,897	(145,759,296)	(107,637)	(0.11)	(0.18)
2029	2.17	23.4%	662,329,661	491,962	(154,669,029)	(114,572)	(0.11)	(0.19)
2030	2.31	30.0%	628,139,560	466,566	(188,441,868)	(139,968)	(0.14)	(0.23)
Sum			**11,917,121,287**	**8,851,734**	**(1,459,169,253)**	**(1,077,901)**	**(1.1)**	**(1.8)**

Table F-4.7 Net Societal Costs Summary

	Policy Option Scenario Costs (all incremental to BAU)								Net Costs		
Year	Cumulative Precision Ag (PA) Variable Rate Timing (VRT) Use	Cumulative Nitrification Inhibitor (NI) Use	PA Total Annualized Costs	NI Total Annualized Costs	N Fertilizer Savings	NI Yield Increase	MN Program Costs	Federal Incentives	Total Policy Option Costs	Total Discounted Policy Option Costs	Cost Effectiveness
	Acres	Acres	MM$	MM$	MM$	MM$	MM$	MM$	MM$	MM$2014	$2014/tCO₂e
2015	436,835	982,880	$5.2	$9.3	($11)	($15)	$1.5	$0.0	($11)	($10)	
2016	417,615	991,836	$5.0	$10	($13)	($16)	$1.5	$0.0	($13)	($12)	
2017	387,948	974,087	$4.8	$10	($15)	($16)	$1.6	$0.0	($15)	($13)	
2018	278,886	741,582	$3.5	$7.5	($14)	($13)	$1.6	$0.0	($15)	($12)	
2019	254,035	716,742	$3.3	$7.4	($16)	($13)	$1.6	$0.0	($17)	($13)	
2020	157,920	473,759	$2.1	$5.0	($16)	($9.2)	$1.7	$0.0	($16)	($12)	
2021	226,628	829,859	$3.0	$8.9	($21)	($17)	$1.7	$0.0	($24)	($17)	
2022	486,592	986,700	$6.6	$11	($25)	($21)	$1.7	$0.0	($27)	($18)	
2023	910,589	982,770	$13	$11	($29)	($22)	$1.8	$0.0	($26)	($17)	
2024	1,305,643	979,232	$18	$11	($33)	($22)	$1.8	$0.0	($24)	($15)	
2025	2,310,490	974,738	$33	$11	($39)	($23)	$1.8	$0.0	($15)	($8.7)	
2026	2,998,280	963,733	$44	$11	($42)	($23)	$1.9	$0.0	($8.1)	($4.5)	
2027	3,592,117	996,443	$54	$12	($46)	($25)	$1.9	$0.0	($2.7)	($1.4)	
2028	4,199,167	994,540	$64	$12	($49)	($25)	$1.9	$0.0	$3.9	$2.0	
2029	4,818,405	960,631	$75	$12	($52)	($25)	$2.0	$0.0	$12	$5.6	
2030	6,951,111	993,016	$111	$13	($64)	($27)	$2.0	$0.0	$34	$16	
Sum			**$446**	**$162**	**($487)**	**($313)**	**$28**	**$0**	**($16 4)**	**($131)**	**($46)**

The estimated cost effectiveness value is -$46/tCO2e reduced. This value is derived by dividing the total cumulative policy option reductions in Table F-4.6 (1.8 MMt) into the net present value (NPV) of policy option costs (-131 million 2014 dollars) shown in Table F-4.7. These estimated costs are sensitive to the relative amount of N reduction expected from the relatively low cost NI implementation mechanism versus the more expensive PA mechanism. The current estimates show that by limiting the incremental NI use to ~1 million acres total requires nearly 11 million acres of PA to be applied to corn, which exceeds the expected future grain corn area in 2030 (about 7.4 million acres of which about 1.7 million acres are expected to have already adopted some form of PA by 2030). This suggests that other implementation mechanisms will need to be analyzed and applied and/or more NI acreage will be needed. Examples of other implementation mechanisms are provided in the Implementation Mechanisms section above.

Key Assumptions

Key assumptions include the build-up of total N application reductions (and NUE increase) that can be achieved by the practices/technologies envisioned. Individually applied, the methods would be expected to achieve a 10-20% reduction in N application, which would be translated directly into N_2O reductions using baseline emission factors. To achieve the total 30% NUE, these methods would need to be layered over one another (i.e. more than one implementation mechanism may be used on the same acres). Other key assumptions:

- Precision Ag. (PA) techniques (GPS, GIS, soil grid sampling, etc.) would reduce nitrogen fertilizer use 15%.
- Use of nitrification inhibitor products would reduce nitrogen fertilizer use 20%.
- Use of NI products would increase yield 2.9%, while PA techniques would result in zero percent yield increase.
- Use of NI products or PA techniques would not result in a change (increase or decrease) in tillage, planting, or harvesting (i.e. change in 'in field effort', fuel use, equipment...).
- N fertilizer prices would increase by 0.4% annually.

Additional background references:

- http://www.usda.gov/oce/climate_change/estimation.htm;
- http://www.usda.gov/oce/climate_change/Quantifying_GHG/USDATB1939_07072014.pdf - start with Chapter 3
- Venterea R.T., A.D. Halvorson, N. Kitchen, M.A. Liebig, M.A. Cavigelli, S.J. Del Grosso, P.P. Motavalli, K.A. Nelson, K.A. Spokas, B.P. Singh, C.E. Stewart, A. Ranaivoson, J. Strock, and H. Collins, Challenges and opportunities for mitigating nitrous oxide emissions from fertilized cropping systems, Frontiers in Ecology and the Environment 2012 10:10, 562-570
- American Carbon Registry (2013), American Carbon Registry Methodology for N2O: Emission Reductions through Changes in Fertilizer Management, Version 2.0., Winrock International, Little Rock, Arkansas.

- Climate Action Reserve (2013), Nitrogen Management Project Protocol, Version 1.1, Los Angeles, CA
- Physiological perspectives of changes over time in maize yield dependency on nitrogen uptake and associated nitrogen efficiencies: A review.- http://www.sciencedirect.com/science/article/pii/S0378429012001013
- Haegele, J.W., K.A. Cook, D.M. Nichols, and F.E. Below. 2013. Changes in nitrogen use traits associated with genetic improvement for grain yield of maize hybrids released in different decades. Crop Sci. 53:1256-1268.
- Abendroth, L.J., R.W. Elmore, M.J. Boyer, and S.K. Marlay. 2011. Corn growth and development. PMR 1009. Iowa State University Extension and Outreach, Ames, Iowa.
- Nitrous oxide emissions in Midwest US maize production vary widely with band-injected N fertilizer rates, timing and nitrapyrin presence. http://iopscience.iop.org/1748-9326/8/3/035031/
- Nitrapyrin Impacts on Maize Yield and Nitrogen Use Efficiency with Spring-Applied Nitrogen: Field Studies vs. Meta-Analysis Comparison. https://www.agronomy.org/publications/aj/abstracts/106/2/753
- Nitrification Kinetics and Nitrous Oxide Emissions when Nitrapyrin is Coapplied with Urea–Ammonium Nitrate - https://dl.sciencesocieties.org/publications/aj/abstracts/105/6/1475
- Nitrogen fertilizer management for nitrous oxide (N_2O) mitigation in intensive corn (Maize) production: an emissions reduction protocol for US Midwest agriculture - http://link.springer.com/article/10.1007%2Fs11027-010-9212-7
- Mulla, D.J. 2013. Twenty five years of remote sensing in precision agriculture: key advances and remaining knowledge gaps. Biosystems Engineering. 114:358-371.
- Hedley, C. 2014. The role of precision agriculture for improved nutrient management on farms. J. Sci. Food and Agric. doi: 10.1002/jsfa.6734.
- David Mulla (Director of the University of Minnesota Precision Agriculture Center http://www.precisionag.umn.edu/); from: http://www.startribune.com/business/259320921.html

Macroeconomic (Indirect) Policy Impacts

Table F-4.8 AG-1 Macroeconomic Impacts on GSP, Employment and Income

Scenario	GSP ($2015 MM)			Employment (Individual)			Personal Income ($2015 MM)		
	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)
AG-1	-$9	-$5	-$73	-360	-200	-2,960	-$22	-$8	-$125

Graphs below show detail in GSP, employment and personal income impact of the AG-1 policy.

Figure F-4.20 AG-1 GSP Impacts ($2015 MM)

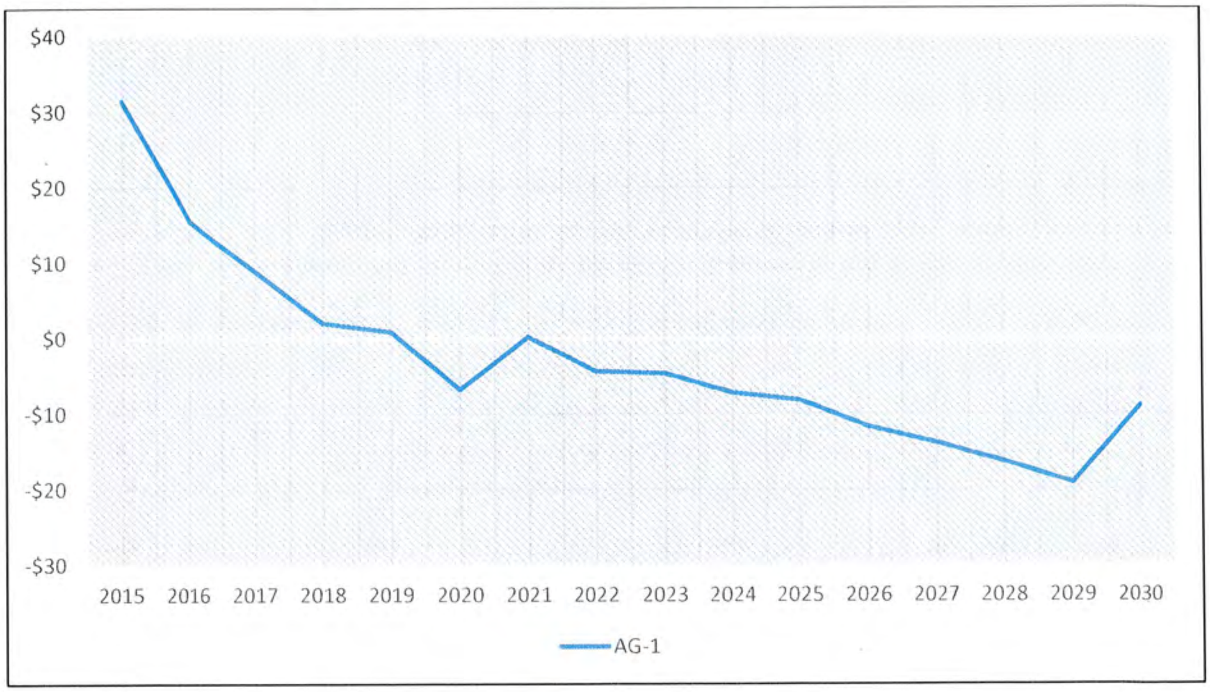


Figure F-4.21 AG-1 Employment Impacts (Individual Jobs)

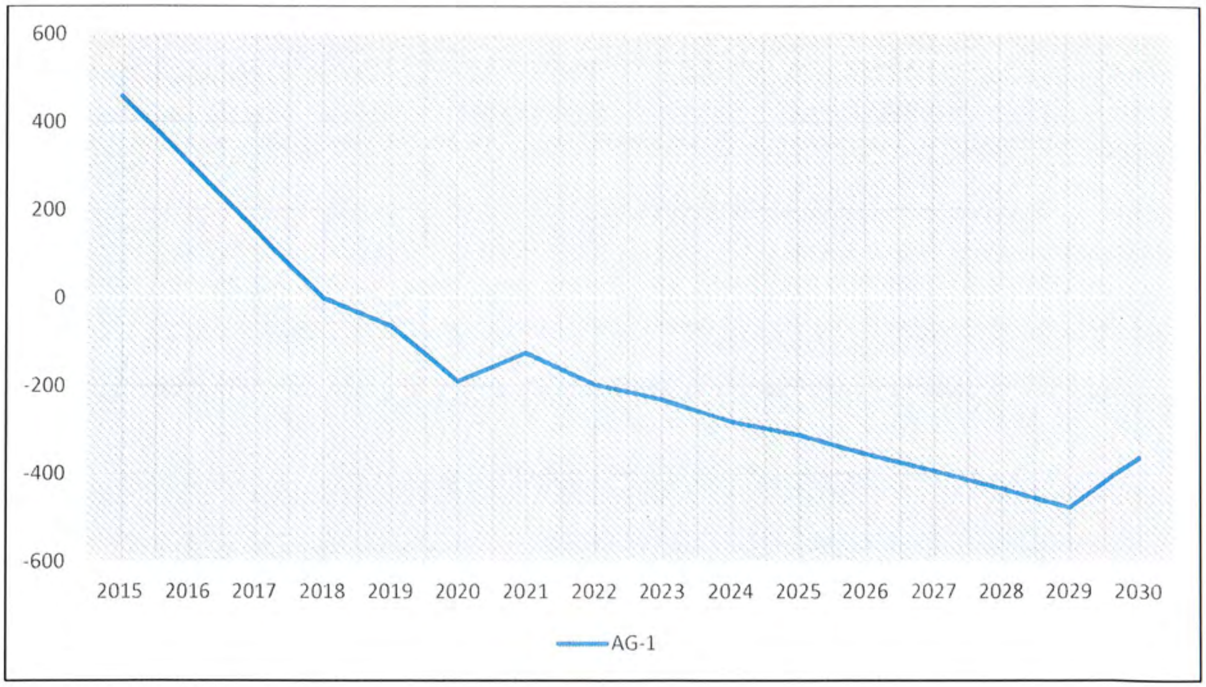
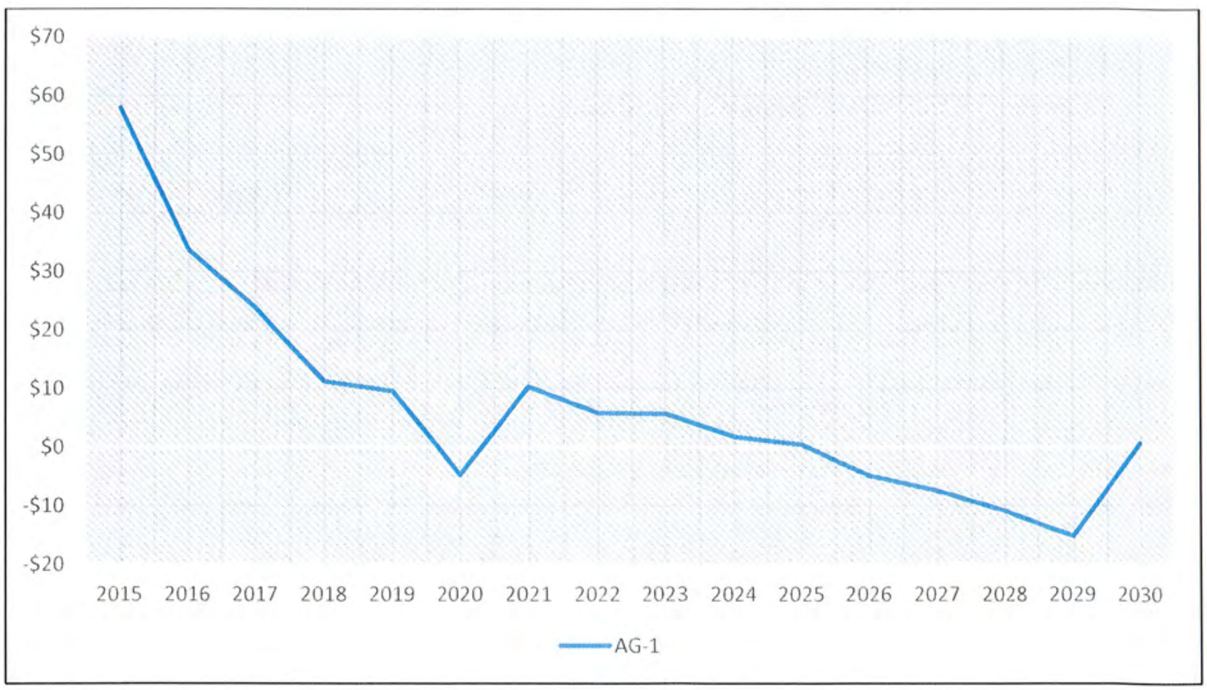
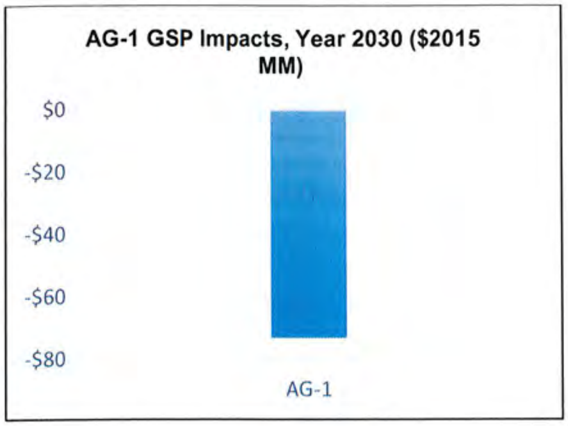
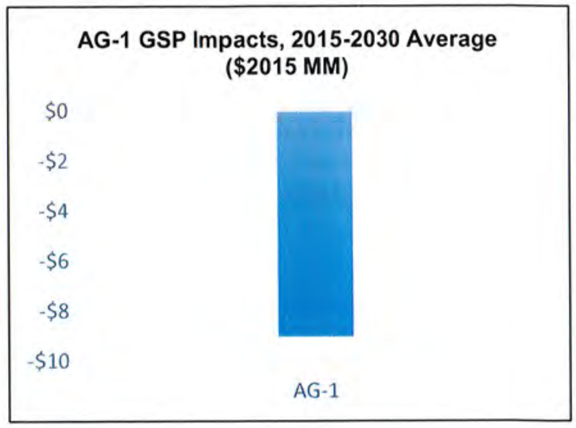
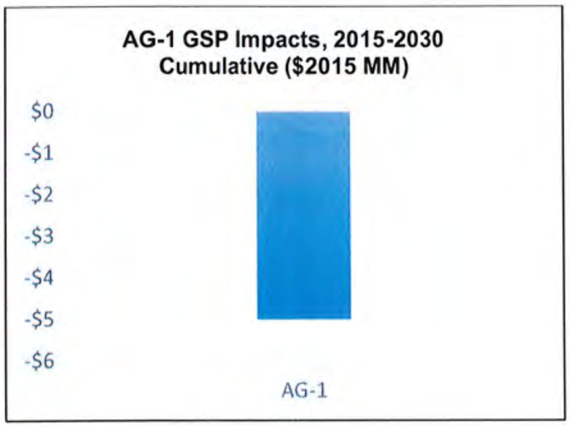


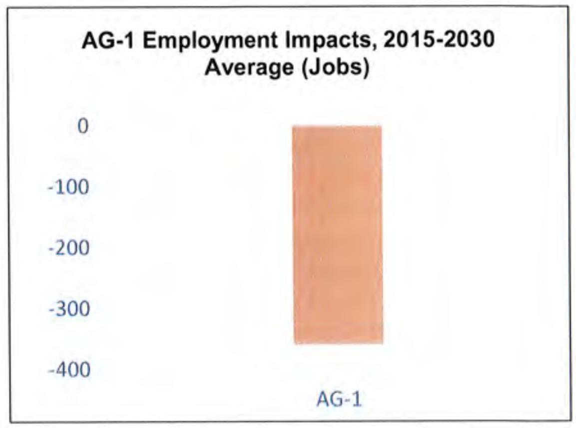
Figure F-4.22 AG-1 Income Impacts ($2015 MM)

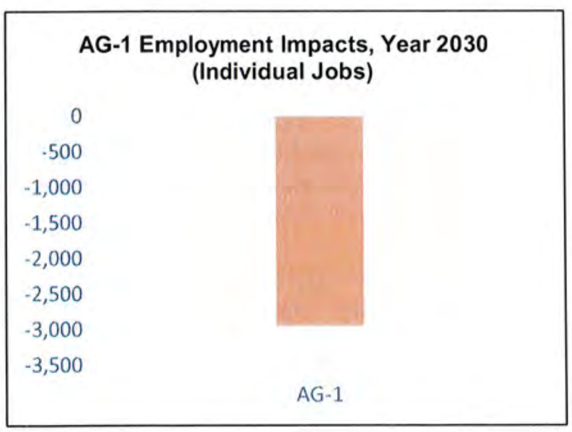


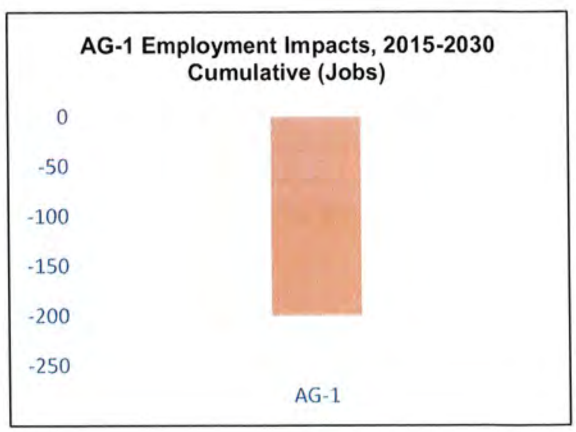

AG-1 GSP Impacts, Year 2030 ($2015 MM)
$0
-$20
-$40
-$60
-$80
AG-1

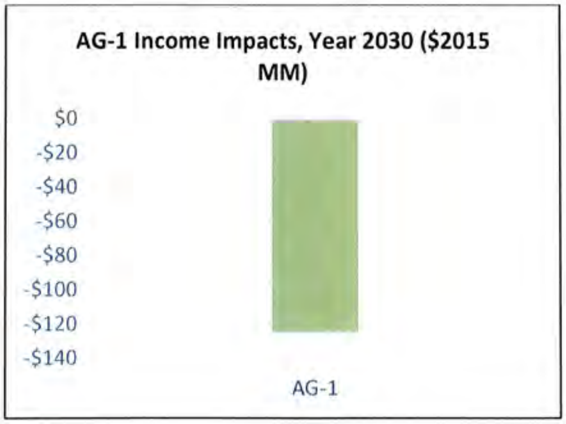

AG-1 GSP Impacts, 2015-2030 Average ($2015 MM)
$0
-$2
-$4
-$6
-$8
-$10
AG-1

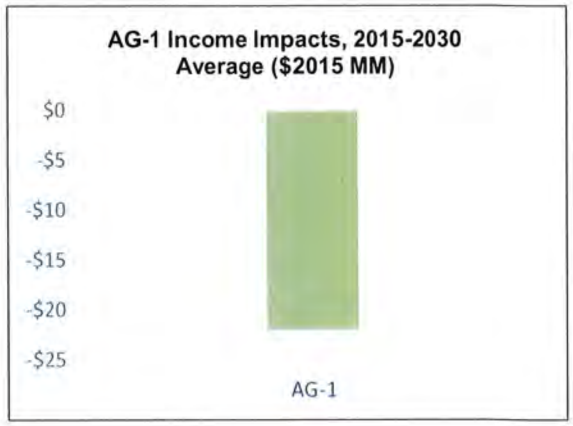

AG-1 GSP Impacts, 2015-2030 Cumulative ($2015 MM)
$0
-$1
-$2
-$3
-$4
-$5
-$6
AG-1

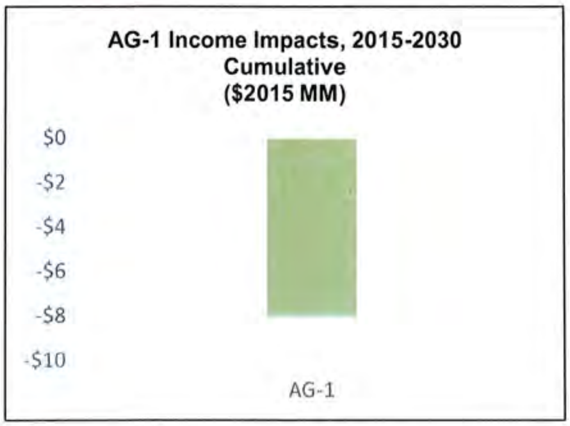

AG-1 Employment Impacts, 2015-2030 Average (Jobs)
0
-100
-200
-300
-400
AG-1


AG-1 Employment Impacts, Year 2030 (Individual Jobs)
0
-500
-1,000
-1,500
-2,000
-2,500
-3,000
-3,500
AG-1


AG-1 Employment Impacts, 2015-2030 Cumulative (Jobs)
0
-50
-100
-150
-200
-250
AG-1







Principal Drivers of Macroeconomic Changes

AG-1 imposes higher costs on farms, all in all, by approximately $100 million by the year 2030. This takes into account the crop-yield increases, which (per the microeconomic analysis) do not appear to pay for the full cost of implementation. The higher costs push down investment, but the direct hiring as part of that cost offsets this impact. Those hires produce consumer spending, which is an effective positive force in economic impacts.

State spending is displacing other existing programs, so its impact directly is positive, but is offset statewide by reductions in spending (and the benefits that produces) in other programs.

Sectors of Economy Most Affected by the Policy

Economic impacts from policies run around the economy, affecting sectors that are sometimes far from the direct target of a policy.

For AG-1, which shows immediate positive gains but slowly shows slightly negative impacts, most of the losses are direct – the agriculture sector sheds around two hundred total positions statewide by 2030. The entire rest of the state sees a net shift of about 150 fewer positions.

GSP and incomes shift downward, but very slightly, and the impacts are so small that they are best understood as representing slight negative pressure on economic activity. No particular sector outside of agriculture sees shifts of any significant scale.

Data Sources

The principal data sources for the macroeconomic impacts analysis of this and all other policies in the CSEO process are the direct spending, saving, cost and price impacts developed as part of the microeconomic (direct impacts) analysis. For each policy, the cost-effectiveness analysis described above develops year-by-year estimates of the costs, savings prices, and changes demand or supply that households, businesses and government agencies are expected to encounter in a scenario where the policy is implemented as designed.

A secondary data source is the policy design. Balancing financial flows for each direct impact identified are established based on understanding the implementation mechanism, and quantitative values for these flows are developed for each direct impact identified. This balancing identifies and quantifies the responsive change that occurs as a result of the direct impact in question. For example, if a household is anticipated to save $100 per year on electricity bills as a result of a policy, the direct impact is a $100 savings to the household (which expands its spending capacity for other things) but the balancing impact is a $100 loss in revenue and demand to the utility provider (which reduces its ability and need to spend on labor, capital, profit, and other inputs). The quantitative measure of both sides of a change is of importance to a complete macroeconomic analysis. This balancing ensures that both the supply and the demand side of each economic change is fully represented in the analysis.

A third data source is direct communication with Minnesota agency staff and others involved in policy design or in a position to understand in detail the financial flows involved in the policy. These people assisted in clarifying the nature of economic changes involved so that the modeling and analysis would be accurate.

The final crucial data source is the baseline and forecast of economic activity within the REMI software. This data is compiled into a scenario that is characterized not only by the total size of the economy and its many consuming and producing sectors, but also the mechanisms by which impacts in one sector can change the broader economy – such as intermediate demands, regional purchase coefficients, and equilibria around price and quantity, labor and capital, and savings and spending, to name a few of many. REMI, Inc. maintains a full discussion of all the sources of the baseline data on its own website, www.remi.com.

In the case of the AG-1 policy, important data included:

- Spending by farms to adopt new equipment and software for the management practices involved.
- Additional hiring by farms to implement this more labor-intensive nitrogen-inhibition method.
- A shift in spending – less total spending on fertilizers, but more on nitrogen inhibitors. The chemical sector sees both sides of this shift, and the net cost is positive to farms.

- The sales value of a forecast crop yield increase that should result from this policy.
- Government costs to administer the program and to implement pilot projects.

Quantification Methods

Utilizing the data developed from the microeconomic analysis, CCS analysts established for each individual change the following characteristics:

- The category of change involved (change in spending, savings, costs, prices, supply or demand)
- The party involved on both sides of each transaction
- The volume of money involved in this change in each year of the period of analysis

These values, so characterized, were then processed into inputs to the REMI PI+ software model built specifically for use by CCS and consistent with that in use by state agencies within Minnesota. These inputs were applied to the model and run. Key results were then drawn from the model and processed for consistency of units and presentation before inclusion in this report.

Key Assumptions

The macroeconomic impact analyses of this policy, as well as of the others in the CSEO process, rely on a consistent set of key assumptions:

- State and local spending is always budget-constrained. If a policy calls for the state or local government to spend money in any fashion, that spending must be either funded by a new revenue stream or offset by reductions in spending on other programs. Savings or revenues collected by the government are also expected to be returned to the economy as spending in the same year as they are collected.
- Federal spending is not budget-constrained. The capacity of the federal government to carry out deficit spending means that no CSEO policy is held responsible for driving either an increase or decrease in federal tax spending by businesses or households in the state of Minnesota.
- Consumer spending increases are sometimes financed. Small-scale purchases or purchases of consumer goods are treated as direct spending from existing household cash flows (or short-term credit). Durable goods, home improvements or vehicle purchases, however, are treated as financed. Consumers were assumed to spread out costs based on common borrowing time frames, such as five years for financing a new vehicle or 10-20 years for home improvements that might be funded by home-equity or other lending. The assumption of financing and the term of years applied was considered anew in each case.
- Business spending increases are often financed. Where spending strikes a sector which routinely utilizes financing or lines of credit to ensure steady payment of recurring costs, significant spending of nearly any type was considered a candidate for financing, thus allowing costs to spread out over time. This methodology is preferable for the modeling

work, as sudden spikes or dips in business operating costs can show up as volatility when the scenario may depict a managed adoption of new equipment in an orderly fashion. The assumption of financing and the term of years applied was considered anew in each case.

- Unless otherwise stated, all changes to consumer spending or to the producers' cost of producing goods and services were treated in a standard fashion. Consumers are assumed to spend on a pre-set mix of goods, services, and basic needs, and businesses spend (based on their particular sector of the economy) on a mix of labor, capital, and intermediate demands from other sectors. Unless a policy specifically defines how a party will react to changes in cost, price, supply or demand, these standard assumptions were applied.
- State and local spending gains and reductions driven by policy are assumed to apply to standard mixes of spending. Again, unless a policy specifically states that a government entity will draw from a specific source or direct savings or revenues to a specific form of spending, all gains and losses were assumed to apply to a standard profile of government spending within the economy.

Key Uncertainties

Current N use by crops and associated measure of nitrogen use efficiency; N type, amount; current and future N fertilizer BMP adoption rates; future crops grown & associated N use; N mobility-mass balance/GHG contribution; development and adoption of new technologies and products as well as current adoption of existing precision agriculture.

Additional Benefits and Costs

- Surface and ground water quality benefits due to decreased NO_3 runoff,
- Decreased fertilizer production and associated upstream environmental impacts, and
- New products and technologies may have limited availability and be cost prohibitive.

Feasibility Issues

- Some nitrogen fertilizer products may or will not prove to be value added,
- New technologies may not be feasible for broad adoption if not shown to be cost effective,
- There may be a need for demonstration and/or incentives to induce adoption,
- Federal Farm Bill legislation may have an influence on crops grown and practices adoption, and
- International markets will influence crops grown as well.

Updating, Monitoring and Reporting

In the current Minnesota GHG emission inventory, emissions from fertilizer application are estimated from annual purchases. This will not capture data that can be used to directly evaluate the effectiveness of this policy option. A common current method of measuring nitrogen use efficiency (NUE) is determining the ratio of bushels of corn produced per pound of N fertilizer input. This can be calculated using bulk N fertilizer sales and the average corn yield over all acres grown. Other methodologies to analyze NUE could be explored.

NASS provides annual survey of corn (and all other major crops) grown. The University of Minnesota has established N fertilizer BMPs that are used as the benchmark for BMP adoption. Other Minnesota Plan/Strategies also seek to address information on N use, BMP adoption, other conservation practices (Nitrogen Fertilizer Management Plan, Nutrient Reduction Strategy) and similar monitoring and reporting may be done.

AG-2 & AG-3. Soil Carbon Management in Agriculture

Policy Option Description

Soils contain vast quantities of carbon and are in fact the largest terrestrial carbon pool. On a global scale, the soil carbon pool is about 3 times larger than the atmospheric pool. Carbon levels in soils vary depending on climate, soil parent material, vegetation type, landscape position, and human activities. Human activities significantly influence the size of soil carbon pools.

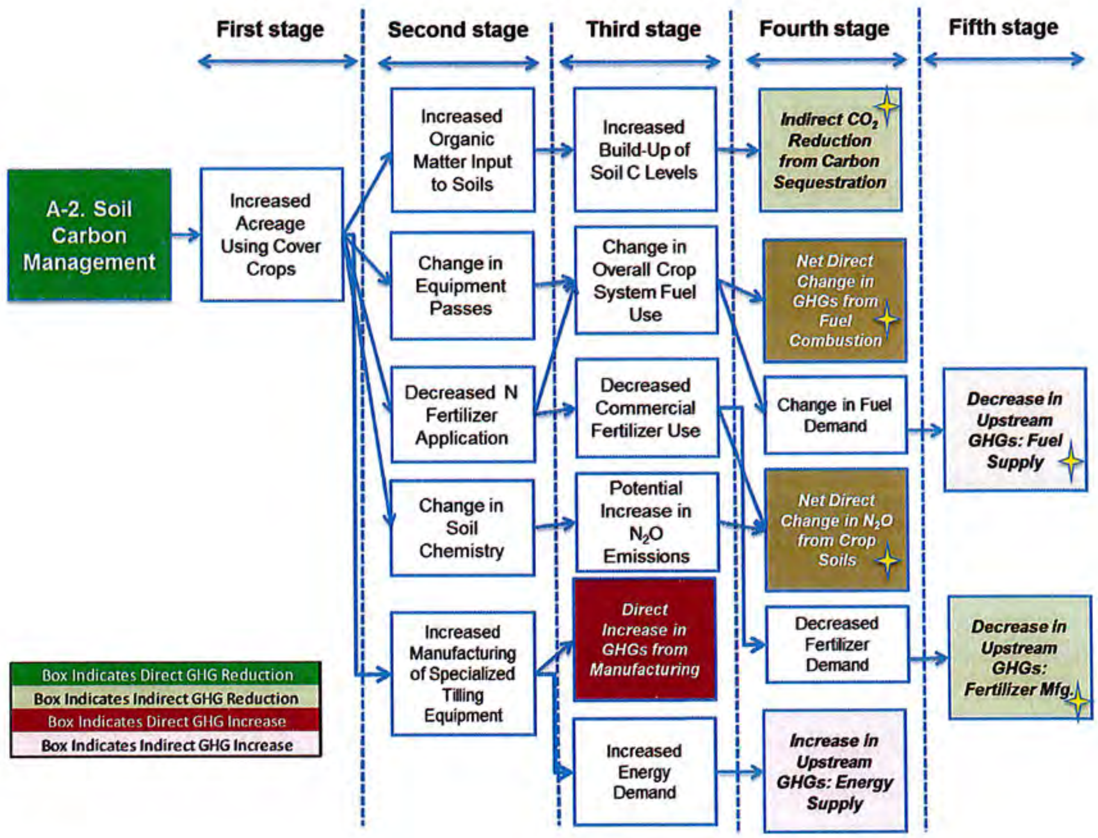
Agricultural soil carbon stocks are increased by diversifying rotations with perennials, minimizing soil disturbance, utilizing manure as a soil amendment, and incorporating cover crops where practicable. These practices are most efficient at sequestering carbon when implemented as a suite of practices rather than stand-alone activities. Minnesota has approximately 19.5 million acres of cropland. Even a modest change in soil carbon content per acre results in a significant total greenhouse gas benefit when considering all agricultural lands in the state.

Logistical, technical, financial and agronomic barriers exist that prevent widespread adoption of cover crop use in traditional corn/soybean systems. New planting technologies, such as robotics and high boy specialized planters (which can efficiently plant cover crop seed below the corn/soybean canopy), may prove to be a dependable and consistent solution for corn and soybean systems in the near future. Information on seeding equipment, establishment and termination techniques needs to be studied and provided to agribusiness and farmers so cover crops have the highest potential for successful establishment. Cover crop seed varieties may need to be developed and sufficient quantities available to meet the new demand. Further research is needed on cover crops' economic cost/benefit and yield effect in major row crop systems. Pilot plots and on-farm demonstrations are needed.

As shown in the causal chains below, two different policies were developed to produce increases in soil carbon levels: AG-2. Increased Use of Cover Crops; and AG-3. Increased Conversion of Row Crops to Perennial Crops. Net costs and benefits have been developed separately for each.

Causal Chains for GHG Reductions

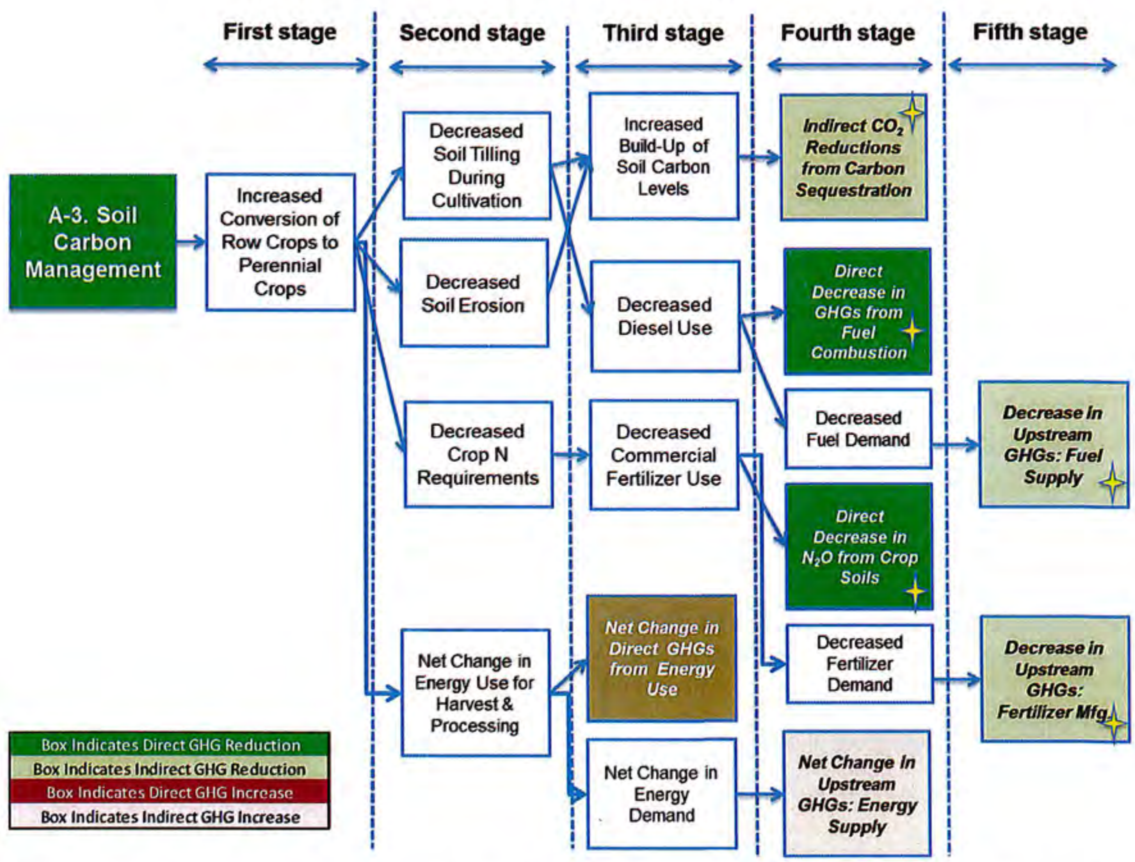
Figure F-4.23 Causal Chain for AG-2 GHG Reductions



The star symbol identifies significant GHG effects for quantification. The tan colored boxes indicate a net change in GHG impacts that could be either positive or negative. The quantification of net benefits detailed in later sections of this document will include an assessment of whether net GHG reductions or emissions are likely to occur as a result of policy option implementation. The increase in GHGs from manufacturing specialized tilling equipment is expected to be small and potentially outside the boundaries of the state. The data required to calculate these reductions would also be difficult to source. For these reasons, these emissions won't be quantified.

Reductions in water use are also a potential benefit with associated energy co-benefits to the extent that groundwater pumping is reduced. There is also a potential for an increase in crop yields associated with higher levels of soil carbon; however, these benefits are not addressed in the quantified results for this policy option. Another benefit associated with cover cropping is a reduction in soil erosion. There is some potential for additional GHG benefits associated with reduced erosion and subsequent oxidation of soil carbon to CO_2; however, more research is needed in this area.

Figure F-4.24 Causal Chain for AG-3 GHG Reductions



The star symbol identifies significant GHG effects for analysis. Reductions in water use are also a potential benefit with associated energy co-benefits to the extent that groundwater pumping is reduced.

Policy Option Design

AG-2. Cover Crop Goals

Cover crops adoption is grouped into cropping systems with high opportunity/high success rate and cropping systems that currently have significant barriers limiting adoption. Targeting 'low-hanging fruit' for early adoption includes: canning crops (some vegetables, sweet corn and peas), corn silage, sugar beets, edible beans, and potatoes. Other 'minor' crops (not significant acres grown) would fall into this category as well. (Numbers below are based on the NASS 2012 State Agriculture Overview).

Overall Goal: Increase cover crop adoption on 5 million acres by 2030.

Policy Option effects to achieve the goal:

Phase I: Cover crop adoption on 500,000 acres of cropland with the highest likelihood of successful implementation. These crops include canning crops, corn silage, edible beans, sugar beets and other fruits and vegetables.

- Fifty percent cover crop adoption on canning crop acreage, approximately 200,000 acres (Vegetables: 227,600, Sweet corn: 106,900, peas: 57,800).
- Thirty percent cover crop adoption on corn silage acreage, approximately 105,000 acres (361,200 total acres).
- Thirty percent cover crop adoption on edible bean acreage, approximately 52,800 (155,200 total acres).
- Thirty percent cover crop adoption on sugar beet acreage, approximately 142,500 acres (480,800 total acres).
- Forty percent cover crop adoption on potato acreage; approximately 20,000 acres (48,200 total acres).

Phase II: Beginning 2020, steady adoption on major row crops by targeting and addressing cover crop implementation barriers. Adoption goal is 4.5 million acres in corn and soybean cropping systems.

Cover Crop Timing: Assume linear growth to achieve all goals by 2030.

Cover Crop Parties Involved: This policy option affects all agricultural producers in the State, agri-business, federal, State and local government, and Soil and Water Conservation Districts.

Cover Crop Other: Cover crop adoption in the major row crops will take more time. Each acre of cover crop adoption in corn production systems potentially increases Nitrogen Use Efficiency by scavenging excess nitrogen or providing nitrogen via legumes. This Nitrogen Use Efficiency benefit overlaps with the goals in AG-1.

AG-3. Perennial Crop Goals

Converting row crops to perennial crops (grasses and legumes) for forage hayland, grazing, or biofuels, increases carbon storage in agricultural soils and biomass. Current market forces do not provide adequate incentives for perennial crop production; and other uses of perennial products are not widely available or do not have significant market penetration (e.g. cellulosic ethanol and biofuels). This policy option includes harvested legume, pasture and hayland, and perennial plantings.[11]

Overall Goals: Increase perennial vegetative cover acreage that can be used for forage, hayland, grazing, or biofuels to 4.6 million acres by 2030. Note: The 2010 Natural Resources Inventory estimates 3.6 million acres of pastureland.

Increase opportunities for grazing livestock on federal, state and conservation organization-owned lands. Multi-purpose land management benefits wildlife, improves habitat management, and allows for increased livestock production. Increase grazing lands to 50,000 acres by 2030 (there are currently 10,000 acres of grazing lands in Minnesota).

Policy Option Effects to achieve the goal:

- Increase perennial vegetative cover acreage for forage, hayland, grazing, and biofuels by 1 million acres.
- Target environmentally sensitive lands, such as Highly Erodible Lands (HEL) lands for hay and pasture planting.
- Develop markets and/or provide incentives to increase perennial crop production.

Perennial Crop Timing: Assume linear growth to achieve goal by 2030.

Perennial Crop Parties Involved: This policy option affects agricultural producers in the State, agri-business, federal, State and local government, and Soil and Water Conservation Districts.

Perennial Crop Other: Perennial crops have multiple benefits including protection of existing soil carbon stores by reducing (or nearly eliminating) soil erosion, improving water quality, and potentially returning ruminant animals back to the landscape. While both cover crops and perennial crops are vegetative practices used on working lands to mitigate greenhouse gases, their impacts are strikingly different over time. There are multiple reasons why cover crops and perennial crops sequester and store different quantities of carbon. The primary reason is that most cover crops are annual species and don't produce nearly as much biomass as perennial plants do. The amount of atmospheric carbon that is assimilated and stored in the soil as soil organic matter increases as plant biomass increases. Secondarily, perennial plants also have a much larger and extensive root system than annual cover crops do. Roots contribute significantly to soil organic matter through annual root turnover and sloughing of polysaccharides. Another reason cover crops have a smaller carbon benefit is that they exist within fields that are disturbed or tilled annually. A portion of the carbon sequestered by cover crops is oxidized and lost at carbon dioxide during tillage and planting operations.

Each acre of perennial crops replacing corn reduced Nitrogen fertilizer input and impacts Nitrogen Use Efficiency in AG-1.

[11] Note that this policy has potential linkage to AG-4 which addresses biofuel production; however, currently, the feedstocks for Policy AG-4 address corn stover and energy beets.

Implementation Mechanisms

AG-2 Cover Crops

- Build on NRCS soil health program to develop support and capacity for cover cropping within the universe of agricultural business advisors (NRCS, SWCDs, Extension, MNSCU farm management program, certified crop advisors, farm management companies, etc.). Cost estimate: unknown.
- Support key research into plant material development, and agronomic and economic impacts of cover crops. Document and disseminate the multiple potential benefits of cover crops including increased water storage, increased infiltration, decreased compaction, reduced fertilizer and herbicide inputs, reduced wind and water erosion, etc. MDA has recently provided funding for cover crop research through the University of Minnesota that will examine:
- Water quality enhancements in corn cropping systems through optimization of cover crop establishment technologies
- Optimizing establishment of corn in cover crops and living mulches to maintain yield while reducing nitrate losses.
- Improvement of field pennycress germplasm for use as a winter annual cover and oilseed crop
- Dual-purpose cover crops and onsite retention of water and nutrients
- Findings from this research should be utilized for cover crop implementation.
- Cost estimate: $12 million.
- The Legislature should appropriate funds for cover crop implementation including establishment, management and technical assistance. MDA and/or BWSR will establish incentive programs for cover crops leveraging NRCS/USDA funding programs with a ramp up (and then down) of state incentive payments to support early adoption and infrastructure development. Cost estimate $5.9 million.
- The Legislature should appropriate funds for pilot plots and on-farm demonstration of new cover-cropping technologies to encourage adoption. Cost estimate: $750,000
- Develop incentive programs to encourage processors to include cover crop requirements in their contracts with farmers. Cost estimate: $100,000
- The State of Minnesota should participate in a carbon market that would ensure adequate oversight, crediting, and insurance of carbon reductions in the Agricultural sector. Cost estimate unknown.

AG-3. Perennial Crops

- Support changes in federal policy option and develop programs at the state level to provide greater incentives for perennial vegetative cover that can be used for forage, hayland, grazing, or biofuels.

- Fund research in multiple areas related to perennial crop production including productivity and quality, and development of multiple uses of perennial crops, including cellulosic biofuels. Cost estimate: $12 million.

Related Policies/Programs in Place and Recent Actions

- Multiple NRCS programs provide funding for cover crop and grazing land practices, including EQIP and CSP. Funds in these programs are limited and additional funding sources are needed to achieve cover crop adoption goals.
- Minnesota Department of Agriculture (MDA) cover crop initiatives and research grants.
- Clean Water Fund accelerated implementation grant (FY14) to Technical Service Area 7 for cover crop technical assistance.

Estimated Policy Impacts

Direct Policy Impacts

Table F-4.9 AG-2 and 3 Estimated Net GHG Reductions and Net Costs or Savings

Policy Option	2030 GHG Reductions (MMt CO_2e)	2015 – 2030 Cumulative Reductions (MMt CO_2e)	Net Present Value of Societal Costs, 2015 – 2030 ($2014)	Cost Effectiveness ($2014/ tCO_2e)
AG-2. Cover Crops	0.57	3.6	($1,346)	($377)
AG-3. Perennial Crops	1.6	14	($2,104)	($153)

Notes:

Each policy option analysis was done over a fifteen year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

The GHG reductions summarized above represent full energy-cycle reductions for the policy option, which include reductions of upstream emissions that may occur outside of Minnesota. For comparison, emission reductions that can be specifically allocated to occur within the State for Policy Option AG-2 are 0.49 MMt CO_2e in 2030 and 3.1 MMt CO_2e cumulatively from 2015 to 2030. For Policy Option AG-3, 1.6 MMt CO_2e are estimated to be reduced in-state by 2030 and cumulatively 14 MMt CO_2e from 2015 to 2030.

Data Sources

Key data sources are referenced within the discussion of Quantification Methods below.

Quantification Methods

AG-2. Cover Crops

GHG Reductions:

- *Soil carbon accumulation:* First a schedule for cover crop adoption by crop type was assembled based on the specifications of the policy option design. Incremental carbon gains for use of cover crops were then estimated for all acres covered using a carbon accumulation factor from a University of Minnesota (UMN) study (0.59 tCO_2/acre-yr).[12] Due to the uncertainty in soil carbon permanence, a permanence factor of 0.20 was applied to all soil carbon accumulation estimates.
- *Fuel requirements:* Other than fuel consumption for initial establishment, other net changes to fuel requirements for each cropping system were assumed to be negligible. Establishment fuel requirements were estimated from the overall cost of cover crop establishment. That cost was presumed to be equal to the low value of the Environmental Quality Incentives Program (EQIP) payment, which in 2014 was $59/acre. Of this value, $28 was presumed to represent seed costs[13]; and for the remaining non-seed costs, one-third was assumed to represent fuel costs. Based on the 2014 average retail price for diesel fuel, the result was 2.0 gallons/acre.
- *Decreased N requirements:* Use of "green manures" (alfalfa, clover, vetch) as cover crops have been shown to produce N inputs (N credits) of 40 or more lb. N/acre annually. A value of 44 lb. N/acre-yr. was applied as an N credit (reduced N application requirement.[14] The decrease in total N requirements was used to estimate the reduction in upstream GHGs from the supply of N fertilizer (by assuming all reductions in N requirements from cover cropping would come from synthetic inputs). As described further under the Key Uncertainties section below, the literature is currently unclear as to the net impact on N_2O emissions; so these were left at BAU levels (i.e. no net change in direct/indirect N_2O emissions from crop soils).

Table F-4.11 below provides a summary of the net GHG impacts assessment. The implementation schedule for each crop is shown first, followed by the BAU energy and emissions associated with BAU cultivation of these crops. Then, the estimated Policy Option Scenario impacts are estimated. Finally, in the "Energy and Emissions Change" columns provide the net results for energy consumption and emissions. "Out of state" emissions refer to the upstream emissions associated with fertilizer and diesel fuel supply (these net impacts can't be presumed to all occur within Minnesota).

Net Societal Costs:

- BAU avoided costs: no BAU operations were found to be avoided through implementation of the policy option (addition of cover crops); so all costs for the policy option were incremental to BAU. These include the fuel and non-fuel costs for establishment. No new equipment costs are expected. Cover crop establishment costs

[12] UMN 2008 Terrestrial Carbon Study; App. II - 40 g C/m^2-yr mean value with an SD of 22. http://www.wrc.umn.edu/prod/groups/cfans/@pub/@cfans/@wrc/documents/asset/cfans_asset_119302.pdf

[13] Value provided by M. Lennon, MN Bureau of Water & Soil Resources (10/17/2014 personal communication to S. Roe, CCS; value for a basic species mix (single species can run up to $37/acre).

[14] http://www.soils.wisc.edu/extension/wcmc/2009/ppt/Ruark.pdf.

were derived from EQIP cover crop payment costs as mentioned above ($59/acre). Of this seed costs were assumed to be $28/acre (47% of establishment costs). The remaining establishments costs were broken down to fuel and non-fuel costs based on assumptions of one-third of remaining costs being fuel costs (result: 18% of establishment costs were fuel costs; 36% labor and operations and maintenance costs).

- Reductions in synthetic fertilizer costs were included. This assumes that all incremental N additions from use of cover crops would reduce synthetic N requirements. N fertilizer costs for 2014 were $589/ton N, and these were escalated at 0.4%/yr. through the planning period.
- Minnesota government incentives as described in the Implementation Mechanisms section ($5.9MM total) were applied during the early years of the planning period using a sliding schedule that ends in 2023. Minnesota government program costs as described in the Implementation Mechanisms section ($12.75MM total) were also applied during the same years as the incentives program.
- Federal EQIP payment costs were also included as a net societal cost savings to the State. The low EQIP payment rate was applied ($59/acre in 2014); and the value in each future year through 2020 was trended based on 2009-2014 EQIP payments. The value in 2020 ($75/acre) was then held constant through 2030.
- The final cost component was an assessment of yield impacts associated with cover crops[15]: corn (+9.6%); and soybeans (+11.6%). All other crops were assumed to have no yield impact based on available information. BAU forecasted yields in 2030 for soybeans were estimated at 49.2 bushels/acre (bu./acre) and 196 bu./acre for corn. Price forecasts were based on the USDA long-term price forecasts: in 2030, the price for corn is estimated to be $4.76/bu.; soybean price is estimated to be $11.12/bu.

Table F-4.14 provides a summary of the net societal cost assessment for Policy Option AG-2. Even if the EQIP incentive was removed, the analysis still indicates that implementation of the policy option would result in a net cost savings to society. While not shown in the table, the resulting cost effectiveness would be -$15/t$CO_2$e. This is because the net savings achieved via fertilizer savings and crop yield benefits is greater than the estimated costs for establishment of cover crops.

AG-3. Conversion to Perennial Crops

For analytical purposes, the general conversion scheme assumes that corn and soybeans will be converted to hay/pasture.

GHG Reductions:

Crop conversion targets: policy option design called for 1 MM acres total; this was assumed to be a 50:50 split of corn and soybeans (about 31,250 acres of each converted each year from

[15] 2012-2013 Cover Crop Survey, June 2013 Survey Analysis, Conservation Technology Information Center, North Central Sustainable Research & Education, June 2013.

2015 to 2030). Based on several studies[16], a sliding scale of sequestration rates were applied to all converted croplands as shown below. For reference, well managed US grazing lands are expected to sequester 0.1 – 0.3 metric tons of carbon per hectare per year (tC/ha-yr.); new grasslands in the US and southern Saskatchewan: 0.5 – 0.6 tC/ha/yr.; and an average of 23 worldwide data points from a National Renewable Energy Labs (NREL) study: 1.0 tC/ha-yr.

Table F-4.10. Assumed Conversion Sequestration Rates

Time after conversion	Sequestration Rate (tC/ha-yr)
Year 1 – Year 5	0.57
Year 6	0.49
Year 7	0.42
Year 8	0.35
Year 9	0.27
Year 10 – Year 20	0.20

- As with the policy option analysis for AG-2, a carbon storage permanence factor of 0.2 was applied to all carbon sequestration estimates.
- Fuel use for establishment was assumed to be negligible; therefore the net fuel impact was equal to the BAU fuel consumption for each crop.
- Net N fertilizer application emissions (N_2O) were also determined based on BAU fertilizer use and the expected use for establishing permanent cover.[17]

Table F-4.19, provides a summary of the net energy and GHG impacts. Total in-state GHG reductions were estimated to be 1.6 MMt CO_2e annually by 2030. Additional out-of-state reductions were estimated to be 0.028 MMt CO_2e/yr. (upstream GHGs associated with fertilizer and fuel supply).

Net Societal Costs:

- Establishment costs and incentives: these included seed costs, fuel costs, other costs (labor and operations/maintenance), and government incentives. Similar costing assumptions were applied here as cited above for establishing cover crops.
- Avoided fertilizer and fuel costs: based on net use of N fertilizers and diesel fuel between BAU crop production and permanent cover.

[16] http://www.fao.org/docrep/007/y5738e/y5738e08.htm; http://www.prairiesoilsandcrops.ca/articles/volume-5-9-screen.pdf; http://www.nrel.colostate.edu/ftp/conant/SLM-proprietary/Conant_et-al_2001.pdf.

[17] Personal communication, J. Berg, MDA, to S. Roe, CCS, 11/5/2014; 30 lb N/acre at establishment applied to 25% of new acreage.

- Change in land use: revenue for the land under the Policy Option Scenario was set at $26/acre (rental value for pasture/grassland).[18] Under BAU land use, the costs for land rental were added to fertilizer, fuel, other production costs, and crop profits to get a total net cost. Fuel and fertilizer use for each crop were taken from the Minnesota BAU crop production forecast. Costs were estimated as described above for Policy Option AG-2. Other production costs were taken from a UMN publication.[19] Corn and soybean profit levels were assumed to remain constant at the average of 2011 and 2012 levels ($197/acre and $211/acre, respectively).[20]
- The Minnesota R&D program cited in the Implementation Mechanisms section ($12MM) was assumed to be spent in a declining schedule through 2023.

Table F-4.14 provides a summary of the net societal cost build-up for the policy option. If the EQIP subsidy is excluded from the net value, the results still show a net cost savings to society (while not shown in the Table, the value would be -$126/t$CO_2$e). While the analysis shows a net societal savings, the high profitability of both corn and soybean production will create challenges for policy option implementation.

Table F-4.11 Net GHG Impacts for Policy Option AG-2: Cover Cropping

	BAU Energy & Emissions							
Year	**Canning Crops Cumulative Acres**	**Corn Silage Cumulative Acres**	**Edible Beans Cumulative Acres**	**Sugar Beets Cumulative Acres**	**Potatoes Cumulative Acres**	**Grain Corn Cumulative Acres**	**Soybeans Cumulative Acres**	**Total Crops Cumulative Acres**
2015	12,500	6,563	3,300	8,906	1,250	0.00	0.00	32,519
2016	25,000	13,125	6,600	17,813	2,500	0.00	0.00	65,038
2017	37,500	19,688	9,900	26,719	3,750	0.00	0.00	97,556
2018	50,000	26,250	13,200	35,625	5,000	0.00	0.00	130,075
2019	62,500	32,813	16,500	44,531	6,250	0.00	0.00	162,594
2020	75,000	39,375	19,800	53,438	7,500	204,545	204,545	604,203
2021	87,500	45,938	23,100	62,344	8,750	409,091	409,091	1,045,813
2022	100,000	52,500	26,400	71,250	10,000	613,636	613,636	1,487,423
2023	112,500	59,063	29,700	80,156	11,250	818,182	818,182	1,929,032
2024	125,000	65,625	33,000	89,063	12,500	1,022,727	1,022,727	2,370,642
2025	137,500	72,188	36,300	97,969	13,750	1,227,273	1,227,273	2,812,252

[18] Average of 2012 and 2013 cash rental rates for MN pasture; http://www.nass.usda.gov/Statistics_by_State/Minnesota/Publications/Prices_Press_Releases/2013/MN%20Cash%20Rent%2012_13.pdf.

[19] Lazarus, 2010 (table 3); costs excluding fertilizer, land rental, and fuel ("miscellaneous" costs assumed as the value for fuel, since fuel was not broken out separately); http://faculty.apec.umn.edu/wlazarus/documents/cropbud.pdf.

[20] Average 2011 and 2012 profit estimates for Heartland Corn and Soybeans; http://landstewardshipproject.org/farmtransitionsvaluingsustainablepracticescornandsoybeanprofitability.

