THE CENTER FOR
CLIMATE STRATEGIES

Minnesota Climate Strategies and Economic Opportunities

The Center for Climate Strategies
In Collaboration with Minnesota State Agencies

February 19, 2016

Acknowledgements

The Center for Climate Strategies (CCS) wishes to gratefully acknowledge Bill Grant of the Minnesota Department of Commerce, David Thornton of the Minnesota Pollution Control Agency, and Will Seuffert and Anna Henderson of the Pollution Control Agency and the Minnesota Environmental Quality Board for their agency leadership and management of the Minnesota Climate Strategies and Economic Opportunities (CSEO) project.

CCS wishes also to thank over 60 representatives of Minnesota agencies who provided significant in kind contributions through their collaborative review, input, and technical assistance in the development of CSEO recommendations and assessments, including representatives from the following state institutions:

- Agriculture Department
- Board of Water and Soil Resources
- Environmental Quality Board
- Department of Commerce
- Department of Employment and Economic Development
- Forest Resources Council
- Department of Health
- Metropolitan Council
- Natural Resources Department
- Office of Energy Security
- Pollution Control Agency
- Public Utilities Commission
- Transportation Department

The CCS project team included Tom Peterson, Project Director; Steve Roe, Technical Manager and lead for Baselines and for Agriculture, Forestry, and Waste Policy Design and Impact Analysis; Holly Lindquist, Baselines and Policy Design and Impact Analysis; Scott Williamson, Macroeconomic Policy Design and Impact Analysis; Loretta Bauer, Waste Management Policy Design and Impact Analysis; Fan Zhang, Research and Communications Assistance; Nikola Pilipovic, Research and Communications Assistance; Bill Dougherty, Energy Supply Policy Design and Impact Analysis; Evelyn Wright, Energy Systems Impact Analysis; David Von Hippel, Residential, Commercial, Industrial, and Institutional Policy Design and Impact Analysis; Jackson Schreiber and Jim Wilson, Transportation and Land Use Policy Design and Impact Analysis; Robert McKinstry, Legal Review; Katie Pasko, Communications Support; and Cecilia Sutter, Communications and Administrative Support.

The CSEO project was generously supported through grant support to CCS by The Rockefeller Brothers Fund, The McKnight Foundation, The Energy Foundation, and the Merck Family Fund.

Table of Contents

Acronyms and Abbreviations

A	Agriculture Policy
AEO 2014	*Annual Energy Outlook 2014* [US DOE Energy Information Administration]
BAU	Business as Usual
BMPs	Best management practices
Btu	British thermal unit
CCS	Center for Climate Strategies
cf	cubic feet
CH_4	methane
CHP	combined heat and power
CIP	Conservation Improvement Program
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
DSM	demand-side management
DNR	[Minnesota] Department of Natural Resources
DOE	[United States] Department of Energy
EIA	Energy Information Administration [US DOE]
EE	energy efficiency
EPA	[United States] Environmental Protection Agency
ES	Energy Supply
eGRID	Emissions & Generation Resource Integrated Database [US EPA]
EF	emissions factor
FOLU	Forestry and Other Land Uses
FIA	Forest Inventory and Analysis [USFS/Minnesota DNR]
FRC	[Minnesota] Forest Resources Council
FSA	Farm Service Agency [USDA]
FSC	[Minnesota] Forest Stewardship Council
ft	foot
gal	gallon
GHG	greenhouse gas
GIS	geographic information system
GMAC	General Motors Acceptance Corporation
GJ	gigajoule
GSP	gross state product
GWh	gigawatt-hour [one million kilowatt-hours]
GWP	global warming potential
HFC	hydrofluorocarbon
IECC	International Energy Conservation Code
IPCC	Intergovernmental Panel on Climate Change
IRP	integrated resource planning
I&F	Inventory and Forecast
kW	kilowatt
kWh	kilowatt-hour
LandGEM	Landfill Gas Emissions Model [US EPA]
LDV	light-duty vehicle

LCOE	levelized cost of energy or electricity
LEED	Leadership in Energy and Environmental Design [Green Building Rating System™
LFG	landfill gas
LPG	liquefied petroleum gas
MJ	megajoule
MM	million
MMBtu	millions of British thermal units
MPG	miles per gallon
MSW	municipal solid waste
MW	megawatt [one thousand kilowatts]
MWh	megawatt-hour [one thousand kilowatt-hours]
N	nitrogen
N_2O	nitrous oxide
N/A	not applicable
NG	natural gas
NGCC	natural gas combined cycle
NGCT	natural gas combustion turbine
NGO	nongovernmental organization
NOx	oxides of nitrogen
NPV	net present value
O&M	operation and maintenance
PFC	perfluororocarbon
PHEV	plug-in hybrid electric vehicle
POD	policy option document
PV	photovoltaic
R&D	research and development
RCII	Residential, Commercial, Institutional and Industrial
RES	Renewable Electricity Standard
SF_6	sulfur hexafluoride
SO_2	sulfur dioxide
SOx	oxides of sulfur
t	metric ton (1,000 kilograms – approximately 2,200 pounds)
Tg	teragram [equal to a million metric tons]
$TgCO_2e$	teragrams of carbon dioxide equivalent
T&D	transmission and distribution
tCO_2	metric tons of carbon dioxide
tCO_2e	metric tons of carbon dioxide equivalent
tCO_2e/MWh	metric tons of carbon dioxide equivalent per megawatt-hour
TLU	Transportation and Land Use
TOD	transit-oriented development
VMT	vehicle miles traveled
WM	Waste Management
WTE	waste to energy
yr	year

Chapter I. Introduction & Executive Summary

The Minnesota Climate Strategies and Economic Opportunities (CSEO) project was convened February 4, 2014 through a Memorandum of Understanding between the Center for Climate Strategies (CCS) and the Minnesota Department of Commerce (COMM) and Minnesota Pollution Control Agency (MPCA). The Minnesota Environmental Quality Board (EQB) provided agency coordination.

The project was designed to improve the state's economic, energy, and environmental conditions and awareness in all sectors; expand the knowledge, planning, and implementing capacities of its agencies; and contribute to attainment and enhancement of state and federal goals across all sectors and agencies. It updates and improves upon Minnesota's 2008 comprehensive climate action plan.[1]

Recommended actions show a high level of potential in all sectors to deliver multiple benefits at competitive cost. If implemented fully, CSEO policies would:

1. Reduce greenhouse gas emissions (GHGs) in line with state goals and federal guidelines. Statewide greenhouse gas emissions experience a 34 percent reduction below the business as usual forecast of emissions in 2030, and a 33 percent reduction in comparison to 2015 base year emissions by 2030. This level parallels state legislative targets of 2008. The scale of reductions associated with the state's electricity system exceeds the US EPA requirements anticipated from the Federal Clean Power Plan (under Clean Air Act Section 111(d)) for Minnesota.
2. Expand macroeconomic output of jobs, income, and growth. Net gains for Minnesota include an average of 24,630 newly created jobs per year, or a total of 369,440 additional years of employment through 2030. Gross State Product (GSP) grows an additional $35.7 billion as a result of the CSEO policies over the 2016-2030 period – an average of $2.38 billion in additional economic activity per year (a 0.5 percent annual increase). Personal income expands by an annual average of $2.3 billion, or 0.6 percent per year.
3. Improve energy and resource efficiency and sustainability. Key improvements through 2030 include reduced energy intensity, greater efficiency, reduction of imported electricity, and shifts to new sources of domestically-generated renewable energy.

Returns on investment (benefits from direct outlays and net social investment) are strong, supported by well-defined financial flows and implementing mechanisms, and create a platform for expanded investment from sources inside and outside the state.

During the course of two years, CCS and over 60 representatives from ten Minnesota agencies worked jointly to identify, design, and evaluate a set of 20 highly-specific, customized policy actions and implementing mechanisms. CCS and the agencies utilized an iterative, stepwise

[1] http://www.climatestrategies.us/library/library/view/1149

process to achieve the combined project goals of economic development and greenhouse gas (GHG) reductions. This process encompassed:

- Goal setting
- Development of baselines (energy, emissions, land use, other emissions drivers)
- Identification of potential new or enhanced options
- Multi-criteria screening for selection of draft priority options
- Design of individual policy options to enable analysis of baseline shifts
- Direct (or microeconomic) impact analysis of individual and aggregate actions
- Indirect (or macroeconomic) impacts of policy options and mechanisms
- Final documentation and transition to implementation planning

The project culminated with a stakeholder exchange program supported by Minnesota agencies and the Minnesota Environmental Initiative (MEI).

Key policy options were developed in the areas of:

- Energy Supply (ES): renewable energy (RE) or lower-emitting heat and power production;
- Residential, Commercial, Institutional and Industrial (RCII): energy efficiency (EE), process improvements, and renewable fuels;
- Transportation and Land Use (TLU): low emissions vehicles, transportation price mechanisms, and improved transit and urban land use;
- Waste Management (WM): energy efficiency, source reduction, re-use, recycling, and composting;
- Agriculture (A): nutrient and soil conservation practices, biofuels production and utilization;
- Forestry, and Land Use (FOLU): urban and rural forest conservation and restoration, and bio-energy generation.

Table EX-1 provides a brief summary of each of the CSEO policy recommendations.

Table EX-1. CSEO Policy Recommendations

Policy ID	Policy Title	Description
ES-1	Increase the Minnesota Renewable Energy Standard	Expands Minnesota's Renewable Portfolio Standard to either 40% or 50% of renewable electricity generation as a share of retail sales by 2030
ES-2	Efficiency Improvements, Repowering, Retirement, and	Repowers or retires two of the largest coal-fired boilers in Minnesota (Sherburne Co plants 1 and 2)

	Upgrades to Existing Plants	
RCII-1	Incentives and Resources for Combined Heat & Power for Biomass and Natural Gas	Implements 800 MW of gas-fired CHP and 300 MW of biomass-fired CHP by 2030
RCII-2	Zero Energy Transition/Codes (SB2030)	Provide incentives for or mandates construction of highly energy efficient buildings and phasing in the use of renewable energy sources
RCII-4	Increase Energy Efficiency Requirements	Increase the requirements of the existing EERS for electric and gas utilities while allowing them to count energy savings from infrastructure improvements, end-use efficiency and CHP
RCII-5	Incentives and Resources to Promote Thermal Renewables	Establish new thermal goal of switching 5% of the future heat load that is fueled with non-electric sources by 2020 and 20% by 2030
TLU-1	Transportation Pricing	Use transportation pricing method to reduce GHG and provide more reliable funding for roads and bridges, including Pay-as-you-go insurance pricing, a carbon tax on fuels with rebates, and a 6.5% state wholesale fuel tax
TLU-2	Improve Land Development and Urban Form	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 VMT and GHG from transportation
TLU-3	Metropolitan Council Draft 2040 Plan	Expansion and operation of the MnPASS System, the Transit System and the Bicycle/Pedestrian System
TLU-4	Zero Emission Vehicle Standard	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
AG-1	Nutrient Management	Achieve gains in nitrogen use efficiency with precision agricultural techniques and nitrification inhibitors
AG-2	Soil Carbon Management: Cover Crops	Improve soil carbon management through cover crop adoption for cropping systems
AG-3	Soil Carbon Management: Row to Perennial Crops Conversion	Sequester carbon and reduced fuel and fertilizer consumption
AG-4	Advanced Biofuels Production	Expand ethanol production through cellulosic and energy-beet production methods
AG-5	Biofuels Consumption (Existing Biofuels Statute)	Replace gasoline consumption with 14% biofuels by 2015, 18% by 2017, 25% by 2020, and 30% by 2025

FOLU-3	Community Forests	Strengthen community forests across the state by increasing and maintaining the overall tree canopy cover of community forests to 40% by 2050
FOLU-4	Tree Planting: Forest Ecosystems	Ensure timely restoration of carbon sequestration following large disturbances on state, county, and private lands
FOLU-5	Conservation on Private Lands	Protect forests and their ability to annually sequester carbon while preventing large one-time emissions associated with forest loss
WM-1	Wastewater Treatment: Energy Efficiency	Statewide reduction in energy usage by wastewater treatment plants of 25% by 2025
WM-2	Front-End Waste Management: Source Reduction	Avoid disposal emissions, reduce upstream product energy-cycle emissions from the manufacture and transport of new products and packaging
WM-3	Front-End Waste Management: Re-Use, Recycling & Composting	Improve front-end waste management to achieve a total recycling rate (including composting) of 75% by 2025
CPP	Comprehensive Effects of Sector Based CSEO Policy Recommendations on Electricity Supply and Demand Related to the EPA Section 111(d) Rule	CSEO policy recommendations affecting CPP 111d implementation goals for Minnesota include ES-1, ES-2, RCII-1, RCII-2, RCII-4, TLU-2, FOLU-3, WM-1, WM-2, WM-3 and AG-4/AG-5

For each CSEO policy recommendation, a series of customized policy design specifics were developed and documented through iterative conferrals between CCS and agencies, including: concept and description, design parameters and performance metrics (timing, level of effort, coverage of parties, eligibility), related actions already in place (both current and planned actions), policy impact analysis approaches and methodologies (data sources, methods, key assumptions, key uncertainties), implementation mechanisms (standards, pricing, incentives, education, funding, etc.), results of analysis (direct, integrative, and indirect impacts), key uncertainties, and critical implementation needs.

Analysis of the direct, integrative, and indirect effects of individual and aggregate CSEO policy options was conducted through the use of standard, systematic principles and guidelines for quantification of climate mitigation actions, regulatory impacts, and economic impacts. These were applied on a customized basis for each Minnesota sector and specific policy option through collaboration between CCS and agency experts using a modeling framework that linked baselines, direct, and indirect impacts. Additional details on the CSEO project, procedures, and results are summarized in the chapters that follow and in a series of technical appendices.

Table EX-2. Summary of Direct Impacts of Policy Recommendations

Direct Impacts of CSEO Policy Recommendations						
Policy Option	2030 Annual In-State	Cumulative In-State 2015-2030	2030 Annual Total	Cumulative Total 2015-2030	NPV Costs/Savings 2015-2030	Cost Effectiveness
	GHG Reductions ($TgCO_2e$)				($2014MM)	($2014/$tCO_2e$)
ES-1	5.3	53	6.3	62	($360)	($5.8)
ES-2	5.8	41	5.5	38	$854	$22
ES Sector Totals	**11**	**94**	**12**	**100**	**$494**	**$4.9**
RCII-1	4.9	46	5.2	49	($1,117)	($23)
RCII-2	9.3	54	11	60	($2,050)	($34)
RCII-4	4.9	34	5.2	40	($1,814)	($45)
RCII-5	2.9	22	4.1	30	$842	$28
RCII Sector Totals	**22**	**156**	**25**	**180**	**($4,140)**	**($23)**
TLU-1	2.0	21	2.6	28	$2,718	$98
TLU-2	0.82	7.0	0.97	8.2	($425)	($52)
TLU-3	0.25	2.0	0.32	2.6	($330)	($127)
TLU-4	1.0	5.5	1.3	6.7	$3,278	$489
TLU Sector Totals	**4.1**	**36**	**5.1**	**45**	**5,241**	**$116**
AG-1	0.13	1.0	0.34	2.7	($127)	($47)
AG-2	0.49	3.1	0.57	3.6	($1,346)	($377)
AG-3	1.6	14	1.6	14	($2,104)	($153)
AG-4+AG-5	0.17	1.76	0.32	3.5	$462	$133
Agriculture Totals	**2.4**	**19**	**2.8**	**23**	**($3,115)**	**($133)**
FOLU-3	0.49	3.2	0.53	3.4	$1,806	$525
FOLU-4	1.9	30	2.0	34	$187	$5.59
FOLU-5	0.34	3.0	0.34	3.0	$1,261	$421
FOLU Sector Totals	**2.7**	**36**	**2.8**	**40**	**$3,254**	**$81**
WM-1	0.068	0.89	0.076	0.99	($56)	($56)
WM-2	0.057	0.073	1.6	9.4	($228)	($24)
WM-3	0.15	(0.45)	2.7	27	($817)	($30)
WM Sector Totals	**0.28**	**0.52**	**4.4**	**37**	**($1,101)**	**($29)**
CPP	**17.0**	**199.2**	**N/A**	**N/A**	**($398)**	**($2.0)**
Total Integrated Plan Results	**42**	**342**	**52**	**426**	**$634**	**$1.5**

Note: CPP results estimate the comprehensive effects of CSEO policy recommendations on the electricity sector.

Figure EX-1. Minnesota Greenhouse Gas Baselines and CSEO Reductions

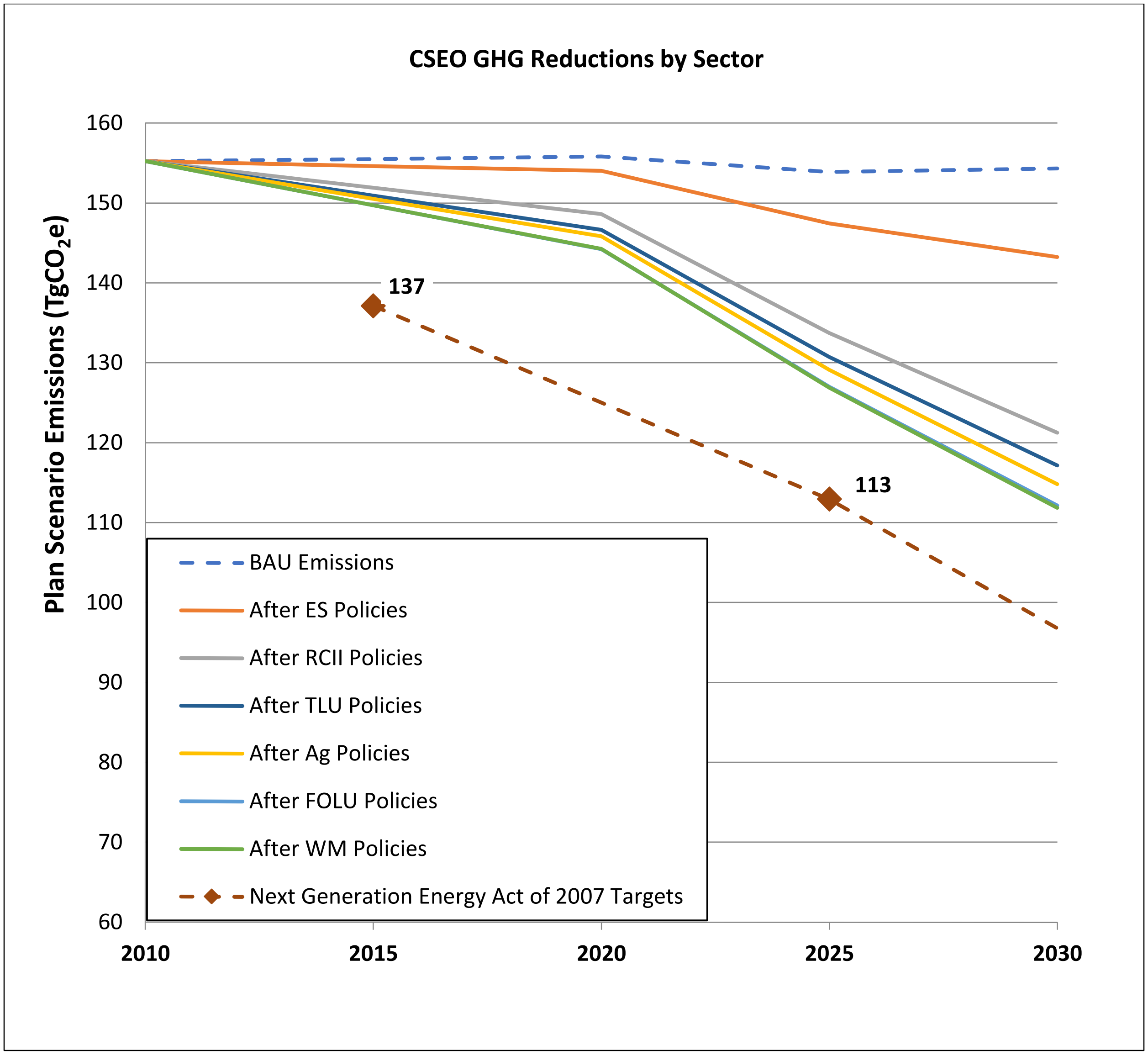


Figure EX-2. GHG Reductions for Policy Recommendations, Year 2030

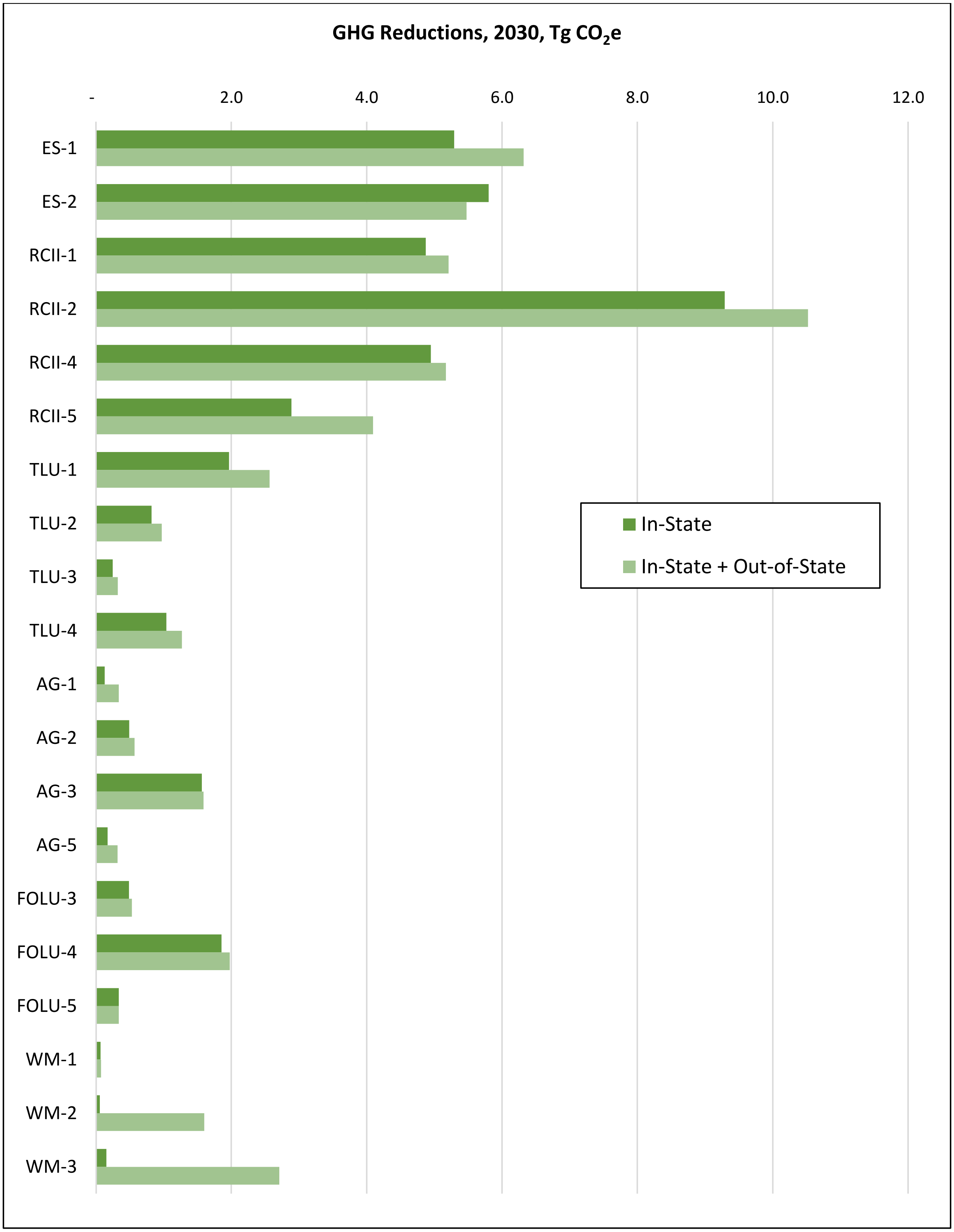
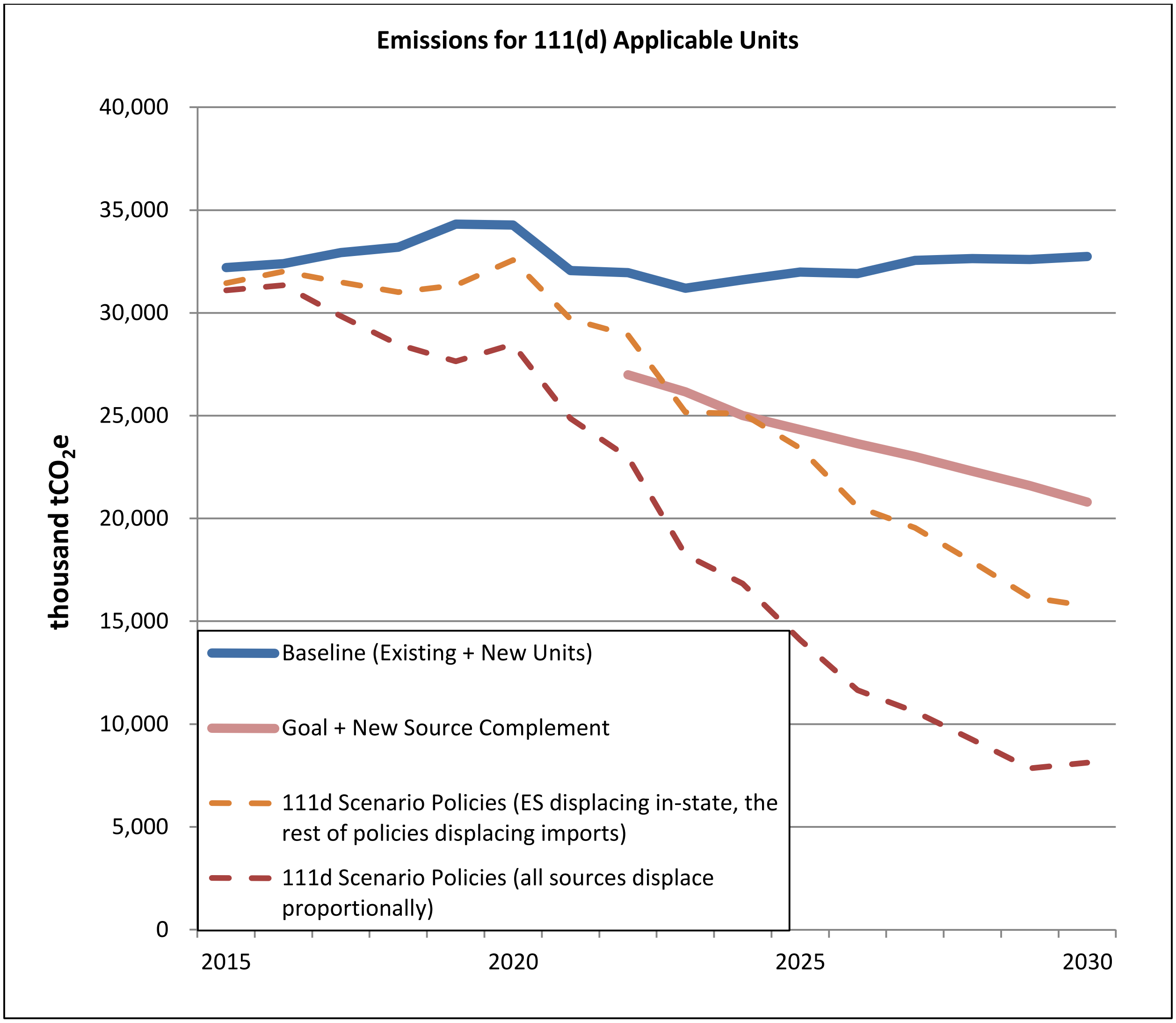


Figure EX-3. Achievement of Clean Power Plan Goals by Policy Recommendations, 2030



Notes:

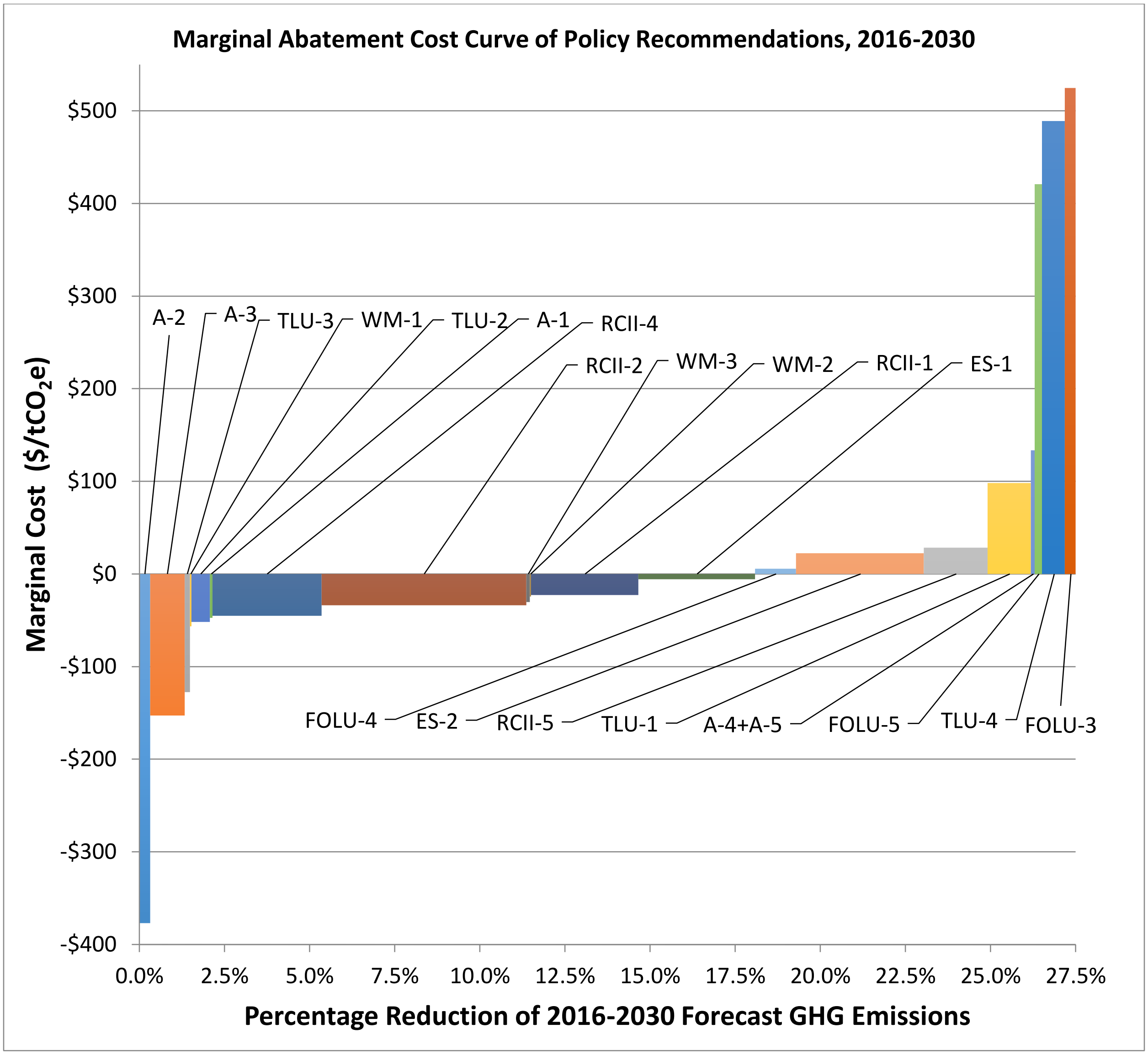
Clean Power Plan (referred to as 111d in graph) Scenarios include comprehensive effects of CSEO policy options that affect electricity supply and demand, adjusted as necessary, including: ES-1, ES-2, RCII-1, RCII-2, RCII-4, TLU-2, FOLU-3, WM-1, WM-2, WM-3 and AG-4/AG-5.

The dashed lines present CSEO policy impacts under two geographic displacement scenarios on a mass-basis for the overall MN electricity sector CO_2 emissions. Rate based evaluations are available in the report and appendices.

The blue solid line presents an estimated MN CO_2 and energy baseline, using marginal resource mix assumptions provided by MPCA.

The red solid line presents Clean Power Plan goal calculated for Minnesota, expressed as mass-based CO_2 emissions pathway.

Figure EX-4. Marginal Costs/Savings of Policy Recommendations, 2016-2030

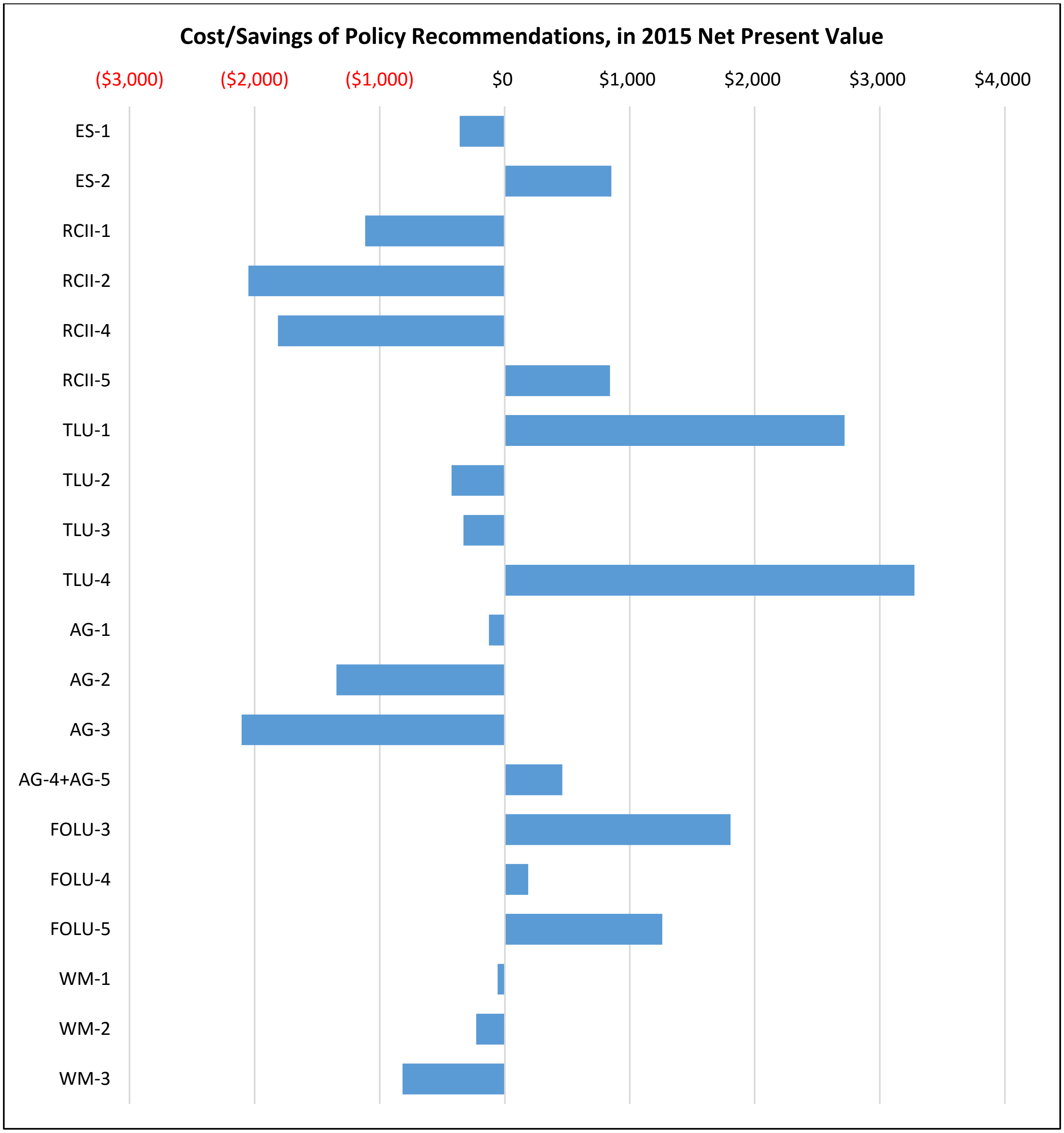


Notes: This curve displays policies from most cost-effective (those which produce net savings) to least (those which produce net costs. The height of each bar indicates the cost-effectiveness, or net cost per ton of emissions reduced, and the width represents the volume of emissions reduced as a percentage of baseline.

Table EX-3. Summary of Macroeconomic Impacts of Policy Recommendations

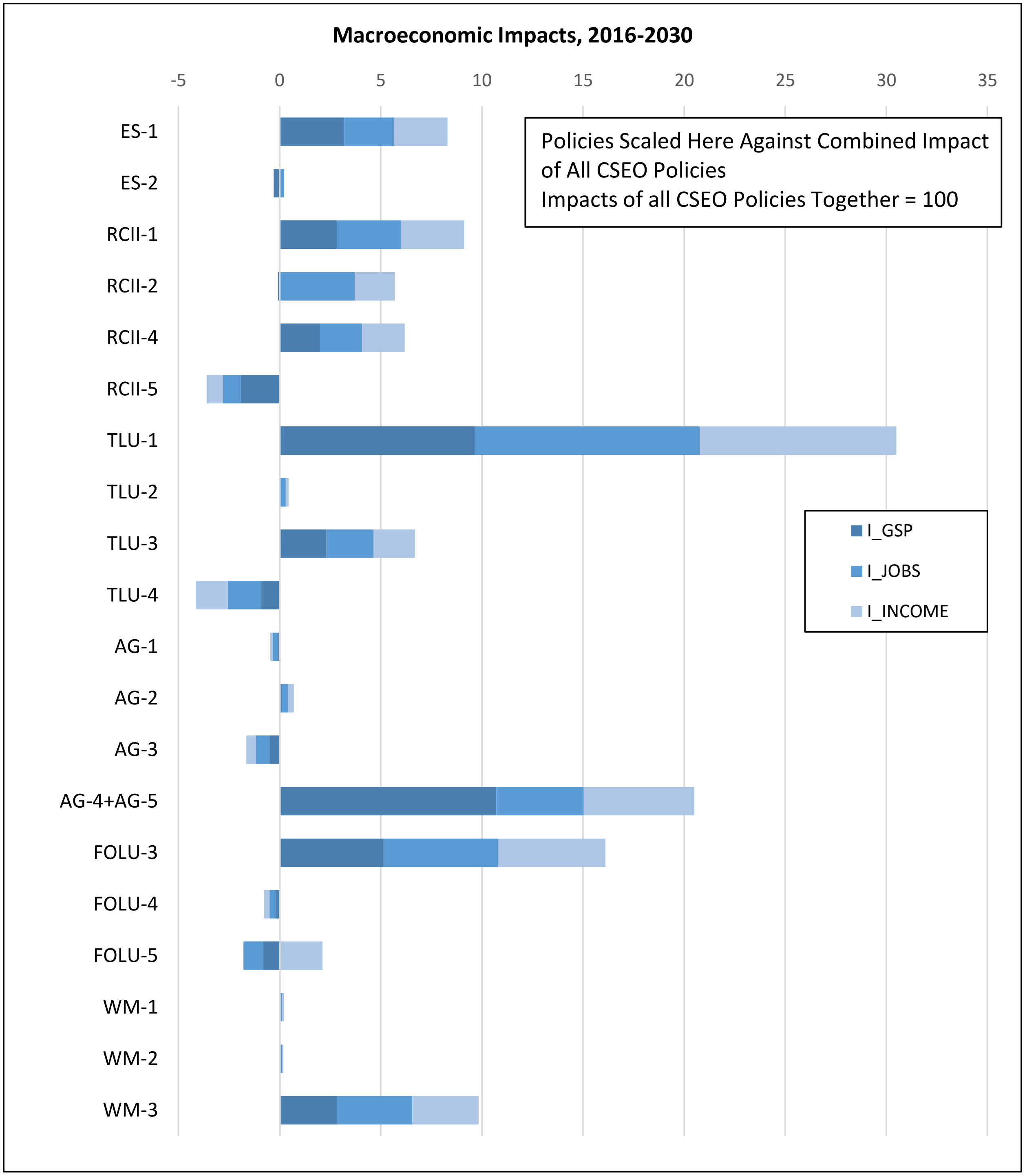
Macroeconomic Impacts of Policy Recommendations									
Policy	Gross State Product (GSP, $2015 Millions)			Employment (Full & Part-Time Jobs)			Income Earned ($2015 Millions)		
	Year 2030	Average	Cumulative (2015-2030)	Year 2030	Average	Cumulative (2015-2030)	Year 2030	Average	Cumulative (2015-2030)
ES-1	$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 Total	**$542**	**$239**	**$3,579**	**4,720**	**2,380**	**35,650**	**$485**	**$204**	**$3,058**
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**
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	$125	$165	$2,477	1,330	1,720	25,860	$78	$138	$2,068
TLU-4	$140	-$65	-$969	-810	-1,220	-18,300	-$56	-$108	-$1,622
TLU Sector Total	**$981**	**$787**	**$11,799**	**9,170**	**8,950**	**134,270**	**$833**	**$699**	**$10,485**
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**
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	-$75	-$59	-$883	-920	-720	-10,750	$117	$144	$2,157
FOLU Sector Total	**$294**	**$290**	**$4,345**	**3,340**	**3,220**	**48,340**	**$567**	**$486**	**$7,292**
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**
CPP	**$2,894**	**$1,914**	**$28,716**	**28,140**	**19,507**	**292,610**	**$2,797**	**$1,672**	**$25,078**
Overall Economy	**$3,246**	**$2,378**	**$35,677**	**30,820**	**24,630**	**369,440**	**$3,235**	**$2,261**	**$33,908**

Figure EX-5. Net Total Direct Costs/Savings of Policy Recommendations, 2016-2030



Notes: This chart shows the net cost of each policy to society in net present value. Positive NPVs indicate a net cost to implement a policy, while negative NPVs indicate a net savings to implement that policy.

Figure EX-6. Macroeconomic Indicators (Jobs, Income, and Economic Growth) of Policy Recommendations, 2016-2030



Notes: I_GSP, I_JOB, I_INCOME represent policy recommendation impacts on GSP, Employment and Income, respectively.

Figure EX-7. Jobs Impacts of CSEO Recommendations by Sectors and Clean Power Plan Goals

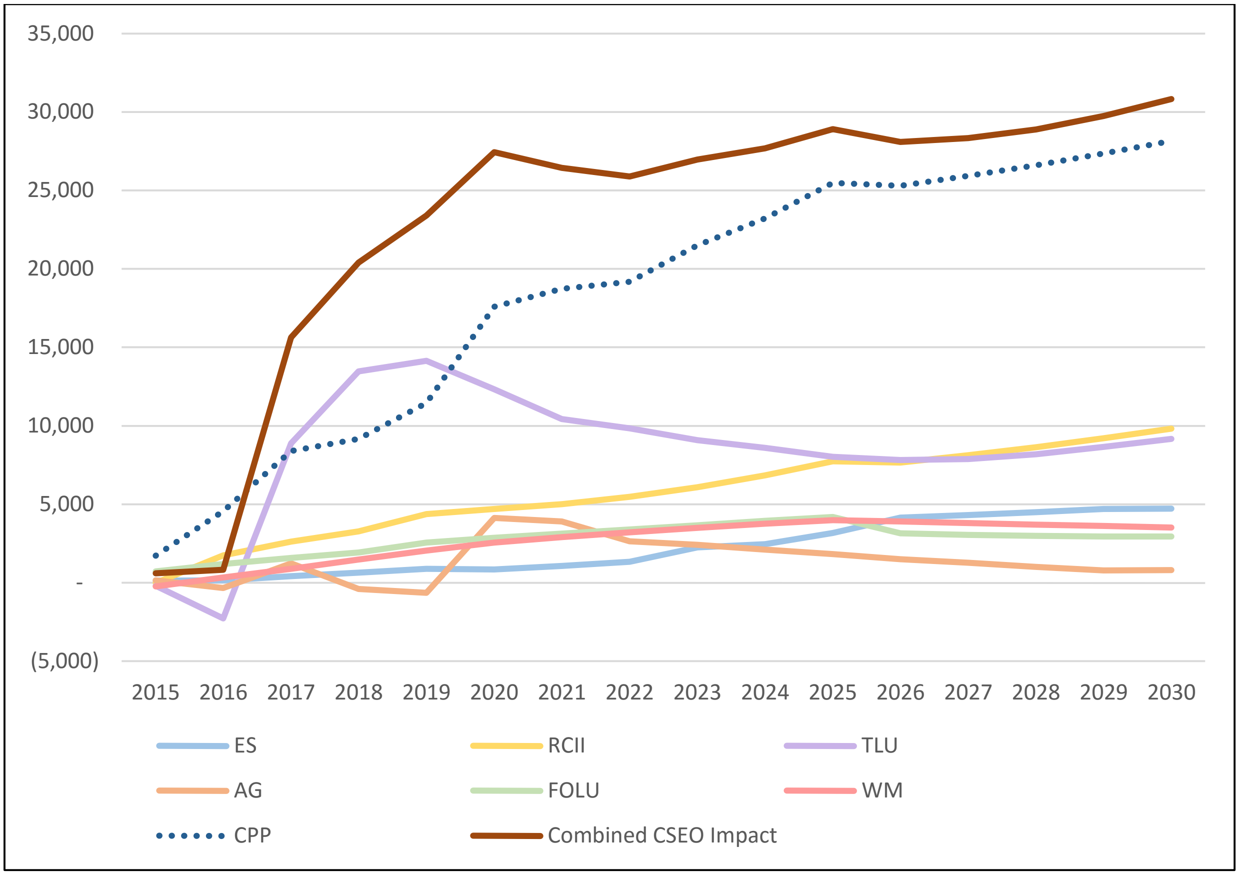


Figure EX-8. Job Gains and GHG Reduction by Policy Recommendations, 2016-2030

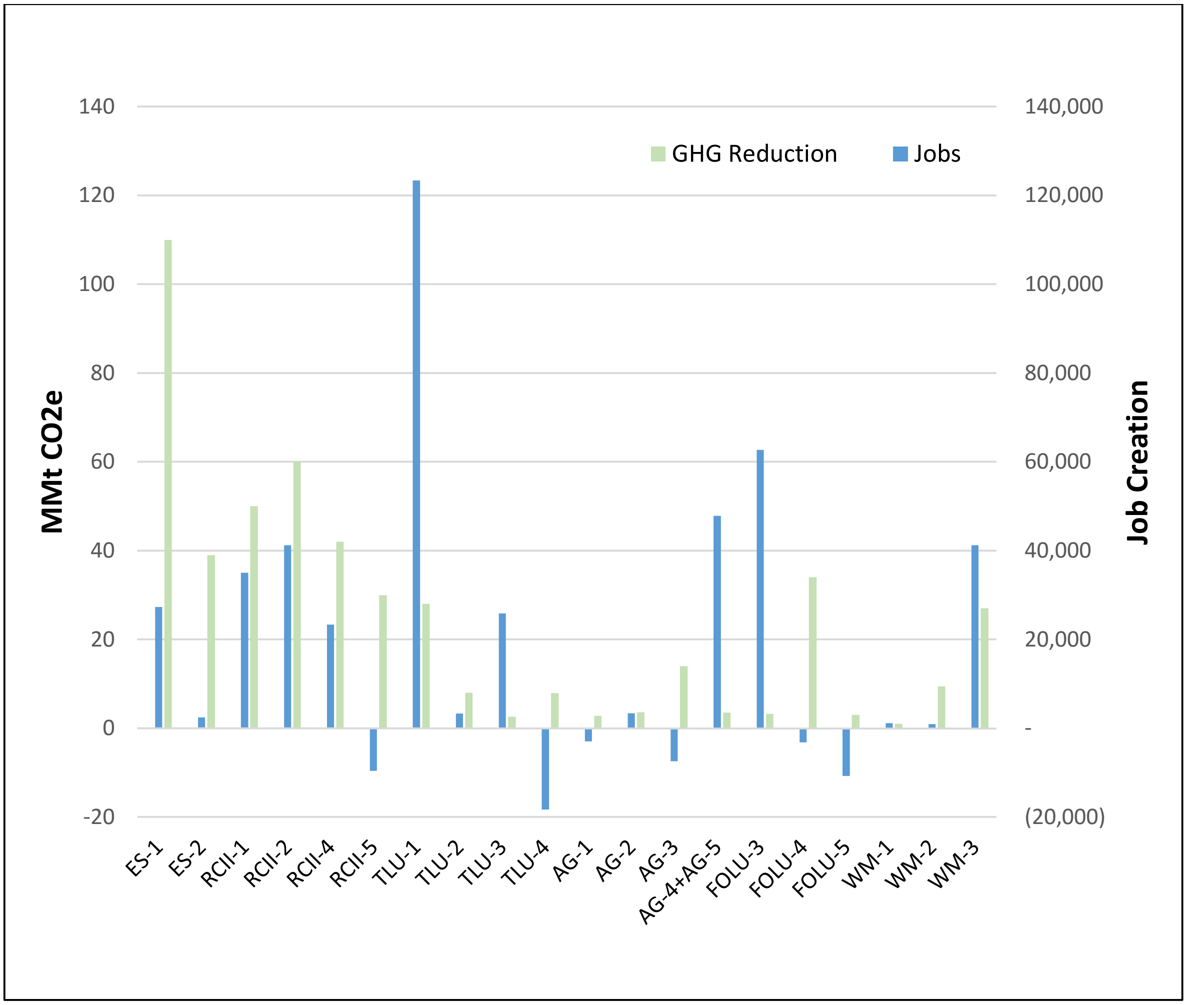


Figure EX-9. Job Gains and GHG Reduction by Sector, 2016-2030

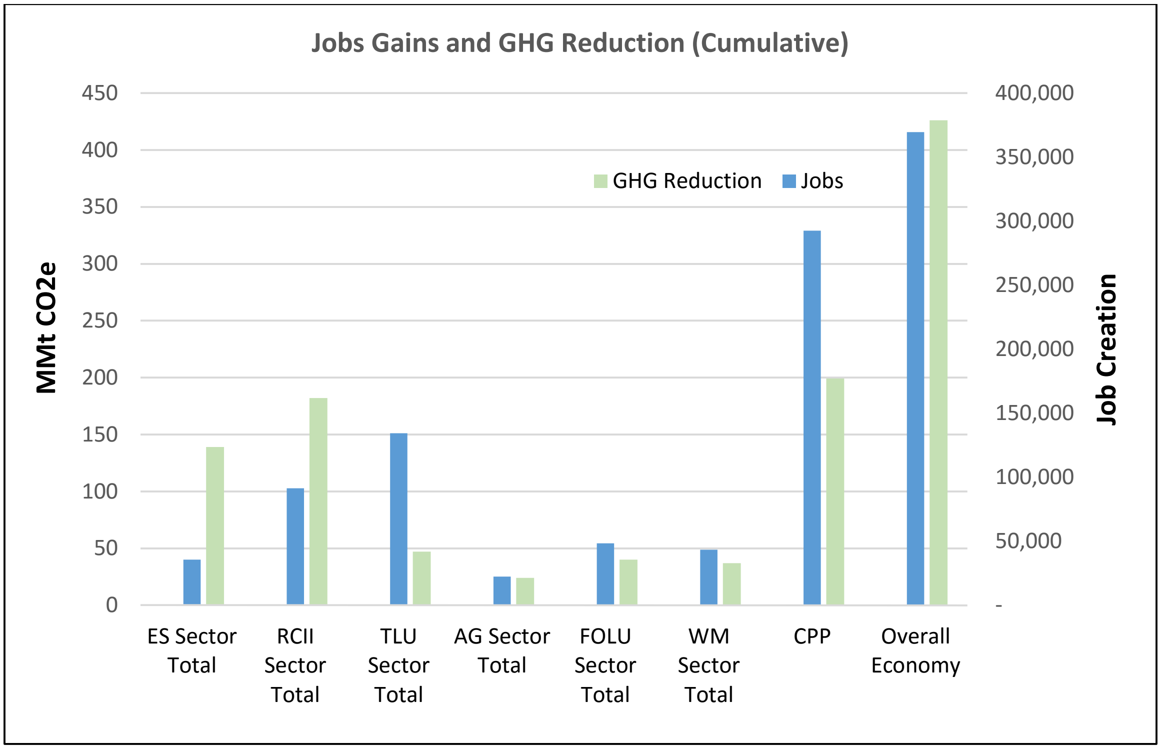


Figure EX-10. Net Job Creation by Policy Recommendations, Average Annual (Jobs)

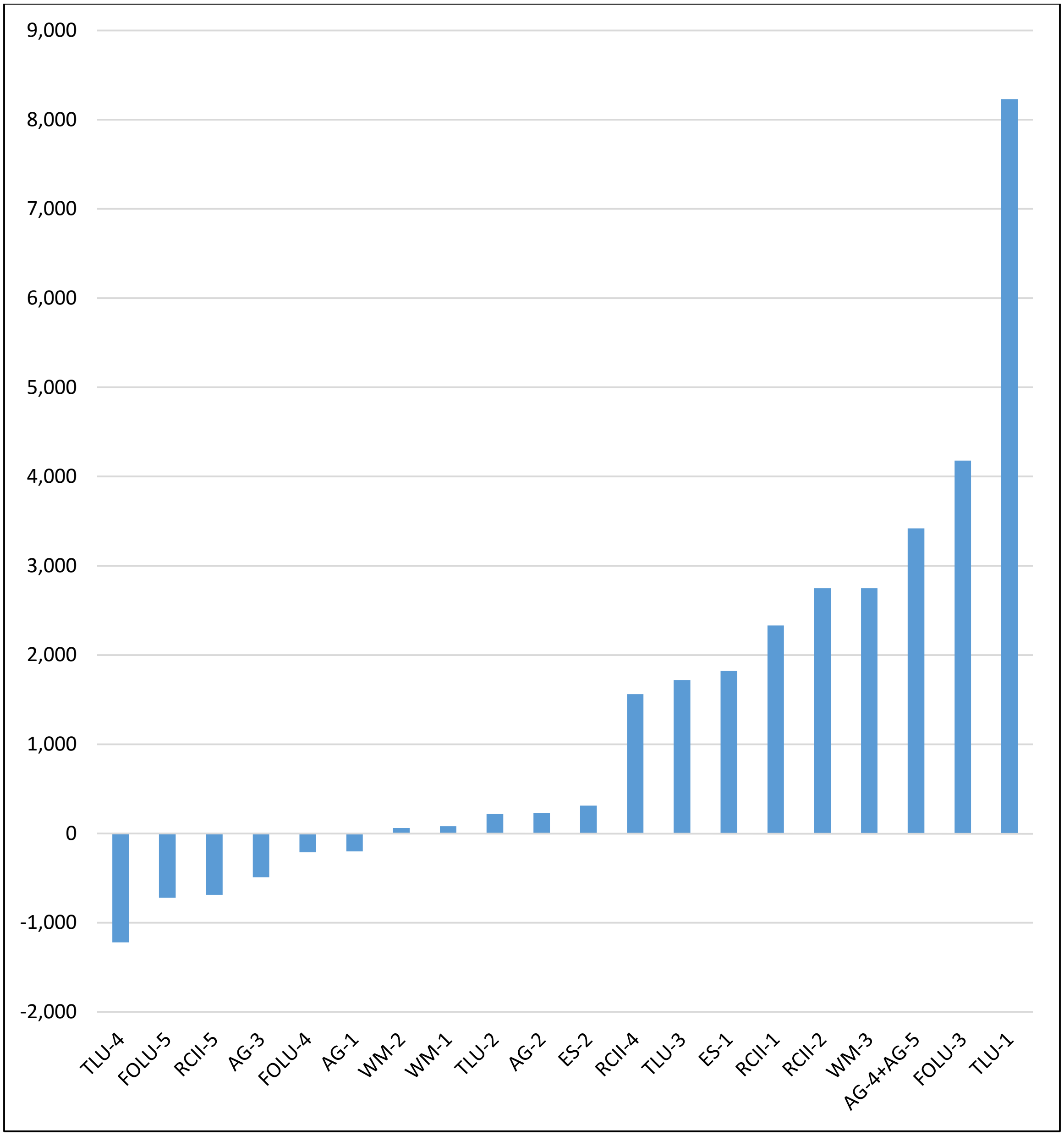
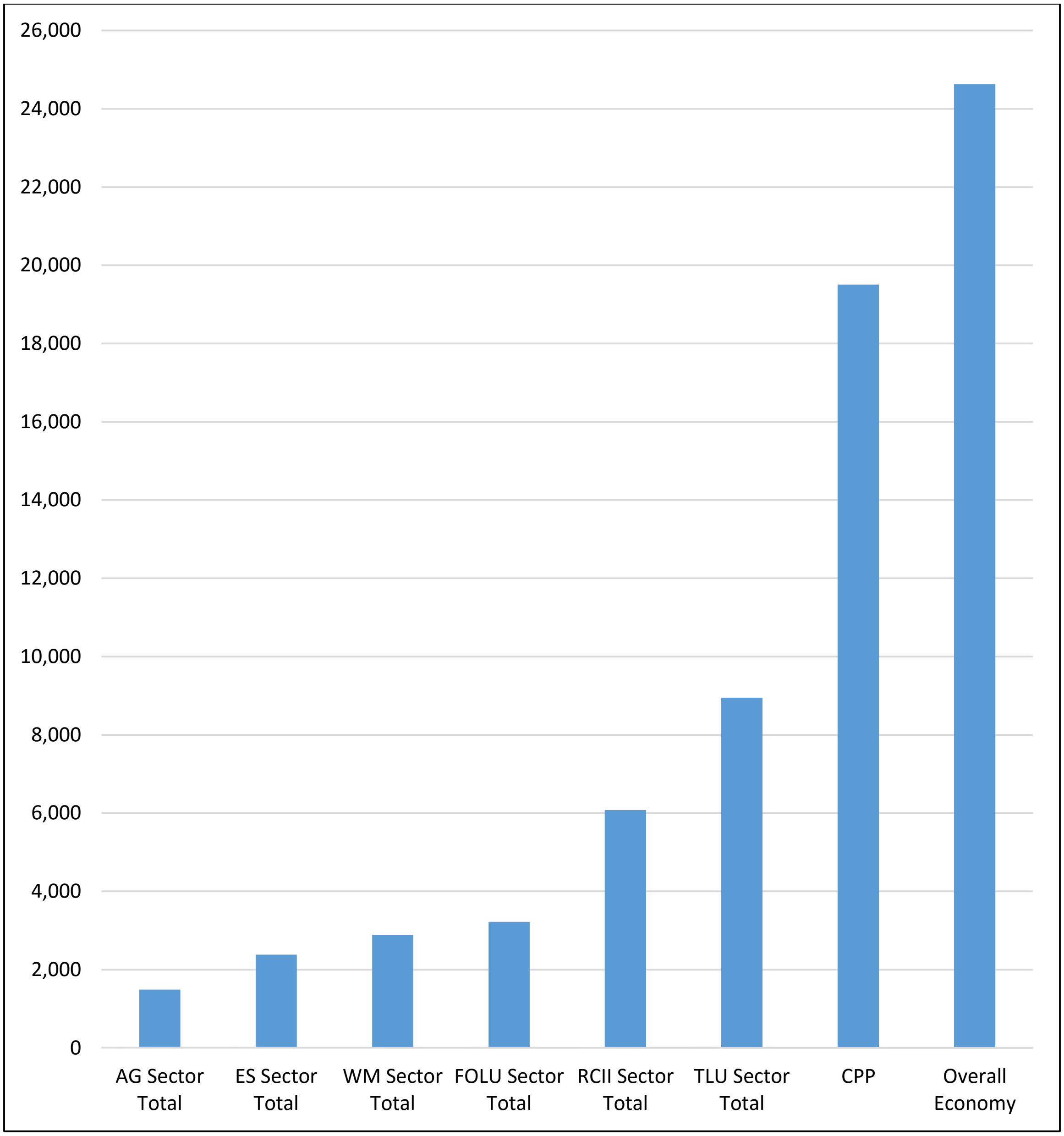


Figure EX-11. Net Job Creation by Sector, Average Annual (Jobs)



Chapter II. Minnesota Greenhouse Gas Baseline Emissions

This chapter provides an overview of the state's greenhouse gas (GHG) emissions inventory and business-as-usual (BAU) forecast (or "baseline"). Most of this information was drawn from the Minnesota Pollution Control Agency's (MPCA's) GHG inventory & forecast (see Appendix B). Some targeted additional work was done as part of this project to fill some gaps in the emissions forecast so that an impact analysis of Climate Solutions & Economic Opportunities (CSEO) policy options could be undertaken. This includes the development of an emissions baseline for the Forestry & Other Land Use (FOLU) sector (see Appendix C) and a BAU forecast for the Agriculture sector, crop production subsector (see Appendix D).

Concepts and Methods

In developing the CSEO baseline, MPCA and the Center for Climate Strategies (CCS) have followed the guidelines for GHG emissions reporting developed by the Intergovernmental Panel on Climate Change (IPCC) and used by the US Environmental Protection Agency (EPA) to report national emissions. All sectors of Minnesota's economy were addressed in the baseline. These follow the common categorization used in national GHG reporting:

- Energy Supply (ES): for Minnesota, this mainly addresses the Power Supply (PS) subsector.
- Residential, Commercial & Institutional (RCI): this covers emissions from fuel combustion in buildings.
- Industry (I): this sector includes emissions from fuel combustion for industrial processes and buildings, as well as non-combustion emissions that occur from industrial processes.
- Transportation: most importantly fuel combustion in onroad vehicles, but also including air, rail and marine vessels.
- Agriculture: covers emissions from crop production and livestock management, including both fuel combustion and non-combustion sources.
- Forestry & Other Land Use (FOLU): the FOLU sector primarily covers carbon sequestration in forests, rangeland, and urban forests. However, other GHG sources are also addressed (importantly, methane emissions from wetlands). See Appendix C for details on the FOLU baseline.
- Waste Management (WM): this includes the solid waste management and wastewater treatment subsectors; these include mostly non-combustion emissions, since, energy consumption for these sectors is difficult to break out of the Transportation and RCI sector supporting data.

The baseline estimates are presented in units of teragrams (Tg) of carbon dioxide equivalent (CO_2e) emissions (1 Tg is equal to 1 million metric tons). These estimates include all GHG emissions within each sector and put them in common units based on their global warming potential (GWP). For this study, GWPs from the IPCC's Fourth Assessment Report (AR4) were used to retain consistency with values that had been used by MPCA. As noted below, emissions for all GHGs required for reporting by the Intergovernmental Panel on Climate Change (IPCC) were addressed in the work done by MPCA and CCS:

- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous oxide (N_2O)
- Hydrofluorocarbons (HFC)
- Sulfur hexafluoride (SF_6)
- Perfluorocarbons (PFC); and
- Nitrogen trifluoride (NF_3)

The CSEO planning period runs through the year 2030. Therefore the baseline addresses emissions from 1990 through 2030. Presentation of the results for Power Supply is provided on a "consumption-based" approach to emissions accounting. This means that emissions from Minnesota's net imports of power have been added to those from in-state generation sources, so that a complete accounting of the emissions associated with electricity consumption results. For the other sectors, only the emissions that occur within the state have been included in the baseline. In this study, reference to a "base year" will be to the year 2010; since this was the latest year across all sectors for which historical data were available to estimate emissions (although in some cases, more recent historical data are used).

This treatment of emissions varies somewhat from the way in which GHG reductions are credited for the CSEO policies. As detailed in Chapter III.1, a full energy-cycle approach to estimation of emissions impacts is taken to assess policy option implementation benefits. These would capture additional upstream reductions from sourcing fuels and materials. In doing that, CCS analysts have constructed two sets of GHG reduction estimates: those known to occur within the state; and those that may or may not occur within the state (i.e. the upstream component).

A more detailed discussion of the principles and guidelines used for quantification of baselines is provided in Chapter II and Appendix E. Policy specific baseline assumptions are provided in the policy option document for each individual CSEO Policy Option in the appendices to the report. Policy baselines are defined as a combination of existing and planned actions, and all analysis of policy options impacts is designed to document effects that are additional to these baseline actions. Emissions baselines are derived from related energy, resource, and economic activities and flows. As a result, GHG baselines provide important baseline data in these areas. Macroeconomic baselines are calculated separately through the REMI PI+ model for a wide range of subsectors, and discussed in Appendix G.

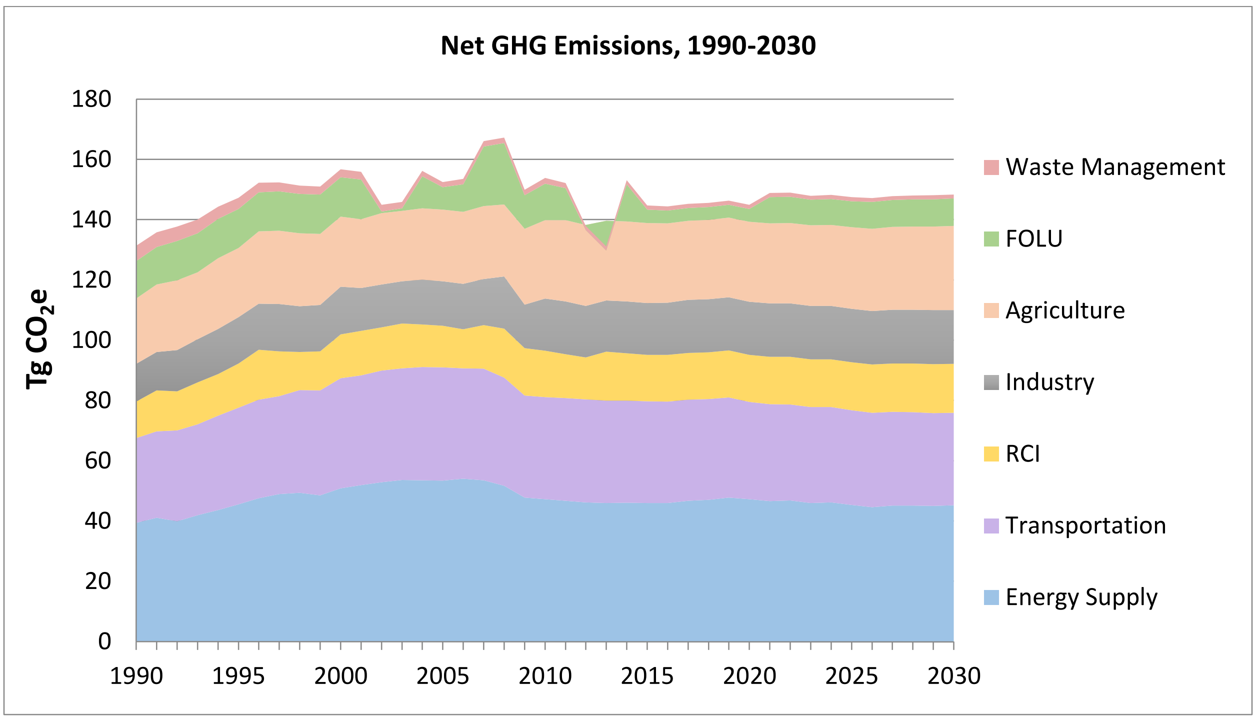
Results of GHG Baseline Assessments

A summary of both the economy-wide baseline and the emissions baseline for key sectors is provided below. Emissions are provided on a "net" emissions basis, meaning that both sources and sinks of GHGs are included (any summarized results indicating "gross" emissions indicate that only emissions sources are included).