2026	150,000	78,750	39,600	106,875	15,000	1,431,818	1,431,818	3,253,861
2027	162,500	85,313	42,900	115,781	16,250	1,636,364	1,636,364	3,695,471
2028	175,000	91,875	46,200	124,688	17,500	1,840,909	1,840,909	4,137,081
2029	187,500	98,438	49,500	133,594	18,750	2,045,455	2,045,455	4,578,690
2030	200,000	105,000	52,800	142,500	20,000	2,250,000	2,250,000	5,020,300
Sum	**200,000**	**105,000**	**52,800**	**142,500**	**20,000**	**2,250,000**	**2,250,000**	**5,020,300**

Table F-4.12 Net GHG Impacts for Policy Option AG-2: Cover Cropping (continued)

Year	BAU Energy & Emissions					Policy Option Scenario Energy & Emissions				
	Total N Additions	Total N_2O Emissions	Diesel Fuel Use	Diesel Fuel Emissions	Total BAU Emissions	Soil C Sequestration	Total N Additions	Total N_2O Emissions	Diesel Fuel Use	Diesel Fuel Emissions
	t N	tCO_2e	TJ	tCO_2e	tCO_2e	tCO_2	t N	tCO_2e	TJ	tCO_2e
2015	4,274	69,986	49	3,416	73,402	3,837	3,757	69,986	58	4,078
2016	8,693	142,348	98	6,842	149,190	7,674	7,644	142,348	117	8,168
2017	13,257	217,084	147	10,280	227,364	11,512	11,661	217,084	176	12,268
2018	17,966	294,196	197	13,729	307,925	15,349	15,807	294,196	235	16,380
2019	22,820	373,683	246	17,175	390,858	19,186	20,084	373,683	294	20,488
2020	56,657	927,759	845	58,915	986,674	71,296	49,840	927,759	1,022	71,228
2021	90,752	1,486,070	1,444	100,708	1,586,777	123,406	79,817	1,486,070	1,750	122,020
2022	125,205	2,050,248	2,043	142,467	2,192,715	175,516	110,115	2,050,248	2,478	172,780
2023	159,954	2,619,260	2,644	184,342	2,803,602	227,626	140,671	2,619,260	3,208	223,654
2024	195,140	3,195,443	3,247	226,377	3,421,819	279,736	171,612	3,195,443	3,940	274,689
2025	231,667	3,793,568	3,849	268,378	4,061,947	331,846	203,884	3,793,568	4,671	325,690
2026	268,059	4,389,489	4,450	310,251	4,699,741	383,956	235,970	4,389,489	5,401	376,563
2027	304,884	4,992,506	5,053	352,335	5,344,841	436,066	268,451	4,992,506	6,133	427,646
2028	342,136	5,602,516	5,658	394,471	5,996,987	488,176	301,322	5,602,516	6,867	478,782
2029	379,810	6,219,423	6,259	436,408	6,655,831	540,285	334,576	6,219,423	7,597	529,718
2030	417,899	6,843,136	6,865	478,626	7,321,762	592,395	368,208	6,843,136	8,332	580,936
	2,639,173	43,216,715	6,865	478,626	7,321,762	3,707,861	2,323,420	43,216,715	52,279	3,645,088

Table F-4.13 Net GHG Impacts for Policy Option AG-2: Cover Cropping (continued)

	Energy & Emissions Change			
Year	Diesel Fuel TJ	Change in N Additions t N	Net In-State GHG Change MMt CO_2e	Out-of-State GHG Change MMt CO_2e
2015	10	(517)	(0.003)	(0.0009)
2016	19	(1,049)	(0.006)	(0.0019)
2017	29	(1,596)	(0.010)	(0.003)
2018	38	(2,159)	(0.013)	(0.004)
2019	48	(2,737)	(0.016)	(0.005)
2020	177	(6,817)	(0.06)	(0.011)
2021	306	(10,934)	(0.10)	(0.018)
2022	435	(15,090)	(0.15)	(0.024)
2023	564	(19,283)	(0.19)	(0.031)
2024	693	(23,528)	(0.23)	(0.037)
2025	822	(27,783)	(0.27)	(0.044)
2026	951	(32,089)	(0.32)	(0.051)
2027	1,080	(36,433)	(0.36)	(0.058)
2028	1,209	(40,814)	(0.40)	(0.064)
2029	1,338	(45,234)	(0.45)	(0.071)
2030	1,467	(49,691)	(0.49)	(0.078)
	9,184	**(315,753)**	**(3.1)**	**(0.50)**

Table F-4.14 Net Societal Costs for Policy Option AG-2: Cover Cropping

	Policy Option Scenario Costs									
Year	Establishment Fuel Costs MM$	Fertilizer Cost MM$	Seed/Other Materials Application MM$	Establishment O&M Costs MM$	MN Gov. Incentives MM$	MN Gov. Program Costs MM$	US Government Incentives MM$	Yield Impacts: Corn MM$	Yield Impacts: Soybeans MM$	Yield Impacts: Other Crops MM$
2015	$0.22	($0.31)	$0.81	$0.62	$0.89	$1.91	($1.7)	$0.00	$0.00	$0.00
2016	$0.45	($0.62)	$1.8	$1.3	$0.89	$1.91	($3.7)	$0.00	$0.00	$0.00
2017	$0.68	($1.0)	$2.8	$2.1	$0.89	$1.91	($6.0)	$0.00	$0.00	$0.00
2018	$0.91	($1.3)	$4.0	$3.1	$0.59	$1.28	($8.6)	$0.00	$0.00	$0.00
2019	$1.14	($1.6)	$5.4	$4.1	$0.59	$1.28	($11)	$0.00	$0.00	$0.00
2020	$4.3	($4.1)	$21	$16	$0.59	$1.28	($45)	($13)	($11)	$0.00
2021	$7.5	($6.6)	$37	$28	$0.59	$1.28	($78)	($27)	($22)	$0.00
2022	$10.7	($9.2)	$52	$40	$0.59	$1.28	($111)	($43)	($34)	$0.00
2023	$14.0	($12)	$68	$51	$0.30	$0.64	($144)	($60)	($46)	$0.00
2024	$17	($14)	$83	$63	$0.00	$0.00	($177)	($76)	($59)	$0.00
2025	$21	($17)	$99	$75	$0.00	$0.00	($210)	($94)	($72)	$0.00

2026	$24	($20)	$114	$87	$0.00	$0.00	($244)	($113)	($85)	$0.00
2027	$28	($23)	$130	$98	$0.00	$0.00	($277)	($134)	($99)	$0.00
2028	$31	($25)	$145	$110	$0.00	$0.00	($310)	($155)	($113)	$0.00
2029	$35	($28)	$161	$122	$0.00	$0.00	($343)	($177)	($128)	$0.00
2030	$38	($31)	$176	$133	$0.00	$0.00	($376)	($201)	($143)	$0.00
	$233	**($195)**	**$1,102**	**$834**	**$6**	**$13**	**($2,347)**	**($1,094)**	**($812)**	**$0.00**

Table F-4.15 Net Societal Costs for Policy Option AG-2: Cover Cropping (continued)

Year	Total Policy Option Costs MM$	Total Discounted Policy Option Costs MM$2014	Cost Effectiveness $2014/tCO2e
2015	$2.2	$2.1	
2016	$1.5	$1.4	
2017	$0.8	$0.7	
2018	($0.9)	($0.8)	
2019	($1.8)	($1.4)	
2020	($34)	($25)	
2021	($68)	($48)	
2022	($104)	($70)	
2023	($142)	($92)	
2024	($181)	($111)	
2025	($220)	($129)	
2026	($261)	($145)	
2027	($304)	($161)	
2028	($348)	($176)	
2029	($394)	($189)	
2030	($441)	($202)	
	($2,494)	**($1,346)**	**($377)**

Table F-4.16 Net GHG Impacts for Policy Option AG-3: Conversion to Perennial Crops

	BAU Energy & Emissions										
Year	Converted Corn Cumulative Acres	Converted Soybeans Cumulative Acres	Converted Corn - N Additions t N	Converted Soybeans - N Additions t N	Converted Corn N_2O Emissions t CO_2e	Converted Soybeans N_2O Emissions t CO_2e	Converted Corn Diesel Consumption TJ Diesel	Converted Soybeans Diesel Consumption TJ Diesel	Converted Corn Diesel Consumption tCO_2e	Converted Soybeans Diesel Consumption tCO_2e	Total In-State BAU GHGs tCO2e
2015	31,250	31,250	3,651	760	59,780	12,441	48	35	3,375	2,459	78,056
2016	62,500	62,500	7,248	1,595	118,693	26,124	97	70	6,763	4,912	156,492
2017	93,750	93,750	10,793	2,493	176,738	40,816	146	106	10,164	7,358	235,076
2018	125,000	125,000	14,285	3,440	233,916	56,330	195	141	13,577	9,798	313,622
2019	156,250	156,250	17,724	4,367	290,226	71,503	244	175	16,987	12,232	390,948
2020	187,500	187,500	21,109	5,319	345,668	87,099	293	210	20,423	14,659	467,850
2021	218,750	218,750	24,707	6,187	404,579	101,310	342	245	23,872	17,080	546,840
2022	250,000	250,000	28,327	7,090	463,861	116,099	392	280	27,307	19,494	626,762
2023	281,250	281,250	31,970	7,988	523,515	130,799	441	314	30,778	21,902	706,994
2024	312,500	312,500	35,664	8,899	584,004	145,715	491	349	34,261	24,336	788,316
2025	343,750	343,750	39,324	10,151	643,936	166,217	542	383	37,757	26,735	874,645
2026	375,000	375,000	43,035	11,219	704,704	183,715	591	418	41,228	29,127	958,773
2027	406,250	406,250	46,769	12,307	765,842	201,533	642	452	44,746	31,513	1,043,634
2028	437,500	437,500	50,525	13,414	827,352	219,656	692	486	48,277	33,892	1,129,178
2029	468,750	468,750	54,304	14,539	889,234	238,071	743	520	51,774	36,265	1,215,344
2030	500,000	500,000	58,106	15,680	951,487	256,766	794	554	55,327	38,632	1,302,211
Sum			**487,541**	**125,446**	**7,983,536**	**2,054,194**	**6,692**	**4,739**	**466,618**	**330,393**	**10,834,741**

Table F-4.17 Net GHG Impacts for Policy Option AG-3: Conversion to Perennial Crops (continued)

	Policy Option Scenario Energy & Emissions				
Year	Forage/Hayland /Pasture Cumulative Acres	Forage/Hayland/ Pasture: N Requirements t N	Forage/Hayland/ Pasture: N2O Emissions tCO_2e	Forage/Hayland /Pasture: Carbon Sequestration tCO_2	Forage/Hayland/ Pasture: Permanent C Storage tCO_2
2015	62,500	213	3,485	(129,479)	(25,896)
2016	125,000	213	3,485	(258,958)	(51,792)
2017	187,500	213	3,485	(388,438)	(77,688)
2018	250,000	213	3,485	(517,917)	(103,583)
2019	312,500	213	3,485	(647,396)	(129,479)
2020	375,000	213	3,485	(760,146)	(152,029)
2021	437,500	213	3,485	(856,167)	(171,233)
2022	500,000	213	3,485	(935,458)	(187,092)
2023	562,500	213	3,485	(998,021)	(199,604)
2024	625,000	213	3,485	(1,043,854)	(208,771)
2025	687,500	213	3,485	(1,089,688)	(217,938)
2026	750,000	213	3,485	(1,135,521)	(227,104)
2027	812,500	213	3,485	(1,181,354)	(236,271)
2028	875,000	213	3,485	(1,227,188)	(245,438)
2029	937,500	213	3,485	(1,273,021)	(254,604)
2030	1,000,000	213	3,485	(1,318,854)	(263,771)
		3,405	**55,757**	**(13,761,458)**	**(2,752,292)**

Table F-4.18 Net GHG Impacts for Policy Option AG-3: Conversion to Perennial Crops (continued)

	Energy & Emissions Change			
Year	Diesel Energy Use TJ Diesel	N Fertilizer Use t N	Net In-State GHG Reductions MMt CO_2e	Out-of-State GHG Reductions MMt CO_2e
2015	(84)	(4,198)	(0.10)	(0.002)
2016	(167)	(8,631)	(0.20)	(0.003)
2017	(251)	(13,073)	(0.31)	(0.005)
2018	(335)	(17,512)	(0.41)	(0.007)
2019	(419)	(21,877)	(0.52)	(0.009)
2020	(503)	(26,216)	(0.62)	(0.010)
2021	(587)	(30,681)	(0.71)	(0.012)

2022	(671)	(35,204)	(0.81)	(0.014)
2023	(756)	(39,745)	(0.90)	(0.015)
2024	(840)	(44,350)	(0.99)	(0.017)
2025	(925)	(49,262)	(1.09)	(0.019)
2026	(1,009)	(54,041)	(1.2)	(0.021)
2027	(1,094)	(58,863)	(1.3)	(0.023)
2028	(1,178)	(63,726)	(1.4)	(0.024)
2029	(1,263)	(68,630)	(1.5)	(0.026)
2030	(1,348)	(73,573)	(1.6)	(0.028)
	(11,431)	**(609,582)**	**(14)**	**(0.23)**

Table F-4.19 Net Societal Costs for Policy Option AG-3: Conversion to Perennial Cover

	BAU Costs							
Year	N Fertilizer Costs	Diesel Fuel Costs	Corn Non-Fuel/ Fert Production Costs	Soybean Non-Fuel/ Fert. Production Costs	Corn Land Rental Cost	Soybeans Land Rental Cost	Corn Profit	Soybeans Profit
	MM$	MM$	MM$	MM$	MM$	MM$	MM$	MM$
2015	$2.7	$2.0	$11	$7.0	$5.1	$5.1	($6.2)	($6.6)
2016	$5.7	$3.9	$22	$14	$10	$10	($12)	($13)
2017	$8.6	$6.0	$33	$21	$15	$15	($18)	($20)
2018	$12	$8.0	$44	$28	$20	$20	($25)	($26)
2019	$14	$10	$55	$35	$26	$26	($31)	($33)
2020	$17	$12	$66	$42	$31	$31	($37)	($40)
2021	$20	$14	$77	$49	$36	$36	($43)	($46)
2022	$24	$17	$88	$56	$41	$41	($49)	($53)
2023	$27	$19	$99	$63	$46	$46	($55)	($59)
2024	$30	$21	$110	$70	$51	$51	($62)	($66)
2025	$33	$23	$121	$77	$56	$56	($68)	($73)
2026	$37	$26	$132	$84	$61	$61	($74)	($79)
2027	$40	$28	$143	$91	$66	$66	($80)	($86)
2028	$44	$30	$154	$98	$72	$72	($86)	($92)
2029	$47	$33	$165	$105	$77	$77	($92)	($99)
2030	$51	$35	$176	$112	$82	$82	($99)	($106)
Sum	**$413**	**$287**	**$1,496**	**$952**	**$695**	**$695**	**($837)**	**($897)**

Table F-4.20 Net Societal Costs for Policy Option AG-3: Conversion to Perennial Cover (continued)

Year	Policy Option Scenario Costs								
	Initial Conversion Costs: Seed	Initial Conversion Costs: Non-Seed/Non-Fuel	Initial Conversion Costs: Fuel	Initial Conversion Costs: Fertilizer	Hay/Pasture Revenue	Federal Gov't Subsidy	State Gov't Subsidy	State Gov't R&D Program Costs	Total Policy Option Scenario Costs
	MM$	MM$	MM$	MM$	MM$	MM$	MM$	MM$	MM$
2015	$1.7	$1.18	$0.58	$0.13	$0.0	($3.3)	$0.00	$1.8	$2.1
2016	$1.7	$1.18	$0.58	$0.13	($1.6)	($7.2)	$0.00	$1.8	($3.4)
2017	$1.7	$1.18	$0.58	$0.13	($3.3)	($12)	$0.00	$1.8	($9.5)
2018	$1.7	$1.18	$0.58	$0.13	($4.9)	($17)	$0.00	$1.2	($17)
2019	$1.7	$1.18	$0.58	$0.13	($6.6)	($22)	$0.00	$1.2	($24)
2020	$1.7	$1.18	$0.58	$0.13	($8.2)	($28)	$0.00	$1.2	($31)
2021	$1.7	$1.18	$0.58	$0.13	($9.8)	($33)	$0.00	$1.2	($38)
2022	$1.7	$1.18	$0.58	$0.13	($11)	($37)	$0.00	$1.2	($44)
2023	$1.7	$1.18	$0.58	$0.13	($13)	($42)	$0.00	$0.6	($51)
2024	$1.7	$1.18	$0.58	$0.13	($15)	($47)	$0.00	$0.0	($58)
2025	$1.7	$1.18	$0.58	$0.13	($16)	($51)	$0.00	$0.0	($64)
2026	$1.7	$1.18	$0.58	$0.13	($18)	($56)	$0.00	$0.0	($71)
2027	$1.7	$1.18	$0.58	$0.13	($20)	($61)	$0.00	$0.0	($77)
2028	$1.7	$1.18	$0.58	$0.13	($21)	($65)	$0.00	$0.0	($83)
2029	$1.7	$1.18	$0.58	$0.13	($23)	($70)	$0.00	$0.0	($89)
2030	$1.7	$1.18	$0.58	$0.13	($25)	($75)	$0.00	$0.0	($96)
Sum	**$28**	**$19**	**$9.3**	**$2.1**	**($197)**	**($627)**	**$0**	**$12**	**($754)**

Table F-4.21 Net Societal Costs for Policy Option AG-3: Conversion to Perennial Cover (continued)

Year	Net Costs		
	Total Policy Option Costs MM$	Total Discounted Policy Option Costs MM$2014	Cost Effectiveness $2014/$tCO_2e$
2015	($18)	($17)	
2016	($44)	($40)	
2017	($70)	($61)	
2018	($98)	($81)	
2019	($126)	($98)	
2020	($154)	($115)	
2021	($181)	($129)	
2022	($208)	($141)	
2023	($236)	($152)	
2024	($264)	($162)	
2025	($291)	($170)	
2026	($318)	($177)	
2027	($346)	($184)	
2028	($374)	($189)	
2029	($401)	($193)	
2030	($429)	($197)	
Sum	**($3,558)**	**($2,104)**	**($153)**

Macroeconomic (Indirect) Policy Impacts

Tables below provides a summary of the expected impacts of Ag-2 policy on jobs and economic growth during the CSEO planning period.

Table F-4.22 AG-2 Macroeconomic Impacts on GSP, Employment and Income

Scenario	GSP ($2015 MM)			Employment (Individual)			Personal Income ($2015 MM)		
	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)
AG-2	-$2	$8	$113	70	230	3,380	$21	$20	$299

Table F-4.23 AG-3 Macroeconomic Impacts on GSP, Employment and Income

Scenario	GSP ($2015 MM)			Employment (Individual)			Personal Income ($2015 MM)		
	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)
AG-3	$23	-$35	-$529	1,170	-490	-7,420	$56	-$32	-$486

Graphs below show detail in GSP, employment and personal income impacts of Ag-2 policy.

Figure F-4.25 AG-2 GSP Impacts ($2015 MM)

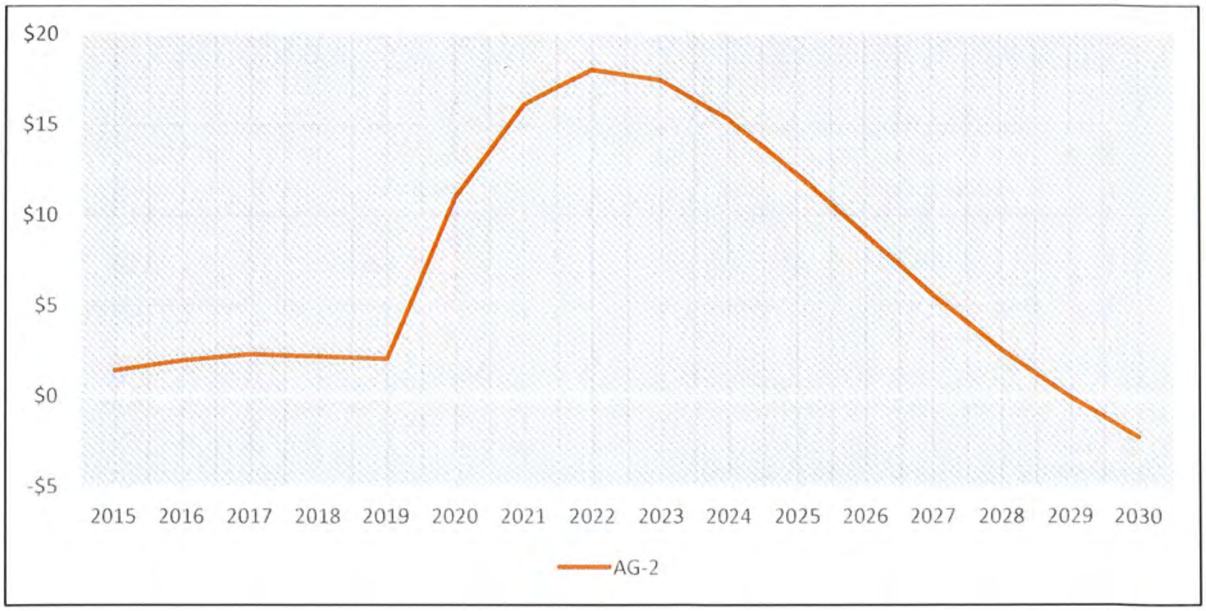


Figure F-4.26 AG-2 Employment Impacts (Individual Jobs)

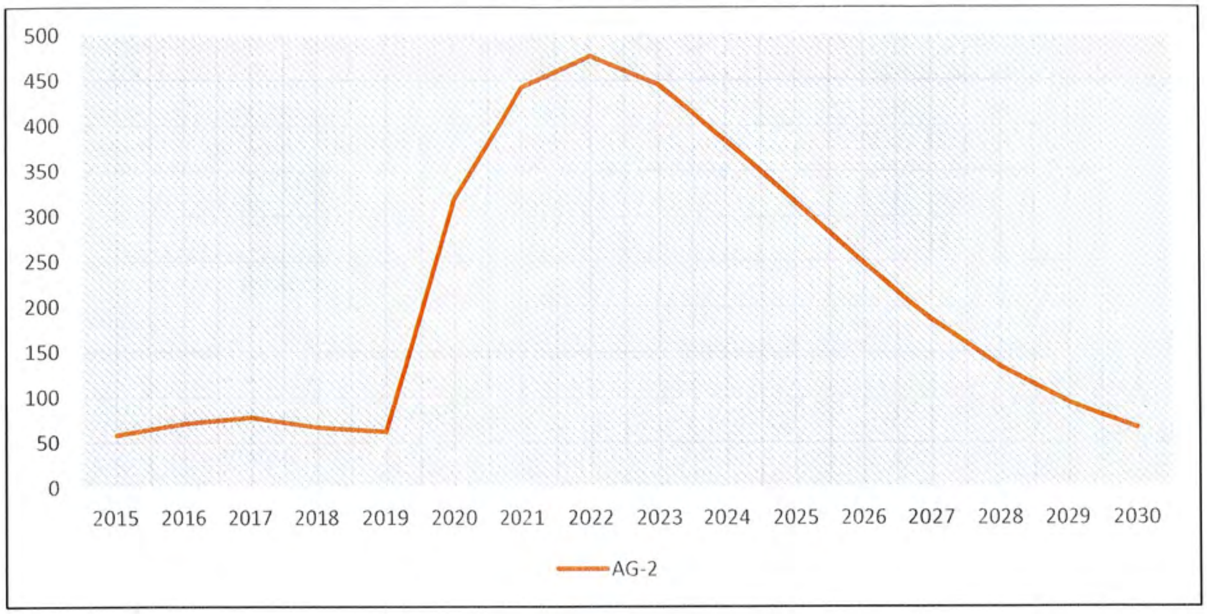
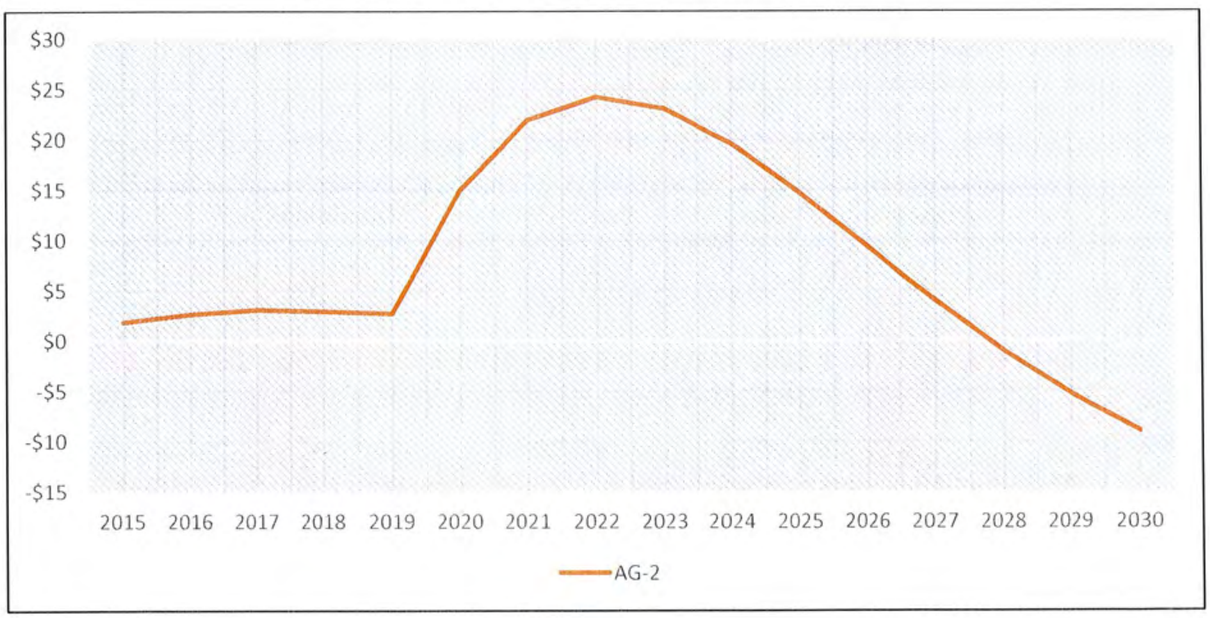
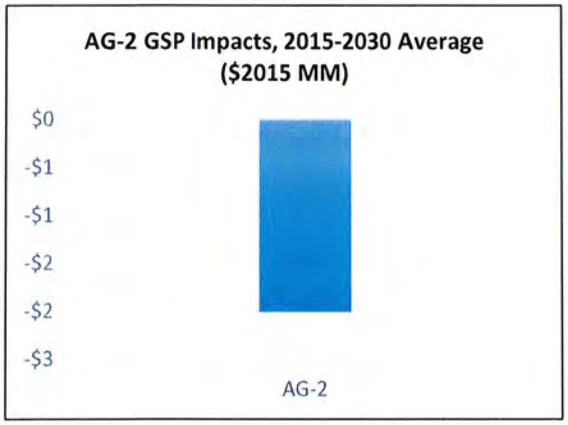
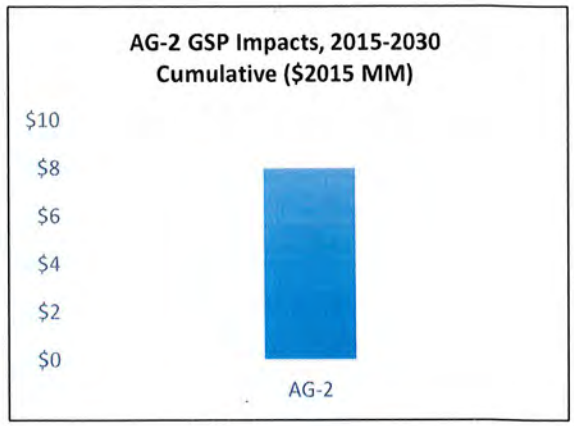


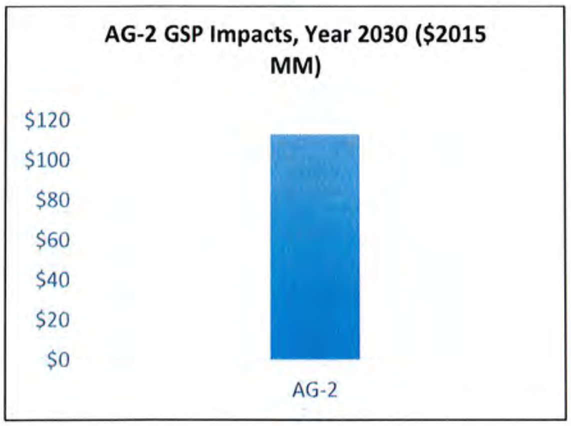
Figure F-4.27 AG-2 Income Impacts ($2015 MM)

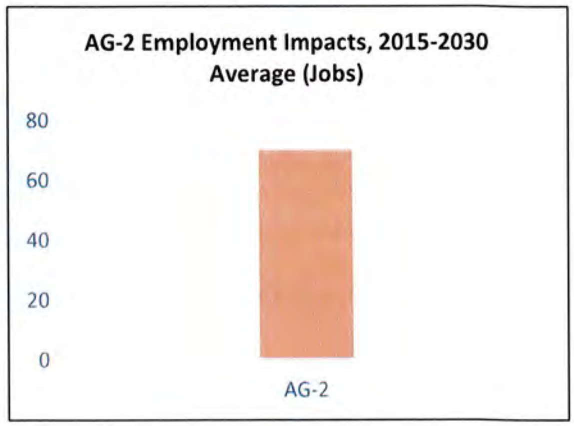


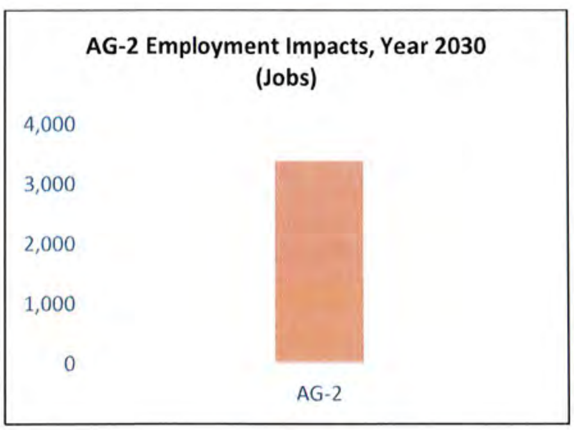
Bar charts below show macroeconomic impacts on GSP, personal income, and employment in the final year (2030), in average (2015-2030) and in cumulative (2015-2030) for Ag-2 policy.

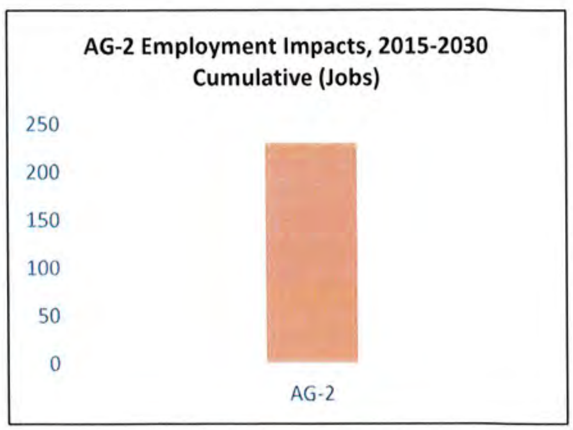

AG-2 GSP Impacts, 2015-2030 Average ($2015 MM)
$0
-$1
-$1
-$2
-$2
-$3
AG-2

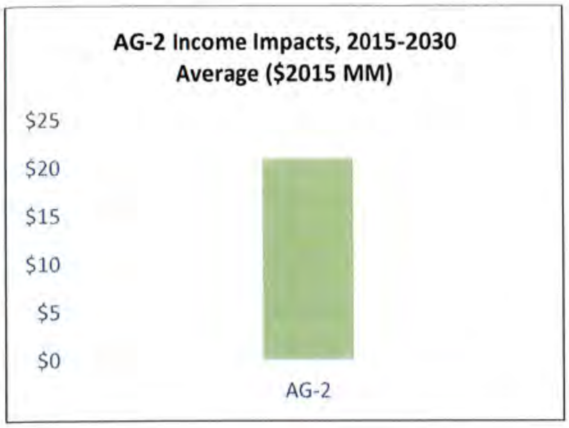

AG-2 GSP Impacts, 2015-2030 Cumulative ($2015 MM)
$10
$8
$6
$4
$2
$0
AG-2

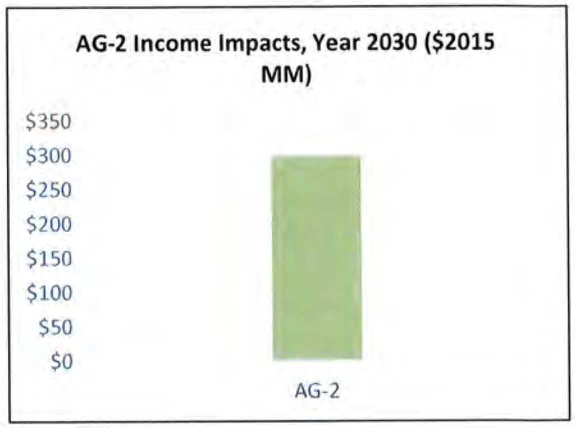

AG-2 GSP Impacts, Year 2030 ($2015 MM)
$120
$100
$80
$60
$40
$20
$0
AG-2

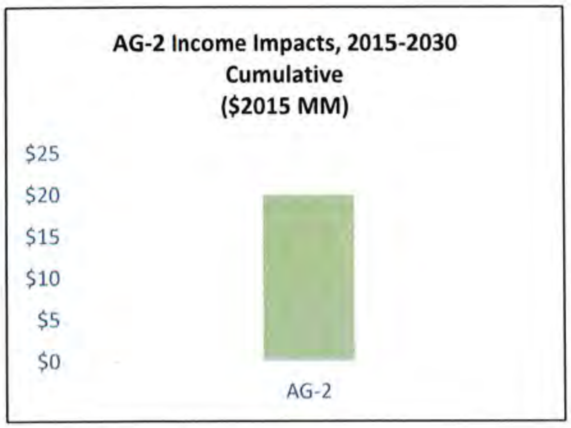

AG-2 Employment Impacts, 2015-2030 Average (Jobs)
80
60
40
20
0
AG-2


AG-2 Employment Impacts, Year 2030 (Jobs)
4,000
3,000
2,000
1,000
0
AG-2


AG-2 Employment Impacts, 2015-2030 Cumulative (Jobs)
250
200
150
100
50
0
AG-2







Principal Drivers of Macroeconomic Changes

AG-2, like AG-1, imposes net higher costs on farms, all in all, by approximately $200 million by the year 2030. The higher costs push down investment, but the direct hiring as the largest of that cost offsets this impact. Those hires produce consumer spending, which is an effective positive force in economic impacts.

State spending follows the same profile as the farm spending, as it is directed mostly to program implementation and to pilot programs. It is displacing other existing programs, so its impact directly is positive, but is offset statewide by reductions in spending (and the benefits that produces) in other programs.

Overall employment is slightly positive – fewer than 500 additional new positions, and as a result, incomes rise slightly in response. GSP change is neutral, with neither significant positive nor significant negative impacts.

Sectors of Economy Most Affected by the Policy

Economic impacts from policies run around the economy, affecting sectors that are sometimes far from the direct target of a policy.

For AG-2, the direct hiring by the agriculture sector to implement this policy drives the policy upward, and constitutes the vast majority of the small shift in employment upward. No other sector shows significant effects.

Data Sources

The principal data sources for the macroeconomic impacts analysis of this and all other policies in the CSEO process are the direct spending, saving, cost and price impacts developed as part of the microeconomic (direct impacts) analysis. For each policy, the cost-effectiveness analysis described above develops year-by-year estimates of the costs, savings prices, and changes demand or supply that households, businesses and government agencies are expected to encounter in a scenario where the policy is implemented as designed.

A secondary data source is the policy design. Balancing financial flows for each direct impact identified are established based on understanding the implementation mechanism, and quantitative values for these flows are developed for each direct impact identified. This balancing identifies and quantifies the responsive change that occurs as a result of the direct impact in question. For example, if a household is anticipated to save $100 per year on electricity bills as a result of a policy, the direct impact is a $100 savings to the household (which expands its spending capacity for other things) but the balancing impact is a $100 loss in revenue and demand to the utility provider (which reduces its ability and need to spend on labor, capital, profit, and other inputs). The quantitative measure of both sides of a change is of importance to a complete macroeconomic analysis. This balancing ensures that both the supply and the demand side of each economic change is fully represented in the analysis.

A third data source is direct communication with Minnesota agency staff and others involved in policy design or in a position to understand in detail the financial flows involved in the policy. These people assisted in clarifying the nature of economic changes involved so that the modeling and analysis would be accurate.

The final crucial data source is the baseline and forecast of economic activity within the REMI software. This data is compiled into a scenario that is characterized not only by the total size of the economy and its many consuming and producing sectors, but also the mechanisms by which impacts in one sector can change the broader economy – such as intermediate demands, regional purchase coefficients, and equilibria around price and quantity, labor and capital, and savings and spending, to name a few of many. REMI, Inc. maintains a full discussion of all the sources of the baseline data on its own website, www.remi.com.

In the case of the AG-2 policy, important data included:

- Spending by farms on fuels, seed, equipment, and additional labor to implement the policy.
- Savings by farms on fertilizer. These savings reach approximately $30 million statewide, which is only about 10-15% of the cost of the program.
- Additional hiring by farms to implement this more labor-intensive nitrogen-inhibition method.

- A shift in spending – less total spending on fertilizers, but more on nitrogen inhibitors. The chemical sector sees both sides of this shift, and the net cost is positive to farms.
- Government costs to administer the program and to implement pilot projects.

Quantification Methods

Utilizing the data developed from the microeconomic analysis, CCS analysts established for each individual change the following characteristics:

- The category of change involved (change in spending, savings, costs, prices, supply or demand)
- The party involved on both sides of each transaction
- The volume of money involved in this change in each year of the period of analysis

These values, so characterized, were then processed into inputs to the REMI PI+ software model built specifically for use by CCS and consistent with that in use by state agencies within Minnesota. These inputs were applied to the model and run. Key results were then drawn from the model and processed for consistency of units and presentation before inclusion in this report.

Key Assumptions

The macroeconomic impact analyses of this policy, as well as of the others in the CSEO process, rely on a consistent set of key assumptions:

- State and local spending is always budget-constrained. If a policy calls for the state or local government to spend money in any fashion, that spending must be either funded by a new revenue stream or offset by reductions in spending on other programs. Savings or revenues collected by the government are also expected to be returned to the economy as spending in the same year as they are collected.
- Federal spending is not budget-constrained. The capacity of the federal government to carry out deficit spending means that no CSEO policy is held responsible for driving either an increase or decrease in federal tax spending by businesses or households in the state of Minnesota.
- Consumer spending increases are sometimes financed. Small-scale purchases or purchases of consumer goods are treated as direct spending from existing household cash flows (or short-term credit). Durable goods, home improvements or vehicle purchases, however, are treated as financed. Consumers were assumed to spread out costs based on common borrowing time frames, such as five years for financing a new vehicle or 10-20 years for home improvements that might be funded by home-equity or other lending. The assumption of financing and the term of years applied was considered anew in each case.
- Business spending increases are often financed. Where spending strikes a sector which routinely utilizes financing or lines of credit to ensure steady payment of recurring costs, significant spending of nearly any type was considered a candidate for financing, thus

allowing costs to spread out over time. This methodology is preferable for the modeling work, as sudden spikes or dips in business operating costs can show up as volatility when the scenario may depict a managed adoption of new equipment in an orderly fashion. The assumption of financing and the term of years applied was considered anew in each case.

- Unless otherwise stated, all changes to consumer spending or to the producers' cost of producing goods and services were treated in a standard fashion. Consumers are assumed to spend on a pre-set mix of goods, services, and basic needs, and businesses spend (based on their particular sector of the economy) on a mix of labor, capital, and intermediate demands from other sectors. Unless a policy specifically defines how a party will react to changes in cost, price, supply or demand, these standard assumptions were applied.
- State and local spending gains and reductions driven by policy are assumed to apply to standard mixes of spending. Again, unless a policy specifically states that a government entity will draw from a specific source or direct savings or revenues to a specific form of spending, all gains and losses were assumed to apply to a standard profile of government spending within the economy.

Graphs below show detail in GSP, employment and personal income impacts of AG-3 policy.

Figure F-4.28 AG-3 GSP Impacts ($2015 MM

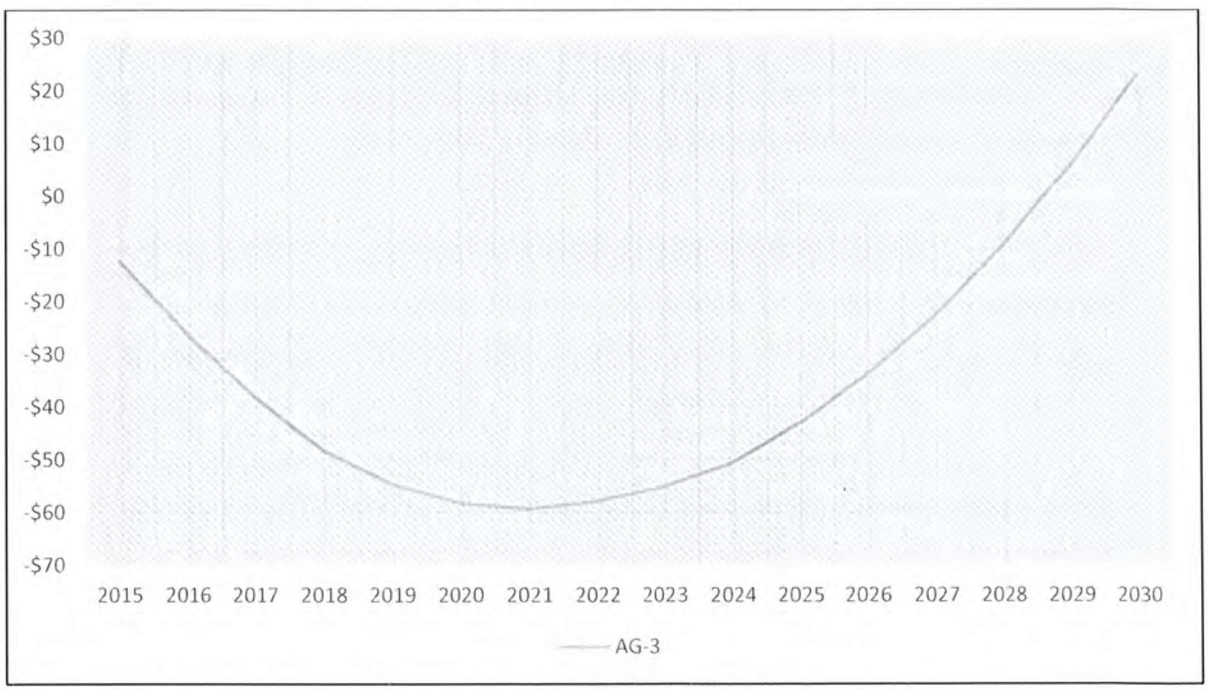


Figure F-4.29 AG-3 Employment Impacts (Individual Jobs)

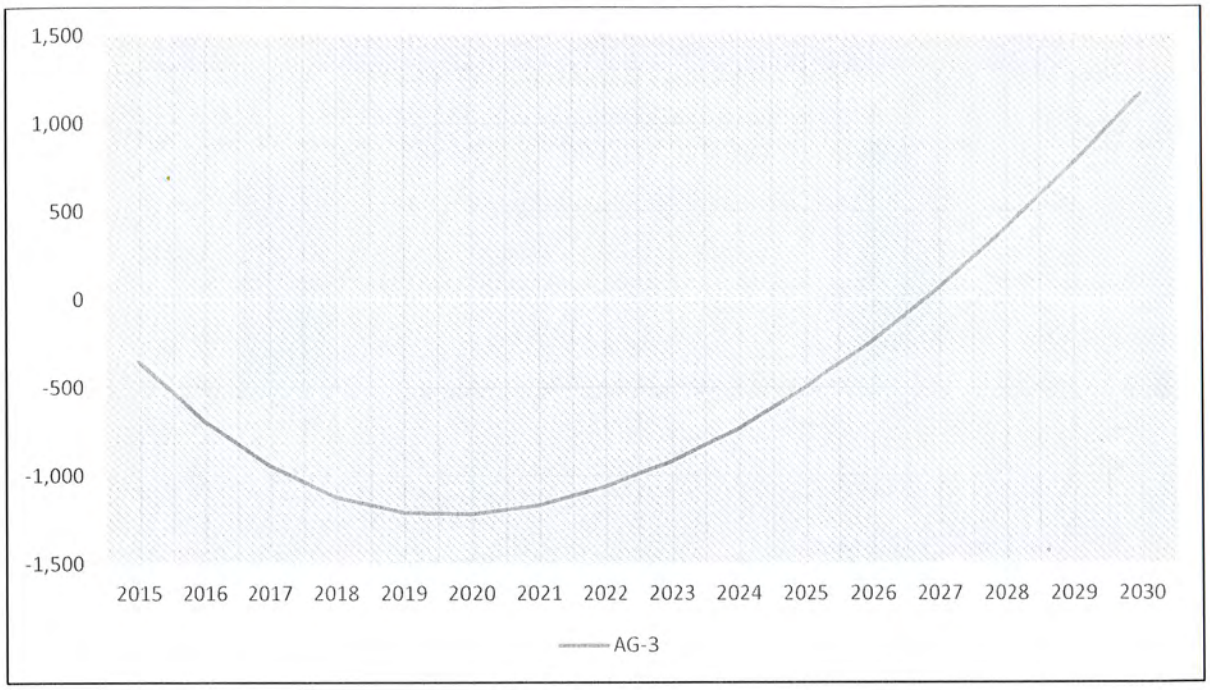
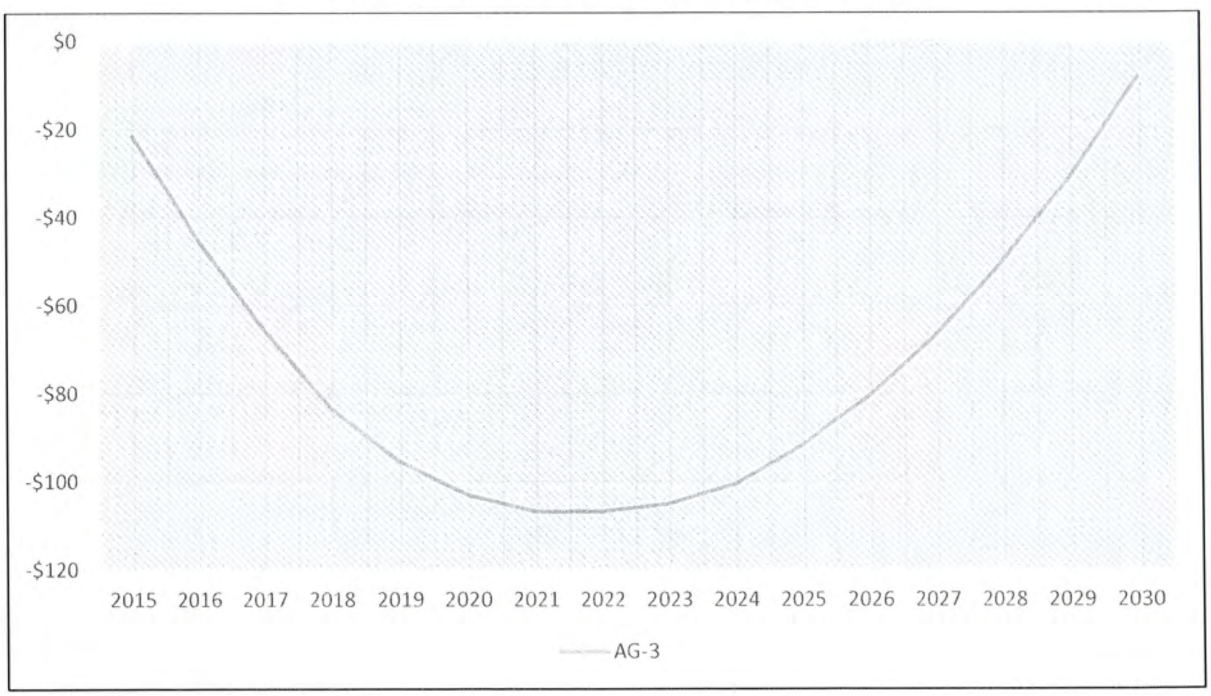
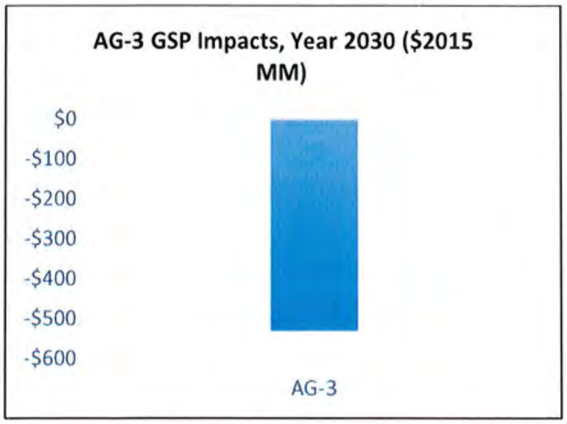
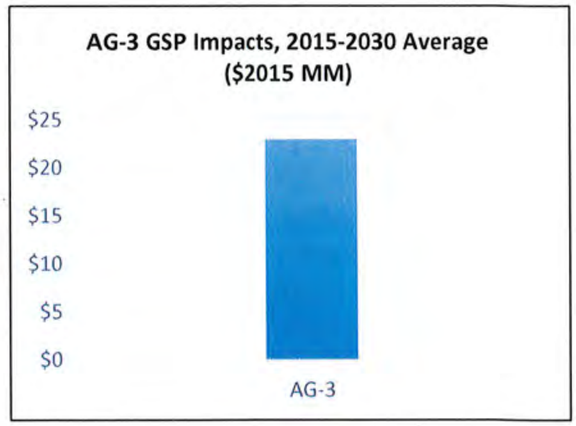


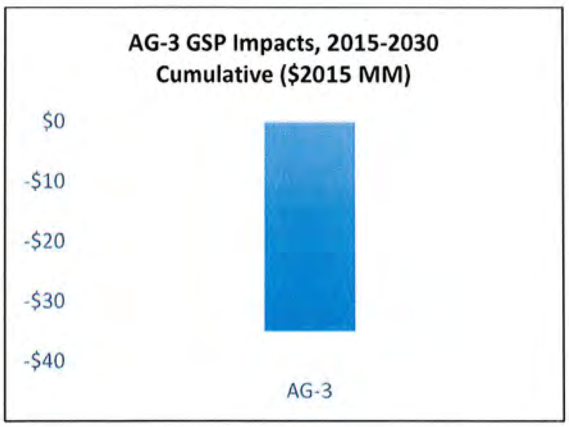
Figure F-4.30 AG-3 Income Impacts ($2015 MM)

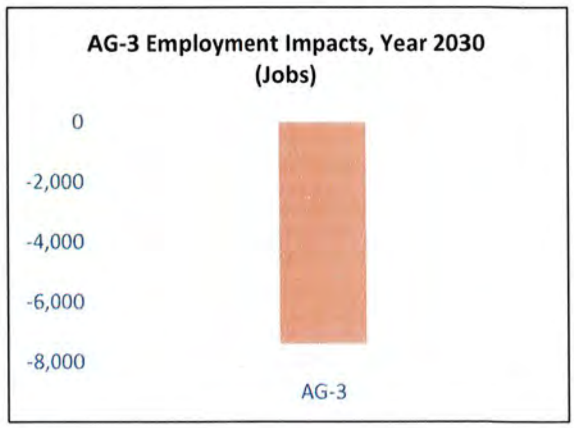


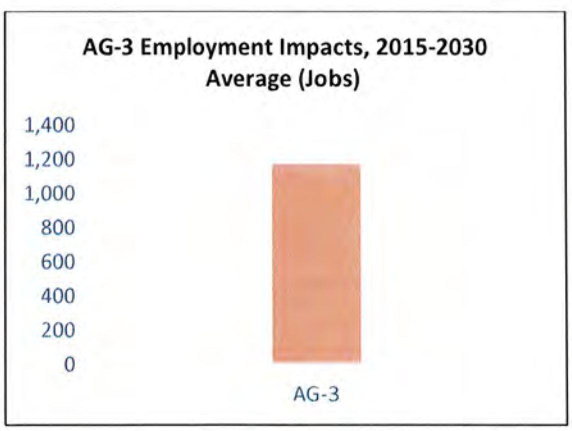
Bar charts below show macroeconomic impacts on GSP, personal income, and employment in the final year (2030), in average (2015-2030) and in cumulative (2015-2030) for Ag-3 policy.

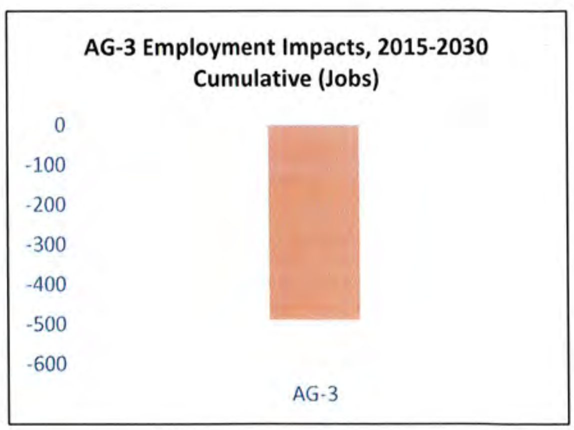

AG-3 GSP Impacts, Year 2030 ($2015 MM)
$0
-$100
-$200
-$300
-$400
-$500
-$600
AG-3

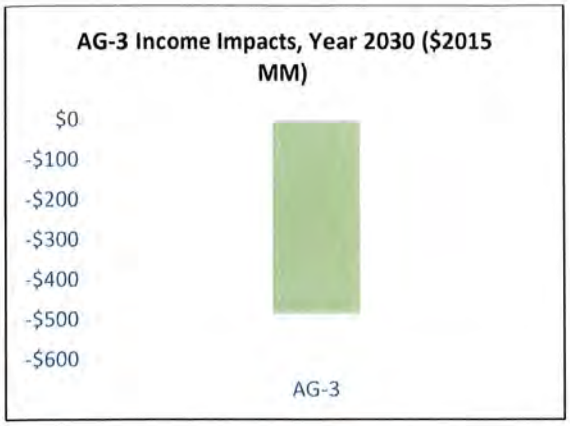

AG-3 GSP Impacts, 2015-2030 Average ($2015 MM)
$25
$20
$15
$10
$5
$0
AG-3

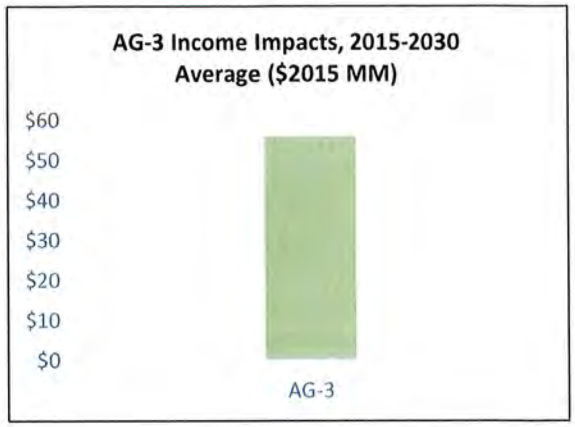

AG-3 GSP Impacts, 2015-2030 Cumulative ($2015 MM)
$0
-$10
-$20
-$30
-$40
AG-3

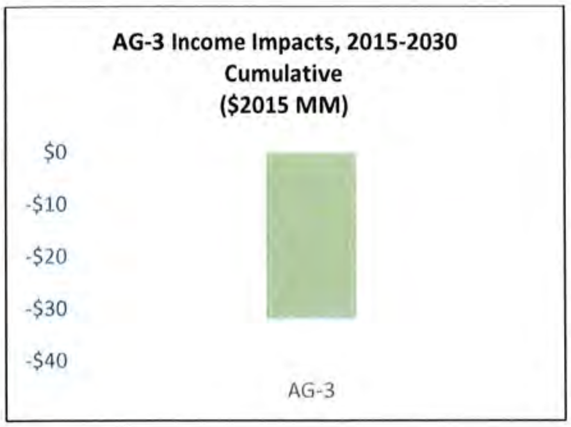

AG-3 Employment Impacts, Year 2030 (Jobs)
0
-2,000
-4,000
-6,000
-8,000
AG-3


AG-3 Employment Impacts, 2015-2030 Average (Jobs)
1,400
1,200
1,000
800
600
400
200
0
AG-3


AG-3 Employment Impacts, 2015-2030 Cumulative (Jobs)
0
-100
-200
-300
-400
-500
-600
AG-3







Principal Drivers of Policy Impact on the Broader Economy

AG-3 has an interesting forecast, in that the policy appears to apply a slight downward pressure on the economy for a dozen years, during which employment, incomes and GSP all fall slightly below neutral. However, as the lower production costs take hold and farms adjust slowly to this cost (through a combination of reduced prices and expanded operations), the sector – and the entire economy – sees a return to neutral and an upward trend in all three indicators from around 2021 to 2030. So the policy is initially dampening to the economy, but over the long term shows the potential to be slightly positive.

The major driver is the voluntary reduction in total activity in the sector – less-expensive farming mechanisms are applied to grow crops that sell for less, and fewer inputs of all sorts are required to make this happen.

However, the lower cost of production shows up in these models as an expansive force, allowing farms to expand slightly and lower prices. These two forces counteract the initial reduction in scale of economic activity that defines this policy.

Sectors of Economy Most Affected by the Policy

Economic impacts from policies run around the economy, affecting sectors that are sometimes far from the direct target of a policy.

For AG-3, however, the impacts are primarily felt directly in the agriculture sector. It sheds economic activity through the first few years, employing over 100 fewer people statewide by the early 2020s, but rebounds back to being the only sector with significant positive (though still small) gains by 2030.

Key Uncertainties

Key uncertainties in managing soil carbon using cover crops are related to impacts on N_2O emissions, commercial fertilizer application rates, and changes in diesel fuel consumption. The literature is mixed on the N_2O emissions consequences of cover cropping. Some studies seem to suggest that cover cropping increases N_2O emissions, rather than decreases them.[21] Basche and Miguez concluded: Cover crops have the potential to increase or decrease nitrous oxide emissions, depending upon the N fertilization level, soil pH, period of measurement and type of cover crop (grass or legume). In some instances, the reported N_2O emissions increase can be large enough to offset completely any emissions reduction from increased soil organic carbon (SOC) accumulation.[22]

N_2O formation in soils is generally favored by high soil organic carbon and increased soil wetness. The presence of cover crops encourages both of these conditions. Target crop yields and nitrogen crediting for cover crops influence commercial fertilizer application rates. Leguminous cover crops provide a source of nitrogen to the following cash crop and reduce the need for synthetic nitrogen fertilizer application. Currently there is no consensus on the best method to credit cover crops nitrogen contribution. Also, it is unknown whether the majority of farmers count the credit and adjust commercial Nitrogen application accordingly. Decreased crop nitrogen needs reduce commercial fertilizer use when per acre yields are constant or declining. When yields increase, it is possible that per acre nitrogen applications could remain constant or increase, depending on how the yield target changes. This is a function of how returns per acre are perceived by the producer to have changed as a result of increased nutrient use efficiency (NUE) (stemming from the use of cover crops).

Fuel costs and fuel savings for cover crop establishment and termination will vary depending on establishment and termination methods. Cover cropping is often done in combination with reduced tillage. Fuel is saved when switch from conventional tillage to reduced tillage. Fuel use increases if additional field passes are need to establish or terminate cover crops. However new technologies exist allowing farmers to seed cover crops while simultaneously side dressing nitrogen, spraying herbicide or applying manure. In this case, no additional fuel is consumed.

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[21] In reviewing the published literature (about 25 studies, about 100 data points) Basche and Miguez (2012) found that in about 60% of the studies cover cropping increased N_2O emissions and decreased them in about 40%. A. Basche and F. Miguez, 'Do Cover Crops Increase or Decrease Nitrous Oxide Emissions? A Meta-Analysis,' http://www.sustainablecorn.org/Publications/Posters_docs/2012/Cover-Crops-and-N20-emissions_Basche.pdf

[22] S. Peterson, et al., 'Tillage Effects on N_2O Emissions as Influenced by a Winter Cover Crop,' Soil Biology and Biochemistry, 30 (2011): 1-9.

There is no one size fits all approach for cover management and it is difficult to pin down generalized estimates.

Key uncertainties in managing soil carbon using perennial cover include cattle herd expansion and subsequent methane and N_2O emissions. A one-million-acre increase in forage acreages, if all in alfalfa and other hay, would increase total hay acres in the state by about 50%. Increased production of forages would lower cattle feed costs, leading to some herd expansion. An increase in methane emissions from ruminant flatulence and methane and N_2O emissions from manure storage and land application then might be expected. The impact of a one million acre expansion of forages on feed costs and livestock populations is challenging to estimate. An 20% expansion in the state cattle herd results in a one half million CO_2e ton annual increase in emissions. However, the expansion of the in-state cattle herd could also be viewed as off-setting the need for higher cattle herds out of state with potentially higher GHG emissions per unit of production. Additional emissions associated with energy use in the livestock sector also would be likely.

The persistence of added soil organic carbon is uncertain and dependent on maintaining land management practices over long periods of time (many decades). An estimate of soil organic carbon persistence is necessary to translate the estimated storage into tons of CO_2 equivalence. For the purposes of this policy option analysis, a soil organic carbon permanence factor of 0.2 was applied to estimate the amount of carbon stored permanently.

Additional Benefits and Costs

Cover Crop Co-benefits: Reduced soil erosion and sedimentation, increased water storage on the landscape due to increased soil organic matter (SOM) content, improved nutrient cycling, and improved water quality. Many practices that sequester soil carbon also buffer the landscape and protect against extreme weather events associated with climate change.

Cover Crop Costs: Some producers may purchase specialized equipment for planting cover crop seeds into standing crops like corn.

Perennial Crop Co-benefits: Reduced soil erosion and sedimentation, improved water quality, wildlife habitat, increased water storage on the landscape due to increased SOM content, and provides resiliency to extreme weather events associated with climate change. Increasing perennial grass acreage in Minnesota has the potential of returning grazing animals to the landscape. Managed grazing by ruminant animals is an effective method of managing perennial landscapes of grasses and legumes (i.e., helps prevent overgrowth by trees and shrubs), and improves vegetative health (increasing carbon uptake) by distributing manure on the landscape. Through physical and chemical processes, manure is incorporated into the soil and a portion is converted to soil organic matter.

Some additional benefits include: reduced soil erosion and sedimentation; reduced nitrogen run-off and leaching and attendant water quality impacts; improved weed control; improved soil physical properties and, potentially, long-term yields. For conversion to perennial cover, trickle through benefits of expanded meat and dairy commodities production might represent an additional benefit that might be considered.

Climate Change Adaptation Benefits: Managing carbon in agricultural soils provides community resiliency and ecosystem co-benefits such as:

- Increasing water availability and reducing drought impacts by holding more water in the soil profile,
- Improving resistance to agricultural pests by utilizing cover crops to enhance bio-control with beneficial insects,
- Improving surface and ground water quality by reducing runoff from agricultural fields and reducing erosion, sedimentation and nutrient export, and
- Increasing resilience of agricultural production by maximizing plant available water in the soil, reducing soil temperatures and evapotranspiration, improving nutrient cycling, and reducing pest outbreaks.

Potential Health Impacts

The two primary soil carbon management practices that the Minnesota CSEO policies address include incorporating cover crops where practical and diversifying annual cover-crop rotations with perennials. Incorporating cover crops may result in a decrease in nitrogen fertilizer use. Switching annual cover crop rotations with perennials could result in reduced use of fossil fuels and subsequent particle pollution emissions due to less tilling and crop management. Perennial vegetation and cover crops may reduce the need for herbicides and pesticides and prevent soil erosion, protecting water quality.[23] The primary health impacts of soil carbon management (primarily perennial vegetation) will result from reductions in nitrate (NO_3) concentrations, as well as other agricultural chemicals, in drinking water (see policy option AG-1); reduced exposure to particle pollution; and reduced exposure of farmers to pesticides and herbicides. Reduced exposure to particle pollution may reduce exacerbations of respiratory and cardiovascular diseases, such as asthma, allergies, and chronic obstructive pulmonary disease (COPD), as well as cancer mortality in exposed populations (EPA[24]; Kappos[25]; Pope 2002, Pope

[23] Sustainable Agriculture Research & Education (SARE). 2012. Benefits of Cover Crops (website). Accessed October 23, 2014. http://www.sare.org/Learning-Center/Books/Managing-Cover-Crops-Profitably-3rd-Edition/Text-Version/Benefits-of-Cover-Crops.

[24] U.S. Environmental Protection Agency. Coal. http://www.epa.gov/cleanenergy/energy-and-you/affect/coal.html, Updated August 2014.

[25] Kappos et al. Health effects of particles in ambient air. International Journal of Hygiene and Environmental Health. Volume 207, Issue 4, 2004, Pages 399–407.

2000[26]; Bernard[27]). If not handled and used properly, exposure to agricultural chemicals (including pesticides and herbicides) may result in both acute and chronic health effects, including acute and chronic neurotoxicity (insecticides, fungicides, fumigants), lung damage (paraquat), chemical burns (anhydrous ammonia), hematopoietic cancers, immunologic abnormalities and adverse reproductive and developmental effects (Weisenburger[28]; Alvanaja et al.[29]). The potential reduction of agrichemical use through the introduction of perennial vegetation and cover crops may reduce farmers' exposure and related health outcomes.

Feasibility Issues

Cover Crops: Cover crop adoption on short season crops has few barriers. However, cover crop adoption in traditional corn/bean system has many barriers. These barriers are:

- A short window of opportunity for establishment,
- Consistent establishment and field coverage,
- Issues and uncertainties regarding crop insurance and USDA Risk Management Agency,
- A potential shortage of cover crop seed, this is especially true if practice adoption is swift,
- Cover crops viewed as an 'unproven' practice by some producers and therefore a reluctance to try, and
- Stable, long-term policy option commitment is needed to incentivize perennial crop practices. At this point it is unknown if the State will develop long-term policies for cover crops.

Perennial Crops:

- Markets may not be ready for an influx of perennial products,
- Reluctance of farmers to convert cash crop land to perennials plantings because of lost opportunity cost, and

[26] Pope CA III, Burnett RT, Thun MJ, Calle EE, Krewski D, Ito K and Thurston GD. 2002. Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. JAMA. Vol. 287 (9): 1132-41.

Pope CA III. 2000. Epidemiology of fine particulate air pollution and human health: biologic mechanisms and who's at risk? Environ Health Perspect; 108:Supple 4:713-23.

[27] Bernard SM, Samet JM, Grambsch A, Ebi KL, Romieu I. 2001. The potential impacts of climate variability and change on air pollution-related health effects in the United States. Environmental Health Perspectives Vol 109, Supplement 2, pp 199-209.

[28] Weisenburger D. 1993. Human health effects of agrichemical use. Human Pathology. Volume 24, Issue 6, June 1993, Pages 571–576. DOI: 10.1016/0046-8177(93)90234-8.

[29] Alavanja M, Hoppin J, Kamel F. 2004. Health Effects of Chronic Pesticide Exposure: Caner and Neurotoxicity. Annual Review of Public Health. Vol. 25: 155-197 (Volume publication date April 2004). DOI: 10.1146/annurev.publhealth.25.101802.123020.

- Stable, long-term policy option commitment is needed to incentivize perennial crop practices. At this point it is unknown if the State will develop long-term policies for cover crops and perennial crops.

Updating, Monitoring and Reporting

The current Minnesota GHG emission inventory does not include soil carbon storage, except for forest soil; carbon storage in forests is not included in the state emission total but presented separately. Carbon emissions from histosol cultivation and soil erosion and oxidation are represented with placeholder estimates because of limited information. The current inventory methods will not be able to evaluate this policy option. Significant data collection and inventory modification would be necessary.

AG-4. Advanced Biofuels Production

Policy Option Description

Production based incentives to support commercial development of advanced biofuels in Minnesota. Advanced biofuel would be sourced primarily from Minnesota biomass feedstocks from agricultural or forestry sources, or the organic content of municipal solid waste. Fuels made from biological materials tend to have lower energy-cycle emissions[30] as compared to fossil-based sources, and thus their use provides net greenhouse gas reductions.

Production based incentives to support commercial development of advanced biofuels in Minnesota are proposed. Proposed legislation for this initiative was introduced in 2014, HF 2456 and SF2101, are expected to return for consideration in 2015. Advanced biofuel (as defined in the legislation, which uses the definition in public law of improving greenhouse gas emissions over the fossil fuel it replaces by 50% or better – this would not include current technology for ethanol or biodiesel) would be sourced primarily from Minnesota biomass feedstocks (at least 80%) from agricultural or forestry sources, or the organic content of municipal solid waste. Fuels made from biological materials tend to have lower energy-cycle

[30] *Energy-cycle emissions* as defined for this project include the upstream emissions associated with the production of fuels and materials. Using gasoline and diesel fuels as examples, the energy-cycle emissions would include the GHG emissions for petroleum extraction, transport, processing, and distribution, as well as those from the combustion of the fuel itself. CCS differentiates energy-cycle from life-cycle based accounting.
Lifecycle emissions involves a cradle-to-grave view of GHG emissions associated with the use of a fuel or product. Such an assessment includes the extraction and transport of raw materials, manufacture, packaging, freight, usage and finally disposal. It also includes the emissions from construction of all facilities within the value chain. Using the previous example, that would include construction of the extraction well (and its components), transport pipelines/ships, refineries, gasoline stations, vehicles, etc.

emissions as compared to fossil-based sources, and thus their use provides net greenhouse gas reductions.

Hand-in-hand with this policy option is Policy Option AG-5 which focuses on biofuel consumption within the state. In many cases installation of infrastructure for storage and delivery of higher biofuels blends must also be accomplished in order to ensure a marketplace for the fuels, especially ethanol-blended gasoline with ethanol content greater than 10% by volume, as current regulation requires, being incentivized in this policy option. A second option would be to require gasoline dispensing locations to upgrade their equipment to a specific, reasonable priced ethanol blend level as the infrastructure turns over into the future.

Causal Chain for GHG Reductions

Figure F-4.31 Causal Chain for AG-4 GHG Reductions

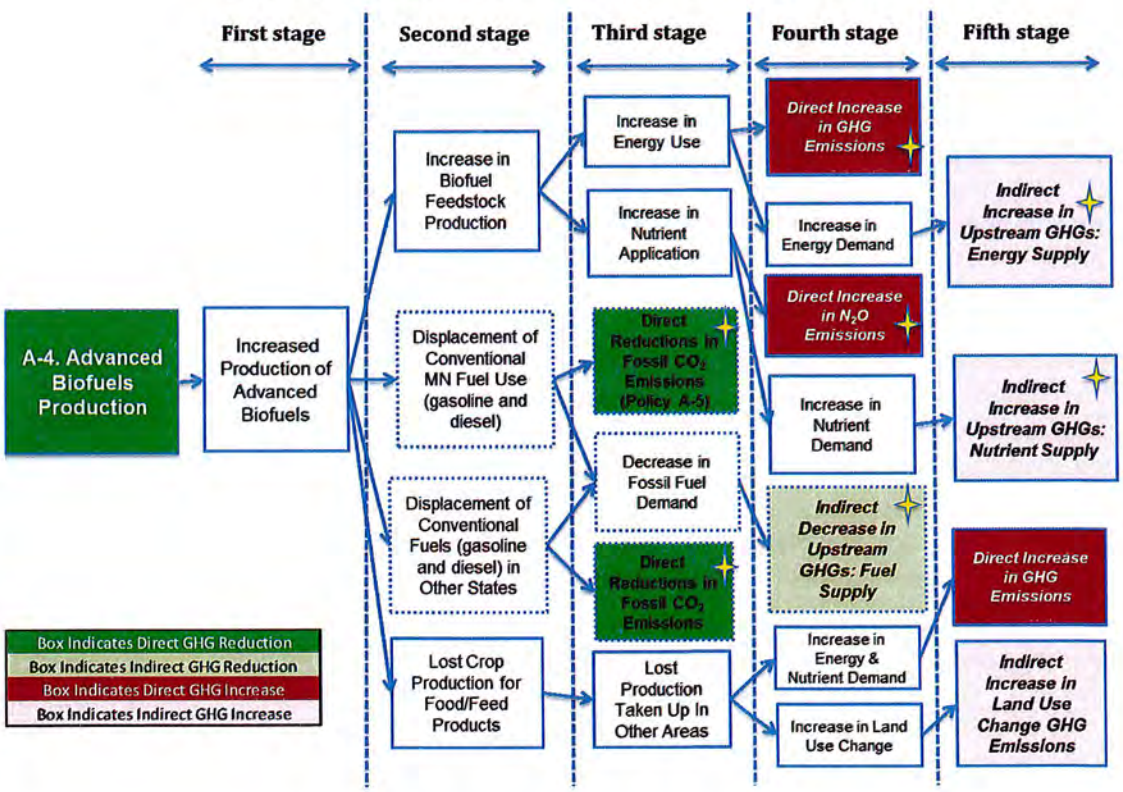
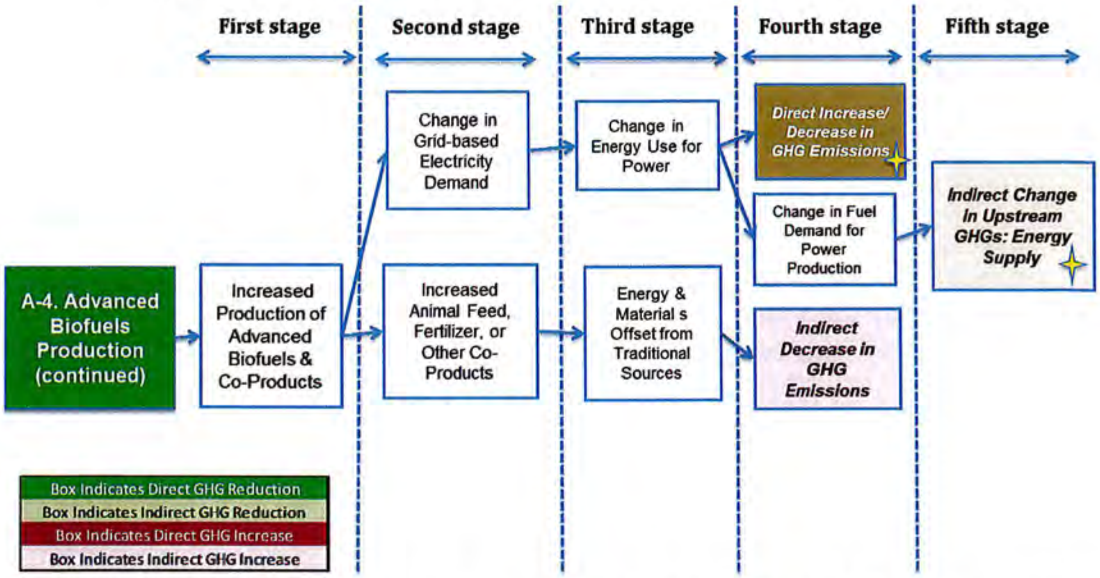


Figure F-4.32 Causal Chain for AG-4 GHG Reductions (continued)



The star symbol identifies significant GHG effects that will be quantified. For this policy option, the analysis will center on developing estimates of the volumes of advanced biofuels produced in the State during each year, their associated carbon content, and their production costs. These results will be used as input to the analysis of Policy Option AG-5 addressing increased biofuels consumption in order to determine the full GHG benefits and costs for in-state biofuels production and use (the dotted lines around the fossil fuel displacement boxes indicate these displacement effects). All of the quantified GHG effects for this policy option analysis will be used to develop the advanced biofuel carbon content for use in the AG-5 analysis.

As shown in the causal chain above, with any biofuels or bio-products production policy option, there is a potential for dis-benefits from lost crop production capacity for food and feed. These include emissions from indirect land use change (e.g. lands in grassland or forest cover are converted to make up for lost food/feed production in Minnesota or elsewhere). These dis-benefits won't be quantified in this policy option analysis; however, the policy option goals and implementation methods were designed to minimize their potential (i.e. by minimizing the loss in crop production capacity in Minnesota). There are also additional co-benefits associated with the co-products from advanced biofuels production. These could include: renewable power production sold to the grid from the excess electricity produced from certain types of biofuels plants (e.g. cellulosic ethanol), animal feed, fertilizer, or other co-products. This policy option analysis will provide an accounting for any excess power production, but will not include any accounting of the additional co-products benefits due to data availability and the likely significance of these in terms of net GHG reductions.

Policy Option Design

Goals: Advanced biofuel production goals:

- 150 million gallons produced from 2015 - 2020
- 500 million gallons by 2025
- 875 million gallons by 2030

Timing: If policy option is passed in 2015, eligible projects could begin production for eligible payments beginning on July 1, 2015. Assume two year time horizon before the first plant is operating with production total of 25 million gallons of starch-based advance ethanol per year; assume five years until the first cellulosic plant of 25 million gallons per year capacity.

Parties Involved: State of Minnesota Department of Agriculture, as the implementer. Other affected parties include: advanced biofuel producers; refiners, to meet renewable fuel standard (RFS) blending requirements under the RFS; corn (if advanced biofuel is butanol) and beet producers; cellulosic feedstock suppliers and producers; cellulosic sugar producers.

Other: The national goal through the Renewable Fuel Standards is 58% of renewable fuels are advanced biofuels by 2022, totaling 21 billion gallons blended into the transportation fuel supply by that time.

The goal for the Minnesota incentive program is $15 million in producer payments annually, which would equate to a range of 7,124,875 - 14,245,014 MMBtu, depending on what portion of the payments is at the lower (starch-based advanced biofuel) or higher (cellulosic-based advanced biofuel) levels. This is the equivalent of a range of 92,500,000 - 185,000,000 ethanol equivalent gallons of biofuel per year. For this policy option we will use ethanol for all calculations with the assumption that other biofuels, such as butanol or drop-in renewable hydrocarbon replacement fuels, could translate into the policy option on a MMBtu basis.

Implementation Mechanisms

The policy option also creates a loan program for capital expenditures needed to build the production facilities. Production incentive payments would be based on the total BTU content of the fuel produced. Payments for cellulosic-based fuel production would be more than for corn starch/other readily available sugar production, currently proposed at $2.1053/MMBtu and $1.053/MMBtu respectively. Total payments in any one year would not exceed $15,000,000 and total payments to any individual producer would not exceed 2,850,000 MMBTU of biofuel production per year. The 2,850,000 MMBtu of production equates to just over 37 million gallons of ethanol-equivalent fuel in production (77,000 Btu/gallon) and $3-6 million based on the type of feedstock being used to produce the biofuel.

Minnesota built a first generation ethanol industry using a producer payment policy option. Over the course of a 10-year program the state spent approximately $450 million to support the development of ethanol plants. Today, the ethanol industry supports 12,600 jobs and generates over $5 billion annually in economic activity. Passage of a production incentive payment program for advanced biofuels would make Minnesota a world-class location for building commercial-scale production facilities. The incentive can be used to help leverage private investment for facility construction. The production incentive approach also helps to protect state investment using taxpayer dollars since no payments are made until production occurs. This type of policy option also has the advantage of removing government from the role of evaluating technology. Projects that cross the finish line are rewarded for their success.

Biobutanol as a transportation fuel made from corn starch would qualify if it improves greenhouse gas emissions compared to gasoline by at least 50%. Considerations will have to be made for ethanol plants that received producer payments for ethanol production (and hence were built to some degree with the payments and the promise of the payments).

Concerns need to be addressed on the sourcing of biomass feedstocks so that the collection is done in an environmentally appropriate way. Incentives could be tied to land management practices.

Legislation:

- Incentive payments ($15 million per year maximum totals for all producers and 2,850,000 MMBtu of biofuel production per year maximum per producer).
- Capital equipment loans.

Related Policies/Programs in Place and Recent Actions

- AG-5, Existing Biofuel Statute, incentivizing the use of the advanced biofuel produced in the state.
- Next Gen Energy Board grant program.
- Bio-economy Coalition of Minnesota.
- Minnesota Governor's Association Academy grant: develop clean energy economy.

Estimated Policy Impacts

Direct Policy Impacts

Table F-4.24 AG-4 Estimated Net GHG Reductions and Net Costs or Savings

	2030 GHG Reductions (short tons CO_2e)	2015 – 2030 Cumulative Reductions (short tons CO_2e)	Net Present Value of Societal Costs, 2015 – 2030 ($2014)	Cost Effectiveness ($2014/ ton CO_2e)
	See Policy Option AG-5	*See Policy Option AG-5*	*See Policy Option AG-5*	*See Policy Option AG-5*

Note: Each policy option analysis was done over a fifteen year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

For this policy option, the analysis will center on developing estimates of the volumes of advanced biofuels produced in the State during each year, their associated carbon content, and their production costs. These results will be used as input to the analysis of Policy Option AG-5 addressing increased biofuels consumption in order to determine the full energy-cycle GHG benefits and costs for in-state biofuels production and use. Any in-state biofuel production that is not expected to be taken up by the state fleet will be assumed to displace gasoline use outside of the state, and these indirect GHG reductions will be reflected in the combined AG-4/AG-5 Biofuels Package.

Although this policy option does not dictate any specific advanced biofuel production method, some method(s) needs to be specified in order to develop estimates of net energy/GHG impacts and societal costs. For the purposes of analysis, the two methods selected for analysis are: cellulosic ethanol production using corn stover as feedstock; and ethanol from energy beets:

- Energy Beets: Production capacity of 25 MMgal/yr. installed by 2016; and 50 MMgal/yr. installed by 2021;
- Cellulosic Ethanol: 25 MMgal production capacity installed by 2020.

Data Sources

- Literature review of current capital and operations costs and energy requirements for cellulosic ethanol and energy beet ethanol production.
- Contacts with industry sources.
- Additional sources include: relevant and available fuel pathways in ANL's GREET Model (for BAU gasoline displacement).

References are footnoted, as applicable below.

Quantification Methods

Energy Impacts and Carbon Content of Advanced Biofuels (Ethanol)

- Quantify biofuel production schedule based on policy option design.
- Quantify the GHG emissions (carbon content) of ethanol feedstocks.
- Data on energy use and N additions taken from the Minnesota BAU inventory and forecast; energy beet acreage is assumed to come from diverted corn production.
- Potential soil carbon impacts of removal of corn stover: the analysis assumes a limitation of 1 ton/acre (20%), which industry sources indicate is a safe level to avoid net losses.[31] BAU stover management assumes 100% is left on the field. Removal at this level is also assumed to not require additional N application as a result of lower crop

[31] Personal communication, S. Hartig, Poet-DSM, with S. Roe, CCS, September 10, 2014. By comparison, N. Clark of DuPont stated that their feedstock sources remove 2 tons/acre (person communication with S. Roe, CCS, September 2014).

residue N input. As a result, impacts on future corn yields are also presumed to be negligible.

- Energy beet yield is 21 ton/acre[32]; energy and GHG impacts are presumed to be similar to sugar beets. Baseline data for sugar beet production used to estimate those for energy beets, except for commercial N application (76 lb. N/acre), which was taken from same USDA study footnoted below.
- Energy requirements of stover harvest and transport: 0.10 gal diesel/acre; this value was derived from the total delivered costs for feedstock ($50/ton) and the assumption that one-third of this cost was attributable to diesel fuel.
- Quantify net plant energy and feedstock requirements based on policy option design, industry contacts and literature review.
- Cellulosic ethanol: 79 gal ethanol/dry ton stover; 149 kWh excess electrical power for the electrical grid.[33]
- Energy beets: 81 lb. beets/gal ethanol,[34] fuel requirements: 1.52 GJ/metric ton beet; electricity: 30 kWh/metric ton beets.[35]
- Quantify feedstock supply carbon content based on sourcing assumptions for advanced ethanol.
- Quantify GHG emissions for each advanced biofuel pathway based on net energy and non-energy impacts of biofuel plants and feedstock production and transport.
- Calculate net carbon content of each biofuel. Production volumes and carbon contents are then used as input to the analysis of Policy Option AG-5.

Table F-4.25 provides a summary of the net energy and GHG impacts of policy option AG-4, including the resulting carbon content of ethanol produced from the presumed fuel pathways (50 MMgal beet ethanol; 25 MMgal cellulosic ethanol). Results can be summarized as follows:

- 2030 C content of advanced ethanol produced: 48.4 tCO_2e/TJ. This is an improvement of 45% over gasoline (88.2 tCO_2e/TJ). Greater relative production volumes of cellulosic ethanol as compared to beet ethanol would push the advanced ethanol carbon content down further for the policy option, as cellulosic ethanol production has a lower fossil energy requirement.

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[32] Value for sugar beets grown in Red River Valley from USDA; *Characteristics and Production Costs of U.S. Sugarbeet Farms*, 2004, http://www.ers.usda.gov/media/943070/sb974-8.pdf.

[33] Based on a model facility in this 2011 National Renewable Energy Labs study: http://www.nrel.gov/docs/fy11osti/47764.pdf.

[34] USDA, 2006. http://www.usda.gov/oce/reports/energy/EthanolSugarFeasibilityReport3.pdf; fuel requirements: $0.01003/lb sugar x 14.18 lb sugar/gal ETOH; App. Table 12; electricity: $0.00283/lb sugar x 14.18 lb sugar/gal ETOH; App. Table 12.

[35] S. Libsack, Independent Consultant, personal communication to S. Roe, CCS, September 12, 2014.

- BAU C content of conventional (corn-based) ethanol in Minnesota was found to be 60.2 tCO_2e/TJ, which is 32% cleaner than conventional gasoline.
- For both advanced and conventional ethanol, the improvement over gasoline could be somewhat higher than reported here. The current assumption for BAU gasoline is based on a US national average mix; whereas, Minnesota sources much of its petroleum from Canadian tar sands, which are expected to produce higher embedded energy and emissions than conventional petroleum derived fuel products.

Net Societal Costs:

- All cost components were assumed to be incremental to BAU (e.g. no costs were avoided as a result of implementing the policy option). For societal costs, the change in production costs and revenue between BAU corn production and Policy Option Scenario energy beet production was not factored in to the analysis.
- Quantify initial investment costs based on literature review of capital costs for plant construction and industry contacts. Annualize these initial investments:
- Energy beet plants: $5.04/gal ethanol capacity;[36]
- Cellulosic ethanol plants: $9.25/gal ethanol capacity:[37]
- All plants assumed to be financed at 8.0% over 10 years with 50% equity share coming from corporate sources located out of Minnesota.
- Quantify non-energy O&M costs based on lit review and industry contacts; feedstock costs based on lit review or data from Minnesota agencies:
- Energy beets: non-energy O&M: variable = $1.68/metric ton beet, fixed = $7.11 metric ton beet (both in $2011), also 0.052 t beet pellet co-product/t beet[38]; value of pellets = $220/t beet.[39]
- Cellulosic ethanol: variable O&M = $2.15/gal; fixed O&M = $0.35/gal.[40]
- Quantify net energy costs based on energy impacts quantified above, wholesale fuel costs, avoided electricity costs, Minnesota production tax credit (assume the credit stated under the Implementation Mechanisms section, $0.16/gal, would be paid to all production targeted by the policy option), and Federal Renewable Identification

[36] Personal communication, S. Libsack, Independent Consultant, to S. Roe, CCS, September 12, 2014.

[37] Average of values provided by DuPont and Poet-DSM. Poet-DSM indicated that costs could come down further into the $8-9/gal capacity range with the next phase of installations.

[38] Personal communication, S. Libsack, Independent Consultant, to S. Roe, CCS, September, 12, 2014.

[39] Internet search in September 2014 found pricing from $220-$225/t on min. 20 t order (Alibaba.com).

[40] Based on the mid-point of the range provided by Poet-DSM of total O&M and a break-down of these costs based on the NREL model facility study cited above.

Number (RIN) value ($0.54/gal based on the current value at time of policy option analysis).

- Derive net costs per gallon of biofuel produced to serve as input to Policy Option AG-5.

As shown in Table F-4.29, ethanol production costs for the policy option were ranged from $1.71/gal in 2017 to $2.86/gal in 2029.

All biofuel supply from AG-4 will be incentivized for sale and use in-state within Policy Option AG-5. Therefore, the results of the AG-4 analysis will include: volumes of biofuel produced; carbon content of biofuel; and production costs. These results will serve as input to the AG-5 analysis to determine net GHG impacts and societal costs for the full Biofuels Package.

Table F-4.25 Production Volumes and Carbon Content

	BAU Energy & Emissions						
Year	Advanced Biofuels Production MMgal	Cumulative Acres of Corn Stover Needed Acres	Energy Use: Corn Stover Mgmt. TJ Diesel	Non-Energy GHGs: Corn Stover Mgmt. tCO_2e	Cumulative Corn Diverted to Beets Acres	Non-Energy GHGs from Diverted Corn tCO_2e	Energy Use: Corn Acres for Beet Production TJ Diesel
2015	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2016	0.00	0.00	0.00	0.00	47,976	96,912	75.7
2017	0.00	0.00	0.00	0.00	47,976	97,392	75.7
2018	0.00	0.00	0.00	0.00	47,976	96,432	82.6
2019	0.00	316,456	0.00	153,491	47,976	96,432	75.7
2020	0.00	316,456	0.00	155,372	95,952	191,905	151.4
2021	0.00	316,456	0.00	157,252	95,952	191,905	151.4
2022	0.00	316,456	0.00	159,132	95,952	190,945	165.1
2023	0.00	316,456	0.00	161,013	95,952	189,986	151.4
2024	0.00	316,456	0.00	163,363	95,952	189,986	165.1
2025	0.00	316,456	0.00	164,774	95,952	189,026	151.4
2026	0.00	316,456	0.00	166,654	95,952	189,986	151.4
2027	0.00	316,456	0.00	168,535	95,952	189,986	165.1
2028	0.00	316,456	0.00	170,415	95,952	190,945	151.4
2029	0.00	316,456	0.00	172,295	95,952	190,945	165.1
2030	0.00	316,456	0.00	174,176	95,952	191,905	151.4
Sum	**0.00**	**316,456**	**0.00**	**1,966,472**	**95,952**	**2,484,687**	**2,030**

Table F-4.26 Production Volumes and Carbon Content

	BAU Energy & Emissions						
Year	Advanced Biofuels Production MMgal	Cumulative Acres of Corn Stover Needed Acres	Energy Use: Corn Stover Mgmt. TJ Diesel	Non-Energy GHGs: Corn Stover Mgmt. tCO_2e	Cumulative Corn Diverted to Beets Acres	Non-Energy GHGs from Diverted Corn tCO_2e	Energy Use: Corn Acres for Beet Production TJ Diesel
2015	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2016	0.00	0.00	0.00	0.00	47,976	96,912	75.7
2017	0.00	0.00	0.00	0.00	47,976	97,392	75.7
2018	0.00	0.00	0.00	0.00	47,976	96,432	82.6
2019	0.00	316,456	0.00	153,491	47,976	96,432	75.7
2020	0.00	316,456	0.00	155,372	95,952	191,905	151.4
2021	0.00	316,456	0.00	157,252	95,952	191,905	151.4
2022	0.00	316,456	0.00	159,132	95,952	190,945	165.1
2023	0.00	316,456	0.00	161,013	95,952	189,986	151.4
2024	0.00	316,456	0.00	163,363	95,952	189,986	165.1
2025	0.00	316,456	0.00	164,774	95,952	189,026	151.4
2026	0.00	316,456	0.00	166,654	95,952	189,986	151.4
2027	0.00	316,456	0.00	168,535	95,952	189,986	165.1
2028	0.00	316,456	0.00	170,415	95,952	190,945	151.4
2029	0.00	316,456	0.00	172,295	95,952	190,945	165.1
2030	0.00	316,456	0.00	174,176	95,952	191,905	151.4
Sum	**0.00**	**316,456**	**0.00**	**1,966,472**	**95,952**	**2,484,687**	**2,030**

Table F-4.27 Production Volumes and Carbon Content (continued)

Year	Policy Option Scenario Energy & Emissions											
	Beet Ethanol Production MMgal	Cellulosic Ethanol Production MMgal	Energy: Corn Stover Mgmt. TJ Diesel	Non-Energy GHGs: Corn Stover Mgmt. tCO_2e	Energy Use: Beet Cultivation TJ (Diesel)	Non-Energy GHGs: Beet Cultivation tCO_2e	Cellulosic ETOH Prod. Energy Use TJ Biomass	Cellulosic ETOH Prod. Excess Energy TJ Natural Gas	Cellulosic ETOH Prod. GHGs tCO_2e	Beet ETOH Energy Reqs. TJ (Natural Gas)	Beet ETOH Energy Reqs. MWh	Beet ETOH Production GHGs tCO_2e
2015	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
2016	0.00	0.00	6.3	0.00	130	151,308	0.00	0.00	0.00	0	0	0
2017	25.0	0.00	6.3	0.00	130	151,308	0.00	0.00	0.00	1,261	24,898	63,277
2018	25.0	0.00	6.3	0.00	130	151,308	0.00	0.00	0.00	1,261	24,898	63,277
2019	25.0	0.00	6.3	122,793	130	151,308	0.00	0.00	0.00	1,261	24,898	63,277
2020	25.0	25.0	12.7	124,297	260	302,617	5,219	(294)	10,020	1,261	24,898	63,277
2021	50.0	25.0	12.7	125,802	260	302,617	5,219	(294)	10,020	2,522	49,796	126,554
2022	50.0	25.0	12.7	127,306	260	302,617	5,219	(294)	10,020	2,522	49,796	126,554
2023	50.0	25.0	12.7	128,810	260	302,617	5,219	(294)	10,020	2,522	49,796	126,554
2024	50.0	25.0	12.7	130,691	260	302,617	5,219	(294)	10,020	2,522	49,796	126,554
2025	50.0	25.0	12.7	131,819	260	302,617	5,219	(294)	10,020	2,522	49,796	126,554
2026	50.0	25.0	12.7	133,323	260	302,617	5,219	(294)	10,020	2,522	49,796	126,554
2027	50.0	25.0	12.7	134,828	260	302,617	5,219	(294)	10,020	2,522	49,796	126,554
2028	50.0	25.0	12.7	136,332	260	302,617	5,219	(294)	10,020	2,522	49,796	126,554
2029	50.0	25.0	12.7	137,836	260	302,617	5,219	(294)	10,020	2,522	49,796	126,554
2030	50.0	25.0	12.7	139,341	260	302,617	5,219	(294)	10,020	2,522	49,796	126,554
	600	**275**	**165**	**1,573,178**	**3,382**	**3,934,016**	**57,404**	**(3,234)**	**110,215**	**30,269**	**597,556**	**1,518,644**

Table F-4.28 Production Volumes and Carbon Content (continued)

Year	Energy & Emissions Change								
	Energy Use	Energy Use	Energy Use	Energy Use	Non-Energy GHGs	Net In-State GHGs	Out-of-State GHGs	ETOH Carbon Content	ETOH Carbon Content
	TJ Diesel	TJ Natural Gas	MWh	TJ Biomass	tCO_2e	MMt CO_2e	MMt CO_2e	g CO_2e/gal	tCO_2e/TJ
2015	0.00	0	0	0	0	0.000	0.000	0	0.0
2016	61	0	0	0	54,396	0.059	0.001	0	0.0
2017	61	1,261	24,898	0	53,917	0.145	0.024	6,772	84.1
2018	54	1,261	24,898	0	54,876	0.146	0.024	6,778	84.2
2019	61	1,261	24,898	0	24,178	0.115	0.024	5,571	69.2
2020	121	967	24,898	5,219	79,638	0.170	0.020	3,810	47.3
2021	121	2,228	49,796	5,219	79,261	0.256	0.043	3,987	49.5
2022	108	2,228	49,796	5,219	79,845	0.255	0.043	3,975	49.4
2023	121	2,228	49,796	5,219	80,428	0.257	0.043	3,999	49.7
2024	108	2,228	49,796	5,219	79,958	0.255	0.042	3,972	49.3
2025	121	2,228	49,796	5,219	80,636	0.257	0.043	3,991	49.6
2026	121	2,228	49,796	5,219	79,300	0.255	0.042	3,967	49.3
2027	108	2,228	49,796	5,219	78,924	0.253	0.042	3,937	48.9
2028	121	2,228	49,796	5,219	77,588	0.253	0.042	3,930	48.8
2029	108	2,228	49,796	5,219	77,212	0.251	0.042	3,902	48.5
2030	121	2,228	49,796	5,219	75,877	0.250	0.042	3,895	48.4
	1,517	**27,035**	**597,556**	**57,404**	**1,056,035**	**3.18**	**0.52**		

Table F-4.29 Net Production Costs

Year	Beet ETOH Initial Investments	Cellulosic ETOH Initial Investments	Annualized Capital: Beet ETOH	Annualized Capital: Cellulosic ETOH	Cellulosic ETOH Feedstock/ Energy	Cellulosic ETOH: Excess Energy Value	Beet ETOH Feedstock	Beet ETOH Natural Gas	Beet ETOH Electricity	Cellulosic ETOH Non-Energy O&M
	MM$	MM$	MM$	MM$	MM$	MM$	MM$	MM$	MM$	MM$
2015	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
2016	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
2017	$126	$0.0	$9.4	$0.0	$0.0	$0.0	$39	$6.2	$1.9	$0.0
2018	$0.0	$0.0	$9.4	$0.0	$0.0	$0.0	$40	$6.4	$1.9	$0.0
2019	$0.0	$0.0	$9.4	$0.0	$0.0	$0.0	$40	$6.5	$2.0	$0.0
2020	$0.0	$231	$9.4	$17	$18	($1.6)	$41	$6.7	$2.0	$70
2021	$126	$0.0	$19	$17	$18	($1.6)	$84	$14	$4.1	$72
2022	$0.0	$0.0	$19	$17	$19	($1.6)	$86	$14	$4.2	$73
2023	$0.0	$0.0	$19	$17	$19	($1.7)	$87	$14	$4.3	$75
2024	$0.0	$0.0	$19	$17	$19	($1.7)	$89	$15	$4.4	$76
2025	$0.0	$0.0	$19	$17	$20	($1.8)	$91	$15	$4.4	$78
2026	$0.0	$0.0	$19	$17	$20	($1.8)	$93	$15	$4.5	$79
2027	$0.0	$0.0	$9.4	$17	$20	($1.8)	$95	$16	$4.6	$81
2028	$0.0	$0.0	$9.4	$17	$21	($1.9)	$97	$16	$4.7	$82
2029	$0.0	$0.0	$9.4	$17	$21	($1.9)	$98	$17	$4.9	$84
2030	$0.0	$0.0	$9.4	$0.0	$22	($2.0)	$100	$17	$5.0	$86
	$252	**$231**	**$188**	**$172**	**$217**	**($19)**	**$1,080**	**$178**	**$53**	**$856**

Table F-4.30 Net Production Costs (continued)

Year	Beet ETOH Non-Energy O&M	Cellulosic ETOH Co-Product Value	Cellulosic ETOH Federal Production Tax Credit	Cellulosic ETOH RIN Value	Beet ETOH Co-Product Value	Beet ETOH Federal Production Tax Credit	Beet ETOH RIN Value	Cellulosic ETOH: MN Production Credit	Beet ETOH: MN Production Credit
	MM$	MM$	MM$	MM$	MM$	MM$	MM$	MM$	MM$
2015	$0.0	$0.0	$0.00	0.00	$0.0	$0.0	$0.0	$0.0	$0.0
2016	$0.0	$0.0	$0.00	0.00	$0.0	$0.0	$0.0	$0.0	$0.0
2017	$8.1	$0.0	$0.00	0.00	($10)	$0.0	($13)	$0.0	$2.0
2018	$8.3	$0.0	$0.00	(12)	($10)	$0.0	($13)	$0.0	$2.0
2019	$8.5	$0.0	$0.00	(12)	($11)	$0.0	($13)	$0.0	$2.0
2020	$8.6	$0.0	$0.00	(12)	($11)	$0.0	($13)	$4.0	$2.0
2021	$18	$0.0	$0.00	(12)	($22)	$0.0	($27)	$4.0	$4.0
2022	$18	$0.0	$0.00	(12)	($22)	$0.0	($27)	$4.0	$4.0
2023	$18	$0.0	$0.00	(12)	($23)	$0.0	($27)	$4.0	$4.0
2024	$19	$0.0	$0.00	(12)	($23)	$0.0	($27)	$4.0	$4.0
2025	$19	$0.0	$0.00	(12)	($24)	$0.0	($27)	$4.0	$4.0
2026	$19	$0.0	$0.00	(12)	($24)	$0.0	($27)	$4.0	$4.0
2027	$20	$0.0	$0.00	(12)	($25)	$0.0	($27)	$4.0	$4.0
2028	$20	$0.0	$0.00	(12)	($25)	$0.0	($27)	$4.0	$4.0
2029	$21	$0.0	$0.00	(12)	($26)	$0.0	($27)	$4.0	$4.0
2030	$21	$0.0	$0.00	(12)	($26)	$0.0	($27)	$4.0	$4.0
	$227	**$0.00**	**$0.00**	**(150)**	**($282)**	**$0.0**	**($323)**	**$44**	**$48**

Table F-4.31 Net Production Costs (continued)

Year	Net Costs			
	Total Policy Option Costs MM$	Total Discounted Policy Option Costs MM$2014	Cost Effectiveness $2014/tCO2e	ETOH Production Costs $/gal ETOH
2015	$0	$0.00	Cost Effectiveness is shown under Policy Option AG-5 to capture the complete production and use of advanced ethanol.	$0.00
2016	$0	$0.00		$0.00
2017	$43	$37		$1.71
2018	$32	$27		$1.29
2019	$33	$26		$1.33
2020	$142	$106		$2.84
2021	$192	$136		$2.55
2022	$195	$132		$2.60
2023	$199	$128		$2.66
2024	$203	$125		$2.71
2025	$207	$121		$2.76
2026	$211	$118		$2.82
2027	$206	$109		$2.75
2028	$210	$106		$2.80
2029	$215	$103		$2.86
2030	$202	$92		$2.69
	$2,290	**$1,367**		

Key Assumptions

- Advanced biofuel production was modeled as advanced forms of ethanol. This is not to assume that ethanol would necessarily be the advanced biofuel of choice in the period of 2015-2030. Data is, however, readily available for both starch-based advanced ethanol and cellulosic ethanol.
- Opening of first 25 million gallon per year (MMgal/yr) starch-based ethanol plant is 2017, and second plant 25 MMgal/yr plant in 2021. A 25 MMgal/yr cellulosic plant opening in 2020 is used for modeling cellulosic production.
- Energy beets are modeled as the feedstock for the starch-based ethanol plants.
- Cellulosic ethanol produced from corn stover is the model for cellulosic production.
- No federal blending credit for ethanol is in place currently, so none is expected outside provisions of the Renewable Fuel Standard Renewable Identification Number, to offset the costs of advanced ethanol production.

Macroeconomic (Indirect) Policy Impacts

Macroeconomic implications of AG-4 policy were evaluated in combination with AG-5 policy, as a package. Macroeconomic analysis assumed a scenario in which these two policies are simultaneously implemented, and their combined impacts on state employment, personal income and GSP were assessed.

The results of these analysis, as well as more detailed discussion about the macroeconomic drivers and assumptions, is provided under AG-5 Macroeconomic (indirect) impact section latter in this appendix.

Key Uncertainties

- Timeline with which cellulosic biofuel production can be installed without supporting grant/loan money from the federal government and the state.
- Determination of feedstocks or methods to be used to harvest cellulosic biomass.
- Need for cellulosic sugar producer intermediary companies.

Additional Benefits and Costs

- Job creation (construction, maintenance, project design, manufacturing, delivery of new feedstock to plant, etc.).
- Increased local property tax from facility creation or expansion.

Feasibility Issues

At this point in time, it appears that Minnesota legislation will be adopted that includes advanced biofuel producer payments. Potential results of the legislation would be development of:

- Biochemical and cellulosic companies that have production capacity;
- Production facilities likely to be located near wood resources; and
- Facilities located in the Minnesota Iron Range regions supported by the Iron Range Resources and Rehabilitation Board (IRRRB). This is another avenue that will assist these fledgling companies with financing.

Other interest has also been shown for value-added projects that involve agricultural byproducts, such as sugar beet tailings, that would have the production of advanced biofuel as a product.

Projects such as those modeled in this report will take longer to take hold in Minnesota than in other states. Large grants enabled the first large scale cellulosic ethanol production to roll out in other states, and a producer payment such as the one modeled for this report (the same that is in the legislation) is unlikely to incentivize plant production in and of itself. The scale of such large projects (20 mgy) will occur first in the other states where these plants have already been constructed and have begun ramping up production.

Part of the 2015 biofuels bill involves the inclusion of perennials and cover crops into the feedstock mix when harvesting agricultural residue. Projects that would be built under this law would be different that the first three large-scale cellulosic plants that have been built and will begin production by the end of this year. They would also be different than what was modeled in this report.

In the meantime, a gradual rollout of advanced biofuel production should be seen within the state as the economics of these projects allows for their construction. The producer payment will help make the economics of these projects more favorable and will likely tip the decision to add these technologies and facilities.

If anything is certain, it is that the future should be friendly to low-carbon fuels and their development. As these fuels produce more and more benefits relative to their petroleum-based counterparts, we will see society move toward them, however slowly.

Updating, Monitoring and Reporting

With the likely passage of a biofuels production incentive in the 2015 legislative session, there will be updating, monitoring, and reporting of any projects that will be created and deployed. The results of the production incentive will be plainly evident.

As projects roll out, companies will be reporting their production and the amount and type of feedstock used. Funding will be on a two-year basis. The program is, however, scheduled to last through 2035 with companies allowed to participate for a period of 10 years. Data used to model plants in this report is likely to change quickly as technology improves, and assumptions made for this policy option analysis will need to be updated based on what comes to pass as plants being to take shape and begin production.

AG-5. In-State Biofuel Consumption

Policy Option Description

The current Minnesota Statute 239.7911 has the following goals for in-state liquid biofuels consumption: replace gasoline with: 14% by 2015, 18% by 2017, 25% by 2020, and 30% by 2025. However, Minnesota is not on track to meet these goals and further policy option to support deployment of infrastructure and vehicles is needed. Additionally, more research and development is needed to design appropriate engines and to bring advanced biofuels to the market in a cost competitive way. Note the linkage of this biofuel consumption policy option with Policy Option AG-4 which addresses in-state advanced biofuels production. This policy option should address known distribution issues and actions needed to assure that the in-state vehicle fleet is capable of consuming the biofuels at the target levels specified in state law and in AG-4 addressing advanced biofuels production.

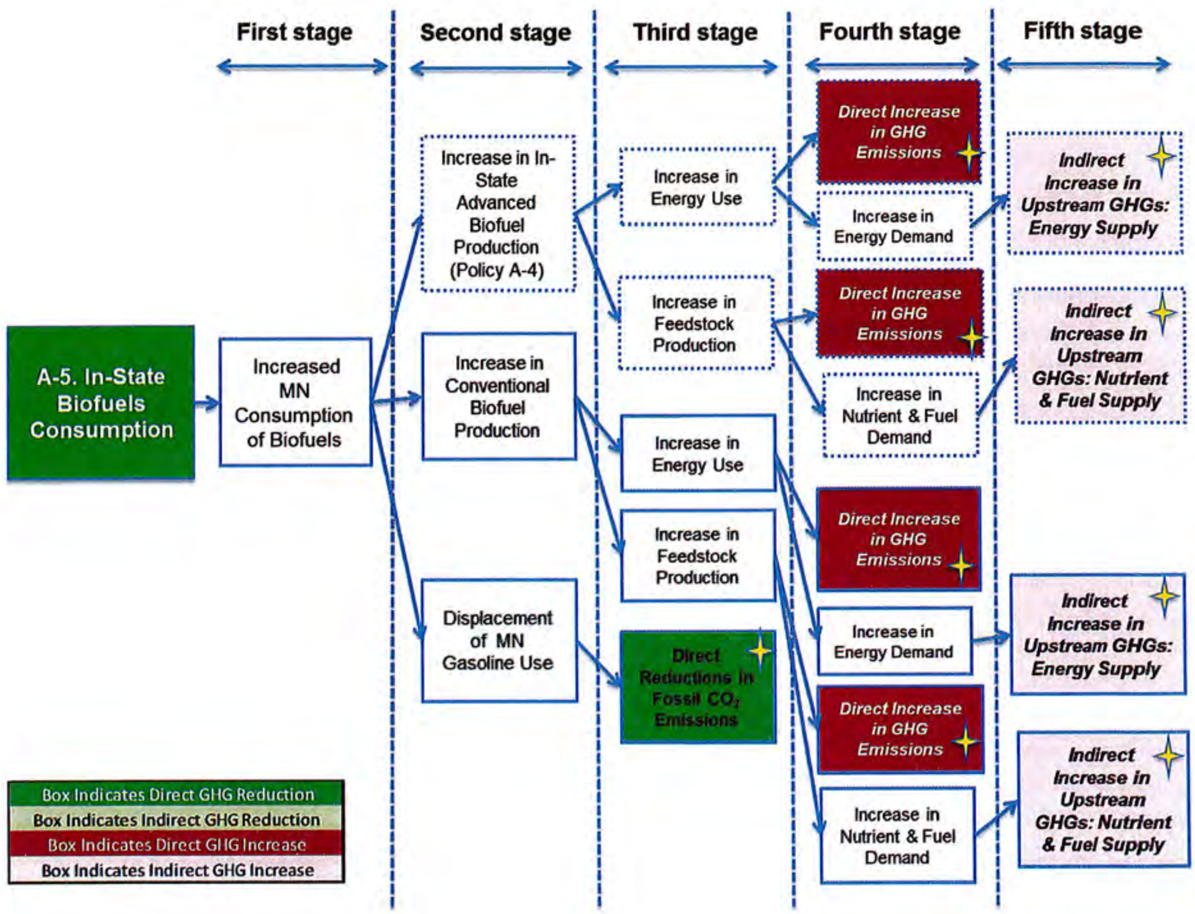
Actions to support these existing goals would include incentives that have as their goal the improvement of the entire infrastructure for delivery of gasoline-blended fuels to a higher level biofuel standard. The expectation is that the statewide infrastructure will need to turnover to compatibility with a higher-level biofuel content requirement which will be necessary to pave the way for the sale of higher blends of biofuel.

The opportunity exists within this policy option to incentivize biofuel blended spark-ignition engine fuels that are not just using advanced biofuel, but also advanced biofuel blends that would have higher octane content and allow for higher efficiency in an engine that is designed to take advantage of that property. Greenhouse gases would therefore be reduced by petroleum displacement, higher efficiency/higher miles-per-gallon vehicles that would use less fuel in total, and with the added fuel component having at least a 50% increase in life-cycle greenhouse gas benefits over straight gasoline as measured by the EPA in its RFS 2 methods.

To simplify this policy option, advanced ethanol has been used as the advance biofuel for all modeling. This does not preclude the use of other biofuels, such as biobutanol or drop-in renewable gasoline, which will also bring with them properties different from ethanol but perhaps advantageous in other properties (energy content, compatibility with existing storage/dispensing infrastructure, etc.).

Causal Chain for GHG Reductions

Figure F-4.33 Causal Chain for AG-5 GHG Reductions



The star symbol identifies significant GHG effects that are quantified. The net energy and emissions impacts of increased in-state advanced biofuel production were quantified under Policy Option AG-4. The net energy/emissions impacts of the consumption of advanced biofuels biofuels produced as a result of Policy Option AG-4 are quantified under this policy option, which provides a full accounting of both production and consumption of advanced biofuels. While the AG-4/AG-5 "biofuels package" is not meant to specify the exact biofuels to be promoted in the State, for the purposes of policy option analysis, the advanced fuel pathways considered in the initial AG-4 analysis are cellulosic ethanol production from corn stover and energy beets. Consumption of this advanced ethanol leads to both direct and indirect GHG reductions (direct fossil CO_2 emissions displaced from gasoline; and indirect reductions associated with lower energy and process emissions for the advanced biofuels.

Policy Option Design

Goals:

- Offer a $0.05 per gallon tax incentive to retailers selling E15 in state with one third of the ethanol content in the blend covered by ethanol that qualifies as advanced biofuel (this would be the ethanol content above the E10 level).
- Offer a $0.15 cent per gallon tax incentive to retailers selling E30 or greater ethanol blends with the portion of ethanol above and beyond E10 coming from ethanol that qualifies as an advanced biofuel.
- Require all new infrastructures installed in the state used for the storage and dispensing of higher ethanol blends be compatible with E30 in order to prepare for a future of high biofuel/higher octane content gasoline.

Timing: See "Statutory Goals" above as a guideline only. The in-state biofuels production goals from AG-4 will be used to gauge what amount of advanced bioethanol will be available for use within the state as part of this incentive. Those cumulative production numbers were estimated by the Great Plains Institute to be:

- 150 million gallons by 2020
- 300 million gallons by 2025
- 600 million gallons by 2030

The cumulative production values from AG-4 are in-line with these values, but are slightly higher (125 MMgal by 2020; 500 MMgal by 2025; and 875 MMgal by 2030). In Great Plain's proposed legislation (on behalf of the Bioeconomy Coalition) in the regular legislative session of 2014 numbers used for production goals were $30 million per year for all producers in the state. At this production level and given the incentives they specified in the legislation of $1.053/MMBtu for starch-based advanced biofuel and $2.1053/MMBtu for cellulosic-based advanced biofuel, a range of 187,250,337 gallons (if all production was cellulosic ethanol at 76,100 Btu/gallon) gallons to 374,376,196 (if all production was starch-based advanced biofuel biofuel) would exist. This is much higher production than estimated from the most recent goals above that were submitted.

Note: Gasoline usage in 2013 was estimated at 2,517,351,045 gallons by the Minnesota Department of Revenue, with approximately 10% of that volume, or 251,735,105 gallons coming from corn-starch ethanol. Assuming gasoline usage as flat into the future, E15 would require an additional 125,867,552 gallons of advanced ethanol and E30 would require an additional 503,470,209 gallons should all of the gasoline supply be blended with those percentages.

Discussion: Two main factors exist to drive a higher ethanol content in the national gasoline engine fleet: RFS2 volumes, which are exclusively increases in advanced and cellulosic biofuel after the year 2015; and the 2025 Corporate Average Fuel Economy (CAFE) standard requirement of an average mile per gallon for a light duty fleet vehicle of 54.5. According to the NACS document *The Future of Fuels 2012*, with full implementation of the RFS by 2022, the program that was enacted in 2007 has "the mandated volume (of biofuel) expected to represent 20-25% of the motor fuels consumption (by 2022)"; and if "the new CAFE standards do reduce the demand for petroleum by 36% in 2025, then the mandated renewable fuel volume would represent 34.1-39.6% of motor fuels consumption." It further says that "clearly, a substantial volume of fuel will have to be blended with greater than 10% ethanol to meet the standard . . . a percentage of fuel volume blended at E15 or beyond must enter the market if the RFS is to be successfully implemented."

One of the solutions to these policy option goals is a higher efficiency engine that requires higher octane fuel with a research octane number (RON) rating of 98. An E25-30 blend would be the least expensive fuel that could be used to meet this octane level. Changes to the storage and dispensing infrastructure need to be implemented in policy option to clear the way for this fuel availability, and for the vehicles that would use that fuel. The cost to begin upgrading to an E25 blend is said to be relatively minimal, as low as an extra $1,000 above an E10-compatible dispenser, and this could be required by the state in its effort to reduce petroleum use. Incentives and grant programs to support infrastructure turnover would of course be helpful in the change, but will not be covered in this policy option.

Parties Involved: State legislature, state departments of Environmental Quality, Agriculture, Natural Resources, fuel providers, agricultural producers, utilities, and auto companies.

Implementation Mechanisms

The state recommends a variety of actions to stimulate the production and use of renewable, low-carbon fuels within the state. These include:

- Establish a Next-Generation Renewable Fuels Feedstock Program,
- Create a Green Fuels Retailers Program for sales of E15 and E30 (or greater) using advanced biofuel for the blend volume that exceeds 10% ethanol. (State agencies of Minnesota's fleet will, whenever possible, adopt the use of vehicles that can run on an E25/30 blend as the vehicles become available. This would include E25/30 hybrid and E25/30 electric vehicles, as well as straight E25/30 higher efficiency (better fuel mileage) vehicles, and
- Require that updates and replacements of petroleum fuel dispensing sites be done to be compatible with at least E25 ethanol volume.

Related Policies/Programs in Place and Recent Actions

The current Minnesota Statute 239.7911 has the following requirements for in-state biofuels consumption to replace gasoline with:

- 14% biofuel by 2015
- 18% by 2017
- 25% by 2020
- 30% by 2025.

Estimated Policy Impacts

Table F-4.32 AG-5 Estimated Net GHG Reductions and Net Costs or Savings

2030 GHG Reductions ($MMt\ CO_2e$)	2015 – 2030 Cumulative Reductions ($MMt\ CO_2e$)	Net Present Value of Societal Costs, 2015 – 2030 ($2014)	Cost Effectiveness ($2014/ tCO_2e)
0.32	3.5	$462	$133

The reductions in the summary table address those that would occur in-state, as well as some reductions for the upstream fuel cycle that occur out of state (e.g. petroleum extraction, transport and processing). The in-state reductions (direct tail-pipe reductions for displacement of gasoline with biofuels) are 0.17 MMt CO_2e in 2030 and 1.8 MMt CO_2e on a cumulative basis.

Data Sources: These are described and cited in more detail below, but include: baseline (BAU) gasoline consumption for the state; additional biofuel distribution infrastructure requirements and costs; number of additional higher ethanol content vehicles (engines/fuel systems) required for the fleet; incremental costs of vehicles requiring higher ethanol content gasoline; advanced biofuel production volumes, carbon content, and costs from the AG-4 Policy Option Analysis; energy-cycle carbon content for conventional gasoline (ANL GREET model).

<u>Quantification Methods</u>

GHG reductions:

- *BAU energy and emissions*: Since no advanced ethanol production and subsequent consumption are included in the baseline, these values are zero.
- *For the Policy Option Scenario*: The advanced ethanol produced in AG-4 is presumed to be consumed within the state during the year in which it is produced, which offsets gasoline use.
- Direct emissions of N_2O and CH_4 from ethanol combustion are quantified using standard emission factors; CO_2 from advanced ethanol combustion is considered to be carbon neutral.

- *Upstream GHGs from advanced ethanol*: Calculated from the production volume and carbon content in each year as calculated from the AG-4 analysis.
- *Offset gasoline emissions*: First, calculate the equivalent amount of gasoline displaced by ethanol (a gallon of ethanol has 66% of the energy that a gallon of gasoline has). On the other hand, optimized vehicle engines are expected to get a performance boost of about 17% on a gallon equivalent basis.[41] Multiply the equivalent amount of gasoline displaced by the GHG emission factors from the baseline.
- *Calculate the upstream GHG reductions from offset gasoline*: Using emission factors from ANL's GREET Model for conventional US gasoline.[42]

Table F-4.33 provides a summary of the net energy and GHG impacts for Policy Option AG-5.

Net Societal Costs:

- *BAU costs avoided by the policy option*: These correspond to the cost of gasoline that is offset through the use of advanced ethanol. The volume of gasoline avoided (as determined above) is multiplied by the CSEO project BAU wholesale gasoline forecasted price in each future year.
- Policy Option Scenario costs:
- *Cost of advanced ethanol use*: Using the volumes and production cost estimates derived from Policy Option AG-4;
- *Add infrastructure "put through" costs*: Covers additional in-state trucking from plants to rack locations[43];
- *Add state fuel incentives*: from the AG-5 Policy Option Design, $0.05/gal for E15 blended gasoline; and $0.15/gal for E30 or greater blends. Assume 50% of total advanced ethanol consumption is blended into E15 and 50% into E30 or greater.
- *Consider the need for incremental costs for vehicles required to meet the consumption needs of the policy option*: $983/vehicle for higher performance engines optimized for using higher ethanol blends.[44] From another viewpoint, these vehicle costs will already be required as manufacturers comply with the Federal CAFE standards, and so cannot be attributed to Policy Option AG-5.

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[41] Energy content difference plus ETOH performance boost. Energy content of gasoline = 115,640 Btu/gal; ethanol = 76,330 Btu/gal. 2013 Fuel Freedom White Paper indicates a 17.2% performance boost for FFVs optimized to use ethanol on a gallon of gasoline equivalent basis: http://www.fuelfreedom.org/whitepaper/is-the-gasoline-gallon-equivalent-an-accurate-measure-of-mileage-for-ethanol-and-methanol-fuel-blends/.

[42] https://greet.es.anl.gov/.

[43] 2015 value based on current $0.030/gal to $0.035/gal range provided by Patrick Griffin-Boyle at RPMG, personal communication with S. Roe, CCS, 10/21/2014. Escalated each year at the rate of inflation.

[44] Cost total breaks down as: $78 for variable valve actuation + $268 for stoichiometric gasoline direct injection + $556 for turbocharging/down-sizing. Mid-point of range selected. NHTSA, *Corporate Average Fuel Economy for MY 2017-MY 2025 Passenger Cars and Light Trucks, Federal Regulatory Impact Analysis*, Table V-121.

- *Consider the need for incremental fuel dispensing costs*: New storage tanks and dispensers that are compliant with higher ethanol blends. A total cost was estimated using an assumption that half of the existing gasoline stations in the State would need to install a new 2 nozzle dispenser with a new 15,000 gallon storage tank.[45] As with the vehicle costs above, it could be argued that this infrastructure will be required to comply with the combination of Federal CAFÉ and Renewable Fuel Standard (RFS2) Programs, and therefore the costs should not be attributed to Policy Option AG-5.

Table F.4.34 provides a summary of the net societal cost analysis. The cost effectiveness value shown (\$133/tCO_2e) excludes the vehicle and fuel dispensing infrastructure costs noted above. If those costs are included, the cost effectiveness value increases to \$228/tCO_2e.

Key Assumptions

- The advanced ethanol incentivized by this policy option is the advanced ethanol produced in Policy Option AG-4.
- All ethanol produced in Policy Option AG-4 will be used within the State of Minnesota.
- Half of the advanced ethanol produced will be blended into E15, and the other half into E30 or higher blends. Vehicles and dispensing facilities will be available to consume the advanced biofuel produced by Policy Option AG-4.
- 2030 business-as-usual carbon content of gasoline = 88.2 tCO_2e/TJ; business-as-usual carbon content of corn ethanol = 60.2 tCO_2e/TJ; Advanced ethanol improvement over business-as-usual ethanol = 20%.

[45] In 2011, there were 2,147 gasoline stations in MN; this value was held constant through the planning period. EPA estimated the cost for dispenser and storage at \$154,000 each installed; EPA RFS2 Final RIA, Feb 2010, http://www.epa.gov/otaq/renewablefuels/420r10006.pdf.

Chapter XVII. Appendix F-5. Forestry and Other Land Use Policy Option Recommendations

Overview

The tables below provide a summary of the microeconomic analysis of Climate Solutions & Economic Opportunities (CSEO) policies in the Forestry and Other Land Use (FOLU) sector. The first table provides a summary of results on a stand-alone basis, meaning that each policy option was analyzed separately against baseline (business as usual or BAU) conditions. Details on the analysis of each policy option are provided in each of the Policy Option Documents (PODs) that follow within this appendix.

The stand-alone results provide the annual greenhouse gas (GHG) reductions for 2020 and 2030 in million metric tons (MMt) of carbon dioxide equivalent reductions (CO_2e), as well as the cumulative reductions through 2030. The reductions shown are just those that have been estimated to occur within the state. Additional GHG reductions, typically those associated with upstream emissions in the supply of fuels or materials, have also been estimated and are reported within each of the analyses in each POD.

Also reported in the stand-alone results is the net present value (NPV) of societal costs/savings for each policy option. These are the net costs of implementing each policy option reported in 2014 dollars. The cost effectiveness (CE) estimated for each policy option is also provided. Cost effectiveness is a common metric that denotes the cost/savings for reducing each metric ton (t) of emissions. Note that the CE estimates use the total emission reductions for the policy option (i.e. those occurring both within and outside of the state).

As indicated in the first summary table, the full benefits of FOLU policies are only realized when considering the full life-span of new trees. For this reason, the costs and benefits of FOLU policies were estimated out to the year 2085. The cumulative emission reductions, NPV, and cost effectiveness for the 2015-2085 period are shown in the notes field for each policy option.

Integrative Adjustments & Overlaps

The second summary table above provides the same values described above after an assessment was made of any policy option interactions or overlaps. There were no interactions of overlaps identified between the FOLU policies; therefore, the values in the second table equal those in the first table.

Macroeconomic (Indirect) Economic Impacts

Table F-5.3 below provides a summary of the expected impacts of FOLU policies on jobs and economic growth during the CSEO planning period. This table focuses on the impact of policies on Gross State Product (the total amount spent on goods and services produced within the state), Employment (the total number of full-time and part-time positions), and Incomes (the total amount earned by households from all possible sources). These metrics represent three

- Advanced ethanol improvement over gasoline should be 50% or greater; however, the production capacity mix in the current AG-4 analysis (50 MMgal energy beets: 25 MMgal/cellulosic) falls just short of that (45% improvement by 2030); however, as noted the baseline gasoline carbon content in Minnesota is likely higher than the value used in this initial CSEO analysis (based on average US conventional gasoline). Still, future work on the Biofuels Package should consider a set of slightly higher goals for cellulosic ethanol production capacity (a larger plant or more than one plant) and take a closer look at energy beet ethanol to assure that it would meet the requirements for an advanced ethanol production method per Federal definitions.
- Minor differences exist between the baseline crop production forecast used as an input to the AG-4/AG-5 analysis and a later revised version of that forecast produced by Minnesota Pollution Control Agency (MPCA) using data developed by USDA's National Agricultural Statistics Service (NASS). Revision of these inputs to match the MPCA values is not expected to produce a significant change to the estimated impacts.

Additional Benefits and Costs

Biofuels burn cleaner and displace fossil fuels in combustion engines. This will impact air quality, benefiting human health. See Policy Option AG-4 for more details on ethanol and air quality.

Feasibility Issues

Infrastructure is the main obstacle to vehicle feasibility and development. If the fuel cannot be stored and dispensed it cannot be offered for sale and vehicle will not have the option to use them. A turnover of infrastructure to ethanol compatibility is a necessary step in the process outlined above.

- Consumer spending increases are sometimes financed. Small-scale purchases or purchases of consumer goods are treated as direct spending from existing household cash flows (or short-term credit). Durable goods, home improvements or vehicle purchases, however, are treated as financed. Consumers were assumed to spread out costs based on common borrowing time frames, such as five years for financing a new vehicle or 10-20 years for home improvements that might be funded by home-equity or other lending. The assumption of financing and the term of years applied was considered anew in each case.
- Business spending increases are often financed. Where spending strikes a sector which routinely utilizes financing or lines of credit to ensure steady payment of recurring costs, significant spending of nearly any type was considered a candidate for financing, thus allowing costs to spread out over time. This methodology is preferable for the modeling work, as sudden spikes or dips in business operating costs can show up as volatility when the scenario may depict a managed adoption of new equipment in an orderly fashion. The assumption of financing and the term of years applied was considered anew in each case.
- Unless otherwise stated, all changes to consumer spending or to the producers' cost of producing goods and services were treated in a standard fashion. Consumers are assumed to spend on a pre-set mix of goods, services, and basic needs, and businesses spend (based on their particular sector of the economy) on a mix of labor, capital, and intermediate demands from other sectors. Unless a policy specifically defines how a party will react to changes in cost, price, supply or demand, these standard assumptions were applied.

State and local spending gains and reductions driven by policy are assumed to apply to standard mixes of spending. Again, unless a policy specifically states that a government entity will draw from a specific source or direct savings or revenues to a specific form of spending, all gains and losses were assumed to apply to a standard profile of government spending within the economy.

Key Uncertainties

Further research and development is needed to:

- Develop automobiles that meet future CAFE standards, with one way to do this being the development of engines requiring a higher octane content that could be satisfied by an E25/30 fuel (higher octane allows for more efficient, smaller engines).
- Bring advanced biofuels into higher levels of production at cost effective rates. There is uncertainty on when innovations and breakthroughs occur.
- Further, compatible infrastructure is needed to comply with EPA regulations for compatibility of materials for the storage and dispensing of ethanol blended fuels greater than 10%.

- However, this additional fuel spending is going to a product that is domestically produced. So while the consumer is burdened, the beneficiary of that burden is entirely within the state. This offsets to a significant degree any loss to the economy.
- The same is true of state spending. The state is a consumer of these fuels under this scenario, and pays more, thus reducing other spending. However, because the vendor is domestic, the price impact is moderated.

Sectors of Economy Most Affected by the Policy

Economic impacts from policies run around the economy, affecting sectors that are sometimes far from the direct target of a policy.

For AG-4 and AG-5, positive gains most impact construction and chemical manufacturing (the sector into which biofuels manufacturing falls). Consumer prosperity is also improved, which we see through increases in indirect sectors such as health care and retail sales.

Quantification Methods

Utilizing the data developed from the microeconomic analysis, CCS analysts established for each individual change the following characteristics:

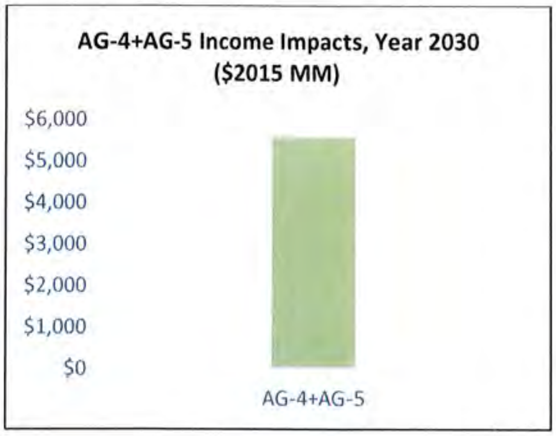
- The category of change involved (change in spending, savings, costs, prices, supply or demand)
- The party involved on both sides of each transaction
- The volume of money involved in this change in each year of the period of analysis

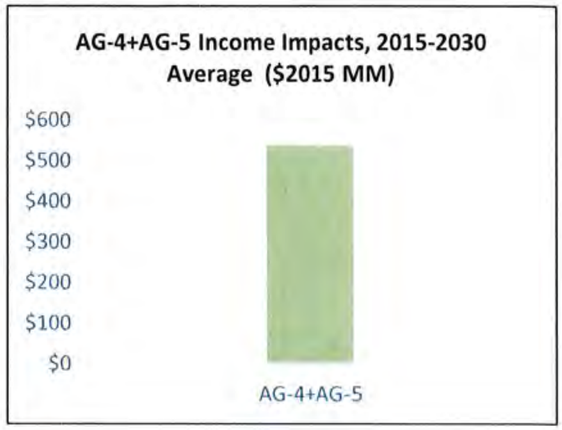
These values, so characterized, were then processed into inputs to the REMI PI+ software model built specifically for use by CCS and consistent with that in use by state agencies within Minnesota. These inputs were applied to the model and run. Key results were then drawn from the model and processed for consistency of units and presentation before inclusion in this report.