All Sectors

Figure II-1 provides an overview of Minnesota's economy-wide baseline. These are shown on a net basis (sinks included). A big change has occurred from previous reported baselines, such as the one constructed for the 2008 CCAG report, in the portrayal of FOLU sector emissions. In the assessment from March 2015 (see Appendix B), CH_4 emissions from both woody and herbaceous wetlands have been included. While there is still a fairly high level of uncertainty around these emissions data, their inclusion shifted the overall net emissions for the sector to be positive in most years (i.e. more than offsetting the carbon sequestered in the state's forests).

Figure II-1. BAU Net GHG Emissions by Sector



The economy-wide baseline summary shown in Figure II-2 is provided on a gross basis, meaning that only GHG emissions sources are included. This includes the significant contributions of methane emissions in the FOLU sector. Unlike many states, where emissions contributions are concentrated mainly in the ES, TLU, and RCI sectors, Minnesota's emissions are more uniform across sectors. In the forecast period (after 2010 in most sectors), emissions overall are expected to remain fairly static. However, modest reductions in some sectors (e.g. Transportation) are offset by slight gains in others (Agriculture).

Figure II-2 BAU Gross GHG Emissions by Sector

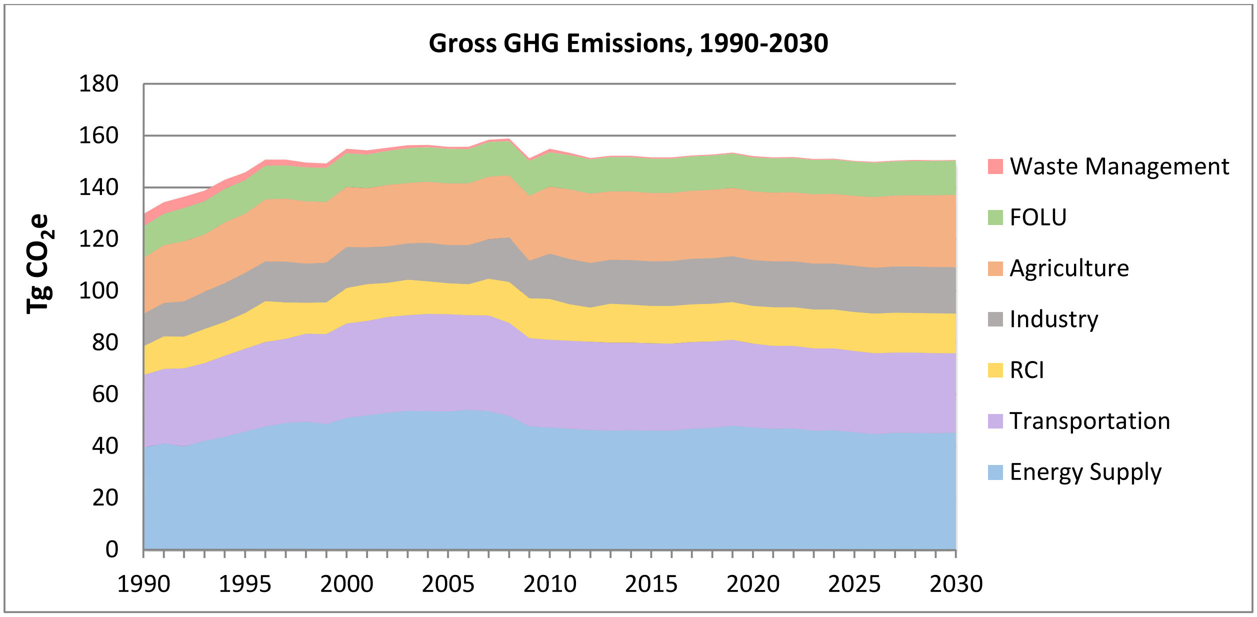
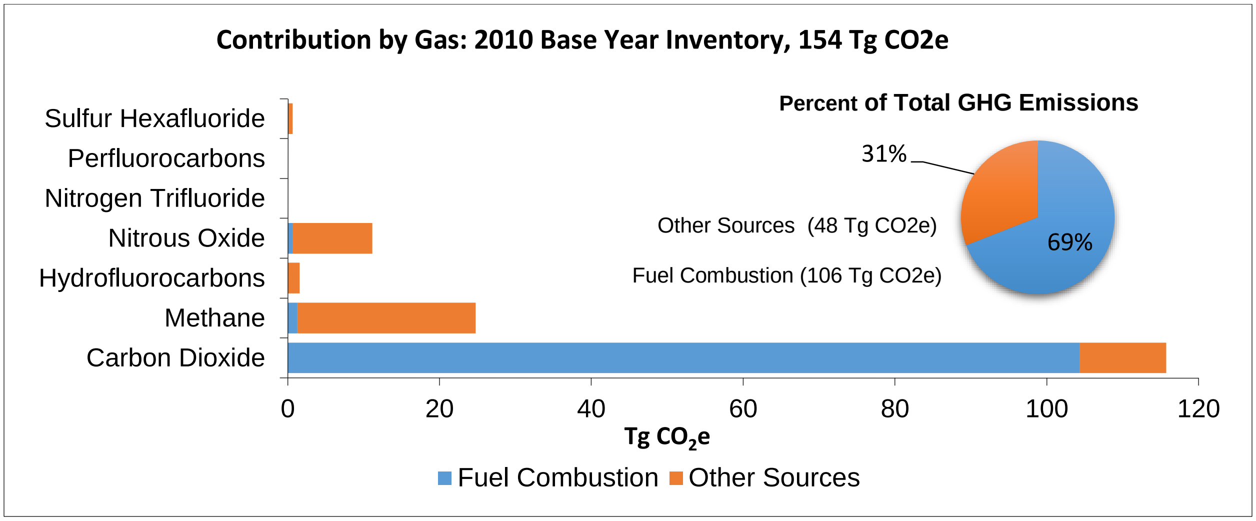


Figure II-3 provides a summary of emissions contribution by each GHG to the 2010 base year emissions. As shown, CO_2 is the dominant contributor (>75% of 2010 emissions), even when emissions are shown on a carbon dioxide equivalent basis (using AR4 GWPs). Methane and nitrous oxide are the next most important contributors to total CO_2e emissions. Also, as indicated in this figure, combustion of fuels produces 70% of the emissions estimated for the 2010 base year. Emissions for the “high global warming potential” (HGWP) gases (SF_6, PFC, HFC) are all very small contributors to base year emissions, as well as the forecasted BAU emissions. Nitrogen trifluoride (NF_3) emissions, most commonly used in the electronics industry, were not identified in Minnesota’s baseline.

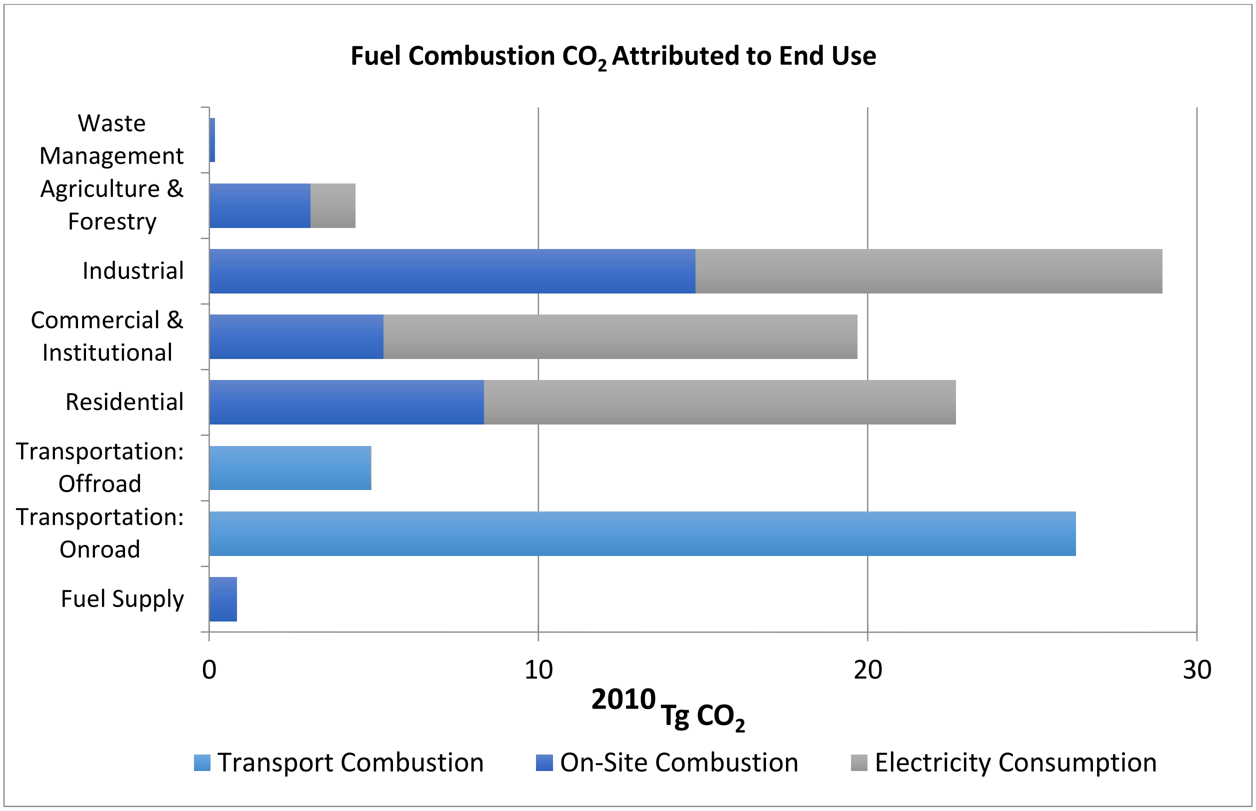
Figure II-3. Baseline Contribution by GHG



To support assessment of GHG mitigation opportunities, attribution of fuel combustion emissions to end use sector is important. Figure II-4 provides this attribution for Minnesota. Here, CO_2 emissions from both direct fuel combustion and indirectly from electricity consumption are attributed to their end use (in this case, emissions from the PS sector are allocated to the end user). The current structure and detail of the baseline does not allow for full attribution of fuel use and electricity consumption to waste management or fuel supply sectors. For example, solid waste transportation emissions are part of Transportation; similarly, electricity consumption related emissions are part of the RCI sector. Electricity consumption in the fuel supply subsector (natural gas transmission and distribution) is probably small.

Figure II-4 indicates the need to identify opportunities for GHG mitigation across both electricity consumption and fuel use in the RCII sectors. On-road transportation is also shown to be a substantial contributor to overall fuel combustion CO_2. The adjoining pie chart provides a snapshot of fuel combustion CO_2 attributed to electricity consumption, on-site fuel combustion (e.g. for industrial use or heating buildings), and transportation.

Figure II-4. Attribution of 2010 End Use Fuel Combustion CO_2



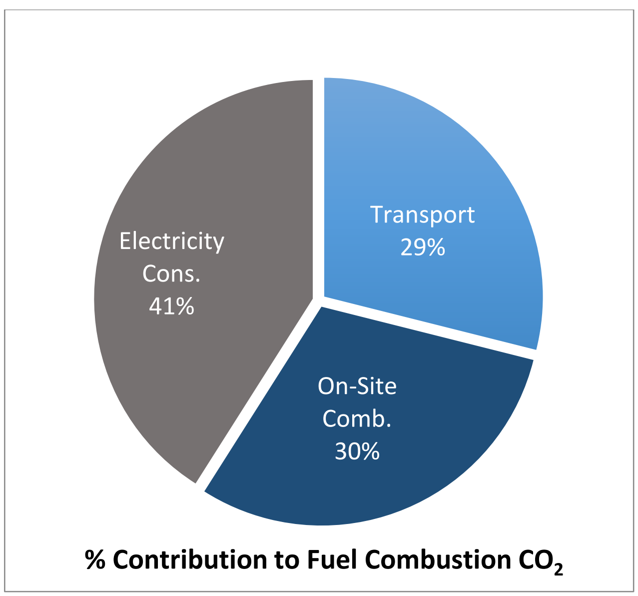


Figure II-5 provides another view of the economy-wide baseline. The GHG emissions values are also shown in five-year increments for each sector. As shown in the figure, net GHG emissions in the BAU forecast are expected to remain fairly constant. In the supporting data table below this figure Table II-1, the sector-level contributions to GHG emissions growth indicate that the Energy Supply, Transportation, and Waste Management sectors are expected to have negative contributions to growth (meaning expected reductions in the future under BAU conditions). The RCI and Industry sectors are expected to contribute moderately to emissions growth. Of the growth indicated for the Agriculture, Forestry & Other Land Use (AFOLU) sectors, over 80% of that is attributed to the FOLU subsector. For more detail on sector level emission baselines, see the individual sections for each sector in Chapter III.2.

Figure II-5. BAU Net GHG Emissions by Sector

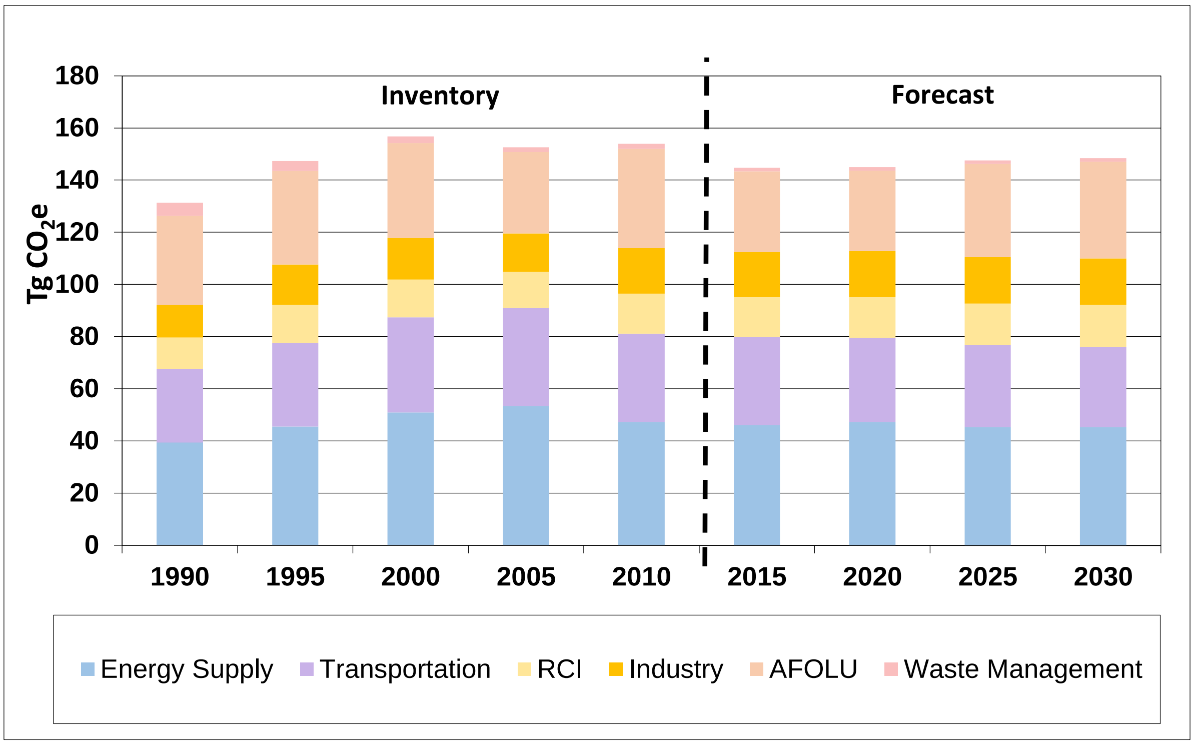


Table II-1. Sector-Level Contributions to GHG Emissions Growth

Sector	Tg CO_2e									
	1990	1995	2000	2005	2010	2015	2020	2025	2030	Contribution to 2015-2030 Growth
Energy Supply	39	46	51	53	47	46	47	45	45	-20%
Transportation	28	32	37	38	34	34	32	31	31	-87%
RCI	12	15	14	14	15	15	16	16	16	23%
Industry	12	15	16	15	17	17	18	18	18	19%

AG and FOLU	34	36	36	31	38	31	31	36	37	168%
Waste Management	5.0	3.7	2.6	1.8	1.9	1.4	1.4	1.3	1.3	-3%
TOTAL NET Emissions	**131**	**147**	**157**	**153**	**154**	**145**	**145**	**147**	**148**	**100%**

Estimates of "carbon intensity" are a common way to compare the emissions of one source, one sector, or one geographic area to another. Figure II-6 provides a comparison of varying measures of Minnesota's population-based carbon intensity to the US national intensity. Minnesota's carbon intensity is expected to fall through the BAU forecast period, whether measured on a gross-basis, net basis, or even when excluding the entire FOLU sector (e.g. due to higher levels of uncertainty in these estimates). However, in all cases, the Minnesota estimates are higher than the national values. The likely primary drivers of this higher intensity for the state include: greater than average energy requirements for space heating purposes; relatively high carbon intensity of power supply; presence of high energy consuming industries (e.g. iron ore and petroleum refining); a significant agricultural industry; and a comparatively low population.

Figure II-6. Carbon Intensity, Per Capita

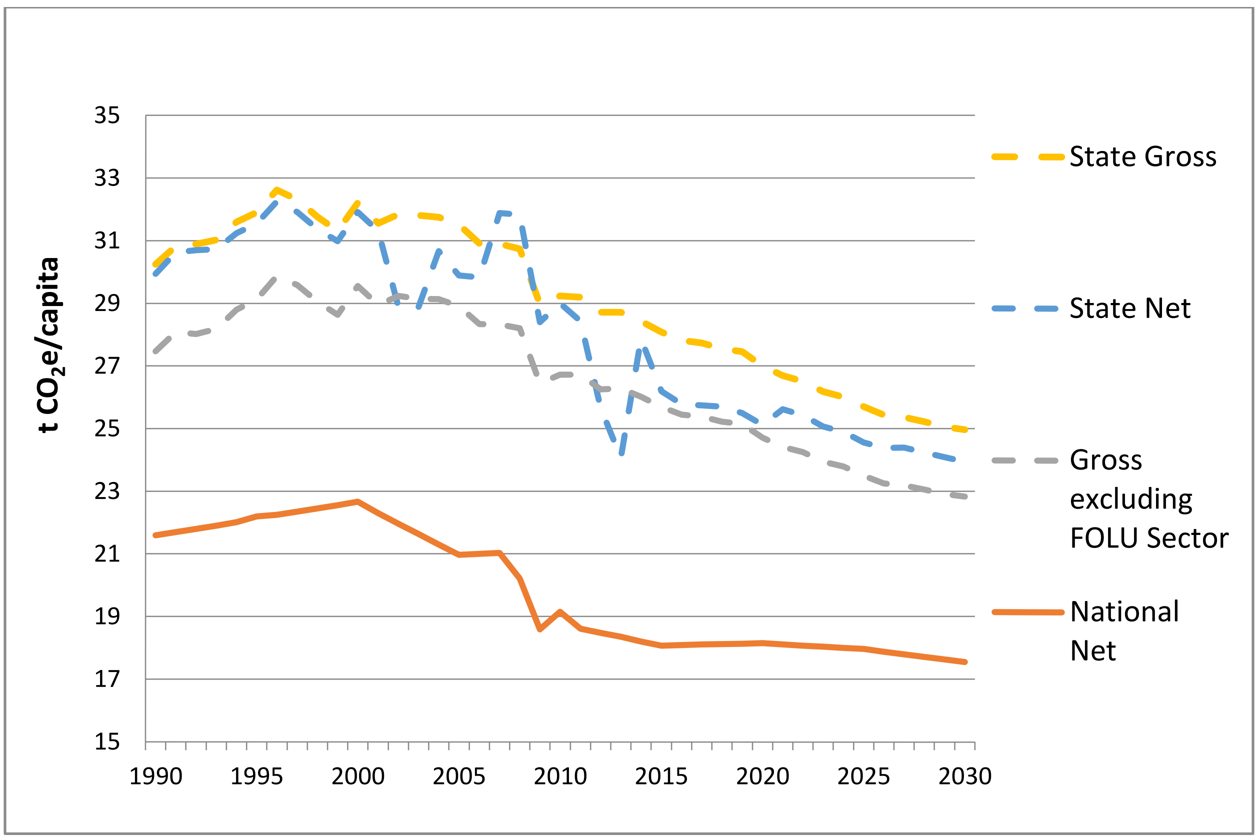
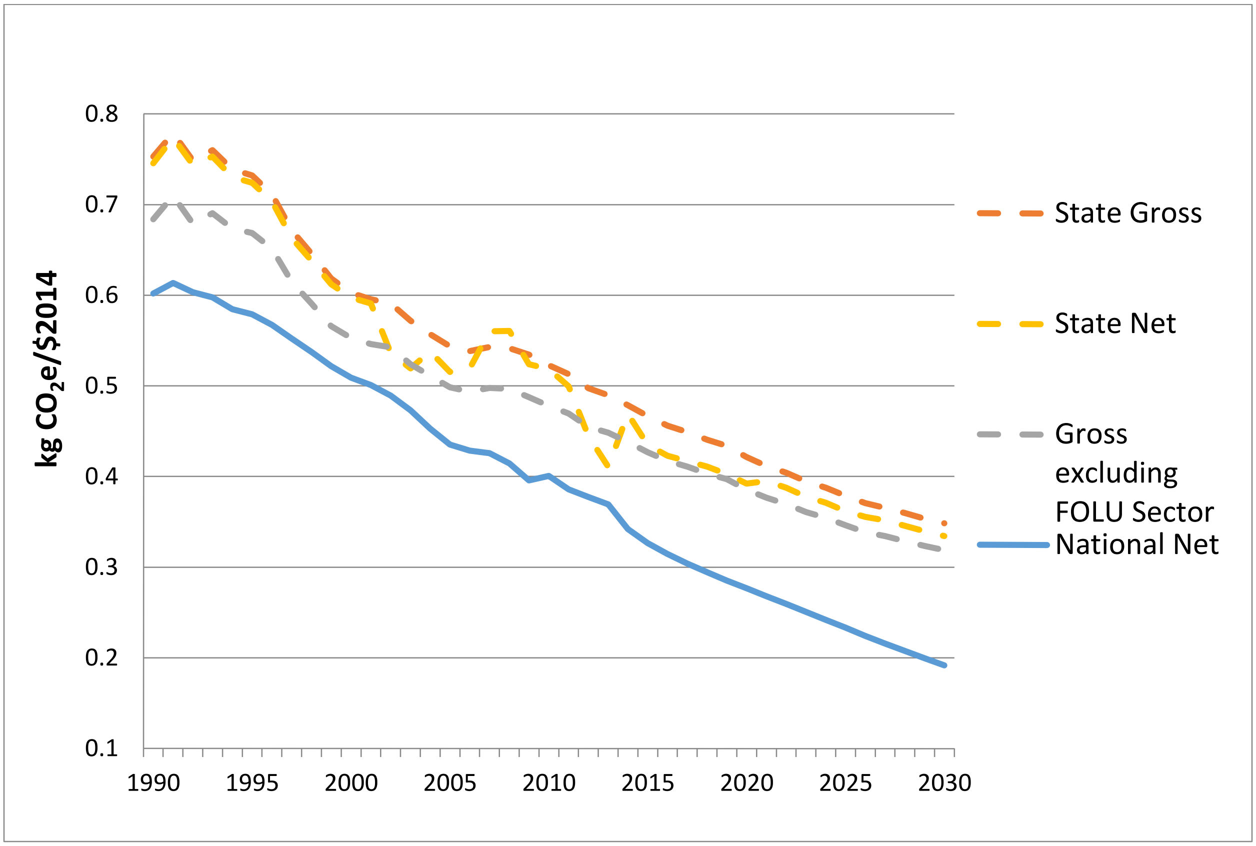


Figure II-7 provides another comparison of carbon intensity. This one indicates the emissions produced per unit of economic output (total economy-wide emissions divided by total gross state product or for national emissions, total domestic product). This summary also indicates expected reductions in future carbon intensity at both the state and national levels. Minnesota's intensity is expected to remain above that of the US as a whole due to the structure of the industry sector, high-energy requirements for space heating, and size of the agriculture sector.

Figure II-7. Carbon Intensity, Per $GSP



See Appendix B for more details on the construction of the Minnesota GHG baseline.

Key Sectors

As shown above, GHG emissions contributions are relatively even by each sector of the economy. In most states, there are two or three key sectors that receive focused attention in GHG mitigation planning. Since that is not the case for Minnesota, details for each sector baseline are presented at the beginning of the discussion on GHG mitigation opportunities for each sector in Chapter III.2.

Chapter III. Minnesota CSEO Recommendations

Policy Development Concepts, Methods, and Guidelines

For the CSEO project a set of policies was selected through a screening process with MN agency team members. The policies were screened based on their expected potential to reduce GHG emissions and promote economic growth in the State (both gross State product and employment). From this initial screening over two dozen policies were selected for further development and analysis.

To support subsequent policy implementation impacts analysis, additional work was carried out by both CCS and MN agencies to enhance the State's GHG inventory and forecast (baseline). This work included updates by MPCA in the energy supply (ES) sector and by CCS and other MN agency contacts to fill some baseline gaps [e.g. a forecast for the crop production sector, a baseline for the Forestry & Other Land Use (FOLU) sector]. Baseline documentation is provided in the appendices to this report. Also, CCS worked with MN agency contacts to develop a set of avoided electricity system costs and emissions for use in impacts analysis corresponding to the expected marginal resource mix for power consumption in the State.

CCS worked with MN agency members to develop policy descriptions and designs (goals and timing) for each policy within a template format. These individual policy templates are assembled into sector level appendices to this report. Following policy design, CCS began work on the direct (microeconomic) impacts assessment of each policy, while MN agency team members continued working on other aspects of policy development including, implementation mechanisms, related policies and programs, key uncertainties, feasibility issues, and co-benefits.

The direct impacts assessment captured the expected energy and GHG impacts of policy implementation as well as net direct societal costs. Following completion of the direct impacts assessment of each policy, an assessment was made of whether any intra-sector overlaps existed to avoid double counting. Methods to adjust for any overlaps were developed and applied. Finally, an assessment was made of any overlaps between sectors (inter-sector overlaps). These are most common among electricity supply and demand sectors; but for CSEO were also found between biofuels supply (in the Agriculture sector) and biofuels consumption (in the Transportation sector).

Output from the direct impacts assessment was then used to construct inputs for analyzing indirect economic impacts (macroeconomic impacts). A macroeconomic model, REMI-PI+, was used to model indirect impacts that include changes to GSP, employment, and incomes

Table III-1 provides a list of the policy options that were selected for initial analysis and that were recommended for the final set of CSEO policy options. Therefore, in some cases, the numbering of policy options is not sequential. Appendix X provides the initial set of CSEO policy options selected for analysis. The initial set of CSEO policy options contained an ES sector policy option that would be used to assess Clean Air Act Section 111d compliance and the need for additional mechanisms (price and non-price) to achieve the necessary reductions in the power supply subsector. That assessment is presented in Chapter IV of this report.

Table III-1. Final Recommended CSEO Policy Options

Sectors:	AG	FOLU	WM	ES	RCII	TLU	CPP
AG-1. Nutrient Management in Agriculture							
AG-2. Soil Carbon Management in Agriculture: Increased Use of Cover Crops							
AG-3. Soil Carbon Management in Agriculture: Increased Use Conversion of Row Crops to Perennial Crops							
AG-4. Advanced Biofuels Production							
AG-5. Biofuels Consumption (Existing Biofuels Statute)							
FOLU-3. Urban Forests: Maintenance and Expansion							
FOLU-4. Tree Planting: Forest Ecosystems							
FOLU-5. Conservation on Private Lands							
WM-1. Wastewater Treatment: Energy Efficiency							
WM-2. Front-End Waste Management: Source Reduction							
WM-3. Front-End Waste Management: Re-Use, Composting & Recycling							
ES-1. Increase the Renewable Energy Standard							
ES-2. Efficiency Improvements, Repowering, Retirement, and Upgrades to Existing Plants							
RCII-1. Incentives and Resources to Promote Combined Heat and Power (CHP) for Biomass and Natural Gas							
RCII-2. Zero Energy Transition/Codes (SB2030)							
RCII-4. Increase Energy Efficiency Requirements							
RCII-5. Incentives and Resources to Promote Thermal Renewables							
TLU-1. Transportation Pricing							
TLU-2. Improve Land Development and Urban Form							
TLU-3. Met Council Draft 2040 Plan							

Sectors:	AG	FOLU	WM	ES	RCII	TLU	CPP
TLU-4. Zero Emissions Vehicle Standard							
CPP. Estimates comprehensive effects of CSEO policy recommendations affecting 111(d) relevant portions of state electricity supply and demand.							

Consistency and Customization

For each CSEO policy option, CCS worked with Minnesota agency staff to develop design parameters needed to support the quantification of direct and indirect impacts and subsequent policy option implementation. These include:

- Timing: start and stop dates for the proposed policy options, as well, as any phase in or ramp up/down schedules.
- Level of effort: quantitative goals for the proposed action.
- Coverage of implementing or affected parties: this includes geographic boundaries and the specific types of entities or groups that will be required to implement the policy option.
- Other definitional issues or eligibility provisions: e.g. such as renewable fuel definitions, small business definitions, hydro-power size classes, etc.

In addition, the instruments or mechanisms used to implement each policy option must be defined, at least in general terms, to capture potential variations in effectiveness. This is particularly true for differences in price and non-price incentives and mandatory versus voluntary approaches). A variety of instruments or mechanisms exist, including:

- Voluntary agreements
- Technical assistance
- Targeted financial assistance: e.g. grants, production credits, low cost loans, loan guarantees
- Taxes or fees
- Cap and trade
- Codes and standards
- Disclosure and reporting
- Information and education
- Others: e.g. pilot programs or projects

The impacts of each are policy option specific and will vary by circumstance. For instance, price instruments, such as taxes and cap and trade, may perform better for policy options that are price responsive in comparison to those that are relatively unresponsive to price. Similarly, non-price instruments, such as codes and standards, may perform better where significant market barriers exist and require barrier removal. Mandatory actions may have higher compliance or market penetration rates.

CSEO policy option developers all worked from the same policy option template to achieve consistency across policy options and sectors. However, the policy option template offers significant flexibility in policy option design, so that each policy option can be highly customized to best fit the needs of Minnesota. Details of policy option design can be found in the respective sector appendices (F.1 through F.6).

Direct (Micro), Integrative, and Indirect (Macroeconomic) Impact Analysis

Direct impacts (also referred to as “microeconomic” impacts) include the estimated change from business as usual conditions in electricity, fuels or materials consumption, GHG emissions, and net direct costs that are expected as a result of policy option implementation. Details of the approach taken for estimating direct costs are provided in Appendix E.

The approach to evaluating indirect or macroeconomic impacts on jobs, income, economic growth, and prices that arise from implementation of new policy options are covered in Chapter III.1. These impacts also include distributional impacts, such as the differential impacts related to size, location, and socio-economic character of affected households, entities, and communities (this topic is often framed as fairness and equity). For instance, this would include disparate effects on small versus big business or wealthy versus low income households.

For direct impacts, the two key analytical endpoints are: cost effectiveness (CE), which is a measure of the implementation costs for every metric ton (t) of GHG avoided (expressed as $/tCO_2e$); and net societal costs/savings, presented as the net present value (NPV) of the stream of costs/savings incurred to implement the policy option over the planning period. These assessments include avoided costs due to policy option implementation, such as the avoided BAU cost of investment in infrastructure or services from efficiency measures. Net societal costs or savings are expressed in terms of a financial base year. For this project, the year 2014 is the financial base year. The CSEO planning period is from 2015 through 2030.

For all policy option analyses, energy and GHG impacts were assessed on the basis of the full energy-cycle, based on the availability of data and relevance. This means that net GHG reductions due to lower fuel or materials demand are quantified along with the net direct emissions impact at the point of combustion/use (i.e. upstream energy and GHG impacts were quantified, wherever possible). Since upstream GHG impacts cannot always be presumed to occur within the State’s boundaries, these impacts were reported separately (as potentially out of State reductions). However, wherever CE is reported, it is based on full energy-cycle emissions accounting.

Whether the analytical end-point is net energy impact, net GHG impact, or net direct societal costs, the general equation for determining these net benefits or costs was as follows:

Net Change = PSc – BAU

The net change brought about by implementing a policy option or action was always derived by subtracting the business as usual (BAU) value from the value estimated for the policy option scenario (PSc). During direct impacts analysis, this general equation is applied to any cost-benefit metric that is being analyzed (as described in the next section, it was also used to determine net macroeconomic impacts). These metrics were estimated on an annual basis and included: energy production, energy consumption, changes in land management, GHG emissions, and changes in direct societal costs (e.g. investment costs, operating and maintenance costs, energy costs, etc.).

For some policy options, where important energy/GHG impacts are expected to occur after the end of the planning period, additional assessment of these impacts are reported. These impacts are important for policy options where substantial investments are needed for new long-lived infrastructure and where full GHG reduction potential is not reached until some point in time after the planning period (e.g. transportation or new buildings infrastructure; land management policy options, such as reforestation). The individual sector-level policy option documents (PODs) in Appendix F provide these details.

Integration (Interaction and Overlaps) Assessment

The initial micro-economic analysis of each policy option was done on a “stand-alone” basis. This assumes that the policy option is to be implemented all by itself, and the results were calculated against BAU conditions as documented in the GHG inventory and forecast.

Policy options will often have overlapping or interacting effects with others that are being implemented at the same time. These interactions/overlaps can occur between policy options within the same sector (intra-sector) or between policy options in separate sectors (inter-sector). An example of an intra-sector overlap would be a policy option that reduces waste emplacement in landfills and another that addresses landfill gas capture. By implementing the first policy option, there will be less waste being emplaced in landfills (as compared to BAU), which will reduce the amount of methane generated in the future and the possible GHG reductions. As well, with implementation of the second policy option, there will be less methane being emitted (as compared to BAU). This will reduce the potential reductions that could be achieved by reducing landfill waste emplacement (assuming no landfill gas collection and control under BAU conditions).