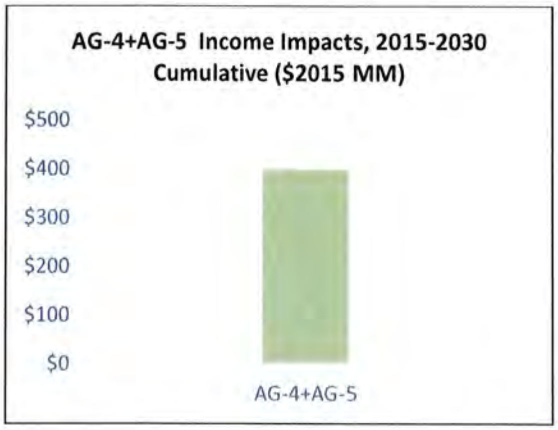
Key Assumptions

The macroeconomic impact analyses of this policy, as well as of the others in the CSEO process, rely on a consistent set of key assumptions:

- State and local spending is always budget-constrained. If a policy calls for the state or local government to spend money in any fashion, that spending must be either funded by a new revenue stream or offset by reductions in spending on other programs. Savings or revenues collected by the government are also expected to be returned to the economy as spending in the same year as they are collected.
- Federal spending is not budget-constrained. The capacity of the federal government to carry out deficit spending means that no CSEO policy is held responsible for driving either an increase or decrease in federal tax spending by businesses or households in the state of Minnesota.







<u>Principal Drivers of Macroeconomic Changes</u>

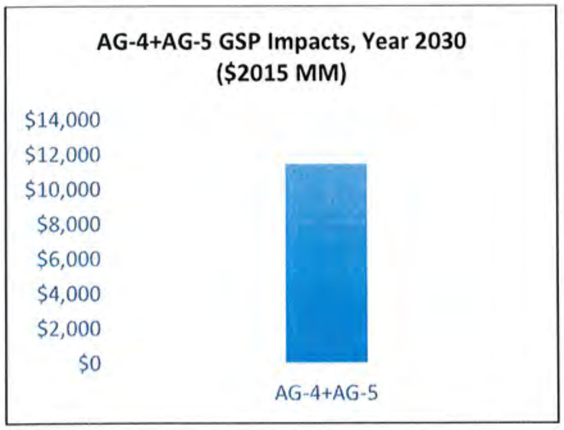
This policy pair (the supply and demand of biofuels) shows positive impacts, occurring primarily outside the metro area. The major positive drivers of these impacts are:

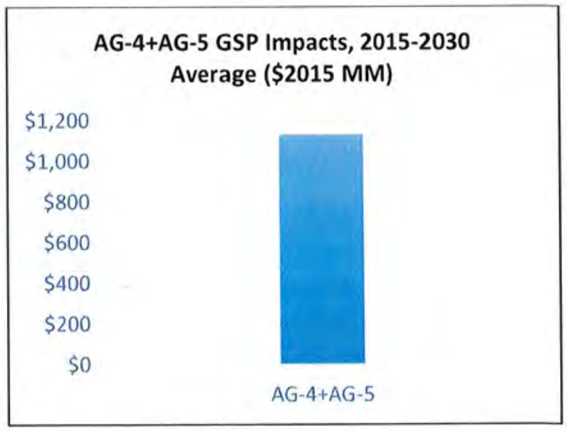
- The construction of biofuels plants in 2017, 2020 and 2021. These produce the often-seen spikes in economic activity and employment associated with short bursts of intensive construction activity. They total approximately $490 million of total spending, but their positive impact disappears as soon as projects are complete.
- Additional labor spending by the industry producing biofuels. This drives an annual volume that reaches approximately $100 million in 2030 (in nominal dollars) of new direct income to employees working in manufacturing of biofuels. The number of people employed directly would be in the range of 1,000 to 1,500.

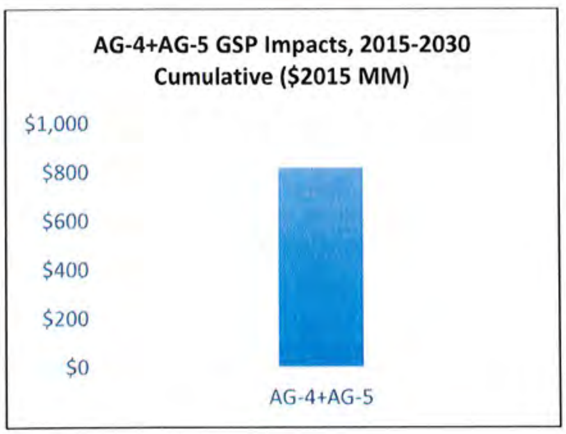
There are negative drivers as well, though smaller in scale:

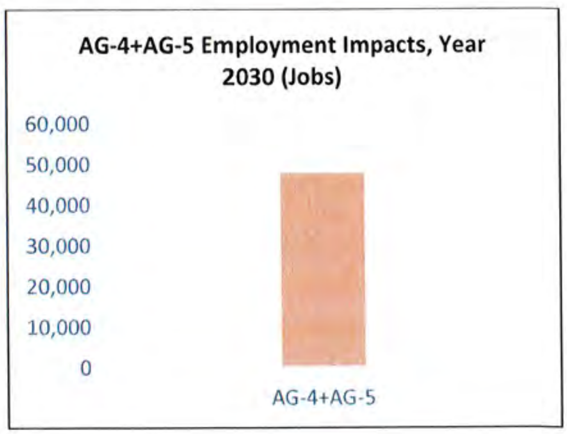
- Consumers are projected to face additional fuel costs every year as biofuels displace petroleum fuels. These additional costs, which take money out of their spending on all other categories of consumption, reach as high as $50 million per year by the year 2030 (in nominal dollars).

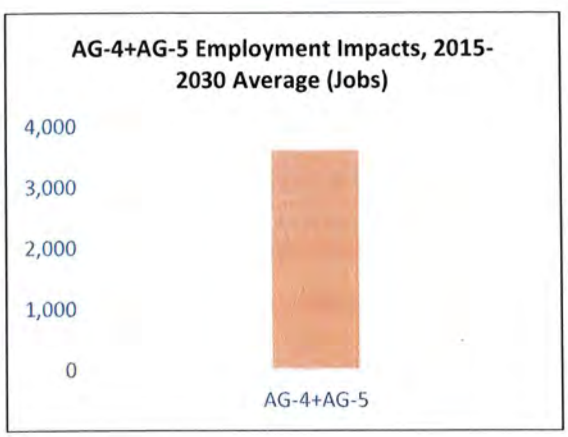
Graphs below show macroeconomic impacts on GSP, personal income, and employment in the final year (2030), in average (2015-2030) and in cumulative (2015-2030). Light color means sensitivity scenarios.











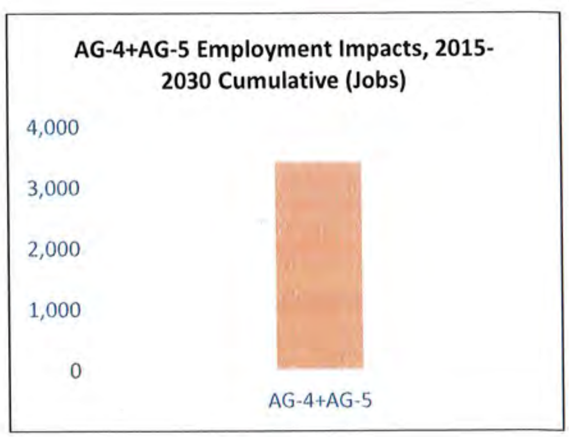


Figure F-4.35 AG-4+AG-5 Employment Impacts (Individual Jobs)

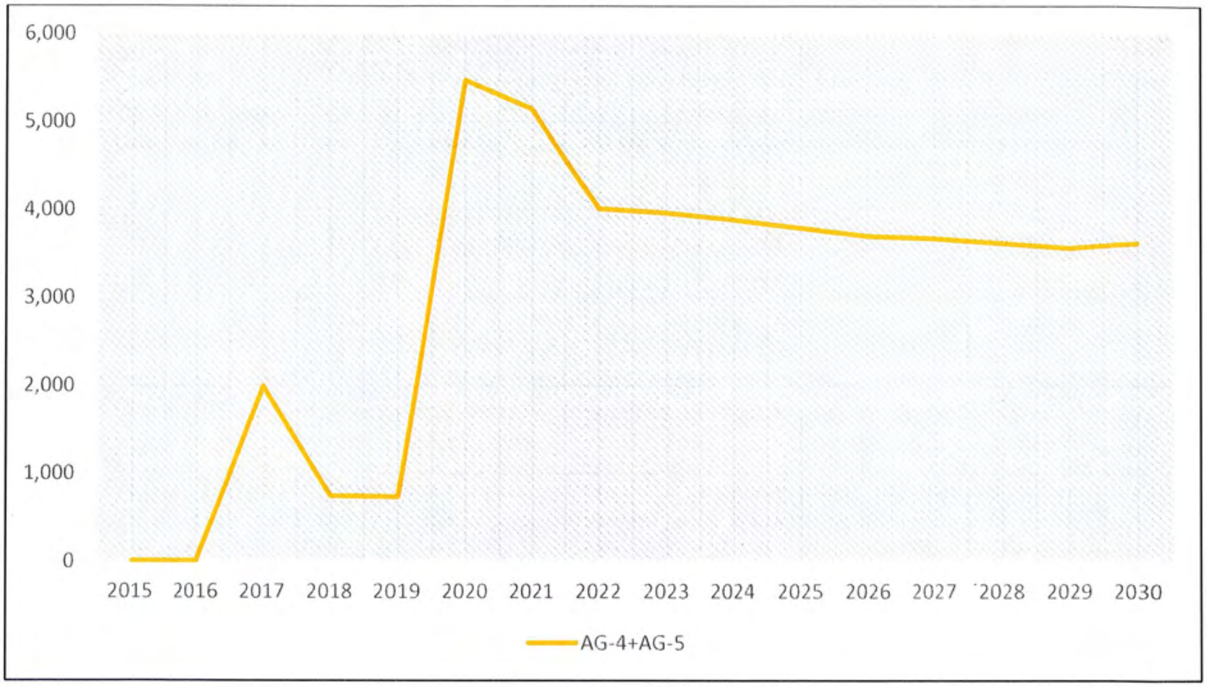
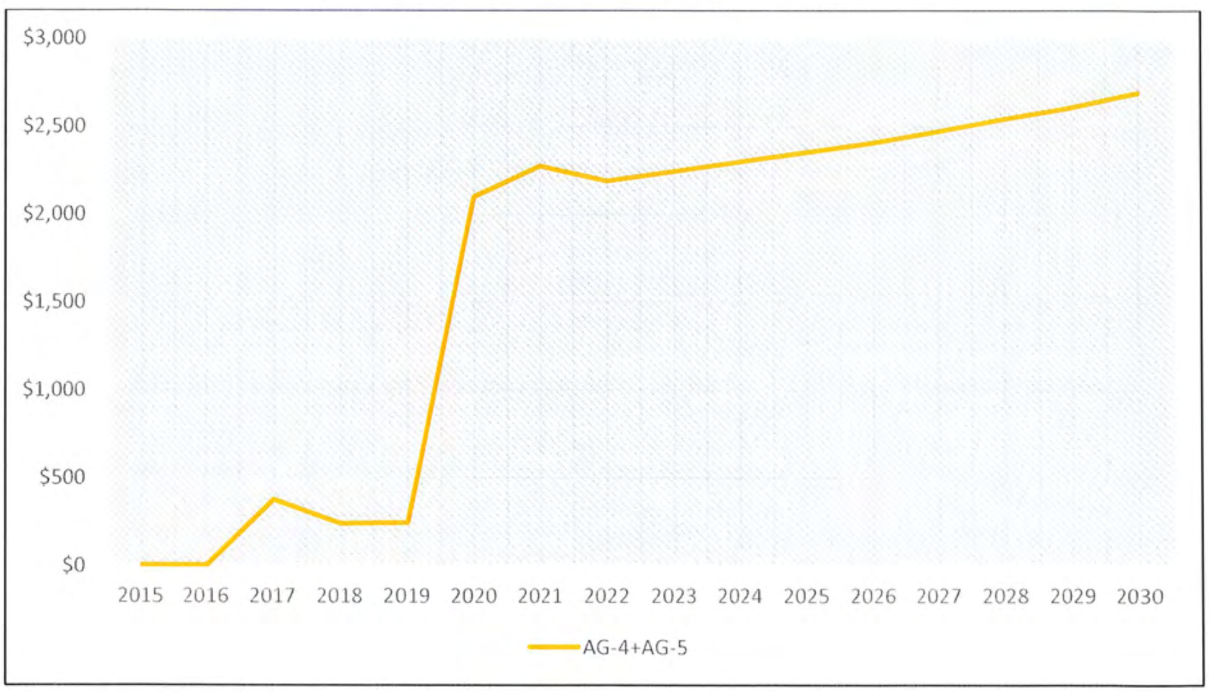


Figure F-4.36 AG-4+AG-5 Income Impacts ($2015 MM)



Macroeconomic (Indirect) Policy Impacts for both A4 and AG-5 Policies

Table F-4.35 AG-4+AG-5 Macroeconomic Impacts on GSP, Employment and Income

Scenario	GSP ($2015 MM)			Employment (Individual)			Personal Income ($2015 MM)		
	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)
AG-4+AG-5	$1,132	$819	$11,469	3,610	3,420	47,820	$539	$398	$5,576

Graphs below show detail in GSP, employment and personal income impact of the AG-4+AG-5 policy.

Figure F-4.34 AG-4+AG-5 GSP Impacts ($2015 MM)

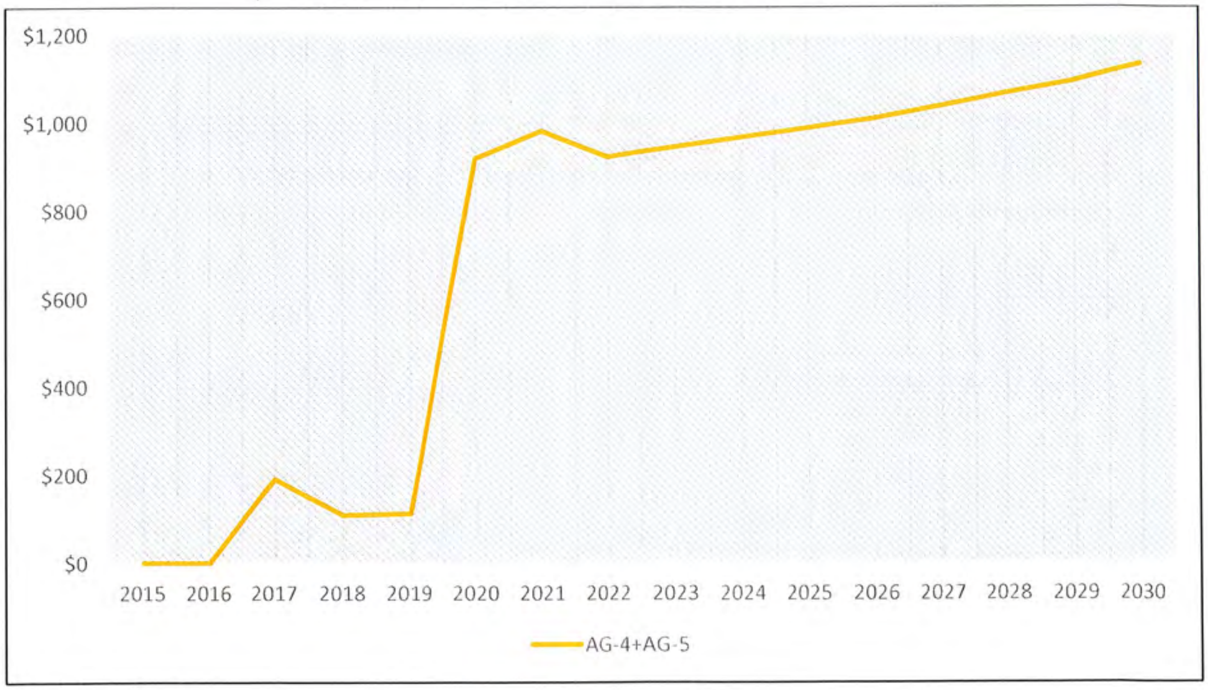


Table F-4.34 Net Societal Costs

	BAU Costs	Policy Option Scenario Costs					Net Costs		
	Avoided Gasoline Use	Advanced Ethanol Use	Infrastructure "Put Through" Costs	Infrastructure Dispensing Costs	MN Gov't Fuel Incentives	Incremental Vehicle Costs	Total Policy Option Costs	Total Discounted Policy Option Costs	Cost Effectiveness
Year	MM$	MM$	MM$	MM$	MM$	MM$	MM$	MM$2014	$2014/tCO₂e
2015	$0.00	$0	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	
2016	$0.00	$0	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	
2017	$53	$43	$0.86	$40	$10	$67	$0.91	$0.79	
2018	$53	$32	$0.88	$0.78	$10	$1.3	($10)	($8.0)	
2019	$53	$33	$0.90	$2.7	$10	$4.4	($8.9)	($7.0)	
2020	$107	$142	$1.8	$46	$21	$77	$58	$43	
2021	$161	$192	$2.8	$49	$31	$82	$65	$46	
2022	$161	$195	$2.9	$4.5	$31	$7.5	$68	$46	
2023	$162	$199	$2.9	$4.8	$31	$8.0	$72	$46	
2024	$162	$203	$3.0	$4.9	$31	$8.1	$75	$46	
2025	$162	$207	$3.0	$7.0	$31	$12	$79	$46	
2026	$163	$211	$3.1	$0.0	$31	$0.00	$83	$46	
2027	$163	$206	$3.2	$0.0	$31	$0.02	$77	$41	
2028	$163	$210	$3.2	$0.0	$31	$0.00	$81	$41	
2029	$164	$215	$3.3	$0.0	$31	$0.00	$86	$41	
2030	$164	$202	$3.3	$5.6	$31	$9.2	$72	$33	
Sum	$1,891	$2,290	$35	$167	$365	$275	$799	$462	$133

Note: Each policy analysis was done over a fifteen-year planning horizon. While implementation of each policy is not expected occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

Table F-4.33 Net GHG and Energy Impacts

Year	Policy Option Scenario Energy & Emissions						Net Change	
	Additional Advanced Biofuel Ethanol 1,000 Gallons	Direct GHGs: Ethanol Combustion MMtCO2e	Additional Upstream ETOH GHG Emissions MMtCO2e	Gasoline Offset by ETOH 1,000 Gallons	Gasoline Offset: Direct GHGs MMtCO2e	Gasoline Offset: Upstream GHGs MMtCO2e	Net In-State GHG Reductions MMt CO2e	Out-of-State GHG Reductions MMt CO2e
2015	0.00	0.0000	0.00	0	0.00	0.00	0.00	0.00
2016	0.00	0.0000	0.00	0	0.00	0.00	0.00	0.00
2017	25,000	0.0048	0.17	(19,340)	(0.16)	(0.048)	0.015	(0.048)
2018	25,000	0.0048	0.17	(19,340)	(0.16)	(0.048)	0.015	(0.048)
2019	25,000	0.0048	0.14	(19,340)	(0.16)	(0.048)	(0.015)	(0.048)
2020	50,000	0.010	0.19	(38,680)	(0.32)	(0.097)	(0.12)	(0.10)
2021	75,000	0.014	0.30	(58,020)	(0.48)	(0.15)	(0.16)	(0.15)
2022	75,000	0.014	0.30	(58,020)	(0.48)	(0.15)	(0.16)	(0.15)
2023	75,000	0.014	0.30	(58,020)	(0.48)	(0.15)	(0.16)	(0.15)
2024	75,000	0.014	0.30	(58,020)	(0.48)	(0.15)	(0.16)	(0.15)
2025	75,000	0.014	0.30	(58,020)	(0.48)	(0.15)	(0.16)	(0.15)
2026	75,000	0.014	0.30	(58,020)	(0.48)	(0.15)	(0.16)	(0.15)
2027	75,000	0.014	0.30	(58,020)	(0.48)	(0.15)	(0.17)	(0.15)
2028	75,000	0.014	0.29	(58,020)	(0.48)	(0.15)	(0.17)	(0.15)
2029	75,000	0.014	0.29	(58,020)	(0.48)	(0.15)	(0.17)	(0.15)
2030	75,000	0.014	0.29	(58,020)	(0.48)	(0.15)	(0.17)	(0.15)
	875,000	**0.17**	**3.6**	**(676,899)**	**(5.6)**	**(1.8)**	**(1.8)**	**(1.7)**

valuable indicators of both the overall size of the economy and that economy's structural orientation toward supporting livelihoods and utilizing productive work.

For the purposes of macro-economic analysis of CSEO policies, CCS utilized the Regional Economic Models, Inc. (REMI) PI+ software. This particular REMI model is developed specifically for Minnesota, and is developed consistently with the design of models in use by state agency staff within Minnesota for a range of economic analyses. Its analytical power and accuracy made REMI a leading modeling tool in the industry used by numerous research institutions, consulting firms, non-government organizations and government agencies to analyze impacts of proposed policies on key macro-economic parameters, such as GDP, income levels and employment.

The main inputs for macro-economic analysis are microeconomic estimates of direct costs and savings expected from the implementation of individual policy options. These inputs are supplemented with additional data and assumptions necessary to complete the picture of how these costs and savings (as well as price changes, demand and supply changes, and other factors) influence Minnesota's economy. These additional data and assumptions typically regard how various actors around the state (households, businesses and governments) respond to change by changing their own economic activity. A full articulation of the general and policy-specific assumptions made by the macroeconomic analysis team is provided in the Policy Option Documents, contained as appendices to this report.

Table F-5.1 FOLU Policy Options, Direct Stand-Alone Impacts

Stand-Alone Analysis							
Policy Option ID	Policy Option Title	GHG Reductions				Costs	
		Annual CO_2e Reductions[a]		2030 Cumulative[a]	2030 Cumulative[b]	Net Costs[c] 2015-2030	Cost Effectiveness[d]
		2020 MMt	2030 MMt	$MMtCO_2e$	$MMtCO_2e$	$Million	$/tCO_2e$
FOLU-1	Protect Peatlands and Wetlands	*Not Quantified*					
FOLU-2[e]	Manage for Highly Productive Forests - Intermediate Stand Treatments	*Not Applicable*					
FOLU-3[f]	Urban Forests: Maintenance and Expansion 40% Canopy Goal	0.086	0.49	3.2	3.2	$1,806	$568
FOLU-4[g]	Tree Planting: Forest Ecosystems	1.4	1.9	30	34	$187	$5.6

FOLU-5[h]	Conservation on Private Lands	0.14	0.34	3.0	3.0	$1,261	$421
Totals		**1.6**	**2.7**	**36**	**40**	**$3,254**	**$81**

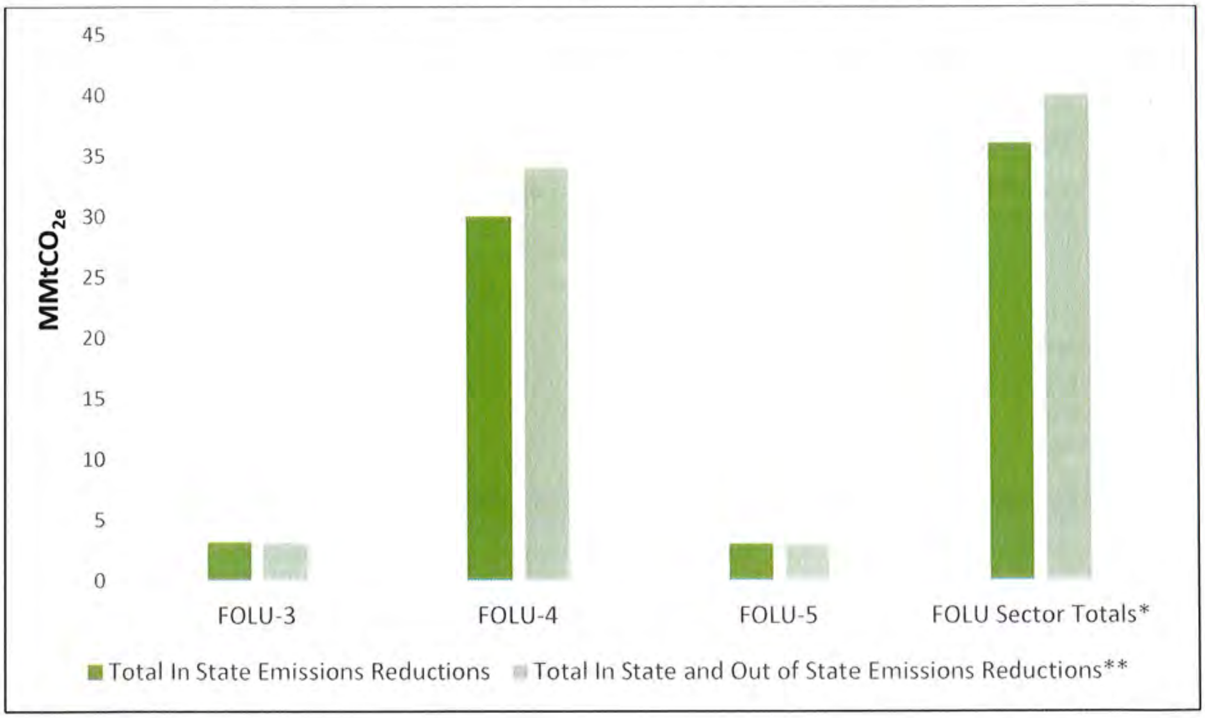
Notes:
[a] In-state (Direct) GHG Reductions.
[b] Total (Direct and Indirect) GHG Reductions.
[c] Net Present Value of fully implemented policy option using 2014 dollars ($2014).
[d] Cost effectiveness values include full energy-cycle GHG reductions, including those occurring out of state. Dollars expressed in $2014.
[e] Net emissions were found to be positive for this policy option; therefore, no cost effectiveness could be calculated.
[f] Full benefits are realized when considering the full life-span of planted trees. 2015-2085 Cumulative Reduction = 67 $MMtCO_2e$; NPV = $2,208; 2085 CE = $33
[g] Full benefits are realized when considering the full life-span of planted trees. 2015-2085 Cumulative Reduction = 108 MMtCO2e; NPV = $183; 2085 CE = $1.76
[h] Full benefits are realized when considering the full life-span of planted trees. 2015-2085 Cumulative Reduction = 25 MMtCO2e; NPV = $1,304; 2085 CE = $53

Table F-5.2 FOLU Policy Options, Intra-Sector Interactions

Intra-Sector Interactions & Overlaps Adjusted Results							
		GHG Reductions				**Costs**	
Policy Option ID	**Policy Option Title**	**Annual[a]**		**2030 Cumulative[a]**	**2030 Cumulative[b]**	**Net Cost[c] 2015-2030**	**Cost Effectiveness[d]**
		2020 MMt	**2030 MMt**	**$MMtCO_2e$**	**$MMtCO_2e$**	**$Million**	**$/tCO_2e$**
FOLU-2.	Manage for Highly Productive Forests - Intermediate Stand Treatments	Not Applicable					
FOLU-3.	Urban Forests: Maintenance and Expansion 40% Canopy Goal	0.086	0.49	3.2	3.2	$1,806	$568
FOLU-4.	Tree Planting: Forest Ecosystems	1.4	1.9	30	34	$187	$6
FOLU-5.	Conservation on Private Lands	0.1	0.3	3.0	3.0	$1,261	$421
Total After Intra-Sector Interactions /Overlap		**1.6**	**2.7**	**36**	**40**	**$3,254**	**$81**

Notes:
[a] In-state (Direct) GHG Reductions.
[b] Total (Direct and Indirect) GHG Reductions.
[c] Net Present Value of fully implemented policy option using 2014 dollars ($2014).
[d] Cost effectiveness values include full energy-cycle GHG reductions, including those occurring out of state. Dollars expressed in $2014.

Figure F-5.1 FOLU Policies GHG Emissions Abatement, 2015-2030



Notes:
All Policies Total's comprise emissions reductions achieved by all the FOLU options combined.
Total in and out-of-state emissions reductions are the reductions associated with the full energy cycle (fuel extraction, processing, distribution and consumption). Therefore, the emissions reductions that occur both inside and outside of the state borders as a result of a policy implementation are captured under this value.

Table F-5.3 Macroeconomic (Indirect) Impacts of FOLU Policies

Macroeconomic (Indirect) Impacts Results									
Scenario	Gross State Product GSP ($2015 Millions)			Employment (Full and Part-Time Jobs)			Income Earned ($2015 Millions)		
	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)
FOLU-3	$382	$366	$5,495	4,420	4,180	62,670	$463	$361	$5,409
FOLU-4	-$10	-$15	-$232	-130	-210	-3,160	-$14	-$19	-$283
FOLU-5 with farms losing income (FOLU-5 low income)	-$114	-$87	-$1,301	-1,350	-1,060	-15,900	-$3	$67	$1,010

FOLU-5 with farms keeping income (FOLU-5 keep income)	-$75	-$59	-$883	-920	-720	-10,750	$117	$144	$2,157
FOLU Sector Total With Farms Losing Income (FOLU Sector Total Low Income)	**$258**	**$264**	**$3,961**	**2,940**	**2,910**	**43,610**	**$446**	**$409**	**$6,135**
FOLU Sector Total with Farms Keeping Income (FOLU Sector Total Keep Income)	**$294**	**$290**	**$4,345**	**3,340**	**3,220**	**48,340**	**$567**	**$486**	**$7,292**

The graph below articulates the relative scale of job-producing potential of the FOLU policies. In this analysis, we considered two alternative scenarios for FOLU-5, in which private landowners put land out of use for forestry easements funded by the state and federal governments. In the default scenario, this land is assumed to be unproductive before the easements are obtained. In the "low income" or "lost income" scenario, that land is assumed to be marginal, but farmed and productive, and its coverage by an easement creates a loss in income to offset the gain in income from the easement. This alternative affects not only the results of FOLU-5 but also the FOLU sector's overall results.

Figure F-5.2 Net Job Creation for FOLU Policies and FOLU Sector, 2015-2030

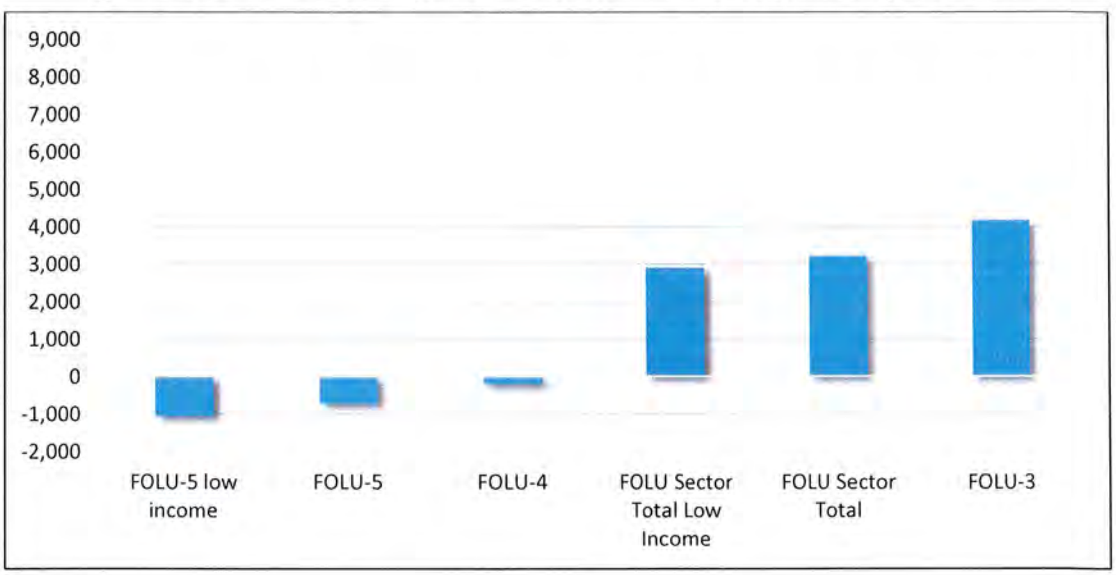
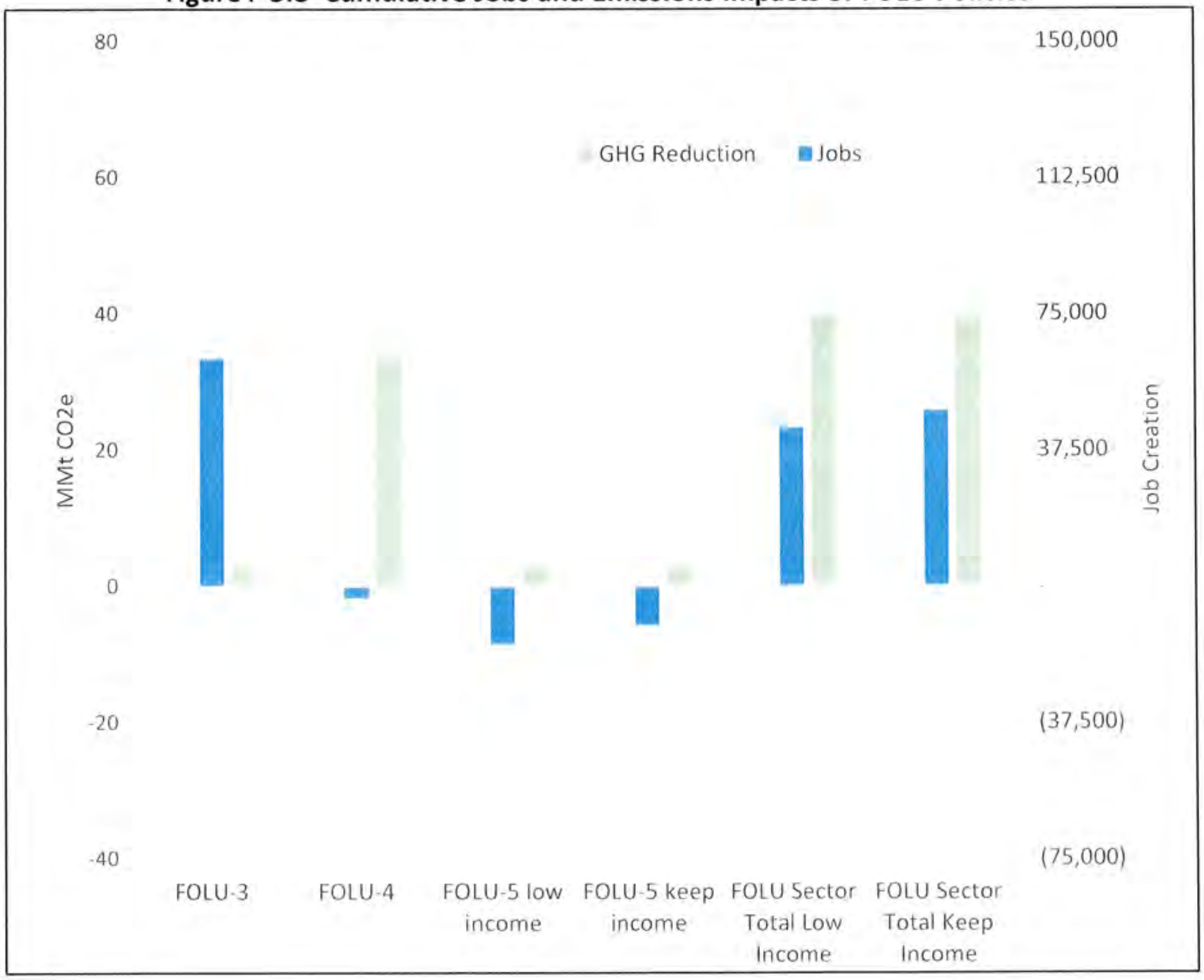


Figure F-5.3 below summarizes a potential for job creation and GHG emissions abatement of FOLU sector policies on the same graph. This allows for a simultaneous assessment of performance of individual options against two crucial environmental and economic indicators.

Figure F-5.3 Cumulative Jobs and Emissions Impacts of FOLU Policies



Macroeconomic Index

The graphs below express the overall economic impact from each scenario in a single score, and compares those scores. CCS created this single score (a Macroeconomic Impact Index) in order to encapsulate in one measurement the relative macroeconomic impacts (including jobs, GSP and incomes) of each policy. We have found in our own work and in the literature that indexed scores can be helpful to many readers when comparing options with multiple characteristics.

To produce this score, CCS set the results from the absolute best-case scenario (i.e. the implementation of all CSEO policies with all their optimal sensitivities in place) equal to 100, with that scenario's jobs, GSP and incomes impacts weighted equally at one third of the total

The FOLU sector generates significant positive impacts – around $250 million in GSP and nearly $350 million in income, with 3,500 jobs more than would exist in the state by 2030 than if these policies were not implemented.

The sector impact on Minnesota's economy, according to this analysis, is really the story of the policy focused on community forest development (FOLU-3). While the other policies are small in their overall impacts, and somewhat negative in terms of job creation, the community forests policy generates significant growth through the year 2025 in all three metrics, and lifts the overall sector up to a total of 4,500 additional positions, and nearly $500 million in overall economic activity (both in GSP and in Incomes). FOLU-4 reduces total employment, incomes and GSP (by less than $100 million). FOLU-5 is slightly positive with regard to income creation, but reduces GSP and jobs as the state bears the burden of funding the program.

Graphs below show the trend of FOLU policy macroeconomic impacts during the year 2015 to 2030.

Figure F-5.7 FOLU GSP Impacts ($2015 MM)

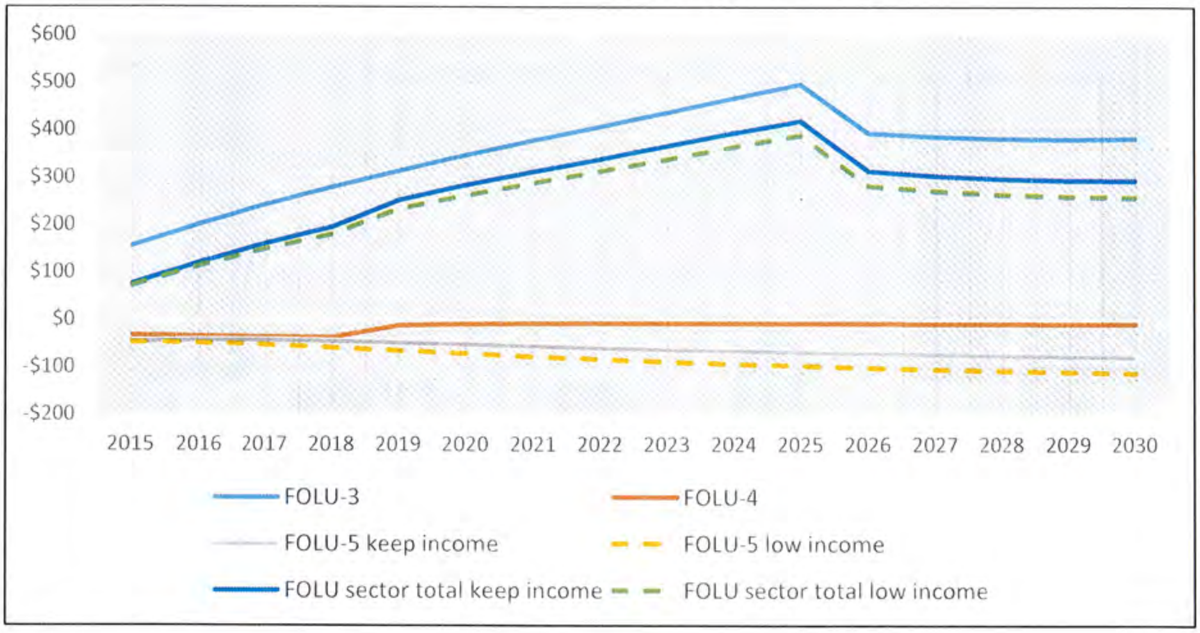


Figure F-5.8 FOLU Income Impacts ($2015 MM)

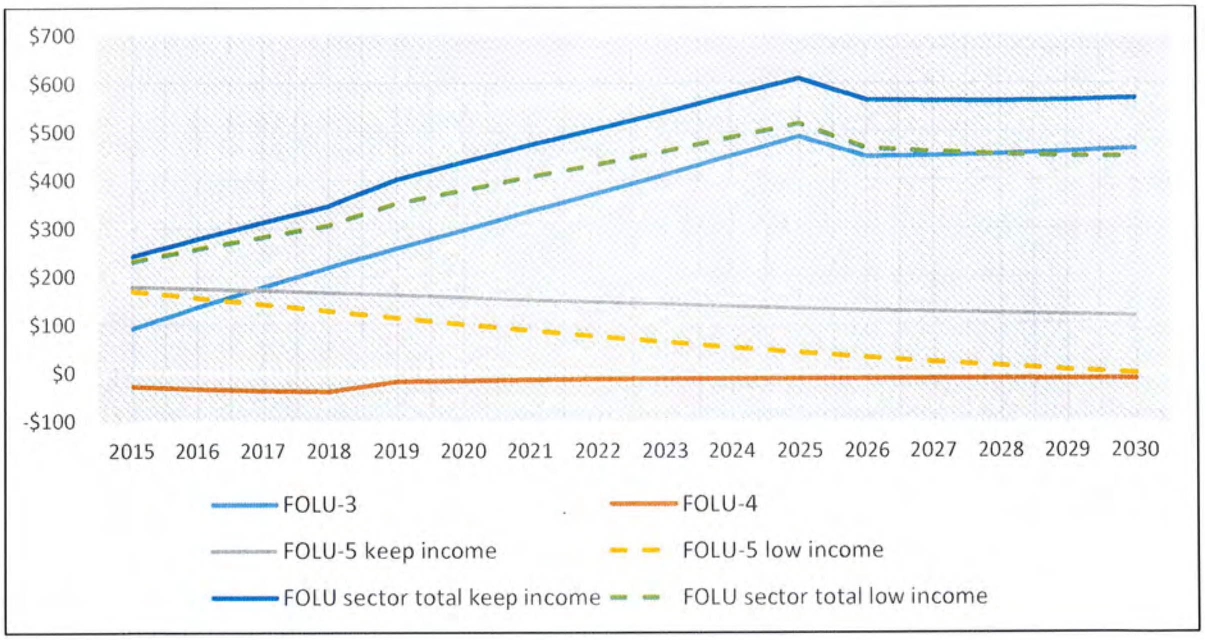
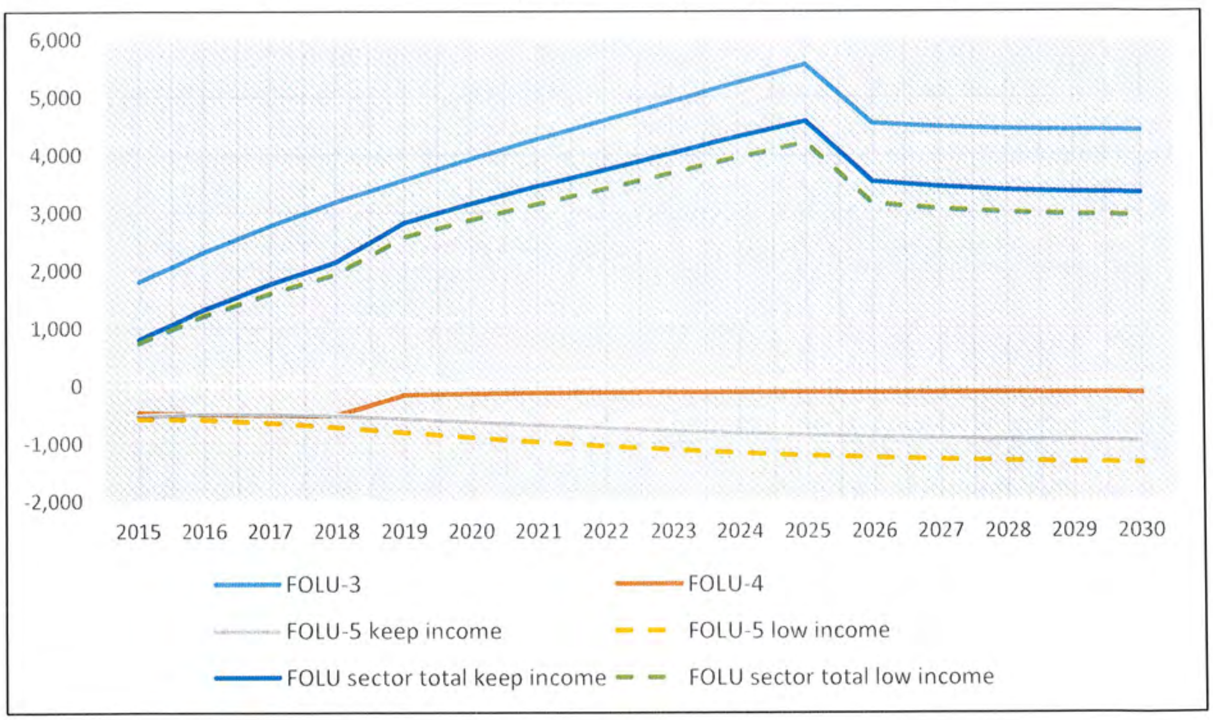


Figure F-5.9 FOLU Employment Impacts (Individual Jobs)



Graphs below show macroeconomic impacts on GSP, personal income, and employment in the final year (2030), in average (2015-2030) and in cumulative (2015-2030). Light color indicates sensitivity scenarios.

Figure F-5.10 FOLU GSP Impacts, Average Annual ($2015 MM)

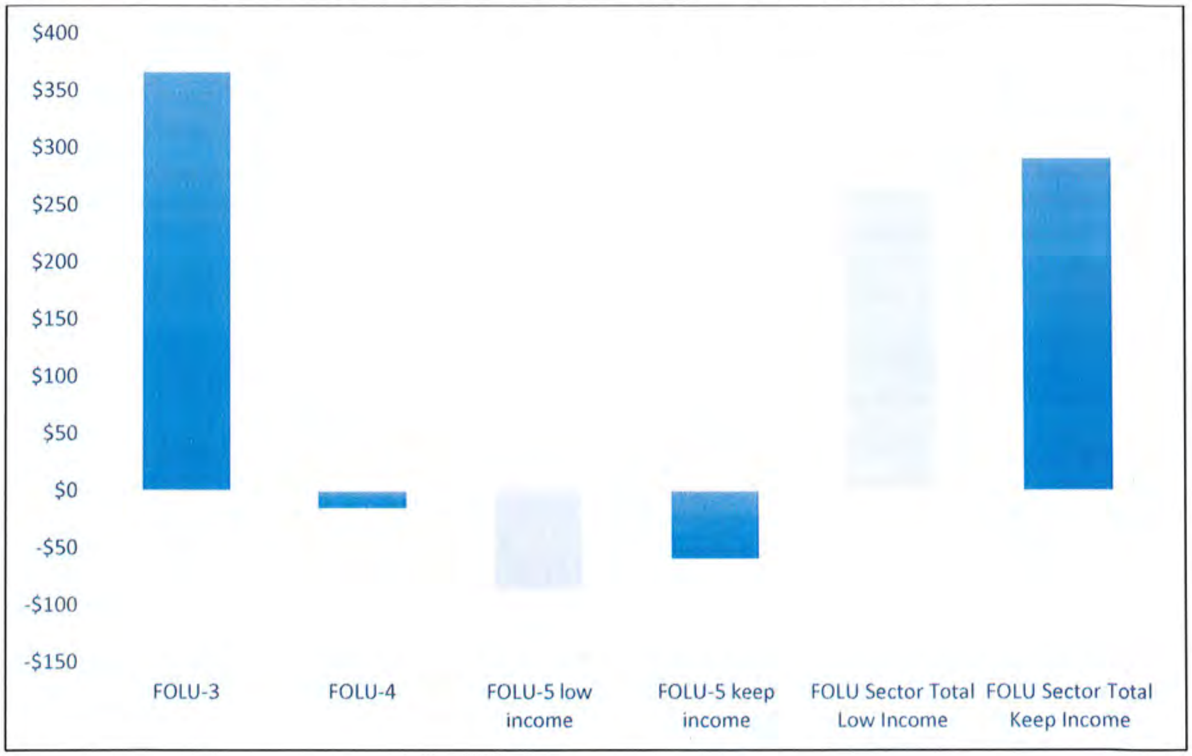


Figure F-5.11 FOLU GSP Impacts, 2015-2030 ($2015 MM)

Figure F-5.12 FOLU GSP Impacts, Year 2030 ($2015 MM)

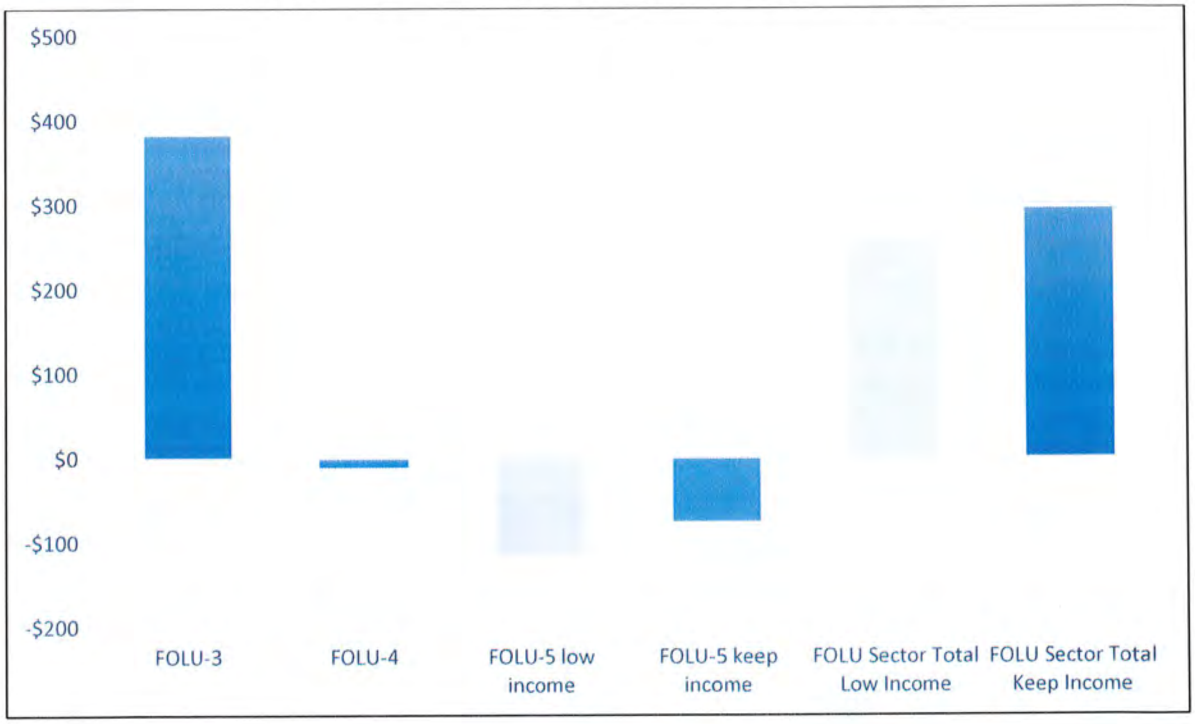


Figure F-5.13 FOLU Employment Impacts, Average Annual (Jobs)

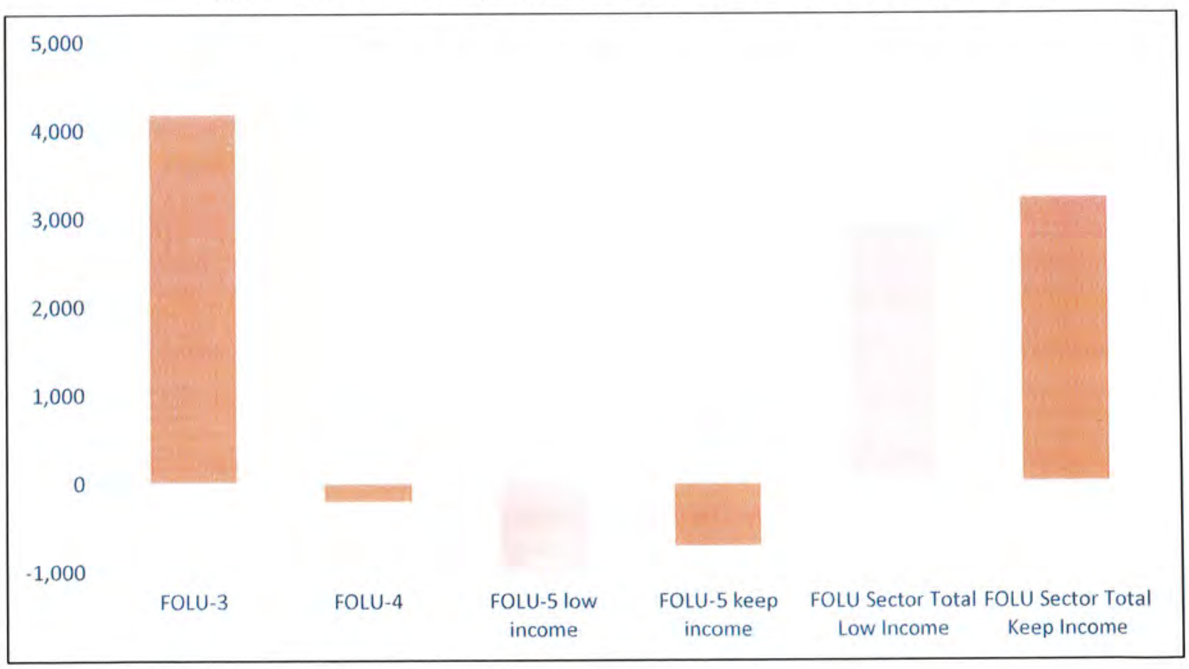


Figure F-5.14 FOLU Employment Impacts, 2015-2030 (Jobs)

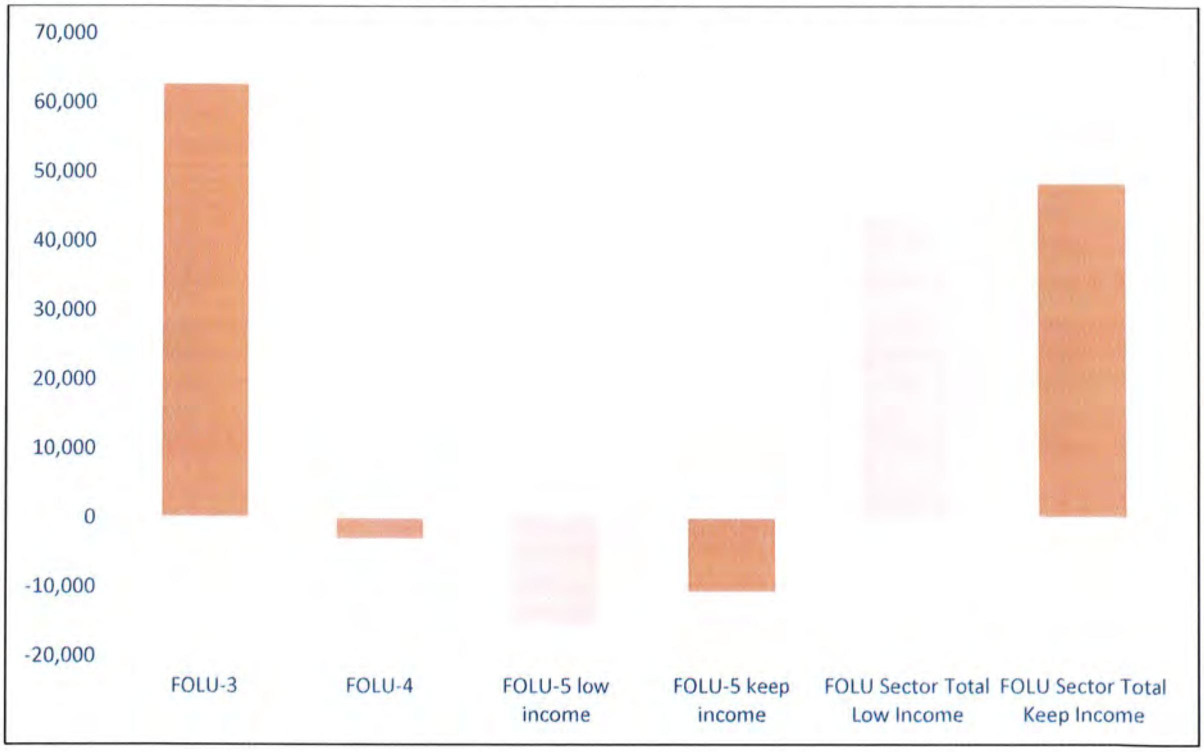


Figure F-5.15 FOLU Employment Impacts, Year 2030 (Jobs)

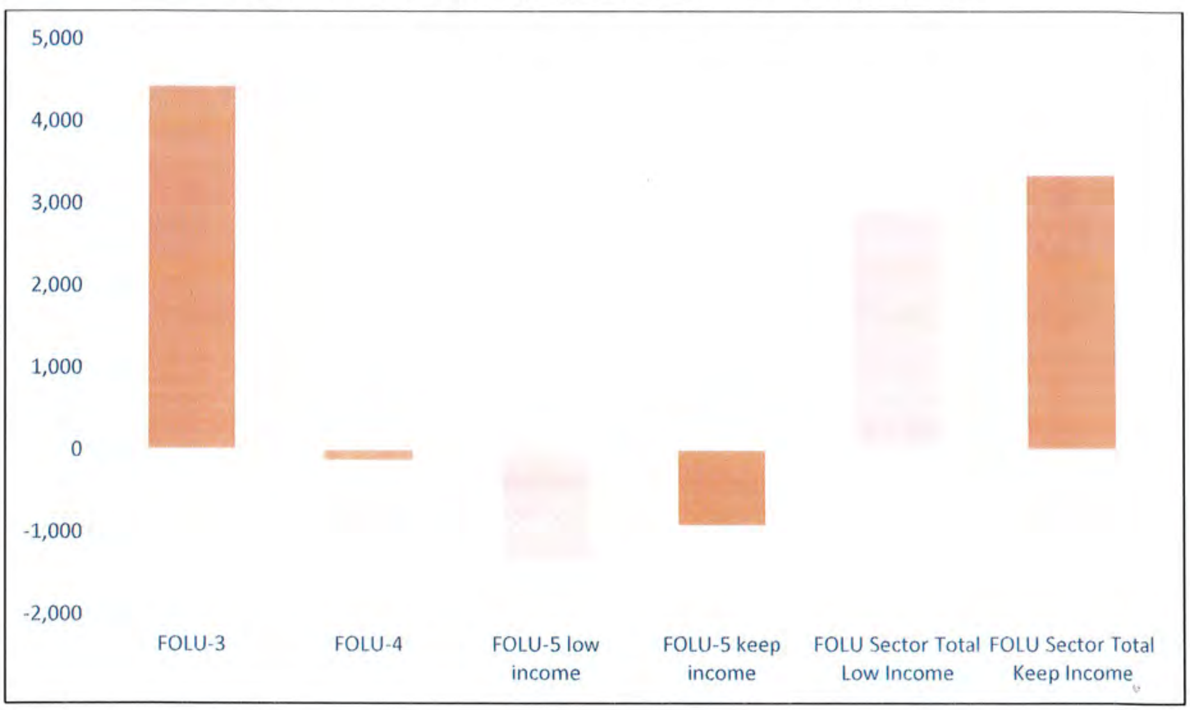
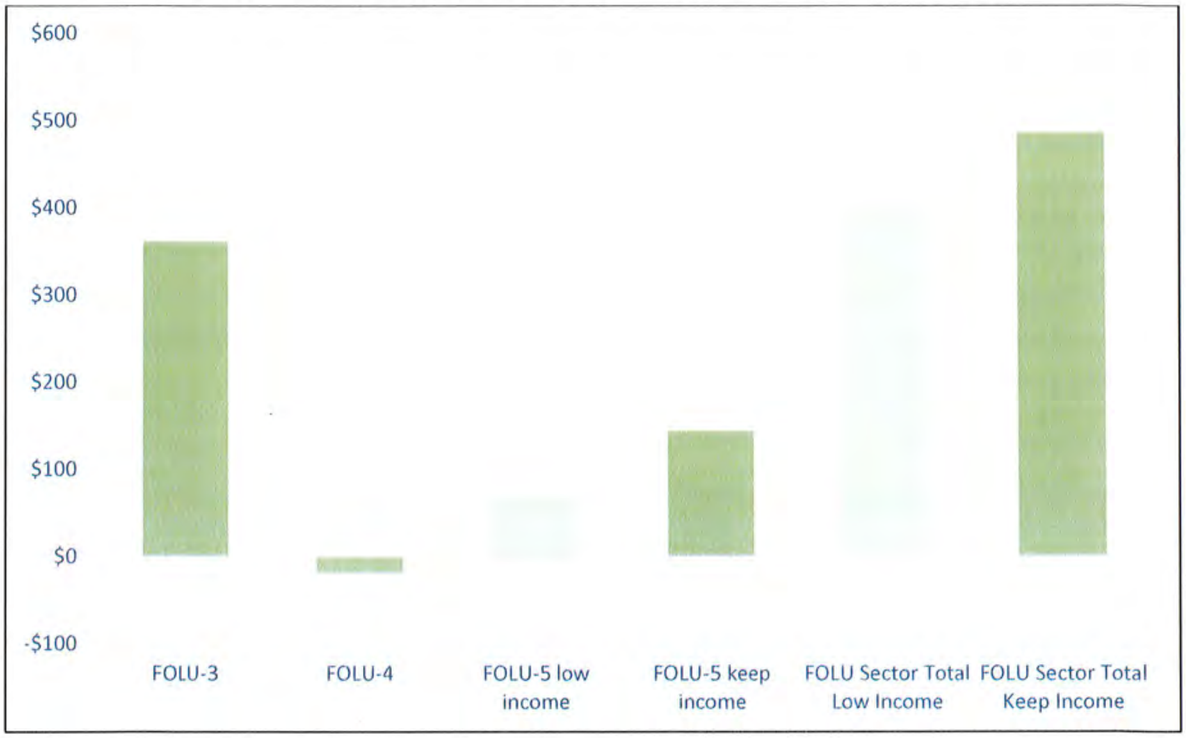


Figure F-5.16 FOLU Income Impacts, 2015-2030 Average Annual ($2015 MM)



FigureF-5.17 FOLU Income Impacts, 2015-2030 ($2015 MM)

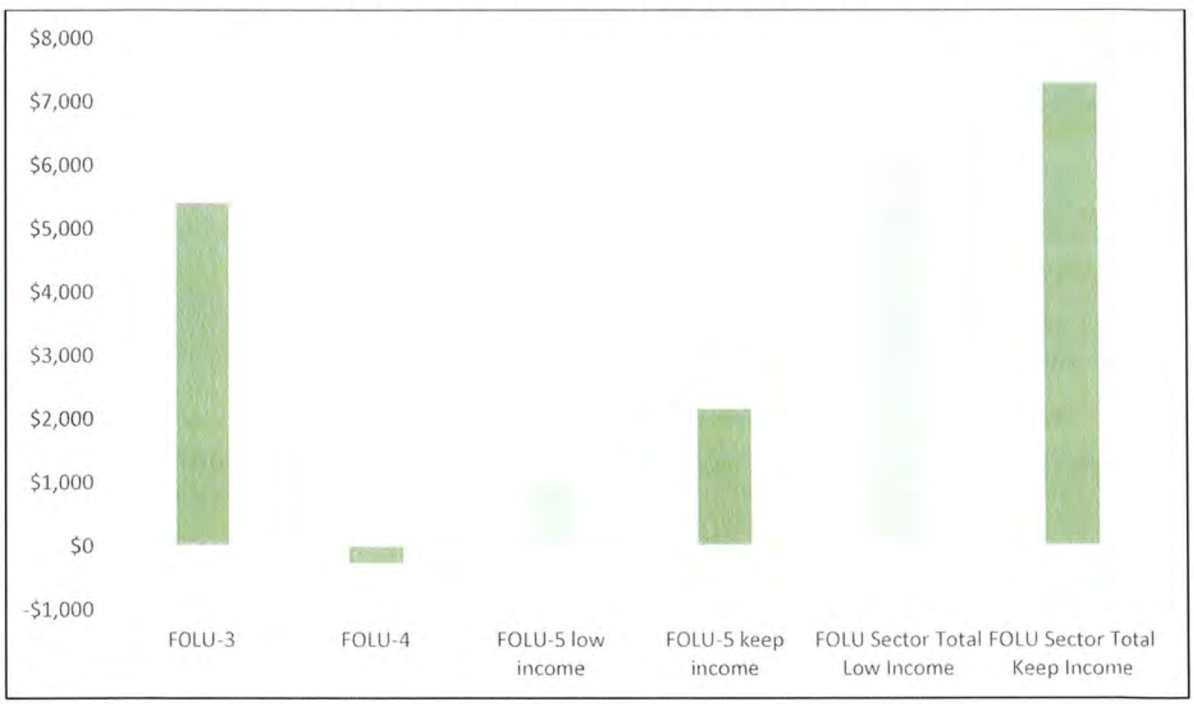


Figure F-5.18 FOLU Income Impacts, Year 2030 ($2015 MM)

FOLU-3. Community Forests

Policy Option Description

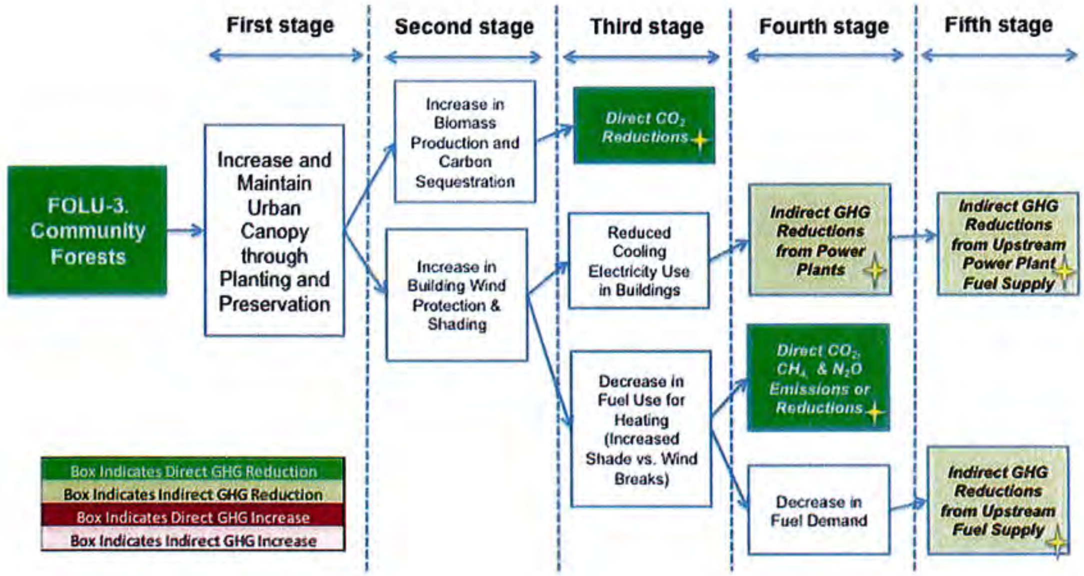
This policy option would strengthen community forests across the state by:

- Increasing the overall tree canopy cover of community forests to 40% by 2050, with discrete goals for residential, commercial/industrial, and other land use types.
- Achieving no net loss of tree canopy cover by 2035.