A common example of inter-sector interactions/overlaps occurs between electricity energy efficiency (EE) policy options in the RCII sector and clean electricity generation policy options in the ES sector. This can occur due to the difference in electrical grid carbon intensity between the BAU forecast and the intensity that results from implementation of all ES supply-side policy options. Chapter III.1 provides details on how the inter-sector interaction/overlap analysis was done for CSEO.

Another common area for interaction/overlap is biofuels supply and demand policy options. For CSEO, this occurs between the biofuels production and consumption policy options developed in the Agriculture sector (Policy Options AG-4 and AG-5). The overlap between AG-4 and AG-5 was addressed by analyzing the results of these two policy options implemented together as a package (the "biofuels package"). The inter-sector overlap with policy options in the TLU sector was addressed separately and is further described in Chapter III.2-3 below.

Identification of intra-sector policy option interactions and overlaps and the methods used to address them is provided at the beginning of the individual sector PODs provided in Appendix F. Inter-sector interaction/overlap assessment is addressed in Chapter III.1.

Indirect Impacts (Macroeconomic) Analysis Methodology

Climate policy analysis often includes an assessment of the direct financial losses and gains likely to be associated with a given policy. Policymakers and decision-makers frequently seek to understand how regulated parties will be affected by any combination of cost increases or decreases, additional or lowered compliance costs, subsidies or taxes, and many other potential financial changes that policies can bring about. Cost-benefit analysis practices seek to expand the understanding of policy impacts beyond these direct impacts by including assessments of some indirect or distributed benefits as well. Social costs of carbon and value assessments of the health benefits of reducing emissions of a certain pollutant are examples of indirect or non-monetary impacts often included in such assessments.

Macroeconomic analysis is distinct in that it seeks specifically to understand how the direct financial and economic impacts of a policy drive responsive changes throughout the rest of the economy, and how those direct and responsive changes all contribute to a single overall change to an area's total employment, consumption, production and earnings levels. These are most commonly expressed as the number of jobs supported by a region's economy, and the estimate of a region's gross state product (GSP).

Though there are many dynamics through which different actors in the economy interact, one important way in which changes move quickly between sectors is through *intermediate demands*, which are the demands that producers of goods and services make on one another in order to deliver their own goods and services to market. Increasing or reducing needs for a good or service will, in turn, increase or reduce the need for all the inputs required for its production. Those inputs can come from all around the economy. Each of these inputs will have its own demand for inputs as well, and those inputs will, in course, have inputs of their own. By following these linkages (almost always in the form of specialized software packages), macroeconomic models are capable of quantifying projections of how a change in one sector will affect every other sector.

A second important mechanism is that of price and quantity equilibria. As policies create new supplies or demands for various goods and services, or as they increase or decrease prices for the same, economies adjust as producers and consumers shift their activity levels in response. These changes can influence the total scale of the economy, or just the total size of a given sector's sales. They also affect buying power and costs of production for businesses. Direct impact analyses typically do not seek to understand these responses to policy initiatives.

A third important way (which factors heavily in some of Pennsylvania's Work Plans) in which changes translate through the economy is through *changes in consumer spending*. Consumers spend on a very wide range of products and services, ranging from basic needs such as food, clothing, shelter, and transportation to a comprehensive range of investment and consumption choices. If a policy influences the level of money available to households to be allocated without restriction, that policy will immediately drive changes in demand in an impressive array of sectors around the economy.

The first step in this process for CSEO was a full review of each policy's descriptive documentation and spreadsheet analyses which informed the emissions-reduction and cost-effectiveness impacts. From these documents CCS developed a) the quantified estimates of expenses, savings, and cost and price changes, and b) understandings of which actors are expected to be on the supply and demand side of each changed financial flow or cost/price change.

The second step was the development of a full list of macroeconomic modeling inputs, which represent not only the spending, savings and cost/price changes, but also the necessary responsive changes to keep financial flows balanced. For example, if a given policy calls for consumers to spend $10 on equipment and save $20 on energy, then there is a net gain of $10 to the consumer (which they will spend or otherwise put to use), a net gain of $10 to the seller of the equipment (which they will also put to use), and a $20 loss to the energy supplier (which will require some adjustment for the supplier to absorb). Not only the original spending changes driven by the policy but also these responsive actions must be identified and quantified.

The third step was to utilize the REMI Policy Insight Plus (REMI PI+) macroeconomic modeling software, which is a dynamic economic forecasting model specific to the Pennsylvania economy and capable of modeling changes to 160 distinct and interconnected productive sectors. This software is the current leader in future scenario economic modeling power, and CCS analysts have significant experience utilizing this tool for greenhouse gas policy analysis. It is from this modeling effort that all results presented in this report were developed.

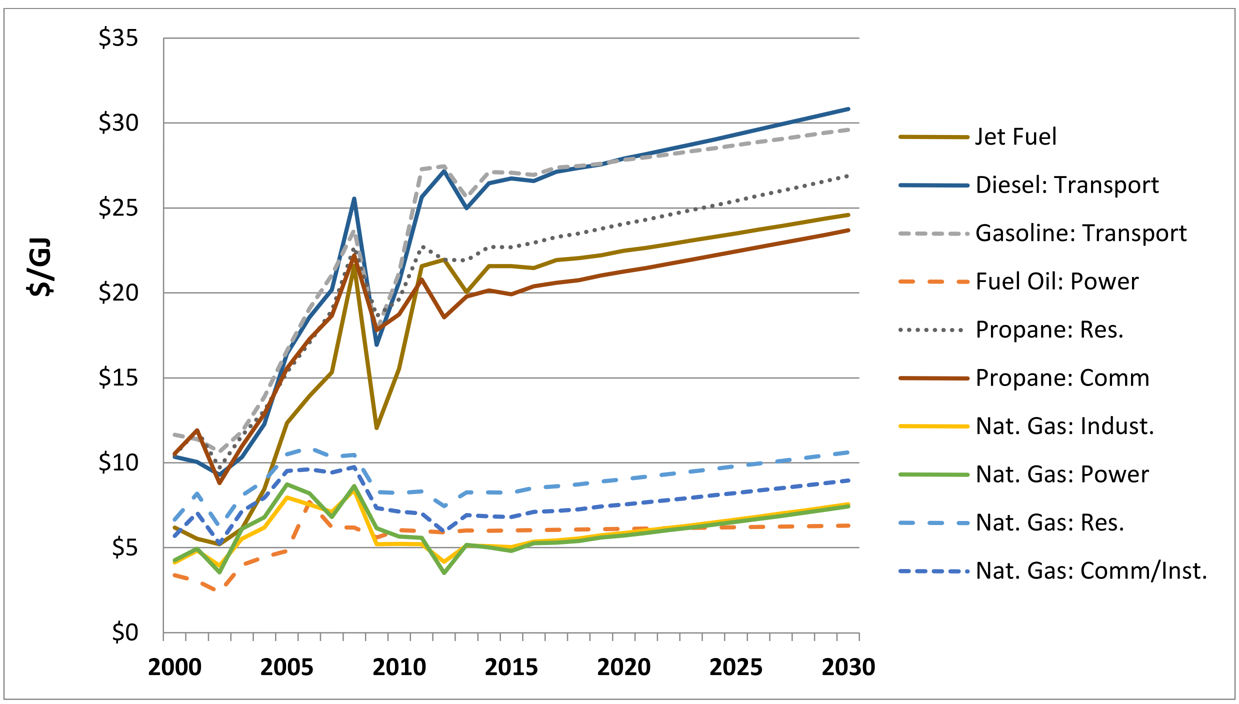
Throughout this effort, CCS bound the macroeconomic modeling work to a requirement to be consistent with the pre-existing analysis, assumptions and design of Work Plans. This is a significant principle, and is necessary to ensure that the macroeconomic analysis represents the Work Plan rather than some other policy with different parameters. Crucially, all assumptions about effectiveness and scale of these policies were retained from the cost-effectiveness analyses. The only independent decisions about design made as part of the macroeconomic analysis had to do specifically with modeling economic impacts. As such, the policy outcomes and projected policy effectiveness were defined before the macroeconomic analyses, and these analyses represent projections of the economic impacts when those outcomes occur. CCS did not, as part of this process, independently assess or verify the likely effectiveness of the emissions-reduction or cost-effectiveness analysis.

It is also worthwhile to keep in mind that while models predict values in extreme detail, the reporting here represents a decision to round results to a level of precision more appropriate to the circumstances. Projections of economic impacts fifteen years in the future are automatically of low precision because many underlying assumptions (such as energy prices, technological advancement, and worker productivity) are highly unpredictable – as is the overall size of the economy so far in the future. As such, results were rounded significantly, and results close to zero are described as neutral, meaning that no clear impact of any significance can be reasonably inferred from such a result. The most valuable information to be taken from these results is an understanding of the direction and the intensity of the pressure each policy can be expected to put on levels of overall economic activity.

Common Assumptions and Metrics for the Sectors

To support the economy-wide impacts analysis of CSEO policy options, an array of supporting data are required starting with the GHG emissions baseline. As described in Chapter II, the baseline was largely developed by MPCA and includes historic and forecasted estimates of energy consumption, "activity" data for non-energy emissions sources (e.g. waste generation, industrial processes and agricultural activity), emission factors, and additional information. Additional information required to conduct policy option impacts analysis includes forecasts of fuel prices (wholesale and retail), electricity prices, emission factors for the upstream fuel supplies and materials consumption, and other information through the end of the CSEO planning period (2030). Examples of these supporting data, shown below, were pulled together through support and review of CSEO Project workgroup members.[2]

Figure III-1. Retail Fuel Price Forecast



[2] Common sources of fuel and retail electricity data include: the US DOE Energy Information Administration's (EIA's) Annual Energy Outlook 2014 with data supplementation by Minnesota Department of Commerce. Upstream emission factors for fuels: Argonne National Labs GREET model; default run on US average fuels.

Figure III-2. Retail Electricity Price Forecast

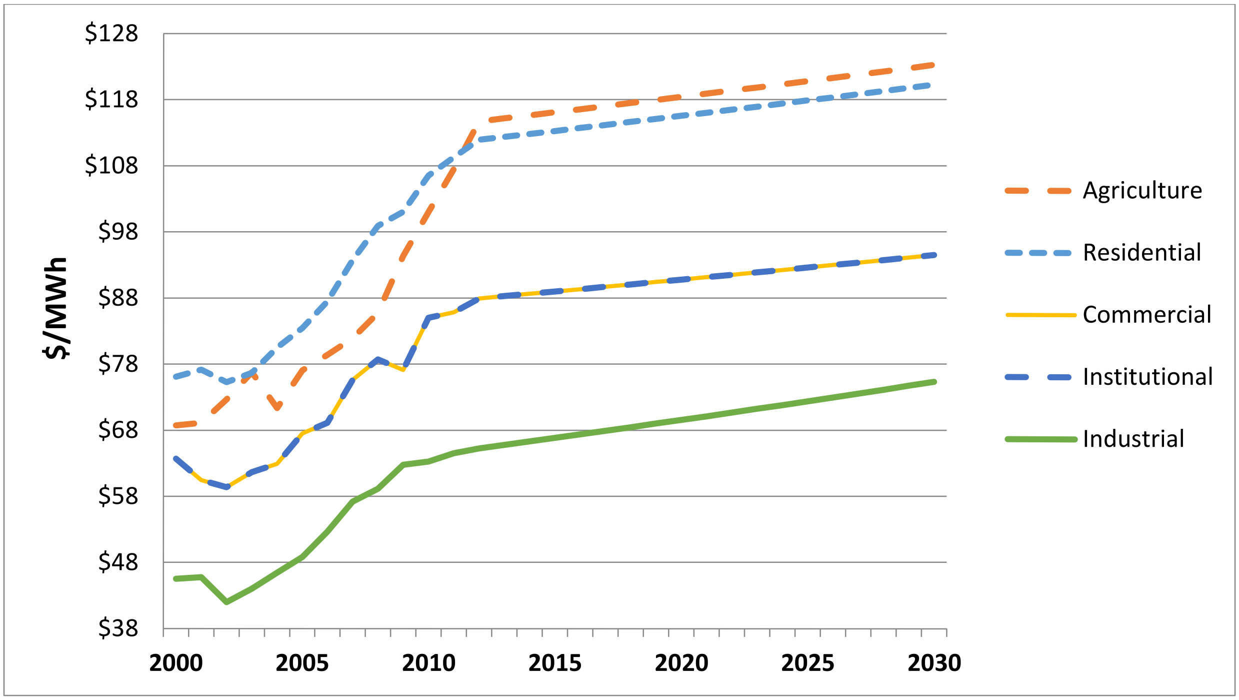
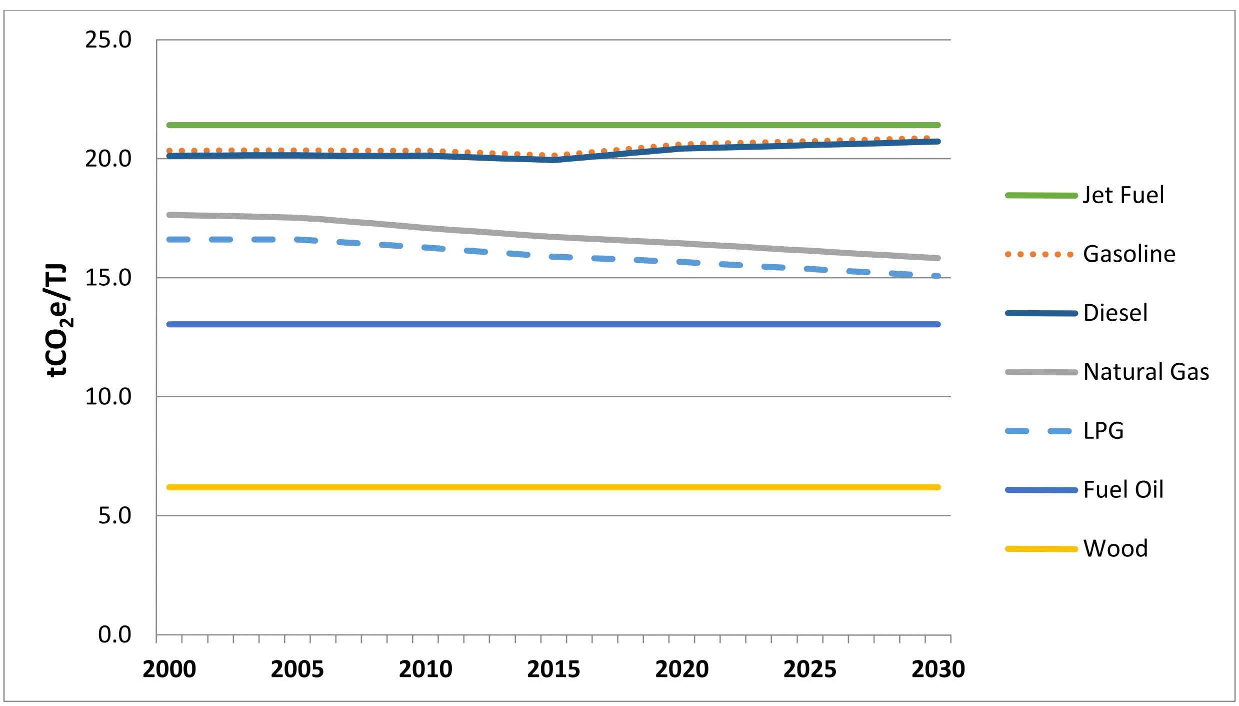


Figure III-3. Upstream GHG Emission Factors for Fuel Supplies



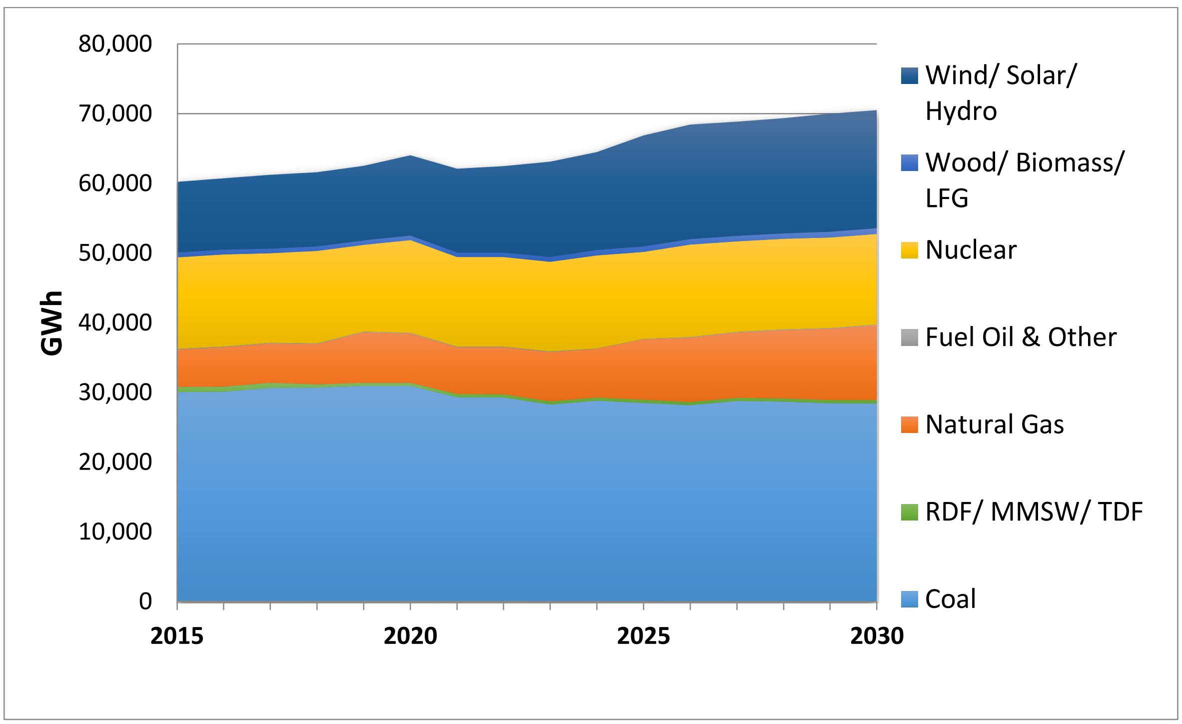
Electricity Supply & Demand Interactions Assessment

An important dataset for assessing the direct impacts of any policy option that affects the electricity system includes estimates of the avoided costs of generation and of the carbon intensity of avoided generation. These “avoided system metrics” are used to assess the net societal costs and GHG reductions for any policy option that either produces electricity (for example, renewable electricity or RE) or reduces consumption (such as energy efficiency or EE). The first step in developing these metrics is to define the “marginal resource mix” for the area being studied:

The marginal generator is the last power plant that is brought online (dispatched) or taken offline to match supply and demand in any given hour. Therefore, the marginal resource mix represents generation from the last set of power plants dispatched/taken off-line to balance supply with demand.

Figure III-4, below provides a summary of the net generation forecast by primary energy source that underlies the estimate of the power sector GHG emissions baseline.

Figure III-4. Net Generation Forecast for Minnesota



Input from the Energy Supply workgroup members provided definitions for the generation resources to be considered “on the margin” for additions of different types of added RE or EE resources, as shown in Table III-2 below.

Table III-2. Marginal Resource Mix Assumptions

System Impact	Marginal Resource Mix: 2012	Marginal Resource Mix: 2030
1. Measures that reduce demand across all hours of the day (EE, combined heat and power, and others)	80% coal: 20% NG	50% coal: 50% NG
2. New wind additions	80% coal: 20% NG	50% coal: 50% NG
3. New solar additions	60% coal: 40% NG	40% coal: 60% NG

Notes:

NG – natural gas. Natural gas generation is presumed to be 90% combined-cycle (NGCC) technology and 10% gas combustion turbine (NGCT). A very small amount of oil-fired generation (<1.0%) during the early years of the planning period was also factored into the marginal resource mix for System Impact #1.

The carbon intensities (expressed as tCO_2e/MWh avoided) for each system impact were calculated using emission rates for different types of generation derived from the GHG baseline, taking into account the 2012-2030 transitions in the marginal resource mix noted above. Two different sets of marginal carbon intensities are shown in Table III-3 below, corresponding to avoided generation and avoided retail sales. The set corresponding to avoided retail sales includes the expected transmission and distribution (T&D) losses of about 5.8% through the planning period. The most commonly applied set of carbon intensities was the set developed for System Impact #1 on the basis of avoided retail sales (gray shaded cells), since these reflect the GHG savings for reduced consumption from the grid (for example, from new EE programs).

Table III-3. Carbon Intensities of the Marginal Resource Mix

Year	tCO_2e/MWh of Generation			T&D Losses (% of sales)	tCO_2e/MWh of Retail Sales Avoided		
	80:20 Coal:Gas Trending to 50:50 Coal:Gas (System Impact #1)	Wind Power (System Impact #2)	Solar Power (System Impact #3)		80:20 Coal:Gas Trending to 50:50 Coal:Gas (System Impact #1)	Distributed Wind Power (System Impact #2)	Distributed Solar Power (System Impact #3)
2012	0.928	0.928	0.827	5.86%	0.982	0.982	0.876
2013	0.913	0.913	0.814	5.85%	0.966	0.966	0.862
2014	0.905	0.905	0.809	5.82%	0.958	0.958	0.857
2015	0.885	0.885	0.792	5.81%	0.936	0.936	0.839
2016	0.873	0.873	0.783	5.81%	0.924	0.924	0.828
2017	0.865	0.865	0.778	5.81%	0.916	0.916	0.823
2018	0.859	0.859	0.774	5.82%	0.909	0.909	0.819
2019	0.853	0.853	0.773	5.81%	0.903	0.903	0.818
2020	0.847	0.847	0.769	5.79%	0.896	0.896	0.813
2021	0.827	0.827	0.750	5.84%	0.875	0.875	0.794
2022	0.816	0.816	0.742	5.85%	0.864	0.864	0.785
2023	0.809	0.809	0.737	5.85%	0.856	0.856	0.780
2024	0.798	0.798	0.728	5.83%	0.845	0.845	0.770
2025	0.781	0.781	0.710	5.79%	0.826	0.826	0.751
2026	0.770	0.770	0.701	5.77%	0.814	0.814	0.742
2027	0.756	0.756	0.690	5.86%	0.800	0.800	0.730
2028	0.743	0.743	0.679	5.79%	0.786	0.786	0.718
2029	0.730	0.730	0.668	5.79%	0.772	0.772	0.706
2030	0.716	0.716	0.656	5.77%	0.758	0.758	0.694
Growth Rate, 2015-2030	**-1.40%**	**-1.40%**	**-1.25%**	**-0.05%**	**-1.40%**	**-1.40%**	**-1.25%**

Since carbon intensities shown above only address emissions from the generation sources themselves, an additional set of carbon intensities were also developed to estimate emissions associated with fuel supplies (that is, the "upstream" GHGs emitted during fuel extraction, processing, shipping, refining, and distribution). For System Impact #1, these values ranged from about 0.085 to 0.095 tCO_2e per MWh of avoided retail sales through the planning period.

Along with the carbon intensities of the marginal resource mix, a set of avoided electricity system costs were developed. These costs capture the capital costs, fixed and variable O&M, and fuel costs for each of the marginal resources (coal-fired steam, NGCC and NGCT plants). A key reference source used to construct levelized costs of electricity generation for each resource type is referenced below.[3] The values derived to represent weighted-average avoided costs by year for each of the three sets of resource mix assumptions provided above are summarized in Table III-4 below. The most commonly applied factors are shaded and correspond to EE measures.

Table III-4. Avoided Electricity System Costs for the Marginal Resource Mix

Year	$/MWh Generated			$/MWh Avoided Retail Sales		
	80:20 Coal:Gas Trending to 50:50 Coal:Gas (System Impact #1)	Wind Power (System Impact #2)	Solar Power (System Impact #3)	80:20 Coal:Gas Trending to 50:50 Coal:Gas (System Impact #1)	Wind Power (System Impact #2)	Solar Power (System Impact #3)
2012	$77.89	$29.09	$47.44	$77.89	$82.45	$30.79
2013	$80.91	$31.38	$51.33	$81.26	$85.64	$33.22
2014	$85.51	$35.08	$57.22	$85.27	$90.49	$37.13
2015	$87.51	$36.29	$58.90	$86.68	$92.59	$38.40
2016	$89.74	$37.74	$60.82	$88.93	$94.96	$39.93
2017	$92.39	$39.63	$63.33	$91.35	$97.76	$41.93
2018	$95.18	$41.61	$65.86	$93.90	$100.72	$44.03
2019	$98.68	$44.28	$69.38	$96.90	$104.42	$46.85
2020	$101.95	$46.68	$72.37	$99.88	$107.85	$49.38
2021	$104.55	$48.37	$74.37	$101.94	$110.66	$51.20
2022	$108.00	$50.88	$77.50	$104.48	$114.32	$53.86
2023	$111.98	$53.89	$81.20	$107.43	$118.53	$57.04
2024	$115.62	$56.52	$84.35	$110.09	$122.36	$59.82
2025	$118.23	$58.12	$86.13	$112.18	$125.07	$61.48
2026	$122.41	$61.26	$89.90	$115.48	$129.47	$64.79
2027	$126.49	$64.27	$93.48	$118.77	$133.90	$68.03
2028	$130.73	$67.40	$97.15	$121.96	$138.30	$71.31
2029	$135.23	$70.75	$101.06	$125.52	$143.06	$74.84
2030	$140.00	$74.31	$105.17	$129.23	$148.08	$78.59
Growth Rate, 2015-2030	**3.18%**	**4.89%**	**3.94%**	**3.18%**	**4.89%**	**3.94%**

During impacts analysis, the avoided system metrics above were applied to all policy options with an electricity system impact to estimate GHG reductions and net societal costs associated with avoided electricity generation. The "stand-alone" results for each policy option assume

[3] Lazard's Levelized Cost of Energy Analysis – Version 8.0, September 2014.

that the policy option will be implemented by itself. The stand-alone results compare implementation of each policy option to the emissions and costs of a “business as usual” electrical system. The stand-alone results for each policy option are described in more detail in Chapter III.2 below, as well as in the sector-specific appendices to this Report (Appendices F.1 thru F.6).

As long as the overall projected output of the marginal resource mix under the BAU forecast has not been exceeded by the cumulative electricity system impacts of all of the CSEO policies combined (that is, by the sum of all EE and new RE and combined heat and power generation), then the stand-alone results do not need to be adjusted to account for structural changes to the electricity system. However, if the cumulative electricity system impacts exceed the size of the marginal resource mix, then under real operating conditions, adjustments to how the electricity system operates will be needed—including which plants are built and run—beyond the marginal resources assumed. In order to appropriately model changes in costs and emissions when system impacts exceed the marginal resource mix, adjustments to the avoided system metrics would be needed. That is, a new set of “Plan Scenario” avoided system metrics (avoided costs and avoided emissions factors) would be needed.

The electricity system for CSEO is not necessarily limited to generation sources within the State’s boundaries; and this is consistent with the way in which the GHG baseline for MN is assessed. The baseline for the power sector is constructed on a “consumption-basis” meaning that the GHG emissions associated with power consumption – regardless of generation location – are considered. Therefore, this includes net imports of power to the State. This creates obvious complexities in assessing net CSEO policy impacts, since it implies some knowledge of not only what policies will be implemented in MN but also within the rest of the States that support the regional grid.

Although there is a lack of information on how other States in the region will implement policies affecting regional electricity supply and demand, an assessment of the size of the overall CSEO policy impacts against the generation sources within MN is useful to gauge whether or not the initial assumptions of the marginal resource mix are still valid following policy implementation. Figure III-5 shows the size of the marginal resource mix defined for CSEO, including all MN coal and natural gas generation and net fossil imports (expected to be mostly a combination of coal and natural gas generation sources). The in-State portion of the mix is dominated by coal-fired generation, but becomes more reliant on gas-fired generation over time as older coal plants are phased out and NGCC plants are phased in.

Figure III-5. Size of the BAU Marginal Resource Mix

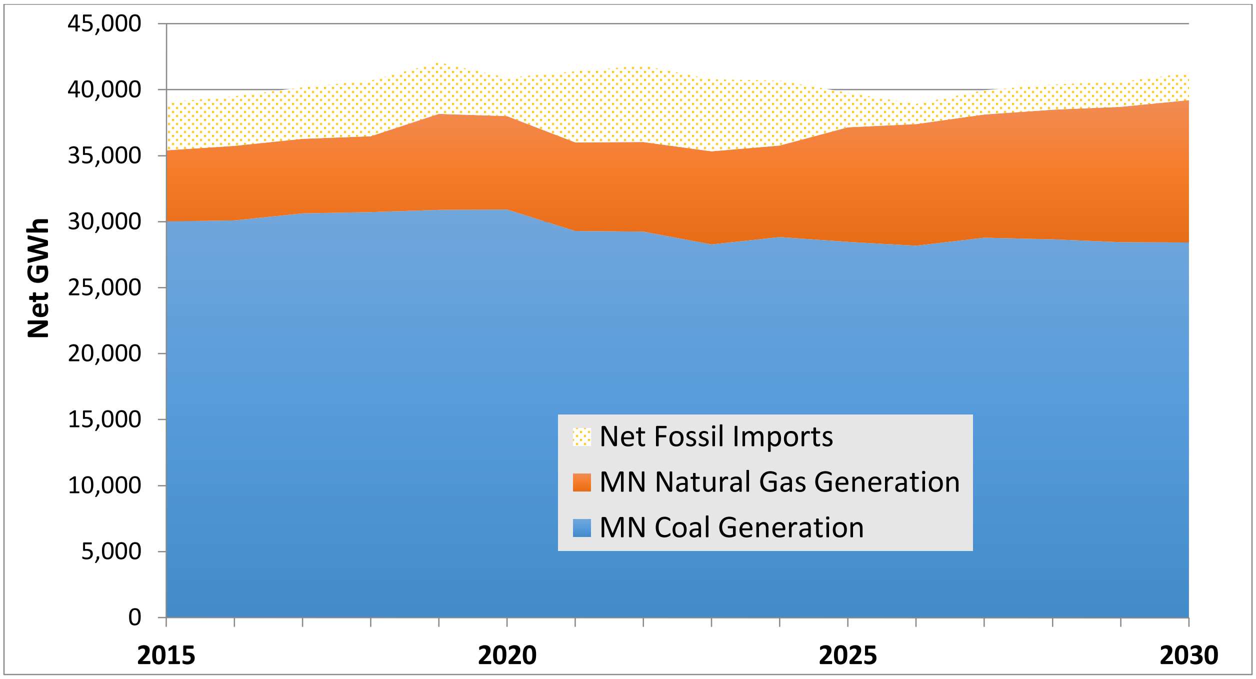


Figure III-6 provides a summary of the impacts on the marginal resource mix due to implementation of ES-2. This includes a shift of generation from coal to a combination of wind and natural gas starting in about 2023. ES-2 calls for repowering and replacement, respectively, of two units of Xcel Energy's Sherburne County (Sherco) coal-fired generating station.

Figure III-6. CSEO Marginal Resource Mix ES-2 Impacts

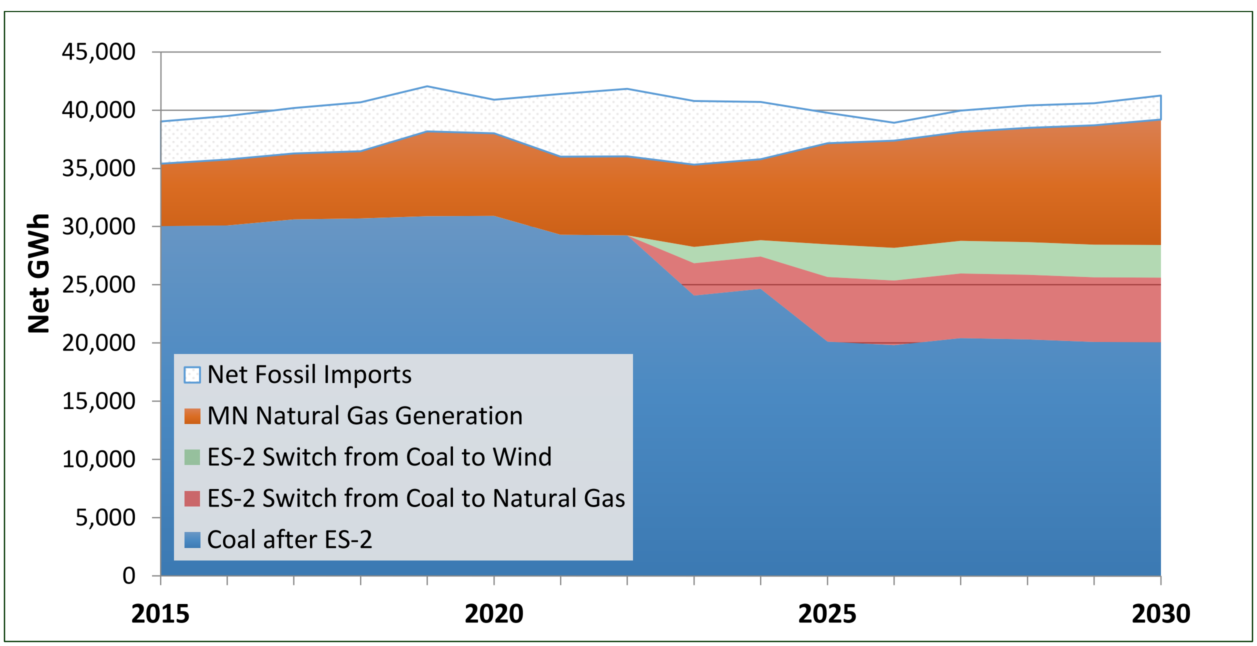
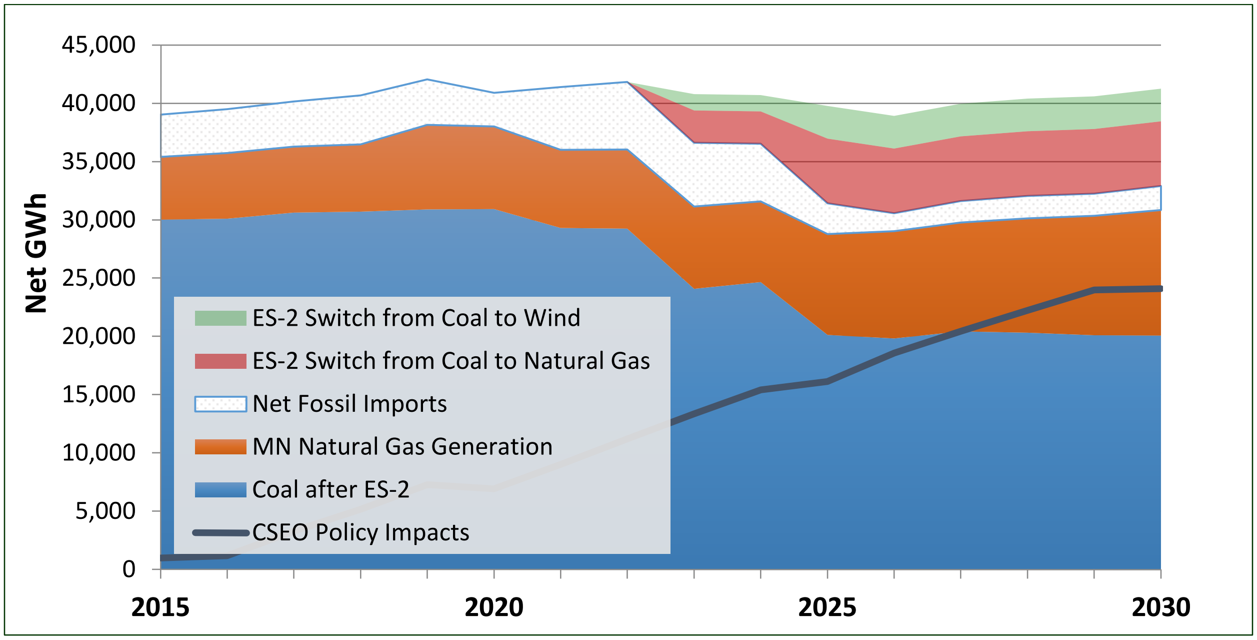


Figure III-7, shows the total gigawatt-hours (GWh) saved and displaced through implementation of the EE and CHP elements in the demand-side sector policies, plus the deployment of additional renewable generation in policy option ES-1. These total impacts are shown in the "CSEO Policy Option Impacts" trend line. Since the total displaced generation indicated by this line does not exceed the overall size of the marginal coal, natural gas and net fossil imports based generation during the planning period, even by 2030, then it there is no need for adjustment of the avoided system metrics due to the size of the CSEO policy impacts.

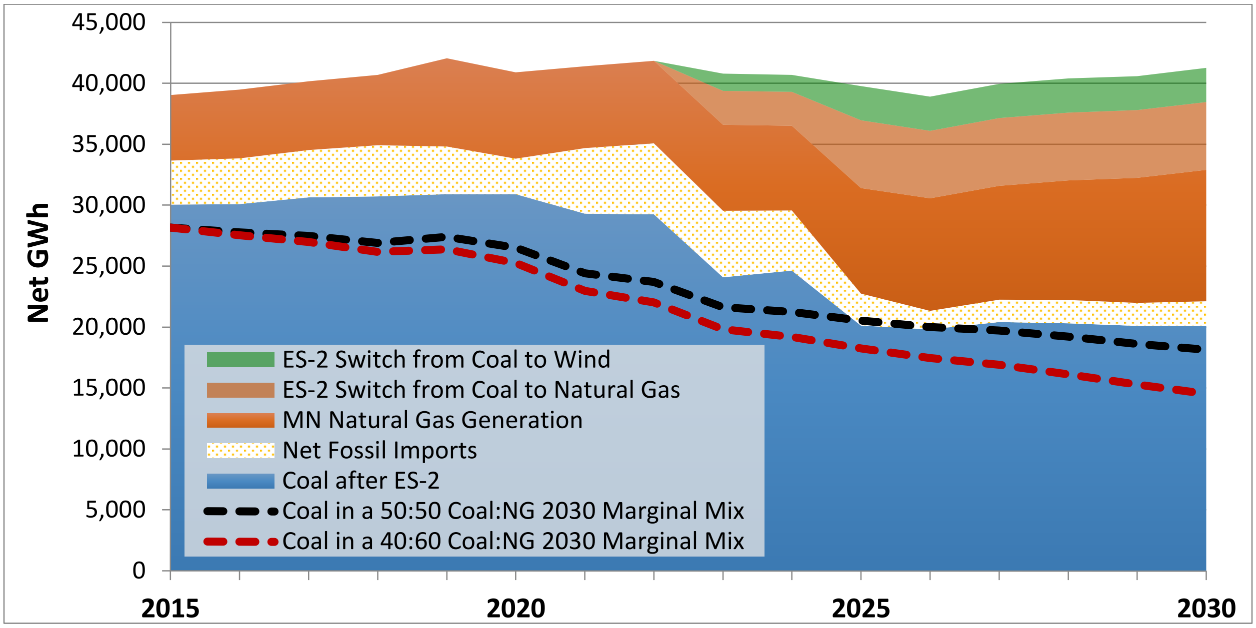
Figure III-7. CSEO Policy Impacts Compared to the Marginal Resource Mix



As indicated in the discussion of the marginal resource definitions above, not only does the marginal resource mix assumed for avoided generation specify the overall marginal resource mix (coal and natural gas-fueled generation), it also describes how that mix is expected to change during the CSEO planning period. As noted in Table III-2, the marginal resource mix is expected (and assumed, for modeling purposes) to include progressively larger proportions of natural gas relative to coal during the latter years of the planning period.

Figure III-8 shows the amount of coal-based generation needed to support the original (BAU) definitions of marginal resources plotted with the resource mix that remains after implementation of ES-2 (re-powering of/replacement of the Sherco units with natural gas). As indicated by the black dotted line, for a 2030 50:50 mix of coal and natural gas, the implementation of ES-2 will remove enough coal-fired generation in the years 2025 and 2026 to create a very small deficit of up to about 400 GWh per year. However, this does not include any additional coal in the net fossil imports. Since any coal in the imported power would like more than make up for this small deficit, there is little need to develop a revised avoided system metrics. Any slight revisions to the marginal system metrics in these two years would have negligible impacts on the estimated GHG reductions and costs for CSEO policies.

Figure III-8. CSEO Electricity System Policy Option Impacts



Additional Potential Electricity Supply and Demand Interactions

Two additional potential interactions between RCII and ES policies were considered, but ultimately considered to be not applicable to the RCII and ES options as designed. First, both ES-1 (expanded renewable energy standard) and RCII-1 (promotion of CHP) include expanded use of biomass/wood-fired CHP. Even combined with the gas-fired CHP included in RCII-1, however, the total CHP included in RCII-1 and ES-1 is significantly less than the industrial, institutional, and commercial technical potential for CHP described in a recent assessment for Minnesota.[4] As such, it was presumed that the biomass-fired CHP objectives of the RCII-1 and ES-1 policies are additive, not overlapping.

Second, ES-1 applies an expanded renewable energy standard as a fraction of retail sales of electricity. Energy efficiency and CHP investments in RCII and other demand-side policies will reduce sales of electricity, so the GHG reductions and costs for ES-1 policy required adjustment. The total electricity demand reductions for all CSEO policies ranged from about 5,100 GWh in 2020 to nearly 18,700 GWh in 2030. This represents 7 to 24% of forecasted electricity demand.

[4] Minnesota Department of Commerce (2014), *Minnesota Combined Heat and Power Policies and Potential: Conservation Applied Research & Development (CARD) FINAL REPORT*, dated July, 2014, and available as https://mn.gov/commerce/energy/images/CHPRegulatoryIssuesandPolicyEvaluation.pdf.

Therefore, the ES-1 renewable energy requirements (and associated costs and GHG reductions) were lowered by fractional reduction in forecasted demand in each year of the planning period.

Transportation Biofuels Interactions Assessment

All four TLU policies involve reducing gasoline emissions, and therefore these policies need to account for the overlap with the two biofuel policies, AG-4 and AG-5, also referred to as the "biofuels package". The biofuels package supports the production and consumption of advanced biofuels in the State (for CSEO analysis purposes, advanced forms of ethanol production was presumed). As more advanced biofuels are consumed by Minnesota vehicles, the average fossil carbon content of these fuels will be reduced. Since the GHG reductions for the TLU policies were measured against a BAU fuel supply containing MPCA's expected ethanol content (and hence, fossil carbon content), the carbon content of fuels consumed as a result of implementation of the CSEO biofuels package needs to be considered and appropriate adjustments made to remove the overlapping GHG reductions (in this case, between the TLU and Agriculture sector policies).

The overlap was addressed based on the change in carbon content of gasoline (tCO_2/TJ) that occurs as a result of adding more advanced ethanol into the fuel supply forecast. This essentially lowers the carbon content slightly during the years where the biofuels package introduces more advanced ethanol into the fuel supply (advanced ethanol displaces an energy equivalent of gasoline for each unit volume displaced). The overlapping emission reductions between the TLU and Agriculture sector policies was addressed by adjusting the TLU policy option GHG reductions downward using the adjusted gasoline carbon content values. This resulted in a reduction in the sum of GHG savings for all four TLU options by 0.7% in 2020 and 1.2% in 2030.

Chapter IV. Policy Option Recommendations and Results

Introduction

This section provides a summary of each individual CSEO policy options and its associated direct, integrated, and indirect impacts. See Chapter III.1 above for a discussion of the approaches, definitions and terminology that are applied for policy option impact screening, design, and analysis during the CSEO project.

Each CSEO policy option analysis was designed for implementation 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 occurring within the next one to two years.

Direct Impacts of CSEO Policies

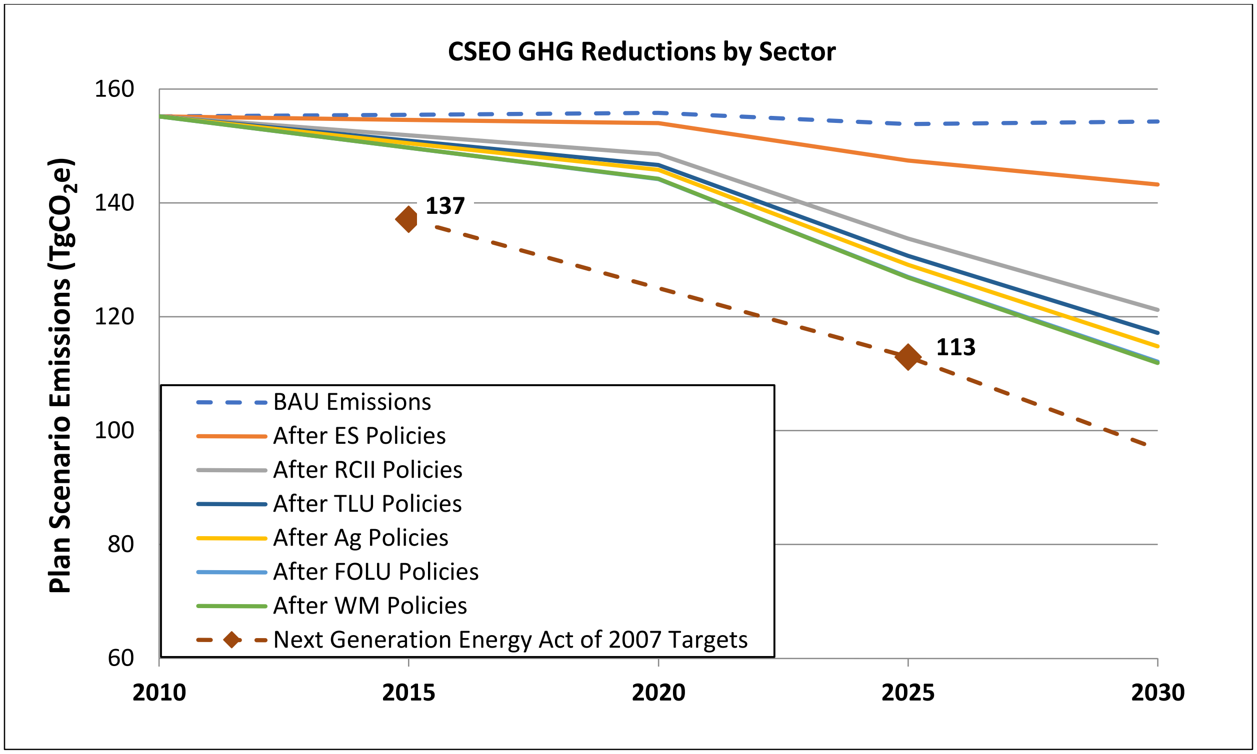
Figure III-9 provides a summary of the GHG reductions expected from full implementation of all CSEO policies. The emissions remaining during the Plan Scenario (PS) only indicate those within the State (expected upstream impacts are excluded). Also, these reductions are net of any intra- and inter-sector interactions and overlaps among the CSEO policies. The chart indicates that most emission reductions (78% in 2030) will occur as a result of policy option implementation in the ES and RCII sectors.

Also plotted on the chart are the Minnesota Next Generation Energy Act (NextGen) targets for 2015 and 2025. The 2007 Act calls for reducing the State's emissions 15% below 2005 levels by 2015, 30% below 2005 by 2025, and 80% below 2005 by 2050. On a gross emissions basis[5], the targets would be 137 $TgCO_2e$ in 2005 and 113 $TgCO_2e$ in 2025. After all CSEO policies are fully implemented, there is still expected to be a shortfall of about 14 $TgCO_2e$ in GHG reductions to meet the State's 2025 target. Note that the emission reductions included here only include those expected to occur within the State; not the full energy-cycle reductions, which include some out-of-State reductions. For example, in 2025, there is an expected additional 6 $TgCO_2e$ of upstream GHG reductions associated with full implementation of policies (e.g. embedded GHGs in fuels and materials that are produced outside of the State).

By 2030, in-State GHG emissions are expected to be 112 $TgCO_2e$, rather than at levels (97 $TgCO_2e$) that would put the State on a trajectory to meet the 2050 goal.

[5] Gross emissions exclude carbon sequestration in building products, landfilled waste, and rural and urban forests.

Figure IV-1 GHG Impacts of CSEO Policy Option Implementation



GHG abatement potentials (the expected emissions reductions) of each individual policy option, as well as sector level expected abatement potentials, are presented in the Figure IV-2 below.

Figure IV-2 GHG Reductions for CSEO Policies

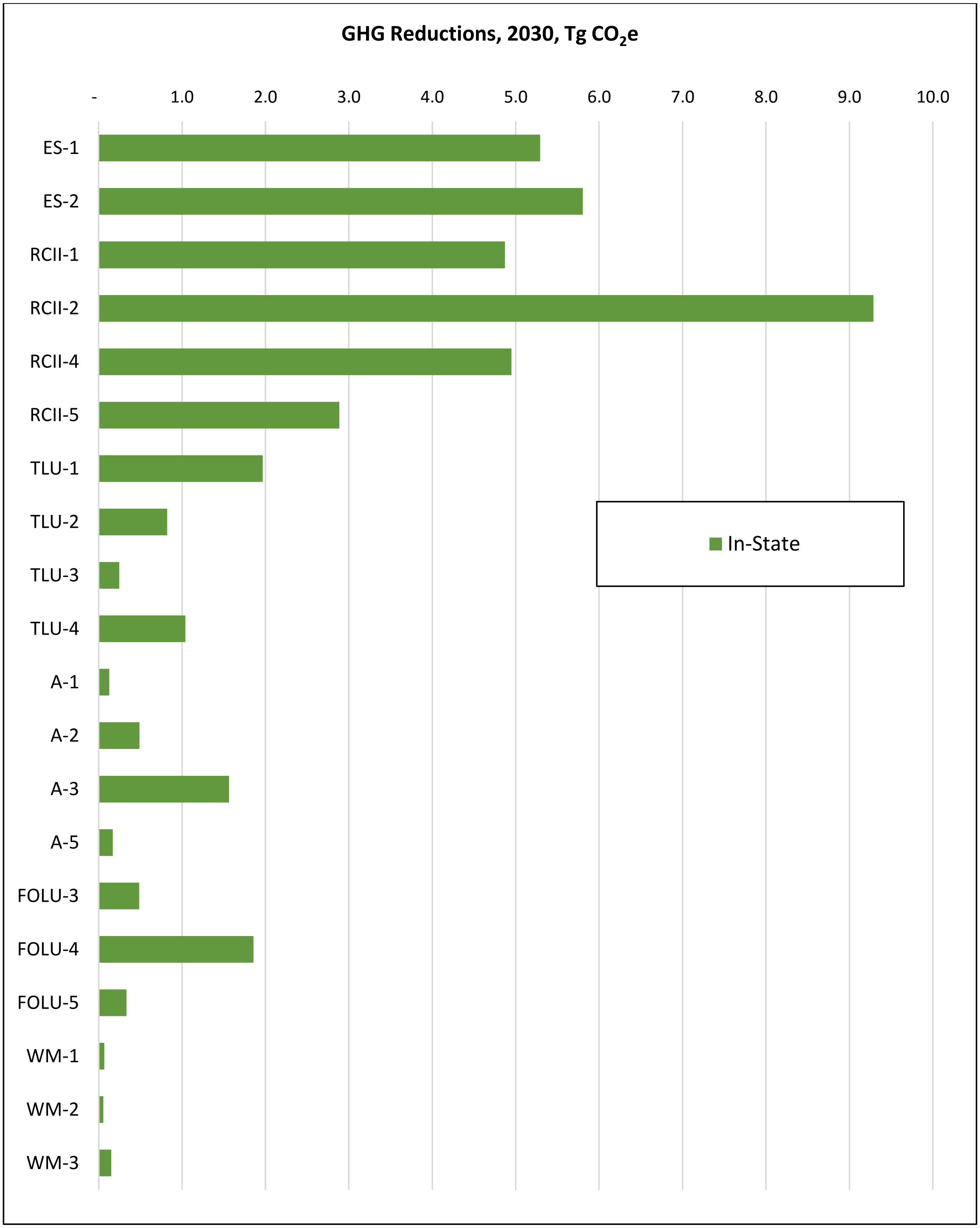


Table IV-1 below provides a summary of the direct impacts of individual CSEO policies and sectors. The values provided are based on the assumption that the policies are implemented on an individual, stand-alone basis (on interactions and overlaps they may occur if policies are implemented simultaneously are considered here).

Table IV-1 Stand Alone Impact Summary of CSEO Policies

CSEO Options Direct Stand-Alone Analysis Impacts								
Sector of the Economy	**Policy Option ID**	**Policy Option Title**	**GHG Reductions**				**Costs**	
			Annual CO_2e Reductions (In-State)		**2030 Cumulative (In-State)**	**2030 Cumulative (Total, In-state + Out-of-State)**	**Net Costs (NPV)[a] 2015-2030 $Million**	**Cost Effectiveness[b] $/tCO_2e$**
			2020 Tg	**2030 Tg**	**$TgCO_2e$**	**$TgCO_2e$**		
Energy Supply	ES-1	Increase Renewable Energy Standards (40% goal)	1.9	7.5	67	75	($620)	($8.20)
	ES-1	*Increase Renewable Energy Standards (50% goal)[c]*	2.4	13	98	110.35	($404)	($3.66)
	ES-2	Efficiency Improvements, Repowering, Retirement, and Up Grades to Existing Plants	0	6.3	44	39	$752	$19
	ES Sector Totals		**1.9**	**14**	**111**	**114**	**$132**	**$1.16**
Residential, Commercial, Industrial and Institutional	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-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)[d]*	*1.0*	*3.2*	*25*	*29*	*($1,272)*	*($44)*
	RCII-5	Incentives and Resources to Promote Thermal Renewables.	0.8	3	22	30	$872	$29
	RCII Sector Totals		**5.3**	**22**	**157**	**182**	**($4,171)**	**($23)**
Transportation and Land Use	TLU-1	Transportation Pricing - Total	1.5	2.03	22	28	$2,718	$96
		- PAYD Insurance Component	0.46	1	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	0.008	0.064	0.064	($74)	($1,155)
	TLU-3	Metropolitan Council Draft 2040 Plan	0.083	0.25	2	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)*	*(0.4)*	*(2.10)*	*(1.10)*	*$3,237*	*N/A*
	TLU Sector Totals		**2**	**4.4**	**37**	**47**	**$5,241**	$112
Agriculture	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
	A Sector Totals		**0.83**	**2.4**	**19**	**24**	**($3,119)**	**($132)**

Forestry and Other Land Use	FOLU-1	Protect Peatlands and Wetlands	*Not Quantified*					
	FOLU-2[f]	Manage for Highly Productive Forests - Intermediate Stand Treatments	*Not Applicable*					
	FOLU-3[g]	Urban Forests: Maintenance and Expansion 40% Canopy Goal	0.086	0.49	3.2	3.2	$1,806	$568
	FOLU-4[h]	Tree Planting: Forest Ecosystems	1.4	1.9	30	34	$187	$5.60
	FOLU-5[l]	Conservation on Private Lands	0.14	0.34	3	3	$1,261	$421
	FOLU Sector Totals		**1.6**	**2.7**	**36**	**40**	**$3,254**	**$81**
Waste Management	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	(0.002)	0.057	0.073	9.4	($277)	($30)
	WM-3[J]	Front-End Waste Management - Re-Use, Composting & Recycling	(0.110)	0.15	-0.45	27	($817)	($30)
	Waste Management Sector Totals		**(0.058)**	**0.28**	**0.52**	**37**	**($1,150)**	**($31)**
CPP	**Clean Power Plan**		**8.56**	**17.0**	**199.2**	**N/A**	**($398)**	**($2.0)**

Notes:

[a] Net Present Value of fully implemented policy option using 2014 dollars ($2014).

[b] Cost effectiveness values include full energy-cycle GHG reductions, including those occurring out of state. Dollars expressed in $2014.

[c] ES-1 50% is an alternative scenario evaluated in the ES sector, and is not included in the "Totals" row calculation.

[d] 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

[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.

[f] Net emissions were found to be positive for this policy option; therefore, no cost effectiveness could be calculated.

[g] Full benefits are realized when considering the full life-span of planted trees. 2015-2085 Cumulative Reduction = 67 TgCO2e; NPV = $2,208; 2085 CE = $33

[h] Full benefits are realized when considering the full life-span of planted trees. 2015-2085 Cumulative Reduction = 108 TgCO2e; NPV = $183; 2085 CE = $1.76

[l] Full benefits are realized when considering the full life-span of planted trees. 2015-2085 Cumulative Reduction = 25 TgCO2e; NPV = $1,304; 2085 CE = $53

[J] Assumes full implementation of WM-2.

Table IV-2 provides a summary of the direct impacts analysis for all CSEO policies, including all inter-sector overlaps and adjustments. These results include:

- Expected in-state emission reductions in 2020, 2030, and cumulatively through 2030; the direct implementation costs during the planning period, and
- Estimated cost effectiveness (CE).

Note that the value for cost effectiveness (CE) is calculated on the basis of full energy-cycle emission reductions, not just the reductions that occur within the State. More discussion of this issue follows at the end of this section.

Note also that these results have been adjusted to account for interactions and overlaps that occur both within (intra-) and between sectors (inter-).

Additionally, this table summarizes indirect, or macro-economic impact of the policies (individual and sector level).

Table IV-2 Inter-Sector Integrated Impact Summary of CSEO Policies

			Direct Impacts		
Policy Option	**Policy Option Title**	**2030 Annual In-State Reductions (Tg CO_2e)**	**Total Reduction 2015-2030[a] ($TgCO_2e$)**	**Net Costs 2015-2030[b] ($2014MM)**	**CE[c] ($2014/$tCO_2$e)**
ES-1	40% Renewable Generation by 2030	5.3	62	$(360)	$(5.8)
ES-2	Energy Supply Scenario #1	5.8	38	$854	$22
Energy Supply Totals		**11.1**	**100**	**$494**	**$4.9**
RCII-1	CHP for Biomass and NG	4.9	49	$(1,117)	$(23)
RCII-2	SB2030/Zero Energy Transition/Codes	9.3	60	$(2,050)	$(34)
RCII-3	Reduce High GWP GHGs	-	*Not Quantified*		
RCII-4	Increase EE Requirements	4.9	40	$(1,814)	$(45)
RCII-5	Thermal Renewables	2.9	30	$842	$28
Residential, Commercial & Institutional Totals		**22**	**180**	**$(4,140)**	**$(23)**
TLU-1	Transportation Pricing and Move Minnesota Plan	2.0	28	$2,718	$98

Policy Option	Policy Option Title	2030 Annual In-State Reductions (Tg CO_2e)	Direct Impacts: Total Reduction 2015-2030[a] ($TgCO_2e$)	Direct Impacts: Net Costs 2015-2030[b] ($2014MM)	Direct Impacts: CE[c] ($2014/$tCO_2e$)
TLU-2	Improve Land Development and Urban Form	0.82	8.2	$(425)	$(52)
TLU-3	Metropolitan Council Draft 2040 Plan	0.25	2.6	$(330)	$(127)
TLU-4	Zero Emission Vehicle Standard	1.04	6.7	$3,278	$489
Transportation & Land Use Totals		**4.1**	**45**	**5,241**	**$116**
AG-1	Nutrient Management	0.13	2.7	$(127)	$(47)
AG-2	Soil Carbon Management: Cover Crops	0.49	3.6	$(1,346)	$(377)
AG-3	Soil Carbon Management: Row to Perennial Crops Conversion	1.6	14	$(2,104)	$(153)
AG-4	Advanced Biofuels Production	*Quantified as Part of AG-5*			
AG-5	Existing Biofuel Statute	0.17	3.5	$462	$133
Agriculture Totals		**2.4**	**23**	**$(3,115)**	**$(133)**
FOLU-2	Manage for Highly Productive Forests		*Not Quantified*		
FOLU-3	Urban Forests: Maintenance and Expansion 40% Canopy Goal	0.49	3.4	$1,806	$525
FOLU-4	Tree Planting: Forest Ecosystems	1.9	34	$187	$5.6
FOLU-5	Conservation on Private Lands	0.34	3.0	$1,261	$421
Forestry & Other Land Use Totals		**2.7**	**40**	**$3,254**	**$81**
WM-1	Waste Water Treatment - Energy Efficiency	0.068	0.99	$(56)	$(56)
WM-2	Front-End Waste Management - Source Reduction	0.057	9.4	$(228)	$(24)
WM-3	Front-End Waste Management - Re-Use, Recycling & Composting	0.15	27	$(817)	$(30)
Waste Management Totals		**0.28**	**37**	**$(1,101)**	**$(29)**
CPP		**199.2**	**N/A**	**$(398)**	**$(2.0)**

			Direct Impacts		
Policy Option	Policy Option Title	2030 Annual In-State Reductions (Tg CO_2e)	Total Reduction 2015-2030[a] ($TgCO_2e$)	Net Costs 2015-2030[b] ($2014MM)	CE[c] ($2014/$tCO_2e$)
Total Integrated Plan Results		42	426	$634	$1.5

Notes:
Totals and subtotals may not add exactly due to rounding.
[a] GHG reductions include those that occur within the State as well as upstream emissions that may occur outside MN's boundaries.
[b] The net present value (NPV) of direct implementation costs for the policy on a net societal basis.
[c] Cost effectiveness of the policy (total reductions divided by the NPV of implementation costs.

Figure IV-3 provides a bar chart showing the cumulative 2015 - 2030 GHG reductions for each policy option on both an in-state basis, as well as a full energy-cycle basis. As indicated by this chart, some policy options produce significant GHG reductions via reduced demand for fuels or materials (e.g. solid waste management, biofuels production and consumption). A large fraction of these reductions could occur outside of the State's boundaries; however, available data do not allow for geographic attribution of reductions. This issue doesn't reduce the importance of these reductions (i.e. a tCO_2e emitted in China contributes as much to climate change as one emitted in Minnesota). Also, since some of these upstream reductions will occur in Minnesota, they can be viewed as "additional insurance" toward progress in achieving the State's GHG reduction target.

Figure IV-3 Comparison of In-State and Out of State GHG Reductions

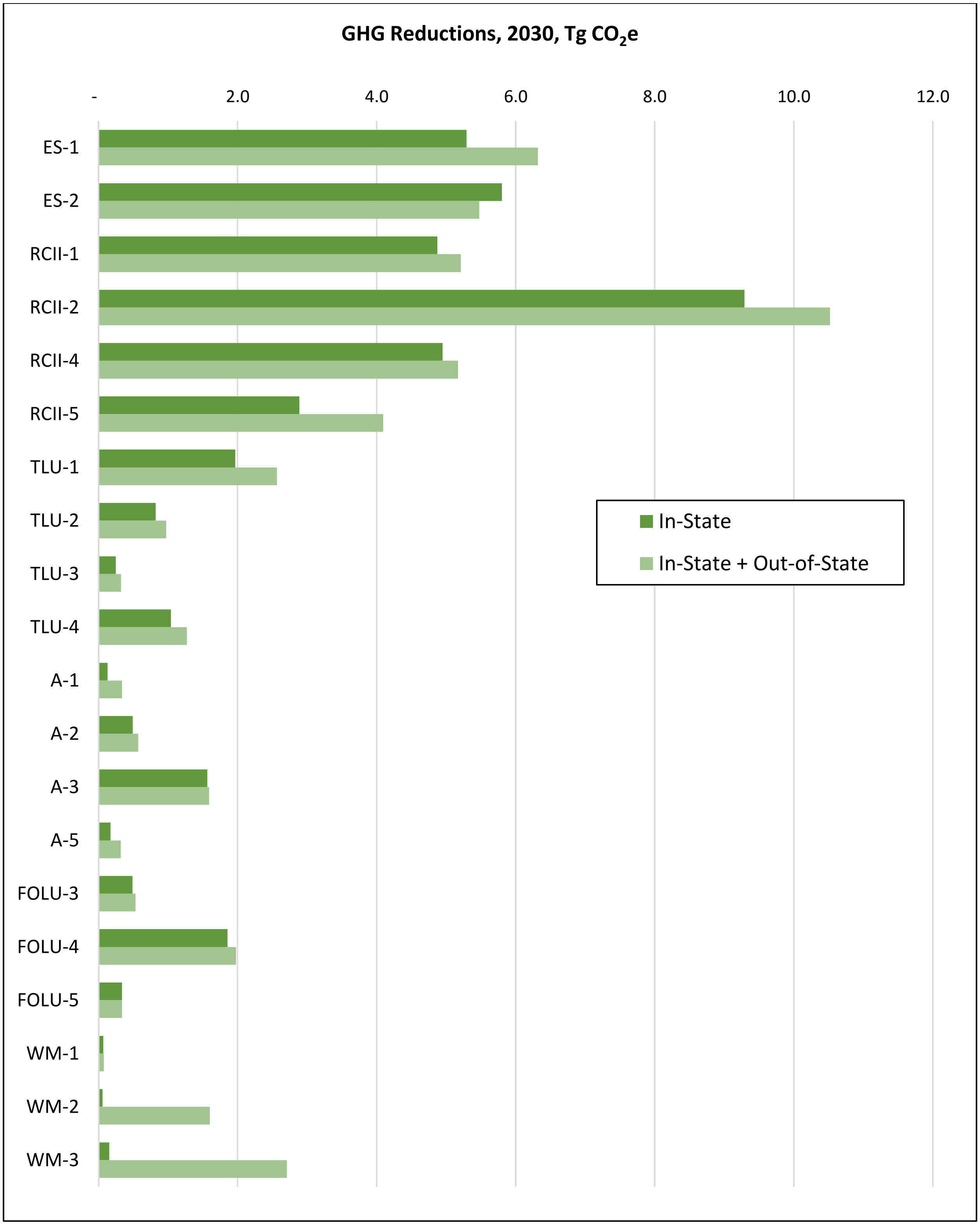
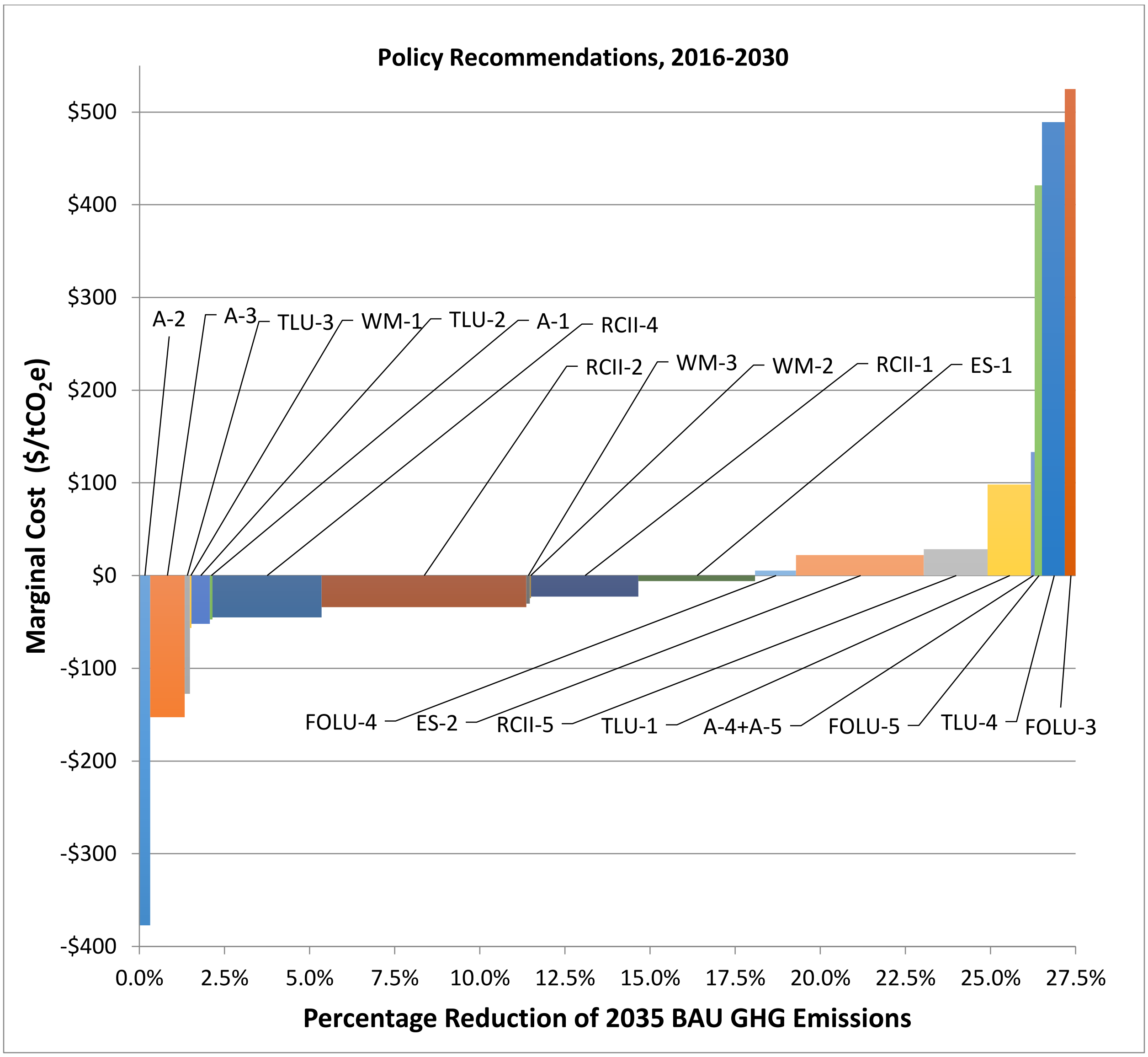


Figure IV-4 below provides the marginal abatement cost curve (MACC) for implementing all CSEO policy options. It was constructed by charting CE on the Y-axis and the percentage reduction of in-State 2030 BAU emissions achieved by the policy option. The results shown indicate that if all policy options are fully implemented as designed, nearly 28% of the 2030 BAU emissions would be reduced. Further, about half of the reductions are expected to be achieved with net societal cost savings. While these negative values represent net cost savings, it is important to note that most of these policy options are still expected to require significant up-front investments.