It has long been recognized that trees conserve energy by providing shade and windbreaks. Recent and ongoing scientific evidence also recognizes that community trees provide substantial benefits for air and water quality. Specific to this policy option, trees sequester carbon. Trees also provide numerous other economic, environmental, and public health benefits.

Causal Chain for GHG Reductions

Figure F-5.19 Causal Chain for FOLU-3 GHG Reductions



The causal chain above identifies the main policy option effects and the subsequent GHG impacts. The star symbol identifies significant GHG effects that will be quantified.

- "First stage" refers to the direct physical impacts of the policy option, namely an increase in overall tree canopy through maintenance and planting.
- In the "Second stage," community forests will grow in size and volume, resulting in increased biomass production and wind protection and shading of buildings.
- The "Third stage" includes direct CO_2 reductions as a result of expansion and growth of community forests. This stage also includes reductions in electricity and heating fuel consumption resulting from the increased shading and wind protection.
- The "Fourth stage" reductions in GHGs resulting from reduced electricity use to cool buildings and fuel use for heating, as well as the reduced demand resulting from reductions in consumption.
- The "Fifth stage" refers to reductions of indirect upstream GHGs from electricity and heating fuel use.

Policy Option Design

The proposed policy option is designed to reverse the decline in community forests and achieve a preferred overall tree canopy cover for Minnesota communities. This will be accomplished through increased tree maintenance and planting.

The policy option design is anchored by a set of best practices in community forestry which includes proper planting and proper maintenance. Proper planting involves considerations of site design, site preparation, soil suitability, planting depth, and species and size diversity. Proper maintenance involves timely and regular pruning of new and existing trees, planning and inventorying, and employing preparedness measures for invasive species including integrated pest management approaches.

Goals:

This policy option is framed around three goals:

- By 2050, all Minnesota cities/towns will have at least 40% overall tree canopy cover, with discrete goals for residential, commercial/industrial, and other land use types.
- By 2035, all Minnesota cities/towns will achieve no net loss of overall tree canopy cover, using DNR's 2010 Rapid Assessment as a baseline. This will be achieved primarily through preservation of canopy cover and secondarily through tree planting. *Goal is strategic in nature, and represents a key milestone toward achievement of the 2050 goal. It is a non-GHG quantified goal.*
- By 2035, 350 Minnesota communities will have implemented inventory base management plans. Similarly, this goal is strategic in nature and represents a key milestone toward achievement of the 2050 goal. This is a non-GHG quantified goal.

Timing:

Increased tree maintenance activities will begin in Year 1 and will be ongoing until 2050. An ambitious tree planting initiative will begin and be ongoing from Year 1 until 2025 so that new trees will have mature canopies by 2050. These efforts (increased maintenance and ambitious planting) will achieve the 40% canopy goal by 2050, resulting in projected GHG emissions and numerous other co-benefits.

Parties Involved:

Implementation of this policy option will occur at the local government level with support and involvement from state government and other parties. Collaborators for maintenance and plantings include federal, state, regional, and local governmental agencies, academic and research institutions, and non-governmental and private sector organizations. In order to achieve overall tree canopy cover goals, planting on residential and privately owned land will be necessary.

Other:

Community trees can sequester more carbon than individual trees in non-urban forests because the more open structure of the growing environment allows individual trees to intercept more light and grow faster. In addition, individual urban trees, on average, contain approximately four times more carbon than individual trees in forest stands.[1] Unfortunately,

[1] Nowak, David, and Daniel Crane. "Carbon Storage and Sequestration by Urban Trees in the USA." Environmental Pollution 116 (2002): p. 385 Accessed on web June 2, 2014.

when trees are stressed, they can lose their normal ability to absorb CO_2. In contrast, healthy, vigorous, growing trees will absorb more CO_2 than will trees that are diseased or otherwise stressed.[2]

Substantial numbers of ash trees are found in community forests across Minnesota. The timeline included in this policy option includes the projected mortality of 100% of the ash population in community forests.

This policy option design does not include the removal of ash or stump grinding because this is presumed to be necessary, regardless of whether or not this policy option is advanced.

Community forests provide significant adaptation and other co-benefits such as improving air quality, providing natural habitat, mitigating temperature extremes, and improving soil health. Trees also contribute toward the aesthetics of communities, including increasing property values and positively impacting the physical and mental well-being of residents. While the value of many of these contributions can be calculated using existing software, they are outside the scope of the policy option and are not quantified or included in this analysis, but should be considered in the overall ROI calculations for investments in urban forests.

When these other benefits are lost due to the declining state of community forests, vulnerable populations including low-income individuals, children, and the elderly experience disproportionate impacts.

Implementation Mechanisms

Existing Infrastructure

This policy option recognizes the current value of existing community forests throughout more than 800 Minnesota cities and towns, which provide an estimated 20% overall tree canopy cover. Since full benefits begin to accrue once a tree reaches maturity (25 to 30 years), maintaining the base tree canopy cover in Minnesota communities is an essential implementation strategy.

Formal Adoption of Goals

A key first step is to formally adopt the goals proposed in this policy option. This could be accomplished statutorily through legislation, Governor's executive order, or some other related mechanism.

State Technical and Financial Assistance to Communities

Community forestry activities will be carried out at the local level. Many Minnesota communities will face challenges in securing adequate resources to carry out necessary activities. Recognizing the important role that individual cities, towns and communities play in maintaining and improving community forests, the state and other supporting institutions and organizations will need to provide increased and sustained assistance from a mix of funding

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[2] Urban Forest Project Protocol, Climate Action Reserve. Version 1.1, March 2010, p. 47, accessed online 5/29/14.

sources including forestry and environmental funds, stormwater utility fees, energy conservation funding, habitat and natural heritage resources, state and local bond funds, and disaster preparedness funding. It is likely that corporate and philanthropic resources will need to be secured to help with community forestry needs and reach overall canopy goals, especially on non-public, non-residential lands.

The substantial additional funding required to implement this policy option will support increased technical and financial assistance, detection and management of pests and diseases, and research on innovations and emerging best practices.

Data Collection

To guide implementation of this policy option, new and improved data around community forestry will be necessary. This data is in the form of tree inventories (tracking the species, location, condition, and size of a given tree), aerial canopy assessments, and other best practices for forestry data management. This data and related analysis will be used to track the progress of the stated goals.

Related Policies/Programs in Place and Recent Actions

Policies related to community forestry in Minnesota statutes place emphasis on terrestrial invasive pest detection, quarantine, and management. These responsibilities are shared between the departments of Agriculture and Natural Resources.

Few statewide community forestry programs are currently in place. Like other states, DNR receives a modest annual USDA Forest Service grant. It is used to fund one staff person and provide pass-through dollars to the University of Minnesota Department of Forest Resources.

As a result of the Clean Air Dialogue in 2009, community forestry is recommended as an approach to mitigate the urban heat island effect and improve air quality. Additionally, community forestry has been identified as a practical climate adaptation strategy in the November 2013 report of the state's interagency climate adaptation team, "Adapting to Climate Change in Minnesota."

Estimated Policy Impacts

Direct Policy Impacts

Table F-5.4 FOLU-3 Estimated Net GHG Reductions and Net Costs or Savings for 40% Canopy Goal

2030 GHG Reductions (short tons CO_2e)	2015 – 2030 Cumulative Reductions (short tons CO_2e)	Net Present Value of Societal Costs, 2015 – 2030 ($2014)	Cost Effectiveness ($2014/ ton CO_2e)

0.49	3.4	$1,806	$568

Recognizing the anticipated lifespan of existing and newly planted trees, costs and benefits of this policy option are quantified over a time period extending to 2085

Table F-5.5 Estimated FOLU-3 Net GHG Reductions and Net Costs or Savings (2015-2085) for 40% Canopy Goal

2085 GHG Reductions (short tons CO_2e)	2015 – 2085 Cumulative Reductions (short tons CO_2e)	Net Present Value of Societal Costs, 2015 – 2085 ($2014)	2085 Cost Effectiveness ($2014/ ton CO_2e)
0.14	67	$2,208	$33

In addition to the 40% canopy goal, GHG reductions and costs were estimated for the goals of 50%, 30%, and 20%. The results for these differing goals are shown below.

Table F-5.6 Estimated FOLU-3 Net GHG Reductions and Net Costs or Savings (2015-2030 and 2015-2085) – Other Canopy Goals

Canopy Goal	2030 GHG Reductions (short tons CO_2e)	2015 – 2030 Cumulative Reductions (short tons CO_2e)	Net Present Value of Societal Costs, 2015 – 2030 ($2014)	Cost Effectiveness ($2014/ ton CO_2e)
50%	0.69	4.5	$2,567	$565

Table F-5.7 Estimated FOLU-3 Net GHG Reductions and Net Costs or Savings (2015-2085) for 40% Canopy Goal

2085 GHG Reductions (short tons CO_2e)	2015 – 2085 Cumulative Reductions (short tons CO_2e)	Net Present Value of Societal Costs, 2015 – 2085 ($2014)	2085 Cost Effectiveness ($2014/ ton CO_2e)
0.14	67	$2,208	$33

In addition to the 40% canopy goal, GHG reductions and costs were estimated for the goals of 50%, 30%, and 20%. The results for these differing goals are shown below.

Table F-5.8 Estimated FOLU-3 Net GHG Reductions and Net Costs or Savings (2015-2030 and 2015-2085) – Other Canopy Goals

Canopy Goal	2030 GHG Reductions (short tons CO_2e)	2015 – 2030 Cumulative Reductions (short tons CO_2e)	Net Present Value of Societal Costs, 2015 – 2030 ($2014)	Cost Effectiveness ($2014/ ton CO_2e)
50%	0.69	4.5	$2,567	$565
30%	0.28	1.8	$1,045	$576
20%	0.069	0.45	$284	$629
Canopy Goal	**2085 GHG Reductions (short tons CO_2e)**	**2015 – 2085 Cumulative Reductions (short tons CO_2e)**	**Net Present Value of Societal Costs, 2015 – 2085 ($2014)**	**Cost Effectiveness ($2014/ ton CO_2e)**
50%	0.20	96	$3,066	$32
30%	0.079	38	$1,350	$35
20%	0.020	9.5	$492	$52

<u>Data Sources</u>

The following data sources were used to quantify costs and benefits for this policy option:

- Data from the National Land Cover Database (NLCD) was used to establish the total Urban/Developed area for the state.
- Minnesota DNR Community Tree Survey 2012 was used to determine the baseline tree species diversity in cities and towns.
- University of Minnesota Department of Forest Resources was consulted in establishing the baseline average community forest canopy cover.
- The 2002 study, "Carbon Storage and Sequestration by Urban Trees in the USA," by David Nowak and Daniel Crane, was used to estimate carbon sequestration by community trees.
- The 2012 study, "Tree and Impervious Cover Change in U.S. Cities," by Nowak and Greenfield, was used to identify BAU average annual canopy loss.
- Guidance from the Minnesota Pollution Control Agency, Department of Natural Resources, and University of Minnesota Department of Forest Resources was used to establish areal coverage of average mature community trees, as well as estimated percents for new plantings in "municipal core," "peri-urban strategic," and "peri-urban other" areas.

- The USDA Forest Service's Midwest Community Tree Guide was consulted for tree installation & maintenance costs and energy impacts.
- The USDA Forest Service's iTree software was used to develop the Minneapolis model which was used to estimate statewide stormwater benefits.

Quantification Methods

Net GHG Benefits:

The number of trees planted in the urban core, strategic suburban, and other suburban areas was estimated based on statewide urban area, current and desired urban canopy coverage, and estimated areal coverage of each tree.

The total number of trees needed to increase canopy was divided equally among the planting years (2015-2025).

To maintain canopy, new trees were assumed to be planted to replace all of those lost to emerald ash borer (EAB) and those lost through normal BAU mortality.

All urban ash trees were assumed to be killed by EAB between 2015 and 2031, giving an estimate of 8 km^2 of canopy lost annually, based on data from the Minnesota DNR Community Tree Survey[3] showing that ash trees comprise 20% of total trees. New trees only provide a fraction of the carbon sequestration and heating/cooling benefits of a mature tree. The fractions for these benefits for tree age ranges were developed based on data in the United States Forest Service (USFS) Midwest Urban Tree Guide. Trees were assumed to be lost to EAB in both the BAU and policy option scenarios; however, in the policy option scenario these trees are assumed to be replaced with new trees, which take time to reach full maturity and provide the same benefits as lost mature trees.

In addition to trees planted to expand and maintain canopy, this policy option is intended to mitigate the further loss of canopy due to inadequate maintenance. An estimate of 0.3% per year of canopy loss, based on a recent study of tree cover lost in US cities[4], was used to estimate BAU losses of heating, cooling, and stormwater runoff savings. Under the policy option scenario, these losses are not realized.

Societal Benefits and Costs:

Several important societal benefits have been deemed to be indirect to this policy option and therefore not quantified in the cost-benefit analysis. Examples include air quality improvements, mitigation of urban heat island effect, as well as public health benefits.

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[3] Minnesota DNR Community Tree Survey, State of Minnesota, Department of Natural Resources, 2012. http://archive.leg.state.mn.us/docs/2012/other/120339.pdf

[4] Nowak and Greenfield, 2012. Tree and Impervious Cover Change in U.S. Cities, Urban Forestry & Urban Greening 11 (2012) 21-31.
http://www.itreetools.org/Canopy/resources/Tree_and_Impervious_Cover_change_in_US_Cities_Nowak_Greenfield.pdf

Costs associated with tree planting and maintenance activities were estimated based on the number of trees planted each year and the costs indicated above under Data Sources.

Savings from reduced electricity and natural gas use and savings from reduced stormwater runoff were estimated for each year based on the age range fractions described above under Net GHG Benefits. Stormwater savings result from the reduction in runoff that has to be handled by water treatment plants. It was assumed that most suburban areas do not have combined sewers that receive stormwater runoff; therefore, these savings were applied to trees in the urban core only.

Under the BAU, lost savings from reductions in canopy due to EAB and inadequate maintenance were estimated, assuming loss of mature trees. BAU losses also assume that 50% of current ash trees are in strategic suburban areas (areas providing shading and wind breaks), based on agency guidance.

BAU maintenance was estimated to be 40% of needed maintenance to mitigate further loss of canopy (based on current maintenance frequency of once every 10 years compared to preferred frequency of once every four years).

Lost cost savings under BAU are subtracted from the policy option scenario costs to give net costs.

Key Assumptions:

Key assumptions used in the quantification of benefits and costs are described above under Net GHG Benefits and Societal Costs. Other key assumptions include:

- One hundred percent ash mortality due to EAB,
- Tree maturity is reached when a tree is 25 to 30 years old,
- All newly planted trees survive to maturity (currently 30-50% die before full maturity), and
- Projected expansion of urban land use is 201 km^2 (from 4,071 km^2 in 2011 to 4,272 km^2) by 2035.

Macroeconomic (Indirect) Policy Impacts

Table below summarizes impacts of FOLU 3 option on GSP, employment and income earned in the state. Impacts of a sensitivity scenario are also evaluated.

Table F-5.9 Macroeconomic (Indirect) Economic Impacts

Scenario	Gross State Product (GSP, $2015 Millions)			Employment (Full & Part-Time Jobs)			Income Earned ($2015 Millions)		
	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)
FOLU-3	$382	$366	$5,495	4,420	4,180	62,670	$463	$361	$5,409

Figure F-5.20 FOLU-3 GSP Impacts ($2015 MM)

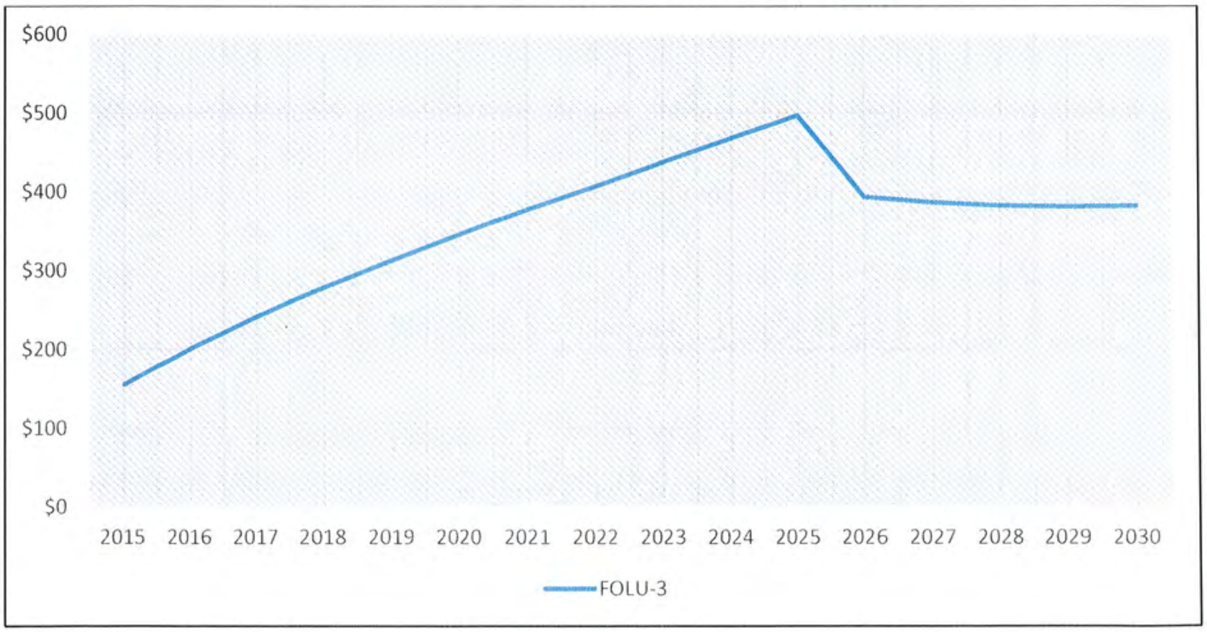


Figure F-5.21 FOLU-3 Income Impacts ($2015 MM)

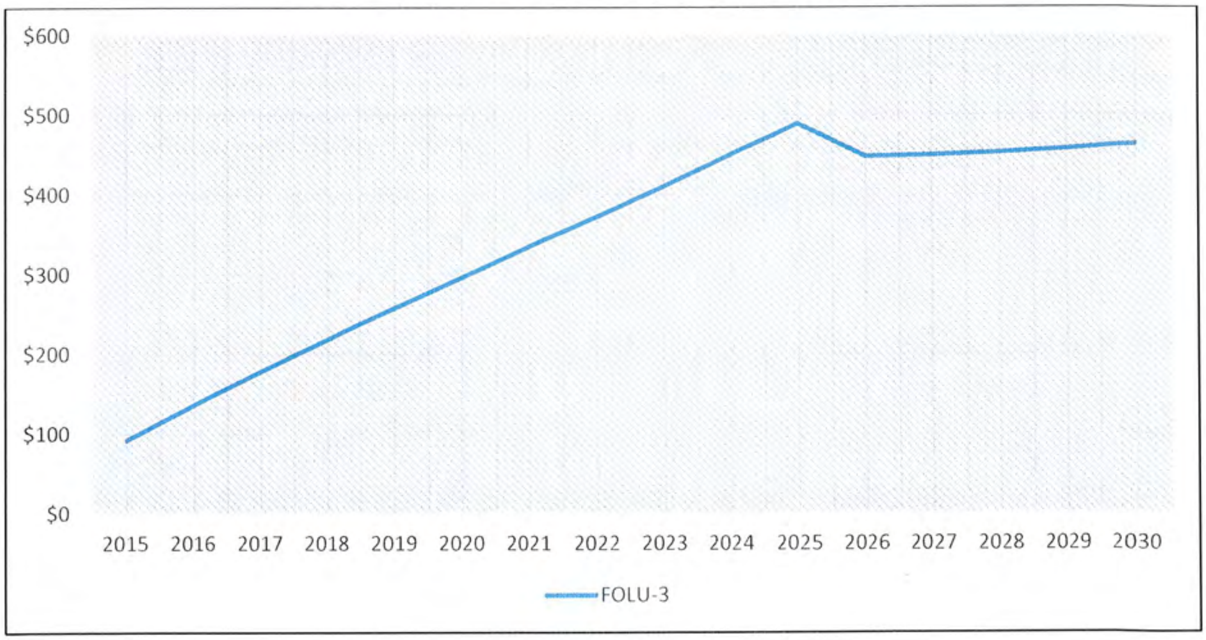
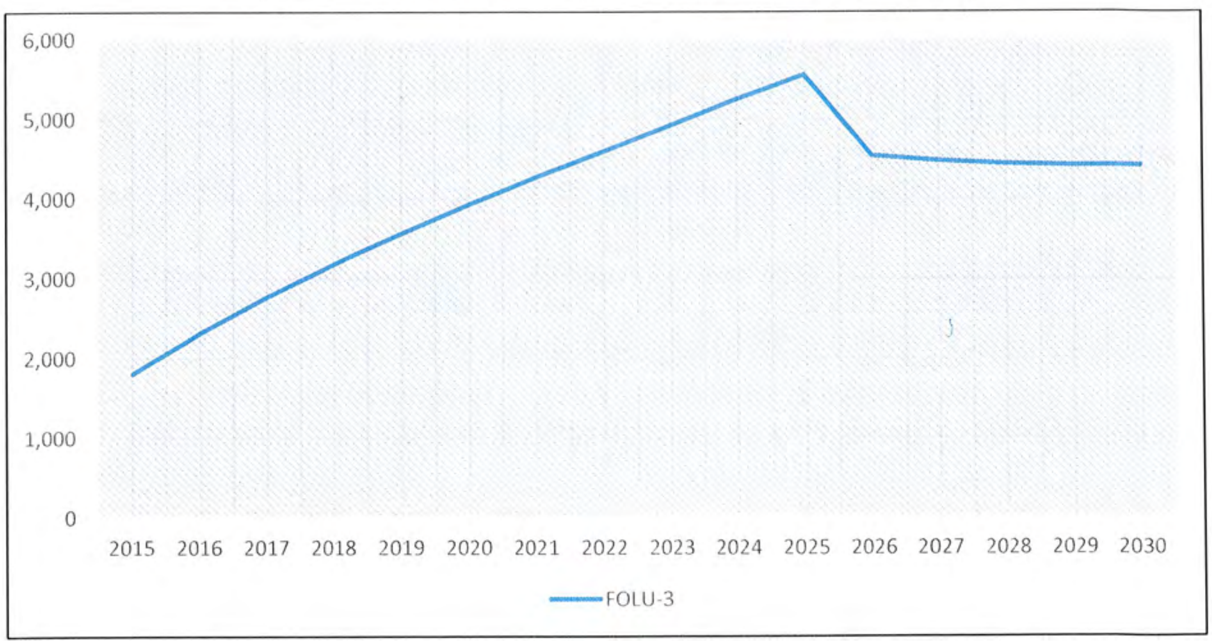


Figure F-5.22 FOLU-3 Employment Impacts (Individual Jobs)



Principal Drivers of Macroeconomic Changes

A major driver of positive macro-economic implications in this policy is the state government spending on strengthening and increasing the tree canopy cover of community forests. This spending is almost entirely on labor to carry out the forestry work. As a result of that spending, there is a constant increase in employment, both in the metro area and the rest of the state. This kind of direct employment has significant indirect impacts as those employees spend their money around the economy.

Another positive macro-economic driver is the energy savings achieved by the policy, due to the reduction in electricity demand for cooling that grows over the entire modeling period.

The state is expected to achieve significant storm water management savings by implementing this policy. Bigger absorption and transpiration of water by expanded community forests reduces the need for storm water management spending.

The state does, however, cut back on other spending in order to fund this effort, and that reduction serves as a downward pressure on GDP, incomes and total employment.

This policy suddenly reduces its government investment in tree-planting after 2025, cutting a $350 million annual expenditure to a $40 million annual expenditure, and this shift drives the abrupt downward shift of the impacts starting in 2026.

Data Sources

- Local government spending, primarily in the metro area, on urban forestry efforts. This steadily rises through the period of analysis to reach approximately $175 million per year in 2030.
- Savings by governments, businesses and households on electricity as a result of shade trees.
- Government savings, reaching as much as $25 million, on storm water management.

Key Assumptions

The macroeconomic impact analyses of this policy, as well as of the others in the CSEO process, rely on a consistent set of key assumptions:

- State and local spending is always budget-constrained. If a policy calls for the state or local government to spend money in any fashion, that spending must be either funded by a new revenue stream or offset by reductions in spending on other programs. Savings or revenues collected by the government are also expected to be returned to the economy as spending in the same year as they are collected.
- Federal spending is not budget-constrained. The capacity of the federal government to carry out deficit spending means that no CSEO policy is held responsible for driving either an increase or decrease in federal tax spending by businesses or households in the state of Minnesota.
- Consumer spending increases are sometimes financed. Small-scale purchases or purchases of consumer goods are treated as direct spending from existing household cash flows (or short-term credit). Durable goods, home improvements or vehicle purchases, however, are treated as financed. Consumers were assumed to spread out

costs based on common borrowing time frames, such as five years for financing a new vehicle or 10-20 years for home improvements that might be funded by home-equity or other lending. The assumption of financing and the term of years applied was considered anew in each case.

- Business spending increases are often financed. Where spending strikes a sector which routinely utilizes financing or lines of credit to ensure steady payment of recurring costs, significant spending of nearly any type was considered a candidate for financing, thus allowing costs to spread out over time. This methodology is preferable for the modeling work, as sudden spikes or dips in business operating costs can show up as volatility when the scenario may depict a managed adoption of new equipment in an orderly fashion. The assumption of financing and the term of years applied was considered anew in each case.
- Unless otherwise stated, all changes to consumer spending or to the producers' cost of producing goods and services were treated in a standard fashion. Consumers are assumed to spend on a pre-set mix of goods, services, and basic needs, and businesses spend (based on their particular sector of the economy) on a mix of labor, capital, and intermediate demands from other sectors. Unless a policy specifically defines how a party will react to changes in cost, price, supply or demand, these standard assumptions were applied.

State and local spending gains and reductions driven by policy are assumed to apply to standard mixes of spending. Again, unless a policy specifically states that a government entity will draw from a specific source or direct savings or revenues to a specific form of spending, all gains and losses were assumed to apply to a standard profile of government spending within the economy.

Quantifications Methods

Utilizing the data developed from the microeconomic analysis, CCS analysts established for each individual change the following characteristics:

- The category of change involved (change in spending, savings, costs, prices, supply or demand)
- The party involved on both sides of each transaction
- The volume of money involved in this change in each year of the period of analysis
- These values, so characterized, were then processed into inputs to the REMI PI+ software model built specifically for use by CCS and consistent with that in use by state agencies within Minnesota. These inputs were applied to the model and run. Key results were then drawn from the model and processed for consistency of units and presentation before inclusion in this report.

Key Uncertainties

Key uncertainties associated with this analysis include:

- The impacts of ash tree mortality as it relates specifically to how much shading and windbreaks these trees currently provide.
- BAU estimates of canopy loss due to inadequate maintenance was based on a national study on current trends in urban canopy. It is uncertain whether Minnesota's annual estimated tree loss parallels national averages.
- In addition to cost savings from reductions in stormwater runoff, there would also be a reduction in electricity usage by water treatment plants. This electricity savings was not quantified in this analysis.
- There is some uncertainty associated with the level of maintenance spending necessary to establish and maintain new urban canopy. The sensitivity of total costs and cost effectiveness to changes in maintenance costs was investigated by increasing and decreasing the maintenance costs by 20%. As shown in the table below, a 20% over-estimate or under-estimate in maintenance costs only changes the calculated total costs and cost effectiveness of the policy option by 6.5%.

Table F-5.10 . Impact of Change in Maintenance Costs on FOLU-3 Results

Change in Maintenance Costs	Net Present Value of Societal Costs, 2015 – 2030 ($2014)	Cost Effectiveness ($2014/ ton CO_2e)
Increased by 20%	$1,974	$571
Original Values	$1,852	$536
Decreased by 20%	$1,730	$500

Additional Benefits and Costs

Significant benefits beyond GHG reductions exist for community tree canopy expansion.

Community forests improve or increase:

- Air quality,
- Quality and quantity of ground and surface waters,
- Extreme weather resilience,
- Use of multi-modal as well as non-motorized ways of commuting and travelling and healthy living behaviors,

- Biodiversity/wildlife habitat, and
- Property values.

Community forests also reduce:

- Urban heat island impacts,
- Flooding,
- Soil erosion,
- Impacts of drought, and
- The need for other infrastructure improvements.

Additionally, activities necessary to achieve the policy option goals will create jobs.

Feasibility Issues

Broad Political Support

Community forestry enjoys broad political support from state and local government officials, citizens, and private and nonprofit stakeholders in Minnesota. The potential for political opposition is low.

Established Best Practices

Best practices for community forestry such as tree planting, tree maintenance, tree inventory, and tree inspection are well established and demonstrated to be feasible. Additionally, there is an existing private sector workforce in place that could grow to support these efforts.

Community Forestry Resources Historically Limited

The feasibility of relying on federal resources for implementing this policy option is low. Federal resources for community forestry activities in Minnesota are estimated at $250,000 per year. State resources for community forestry activities are presently limited and would require a substantial increase to achieve the targeted goals proposed in this policy option.

Other potential obstacles include the low priority placed on community forestry by state government. The relative priority level placed on community forestry is gradually increasing in light of broader recognition of the numerous environmental, economic, and societal benefits associated with community forests.

Clock is ticking

Without decisive and concerted efforts to stem the decline of community forests and increase planting activities, the barriers and challenges faced in achieving the proposed policy option goals will become higher.

Updating, Monitoring and Reporting

Baseline measures of tree canopy cover and tree inventories are important data sets that require periodic updates.

This policy option should be updated to utilize ongoing developments in available tools and technology used to quantify benefits of community forests.

If this policy option is advanced, additional reporting requirements will be necessary including tracking of outputs, outcomes, and expenditures.

FOLU-4. Tree Planting: Forest Ecosystems

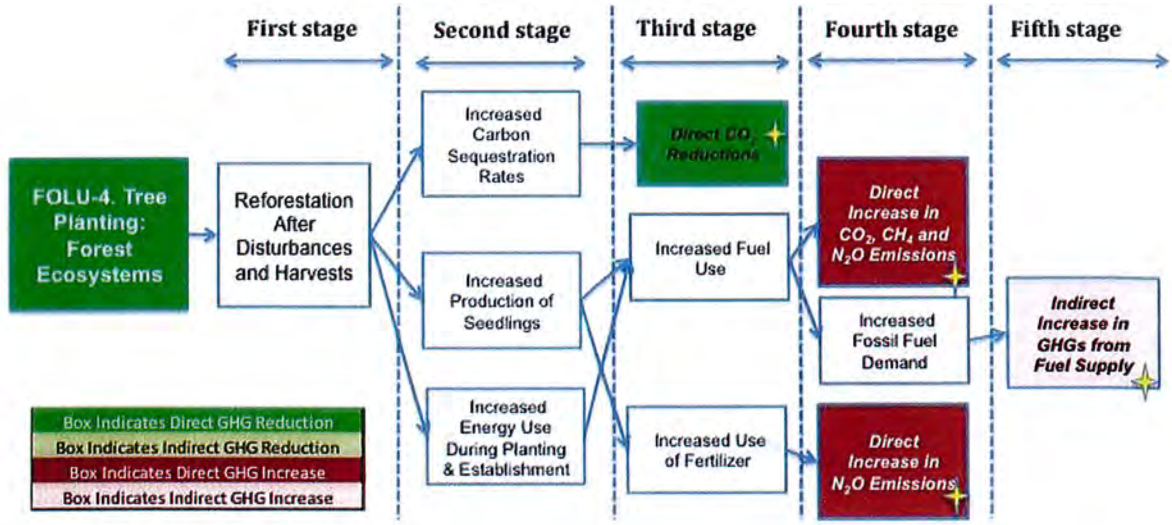
Policy Option Description

Minnesota forests contain about 1.6 million metric tons of carbon and over the past ten years have accumulated carbon at the rate of about 0.66 metric tons per acre per year (Forest Inventory and Analysis 2009-2013 Evalidator report for Minnesota). Although disturbances, such as blowdowns, fire, pest and disease outbreaks, are common, natural features of forest ecosystems, they release large amounts of carbon and reduce the rate at which the state's forest as a whole removes carbon from the atmosphere. With anticipated changes in climate, the frequency and intensity of landscape-level forest disturbance (tens to a few hundreds of thousands of acres) in Minnesota will likely increase. Since younger forests accumulate carbon more quickly than older forests do, re-establishing forests without delay on disturbed sites helps maintain high levels of carbon sequestration.

Dedicated resources are needed to ensure timely restoration of carbon sequestration following large disturbances on state, county, and private lands. DNR meets legislative requirements for routine post-harvest reforestation using a combination of funds allocated biennially by the legislature. Large-scale natural disturbances, however, are exceptions: following such disturbances, the areas in need of reforestation are typically many times larger than the largest harvest sites, the plant communities to be restored are more diverse, and the site preparation required is usually extensive. Without additional funding to address these disturbances, reforestation of such areas is delayed and carbon uptake is reduced or delayed, or staff and other resources are diverted from equally essential, but more routine, management activities.

Causal Chain for GHG Reductions

Figure F-5.23 Causal Chain for FOLU-4 GHG Reductions



The causal chain above identifies the main policy option effects and the subsequent GHG impacts. The star symbol identifies significant GHG effects that will be quantified. The increase in emissions for sourcing planting feedstocks and for planting and establishment activities are not considered to be significant.

Policy Option Design

Goals:

- Ensure that reforestation efforts (natural regeneration monitoring, site preparation, seeding or planting, and protection) are underway within one year of disturbance on state, county, and private non-industrial forestlands.
- Ensure that planned timber harvest and other management activities continue in accordance with sub-section forest resource management plans and that post-harvest reforestation is initiated within one year of harvest.

Timing: This policy option can be implemented immediately.

Parties Involved: This policy option applies primarily to public forestland managers (MN DNR, county land departments) but private, non-industrial forest landowners and national forests will also be affected. Consulting foresters and tree nurseries will also be involved.

Implementation Mechanisms

- Anticipate reoccurring landscape level disturbances by maintaining $2 million in a fund reserved for reforestation on state, county, and private lands following large-scale natural disturbance.
- Align funding for post-harvest reforestation and associated protection practices with planned harvest levels.

Related Policies/Programs in Place and Recent Actions

This policy option contributes to meeting the goals of FOLU-2 (Manage for Highly Productive Forests).

This policy option supplements existing budgeting processes and policies that ensure reforestation of harvested state lands within one year of harvest.

Estimated Policy Impacts

Direct Policy Impacts

Table F-5.11 FOLU-4 Estimated Net GHG Reductions and Net Costs or Savings

2030 GHG Reductions (short tons CO_2e)	2015 – 2030 Cumulative Reductions (short tons CO_2e)	Net Present Value of Societal Costs, 2015 – 2030 ($2014)	Cost Effectiveness ($2014/ ton CO_2e)
1.9	30	$187	$5.6

For Forestry Policies, full policy option benefits are only realized when considering the full lifetime of planted or preserved trees. Therefore, cost and benefits of FOLU policies were quantified over a longer time period (2015-2085) as shown in the table below.

Table F-5.12 Estimated FOLU-4 Net GHG Reductions and Net Costs or Savings (2015-2085)

2085 GHG Reductions (short tons CO_2e)	2015 – 2085 Cumulative Reductions (short tons CO_2e)	Net Present Value of Societal Costs, 2015 – 2085 ($2014)	Cost Effectiveness ($2014/ ton CO_2e)
0.67	104	$183	$1.8

The policy option was estimated to produce almost 250,000 TJ of biomass fuel, offset 23.4 $MMtCO_2e$, over between 2015 and 2030, as shown below. The first few years show more biomass production than later years, because of the lag in reforestation/land clearing in the BAU case, which considers only disturbances happening in 2015 and later.

Table F-5.13 Biomass Fuel and Fossil Fuel Offsets

Year	Biomass Fuel (TJ)	Fossil Fuel Offset ($MMtCO_2e$)
2015	36,960	-2.69
2016	37,004	-2.69
2017	37,049	-2.70
2018	37,093	-2.70
2019	8,309	-1.06
2020	8,319	-1.06
2021	8,329	-1.06
2022	8,339	-1.05
2023	8,349	-1.05
2024	8,359	-1.05
2025	8,369	-1.05
2026	8,379	-1.05
2027	8,389	-1.05
2028	8,399	-1.05
2029	8,409	-1.05
2030	8,419	-1.05
Total	248,474	-23.4

Data Sources

Current data on forest area and forest carbon density by stand age for Minnesota forests was obtained from the Forest Inventory Data Online web-application[5]. The area of forest land affected by fire, wind damage, and pest and disease were obtained from the 2013 DNR Forest Health Report.[6] Estimates of the annual increase in extent of disturbance were obtained from the baseline Inventory and Forecast. The model variables in the table below were set based on MN DNR guidance.

[5] Forest Inventory Data Online web-application version: FIDO 1.5.1.05b, http://apps.fs.fed.us/fia/fido/index.html.

[6] Minnesota Department of Natural Resources. 2013 Forest Health Report. http://files.dnr.state.mn.us/assistance/backyard/treecare/forest_health/annualreports/2013annualReport.pdf

Table F-5.14 Variables Used in Modeling

Model Variables	Fraction
Fraction of Area Requiring Reforestation	
Fire	55%
Wind	55%
Pest/Disease	30%
Reforestation Method	
Seeding	50%
Planting	50%
Fraction of Reforested Area Requiring Site Prep.	
Fire	0%
Wind	100%
Pest/Disease	100%
Fate of Removed Residue	
Fuel	50%
Fiber	50%

Quantification Methods

GHG Benefits:

Based on input from MN DNR, BAU reforestation following large scale disturbance was assumed to happen on 100% of public land and 50% of private land, but with a delay of five years. In the policy option, scenario 100% of land needing reforestation is reforested within one year. Carbon sequestered by reforested land and emissions associated with seedling production and site preparation was estimated for both the BAU and policy option scenarios, with net emissions estimated as the policy option scenario emissions minus the BAU scenario emissions.

The areas replanted and reseeded each year were estimated based on the disturbance area for each year and the model variables listed in the table above. The amount of carbon sequestered by the reforested land was estimated based on the acreage and stand age of each reforested area. Emissions associated with seedling production (fossil fuel and fertilizer usage) were estimated based on the area replanted and emission factors from a 2006 study of life-cycle emissions from forestry operations[7]. Emissions associated with site preparation (felling, skidding, loading) were estimated based on the area needing site preparation (estimated using the model variables in the table above) and a diesel fuel consumption factor of 0.41 gallon per ton of wood.[8] For wood coming from site preparation, it was assumed that 70% of residue was removed from the forest, and 50% of that wood would be used for fuel, with the other half going to fiber.

Societal Costs:

As with GHG Benefits, costs were estimated for both the BAU and policy option scenarios using the assumptions for extent and timing of reforestation described above, with net emissions estimated as the policy option scenario emissions minus the BAU scenario emissions. Costs were estimated for seeding, planting, and site preparation based on the costs shown in the table below set based on Minnesota Agency guidance. Minnesota forests were assumed to be 64% hardwood and 36% softwood, based on FIA data. Revenue for salvaged wood was also estimated based on stumpage from the 2012 Minnesota's Forest Resources report and the assumption that salvage wood brings in 45% the revenue of other wood. Also, the value of incremental value of the timber planted during reforestation were estimated based on forest sequestration rates, developed from FIA data, and the same stumpage values reference above (adjusted for inflation) starting at 35 years in the future, the assumed age for harvest. Costs associated with preparing wood for biomass usage (chipping) were taken from the EPA Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis.[9]

Table F-5.15 Costs Used in Modeling

Activity	Costs per acre
Seeding Costs	$35/acre
Planting Costs (softwood)	$190/acre
Planting Costs (hardwood)	$270/acre
Site Preparation Costs	$100/acre

Key Assumptions

[7] Sonne, 2006. Greenhouse Gas Emissions from Forestry Operations: A Life Cycle Assessment. http://www.lanecounty.org/departments/pw/lmd/landuse/documents/lane%20county%20land%20use%20task%20force/jim%20just_greenhouse%20gas%20emissions%20from%20forestry%20operations.pdf

[8] Timmons and Mejía, 2010. Biomass Energy from Wood Chips: Diesel Fuel Dependence? Biomass and Bioenergy 34 (2010) 1419-1425. http://www.academia.edu/4582400/Biomass_energy_from_wood_chips_Diesel_fuel_dependence

[9] EPA, Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis, Table 4.1-6, http://www.epa.gov/otaq/renewablefuels/420r10006.pdf

While the design of this policy option does not include demand-side implementation mechanisms for biomass usage, increased biomass usage from this policy option is assumed to result in incremental residential heating reductions (propane). Other key assumptions are discussed above under GHG Benefits and Societal Costs.

Macroeconomic (Indirect) Policy Impacts

Table below summarizes impacts of FOLU 4 option on GSP, employment and income earned in the state.

Table F-5.16 Macroeconomic (Indirect) Impacts

Scenario	Gross State Product (GSP, $2015 Millions)			Employment (Full & Part-Time Jobs)			Income Earned ($2015 Millions)		
	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)
FOLU-4	-$10	-$15	-$232	-130	-210	-3,160	-$14	-$19	-$283

Figure F-5.24 FOLU-4 GSP Impacts ($2015 MM)

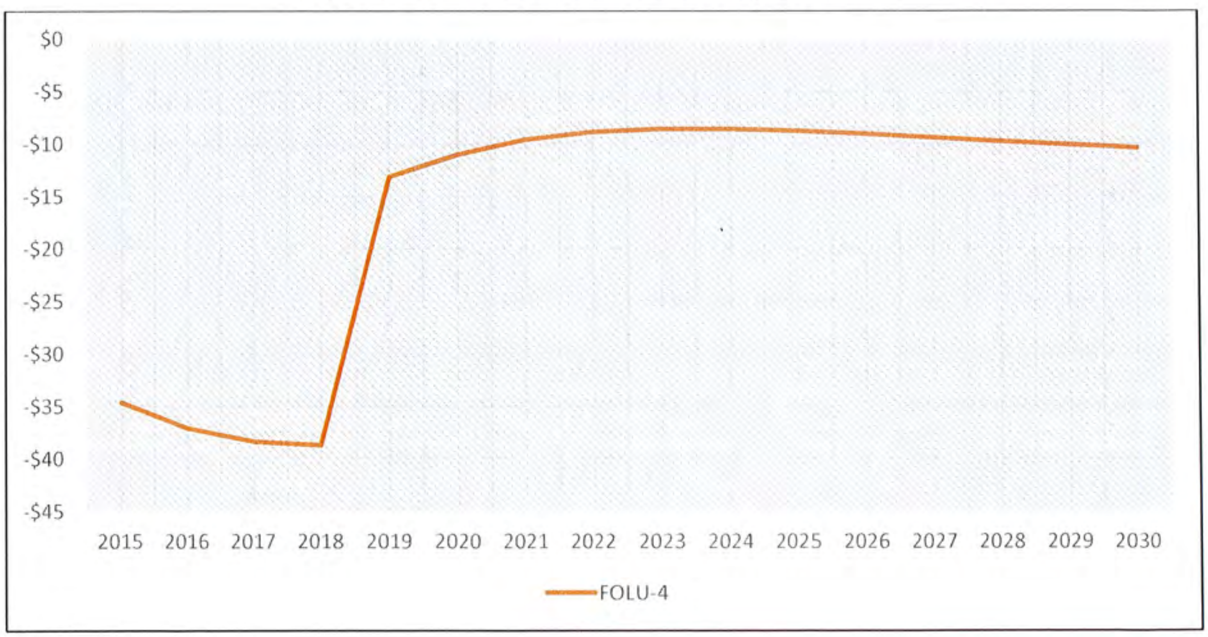


Figure F-5.25 FOLU-4 Income Impacts ($2015 MM)

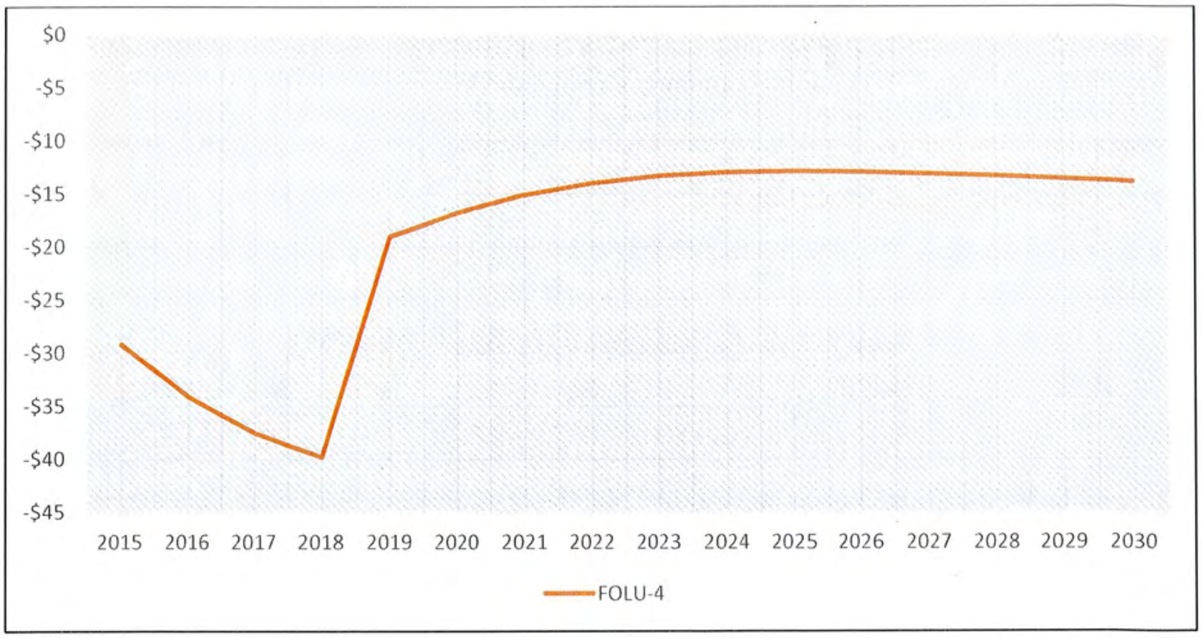
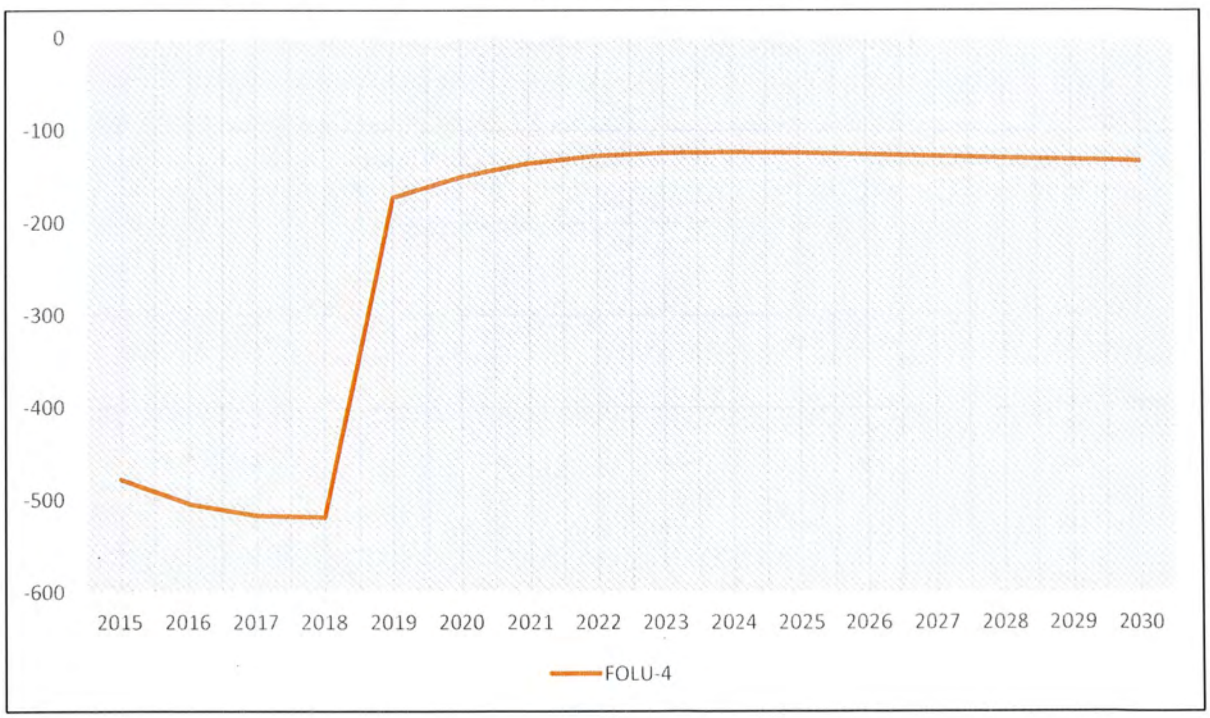


Figure F-5.26 FOLU-4 Employment Impacts (Individual Jobs)



Principle Drives of Macroeconomic Changes

- This policy has relatively small effects on the state economy in comparison to the rest of FOLU policies.
- This policy is characterized almost entirely by streams of state government spending in the forestry and transportation sectors. These drive new activity, output and labor into these sectors, but must be paid for by reducing other government spending, and so these benefits are significantly offset.
- The policy does produce a burst of additional revenue to public and private landowners from higher sales of timber, which will add to GDP directly as well as creating new spending power for both individual landowners and the government. This spending power also enters the economy as new GDP (which is calculated by summing total spending by governments, consumers and businesses).

Data Sources

- Costs to state government agencies associated with public and private lands reforestation efforts funded by state government funds.
- Revenue resulting from an increase in managed timber sales.
- State spending on transportation of biomass as part of forestry and managed logging efforts.

Key Assumptions

The macroeconomic impact analyses of this policy, as well as of the others in the CSEO process, rely on a consistent set of key assumptions:

- State and local spending is always budget-constrained. If a policy calls for the state or local government to spend money in any fashion, that spending must be either funded by a new revenue stream or offset by reductions in spending on other programs. Savings or revenues collected by the government are also expected to be returned to the economy as spending in the same year as they are collected.
- Federal spending is not budget-constrained. The capacity of the federal government to carry out deficit spending means that no CSEO policy is held responsible for driving either an increase or decrease in federal tax spending by businesses or households in the state of Minnesota.
- Consumer spending increases are sometimes financed. Small-scale purchases or purchases of consumer goods are treated as direct spending from existing household cash flows (or short-term credit). Durable goods, home improvements or vehicle purchases, however, are treated as financed. Consumers were assumed to spread out costs based on common borrowing time frames, such as five years for financing a new vehicle or 10-20 years for home improvements that might be funded by home-equity or other lending. The assumption of financing and the term of years applied was considered anew in each case.

- Business spending increases are often financed. Where spending strikes a sector which routinely utilizes financing or lines of credit to ensure steady payment of recurring costs, significant spending of nearly any type was considered a candidate for financing, thus allowing costs to spread out over time. This methodology is preferable for the modeling work, as sudden spikes or dips in business operating costs can show up as volatility when the scenario may depict a managed adoption of new equipment in an orderly fashion. The assumption of financing and the term of years applied was considered anew in each case.
- Unless otherwise stated, all changes to consumer spending or to the producers' cost of producing goods and services were treated in a standard fashion. Consumers are assumed to spend on a pre-set mix of goods, services, and basic needs, and businesses spend (based on their particular sector of the economy) on a mix of labor, capital, and intermediate demands from other sectors. Unless a policy specifically defines how a party will react to changes in cost, price, supply or demand, these standard assumptions were applied.

State and local spending gains and reductions driven by policy are assumed to apply to standard mixes of spending. Again, unless a policy specifically states that a government entity will draw from a specific source or direct savings or revenues to a specific form of spending, all gains and losses were assumed to apply to a standard profile of government spending within the economy.

<u>Quantifications Methods</u>

Utilizing the data developed from the microeconomic analysis, CCS analysts established for each individual change the following characteristics:

- The category of change involved (change in spending, savings, costs, prices, supply or demand)
- The party involved on both sides of each transaction
- The volume of money involved in this change in each year of the period of analysis

These values, so characterized, were then processed into inputs to the REMI PI+ software model built specifically for use by CCS and consistent with that in use by state agencies within Minnesota. These inputs were applied to the model and run. Key results were then drawn from the model and processed for consistency of units and presentation before inclusion in this report.

Key Uncertainties

This analysis estimates the area of disturbance that requires reforestation using data on disturbances in the recent past. Under most climate change scenarios, however, increases in the frequency and intensity of weather-related disturbances will result in much more area that requires reforestation.

While the biomass produced as a result of this policy option was assumed to replace residential propane, this policy option does not contain a mechanism for directing the biomass produced as a result of this policy option to a particular use or sector (i.e., propane to wood stove conversion). Because of this lack of demand-side implementation mechanisms, the fate of this biomass fuel is uncertain.

Additional Benefits and Costs

The risk of catastrophic wildfire is much higher following large disturbances in which trees are uprooted or killed but left standing. Timely removal of fuel loads and reestablishment of growing stock reduces the risk that lives or property will be lost.

Soils from which vegetation has been removed by fire and soils that have been disturbed as trees are uprooted are more susceptible to wind and water erosion than undisturbed soils. Trees that have been defoliated by pests or diseases intercept less rainfall and don't moderate the erosive effects of heavy downpours as effectively as healthy trees. Re-establishing forest vegetation following such disturbances helps protect those soils and helps minimize sediment and nutrient accumulation in surface waters.

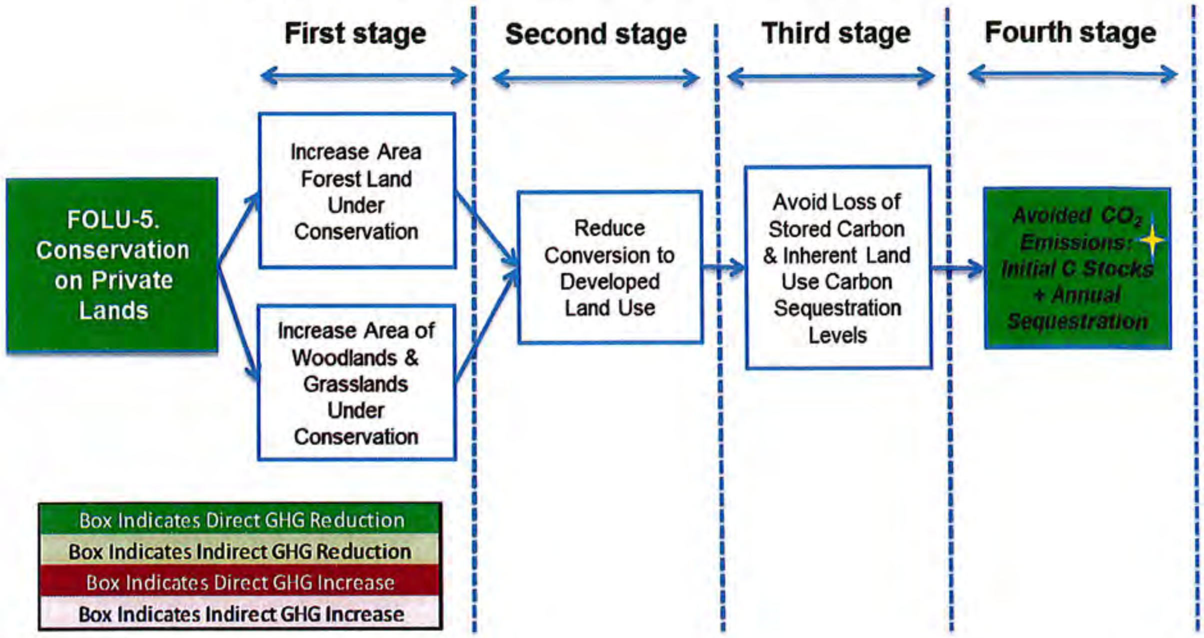
FOLU-5. Conservation on Private Lands

Policy Option Description

Permanent vegetative covers in natural ecosystems and agricultural systems sequester more carbon than do annual cropping systems. Restoring and protecting perennial vegetation (prairie, wetland, forest, hay, and pasture) will increase carbon sequestration in soils and plant biomass. In addition, restoring wetlands will improve water quality and reduce flooding. Protecting forests sustain their ability to sequester carbon while preventing large emissions associated with forest loss.

Causal Chain for GHG Reductions

Figure F-5.27 Causal Chain for FOLU-5 GHG Reductions



The causal chain above identifies the main policy option effects and the subsequent GHG impacts. The star symbol identifies significant GHG effects that will be quantified.

Policy Option Design

The policy option will deploy conventional conservation tools to restore native vegetation and protect land with permanent vegetative cover from urban and agricultural development. Land protection will mirror the Minnesota Prairie Conservation Plan and target the protection of 1.5 million acres of agricultural land and 500,000 acres of forest land. Forest land will be protected through permanent conservation easements under the Minnesota Forests for the Future Program. Grassland and wetland habitat will be restored and using a range of federal and state conservation tools and funding. These tools include: conservation easements, such as State RIM, Prairie Bank, USF&WS wetlands easements, USDA Agricultural Conservation Easement (Wetlands Reserve Easement and Grasslands Reserve Easement), as well as fee title acquisitions by MN DNR, USF&WS and the Nature Conservancy. They will also include shorter term contracts programs such as the USDA Conservation Reserve Program. Federal funding opportunities such as the Conservation Reserve Enhancement program will be utilized to the fullest extent possible. Working grass lands strategies are of growing importance. Conservation programs such as GRE will continue to provide for on-going grazing and haying, and traditional conservation programs are integrating more grazing and haying to support enhanced grassland management.

Funding for the projects will be approximately 50% federal and 50% state.

Goals:

- **Forest Conservation:** Permanent conservation easements on an additional 500,000 acres of forestland.
- **Grasslands and Wetlands Conservation:** Restore and/or protect an additional 1.2 million acres of grasslands and wetlands from development via conservation easements or other less permanent protection strategies and tools.
    - Native Prairie Protection:
        - Fee title 30,000 acres
        - Easement 75,000 acres
    - Other Existing Grassland /Wetland Protection (2:1 grassland to wetland acreage)
        - Fee title 210,000 acres
        - Easement 400,000 acres (includes working lands easements)
    - Grassland/Wetland Restoration from Ag Land (3:1 grassland to wetland acreage)
        - Fee title: 50,000 acres
        - Easement: 125,000
        - Contract (CRP) 500,000 acres
- It is anticipated that approximately 30% of the land area protected or restored will be available for forage production through grazing or haying.