Figure IV-4 CSEO Marginal Abatement Cost Curve



Indirect (Macroeconomic) Impacts of CSEO Policy Recommendations

The tables and figures below show the Indirect (Macroeconomic) impacts of policy recommendations, including gross state product (GSP), Employment, and Personal Income impacts compared to BAU scenario. GSP and Personal Income are used in 2015$ in the table and figure, and employments are measured in individual jobs.

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 2016-2030 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. I_GSP, I_Jobs, and I_Income represent the index score for GSP, Jobs and Income, respectively.

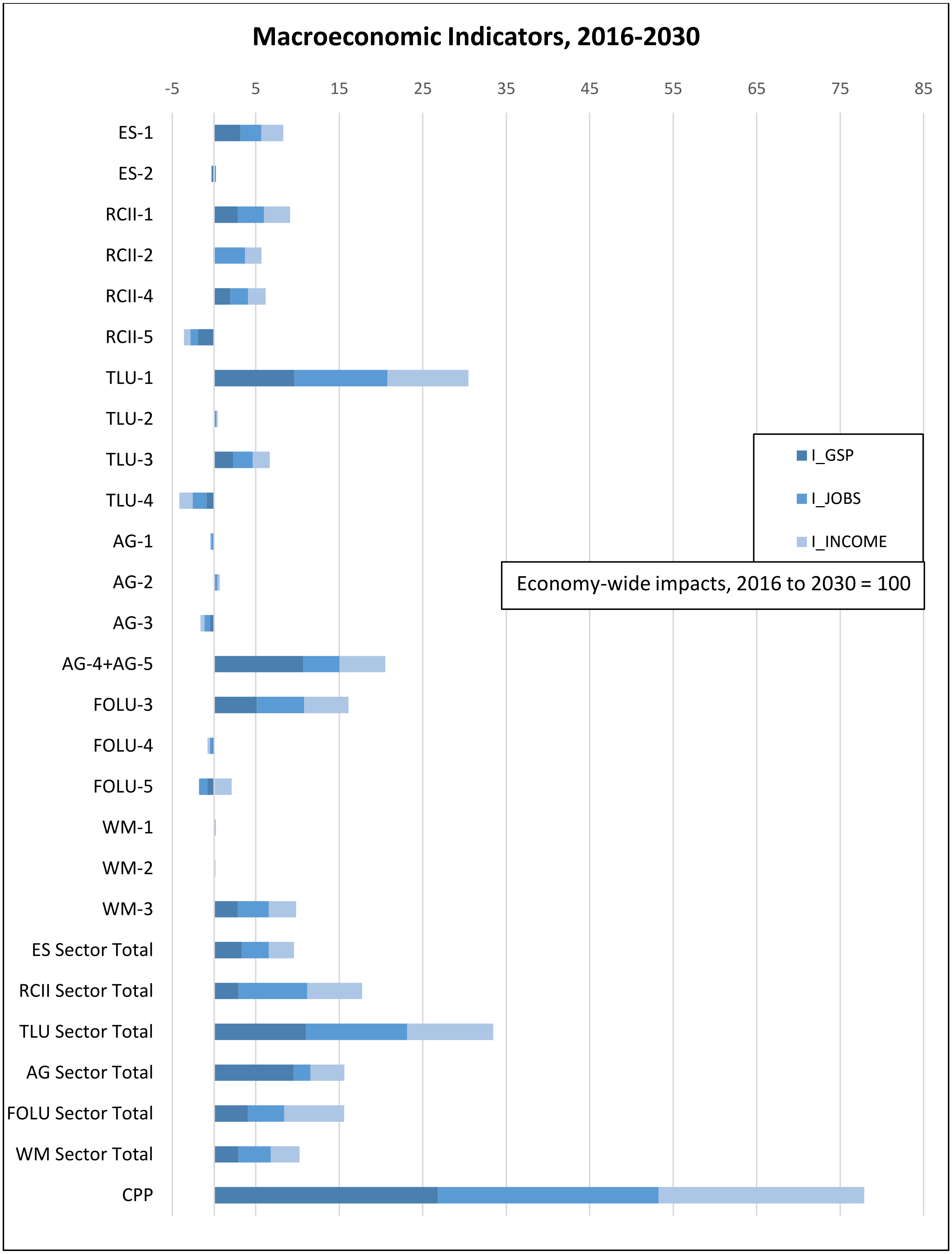
Table IV-3 Macroeconomic Impacts of Policy Recommendations

Indirect Macroeconomic Summary Impacts Results									
Scenario	Gross State Product (GSP, $2015 MM)			Employment (Full & Part-Time Jobs)			Income Earned ($2015 MM)		
	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)
ES-1 40% Renewables Target	$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*
ES-2	$(70)	$(40)	$(310)	170	310	2,470	$(20)	$-	$(20)

ES Sector (ES-1 @ 40%)	**$320**	**$160**	**$2,340**	**3,070**	**1,670**	**25,020**	**$290**	**$140**	**$2,050**
ES Sector (ES-1 @ 50%)	***$540***	***$240***	***$3,580***	***4,720***	***2,380***	***35,650***	***$480***	***$200***	***$3,060***
RCII-1	$510	$200	$3,030	3,840	2,330	35,020	$430	$210	$3,190
RCII-2	$(70)	$(10)	$(90)	6,020	2,750	41,190	$340	$130	$2,010
RCII-4	$140	$140	$2,110	1,430	1,560	23,340	$160	$140	$2,140
RCII-5	$(350)	$(150)	$(2,080)	(1,680)	(690)	(9,610)	$(150)	$(60)	$(810)
RCII Sector	**$260**	**$210**	**$3,150**	**9,820**	**6,080**	**91,270**	**$800**	**$440**	**$6,660**
TLU-1	$710	$690	$10,320	8,140	8,230	123,400	$780	$660	$9,890
TLU-2	$-	$-	$(30)	500	220	3,290	$30	$10	$150
TLU-3 Low Transit Capital Cost	$90	$40	$610	830	450	6,740	$40	$20	$300
TLU-3 High Transit Capital Cost	$130	$170	$2,480	1,330	1,720	25,860	$80	$140	$2,070
TLU-4 High EV prices	$(710)	$(350)	$(5,320)	(7,910)	(3,750)	(56,240)	$(860)	$(370)	$(5,550)
TLU-4 Falling EV Prices	$140	$(60)	$(970)	(810)	(1,220)	(18,300)	$(60)	$(110)	$(1,620)
TLU Sector with Low Transit Capital Cost	**$100**	**$370**	**$5,590**	**1,580**	**4,560**	**68,360**	**$(10)**	**$320**	**$4,790**
TLU Sector with High Transit Capital Cost	***$130***	***$500***	***$7,450***	***2,080***	***6,420***	***96,350***	***$30***	***$440***	***$6,550***
TLU Sector Falling EV Prices	***$950***	***$620***	***$9,290***	***8,670***	***7,680***	***115,170***	***$800***	***$580***	***$8,720***
TLU Sector High Transit Capital & Falling EV Prices	***$980***	***$790***	***$11,800***	***9,170***	***8,950***	***134,270***	***$830***	***$700***	***$10,490***
AG-1	$(10)	$-	$(70)	(360)	(200)	(2,960)	$(20)	$(10)	$(120)
AG-2	$-	$10	$110	70	230	3,380	$20	$20	$300

AG-3	$20	$(40)	$(530)	1,170	(490)	(7,420)	$60	$(30)	$(490)
AG-4+AG-5	$1,130	$820	$11,470	3,610	3,420	47,820	$540	$400	$5,580
Ag Sector	**$980**	**$680**	**$10,200**	**810**	**1,490**	**22,300**	**$350**	**$280**	**$4,150**
FOLU-3	$380	$370	$5,500	4,420	4,180	62,670	$460	$360	$5,410
FOLU-4	$(10)	$(20)	$(230)	(130)	(210)	(3,160)	$(10)	$(20)	$(280)
FOLU-5 farms lose crop income	$(110)	$(90)	$(1,300)	(1,350)	(1,060)	(15,900)	$-	$70	$1,010
FOLU-5 farms keep crop income	$(80)	$(60)	$(880)	(920)	(720)	(10,750)	$120	$140	$2,160
FOLU Sector Farms Lose Crop Income	**$260**	**$260**	**$3,960**	**2,940**	**2,910**	**43,610**	**$450**	**$410**	**$6,130**
FOLU Sector Farms Keep Crop Income	***$290***	***$290***	***$4,340***	***3,340***	***3,220***	***48,340***	***$570***	***$490***	***$7,290***
WM-1	$-	$-	$30	90	80	1,130	$10	$10	$90
WM-2	$10	$-	$30	150	60	930	$10	$-	$70
WM-3	$240	$200	$3,040	3,290	2,750	41,210	$320	$220	$3,340
WM Sector	**$250**	**$210**	**$3,100**	**3,530**	**2,890**	**43,280**	**$340**	**$230**	**$3,500**
ES+RCII (40% target)	**$580**	**$360**	**$5,420**	**12,840**	**7,720**	**115,830**	**$1,080**	**$580**	**$8,630**
ES+RCII (50% target)	**$780**	**$440**	**$6,600**	**14,340**	**8,390**	**125,880**	**$1,260**	**$640**	**$9,610**
CPP (ES-1 40%)	**$2,669**	**$1,831**	**$27,463**	**26,480**	**18,796**	**281,940**	**$2,605**	**$1,604**	**$24,063**
CPP (ES-1 50%)	**$2,894**	**$1,914**	**$ 28,716**	**28,140**	**19,507**	**292,610**	**$2,798**	**$1,672**	**$25,078**
Overall Economy Default Scenario	**$2,190**	**$1,910**	**$28,650**	**22,090**	**20,460**	**306,970**	**$2,330**	**$1,890**	**$28,370**
Overall Economy Best Case Scenario	**$3,250**	**$2,380**	**$35,680**	**30,820**	**24,630**	**369,440**	**$3,240**	**$2,260**	**$33,910**

Figure IV-5 Macroeconomic Indicators of Policy Recommendations



Notes:

The graph above 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 2016-2030 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.

In each of the subsections that follow a brief discussion of each sector's GHG baseline is followed by a description of key drivers of baseline trends and key policy response strategies designed to improve economic, energy, and environmental benefits as well summaries of the recommended CSEO policy options and their direct and indirect impacts.

1. Energy Supply

The Energy Supply (ES) sector covers sources of electricity, heat, and fuel supply for buildings, facilities, manufacturing, and other stationary uses. Most important of these in Minnesota (MN) is the electricity supply subsector, which includes emissions from all sources of generation used to supply the state's consumption of power. In 2010, the ES sector contributed over 30% of the state's greenhouse gas (GHG) emissions and in 2030, the sector is still expected to contribute about the same amount of the emissions total. Important drivers to these emissions levels are growth in retail electricity sales and the efficiency and operating characteristics of the state's power generation fleet (e.g., fuel and technology choices).

Strategies that can be applied to reduce emissions and bolster economic performance include: increased naturally occurring renewable electricity generation (e.g., wind, solar); low emitting technologies and fuels such as nuclear power; efficiency upgrades or re-powering of existing power plants to lower carbon technologies or fuels; and fuel switching, especially to locally-sourced low carbon fuels.

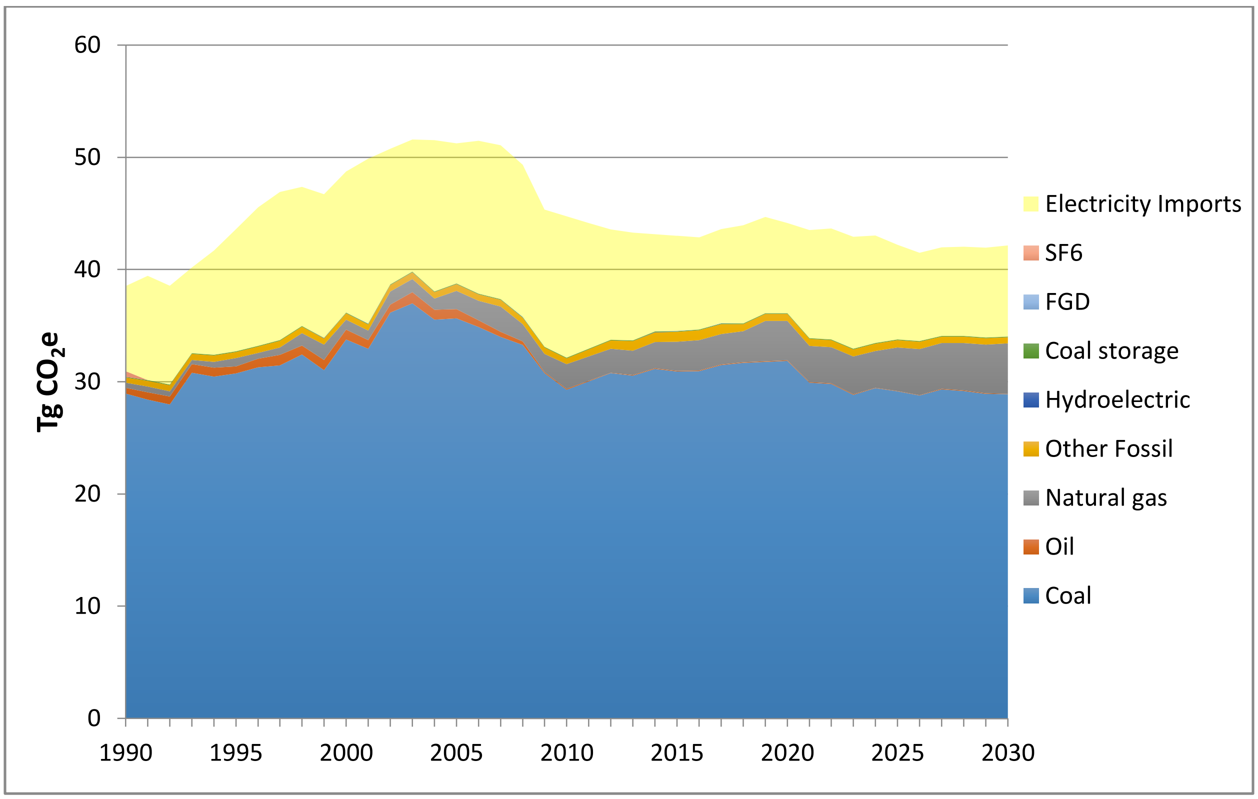
Baseline and Emissions Sources

The GHG emissions baseline for the ES sector is detailed in Figure IV-6. This baseline is constructed on an electricity consumption accounting basis, which means that the emissions associated with Minnesota's net imports of electricity are included (transparent wedge at the top of the chart). Coverage includes emissions from fuel combustion at power generation facilities, as well as a number of non-energy sources described further below. The baseline is dominated by in-state coal-based power generation sources. Imported electricity is the next highest contributor toward emissions, followed by in-state natural gas-fired generation sources. Note that Minnesota categorizes fuel supply sources, such as natural gas transmission and distribution and oil refining in the Residential, Commercial, Industrial, and Institutional (RCII) sector.

Smaller emissions contributors, most of which are too small to show up in Figure IV-6, are: sulfur hexafluoride emissions from electrical distribution equipment (SF_6); carbon dioxide emissions from chemicals used in flue gas desulfurization (FGD) equipment; methane emissions from hydroelectric reservoirs and coal storage piles; oil-fired generation resources; and other fossil fuel generation resources.

ES sector emissions are shown to decline slightly during the forecast period. These reductions are primarily brought on by slightly lower generation from in-state coal, and increasing generation from natural gas and renewables (mostly wind) through 2030. See Chapter II for more information on the contribution of the ES sector to the state's GHG baseline.

Figure IV-6 ES Sector GHG Baseline



CSEO Policy Options

Two policy options were developed for the ES sector. These are detailed in Policy Option Documents Appendix F.1 and are summarized as follows:

ES-1. Increase Renewable Energy Standards

Legislation passed in 2013 supports the investigation of higher levels of renewable energy use in Minnesota, starting with increasing the Renewable Electricity Standard (RES) to 40% by 2030, and to higher proportions thereafter. State legislation also sets the goal that by 2030, 10% of the retail electric sales in Minnesota be generated by solar energy. This policy option aims to expand RES to 40% by 2030. A 50% RES was also evaluated (see Appendix F.1 for details).

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

Of the 24 utility-owned coal-fired boilers operating in Minnesota, most have been retrofitted to meet Clean Air Act requirements (1758 MWs), repowered with natural gas (776 MWs), or are retired or scheduled to retire by 2020 (734 MWs). 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 carbon dioxide (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.

Three scenarios were evaluated for Sherco Units 1 and 2 including: 1) repowering Unit 1 by 2025 and retirement of Unit 2 by 2023; 2) retirement of both plants by 2020; and 3) repowering of Unit 1 by 2020 and retirement of Unit 2 by 2020. Scenario 1 was chosen for the purposes of analyzing integrative effects with other sectoral policies.

Direct and Indirect Policy Option Impacts

Table below provides a summary of the direct impacts of the ES policy options. These results assume that each policy option is fully implemented on a stand-alone basis against the business as usual baseline. As indicated, the ES policy options are expected to achieve 1.9 $TgCO_2e$ in-state reductions in 2020 and 14 $TgCO_2e$ in 2030. On a cumulative basis, the policy options would achieve 114 $TgCO_2e$ reductions through 2030. Net societal costs for both policy options are $111 million ($2014). The total cost effectiveness of these policy options is $1.2 /$tCO_2e$ (this value includes additional upstream GHG reductions from the fuel supply that may not occur within Minnesota). 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.

Table IV-4 . ES 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 Tg	2030 Tg	$TgCO_2e$	$TgCO_2e$	$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.

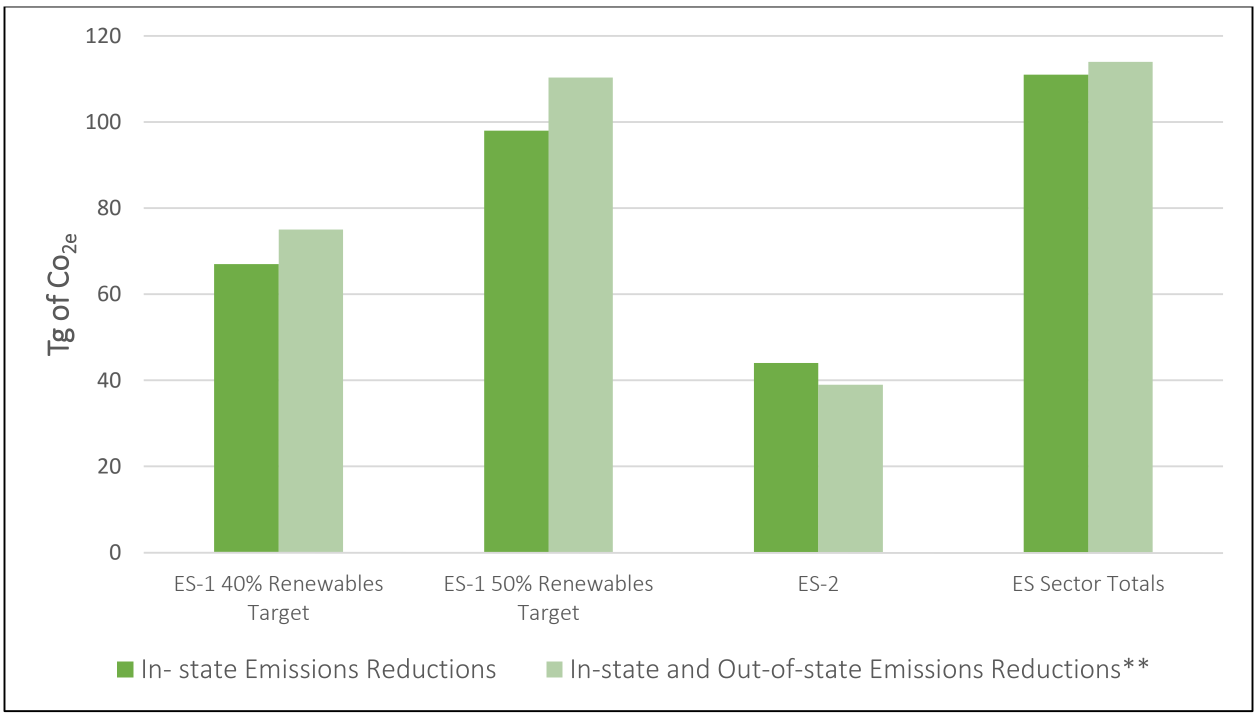
Table IV-5 ES Policy Options, Intra-Sector Interactions & Overlaps

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 Tg	2030 Tg	$TgCO_2e$	$TgCO_2e$	$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.
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 IV-7 ES Policies GHG Emissions Abatement, 2016-2030



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 IV-6 Macroeconomic (Indirect) Impacts of ES Policies

Macroeconomic (Indirect) Impacts Results									
Scenario	**GSP[a] ($2015 MM)**			**Employment[b] (Individual)**			**Personal Income[c] ($2015 MM)**		
	Year 2030[d]	**Average (2016-30)[e]**	**Cumulative (2016-2030)[f]**	**Year 2030**	**Average (2016-2030)**	**Cumulative (2016-2030)**	**Year 2030**	**Average (2016-2030)**	**Cumulative (2016-2030)**
ES-1 40% Renewables Target (Default) (ES-1 40%)	$394	$177	$2,652	2,900	1,510	22,580	$311	$138	$2,075
ES-1 50% Renewables Target (ES-1 50%)	$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 with ES-1 40% (Default) (ES Sector Total 40%)	**$319**	**$156**	**$2,336**	**3,070**	**1,670**	**25,020**	**$294**	**$137**	**$2,050**
ES Sector with ES-1 50% (ES Sector Total 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 2016-2030 time period.

Figure IV-8 Net Job Creation for ES Policies and ES Sector by Ascending Order, 2016-2030

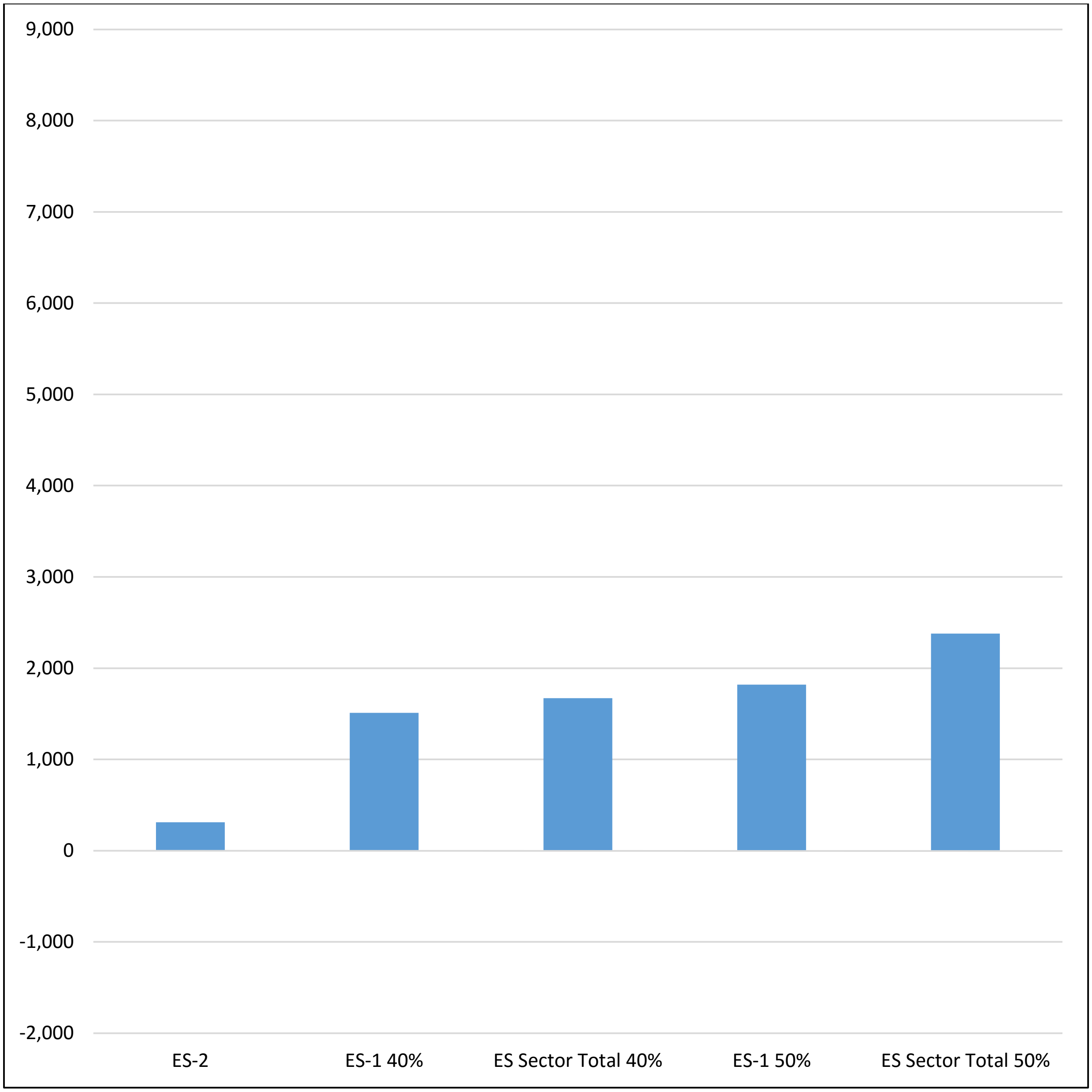
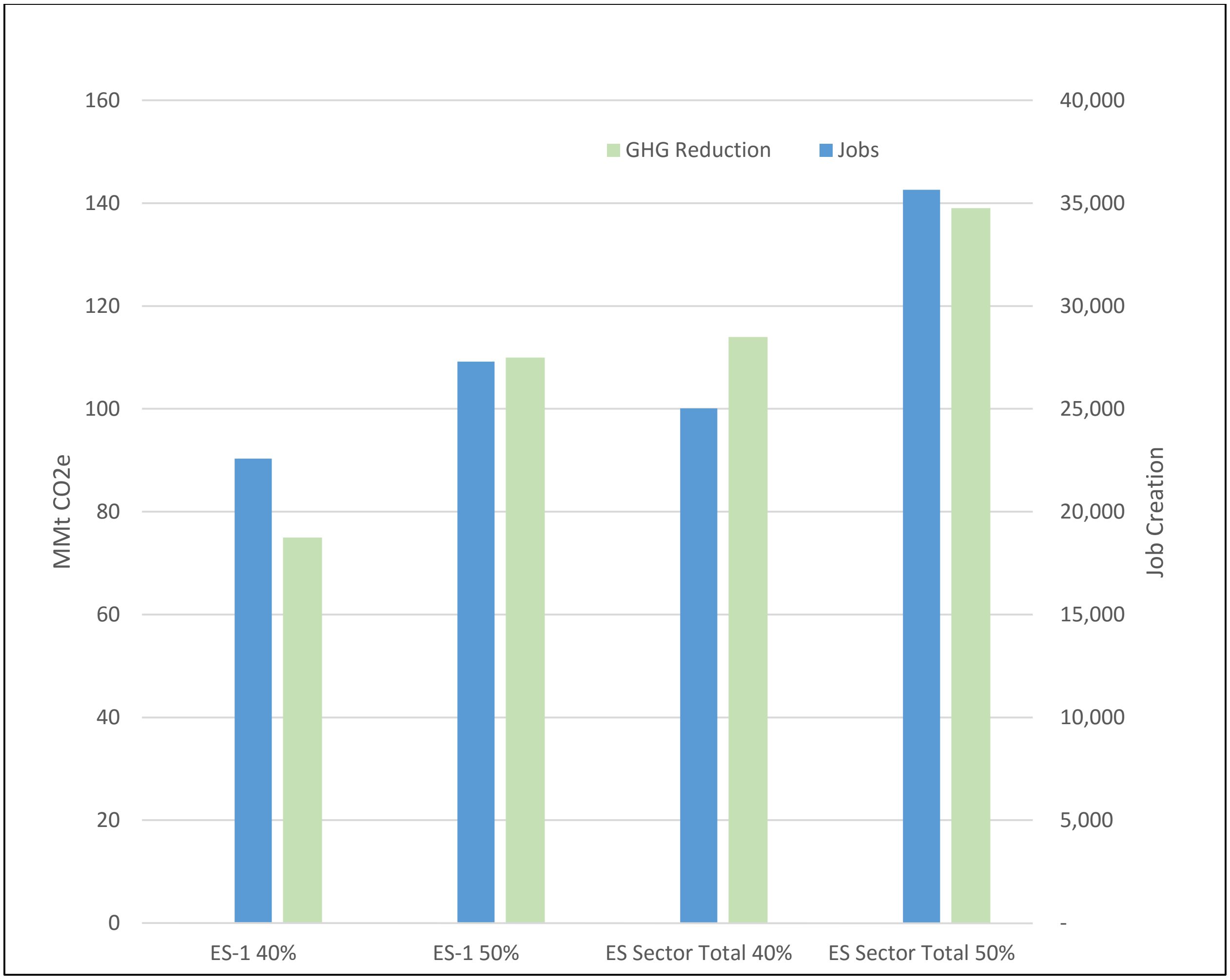


Figure below summarizes a potential for job creation and GHG emissions abatement of ES sector policies on the same graph. This allows for a simultaneous assessment of performance of individual CSEO options against two crucial environmental and economic indicators.

Figure IV-9 Job Gains and GHG Reduction by ES Policy Recommendations, 2016-2030



Macroeconomic Indicators

Graphs below present the overall macroeconomic impacts of each policy in ES sector, as well as the sector-level impacts, by using the Macroeconomic Impact Index. Jobs, Income, and GSP indicators are combined in a blended score indicating an overall macroeconomic impact of a policy or a set of policies on GSP, income and employment. In this project, the three variables are weighted equally, and indexed based on the maximum value among all the policies in the project. I_GSP, I_Jobs, and I_Income represent the index score for GSP, Jobs and Income, respectively.

Figure IV-10 ES Macroeconomic Indicators, Final Year 2030

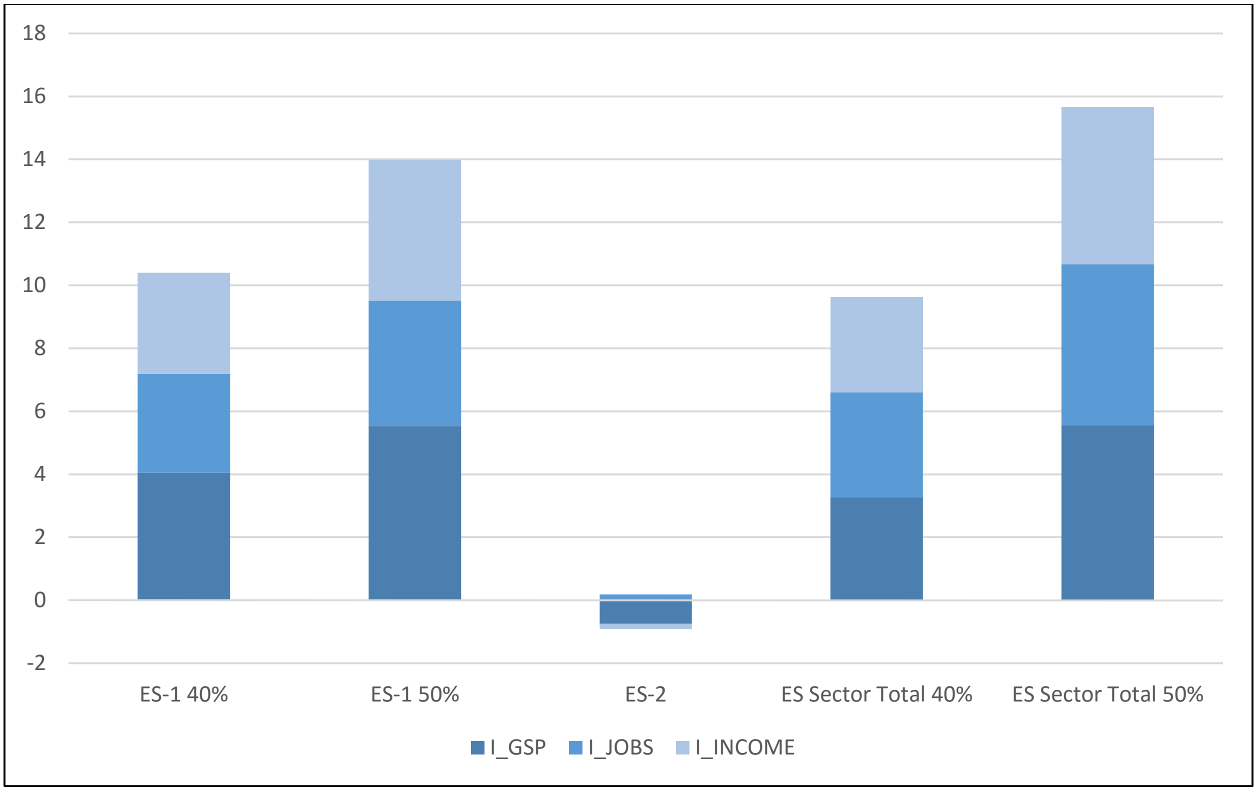


Figure IV-11 ES Macroeconomic Indicators, Average Annual

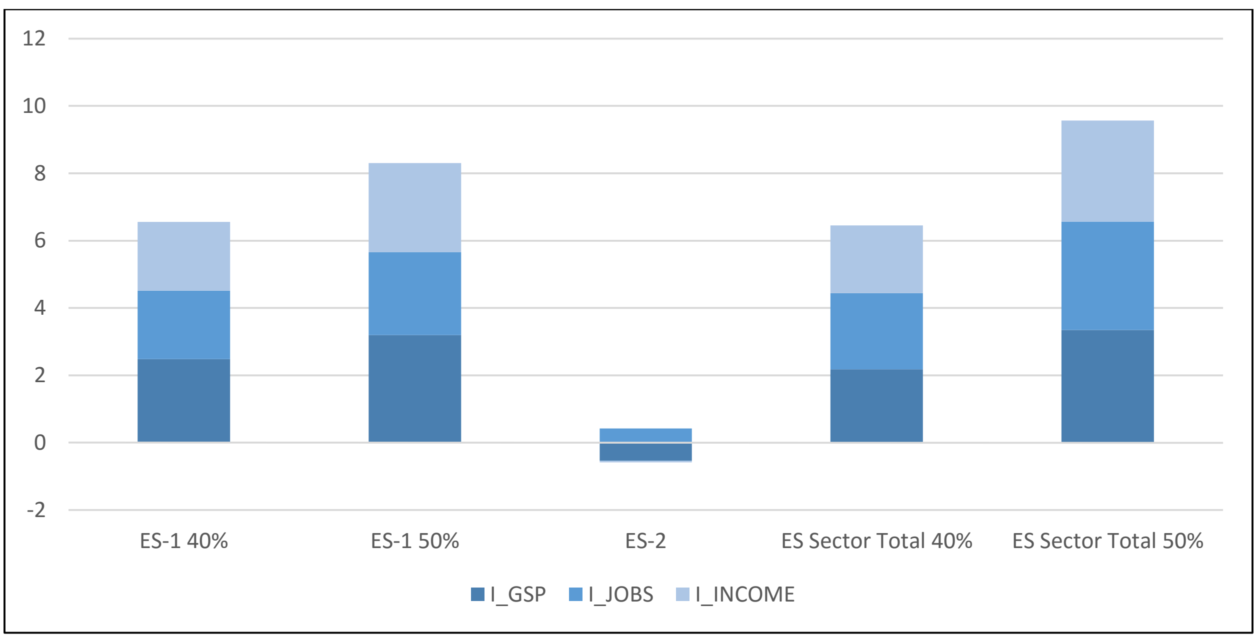
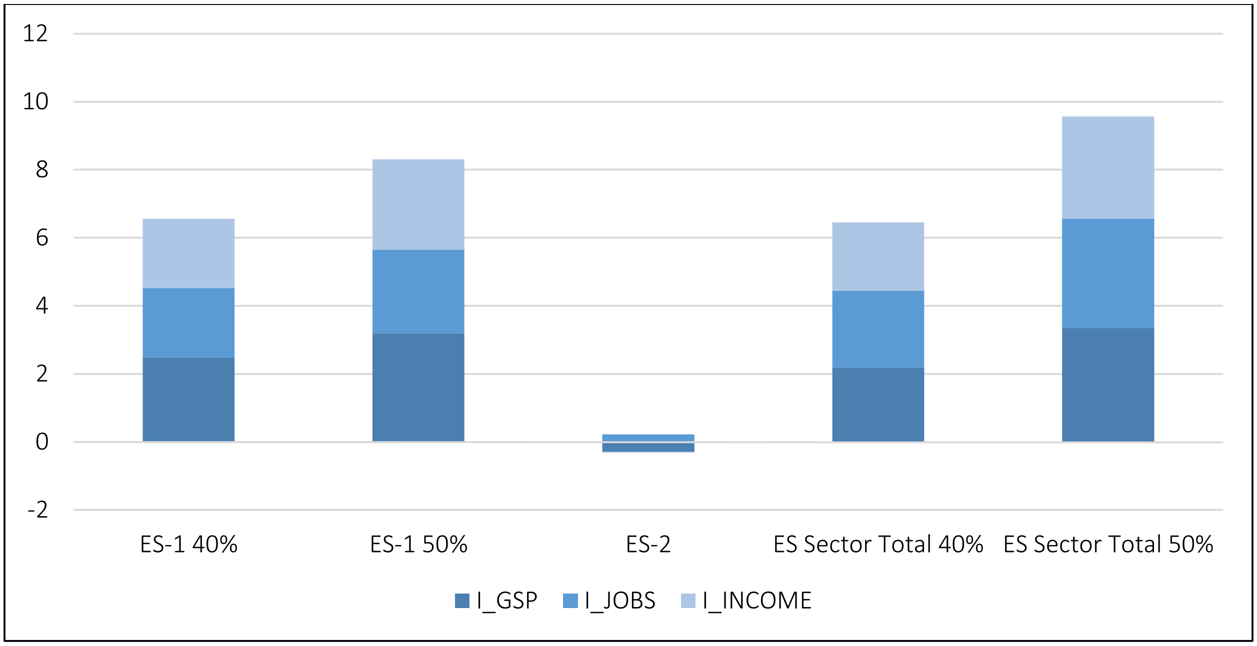


Figure IV-12 ES Macroeconomic Indicators, 2016-2030



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

Figure IV-13 ES GSP Impacts ($2015 MM)

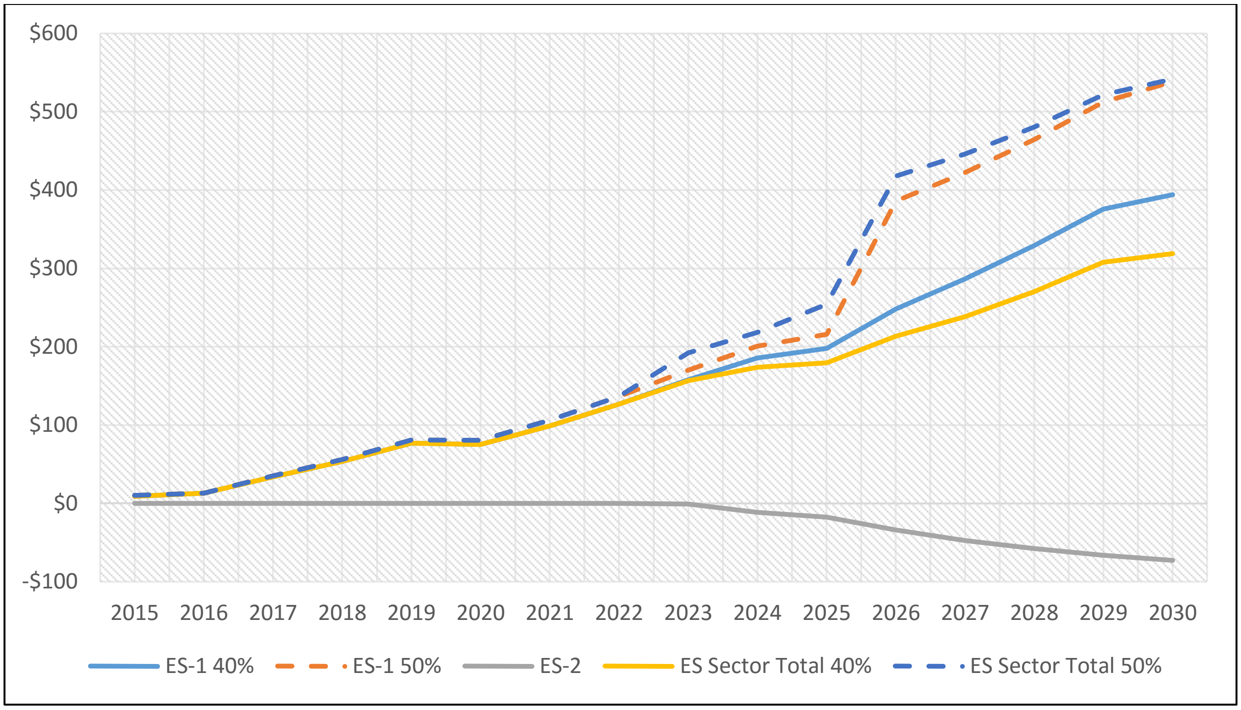


Figure IV-14 ES Employment Impacts 2016-2030 (Jobs)

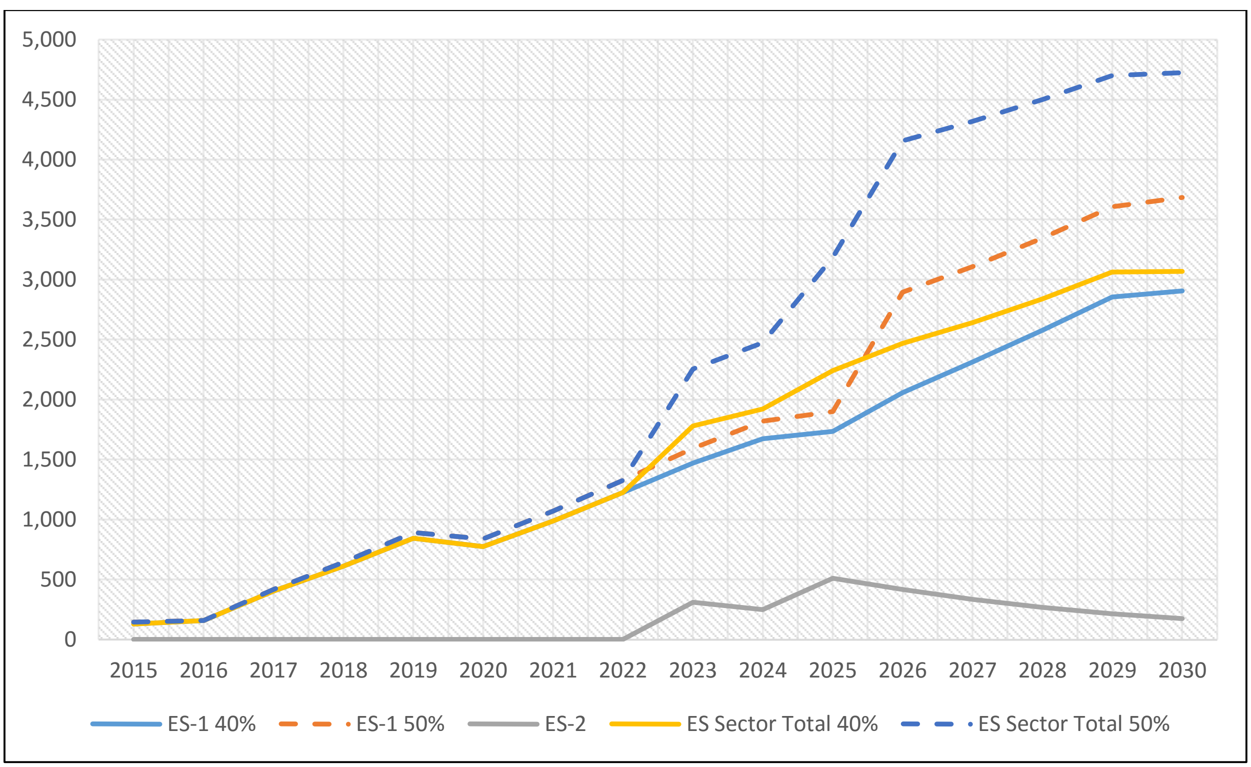


Figure IV-15 ES Income Impacts ($2015 MM)

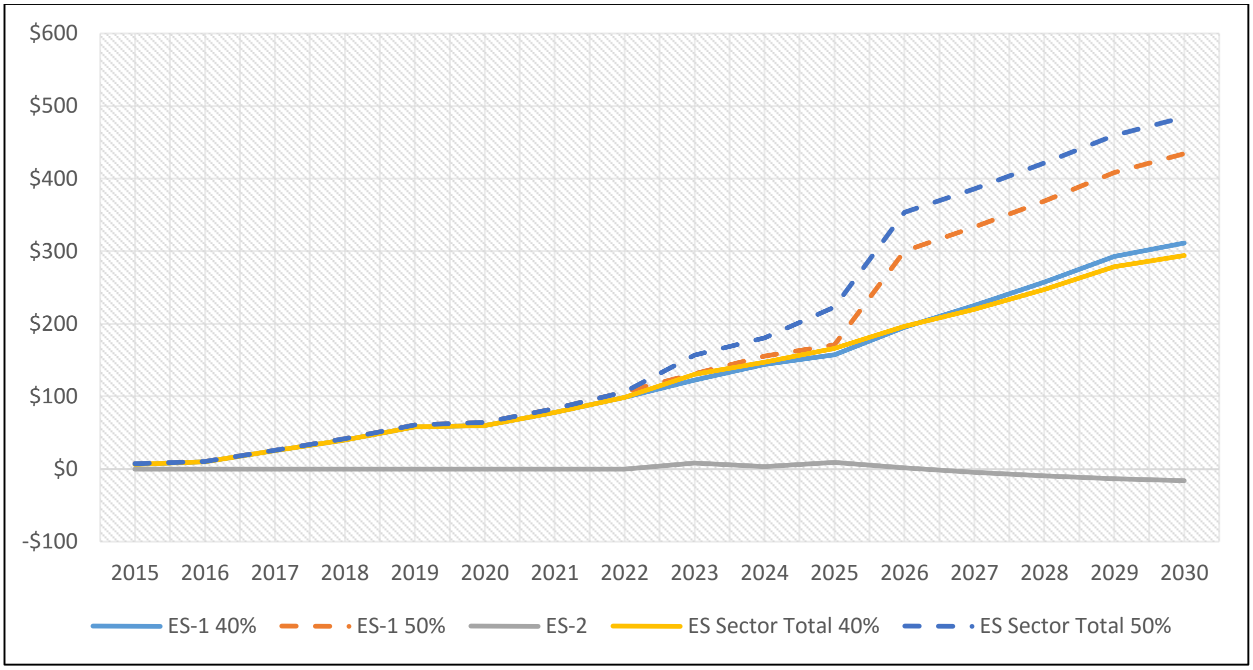


Figure IV-16 ES GSP Impacts, Average Annual ($2015 MM)

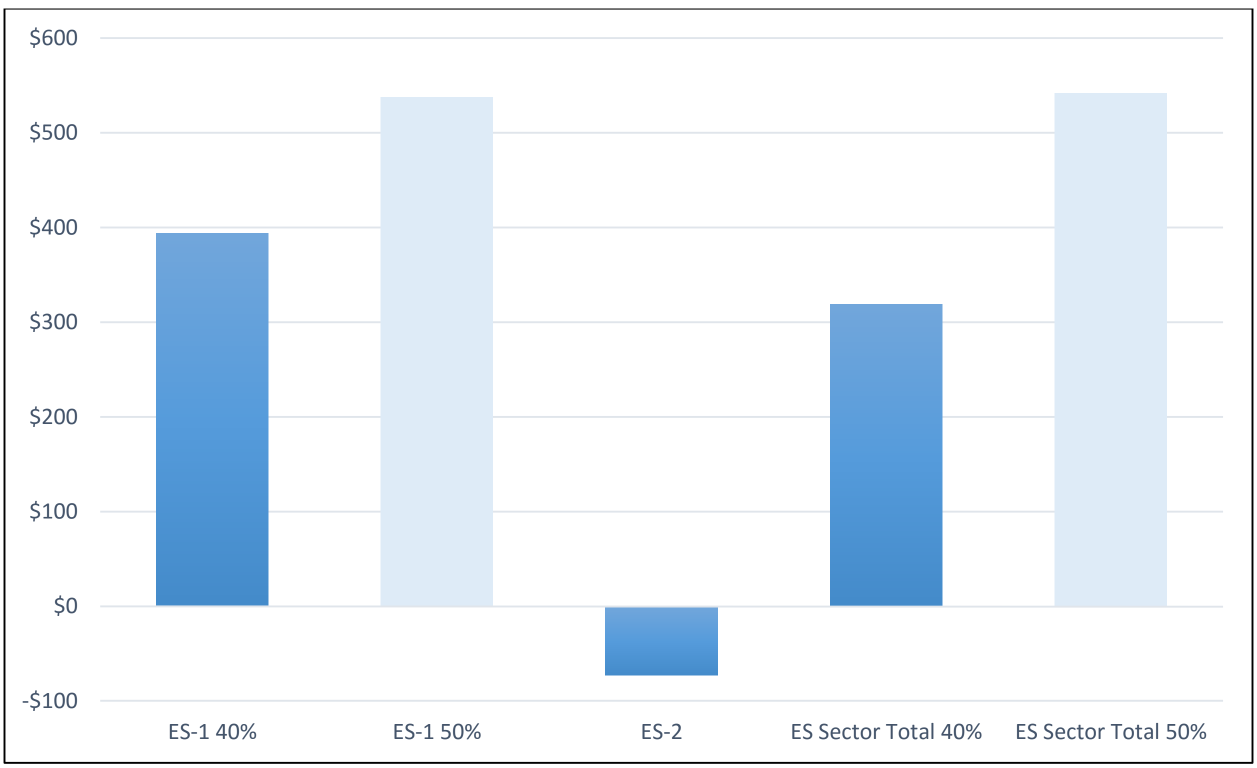


Figure IV-17 ES GSP Impacts, 2016-2030 ($2015 MM)

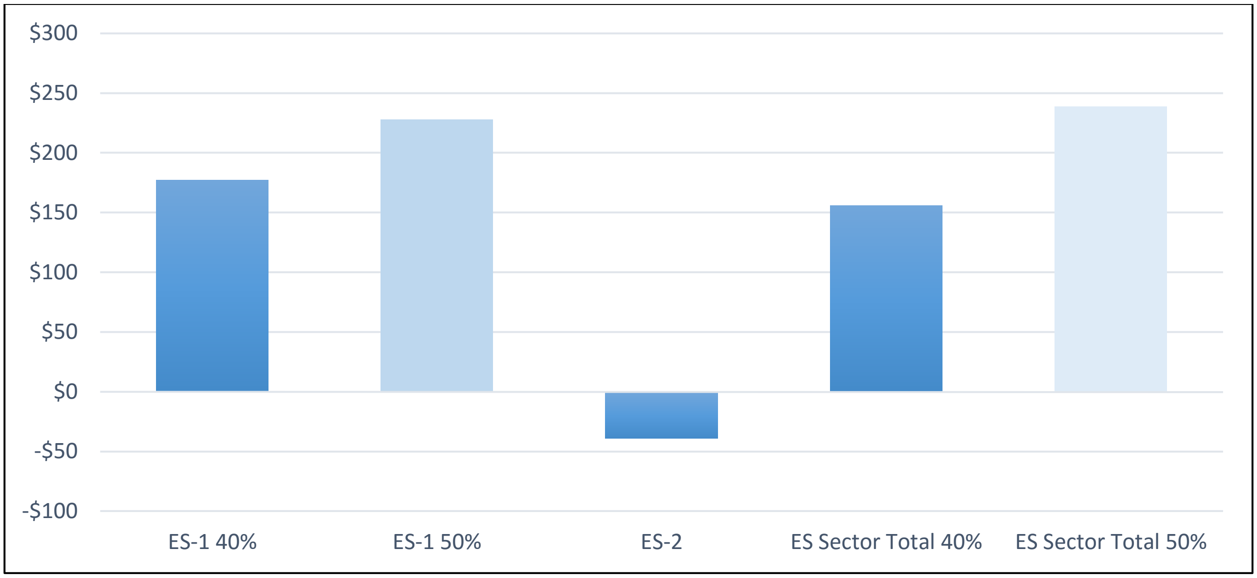


Figure IV-18 ES GSP Impacts, Year 2030 ($2015 MM)

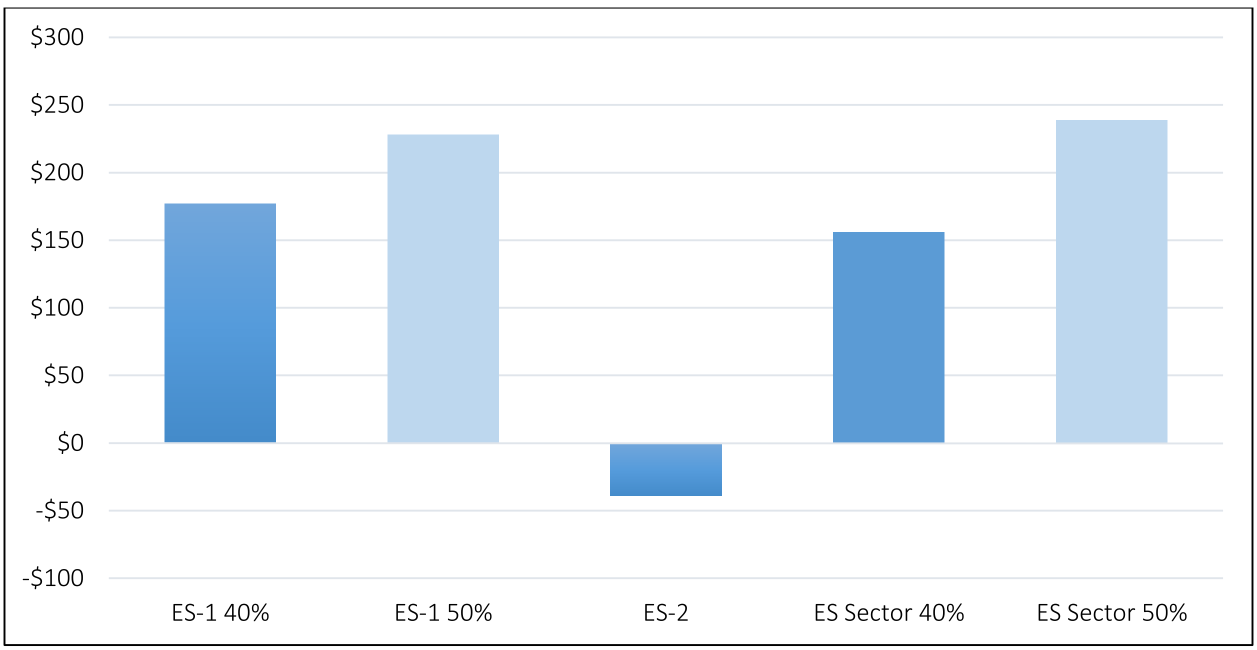


Figure IV-19 ES Employment Impacts, Average Annual (Jobs)

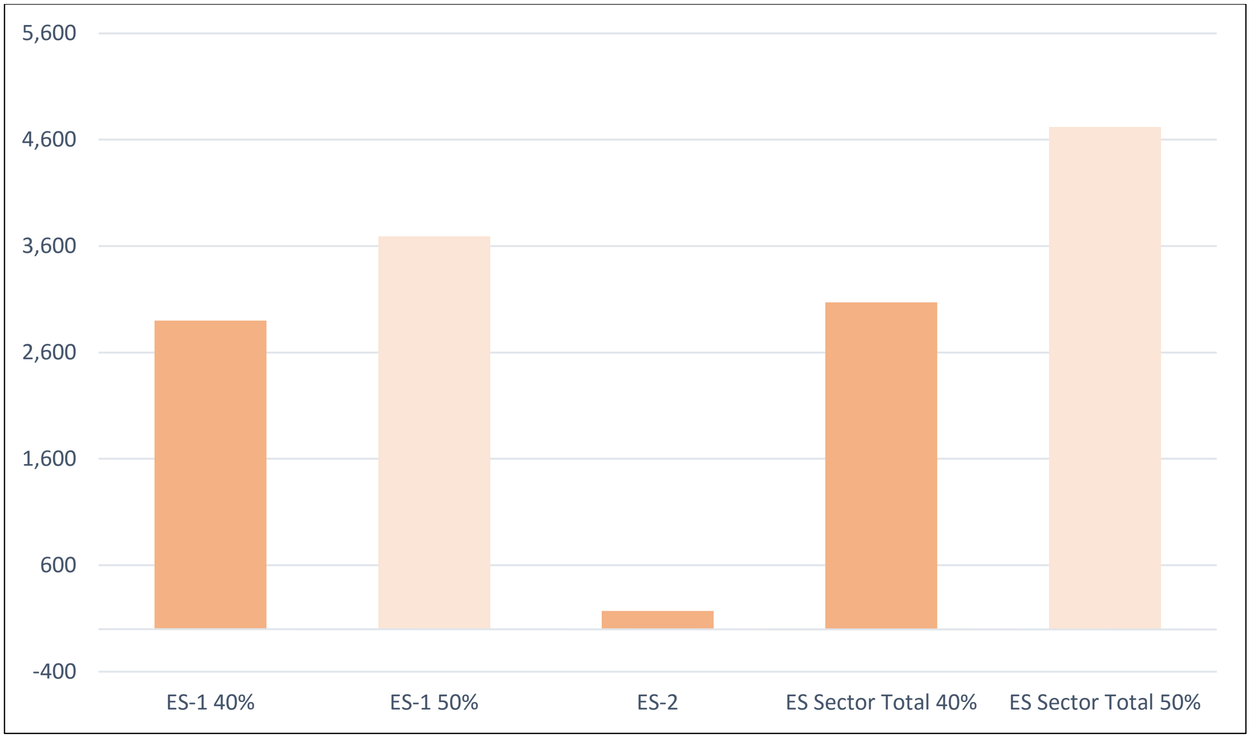


Figure IV-20 ES Employment Impacts, 2016-2030 (Job Years)

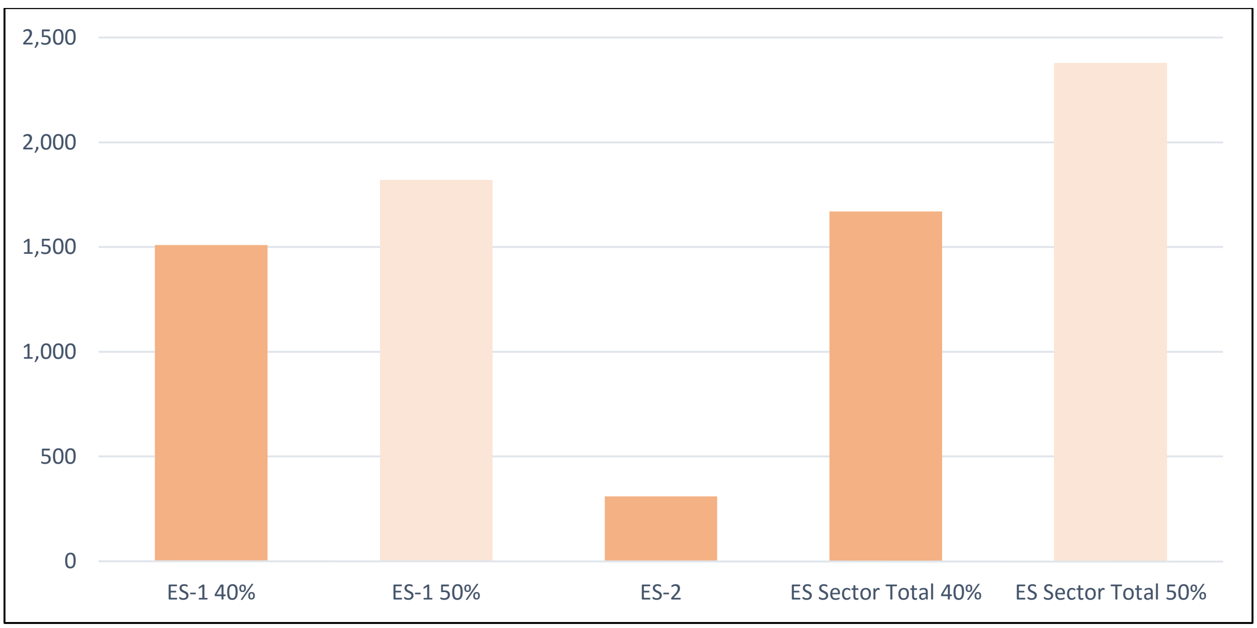


Figure IV-21 ES Employment Impacts, Year 2030 (Jobs)

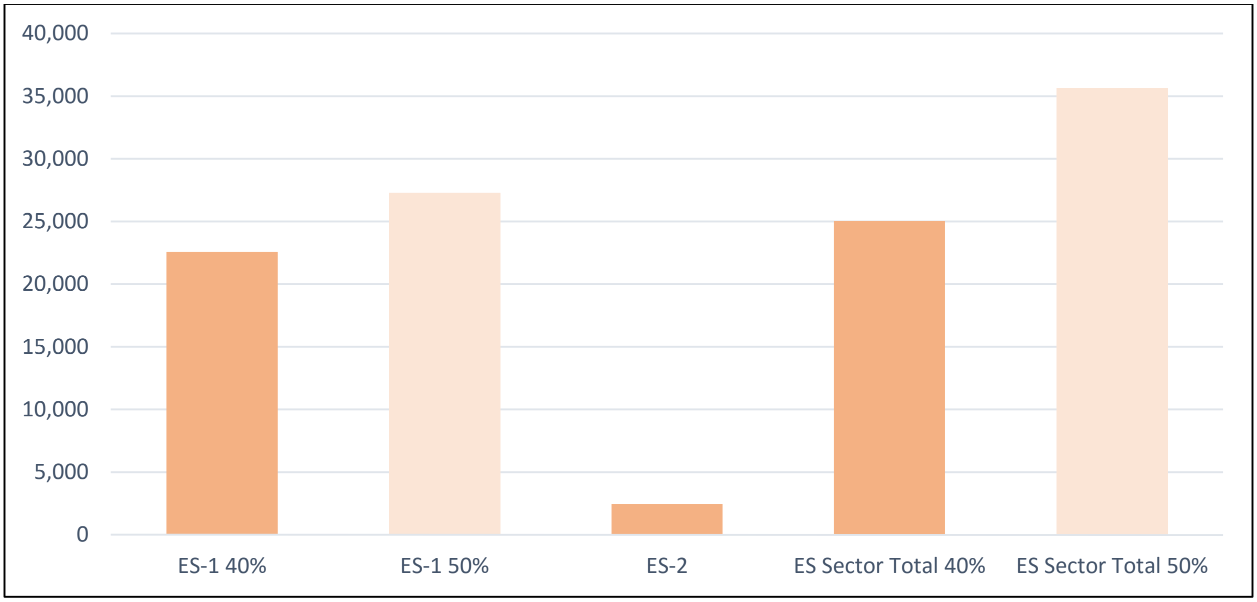


Figure IV-22 ES Income Impacts, Average Annual ($2015 MM)

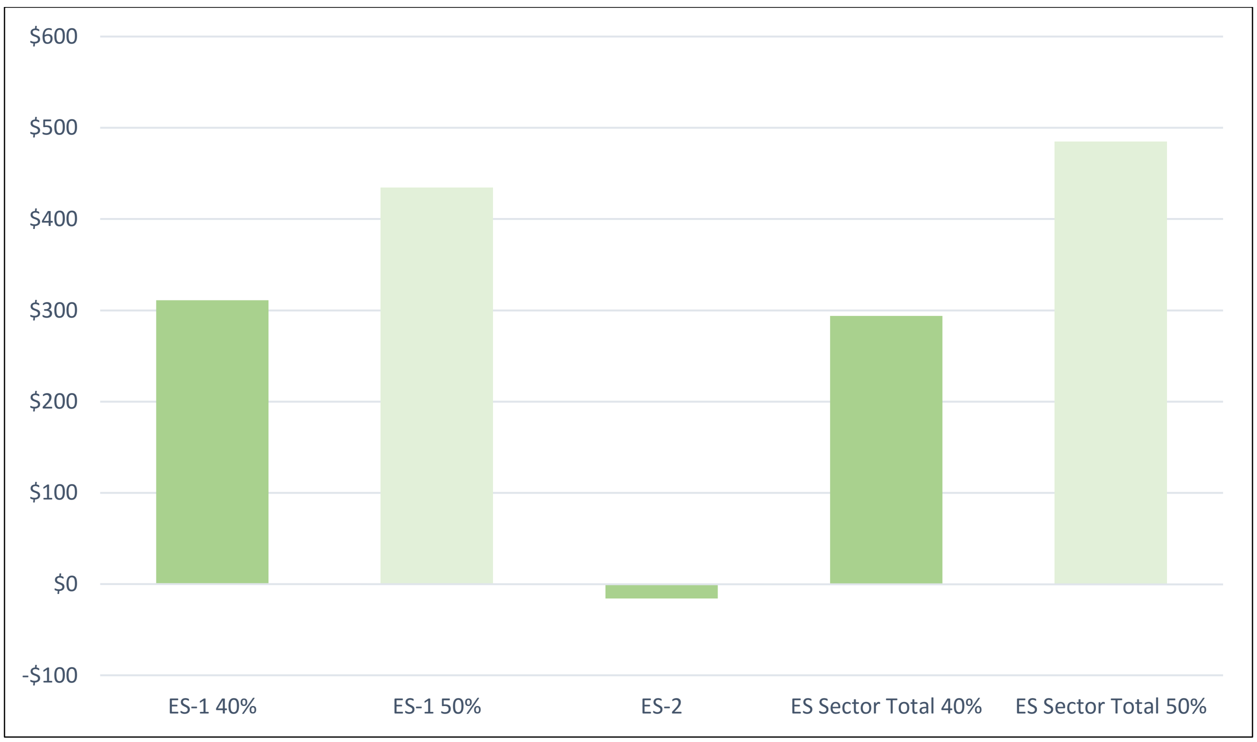


Figure IV-23 ES Income Impacts, 2016-2030 ($2015 MM)