Timing: Implementation will be on a linear basis from now through 2034, with the expiration of the Minnesota Legacy Amendment.

Parties Involved: A wide range of parties will be involved. Forest for the Future easements will involve non-industrial private forest land owners, industrial forest land owners, forestry consultants and forest products industries. Parties involved in grasslands and wetland conservation will include individual land owners and farm operators, conservation agencies, agriculture agencies, and farm groups.

Implementation Mechanisms

Continue implementation of the Minnesota Forests for the Future Plan:

- Resolve ancillary policy option issues such as property tax treatment of easement lands and Sustainable Forestry Incentive Act (SFIA) program.
- Utilize state funding sources to leverage federal programs to secure permanent conservation easements.

Protect 1.2 million acres of grasslands and wetlands:

- Implement strategies outlined in the Minnesota Prairie Plan to reach protection goals:

- Use a mix of permanent (fee title and easement acquisition) and mid-term (CRP contracts) land protection and restoration tools.
- Funding Leverage; use Lessard-Sams Outdoor Heritage Fund, Minnesotan Environmental and Natural Resource Trust Fund and State Bonding to maximize Minnesota share of federal farm bill programs resources as well as other federal resources such as the Prairie Pothole Joint Venture.
- Integrate working lands conservation strategies, including managed haying and grazing in land retirement programs, to ensure that grass based agriculture remains viable in the state of Minnesota.
- Utilize strategic targeting and precision conservation tools to maximize the benefits of land retirements, restoration and protection efforts including targeting soil types most appropriate for greenhouse gas management.
- Continue Farm Bill Assistance program efforts to drive targeted outreach, promotion and enrollment of private land into the most appropriate conservation programs.

- Invest in research and development of markets for perennial crops that provide multiple environmental benefits in order to enhance the economic sustainability of increased grassland.

Related Policies/Programs in Place and Recent Actions

This policy option connects directly to A-2 (enhancing soil carbon), specifically perennial crop retention and expansion.

There is a suite of traditional conservation programs run through state and federal agencies with the goal of conserving natural and conservation lands. Conservation partners have aligned long term efforts in Western and Southern Minnesota through the Minnesota Prairie Plan. The Minnesota Forests for the Future initiative provides similar landscape scale direction for the conservation of forest cover.

The key funding mechanisms were established in the Minnesota Constitution through the Clean Water Land and Legacy Amendment as well as through the creation of the Environment and Natural Resources Trust Fund. These dramatically expand resources beyond those traditionally invested such as license fees, bonding, general fund appropriation, USDA conservation programs, and federal aid for fish and wildlife management.

Minnesota programs, such as RIM and Prairie Bank easements, complement and support federal programs such as CRP and NRCS and US Fish and Wildlife Service conservation easements.

Estimated policy Impacts

Direct Policy Impacts

Table F-5.17 FOLU-5 Estimated Net GHG Reductions and Net Costs or Savings

2030 GHG Reductions (short tons CO_2e):	2015 – 2030 Cumulative Reductions (short tons CO_2e)	Net Present Value of Societal Costs, 2015 – 2030 ($2014):	Cost Effectiveness ($2014/ ton CO_2e):
0.34	3.0	$1,261	$421

For Forestry Policies, full policy option benefits are only realized when considering the full lifetime of planted or preserved trees. Therefore, cost and benefits of FOLU policies were quantified over a longer time period (2015-2085).

Table F-5.18 FOLU-5 Estimated Net GHG Reductions and Net Costs or Savings (2015-2085)

2085 GHG Reductions (short tons CO_2e):	2015 – 2085 Cumulative Reductions (short tons CO_2e)	Net Present Value of Societal Costs, 2015 – 2085 ($2014):	2085 Cost Effectiveness ($2014/ ton CO_2e):
0.39	25	$1,304	$53

Data Sources

The sequestration rate for forests (1.00 Mg C/acre) was estimated from FIA data for Minnesota forests obtained from the Forest Inventory Data Online (FIDO) tool. [10] Sequestration rates for grassland, peatland, and prairie pothole lands were obtained from a 2008 report on terrestrial carbon sequestration in Minnesota.[11] Emission factors for wetland methane were developed as part of the Inventory and Forecast based on recent wetland methane studies.

Quantification Methods

Net emission reductions for this policy option were estimated as the total policy option scenario emissions/reductions minus the BAU scenario emissions/reductions. BAU scenario emissions include the lost carbon sequestration on forestland, grassland, and wetlands that are lost to development and lost methane emissions from lost wetlands. Policy option scenario emissions/reductions include carbon sequestration from restored grassland and wetland and methane emissions from restored wetlands. Only a portion of the lands being conserved in a given year is expected to be lost to development in that year under BAU conditions. The

[10] Forest Inventory Data Online web-application version: FIDO 1.5.1.05b, http://apps.fs.fed.us/fia/fido/index.html.

[11] The Potential for Terrestrial Carbon Sequestration in Minnesota: Appendix II, 2008. http://www.wrc.umn.edu/prod/groups/cfans/@pub/@cfans/@wrc/documents/asset/cfans_asset_119302.pdf

following fractions for conservation areas expected to be lost under BAU were set based on Minnesota Agency input:

- Forest – 5%
- Native Prairie – 40%
- Other Grassland – 40%
- Other Wetland – 25%

Net Societal Costs:

The following costs associated with land conservation and restoration were supplied by Minnesota Agency staff.

Table F-5.19 Conservation and Restoration Costs Used in Modeling

Cost Variable	$/acre
Average Forest Easement Payment	$235
Average Wetland/Grassland Easement Payment	$5,500
Average Fee Title Cost	$6,000
Average CRP Rental Payment	$81
Average Prairie Planting Cost	$300
Average Wetland Restoration Cost	$2,000
Forest Program Costs	$0.50
Wetland/Grassland Program Costs	$1.30
Federal Cost Share	50%

Key Assumptions

Key assumptions are discussed above under GHG Benefits and Societal Costs.

Macroeconomic (Indirect) Impacts

Table below summarizes impacts of FOLU 5 option on GSP, employment and income earned in the state. Impacts of a sensitivity scenario are also evaluated.

Table F-5.20 Macroeconomic (Indirect) Economic Impacts

Scenario	Gross State Product (GSP, $2015 Millions)			Employment (Full & Part-Time Jobs)			Income Earned ($2015 Millions)		
	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)
FOLU-5 Low Income	-$114	-$87	-$1,301	-1,350	-1,060	-15,900	-$3	$67	$1,010
FOLU-5 Keep Income	-$75	-$59	-$883	-920	-720	-10,750	$117	$144	$2,157

Figure F-5.28 FOLU-5 Macroeconomic Impacts of Assuming Farms Lose Crop Revenue

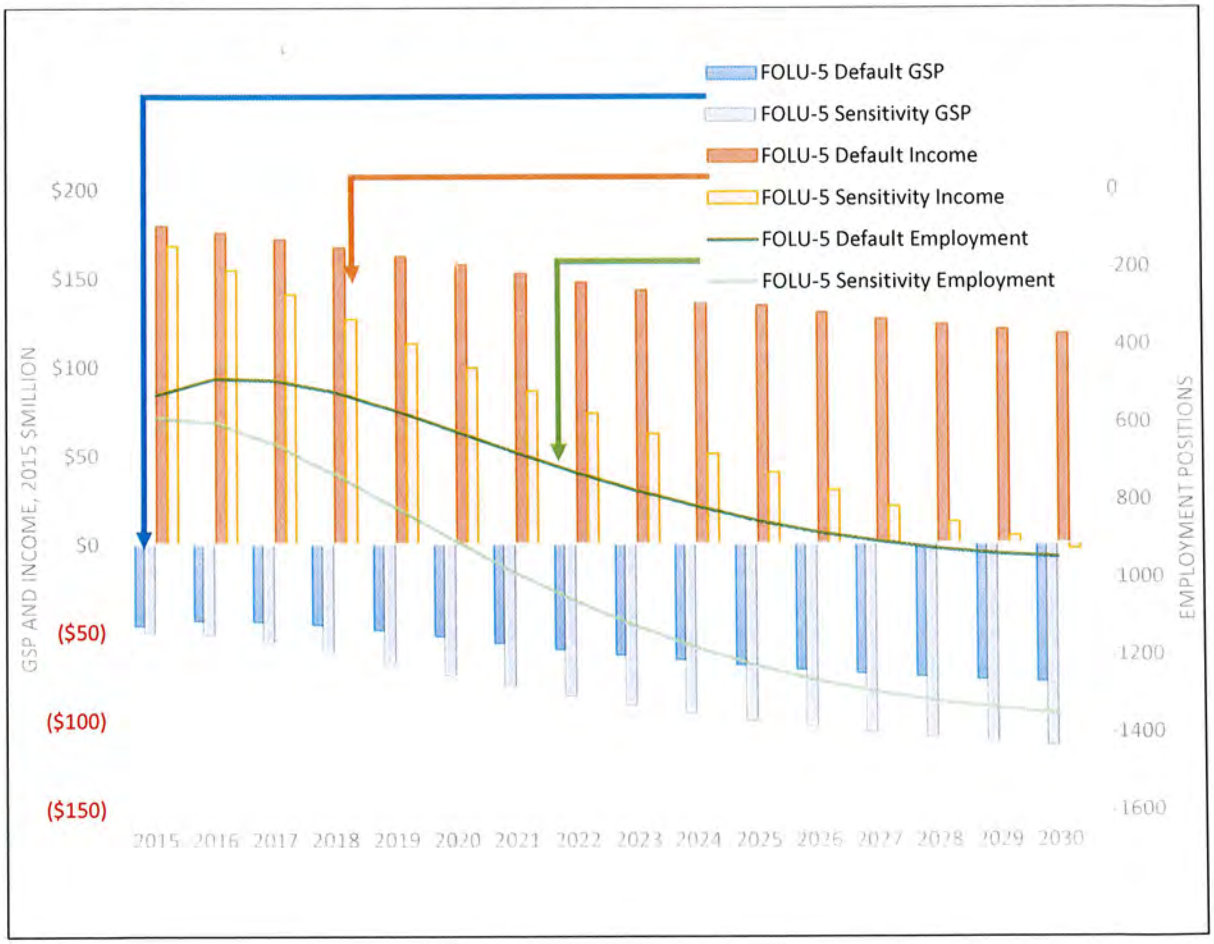


Figure F-5.29 FOLU-5 GSP Impacts ($2015 MM)

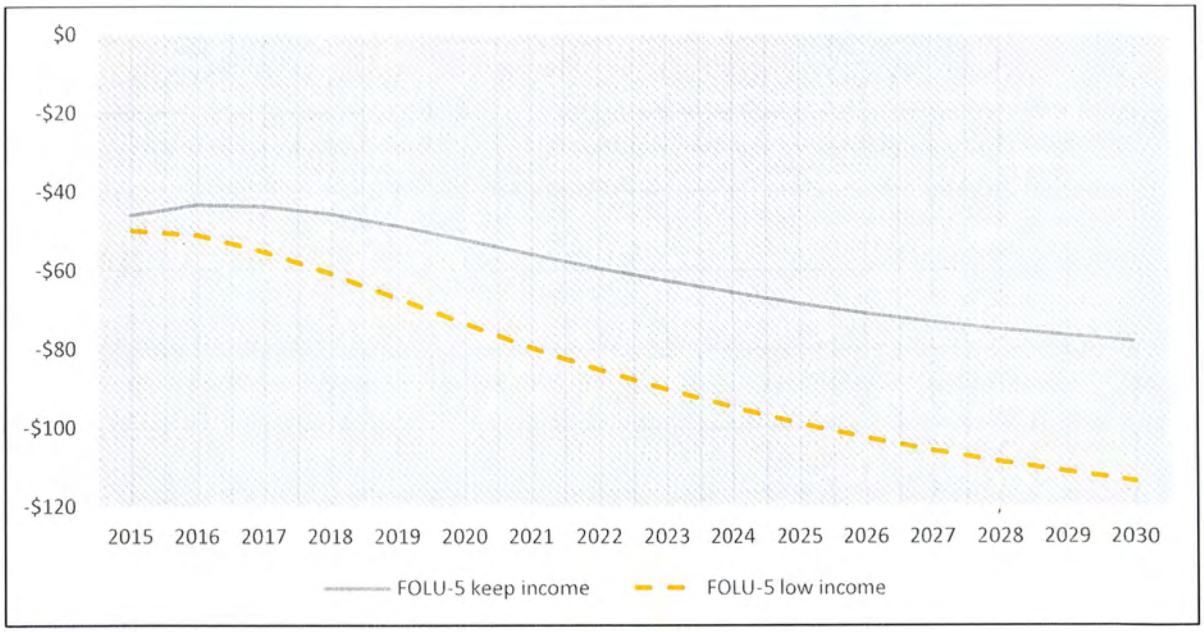


Figure F-5.30 FOLU-5 Income Impacts ($2015 MM)

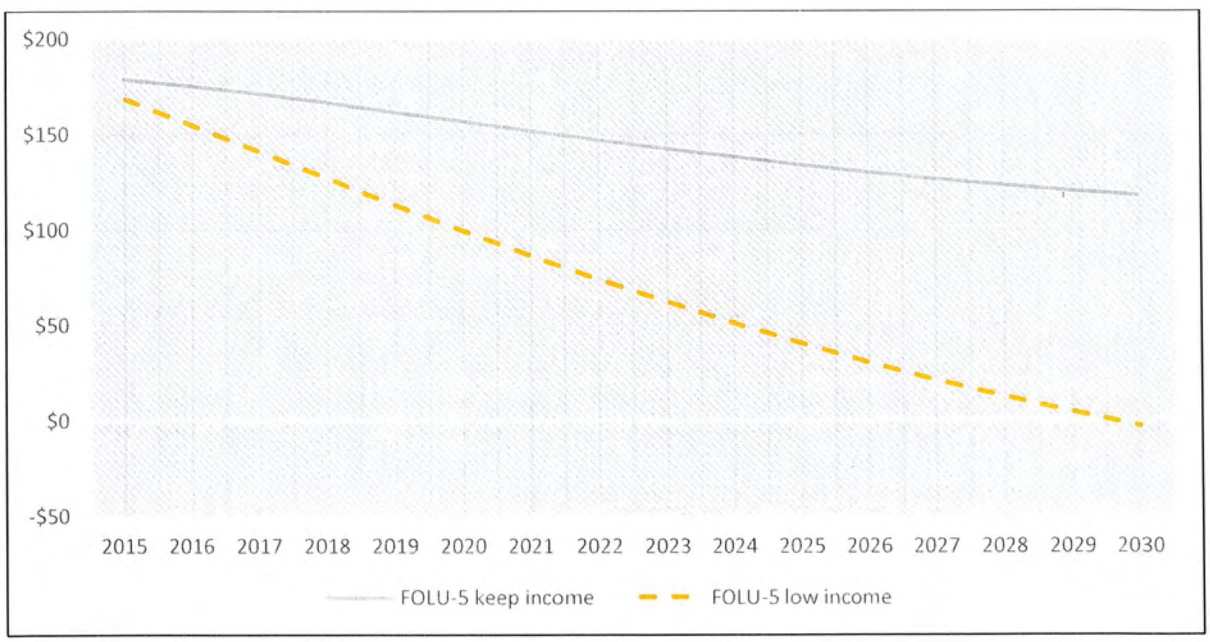
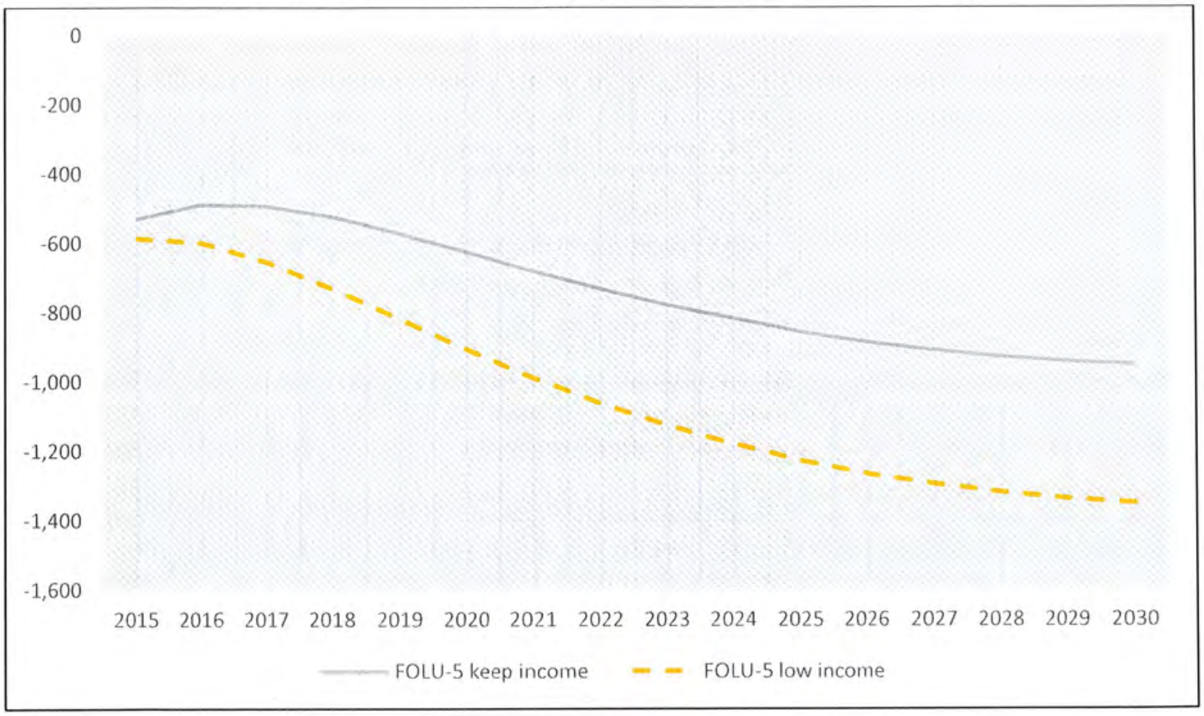


Figure F-5.31 FOLU-5 Employment Impacts (Individual Jobs)



Principal Drivers of Macroeconomic Changes

This policy is characterized by state and federal funds disbursed to landowners to purchase easement and other property access rights to advance preservation, reforestation and afforestation goals.

The influx of federal dollars into the state to support spending on easements and private land property rights, for the purposes of conservation, is the principal driver of the state economy expansion in this policy.

The fact that the state's tax base only bears half the cost of some of these easement programs means that significant new money enters the state in ways that either quickly turn into consumer spending (payments to individual land owners) or lower production costs (payments to corporate landowners). Both of these impacts are positive.

The total federal stimulus anticipated reaches approximately $175 million (in nominal dollars) by 2030.

Data Sources

- Easement costs paid by government, including 50% federal support to that expenditure.
- Easement earnings to private landowners, whether farms, private property owners, or corporate entities.
- CRP payments to landowners from federal programs.

Landscape restoration work costs.

<u>Key Assumptions</u>

The macroeconomic impact analyses of this policy, as well as of the others in the CSEO process, rely on a consistent set of key assumptions:

- State and local spending is always budget-constrained. If a policy calls for the state or local government to spend money in any fashion, that spending must be either funded by a new revenue stream or offset by reductions in spending on other programs. Savings or revenues collected by the government are also expected to be returned to the economy as spending in the same year as they are collected.
- Federal spending is not budget-constrained. The capacity of the federal government to carry out deficit spending means that no CSEO policy is held responsible for driving either an increase or decrease in federal tax spending by businesses or households in the state of Minnesota.
- Consumer spending increases are sometimes financed. Small-scale purchases or purchases of consumer goods are treated as direct spending from existing household cash flows (or short-term credit). Durable goods, home improvements or vehicle purchases, however, are treated as financed. Consumers were assumed to spread out costs based on common borrowing time frames, such as five years for financing a new vehicle or 10-20 years for home improvements that might be funded by home-equity or other lending. The assumption of financing and the term of years applied was considered anew in each case.
- Business spending increases are often financed. Where spending strikes a sector which routinely utilizes financing or lines of credit to ensure steady payment of recurring costs, significant spending of nearly any type was considered a candidate for financing, thus allowing costs to spread out over time. This methodology is preferable for the modeling work, as sudden spikes or dips in business operating costs can show up as volatility when the scenario may depict a managed adoption of new equipment in an orderly fashion. The assumption of financing and the term of years applied was considered anew in each case.
- Unless otherwise stated, all changes to consumer spending or to the producers' cost of producing goods and services were treated in a standard fashion. Consumers are assumed to spend on a pre-set mix of goods, services, and basic needs, and businesses spend (based on their particular sector of the economy) on a mix of labor, capital, and intermediate demands from other sectors. Unless a policy specifically defines how a party will react to changes in cost, price, supply or demand, these standard assumptions were applied.

State and local spending gains and reductions driven by policy are assumed to apply to standard mixes of spending. Again, unless a policy specifically states that a government entity will draw from a specific source or direct savings or revenues to a specific form of spending, all gains and losses were assumed to apply to a standard profile of government spending within the economy.

Quantifications Methods

Utilizing the data developed from the microeconomic analysis, CCS analysts established for each individual change the following characteristics:

- The category of change involved (change in spending, savings, costs, prices, supply or demand)
- The party involved on both sides of each transaction
- The volume of money involved in this change in each year of the period of analysis

These values, so characterized, were then processed into inputs to the REMI PI+ software model built specifically for use by CCS and consistent with that in use by state agencies within Minnesota. These inputs were applied to the model and run. Key results were then drawn from the model and processed for consistency of units and presentation before inclusion in this report.

Key Uncertainties

The analysis is very sensitive to the degree to which existing forests, wetlands, and grasslands conserved through these policies are likely to be converted to row crop production or other development. There is limited in-state analysis and projection of these trends.

Wetland methane emissions are a significant variable in this analysis. There is some literature that suggests that northern prairie pothole type wetlands with mineral soils, and which are subject to seasonal freezing, are likely to contribute less methane than assumed here.

Additional Benefits and Costs

The strategy builds upon and extends the range of conservation values associated with land protection including:

- Sustaining landscape level ecological functions and habitats for native wildlife species and plant communities.
- Outdoor recreation opportunities associated with open lands and wildlife populations.
- Water retention and filtration to reduce peak flows and filter and purify storm water flows.
- Water retention to sustain ground water recharge and base stream flows.

Feasibility Issues

Minnesotans have voted to support land conservation through the Environmental and Natural Resource Trust Fund and the Legacy Amendment. These resources plus other traditional funding sources provide Minnesota with a unique opportunity to protect and conserve quality habitats, forage production and open lands. However, the existing resources are not likely to be sufficient to meet these goals. The proposal will rely on leveraging significant levels of federal funding as well as continued state investments from the general fund.

Most importantly, conservation land protection is dependent upon voluntary participation by landowners. Market conditions and land prices have significant impact on the level of interest and willingness to participate in programs. Some initiatives have seen very successful large-scale implementation (Minnesota River Conservation Reserve Enhancement Program [CREP] and WRP/RIM) and others have not (CREP II).

Permanent conservation easement programs in the past, such as the Conservation Reserve Enhancement Program, have faced strong opposition from agricultural groups.

Farm groups and others have noted the potential interest in perennial production systems if there were markets that could sustain profitable production. Traditional forage markets exist, but new markets are needed to expand the market potential for perennial crops.

Updating, Monitoring, and Reporting

The Minnesota Prairie Plan co-signatories have developed a Prairie Plan implementation team that is charged with tracking and monitoring progress towards achieving the plan goals. This effort builds upon a variety of individual program tracking efforts. Also the MN DNR and PCA are coordinating the Wetlands Status and Trends Program, which assess and quantified changes in wetland quantity and quality every five years.

Chapter XVIII. Appendix F-6. Waste Management Policy Option Recommendations

Overview

The tables above provide a summary of the microeconomic analysis of Climate Solutions & Economic Opportunities (CSEO) policy options in the Waste Management (WM) sector. The first table provides a summary of results on a stand-alone basis, meaning that each policy option was analyzed separately against baseline (business as usual or BAU) conditions. Details on the analysis of each policy option are provided in each of the Policy Option Documents (PODs) that follow within this appendix.

Direct, Stand Alone Economic Impacts

The stand-alone results provide the annual greenhouse gas (GHG) reductions for 2020 and 2030 in million metric tons (MMt) of carbon dioxide equivalent reductions (CO_2e), as well as the cumulative reductions through 2030. The reductions shown are only those that have been estimated to occur within the state. Additional GHG reductions, typically those associated with upstream emissions in the supply of fuels or materials, have also been estimated and are reported within each of the analyses in each POD.

Also reported in the stand-alone results is the net present value (NPV) of societal costs/savings for each policy option. These are the net costs of implementing each policy option reported in 2014 dollars. The cost effectiveness (CE) estimated for each policy option is also provided. Cost effectiveness is a common metric that denotes the cost/savings for reducing each metric ton (t) of emissions. Note that the CE estimates use the total emission reductions for the policy option (i.e. those occurring both within and outside of the state).

As indicated in the first summary table, WM-2 builds upon and assumes full implementation of WM-3. For both WM-2 and WM-3, the policy options result in net in-state emissions in 2020. However, the total impact of each of these policy options, including out-of-state impacts, is a net reduction in emissions in 2020.

Integrative Adjustments & Overlaps

The second summary table above provides the same values described above after an assessment was made of any policy option interactions or overlaps. In the Waste Management sector there are no overlaps, as removal of any potential overlap between WM-2 and WM-3 was already removed in the analysis. Therefore, the values in the second table are the same as those in the stand-alone table.

Macroeconomic (Indirect) Economic Impacts

Table below provides a summary of the expected impacts of WM policies on jobs and economic growth during the CSEO planning period. This table focuses on the impact of policies on Gross State Product (the total amount spent on goods and services produced within the state), Employment (the total number of full-time and part-time positions), and Incomes (the total amount earned by households from all possible sources). These metrics represent three valuable indicators of both the overall size of the economy and that economy's structural orientation toward supporting livelihoods and utilizing productive work.

For the purposes of macro-economic analysis of CSEO policies, CCS utilized the Regional Economic Models, Inc. (REMI) PI+ software. This particular REMI model is developed specifically for Minnesota, and is developed consistently with the design of models in use by state agency staff within Minnesota for a range of economic analyses. Its analytical power and accuracy made REMI a leading modeling tool in the industry used by numerous research institutions, consulting firms, non-government organizations and government agencies to analyze impacts of proposed policies on key macro-economic parameters, such as GDP, income levels and employment.

The main inputs for macro-economic analysis are microeconomic estimates of direct costs and savings expected from the implementation of individual policy options. These inputs are supplemented with additional data and assumptions necessary to complete the picture of how these costs and savings (as well as price changes, demand and supply changes, and other factors) influence Minnesota's economy. These additional data and assumptions typically regard how various actors around the state (households, businesses and governments) respond to change by changing their own economic activity. A full articulation of the general and policy-specific assumptions made by the macroeconomic analysis team is provided in the Policy Option Documents, contained as appendices to this report.

Table F-6.1 Waste Management Policy Options, Direct Stand-Alone Impacts

Stand-Alone Analysis							
		GHG Reductions				Costs	
Policy Option ID	Policy Option Title	Annual CO_2e Reductions[a]		2030 Cumulative	2030 Cumulative[b]	Net Costs[c] 2015-2030	Cost Effectiveness[d]
		2020 MMt	2030 MMt	$MMtCO_2e$	$MMtCO_2e$	$Million	$/tCO_2e$
WM-1	Waste Water Treatment - Energy Efficiency	0.051	0.068	0.89	0.99	($56)	($56)
WM-2	Front-End Waste Management - Source Reduction	(0.0020)	0.057	0.073	9.4	($277)	($30)
WM-3[e]	Front-End Waste Management - Re-Use, Composting & Recycling	(0.11)	0.15	(0.45)	27	($817)	($30)
Totals		**(0.058)**	**0.28**	**0.52**	**37**	**($1,150)**	**($31)**

Notes:
[a] In-state (Direct) GHG Reductions.
[b] Total (Direct and Indirect) GHG Reductions.

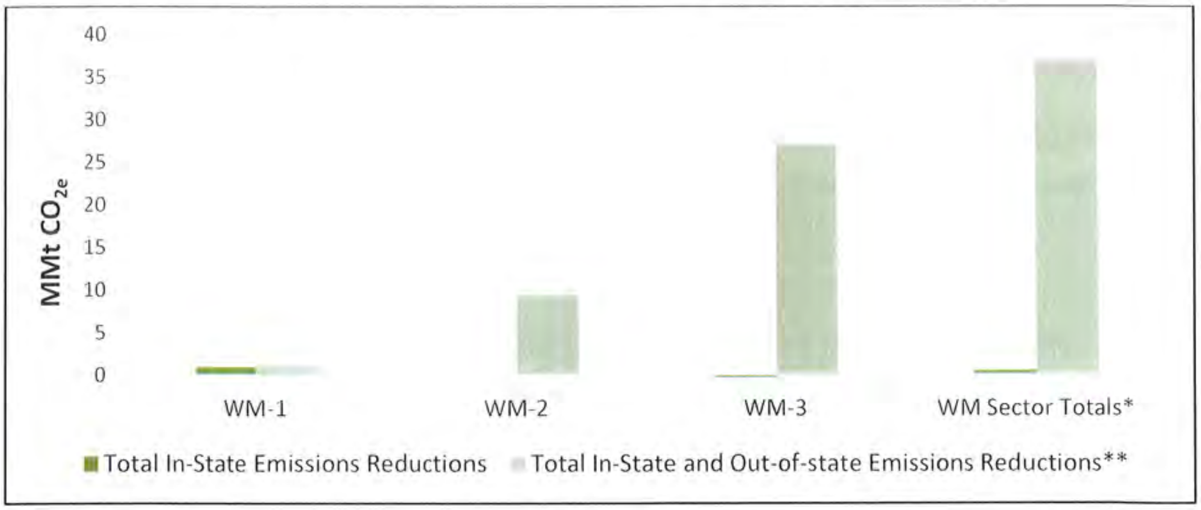
[c] Net Present Value of fully implemented policy option using 2014 dollars ($2014).
[d] Cost effectiveness values include full energy-cycle GHG reductions, including those occurring out of state. Dollars expressed in $2014.
[e] Assumes full implementation of WM-2.

Table F-6.2 Waste Management Policy Options, Intra-Sector Interactions & Overlaps

Intra-Sector Interactions & Overlaps Adjusted Results							
Policy Option ID	Policy Option Title	GHG Reductions				Costs	
		Annual[a]		2030 Cumulative[a]	2030 Cumulative[b]	Net Cost[c] 2015-2030	Cost Effectiveness[d]
		2020 MMt	2030 MMt	$MMtCO_2e$	$MMtCO_2e$	$Million	$\$/tCO_2e$
WM-1	Waste Water Treatment - Energy Efficiency	0.051	0.068	0.89	0.99	($56)	($56)
WM-2	Front-End Waste Management - Source Reduction	(0.0020)	0.057	0.073	9.4	($277)	($30)
WM-3	Front-End Waste Management - Re-Use, Composting & Recycling	(0.11)	0.15	(0.45)	27	($817)	($30)
Totals After Intra-Sector Interactions /Overlap		**(0.058)**	**0.28**	**0.52**	**37**	**($1,150)**	**($31)**

Notes:
[a] In-state (Direct) GHG Reductions.
[b] Total (Direct and Indirect) GHG Reductions.
[c] Net Present Value of fully implemented policy option using 2014 dollars ($2014).
[d] Cost effectiveness values include full energy-cycle GHG reductions, including those occurring out of state. Dollars expressed in $2014.
[e] WM-3 builds off of WM-2 and assumes full implementation; so no overlaps.

Figure F-6.1 WM Policies GHG Emissions Abatement, 2015-2030



Notes:
All Policies Total's comprise emissions reductions achieved by WM policies combined.
Total in and out-of-state emissions reduction are the reductions associated with the full energy cycle (fuel extraction, processing, distribution and consumption). Therefore, the emissions reductions that occur both inside and outside of the state borders as a result of a policy implementation are captured under this value.

Table F-6.3 Macroeconomic (Indirect) Impacts of WM Policy Options

Macroeconomic (Indirect) Impacts Results									
Scenario	Gross State Product GSP ($2015 Millions)			Employment (Full and Part-Time Jobs)			Income Earned ($2015 Millions)		
	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)
WM-1	$2	$2	$31	90	80	1,130	$8	$6	$86
WM-2	$6	$2	$31	150	60	930	$13	$5	$72
WM-3	$240	$203	$3,039	3,290	2,750	41,210	$319	$223	$3,338
WM Sector Total	**$248**	**$207**	**$3,101**	**3,530**	**2,890**	**43,280**	**$340**	**$233**	**$3,496**

Notes:
[a] Gross State Production changes in Minnesota. Dollars expressed in $2015.
[b] Total employment changes in Minnesota.
[c] Personal Income changes in Minnesota. Dollars expressed in $2015.
[d] Single final year value. Year 2030 is the final year of analyses in this project.

[e] Average value from the year 2016 to the year 2030. The average value is calculated from the first year of the policy implementation through the year 2030 if implementation of the policy starts after year 2016.
[f] Cumulative value from 2015-2030 time period.

Figure F-6.2 Net Job Creation for WM Policies and WM Sector by Ascending Order, 2015-2030

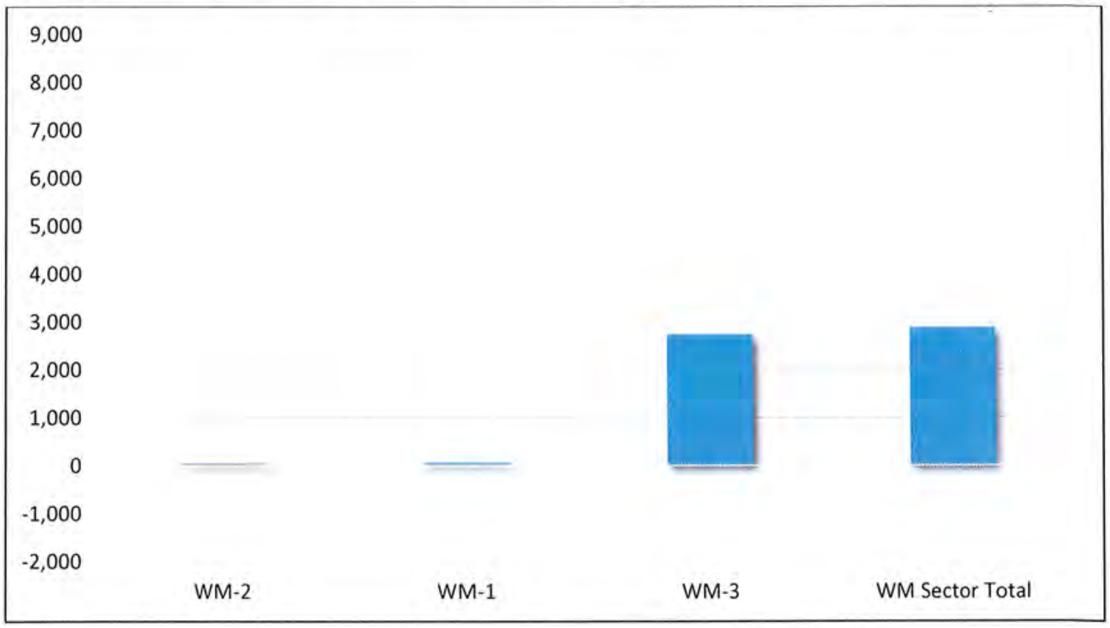
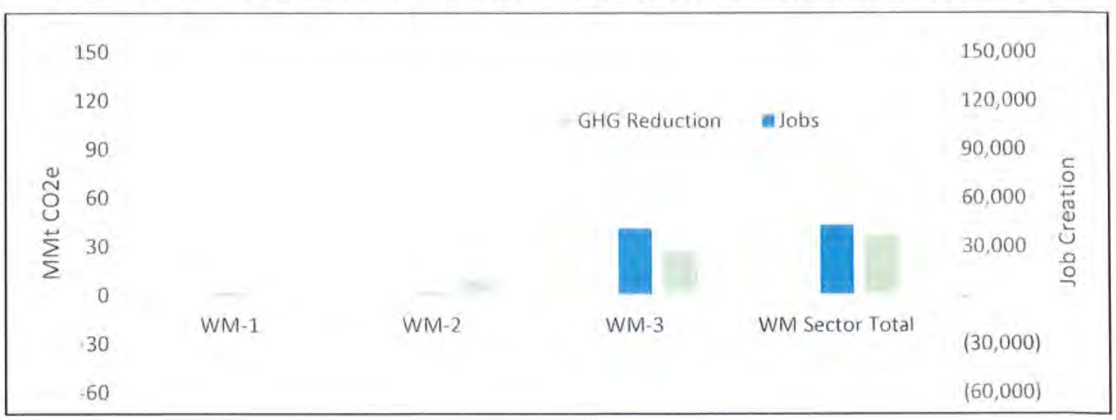


Figure F-6.3 below summarizes a potential for job creation and GHG emissions abatement of TLU sector policies on the same graph. This allows for a simultaneous assessment of performance of individual CSEO options against two crucial environmental and economic indicators.

Figure F-6.3 – Job Gains and GHG Reduction by WM Policy Options, 2015-2030



Sector Level Index

The graphs below express the overall economic impact from each scenario in a single score, and compares those scores. CCS created this single score (a Macroeconomic Impact Index) in order to encapsulate in one measurement the relative macroeconomic impacts (including jobs, GSP and incomes) of each policy. We have found in our own work and in the literature that indexed scores can be helpful to many readers when comparing options with multiple characteristics.

To produce this score, CCS set the results from the absolute best-case scenario (i.e. the implementation of all CSEO policies with all their optimal sensitivities in place) equal to 100, with that scenario's jobs, GSP and incomes impacts weighted equally at one third of the total score. Each policy's jobs, GSP and income impacts are scaled against that measure, and given a total score. The overall score indicates how significant a policy's impact is projected to be. Negative impacts are scaled the same way, except that those impacts are given negative scores and pull down the total score of the policy.

These scores are calculated separately for the final year of the study (2030), the *average* impact over the 2015-2030 period, and the *cumulative* impact of the policies over that period. While each scenario has one line, the relative importance of jobs, income and GSP remain visible as differently-shaded segments of that line.

Figure F-6.4 WM Macroeconomic Indicators, 2030

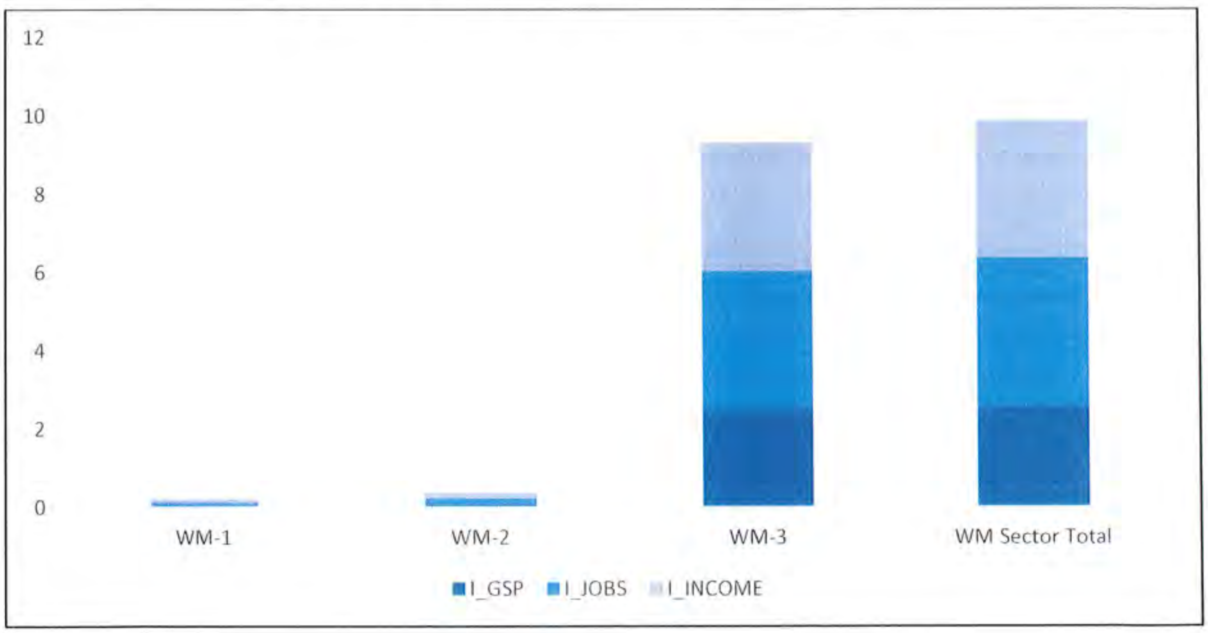


Figure F-6.5 WM Macroeconomic Indicators, Average Annual

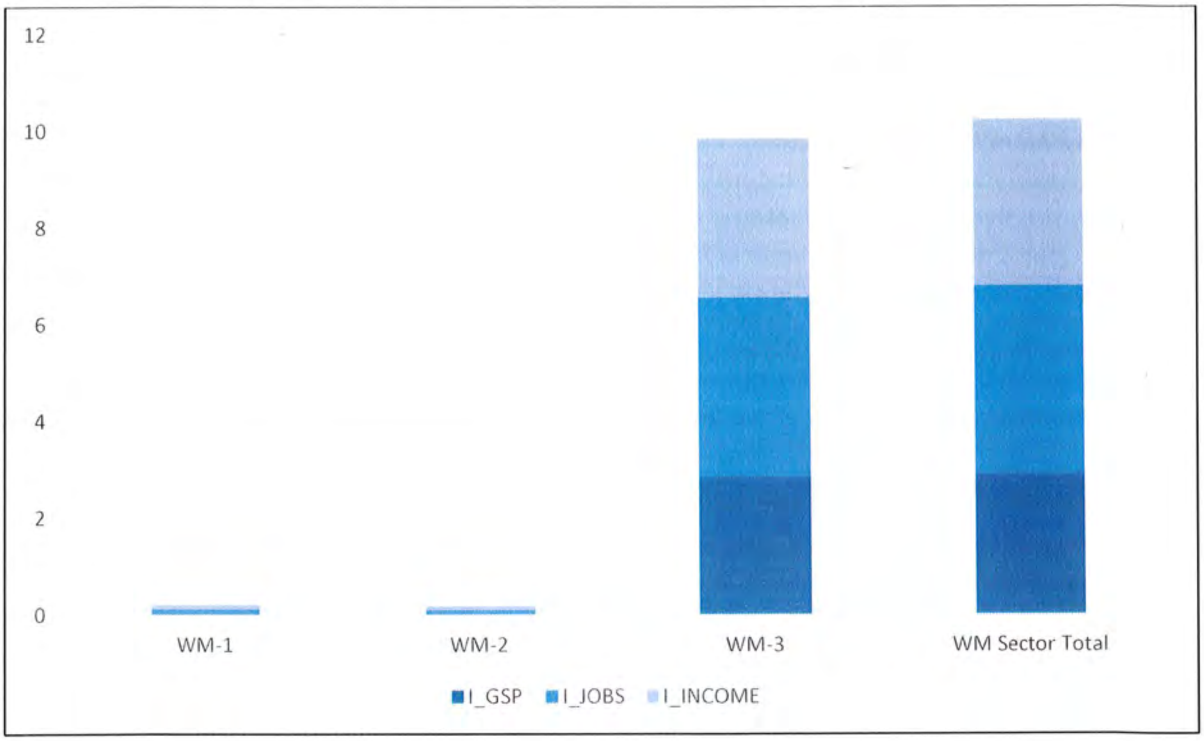
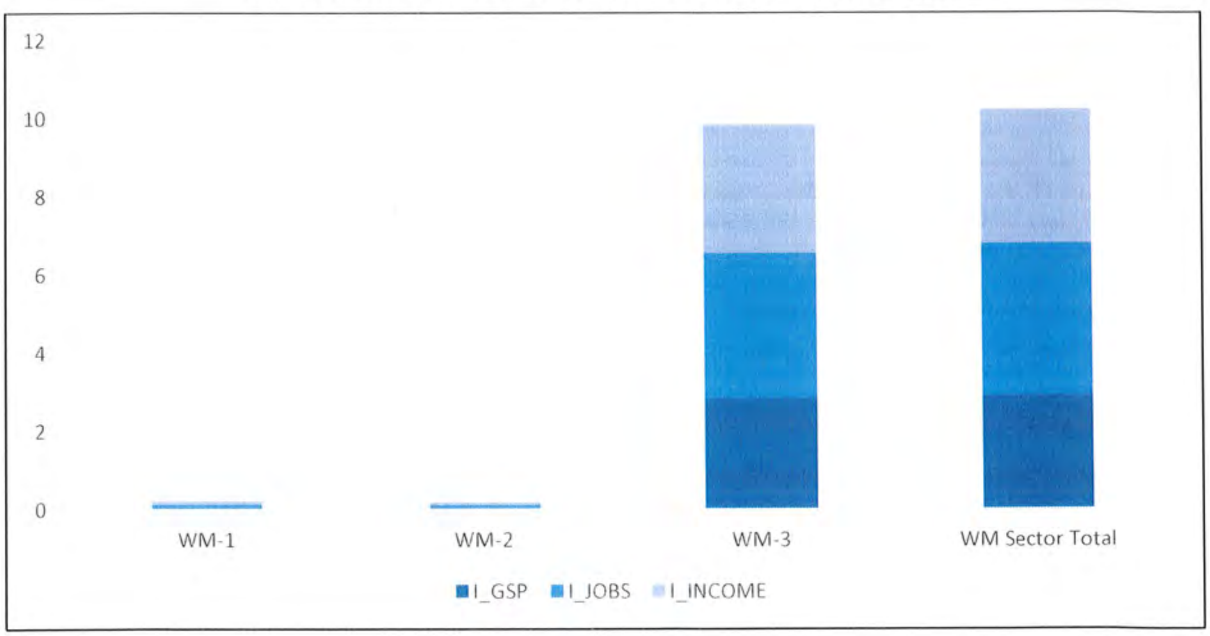


Figure F-6.6 WM Macroeconomic Indicators, 2015-2030



Graphs below show the trend of WM policy macroeconomic impacts during the year 2015 to the year 2030.

The Waste sector generates significant positive impacts – around $250 million in GSP and nearly $350 million in income, with 3,500 jobs more than would exist in the state by 2030 than if these policies were not implemented.

The sector impact on Minnesota's economy, according to this analysis, is really the story of the waste reduction policy focused on recycling, re-use and composting waste (WM-3). While the other policies are tiny in their overall impacts, driving very small positive or negative shifts over time, the WM-3 policy is responsible for effectively all of the sector's gains.

Figure F-6.7 WM GSP Impacts ($2015 MM)

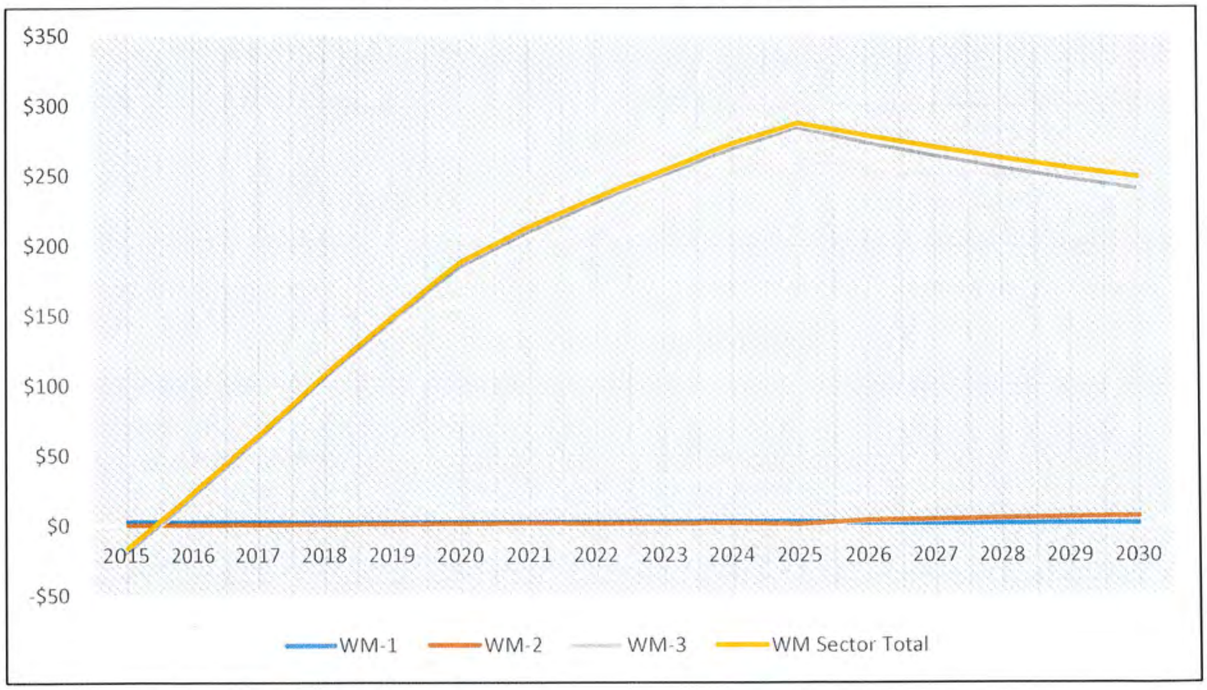


Figure F-6.8 WM Employment Impacts (Individual Jobs)

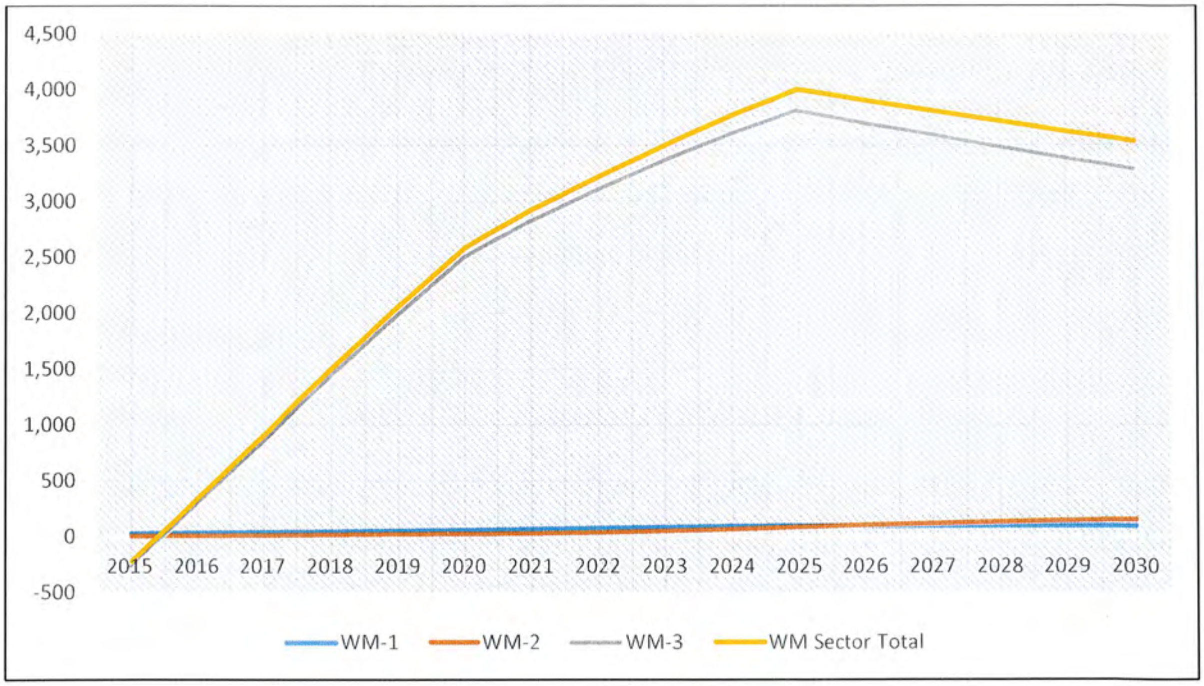
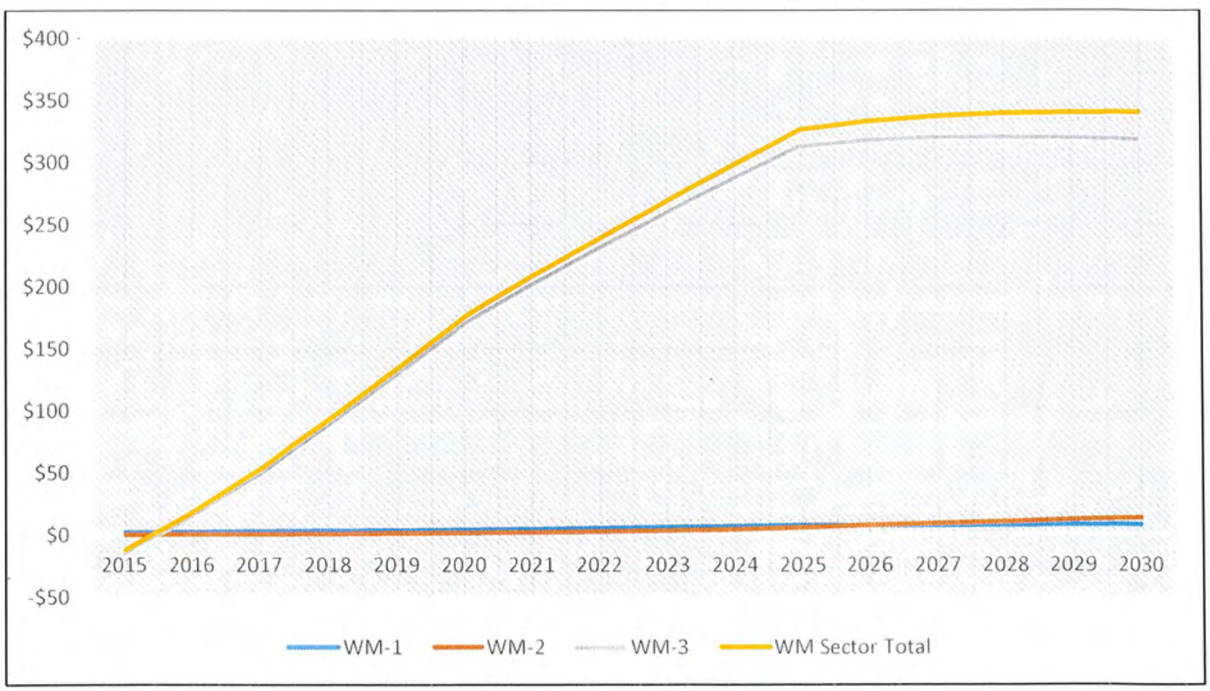


Figure F-6.9 WM Income Impacts ($2015 MM)



Graphs below show macroeconomic impacts on GSP, personal income, and employment in the final year (2030), in average (2015-2030) and in cumulative (2015-2030).

Figure F-6.10 WM GSP Impacts, Average Annual ($2015 MM)

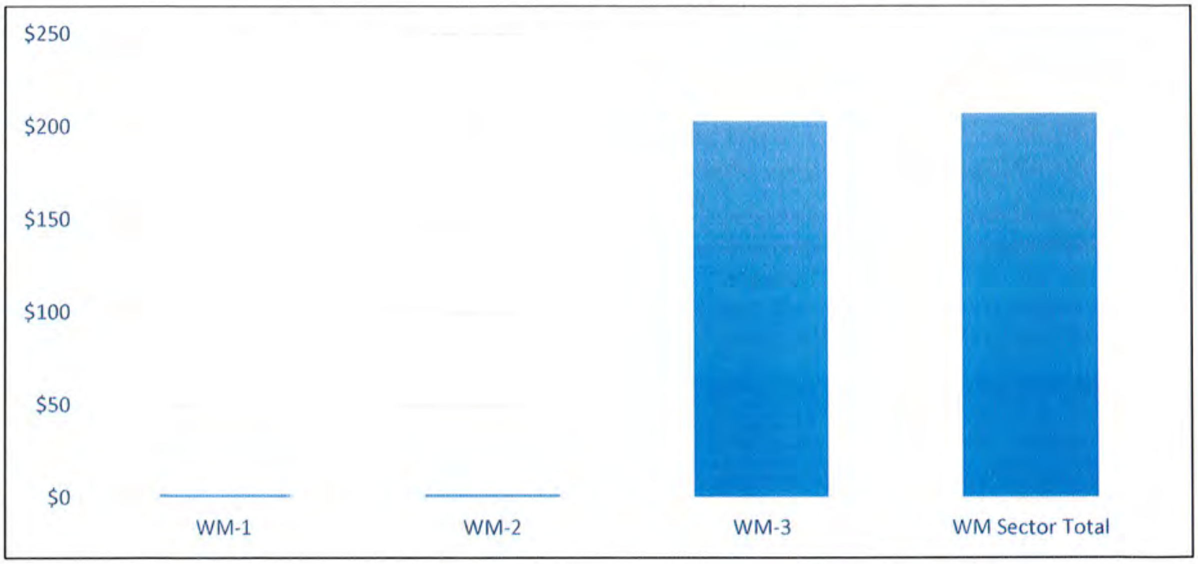


Figure F-6.11 WM GSP Impacts, 2015-2030 ($2015 MM)

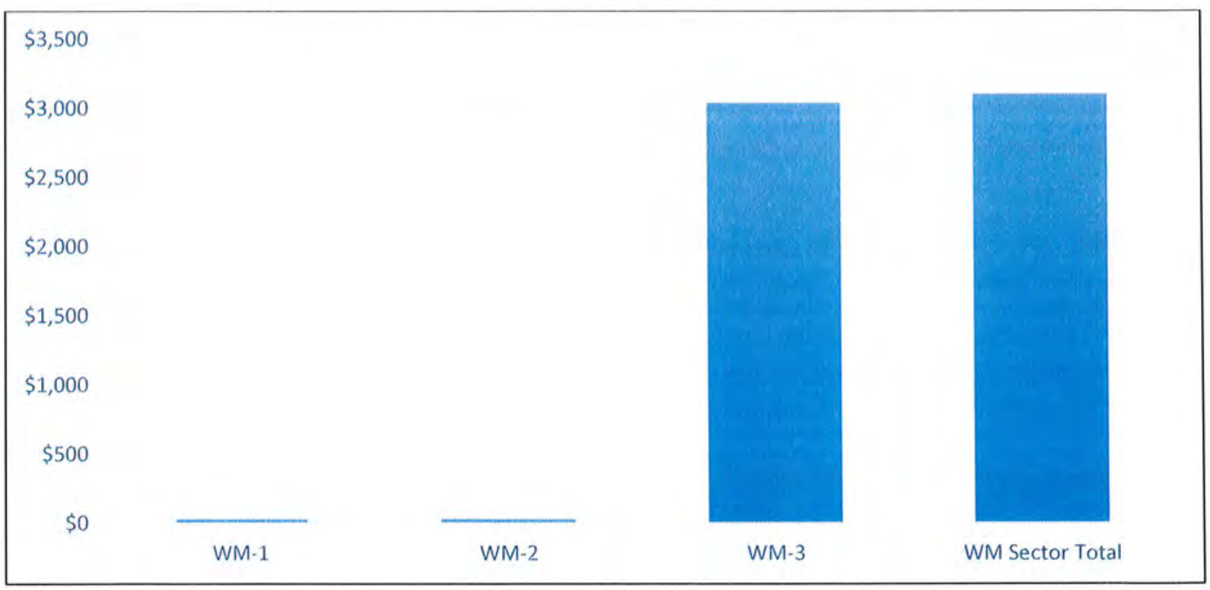


Figure F-6.12 WM GSP Impacts, Year 2030 ($2015 MM)

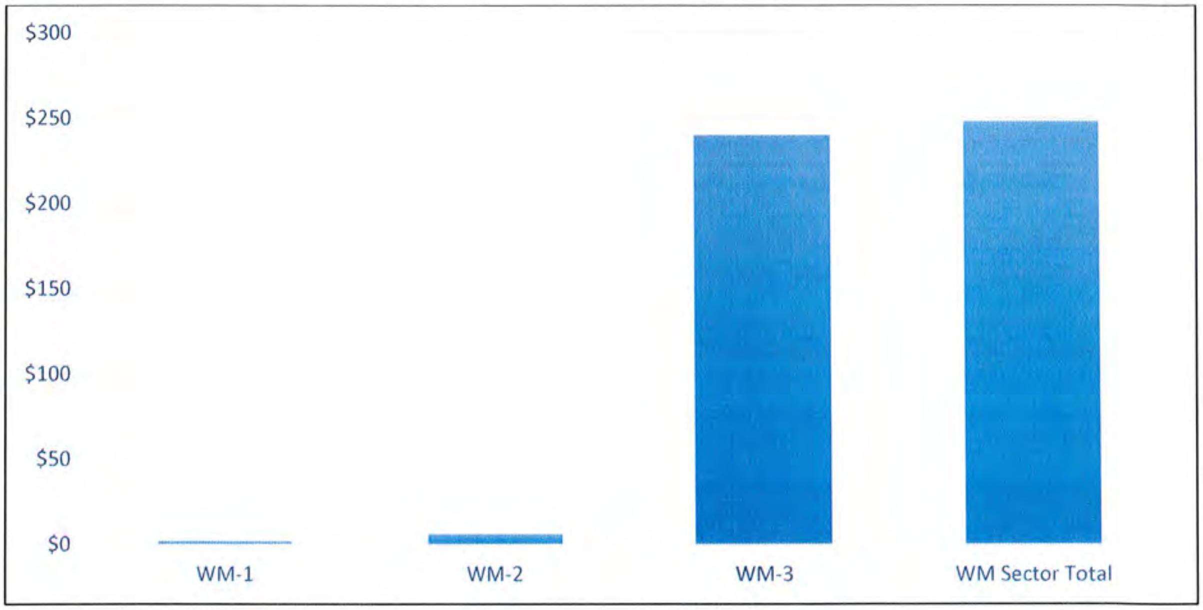


Figure F-6.13 WM Employment Impacts, Average Annual (Jobs)

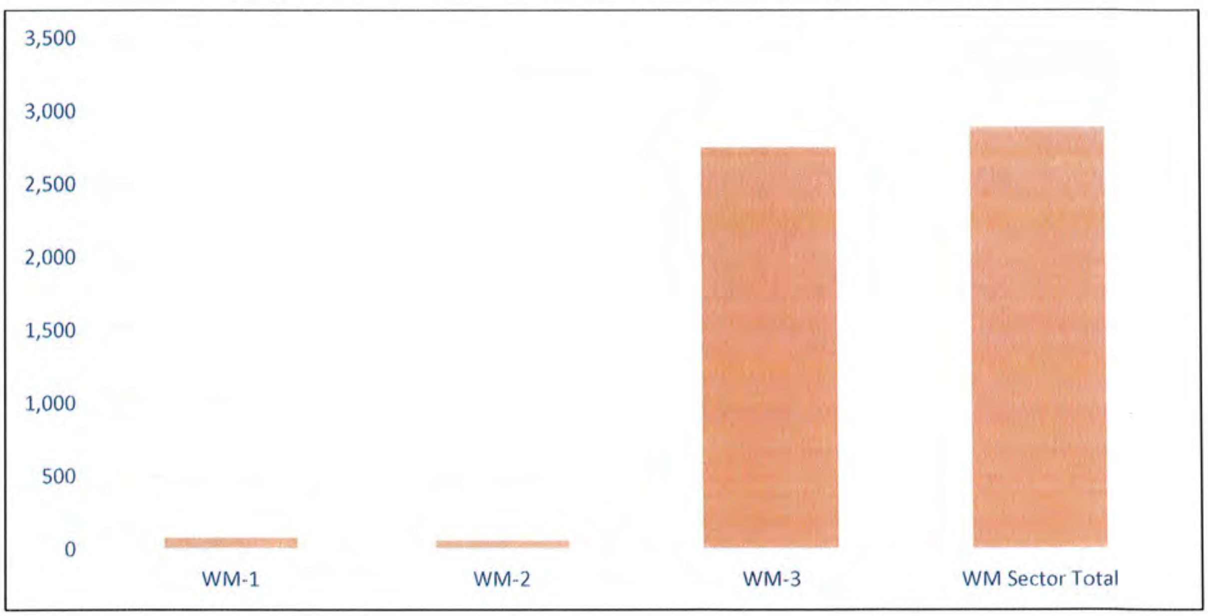


Figure F-6.14 WM Employment Impacts, 2015-2030 (Jobs)

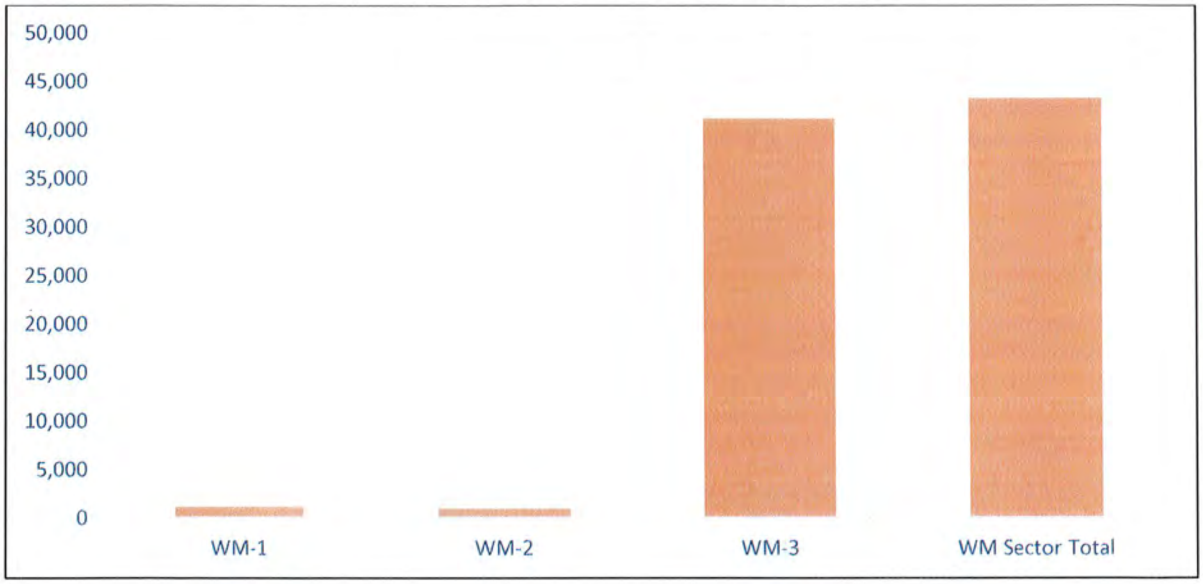


Figure F-6.15 WM Employment Impacts, Year 2030 (Jobs)

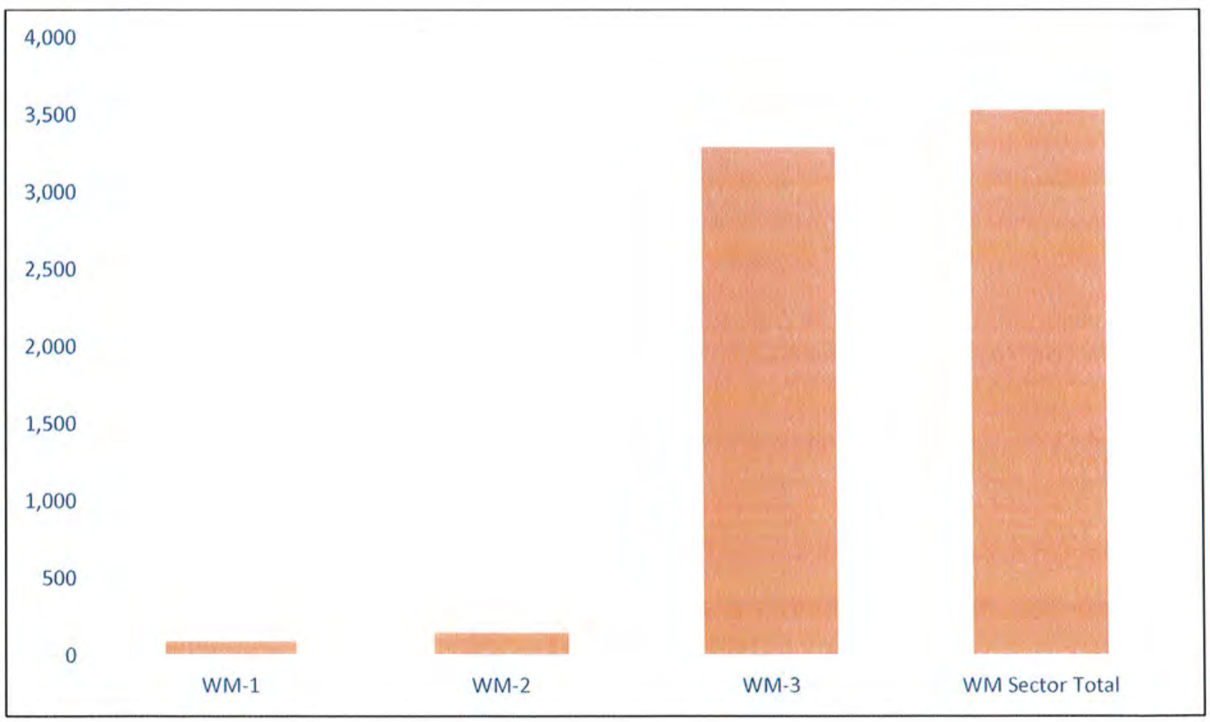


Figure F-6.16 WM Income Impacts, Average Annual ($2015 MM)

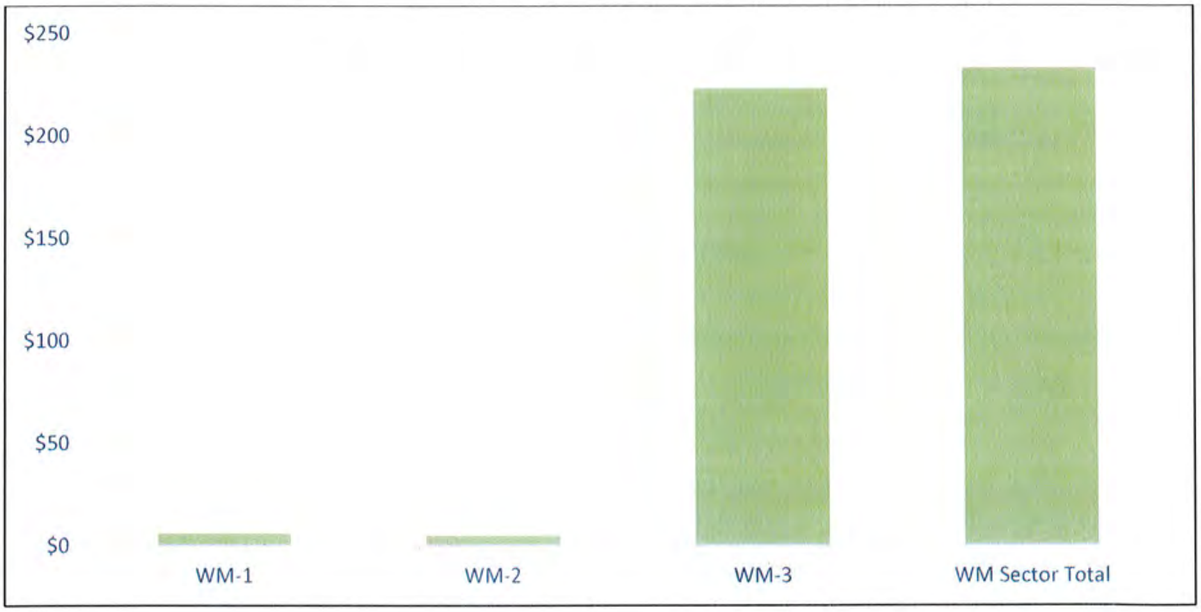


Figure F-6.17 WM Income Impacts, 2015-2030 ($2015 MM)

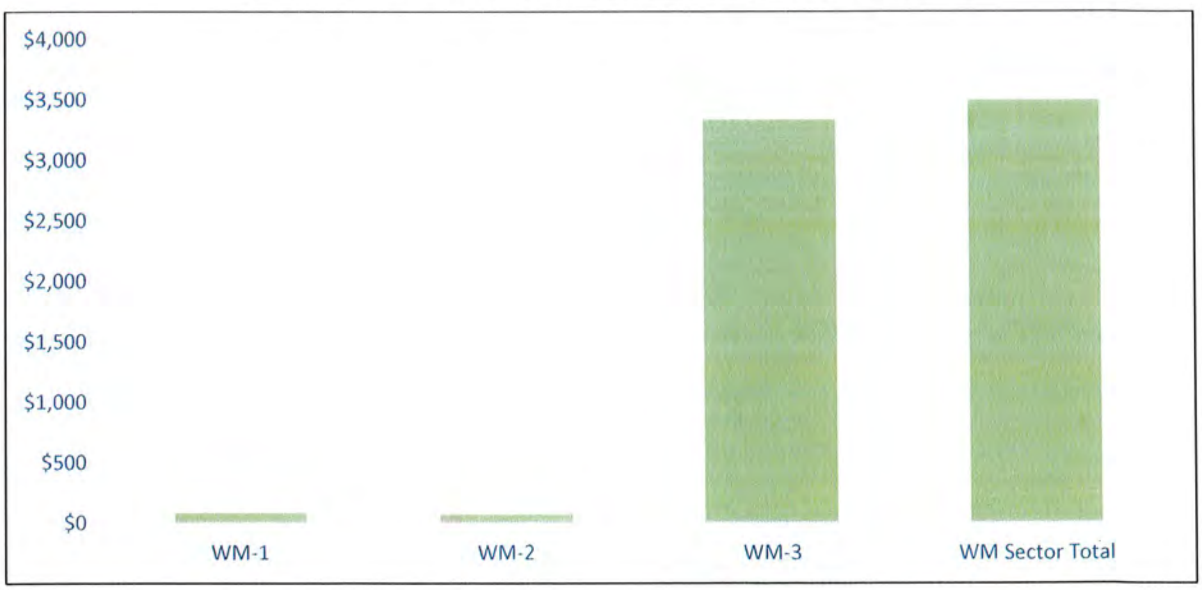
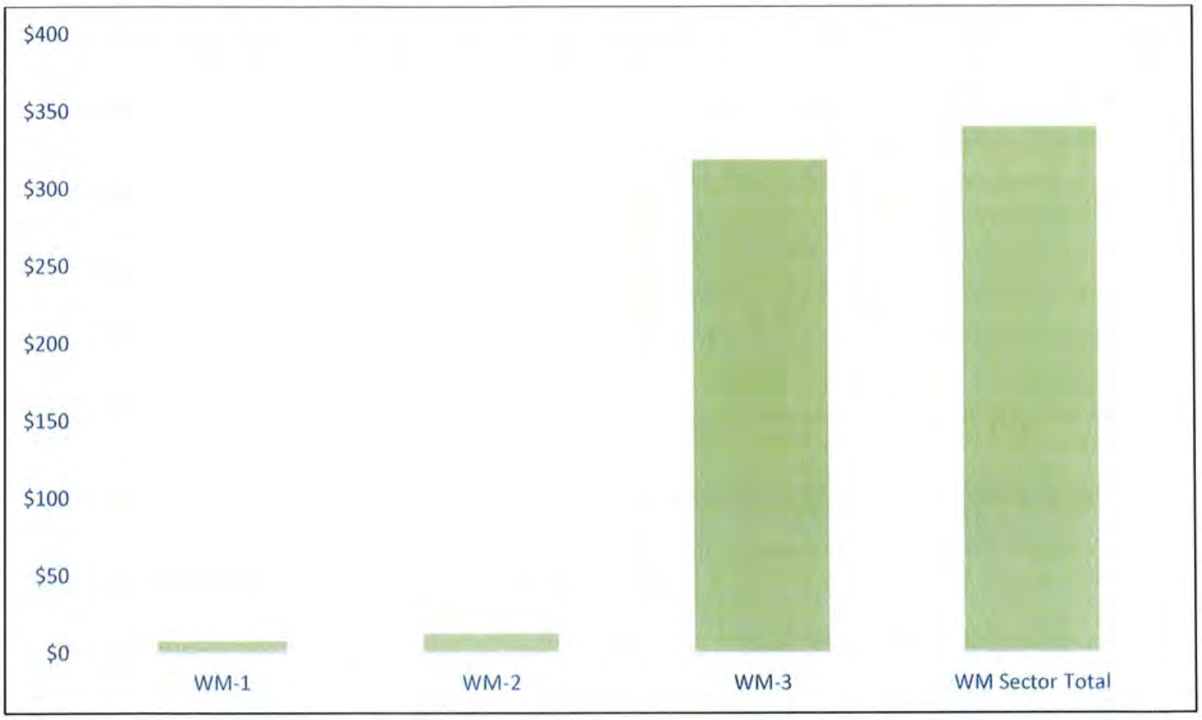


Figure F-6.18 WM Income Impacts, Year 2030 ($2015 MM)



WM-1. Wastewater Treatment – Energy Efficiency

Policy Option Description

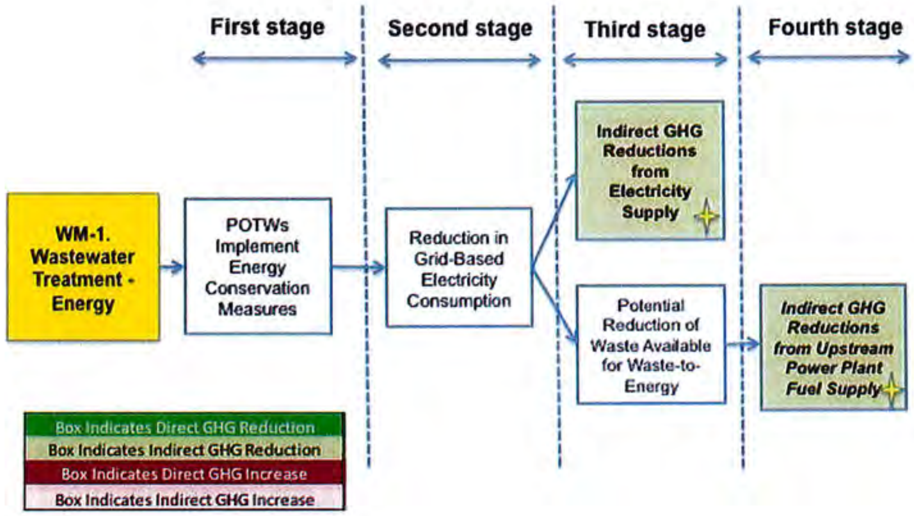
Publicly Owned Treatment Works (POTWs) are large energy consumers nationally, and in Minnesota. For instance, the Metropolitan Council's Environmental Services (MCES) is among the top 10 of Xcel Energy's customers in Minnesota and has successfully achieved great savings through energy conservation. However, the potential for conservation is still large and offers savings in utility bills for the Metro.

This policy option addresses opportunities for energy conservation within POTWs. The conservation mandate is technology agnostic to allow for flexibility. Biogas or other in-plant generation of energy can also be used to reduce the grid power purchase required. This could include, but is not limited to: wind, solar, anaerobic digestion (with or without co-digestion of non-wastewater feedstock), micro-hydro, recovery of heat (from wastewater or POTW processes, etc.).

GHG reductions are primarily achieved by reducing or off-setting the use of grid-based power and the associated fossil fuels combusted to generate power.

Causal Chain for GHG Reductions

Figure F-6.19 Causal Chain for WM-1



The causal chain above identifies the main policy option effects and the subsequent GHG impacts. The star symbol identifies GHG effects that will be quantified.

Policy Option Design

Goals: Mandate for Publicly-Owned Treatment Works (POTW) owners:

Energy Conservation: Reduce electrical energy purchase by 25% from continuing operations by 2025.

Timing: See above; assume a linear progression toward the goal with implementation beginning in 2015.

Parties Involved:

- Division of Energy Resources (DER) in the Department of Commerce, Pollution Control Agency, and Public Facilities Authority are state agencies that should coordinate implementation of the program.
- Energy utilities are impacted by the conservation and demand for Conservation Improvement Program (CIP) funding.

- MCES, other sanitary districts, and cities with their own POTWs will be affected. Their ratepayers may be affected by changed costs. Most conservation measures will save costs, over the lifecycle.

Implementation Mechanisms

The state should adopt the mandate listed above; state laws and rules will also need to be changed. It is proposed that the mandate have exemptions for economic hardship, to be defined later, and that state Wastewater Infrastructure Fund (WIF) program be targeted at energy efficiency improvements to make it economical for those exempted to get the needed energy work done. WIF is state capital bonding dollars and is available for those with economic hardships now; administered by Public Facilities Authority (PFA).

State agencies should budget as needed for their roles:

- PCA and DER are expected to generate and maintain a toolkit for POTW energy projects, and pursue program funding via alternative Conservation Improvement Program (CIP) dollars from energy utilities. PCA staff may be able to facilitate further energy savings by bringing together groups of similar facilities to work together on design changes and group buying of equipment.
- PCA should determine credit for early action (e.g. MCES work since 2007 which was verified by utilities and DER through CIP).
- Public Facilities Authority should (PFA), as allowable by federal rules, make:
- State Revolving Fund (SRF) green reserve funding available primarily for energy projects, and available independently of other POTW work rankings, and
- Wastewater Infrastructure Fund (WIF) grants available only for good energy designs.
- The POTWs should be entirely responsible to pick technologies and implement the projects.

In addition to the mandate incentives should be provided:

- The PFA should, within the state revolving funds, be required to de-link the green reserves from the usual water and wastewater facility project rankings, or preserve the green funds for emissions reducing improvements to the maximum extent allowed by federal law and EPA rules. PCA should create a separate ranking that provides funds based primarily on emissions reduction expectations at POTWs.
- Within the state WIF program, the PFA should be required to adopt the Energy Star methodology for measuring the energy efficiency in a POTW, and limit regular funding to those that meet an energy star ranking of 75 or more, in their designs (that is, POTWs whose design is expected to perform better than 75% of peers for size and level of treatment technology).

- DER has, and should, continue to pursue federal grant money to assist a POTW energy program; and
- The PCA should pursue an alternative CIP to make funding available to POTWs from energy utilities' CIP programs for studies and enhanced conservation rebates.

Related Policies/Programs in Place and Recent Actions

The MCES wastewater division has a goal of 10% reduction every 5 years through EE and 10% of baseline "advancing renewable energy in the Metro region" based on a 2006 baseline. Through 2014, 19% reduction has been accomplished, saving approximately $4 million/year for MCES ratepayers.

Estimated policy Impacts

Direct Policy Impacts

Table F-6.4 WM-1 Estimated Net GHG Reductions and Net Costs or Savings

2030 GHG Reductions ($MMtCO_2e$)	2015 – 2030 Cumulative Reductions ($MMtCO_2e$)	Net Present Value of Societal Costs, 2015 – 2030 ($2014)	Cost Effectiveness ($2014/ tCO_2e)
0.07	0.88	-$56	-$57

Data Sources

Facility-level flow rates for mechanical wastewater facilities were obtained from the Environmental Protection Agency (EPA) Clean Water Needs Survey (CWNS) 2008 Database. This database contained data for 144 Minnesota facilities. According to the MnTAP EPA R5 Study, there are 600 facilities in Minnesota; 300 of these are mechanical, and the other half is pond systems. An additional 138 mechanical facilities and 33 aerated pond systems were identified in the Minnesota Pollution Control Agency (MPCA) facility database, which contains design flow data. A comparison of design flow and existing flow between the two data sets indicated that most facilities are operating at around 50% of design flow. Therefore, existing flow for the additional facilities was estimated as 50% of design flow.

Baseline electricity consumption for typical mechanical wastewater facilities was estimated from data from the EPA report, "Energy Efficiency Demonstration Projects and Audits for Minnesota's Wastewater Treatment Plants." Electricity consumption values were estimated for four different wastewater capacities: less than 1 million gallons per day (mgd), 1-5 mgd, 5-10 mgd, and more than 10 mgd.

Quantification Methods

GHG Reductions:

According to the MnTAP EPA R5 Study, there are 600 wastewater facilities in Minnesota. Roughly half of these facilities are mechanical systems, the other half are pond systems. The two main types of ponds systems are stabilized lagoons and aerated lagoons. Stabilized lagoons are primarily gravity fed systems with no aeration. These systems have very low energy usage. Therefore, energy reductions and the associated GHG reductions were calculated for mechanical facilities and aerated lagoon systems only.

For mechanical facilities, the BAU energy consumption for different flow rate classes was based on estimated values for electricity consumption per unit of flow and the plant-level flow rates from the facility databases listed under Data Sources. BAU efficiency measures were assumed to reduce the baseline energy consumption over the forecast period. The BAU forecast assumes that 15% of facilities have initiated energy efficiency measures by 2015, with additional one percent initiating measures each year thereafter. BAU energy efficiency measures were assumed to reduce plant-wide electricity consumption by eight percent.

For aerated lagoon systems, most of the electricity consumption is from the aeration system. Baseline electricity consumption was estimated based on the assumption that the aeration blowers have a rated power of ten hp per million gallons of lagoon capacity.[1] Lagoon capacities were estimated from plant-level flow rates and estimated detention times (three days for aerated polishing ponds, and 25 days for aerated lagoons). [2]

Reductions in electricity consumption and associated emissions were estimated by applying the target reductions to the baseline consumption values.

Net Societal Costs:

Case studies of high-efficiency blower equipment installations were identified for six wastewater treatment facilities. These studies showed a cost and electricity reduction; installed, high-efficiency blowers are estimated to save $0.55 per annual kWh. This value was applied to the estimated reductions in electricity consumption to calculate capital costs. Capital costs were annualized assuming financing at five percent interest over 20 years.

The other component of the net costs is electricity savings, which was estimated based on the reductions in electricity consumption and the avoided costs for electricity.

Key Assumptions

While the policy option is technology agnostic, for the purposes of analysis, facilities were assumed to achieve energy efficiency goals by replacing aeration equipment. Aeration equipment accounts for slightly more than half the energy usage of mechanical facilities and most of the energy consumption for aerated lagoon facilities. Replacement of older aeration blowers with new high-efficiency blowers can reduce energy consumption for aeration by 50%

[1] EPA, 2002. "Wastewater Technology Fact Sheet: Aerate, Partial Mix Lagoons."
[2] MPCA, 2013. "Stabilization Pond Systems: Operations, Maintenance, Management."

or more. Therefore, it was assumed that replacing these systems would be sufficient to achieve the 25% energy consumption reduction goal of this policy option.

Other key assumptions are listed above under GHG Reductions and Net Societal Costs.

Macroeconomic (Indirect) Impacts

Table F-6.5 WM-1 Macroeconomic Impacts on GSP, Employment and Income

Scenario	GSP ($2015 MM)			Employment (Individual)			Personal Income ($2015 MM)		
	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)
WM-1	$2	$2	$31	90	80	1,130	$8	$6	$86

Graphs below show detail in GSP, employment and personal income impact of the WM-1 policy.

Figure F-6.20 WM-1 GSP Impacts ($2015 MM)

Figure F-6.21 WM-1 Employment Impacts (Individual Jobs)

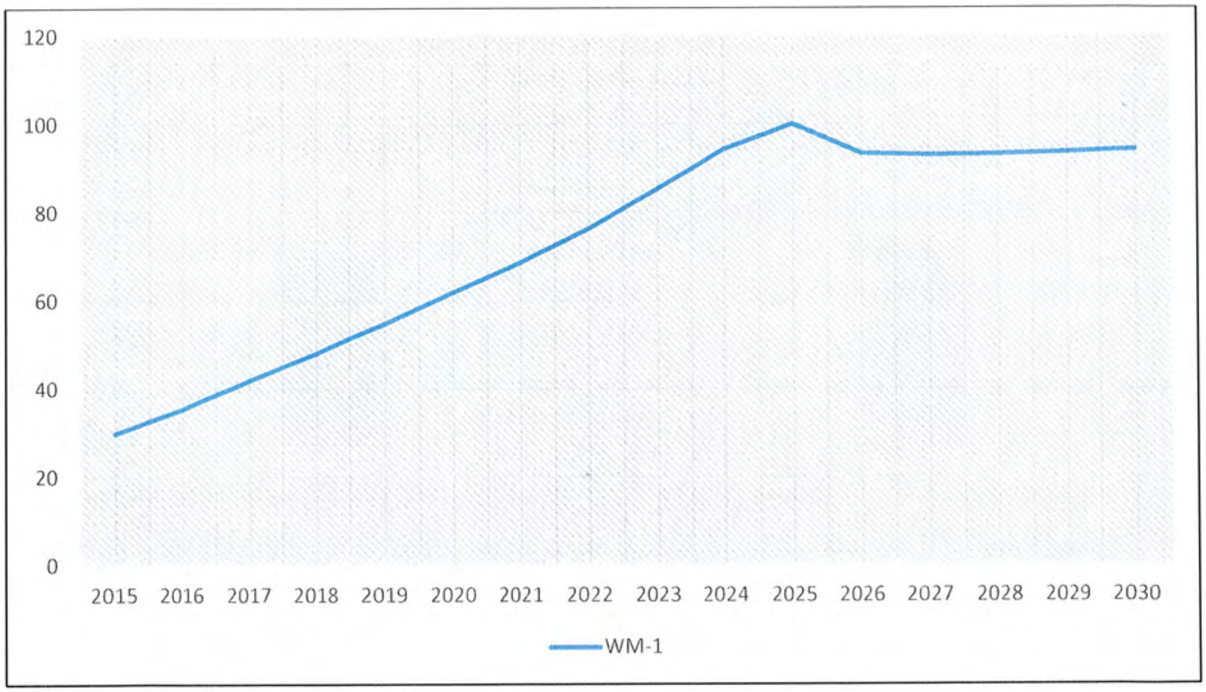
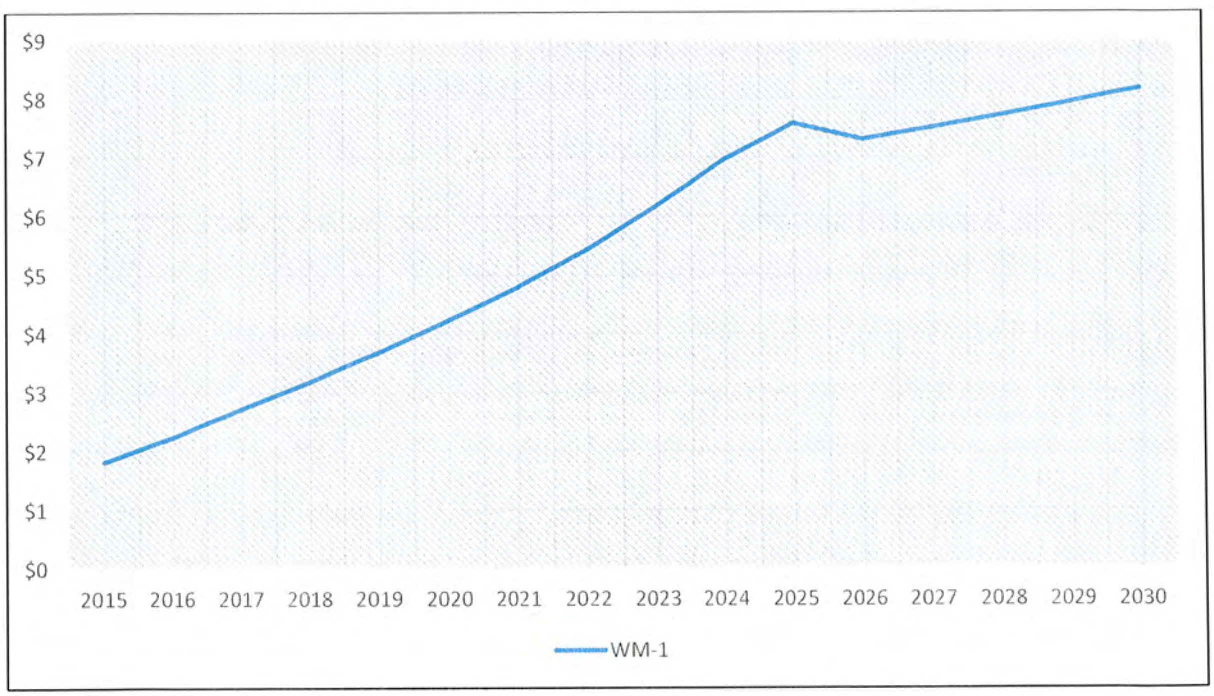
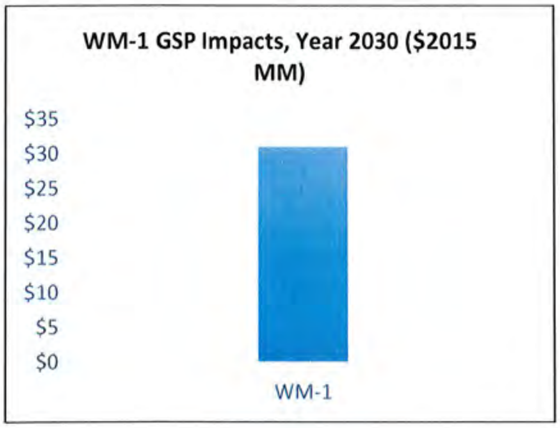
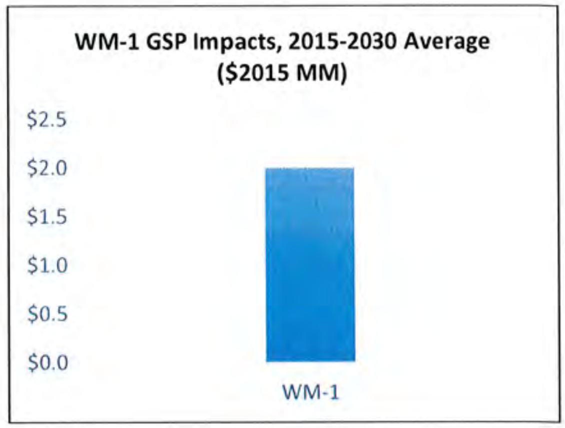


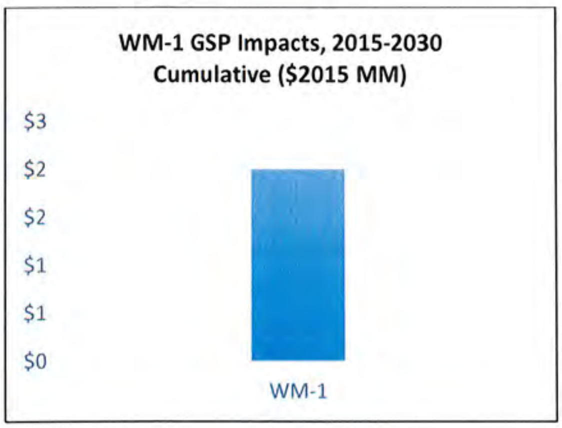
Figure F-6.22 WM-1 Income Impacts ($2015 MM)

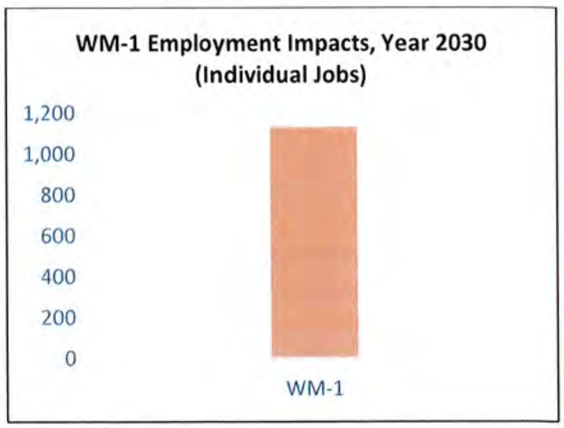


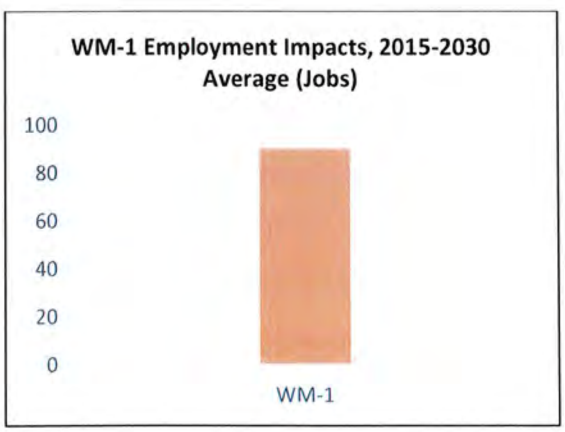
Graphs below show macroeconomic impacts on GSP, personal income, and employment in the final year (2030), in average (2015-2030) and in cumulative (2015-2030).

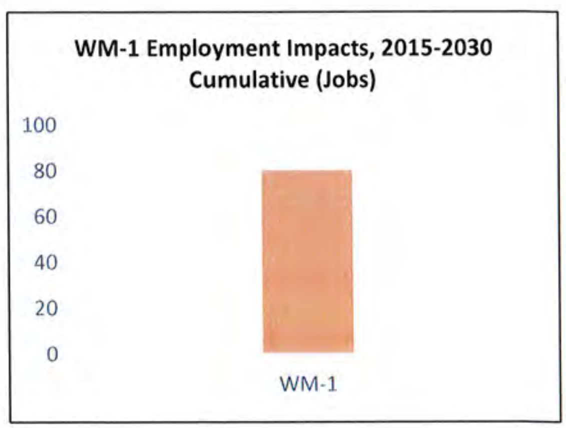












Principal Drivers of Policy Impact on the Broader Economy

This policy shows slight positive impacts. The net savings to the government to carry out water treatment expands its ability to spend in other programs, though the volumes of spending changes are very small. GSP and incomes are never forecast by this analysis to vary more than a few million dollars statewide, and total employment never more than 100 total positions. This is best understood.

Data Sources

The principal data sources for the macroeconomic impacts analysis of this and all other policies in the CSEO process are the direct spending, saving, cost and price impacts developed as part of the microeconomic (direct impacts) analysis. For each policy, the cost-effectiveness analysis described above develops year-by-year estimates of the costs, savings prices, and changes demand or supply that households, businesses and government agencies are expected to encounter in a scenario where the policy is implemented as designed.

A secondary data source is the policy design. Balancing financial flows for each direct impact identified are established based on understanding the implementation mechanism, and quantitative values for these flows are developed for each direct impact identified. This balancing identifies and quantifies the responsive change that occurs as a result of the direct impact in question. For example, if a household is anticipated to save $100 per year on electricity bills as a result of a policy, the direct impact is a $100 savings to the household (which expands its spending capacity for other things) but the balancing impact is a $100 loss in revenue and demand to the utility provider (which reduces its ability and need to spend on labor, capital, profit, and other inputs). The quantitative measure of both sides of a change is of importance to a complete macroeconomic analysis. This balancing ensures that both the supply and the demand side of each economic change is fully represented in the analysis.

A third data source is direct communication with Minnesota agency staff and others involved in policy design or in a position to understand in detail the financial flows involved in the policy. These people assisted in clarifying the nature of economic changes involved so that the modeling and analysis would be accurate.

The final crucial data source is the baseline and forecast of economic activity within the REMI software. This data is compiled into a scenario that is characterized not only by the total size of the economy and its many consuming and producing sectors, but also the mechanisms by which impacts in one sector can change the broader economy – such as intermediate demands, regional purchase coefficients, and equilibria around price and quantity, labor and capital, and savings and spending, to name a few of many. REMI, Inc. maintains a full discussion of all the sources of the baseline data on its own website, www.remi.com.

In the case of the WM-1 policy, important data included:

- The cost of installing high-efficiency pumps in water treatment facilities.
- The electricity savings achieved as a result of using those pumps.
- The responsive ability of the government to spend more on other programs, as the savings from electricity overwhelm the financed capital cost of the new infrastructure.

Quantification Methods

Utilizing the data developed from the microeconomic analysis, CCS analysts established for each individual change the following characteristics:

- The category of change involved (change in spending, savings, costs, prices, supply or demand)
- The party involved on both sides of each transaction
- The volume of money involved in this change in each year of the period of analysis

These values, so characterized, were then processed into inputs to the REMI PI+ software model built specifically for use by CCS and consistent with that in use by state agencies within Minnesota. These inputs were applied to the model and run. Key results were then drawn from the model and processed for consistency of units and presentation before inclusion in this report.

Key Assumptions

The macroeconomic impact analyses of this policy, as well as of the others in the CSEO process, rely on a consistent set of key assumptions:

- State and local spending is always budget-constrained. If a policy calls for the state or local government to spend money in any fashion, that spending must be either funded by a new revenue stream or offset by reductions in spending on other programs. Savings or revenues collected by the government are also expected to be returned to the economy as spending in the same year as they are collected.
- Federal spending is not budget-constrained. The capacity of the federal government to carry out deficit spending means that no CSEO policy is held responsible for driving either an increase or decrease in federal tax spending by businesses or households in the state of Minnesota.
- Consumer spending increases are sometimes financed. Small-scale purchases or purchases of consumer goods are treated as direct spending from existing household cash flows (or short-term credit). Durable goods, home improvements or vehicle purchases, however, are treated as financed. Consumers were assumed to spread out costs based on common borrowing time frames, such as five years for financing a new vehicle or 10-20 years for home improvements that might be funded by home-equity or other lending. The assumption of financing and the term of years applied was considered anew in each case.
- Business spending increases are often financed. Where spending strikes a sector which routinely utilizes financing or lines of credit to ensure steady payment of recurring costs, significant spending of nearly any type was considered a candidate for financing, thus allowing costs to spread out over time. This methodology is preferable for the modeling work, as sudden spikes or dips in business operating costs can show up as volatility when the scenario may depict a managed adoption of new equipment in an orderly fashion. The assumption of financing and the term of years applied was considered anew in each case.
- Unless otherwise stated, all changes to consumer spending or to the producers' cost of producing goods and services were treated in a standard fashion. Consumers are assumed to spend on a pre-set mix of goods, services, and basic needs, and businesses spend (based on their particular sector of the economy) on a mix of labor, capital, and intermediate demands from other sectors. Unless a policy specifically defines how a party will react to changes in cost, price, supply or demand, these standard assumptions were applied.
- State and local spending gains and reductions driven by policy are assumed to apply to standard mixes of spending. Again, unless a policy specifically states that a government entity will draw from a specific source or direct savings or revenues to a specific form of

spending, all gains and losses were assumed to apply to a standard profile of government spending within the economy.

Key Uncertainties

Changes in rates of electricity or innovations that make efficiency technologies cheaper are uncertainties on the cost of implementation. In particular, the cost of generating biogas and using that energy may rapidly change with advances in technology.

Additional Benefits and Costs

Reducing unnecessary energy use saves municipalities money and reduces air and water impacts of electricity generation.

Feasibility Issues

It is acknowledged that without strong financial support, the mandate will be politically very difficult and that outreach to find an acceptable level needs to be done before this policy option should be publicly proposed or supported.

WM-2 & WM-3. Front-End Solid Waste Management

Policy Option Description

Front-end solid waste management (SWM) technologies promote the reduction of the sheer volume of waste needing disposal, as well as reduction in consumption through incentives, awareness, and increased efficiency. Four major areas of focus in Minnesota are source reduction, reuse, advanced recycling, and organics diversion. Source reduction, reuse, and recycling provide GHG benefits not only from avoided disposal emissions, but also from reducing product energy-cycle emissions that would otherwise come from the manufacture and transport of new products and packaging. Redirecting organic materials into food-to-people, food-to-livestock, and composting programs cuts GHG emissions compared to disposal in landfills (food-to-people and food-to-livestock programs also reduce upstream energy-cycle emissions).

This policy option reflects a continuation of the AFW-7 policy option from the Minnesota Climate Change Advisory Group (MCCAG) report. Following that report in 2008, the 2014

Legislature codified a 75% total recycling goal (that is, a total that combines conventional dry recycling and composting, food-rescue, and food-to-animals) for the seven Metro counties.[3] Following the MCCAG report, Minnesota has taken several important steps at the state and local levels to make those goals attainable. As of 2012, the statewide dry recycling rate was 42%, and the organics diversion rate was seven percent including yard waste, for a combined recycling rate of 49%.

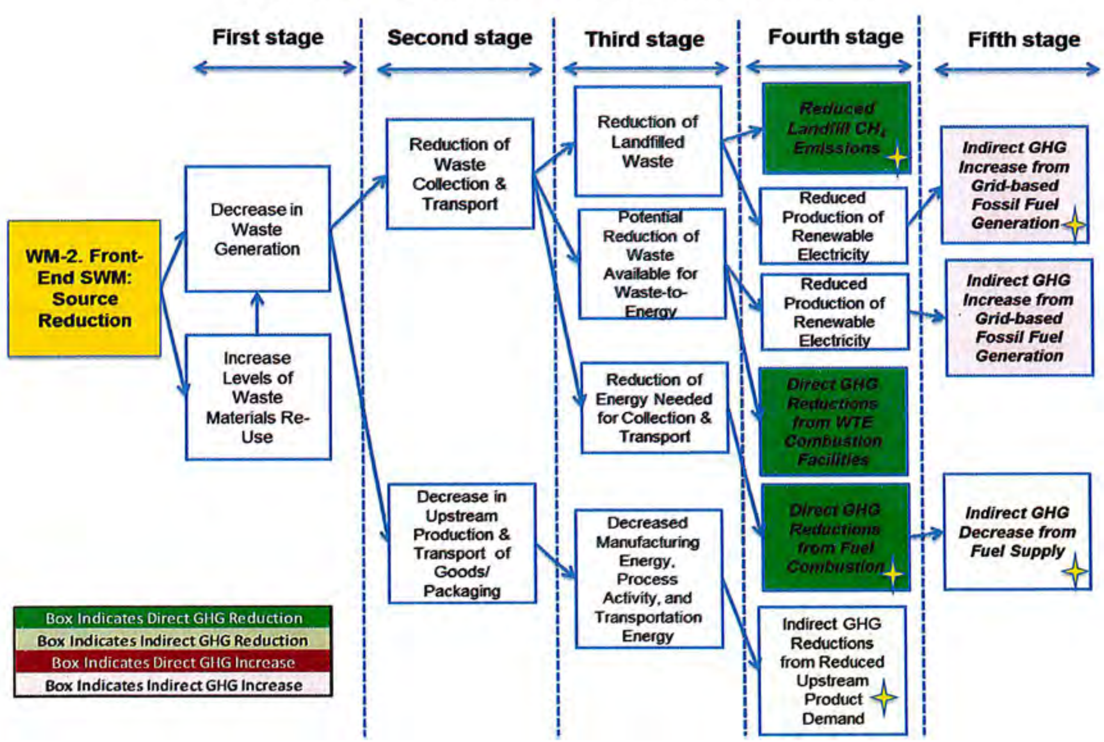
This policy option would be implemented using two distinct policy option components:

- WM-2. Source Reduction
- WM-3. Re-Use, Recycling, and Composting

Details on goals for each component are provided in the Policy Option Design section below. The GHG reduction causal chains below provide a schematic for each component that indicates the policy option effects and the associated energy and GHG impacts.

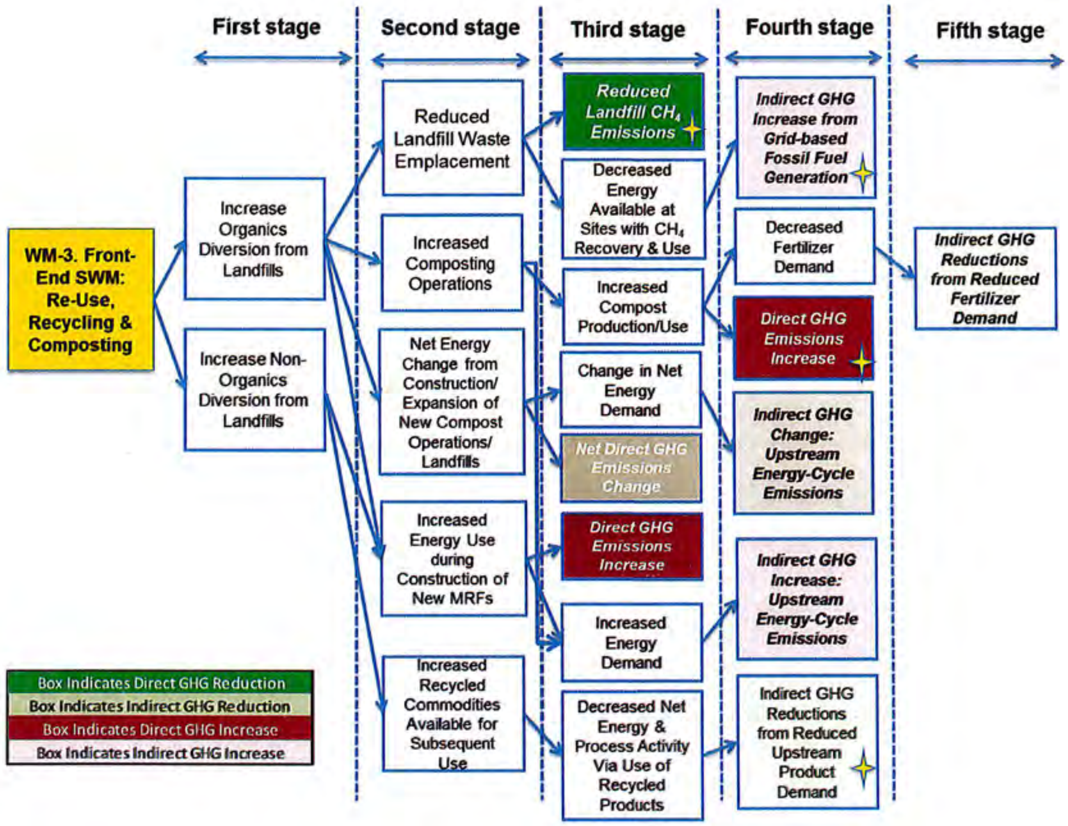
Causal Chains for GHG Reductions

Figure F-6.23 Causal Chain for W-2 GHG Reductions



[3] NOTE: commonly, within the SWM industry, this would be referred to as a "diversion" goal (diversion from landfills or combustion), rather than a "recycling" goal, since more management methods are being used than just recycling.

Figure F-6.24 Causal Chain for W-3 GHG Reductions



The star symbol identifies GHG effects that were quantified. GHG effects that were not quantified were not readily quantifiable (e.g. due to data or methodological limitations), but are also not considered to be significant. This policy option analysis assumes that the current mass of waste managed via waste-to-energy (WTE) combustion facilities stays constant through the CSEO planning period. Therefore, WTE impacts are not quantified.

Note that both landfilling and composting are often considered to store biogenic carbon (e.g. food/yard waste, paper, wood, cardboard). This GHG effect is not shown in the causal chain above; however, the net difference between these two management methods will also be quantified. Shifts away from downstream waste management (e.g. between landfilling and composting) as a result of source reduction and reuse also result in changes in energy consumption and GHG emissions associated with waste collection and transport which will be quantified.

Implementation of the policy option would involve some construction of new composting facilities and associated equipment manufacturing. The associated GHG emissions would be temporary, and, for the purposes of this analysis, are not considered to be significant. MPCA believes that the current capacity of material recovery facilities (MRFs) in the metro-region is sufficient for the additional recycling activity envisioned by this policy option.

Policy Option Design

Goals:

- *WM-2. Source Reduction Goal:* Achieve a zero percent per-capita increase by 2020 and a reduction of waste generation per capita of three percent by 2025.
- *WM-3. Reuse, Recycling and Composting*: Achieve a total recycling[4] rate (including composting) of 75% by 2025.

Timing:

- *Source Reduction & Reuse:* Achieve a zero percent per-capita increase by 2020 and a reduction of waste generation per capita of three percent by2025 statewide.
- *Recycling, Food to People, Food to Livestock and Composting:* The 75% goal is gradually introduced at a linear rate from 2016 to 2025. MSW is not diverted from WTE.[5]

Parties Involved: MPCA, Governor's Office, legislators, organic diversion and permitting staff, counties and other local units of government, private waste management industry, and general private industry (end markets for recycled materials). Significant societal changes will be needed to achieve the goals, which in turn will require significant support from policy option makers, decision makers, manufacturers, retailers, regulatory agencies, environmental and non-profit organizations, and the general public.

Other: As the recession hit, not surprisingly, Minnesota saw a decrease in the amount of MSW generated. Importantly, even after the economic recovery, as of 2012, the per-capita rate of MSW generation remained more than seven percent below 2005 levels. MPCA has also analyzed personal consumption expenditures of Minnesotans and has seen a weakening relationship between consumption expenditures and solid waste generated. While the source reduction numbers may not be caused by any one factor, one change that could be responsible for some of the reduction is that more people are choosing to live with less. We have seen trends that younger people are looking to live in the city, use public transportation/walk/bike to work and live in less square footage. All of these, plus light-weighting and material changes, lead to buying (and eventually disposing) of fewer goods and associated packaging.

Since the 1989 enactment of legislation based on recommendations of the Governor's Select Committee on Recycling and the Environment (SCORE), annual reports have estimated recycling in the state. According to the SCORE reports covering waste management in Minnesota, the rates of recycling have leveled off since 1989. In 2012, Minnesota had a statewide recycling rate

[4] The Recycling sub-policy goal includes composting, recycling, and re-use. CCS understands the State of Minnesota's definition of recycling includes all three of these waste management methods, which is different in other jurisdictions (e.g. re-use and composting are considered by many to be organics management methods, but these aren't included within a definition of recycling).

[5] Assumption is based upon WTE's running at capacity to achieve maximum electricity generation.

of 49.2%, including an organics recycling (food to livestock, food to people, and source-separated composting). Minnesota had an estimated source reduction rate of three percent.

Though there are two separate sub-components included with this overall policy option, the two sub-components are quantified in a way that captures the results of both being implemented together. The over-arching assumption behind quantifying the sub-components together is: if there is a per-capita source reduction, this will affect the amount of resources available for the recycling sub-policy option.

Implementation Mechanisms

The following priority list of implementation mechanisms would benefit all aspects of front-end SWM:

- More attention to better recycling and composting practices at businesses, including non-MSW materials, such as industrial-process waste. Address outdated provisions in state rules and laws that have been encouraging businesses to switch garbage (mixed municipal solid waste, or MMSW) into non-MMSW waste categories that allow cheap dumping into non-MMSW landfills.
- Expand organized collection opportunities for traditional recyclables and organics at curbside, with particular attention to commercial generators.
- Changes to waste disposal fees (e.g. pay-as-you-throw plans and the SWM Tax at the generator level). The goal is to more accurately internalize costs and unfunded risks to the public. Among those currently externalized costs are gas emissions now being vented from some landfills (rather than flared or captured for energy), and long-term post-closure risks.
- Education of the public and those who produce goods and packaging: including product stewardship, reduction, and sustainable design. Barring some significant advance in source reduction or reusability as shown by a peer-reviewed life-cycle study, in general, packaging materials should be designed for recyclability or compostability. These save energy and offer a much higher job-creation potential than direct disposal.
- Better product design is not sufficient; valuable goods and materials must also be captured before discard. Residents need more feedback about good practices, particularly in single-sort systems now prone to high residue fractions. This feedback can and should be benchmarked on real data, such as the statewide waste-composition sort published in 2013, and on periodic waste-composition sorts already being done under permit requirements at WTE plants. If landfills were also to conduct periodic composition sorts of incoming waste like WTE plants now do, decision makers would know whether curbside separation should be supplemented by mechanical sorting of MMSW before burial. Policy option responses to the "uncaptured and valuable materials" problem could include disposal bans on certain materials, and/or recovery targets.

Also, specific to organics:

- Provide a financially viable infrastructure for organics processing, including improved markets and public education. Better economics for expanded organics recovery is important because it won't be possible to reach a combined rate of 75% recycling/organics rate by 2025 without major gains in affordable organics-processing and collection capacity.

Following is a secondary list of implementation mechanisms, depending on progress achieved with the primary methods listed above:

WM-2. Source Reduction:

- Better product design: in general, products with extended usefulness and reparability offer much better greenhouse gas avoidance than recycling after a short useful life. It's important to have more reusability and reparability as well as recycled content into products in the design phase.
- Prevent food waste: Work on preventing food waste using the tools that have been developed by the EPA and the Minnesota resources. Multi-partner effort aimed at both residents and businesses.
- Expand Environmentally-Preferable Purchasing (EPP): Expand local, state and national EPP guidelines to include environmental life-cycle analysis on government purchasing (or at least energy-cycle analysis). Choose products and services that would have large greenhouse gas emission reductions and use the state purchasing contract to request vendors to offer lower-impact goods and services or use best practices. Encourage eligible users to purchase off the state contract.
- Acquire and track information about GHG and waste:
    - Identify consumer products and packaging that have high GHG footprints or that are neither recyclable nor compostable. Share this information with other government, institutions, business entities, and public.
    - MPCA tracks and reports **all** solid waste – including construction, demolition and industrial (CD&I) waste along with MSW. Not counting CD&I excludes approximately 50% of Minnesota's waste (including high-GHG concrete and wood) from consideration and policy option attention.
    - Employ Minnesota Consumption Based Emissions Inventory as a supplement to the conventional "territorial boundary" inventory. By looking beyond the state borders, this will allow for more accurate assessment and understanding of Minnesota-driven GHGs. It will estimate reductions of upstream GHG emissions when goods produced outside of but consumed in Minnesota are source reduced, and upstream benefits of recycling that accrue outside of Minnesota but due to Minnesota's increased recycling.

- Create voluntary initiatives, including increasing consumer education about consumption and waste and working with manufacturers and retailers to change product or packaging. These initiatives would be developed, prioritized, and targeted at products and packaging based on quantities in the waste stream, energy intensiveness of production, and disposal-related emissions.
- Participate in development of international or national product or packaging regulations (based on high footprint priorities) light-weighting of packaging, etc.
- Expand "Green Building" programs.

WM-3 Re-use, Recycling & Composting:

Increase reuse and recycling to limit GHG emissions associated with landfill methane generation, waste combustion, WTE combustion processes, and the extraction of raw materials and energy consumption during the manufacturing process. Mechanisms to achieve the recycling goals include:

- Significantly expand the types of materials collected, to include significant new materials (more types of plastics, mattresses, demolition and construction materials, industrial wastes, etc.) with associated funding for changes in collection infrastructure.
- Expand traditional and nontraditional recycling end markets.
- Assist local governments with organized recycling systems so that there is a clear and standardized list of recyclable materials within a particular community.
- Establish state and national recycled-content requirements.
- Establish state and national "design for recycling" requirements.
- Require up-front processing before disposal.
- Strengthen existing mandatory recycling requirements for all schools and public entities.

Organic Materials Recovery: Increase recycling of organic materials (e.g., lawn and garden, food waste, wood, and non-recyclable paper) to reduce methane emissions associated with landfilling. Mechanisms to achieve the organics goals include:

- For food waste, where possible, prioritize recovery options at the top of the EPA Food Recovery Hierarchy including source reduction, food to people (food recovery) and food-to-livestock.
- Improve measurement of yard waste recycling collections and on-site composting (small site and backyard) composting efforts.

Related Policies/Programs in Place and Recent Actions

Reuse as an Emerging Focus

Reuse, Rental and Repair Economic Analysis: Reuse of secondhand items of all kinds, rental of certain equipment and supplies, and repair services are all part of source reduction. They had never been studied here prior to the MPCA analysis in 2011 that showed that Minnesota's reuse, rental, and repair sector contributes about 46,000 direct jobs and $4 billion to the economy each year. Much of this is through used auto sales and repair, but also important are small reuse, repair, and rental businesses that typically employ one to three people. There were over 15,000 total businesses of this type. This study ignited more promotion of reuse in Minnesota and in many other parts of the country.

In recent years, MPCA has provided grant funding for reuse projects. Funded reuse projects included: determining average weights for common re-used materials, developing a network community for reuse, comparing reusable utensils and bowls in a school cafeteria to disposables, and trying to establish a sustainable system so that universities can capture and re-use off-campus goods (such as couches that would otherwise be disposed between school years).

Following the establishment of ReUseMN, there has been an increased amount of re-used goods exchanged between re-use. ReUseMN is a trade association that allows reuse organizations to network with one another. Through networking many of the organizations have reported an increase in material that they get for reuse. We only have anecdotal information until our data base is established in ReTRAC, which is underway.

Environmental Preferable Purchasing: Better government purchasing practices can reduce environmental impacts: raw materials acquisition, manufacturing, product transportation, and product disposal. MPCA recently completed an EPA-funded project to take the first steps to expand the environmental scope and improve the analysis of our EPP program. As a result of that work, the EPP focus has expanded from office supplies and office paper to include the top impact purchasing categories – fuel, information/communication technologies, food, and construction. These have high climate, ecosystem quality, resource depletion, and water consumption impacts. Now we look not just at a single attribute – like recycled content – but also environmental specifications based on much more sophisticated understanding of what parts of product or service carry the biggest environmental impacts.

A state pilot test of packaging reduction at two state agencies (MPCA and Department of Human Services [DHS]), tested replacement corrugated shipping boxes that are used just once compared to reusable plastic boxes that can be used a hundred times or more. The pilot showed that if fully implemented to state agencies, 52 metric tons of corrugated waste otherwise needing management could be avoided. This single action would reduce over 156 metric tons of GHG, primarily from reduced emissions from replacing the need for 208,000 boxes with only 2,100 plastic totes over a 16-year useful life.

Requirement of source reduction activities in Metro Solid Waste Policy Plans: Metro counties have made commitments to source reduction actions in their plans. Hennepin County has been especially strong in taking action in this area as a result, having documented over 7,000 pounds of household goods repaired at their Fixit Clinics in only about 18 events and partnering with City of Minneapolis and UM on reusing goods left behind by students moving out.

Source Reduction of paper containing priority chemicals: MPCA has undertaken a voluntary campaign to encourage businesses to source reduce receipt papers that contain endocrine active chemicals (BPA and BPS) by switching to electronic/digital receipts.

Recycle More Minnesota Campaign: This is an MPCA campaign to "reinvigorate recycling" and should be funded on a regular basis. Studies have proven that continual education will increase recycling; MPCA intends to increase that rate. Of MSW not recycled, one million tons is potentially recyclable. In fact, this material would have been worth more than $210 million in 2014, had it been separated for recycling. Even a slight increase in the rate would have a significant impact on reducing GHG emissions.

State Agency Recycling: The Minnesota State Resource Recovery Program was eliminated by the Legislature in 2009, and since 2012 recycling data has been collected from state agencies by the MPCA. Reporting for CY2012 data was minimal with 71% of metro area agencies not submitting any data. Data received indicates that only a handful of metro area agencies are meeting the 60% recycling goal. In the 2014 session, the legislature expanded reporting requirements to all agencies statewide. While this will give a better picture of state agency recycling as a whole, it will require additional staffing to meet for data collection needs and to adequately provide support agencies in implementing or improving recycling programs.

Increase Organics Recovery and Utilization: MPCA promotes increased composting of yard waste and other source-separated organics. And the need for better organics capture continues: while a 1991 statute prohibits the disposal of yard waste through landfilling or waste-to-energy, the 2013 waste characterization study found that approximately three percent of trash in Minnesota is yard waste, despite that law.

MPCA has completed updates to rules for source-separated composting facilities in Minnesota, as well as small site composting. Through SCORE, the 2014 Legislature has designated additional funding for organics recycling programs in the metro area.

MPCA is also promoting the collection of restaurant and grocery store waste to be used as food for livestock and other recovery options.

Estimated Policy Impacts

Direct Policy Impacts

Table F-6.6 WM – 2/3 Estimated Net GHG Reductions and Net Costs or Savings

Policy Option	2030 GHG Reductions ($MMtCO_2e$)a	2015 – 2030 Cumulative Reductions (MMtCO2e)[a]	Net Present Value of Societal Costs, 2015 – 2030 ($2014)	Cost Effectiveness ($2014/ tCO_2e)	2015 – 2030 In-state GHG Reductions[b]

WM-2	1.6	9.4	- $228	- $24	- 0.057
WM-3	2.7	27	- $817	- $30	0.15

[a] Reductions represent full energy-cycle reductions.

[b] Net emissions change that can be attributed to in-state policy option effects (meaning a slight net increase in emissions that can be attributed in-state). These in-State effects include lower levels of landfill carbon storage and reduced landfill gas to electricity generation potential.

The analysis of both policy option components found that significant reductions could be achieved by 2030 and on a cumulative basis. The values shown above include full energy-cycle GHG impacts (including upstream GHG emissions within the waste materials). Net societal costs were found to result in net savings, as shown above.

Due to data and modeling limitations, the upstream GHG reductions cannot be attributed to occur within the State. When the upstream GHG reductions are removed from the results, the net GHG impacts are reduced substantially. As shown in the final column above, the overall impacts within the state show slight increases above baseline. This is due to two main influences (as described in more detail below): 1: A lower amount of biogenic carbon storage in landfills; and 2: Lower levels of landfill methane production and subsequent renewable power generation, which offsets grid-based power. It should be noted that this potential increase is only about two percent of the total net GHG benefit for the entire policy option (0.79 MMt/36.2 MMt).

The following definitions should be useful when referring to GHG emissions results for this policy option:

- **Upstream emissions**: Emissions that occur at life-cycle stages prior to use: e.g., raw materials acquisition, manufacturing, and transportation[6].
- **Downstream emissions**: Emissions that occur at life-cycle state after use: e.g., waste management.
- **Total Emissions:** Are the sum of both up and downstream emissions.
- **In-State Emissions:** Are downstream emissions minus the waste management of MSW exported out-of-state.

Data Sources

MPCA's BAU GHG I&F with associated data on historic waste management practices; additional Minnesota data on historic recycling and organics management provided by MPCA. Data on presumed waste compositions of waste managed by each method (source reduced composition, composting composition, recycled composition, etc.), EPA's Landfill Gas Emissions Model (LandGEM) for estimating avoided landfill methane emissions (need data or assumptions

[6] http://epa.gov/epawaste/conserve/tools/warm/pdfs/warm-definitions-and-acronyms.pdf.

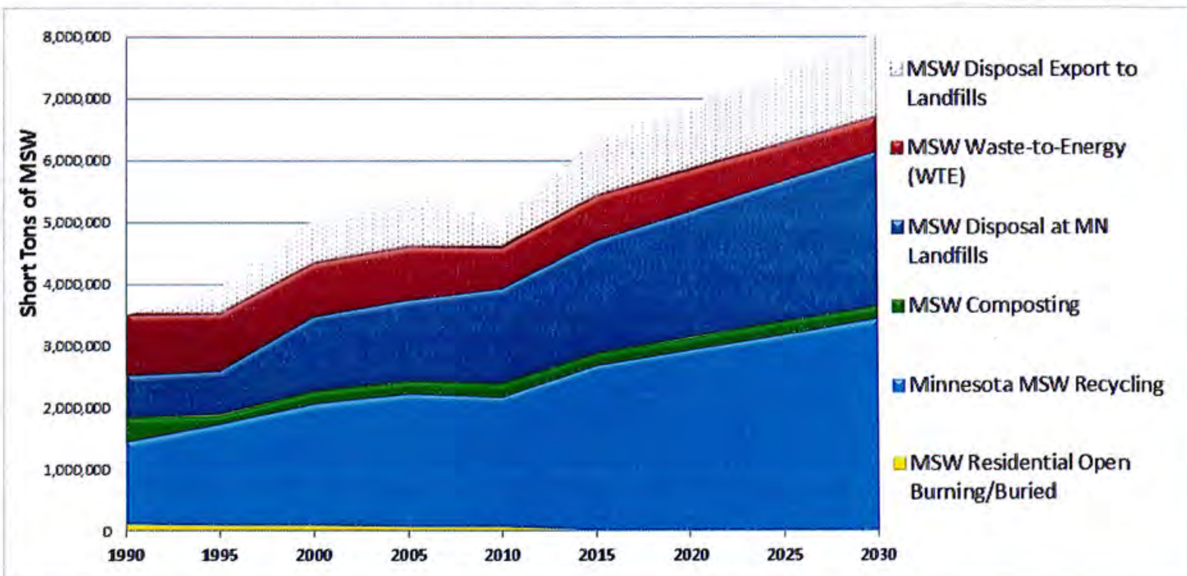
on BAU levels of landfill gas management for active Minnesota landfills); EPA's Waste Reduction Model (WARM) for estimating upstream emissions for waste materials, fuel consumption for waste collection and waste management at the landfill site; International Panel on Climate Change (IPCC) Waste Modeling tool to calculate landfill carbon storage; and other literature data for costs associated with composting operations and source reduction programs.

Quantification Methods

Net GHG & Energy Impacts:

Center for Climate Strategies (CCS) first developed a Solid Waste Management Profile (SWMP) to serve as a baseline of the state's management methods and to serve as a primary input to estimating emission reductions for each management method, including a reduction in waste generation. The SWMP is shown in the figure below. It covers residential open burning, recycling, composting, landfill emplacement, waste-to-energy combustion, and MSW that is managed and exported out of the state.

Figure F-6.25 Minnesota State-Wide Solid Waste Management Profile (1990-2030)



WM-2: Source Reduction

Using the SWMP, CCS developed a baseline of per capita waste generation. The baseline per capita waste generation is expected to increase 1.2% annually over the planning period. To achieve the policy option scenario (PS) goal, per capita waste generation will stabilize at 1.46%, which is the BAU per capita waste generation rate in 2019. Between years 2015-2019, a small linear decrease in the per capita waste generation rate will occur via policy option implementation. Beginning in 2020, a linear decrease in per capita waste generation will occur until 2025 is reached, when the three percent reduction in per capita waste generation goal is achieved. The table below outlines the BAU and Policy Option Scenario per capita waste generation rates and the total amount of MSW generated, reduced due to source reduction, and the total policy option scenario landfilled material amount.

Table F-6.7 BAU and Policy Option Scenario MSW Generation

Item	2015	2017	2020	2025	2030
Per Capita Generation (BAU): short tons/capita	1.37	1.41	1.48	1.58	1.65
Per Capita Generation (PS): short tons/capita	1.37	1.41	1.46	1.43	1.43
Total MSW Generation (BAU): short tons	7,541,463	7,880,509	8,389,077	9,252,691	9,886,565
Total MSW Generation (PS): short tons	7,541,463	7,840,586	8,289,270	8,337,392	8,538,607
Total MSW Reduction (PS minus BAU): short tons	0	-39,923	-99,808	-915,299	-1,347,957
Landfilled Material (Goal): short tons	3,411,495	3,592,106	3,863,024	3,598,869	3,717,546

To determine the GHG impact of the policy option, CCS used several resources and input assumptions to calculate the total GHG reductions. For both WM-2A and 2B, CCS used EPA's WARM model.[7] WARM allows the user to input a BAU scenario and a Policy Option Scenario waste stream. WARM then provides a combination of upstream and downstream emissions. To break-out the upstream from the downstream emissions, CCS calculated an amount of emissions that are associated with upstream emissions from the WARM Landfilling Chapter methodology.[8] CCS calculated a total of 2.6 metric tons (t) of upstream CO_2e is reduced from each ton of source reduced MSW. This value is based upon an assumption that all waste materials will be source reduced at the levels they are found in the waste composition profile used for this study (i.e. no materials are reduced at a higher rate than others). That composition is shown in the table below.

Table F-6.8 WARM Inputs for 2017 and 2025

WARM Entry (t MSW)	2017			2025			
	Total BAU	Total Goal	Source Red.	WARM Entry	Total BAU	Total Goal	Source Red.
Aluminum Cans	115,365	114,097	1,268	143,249	114,295	28,954	143,249
Steel Cans	73,414	72,607	807	91,158	72,733	18,425	91,158
Copper Wire	6,960	6,883	76	8,425	6,867	1,558	8,425
Glass	95,694	94,642	1,052	118,938	94,822	24,116	118,938
HDPE	80,043	79,163	880	99,486	79,314	20,172	99,486
LDPE	487,536	482,177	5,359	605,958	483,093	122,865	605,958
PET	94,597	93,557	1,040	117,574	93,734	23,839	117,574

[7] http://epa.gov/epawaste/conserve/tools/warm/Warm_Form.html (CCS used the downloaded version)

[8] http://epa.gov/epawaste/conserve/tools/warm/pdfs/Landfilling.pdf

PP	43,660	43,180	480	54,265	43,262	11,003	54,265
PS	72,767	71,967	800	90,441	72,103	18,338	90,441
Corrugated Containers	581,554	575,161	6,392	722,812	576,254	146,558	722,812
Magazines/ Third-class Mail	101,772	100,653	1,119	126,492	100,844	25,648	126,492
Newspaper	203,544	201,306	2,237	252,984	201,689	51,295	252,984
Office Paper	159,927	158,169	1,758	198,773	158,470	40,304	198,773
Phonebooks	14,539	14,379	160	18,070	14,406	3,664	18,070
Dimensional Lumber	292,243	289,030	3,212	363,228	289,579	73,649	363,228
Food Waste (non-meat)	912,618	902,586	10,031	1,134,290	904,300	229,990	1,134,290
Yard Trimmings	143,558	141,980	1,578	178,428	142,249	36,178	178,428
Carpet	100,044	98,944	1,100	124,344	99,132	25,212	124,344
Personal Computers	52,197	51,623	574	64,875	51,721	13,154	64,875
Totals	**3,632,029**	**3,592,106**	**39,923**	**4,513,792**	**3,598,869**	**914,923**	**4,513,792**

Once the upstream emissions were calculated, CCS then calculated the downstream emissions. The downstream emissions include landfill methane (CH_4) that is not captured, flared, combusted in landfill gas to energy (LFGTE) equipment, or oxidized in the soil; diesel fuel emissions, including vehicles used for curb side pick-up and vehicles used to move MSW once it reaches the landfill; landfill biogenic carbon storage; and grid offset emissions from the reduced landfill gas (LFG) generation and subsequent reduced renewable energy generation.

To calculate the total amount of landfill gas that is emitted from landfilled waste, CCS input the total amount of MSW emplaced into landfills for both the BAU and Policy Option Scenario into EPA's LandGEM.[9] LandGEM provides the user with the total amount of CH_4 generated from a landfill without controls or applying the standard ten percent oxidation factor.[10]

In Minnesota's waste management forecast excel file provided to CCS,[11] Minnesota provides the waste baseline assumptions for waste sent to landfills with no controls, landfills with flaring technology, and LFGTE. Below are the percentages used for each type of landfill:

Table F-6.9 Percent of Future Waste Emplacement into Landfills

Landfill Emplacement into uncontrolled landfills	21%
Landfill Emplacement into flared landfills	31%

[9] http://www.epa.gov/nrmrl/appcd/combustion/cec_models_dbases.html

[10] http://epa.gov/epawaste/conserve/tools/warm/pdfs/Landfilling.pdf. The 10% factor addresses methane that is typically oxidized to CO_2 as it migrates through the surface layers of the landfill.

[11] Uploaded to CCS' online workspace by Peter Ciborowski, MPCA, on March 11, 2015.

Landfill Emplacement into LFGTE controlled landfills	48%

Using the above percentages, CCS applied these and the ten percent oxidation factor to determine the total amount of landfill CH_4 that is not captured, flared, or oxidized. Below are the total metric tons of CO_2e emitted from the BAU and policy option scenario landfill MSW emplacement. Landfill GHG reductions account for the majority of CO_2e reductions under the policy option scenario.

Table F-6.10 Percent of Future Waste Emplacement into Landfills

Year	BAU	Policy Option Scenario
	CH_4 Emissions (tCO_2e)	CH_4 Emissions (tCO_2e)
2016	45,584	45,584
2020	222,338	190,861
2025	421,749	296,351
2030	575,355	332,656
2016 - 2030	**4,979,144**	**3,509,149**

The second source of CO_2e emission reductions under this policy option scenario are those associated with transportation. EPA's WARM model assigns an emission factor to both emissions from vehicles that perform curbside pick-up and vehicles that move the MSW once it arrives at the landfill.

Table F-6.11 Refuse Collection Emission Factors

Fuel Combustion Source	Diesel Fuel gallons/ 10^3 lbs Landfilled	TJ Diesel/ t waste
Collection Vehicles	0.90	0.00027
Landfill Site Fuel Use	0.04	0.000012

Removing MSW from the landfill also results in CO_2e emissions to increase on an indirect basis. Sources of CO_2e include biogenic landfill carbon storage and offset grid emissions from the reduced LFG available to convert into electricity. The lost renewable generation capacity will need to be made up from the local grid. Per the CSEO project determinations of the make-up of the marginal resource mix, this lost capacity will need to be made up from a combination of natural gas and coal-fired resources.[12]

Landfill biogenic carbon storage was included in the downstream emissions to account for the biogenic carbon that is stored long-term in landfills. According to the IPCC waste modeling

[12] The carbon intensity of the CSEO marginal resource mix ranges from 0.936 tCO_2e/MWh in 2015 to 0.758 tCO_2e/MWh in 2030 (lower future intensity driven by higher amounts of natural gas generation in the future marginal resource mix relative to coal).

methodology, an estimated amount of 50% of all biogenic carbon that is emplaced in a landfill is stored over many decades.[13] To determine the total amount of actual biogenic carbon stored in the landfill, CCS used an average value for fraction of degradable organic carbon (DOC) from IPCC's waste model.[14] CCS split food/yard/other MSW apart from paper and wood because of their vastly different DOC fractions. After determining the amount of DOC for each year, that value was multiplied by 0.5 to determine the amount of biogenic carbon stored.

Table F-6.12 . DOC Values for IPCC's Waste Model

Food/Yard/Other	0.175
Paper and Wood	0.415

A certain percentage of the landfilled material will be emplaced into landfills that have LFGTE technologies. These landfills capture the CH_4 emissions from the landfill and convert the CH_4 into electricity that offsets power from the grid. When the LFGTE landfill emplacement rates are reduced, these landfills will produce less CH_4. The lost renewable energy that results will require an increase in generation from plants that supply the grid. CCS refers to the associated emissions from grid resources as "lost grid offsets". These are summarized in the table below.

Table F-6.13 Lost Grid Offsets

Year	BAU		Policy Option Scenario		
	Power Produced by LFGTE	Offset Grid Emissions from LFGTE	Power Produced by LFGTE	Offset Grid Emissions from LFGTE	Lost Grid Offsets
	MWh	$MMtCO_2e$	MWh	$MMtCO_2e$	$MMtCO_2e$
2016	12,354	(0.011)	3,014	(0.0028)	0.0090
2020	60,258	(0.054)	12,621	(0.011)	0.043
2025	114,303	(0.094)	19,597	(0.016)	0.078
2030	155,933	(0.12)	21,998	(0.017)	0.10
2016 - 2030	**1,349,449**	**(1.11)**	**232,056**	**(0.19)**	**0.92**

Table F-6.14 Total GHG Emissions Change

Year	In-State Reductions	Upstream (Out of State) Reductions	Total
	$MMtCO_2e$		

[13] http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_3_Ch3_SWDS.pdf

[14] http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol5.html

2015	(0.0071)	0.0000	(0.0071)
2016	0.028	(0.27)	(0.25)
2017	0.055	(0.53)	(0.48)
2018	0.079	(0.83)	(0.75)
2019	0.10	(1.2)	(1.1)
2020	0.11	(1.4)	(1.3)
2021	0.10	(1.6)	(1.5)
2022	0.097	(1.8)	(1.7)
2023	0.087	(2.0)	(2.0)
2024	0.073	(2.3)	(2.2)
2025	0.054	(2.5)	(2.4)
2026	0.025	(2.7)	(2.6)
2027	(0.022)	(2.6)	(2.7)
2028	(0.067)	(2.6)	(2.7)
2029	(0.11)	(2.6)	(2.7)
2030	(0.15)	(2.6)	(2.7)
Total	**0.45**	**(27)**	**(27)**

The sum of the in-state and out-of-state (upstream) emission reductions is 9.2 $MMtCO_2e$. The total out-of-state CO_2e emission reductions are 9.3 $MMtCO_2e$, and the total amount of emissions associated with in-state activity slightly increases CO_2e emissions by 0.13 $MMtCO_2e$. The increase of emissions is a result of two factors: the lower amount of biogenic carbon storage in landfills; and the grid offset CO_2e emissions. The sum of these two factors is slightly greater than the amount of methane reduction at landfill sites. However, the net result of the policy option shows significant GHG reduction potential when the complete energy-cycle results are included (i.e. both upstream and downstream GHGs associated with production of waste materials and their subsequent management via the waste stream).

Net Cost Results:

The costs associated with WM-3A are driven by landfill tipping fees (used as a proxy for estimating total waste management system costs via landfilling), diesel fuel costs, and the program implementation costs. To calculate BAU landfilling costs, CCS used an average landfill tipping fee provided by MPCA.[15] Total annual landfilled MSW under both BAU and PS were multiplied by the average landfill tipping fee to estimate the total landfilling costs. Since the total amount of landfilled material under the BAU scenario is greater than under the policy option scenario, the net cost is a cost savings.

Table F-6.15 Cost of Landfill

Year	Landfilling Costs	Landfilling Costs	Net Source Reduction Landfilling Costs Savings
	MM$	MM$	MM$
2016	$ 107	$ 106	$ (0.52)

[15] Provided by J. Chiles, MPCA to L. Bauer, CCS, August, 2014

2020	$ 120	$ 118	$ (2.5)
2025	$ 139	$ 112	$ (27)
2030	$ 158	$ 117	$ (41)
2016 - 2030	**$ 2,078**	**$ 1,839**	**$ (239)**

CCS also separately calculated the costs associated with diesel fuel use. The total amount of diesel fuel consumed is described above. The cost in each year was calculated using the CSEO project fuel price forecast used across all sectors and policy options. Since the total amount of landfilled MSW is reduced in the policy option scenario, then that directly translates into lower PS fuel costs for collecting and managing the MSW at the landfill site. The diesel fuel costs were subtracted out of the total landfilling costs (with the assumption that these would already be accounted for in the tipping fees).

Table F-6.16 Diesel Fuel Costs

Year	Diesel Fuel Costs	Diesel Fuel Costs	Net Diesel Fuel Cost Savings
	MM$	MM$	MM$
2016	$ 12.9	$ 12.7	$ (0.16)
2020	$ 15.0	$ 14.1	$ (0.88)
2025	$ 18.0	$ 13.4	$ (4.6)
2030	$ 21.0	$ 14.0	$ (6.9)
2016 - 2030	**$ 265**	**$ 220**	**$ (45)**

The final cost piece was the source reduction program costs. These are the costs associated with implementing the program each year (by state and local agencies). CCS used a study developed by the Bio Intelligence Service under the European Union (EU).[16] The EU study targets food waste source reduction. The program costs are associated with a waste reporting program to encourage legislation and behavioral changes. The annual cost to implement the source reduction program was estimated to be $3.9 million. CCS applied a 2% annual escalation to the $3.9 million annual costs each year to account for program cost increases. Total net societal costs are shown below. These total a net savings of $283 million (in $2014) with a cost effectiveness of $-17/t$CO_2$e.

Table F-6.17 Source Reduction Program Costs

Year	Net Source Reduction Landfilling Costs	Net Diesel Fuel Costs	Program Costs	Total Policy Option Cost	Total Discounted Policy Option Cost	Cost Effectiveness

[16] http://www.biois.com/en/menu-en/expertise-en/assess/highlights-a/ec-preparatory-study-on-food-waste-eu27.html.

	MM$	MM$	MM$	MM$	MM$2014	$2014/tCO₂e
2016	$ (0.52)	$ (0.16)	4.0	$ 3.4	$ (0.7)	
2020	$ (2.5)	$ (0.88)	4.4	$ 0.97	$ (3.4)	
2025	$ (27)	$ (4.6)	4.8	$ (27)	$ (32)	
2030	$ (41)	$ (6.9)	5.3	$ (42)	$ (48)	
2016 - 2030	**$ (239)**	**$ (45)**	**74**	**$ (209)**	**$ (283)**	**$ (17)**

WM-3: 75% Recycling Goal:

CCS used the policy option scenario results from WM-2 to create a revised set of WM-3 BAU values for landfill waste emplacement. The BAU upstream emissions (mainly out-of-state emissions) were calculated using the same WARM output based emission factors as in WM-2. The downstream GHG emissions include: landfill methane not captured, flared, or oxidized; nitrous oxide (N_2O) and CH_4 emissions from composting; biogenic carbon stored long term in landfills; and grid offset emissions associated with the reduction in landfill CH_4 generation.

The BAU landfill CH_4 emissions for WM-3 were taken from the WM-2 policy option scenario results. The policy option scenario LFG results were derived from using EPA's LandGEM model. Below are the input data to LandGEM.

Table F-6.18 Data Used in LandGEM Model

Year	BAU Landfilled MSW	PS Landfilled MSW	BAU Landfill CH_4 Emissions	PS Landfill CH_4 Emissions
	MMt	MMt	$MMtCO_2e$	$MMtCO_2e$
2016	1.9	1.8	0.025	0.025
2020	2.1	1.4	0.12	0.10
2025	2.0	0.80	0.23	0.16
2030	2.1	0.84	0.33	0.19
2016 - 2030	**33**	**20**	**2.8**	**1.9**

Below are the total landfill Gas Emissions outputs from LandGEM accounting for capture, flaring, and oxidation.

Table F-6.19 Landfill Gas Emissions Calculated from LandGEM Model

Year	BAU Landfill CH_4 Emissions	Policy Option Scenario Landfill CH_4 Emissions
	$MMtCO_2e$	$MMtCO_2e$
2016	0.025	0.025
2020	0.12	0.10

2025	0.23	0.16
2030	0.33	0.19
2016 - 2030	**2.8**	**1.9**

CCS also quantified the total amount of CO_2e emissions from composted material. To quantify the amount of CO_2e emission from composting, CCS used the emission factors below:[17]

Table F-6.20 Compost Emission Factors

CH_4 Emission Composting Factor (tCH_4/t compost)	7.89×10^{-4}
N_2O Emission Composting Factor (tN_2O/t compost)	4.74×10^{-5}

The table below provides the estimated GHG emissions for increased composting activity under the policy option scenario.

Table F-6.210 Estimated GHG Emissions from WM-3

Year	BAU Composted Material	PS Composted Material	BAU Composting CH_4 & N_2O Emissions	PS Composting CH_4 & N_2O Emissions
	MMt	MMt	$MMtCO_2e$	$MMtCO_2e$
2016	0.11	0.11	0.004	0.004
2020	0.11	0.37	0.004	0.010
2025	0.12	0.57	0.004	0.014
2030	0.12	0.60	0.004	0.020
2016 - 2030	**1.8**	**6.8**	**.047**	**0.23**

Landfilled biogenic carbon storage was quantified using the same methodology as in WM-2.

Table F-6.221 Landfilled Biogenic Carbon Storage

Year	BAU Scenario		Policy Option Scenario	
	Landfill Carbon Storage (Food/Yard Waste/Other Organics)	Landfill Carbon Storage (Wood and Paper Products)	Landfill Carbon Storage (Food/Yard Waste/Other Organics)	Landfill Carbon Storage (Wood and Paper Products)

[17] UNFCCC. 2005. "Approved Baseline Methodology AM0025; Avoided emissions from organic waste composting at landfill sites." Available at: http://cdm.unfccc.int/EB/021/eb21repan15.pdf.

	$MMtCO_2e$	$MMtCO_2e$	$MMtCO_2e$	$MMtCO_2e$
2015	(0.042)	(0.12)	(0.042)	(0.12)
2020	(0.048)	(0.13)	(0.033)	(0.09)
2025	(0.045)	(0.12)	(0.018)	(0.05)
2030	(0.048)	(0.13)	(0.019)	(0.05)
2016 - 2030	**(0.75)**	**(2.1)**	**(0.45)**	**(1.3)**

The final piece of the in-state net GHG emissions impact analysis is the lost grid offset from the reduction in landfill gas generation. Again, the reduction in waste emplaced into the landfills, specifically those that capture CH_4 for electricity generation, creates less CH_4 for collection and LFGTE. The power not produced due to lower levels of CH_4 generation will need to be offset by grid-based power. These impacts are summarized below:

Table F-6.232 Lost Grid Offset for Landfill Gas Generation

Year	BAU		Policy Option Scenario	
	Power Produced from LFGTE (MWh)	Offset Grid Emissions from LFGTE Power ($MMtCO_2e$)	Power Produced from LFGTE (MWh)	Offset Grid Emissions from LFGTE Power ($MMtCO_2e$)
2016	4,321	(0.0040)	4,321	(0.0040)
2020	21,223	(0.019)	18,219	(0.016)
2025	40,884	(0.034)	28,728	(0.024)
2030	56,799	(0.043)	32,840	(0.025)
2016 - 2030	**483,375**	**(0.40)**	**340,064**	**(0.28)**

Total net CO_2e emission results for downstream sources (in-state) and upstream sources (out-of-state) are shown below. The in-state totals assume that all landfill diversion is occurring from landfills within the state. As shown in the SWMP figure above, Minnesota exports a fair amount of waste for landfilling. Therefore, there is potential for some of the downstream reductions to actually occur out of state. Similar to the results for WM-2, the net results show that due to lower renewable energy output and lower biogenic carbon storage, the in-state portion of the results is a net increase over BAU. However, overall, just as with WM-2, the policy option is shown to result in substantial GHG reductions due to the large upstream emissions reduction potential which far outweighs any downstream impacts.

Table F-6.243 Summary of GHG Emissions Reductions

Year	Total Out-of-State Emissions	Total In-State	Total
	$MMtCO_2e$	$MMtCO_2e$	$MMtCO_2e$
2015	-	0.000	0.00
2016	(0.27)	0.022	(0.24)
2017	(0.52)	0.042	(0.48)
2018	(0.81)	0.064	(0.75)

2019	(1.1)	0.088	(1.06)
2020	(1.4)	0.10	(1.3)
2021	(1.6)	0.11	(1.5)
2022	(1.8)	0.12	(1.7)
2023	(2.0)	0.13	(1.9)
2024	(2.2)	0.14	(2.1)
2025	(2.5)	0.15	(2.3)
2026	(2.7)	0.15	(2.5)
2027	(2.6)	0.14	(2.5)
2028	(2.6)	0.13	(2.5)
2029	(2.6)	0.11	(2.5)
2030	(2.6)	0.10	(2.5)
2015 - 2030	(27)	1.6	(26)

Net Societal Cost Analysis:

Like in WM-2, CCS used tipping fees to calculate the BAU and policy option scenario costs for landfilled, composted, and recycled material (as proxies for the total levelized costs for constructing and operating these differing waste management systems). The tipping fees were average values derived from data provided by MPCA.

Table F-6.254 Landfill Tipping Fees

Landfilling Tip Fee Average ($/t MSW):	$ 62.53
Composting Tip Fee Average ($/t MSW):	$ 46.81
Recycling Tip Fee Average ($/t MSW):	$ 61.30

The cost results for BAU and policy option scenario are outlined below:

Table F-6.265 WM-3 Cost Results

Year	BAU Landfilling Costs	BAU Composting & Recycling Tipping Fees	PS Landfilling Costs	PS Composting & Recycling Tipping Fees
	MM$	MM$	MM$	MM$
2015	$ 116	$ 110	$ 116	$ 110
2020	$ 132	$123	$ 90	$ 161
2025	$ 125	$ 138	$ 50	$ 204
2030	$ 131	$143	$ 52	$ 213
2015 - 2030	**$ 2,062**	**$ 86**	**$ 1,227**	**$ 2,794**

Under the policy option scenario, additional composting facilities will be constructed. MPCA recommended that CCS model an Aerated Static Pile composting facility.[18] According to guidance from MPCA, no additional materials recover facilities (MRF) will be needed under the policy option scenario.[19] Below are the capital and O&M costs associated with the construction of composting facilities. Total capital costs were spread evenly across the planning period. Capital costs for these facilities were estimated assuming 100% financing at 5% over 10 years.

Table F-6.276 Capital Costs of Composting

Year	Composting Operating Costs	Composting Capital Costs	Annualized Capital Costs
	MM$	MM$	MM$
2015	$ 124	$ 1.7	0.22
2020	$ 176	$ 1.7	1.3
2025	$ 221	$ 1.7	2.4
2030	$ 230	$ 1.7	2.4
2015 - 2030	**$ 3,042**	**$ 22**	**26**

To calculate the capital and O&M costs above for composting facilities, CCS used the below factors:

Table F-6.287 Cost Factors for Capital Cost Calculation

Capital Cost to Construct Composting Facility ($/t Compost)[20]	$ 52.10
Composting Operation Costs ($/t Compost)[21]	$ 30.62

CCS also calculated the average commodity value for recycling and composted material. The values for the recycling commodity values were provided by MPCA.

Table F-6.298 Commodity Values of Compost

Average Recycling Commodity Value $/t Compost[22]	$ 317
Average Composting Commodity Value $/t Compost[23]	$ 33

[18] http://www.compost.org/pdf/compost_proc_tech_eng.pdf, provided my Jim Chiles, MPCA

[19] J. Chiles MPCA (Personal Communication) to L. Bauer, CCS, August 2014

[20] http://www.compost.org/pdf/compost_proc_tech_eng.pdf

[21] http://www.compost.org/pdf/compost_proc_tech_eng.pdf

[22] Values provided by J. Chiles on July 21, 2014

[23] http://www.co.olmsted.mn.us/environmentalresources/garbagerecycling/compostsite/Pages/default.aspx

Below are the calculated commodity values for the BAU and Policy Option Scenario.

Table F-6.29 Calculated Commodity Values for Compost

Year	BAU Recycling & Composting Commodity Value	PS Recycling & Composting Commodity Value
	MM$	MM$
2015	($ 497)	($ 497)
2020	($ 558)	($ 686)
2025	($ 624)	($ 852)
2030	($ 647)	($ 888)
2015 - 2030	**($ 9,341)**	**($ 11,833)**

Below are the net costs of the policy option. Net societal results indicate a net savings. The net present value of policy option costs is -$860 million (in $2014). Cost effectiveness is -$32/t$CO_2$e reduced:

Table F-6.30 Net Costs of Policy Option

Year	Total Policy Option Cost	Total Discounted Policy Option Cost	Cost Effectiveness
	MM$	MM$2014	tCO_2e
2015	$4	$0.0	
2016	$3	($1.2)	
2017	$2	($2.5)	
2018	$0	($3.7)	
2019	($1)	($5.0)	
2020	($2)	($6.2)	
2021	($3)	($7.9)	
2022	($13)	($17)	
2023	($22)	($27)	
2024	($31)	($36)	
2025	($52)	($57)	
2026	($48)	($53)	
2027	($56)	($61)	
2028	($63)	($69)	
2029	($71)	($76)	
2030	($79)	($84)	
Totals	**($434)**	**($508)**	**($54)**

Notes:

Each policy option analysis was done over a fifteen-year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

Macroeconomic (Indirect) Impacts for WM-2 and WM-3

WM-2 Policy

Table F-6.31 WM-2 Macroeconomic Impacts on GSP, Employment and Income

Scenario	GSP ($2015 MM)			Employment (Individual)			Personal Income ($2015 MM)		
	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)
WM-2	$6	$2	$31	150	60	930	$13	$5	$72

What follows are graphs that show expected changes in GSP, employment and personal income as a results of WM-2 policy implementation.

Figure F-6.26 WM-2 GSP Impacts ($2015 MM)

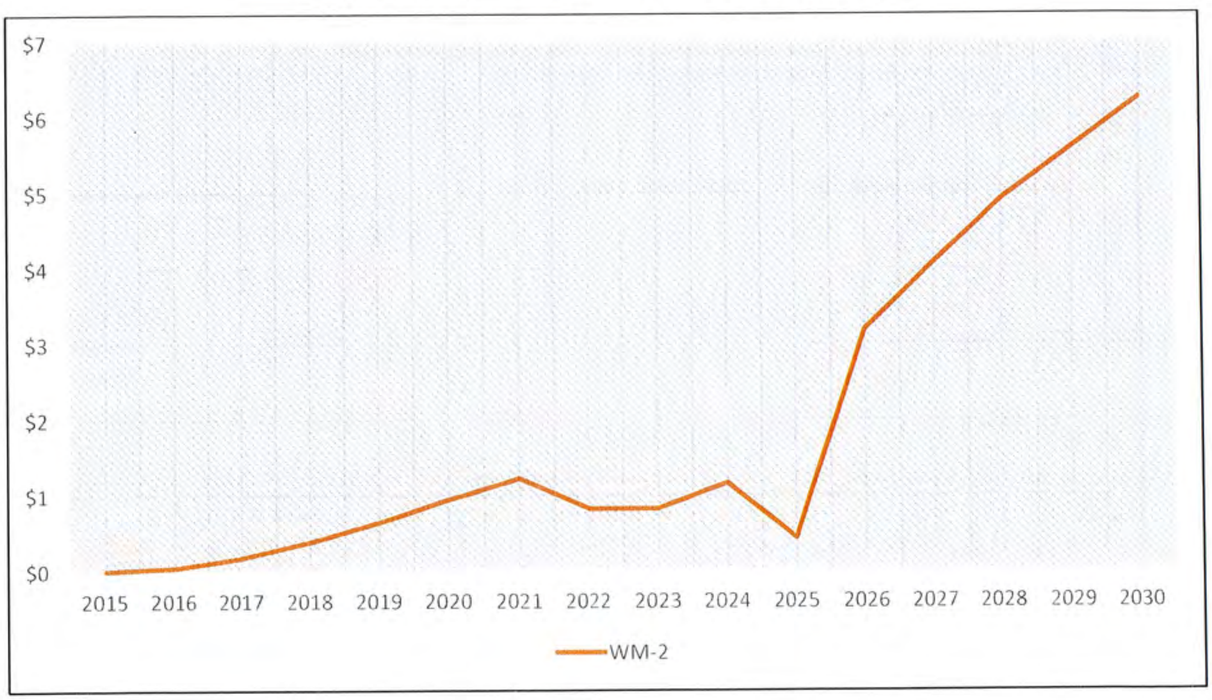


Figure F-6.27 WM-2 Employment Impacts (Individual Jobs)

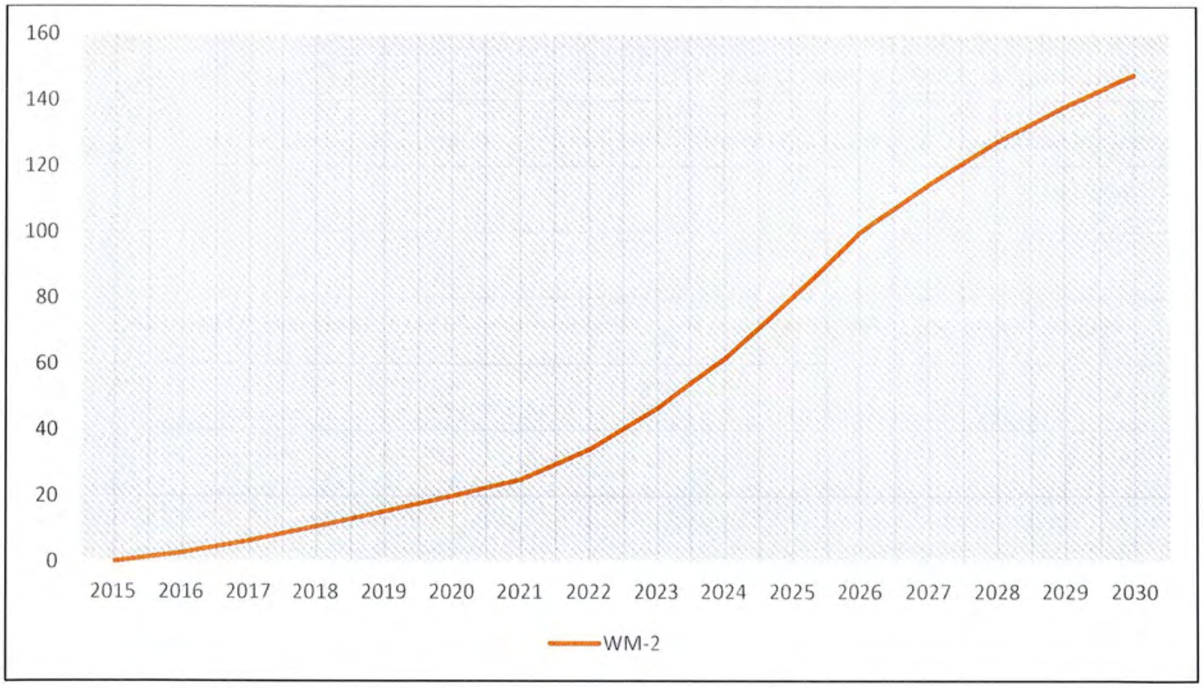
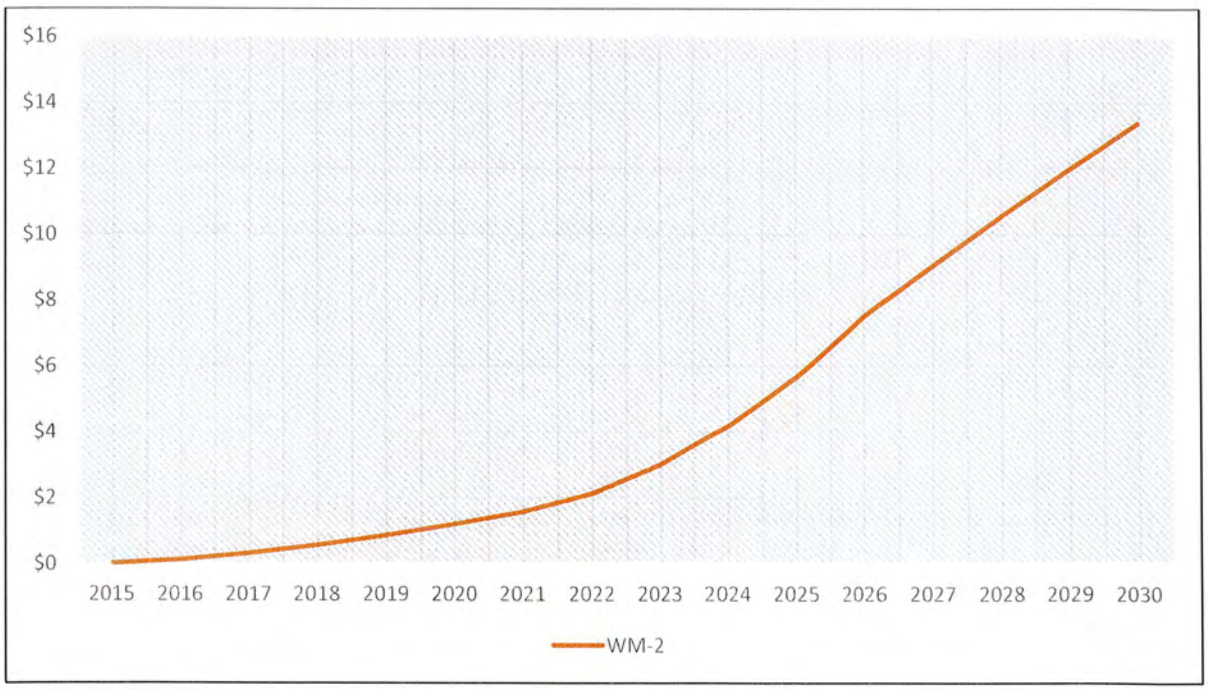
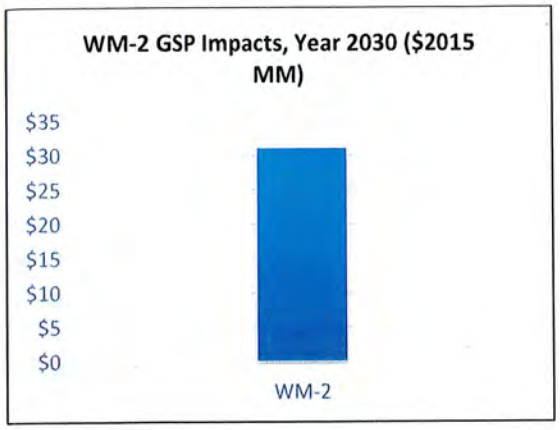
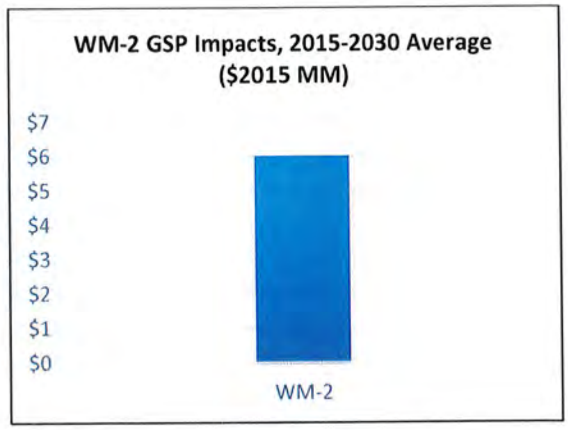


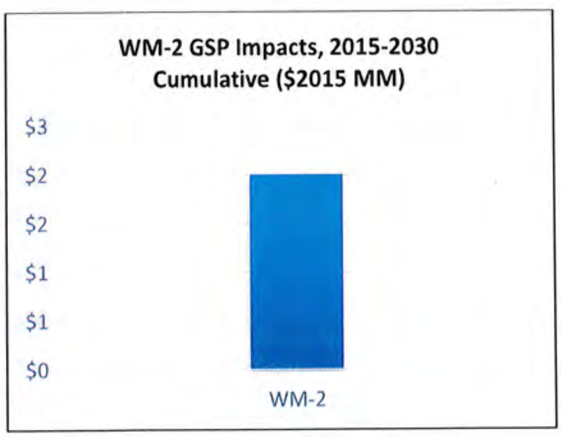
Figure F-6.28 WM-2 Income Impacts ($2015 MM)

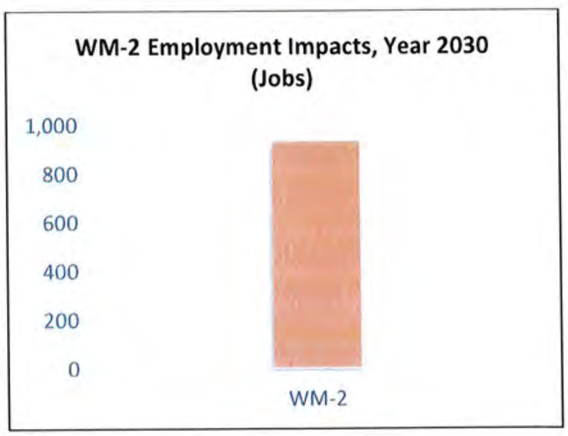


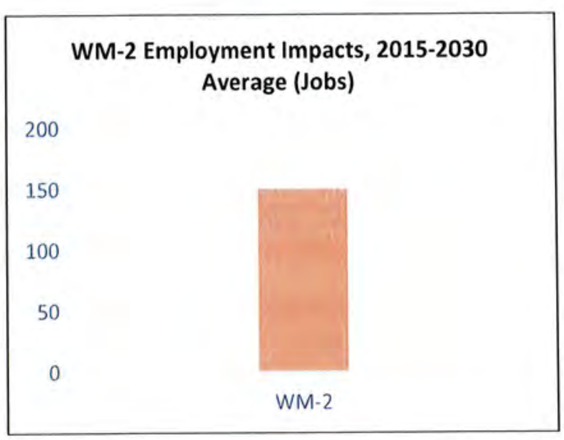
Graphs below show WM-2 macroeconomic impacts on GSP, personal income, and employment in the final year (2030), average (2015-2030) and cumulative (2015-2030).











Principal Drivers of Macroeconomic Changes

Similar to WM-1, WM-2 policy shows slight positive impacts. The net savings to the government to carry out water treatment expands its ability to spend in other programs, though the volumes of spending changes are very small. GSP and incomes are never forecast by this analysis to vary more than a few million dollars statewide, and total employment never more than 100 total positions.

This is the result of a balancing upward pressure from the additional spending power of homes and businesses as they reduce their spending on waste management and the reduction in scale of the waste management sector itself. Other sectors see slight gains while waste management and the sectors that support it see slight losses.

WM-3 Policy

Table F-6.302 WM-3 Macroeconomic Impacts on GSP, Employment and Income

Scenario	GSP ($2015 MM)			Employment (Individual)			Personal Income ($2015 MM)		
	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)
WM-3	$240	$203	$3,039	3,290	2,750	41,210	$319	$223	$3,338

Graphs below show expected temporal changes in GSP, employment and personal income as a result of the WM-3 policy implementation.

Figure F-6.29 WM-3 GSP Impacts ($2015 MM)

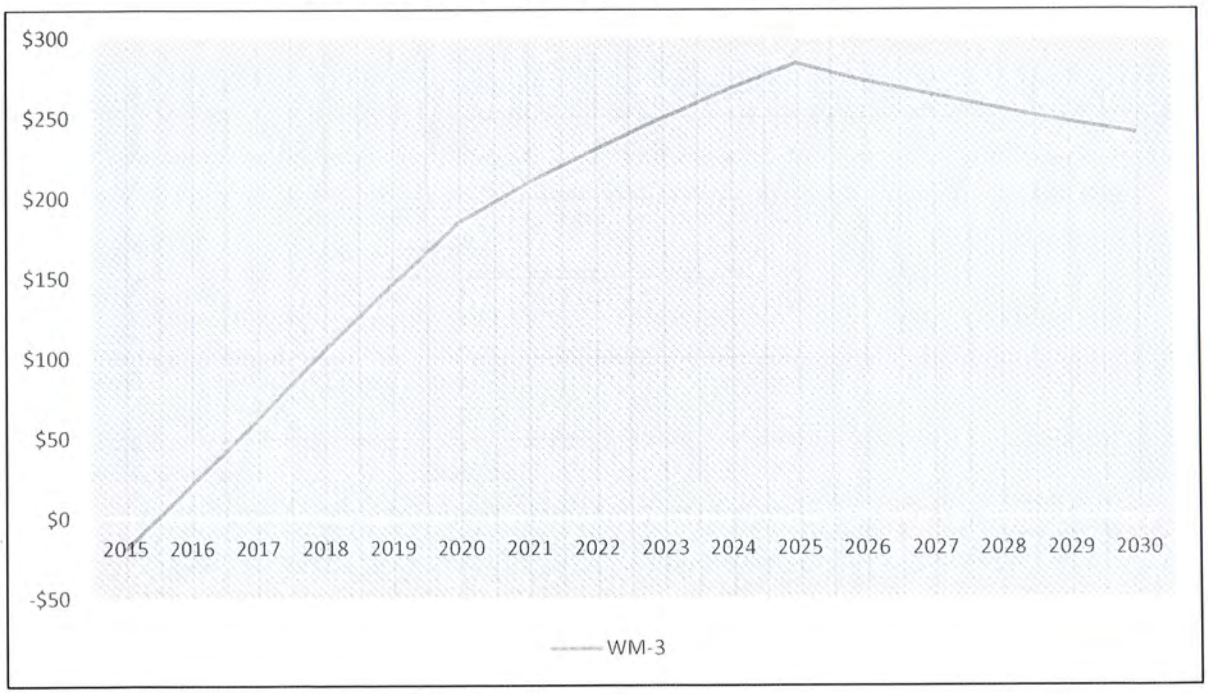


Figure F-6.30 WM-3 Employment Impacts (Individual Jobs)

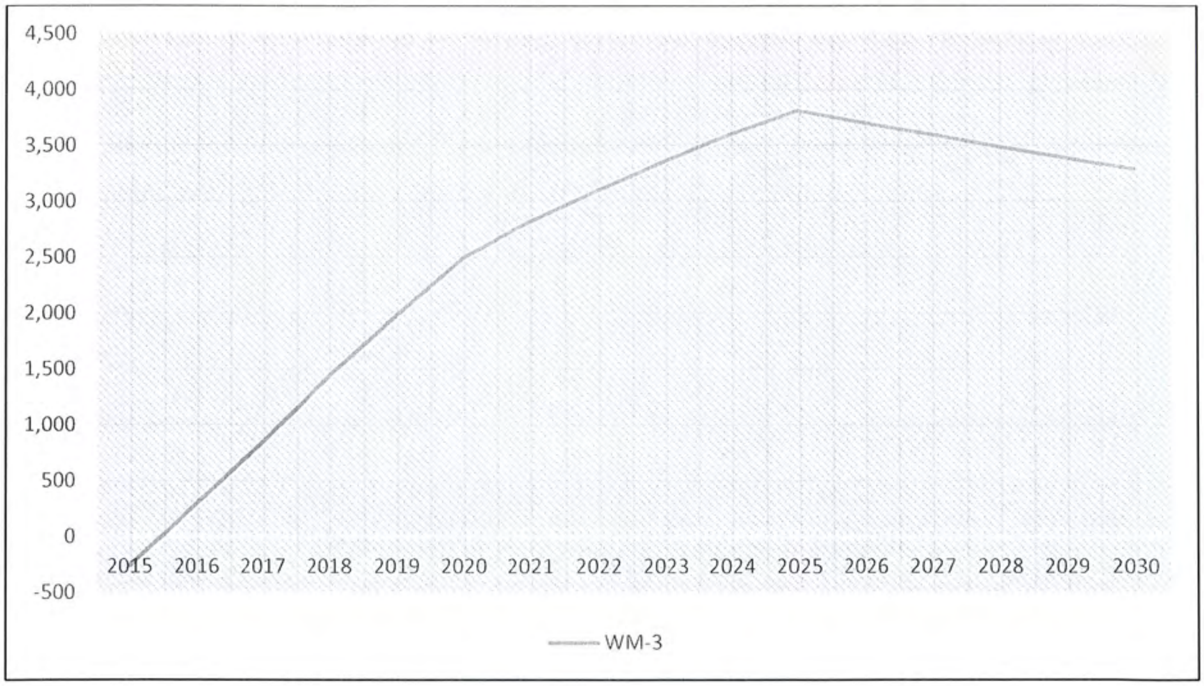
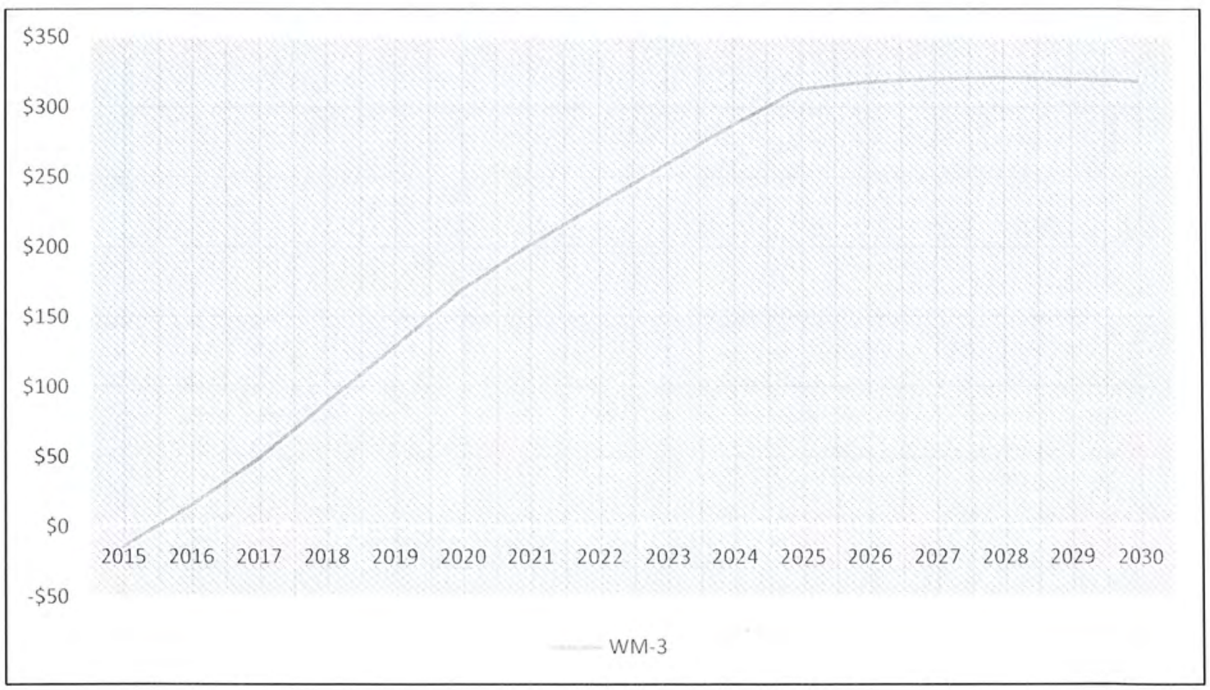
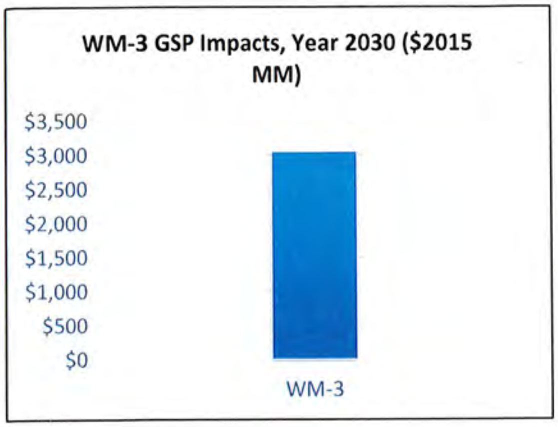
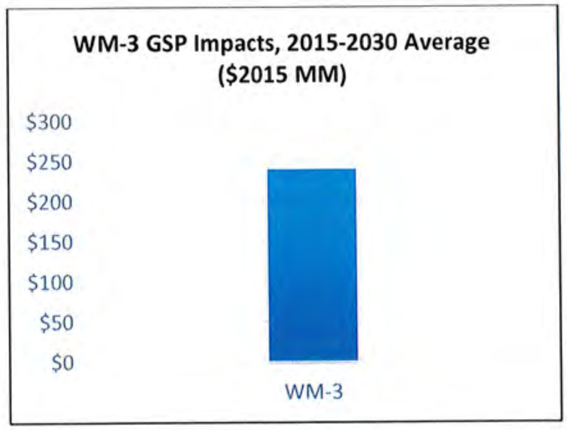
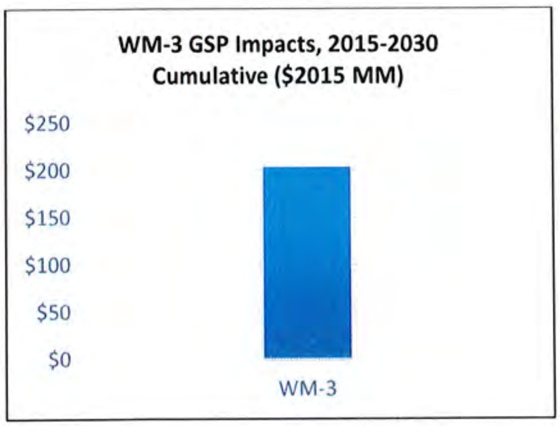


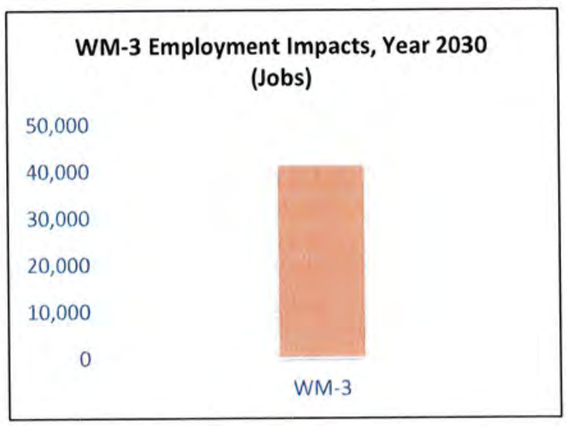
Figure F-6.31 WM-3 Income Impacts ($2015 MM)

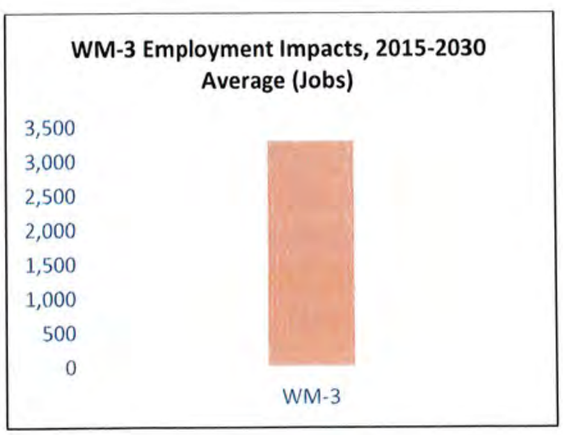


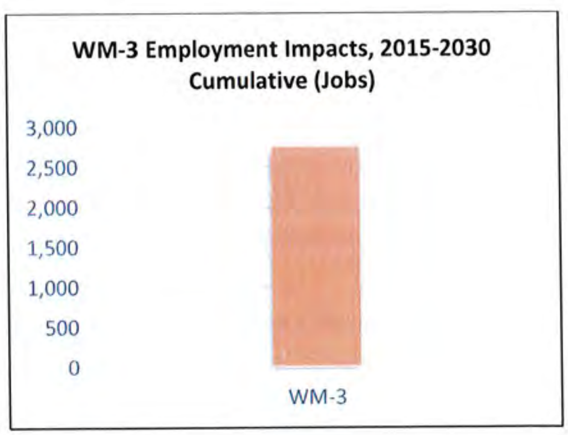

WM-3 GSP Impacts, Year 2030 ($2015 MM)
$3,500
$3,000
$2,500
$2,000
$1,500
$1,000
$500
$0
WM-3

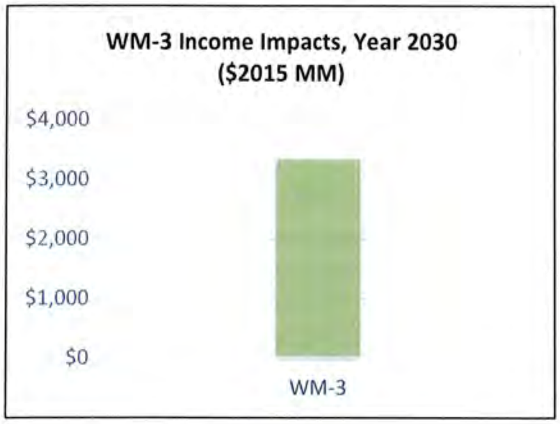

WM-3 GSP Impacts, 2015-2030 Average ($2015 MM)
$300
$250
$200
$150
$100
$50
$0
WM-3

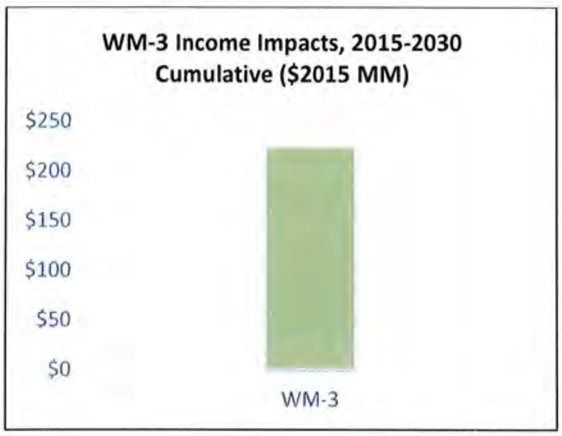

WM-3 GSP Impacts, 2015-2030 Cumulative ($2015 MM)
$250
$200
$150
$100
$50
$0
WM-3


WM-3 Employment Impacts, Year 2030 (Jobs)
50,000
40,000
30,000
20,000
10,000
0
WM-3


WM-3 Employment Impacts, 2015-2030 Average (Jobs)
3,500
3,000
2,500
2,000
1,500
1,000
500
0
WM-3


WM-3 Employment Impacts, 2015-2030 Cumulative (Jobs)
3,000
2,500
2,000
1,500
1,000
500
0
WM-3





Principal Drivers of Macroeconomic Changes

WM-3 is a larger policy in scale, but the real gains it provides to the statewide Minnesota economy are due to the anticipated revenue from recyclable materials collected by governments under this program. While the recycling effort itself is roughly self-funding through fees to homes and businesses, the revenue from sales of recycled materials rises steadily from about $15 million in the first year to nearly $250 million in the final year. This expands the state's budget and serves as a pure export, as these commoditized materials either displace imports or are sold externally.

Data Sources

The principal data sources for the macroeconomic impacts analysis of this and all other policies in the CSEO process are the direct spending, saving, cost and price impacts developed as part of the microeconomic (direct impacts) analysis. For each policy, the cost-effectiveness analysis described above develops year-by-year estimates of the costs, savings prices, and changes demand or supply that households, businesses and government agencies are expected to encounter in a scenario where the policy is implemented as designed.

A secondary data source is the policy design. Balancing financial flows for each direct impact identified are established based on understanding the implementation mechanism, and quantitative values for these flows are developed for each direct impact identified. This balancing identifies and quantifies the responsive change that occurs as a result of the direct impact in question. For example, if a household is anticipated to save $100 per year on electricity bills as a result of a policy, the direct impact is a $100 savings to the household (which expands its spending capacity for other things) but the balancing impact is a $100 loss in revenue and demand to the utility provider (which reduces its ability and need to spend on labor, capital, profit, and other inputs). The quantitative measure of both sides of a change is of importance to a complete macroeconomic analysis. This balancing ensures that both the supply and the demand side of each economic change is fully represented in the analysis.

A third data source is direct communication with Minnesota agency staff and others involved in policy design or in a position to understand in detail the financial flows involved in the policy. These people assisted in clarifying the nature of economic changes involved so that the modeling and analysis would be accurate.

The final crucial data source is the baseline and forecast of economic activity within the REMI software. This data is compiled into a scenario that is characterized not only by the total size of the economy and its many consuming and producing sectors, but also the mechanisms by which impacts in one sector can change the broader economy – such as intermediate demands, regional purchase coefficients, and equilibria around price and quantity, labor and capital, and savings and spending, to name a few of many. REMI, Inc. maintains a full discussion of all the sources of the baseline data on its own website, www.remi.com.

In the case of the WM-3 policy, important data included:

- The savings in reduction of costs to pay for waste management services, as the total amount of waste is reduced.
- Lost sales to the government and private waste managers from tipping fees at landfills
- New government spending on composting infrastructure
- The collection by government of recycling fees and the reallocation of those fees back into other government spending (by local governments, in this case).
- Expanded cost to government of operating recycling facilities, which is a productive activity but displaces other government spending.
- Significant revenue to governments from the sale of recyclable material.

Quantification Methods

Utilizing the data developed from the microeconomic analysis, CCS analysts established for each individual change the following characteristics:

- The category of change involved (change in spending, savings, costs, prices, supply or demand)

- The party involved on both sides of each transaction
- The volume of money involved in this change in each year of the period of analysis

These values, so characterized, were then processed into inputs to the REMI PI+ software model built specifically for use by CCS and consistent with that in use by state agencies within Minnesota. These inputs were applied to the model and run. Key results were then drawn from the model and processed for consistency of units and presentation before inclusion in this report.

Key Assumptions

The macroeconomic impact analyses of this policy, as well as of the others in the CSEO process, rely on a consistent set of key assumptions:

- State and local spending is always budget-constrained. If a policy calls for the state or local government to spend money in any fashion, that spending must be either funded by a new revenue stream or offset by reductions in spending on other programs. Savings or revenues collected by the government are also expected to be returned to the economy as spending in the same year as they are collected.
- Federal spending is not budget-constrained. The capacity of the federal government to carry out deficit spending means that no CSEO policy is held responsible for driving either an increase or decrease in federal tax spending by businesses or households in the state of Minnesota.
- Consumer spending increases are sometimes financed. Small-scale purchases or purchases of consumer goods are treated as direct spending from existing household cash flows (or short-term credit). Durable goods, home improvements or vehicle purchases, however, are treated as financed. Consumers were assumed to spread out costs based on common borrowing time frames, such as five years for financing a new vehicle or 10-20 years for home improvements that might be funded by home-equity or other lending. The assumption of financing and the term of years applied was considered anew in each case.
- Business spending increases are often financed. Where spending strikes a sector which routinely utilizes financing or lines of credit to ensure steady payment of recurring costs, significant spending of nearly any type was considered a candidate for financing, thus allowing costs to spread out over time. This methodology is preferable for the modeling work, as sudden spikes or dips in business operating costs can show up as volatility when the scenario may depict a managed adoption of new equipment in an orderly fashion. The assumption of financing and the term of years applied was considered anew in each case.
- Unless otherwise stated, all changes to consumer spending or to the producers' cost of producing goods and services were treated in a standard fashion. Consumers are assumed to spend on a pre-set mix of goods, services, and basic needs, and businesses spend (based on their particular sector of the economy) on a mix of labor, capital, and

intermediate demands from other sectors. Unless a policy specifically defines how a party will react to changes in cost, price, supply or demand, these standard assumptions were applied.

State and local spending gains and reductions driven by policy are assumed to apply to standard mixes of spending. Again, unless a policy specifically states that a government entity will draw from a specific source or direct savings or revenues to a specific form of spending, all gains and losses were assumed to apply to a standard profile of government spending within the economy.

Key Uncertainties

Key uncertainties are the assumptions underlying the BAU waste management forecast, which affects the estimated GHG reductions. Other uncertainties: an incomplete data record of individual components of the Minnesota solid waste stream, limitations of modeling within WARM (inability to model source reduction within mixed waste categories), and data rounding. Statewide waste composition studies have been done infrequently. Some additional information will be forthcoming in future years as the ReTRAC reporting system matures.

Assuming that source reduction continues on an accelerated schedule, a key uncertainty in the projection is the composition of that avoided waste in future years, as consumer habits and the marketplace continue to evolve.

Additional Benefits and Costs

Implementation of this policy option is expected to lead to job growth in the state based on previous macro-economic analysis of waste management policies.

Feasibility Issues

Transforming Minnesota's waste management practices to achieve these higher levels of source reduction, recycling, and composting will present significant challenges: hitting the 75% combined diversion goal will require more than doubling the best rolling-average "recycling improvement rate" per year (from about a half of one percent gain per year, to more than one percent gain per year). On a positive note, some encouragement came from legislative actions after MCCAG's final report, which institutionalized the 75% diversion goal for the Metro counties, and provided additional funding for all counties.