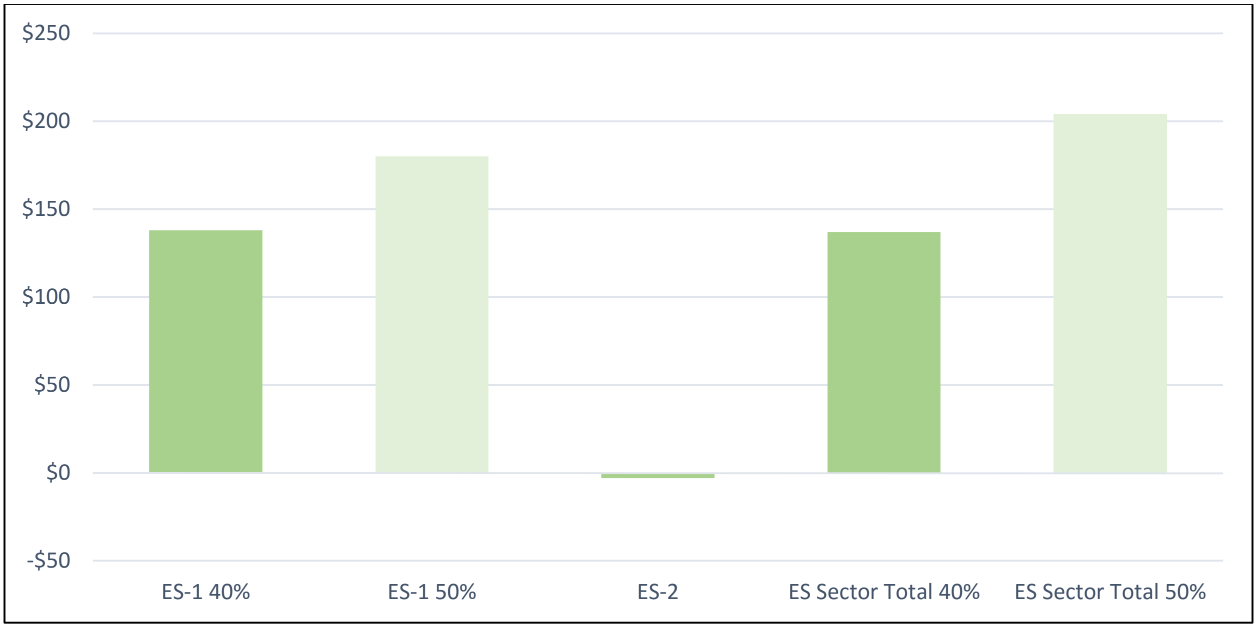
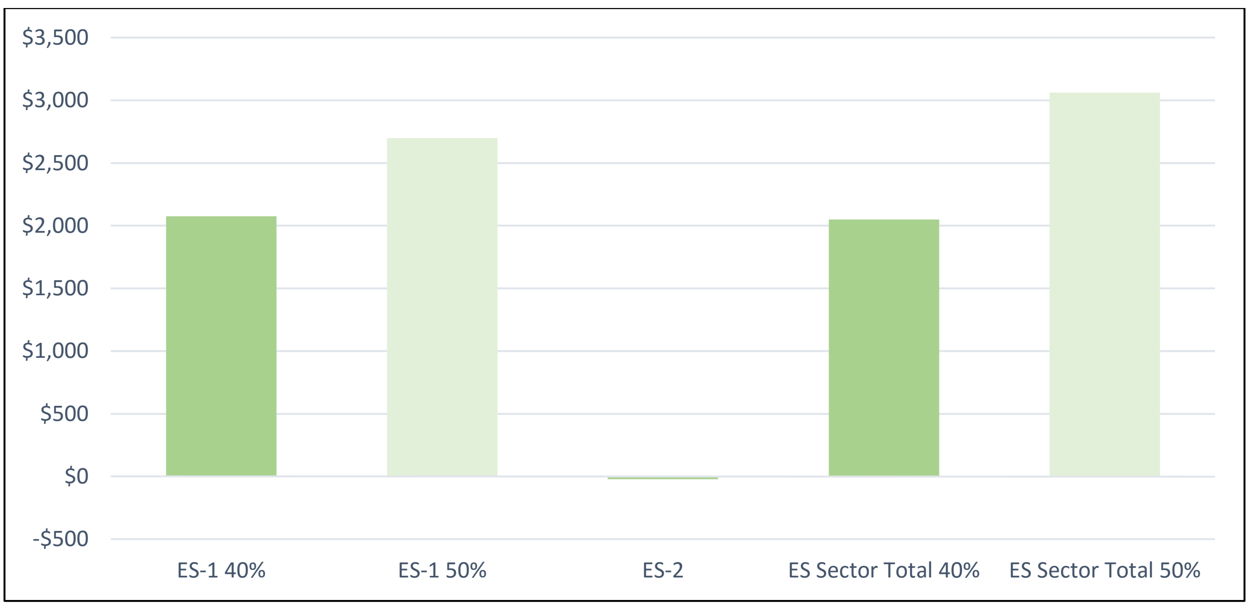


Figure IV-24 ES Income Impacts, Year 2030 ($2015 MM)



2. Residential, Commercial, Institutional, and Industrial Sector

The Residential, Commercial, Institutional, & Industrial (RCII) sector covers energy consumption (fuels and electricity) in buildings, facilities, municipal infrastructure, and industrial process. It also covers non-energy (process) emissions in the Industrial subsector. In 2010, the RCII sector contributed about 21% of the state's emissions (these are just the direct greenhouse gas [GHG] emissions; emissions from the consumption of power are included in the Energy Supply sector). The sector's contribution to state total emissions is expected to be about 23% in 2030. The important GHG drivers in this sector include power consumption by each subsector, the consumption of fuels for both space heating and industrial process heat, and process emissions in petroleum refining and taconite induration (iron ore pelletization).

Strategies that can be employed to reduce GHG emissions and produce positive economic outcomes include: energy efficiency (EE) measures for homes, institutions, and businesses; distributed renewable energy (RE) generation (such as rooftop solar); commercial and industrial process improvements; and fuel switching to lower carbon fuels sourced within the state (e.g., biomass).

Baseline and Emissions Sources

The GHG emissions baseline for the RCII sectors is provided in figure below. In the figure, historic emissions are shown divided into three categories -- Residential, Commercial (including institutional), and Industrial. In all sectors, historical and forecast emissions include emissions from the energy sector-emissions of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) from combustion of coal and coal products, oil products, and natural gas, and emissions of CH_4 and N_2O from combustion of wood and other biomass-based fuels--and non-energy emissions. Overall, the GHG impacts of RCII emissions are dominated by CO_2 emissions from energy use. Not directly included in the figure are emissions associated with RCII use of electricity. Most electricity used in Minnesota is consumed in the RCII sectors, but these emissions are tracked in the ES Sector (Chapter II).

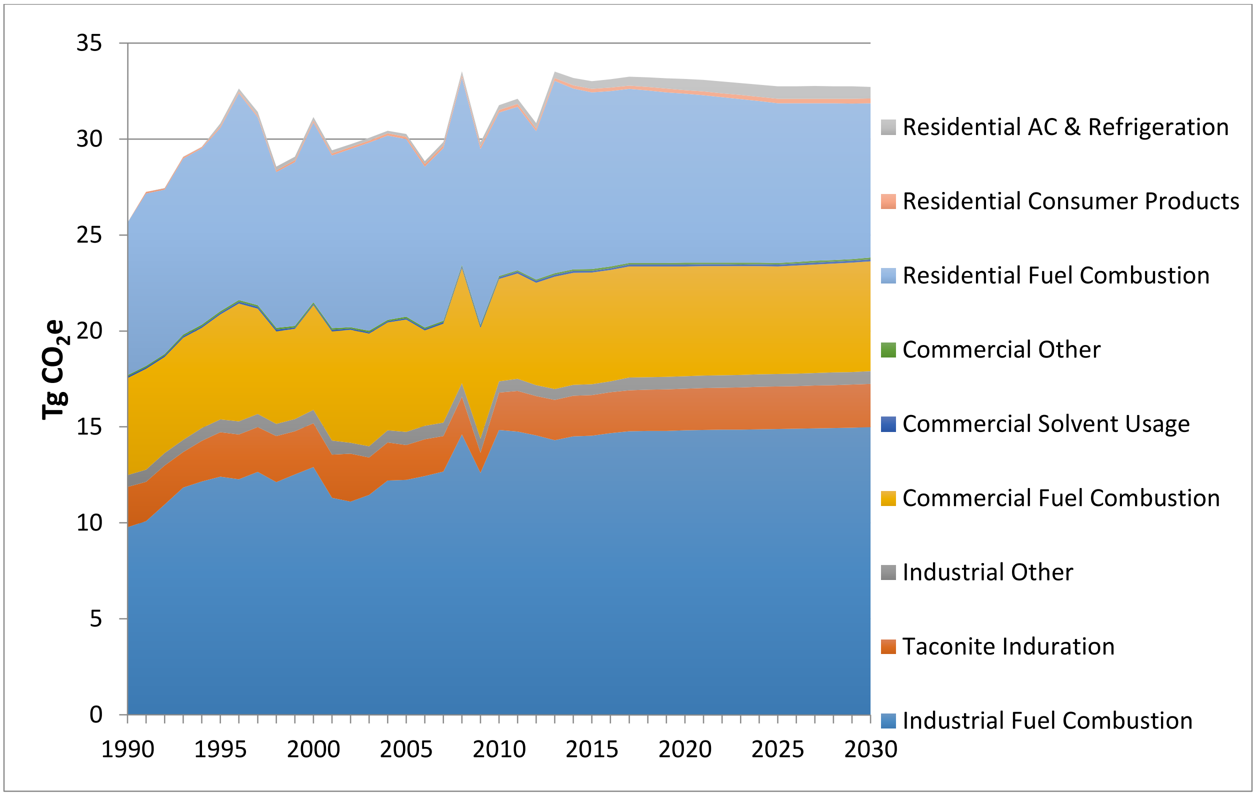
In the residential sector, emissions from fuel combustion are further broken into four end-uses: space heating, water heating, cooking, and clothes drying (see Appendix B for details). Non-energy sources of GHGs in the residential sector include food additives, soaps, shampoos and detergents, urban lawn fertilizer, air conditioning refrigerants, refrigerator refrigerants, and aerosols. The residential sector is also credited with carbon stored in wood in residential structures. Overall, residential sector emissions, expressed as CO_2 equivalents, are forecast to slowly decline after 2016. Emissions from fuel use dominate the residential sector, primarily natural gas with liquefied petroleum gas (LPG) accounting for most of the rest. The residential sector receives an "emissions credit" varying from 0.7 to 1.1 $TgCO_2$ per year for carbon sequestered in wood used in housing. This credit largely offsets non-energy emissions from the sector.

In the commercial/institutional sector, emissions from fuel combustion also dominate total GHG emissions, but fuel combustion emissions fall slowly over time, from about 5.9 $TgCO_2e$ in 2012 to about 5.7 $TgCO_2e$ in 2030. Of note for the non-energy commercial sector emissions space cooling and refrigeration emissions are forecast to more than double, from about 1.0 $TgCO_2e$ in 2012 to 2.3 $TgCO_2e$ in 2030.

Overall industrial sector emissions in Minnesota are projected to rise slowly over the forecast period. Emissions from fuel combustion account for slightly less than three quarters of CO_2e emissions throughout the forecast. Non-energy emissions from the industrial sector include CO_2 and CH_4 emissions from a variety of industrial processes, as well as sulfur hexafluoride (SF_6)

used in magnesium die casting, perfluorocarbons (PFC) and hydrofluorocarbons (HFC) used in semiconductor manufacture, HFC and PFC used as solvents, and HFCs from foam insulation manufacturing and appliances. Non-energy emissions are dominated by two categories, namely CO_2 from "induration taconite flux"--the processing of low-grade iron ores--and CO_2 from the oil refining industry. Both of these sources are forecast to rise somewhat over time.

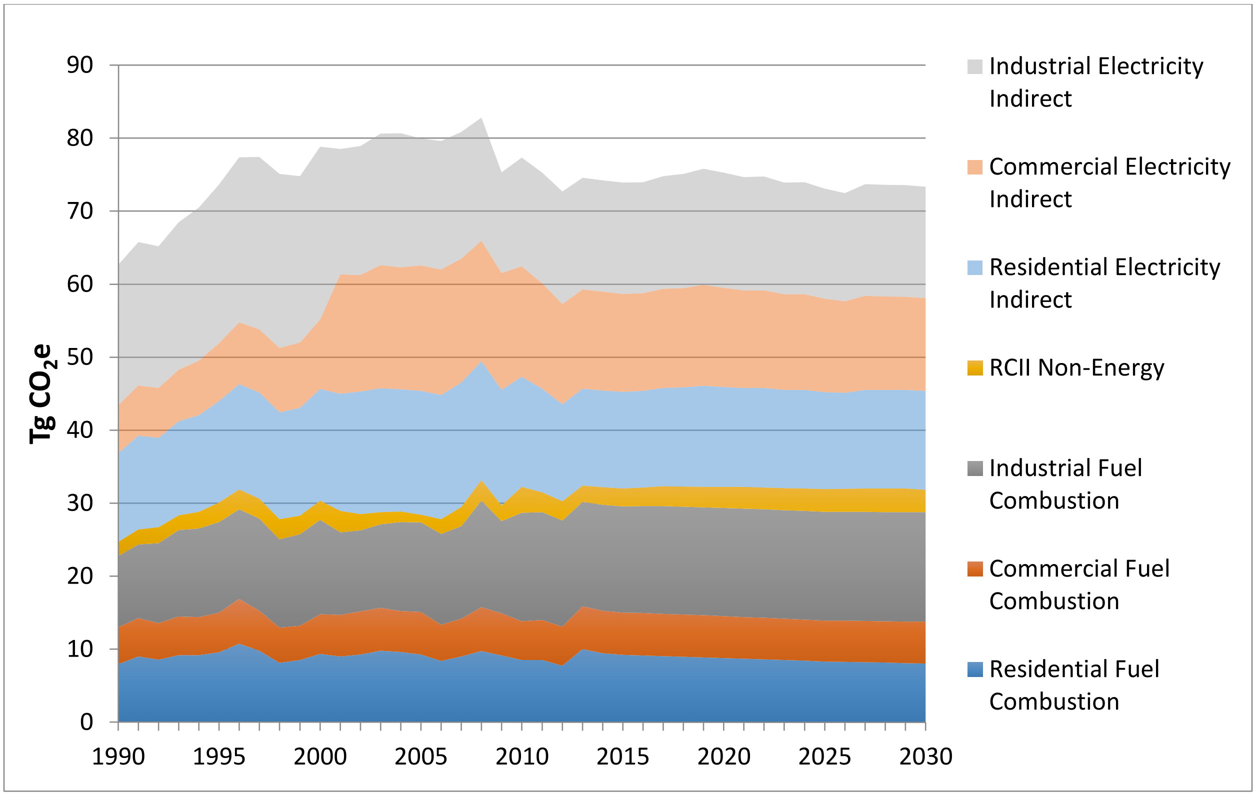
Figure IV-25 RCII Sectors GHG Baseline



Notes: This chart excludes ~1 $TgCO_2$ annually for carbon storage in residential building materials.

Figure below provides another summary of the RCII sector baseline. This summary focuses on energy consumption for the sector, both direct use of fuels, as well as electricity consumption (shown as "indirect" transparent wedges in the chart). Non-energy emissions (e.g., from industrial processes) are shown to represent only a small portion of the overall emissions for the sector. Electricity consumption related emissions account for well over half of the emissions through both the historical and forecast periods.

Figure IV-26 RCII GHG Baseline for Energy Consumption



Notes: The Commercial subsector emissions in this chart also include the Institutional subsector.
RCII Non-Energy represent net emissions including carbon storage in residential building materials.

See Chapter II for more information on the contribution of the RCII sector to the state's GHG baseline. See Appendix B for more details on the development of the RCII baseline.

CSEO Policy Options

Five policies were developed for the RCII sectors. These are detailed in Appendix F.2 and are summarized as follows:

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

Combined heat and power (CHP) systems reduce fossil fuel use and reduce 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 in implementing 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. RCII-1 includes targets for implementing CHP systems fueled with natural gas, and systems fueled with biomass (typically wood) to displace central grid electricity and natural gas and fossil fuels use for commercial and industrial space, water, and process heating and cooling. The overall goals of this option are to implement 800 MW of gas-fired CHP and 300 MW of biomass-fired CHP by 2030.

RCII-2. SB2030/ Zero Energy Transition/Codes

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 the commercial/institutional sector consumed 18.3%. Making a transition to "Zero Energy" buildings means constructing highly energy efficient buildings and phasing in the use of renewable energy sources--such as solar thermal, solar photovoltaic, and biomass-fired heat use--to provide for the remaining energy needs of the buildings, and in some cases to export energy for use outside the building (for example, electrical energy sent to the local grid). Initiatives such as the national Architecture 2030, Zero Energy Ready, and Minnesota's Sustainable Building 2030 (SB2030) provide guidance for this option. Existing 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. As such, this policy option will provide incentives for or mandates construction of buildings so that net zero energy use in new and renovated buildings is achieved incrementally by 2030.

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

Minnesota utilities must comply with utility energy efficiency resource standard (EERS) requirements established in the Conservation Improvement Program (CIP). EERS standards require utilities to offer their customers energy efficiency programs that result in the reduction of annual sales by a specified amount annually. This option increases the requirements of the existing EERS by increasing the EERS for electric utilities to 2.5% annually, while allowing utilities 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, this option retains 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% of the overall requirement.

RCII-5. Incentives and Resources to Promote Thermal Renewables

Minnesota has a significant resource of forest and other biomass, and Minnesota residences have a history of heating with wood. 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. This option takes advantage of this resource and builds on existing experience with biomass fuels by establishing a renewable thermal goal of switching five percent of the total forecast heating load (measured as fuel delivered for heating use) that is currently fueled with non-electric sources including natural gas, fuel oil, and propane to renewable thermal resources--including solar heat and biomass fuel--by 2020, and 20% by 2030. To pay for incentives to encourage consumers to purchase renewable--fueled heating systems, the option includes establishment of a state-wide 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 (100,000 Btu.) of energy content on natural gas, fuel oil, and propane sold in Minnesota.

Direct and Indirect Policy Option Impacts

Table IV-7 below provides the direct stand-alone policy option impacts for the RCII sectors. On a stand-alone basis, the complete set of RCII policies is expected to produce in-state GHG reductions of 5.3 $TgCO_2e$ in 2020 and 22 $TgCO_2e$ in 2030. These reductions include avoided direct emissions from fossil-fueled systems such as boilers and furnaces, as well as indirect emissions avoided from the electricity sector due to reduced requirements for electricity from the central grid. The reductions are calculated net of additional emissions, for example, from gas-fired CHP or wood-fired heating systems (only N_2O and CH_4 emissions are counted for the latter). As with all results, these presume that the policies will be fully implemented as designed (see Appendix F.2 for details on the design of each policy option). On a cumulative basis, the RCII policies are expected to reduce 157 $TgCO_2e$ in-state (and 182 $TgCO_2e$ total, including upstream emissions) through 2030.

Policies RCII-1, RCII-2, and RCII-4 produce net cost savings for Minnesota. This occurs through a combination of reduced net use of fossil fuels and electricity, partially offset by the somewhat higher capital costs and outlays for biomass fuels. RCII-5 has a net positive cost for Minnesota, as the additional capital and fuel costs outweigh the savings from reduced fossil fuel use, but RCII-5 results in significant in-state investments in infrastructure, which drives positive macroeconomic impacts described in the next section. Overall, the set of RCII policies quantitatively evaluated produces a net savings of -$4.1 billion ($2014) for Minnesota in net present value terms over 2015 - 2030, yielding an average cost-effectiveness (cost per metric ton of CO_2e reduced) of -$23, based on the overall in-state plus upstream emissions total.

Table IV-7 RCII Policy Options, Direct Stand-Alone Impacts

"Stand-Alone" Analysis							
Policy Option ID	Policy Option Title	GHG Reductions				Costs	
		Annual CO_2e Reductions[a]		2030 Cumula-tive[a]	2030 Cumula-tive[b]	Net Costs[c] 2015-2030	Cost Effective-ness[d]
		2020 Tg	2030 Tg	$TgCO_2e$	$TgCO_2e$	$Million	$/t$CO_2$e
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)**

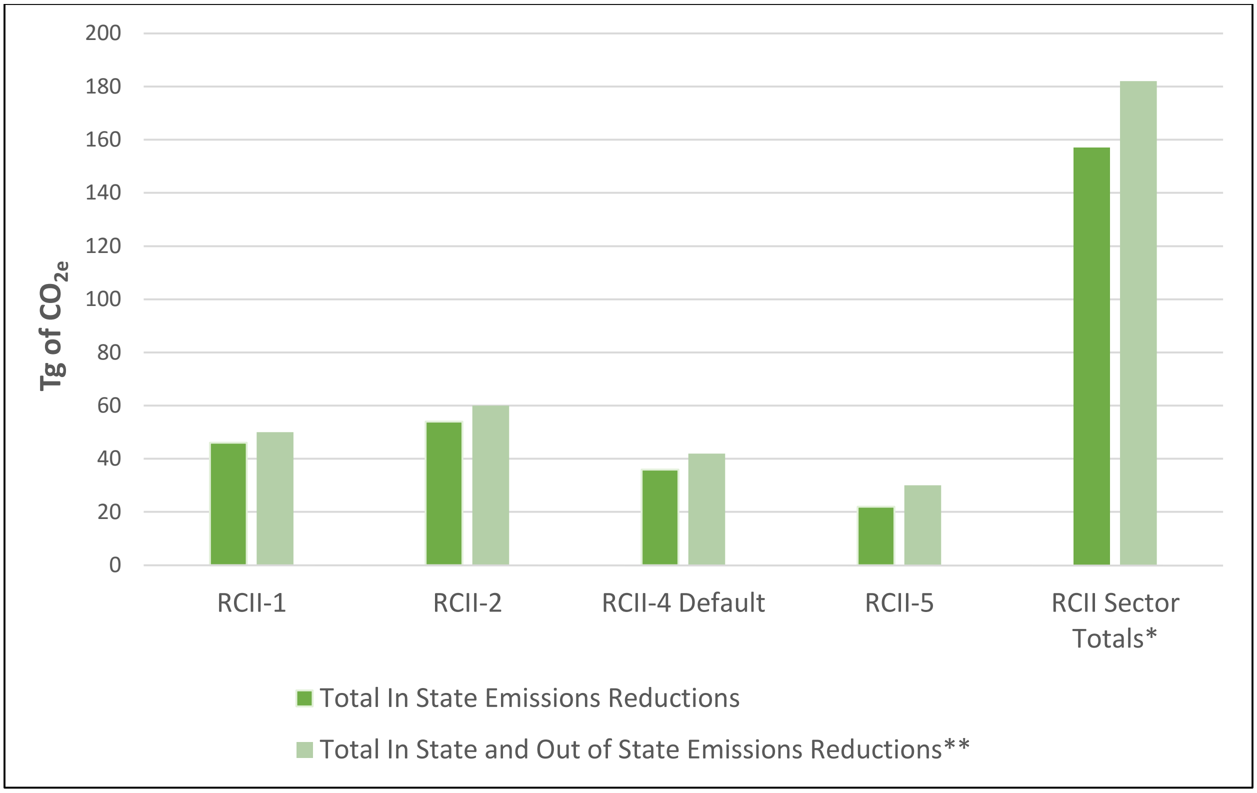
Notes:
[a] In-State (Direct) GHG Reductions
[b] Total (Direct and Indirect) GHG Reductions
[c] Net Present Value of fully implemented policy option using 2014 dollars ($2014)
[d] Cost effectiveness values include full energy-cycle GHG reductions, including those occurring out of State. Dollars expressed in 2014$.
[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 IV-8 RCII 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 Cumula-tive[a]	2030 Cumula-tive[b]	Net Costs[c] 2015-2030	Cost Effective-ness[d]
		2020 Tg	2030 Tg	$TgCO_2e$	$TgCO_2e$	$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)[j]	*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.
[j] 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 IV-27 RCII Policies GHG Emissions Abatement, 2016-2030



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 IV-9 Macroeconomic Impacts of RCII Policies

Macroeconomic (Indirect) Impacts Results									
Scenario	GSP[a] ($2015 MM)			Employment[b] (Individual)			Personal Income[c] ($2015 MM)		
	Year 2030[d]	Average (2016-2030)[e]	Cumulative (2016-2030)[f]	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)
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.
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 IV-28 Net Job Creation for RCII Policies and RCII Sector by Ascending Order, 2016-2030

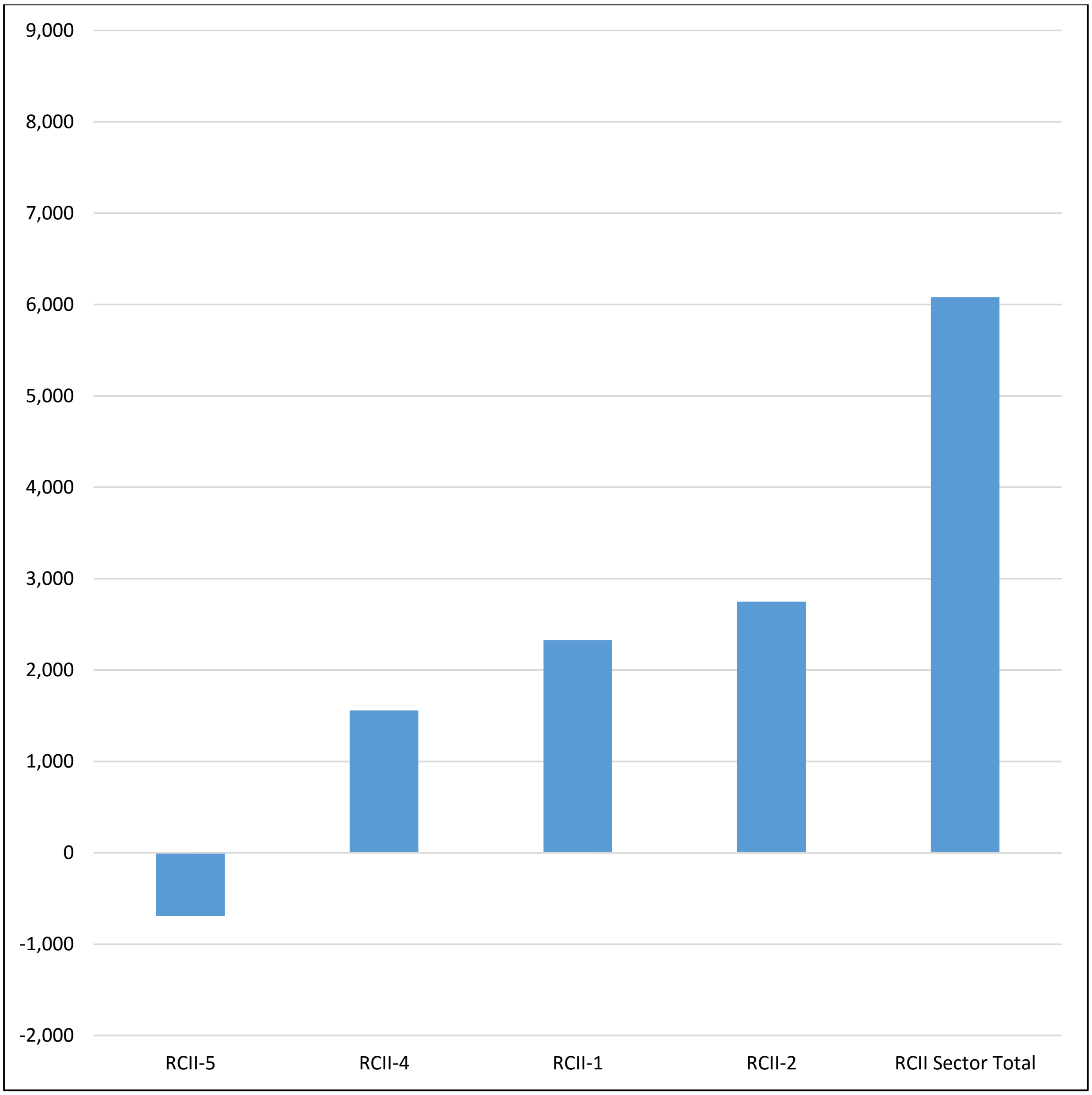
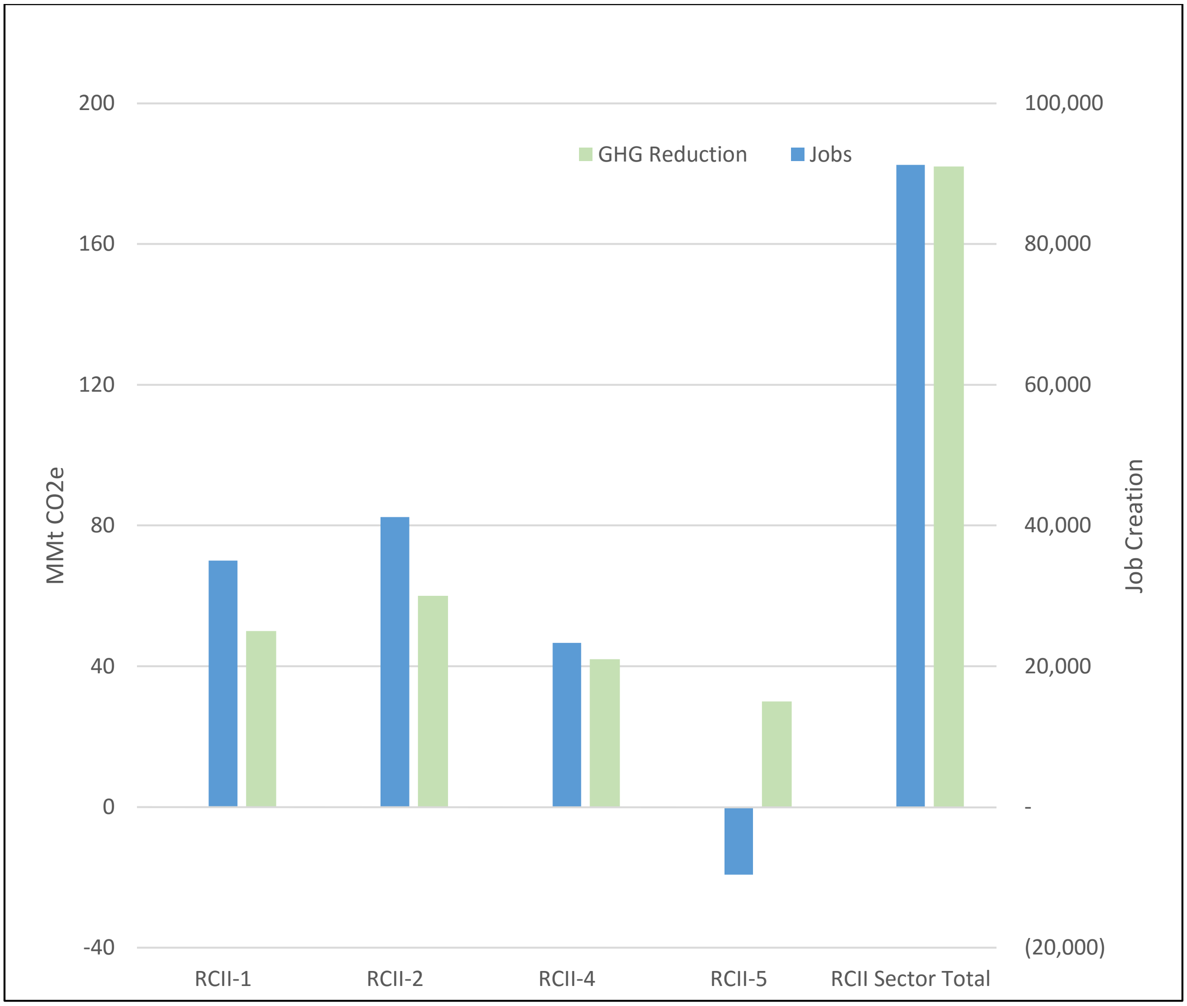


Figure below summarizes a potential for job creation and GHG emissions abatement of RCII sector policies on the same graph. This allows for a simultaneous assessment of performance of individual CSEO options against two crucial environmental and economic indicators.

Figure IV-29 Job Gains and GHG Reduction by RCII Policy Recommendations, 2016-2030



Macroeconomic Index

Graphs below present the overall macroeconomic impacts of each policy in RCII sector, as well as the sector-level impacts, by using the Macroeconomic Impact Index. The index is a blended score indicating an overall macroeconomic impact of a policy or a set of policies on GSP, income and employment. In this project, the three variables are weighted equally, and indexed based on the maximum value among all the policies in the project. I_GSP, I_Jobs, and I_Income represent the index score for GSP, Jobs and Income, respectively.

Figure IV-30 RCII Macroeconomic Impacts, Year 2030

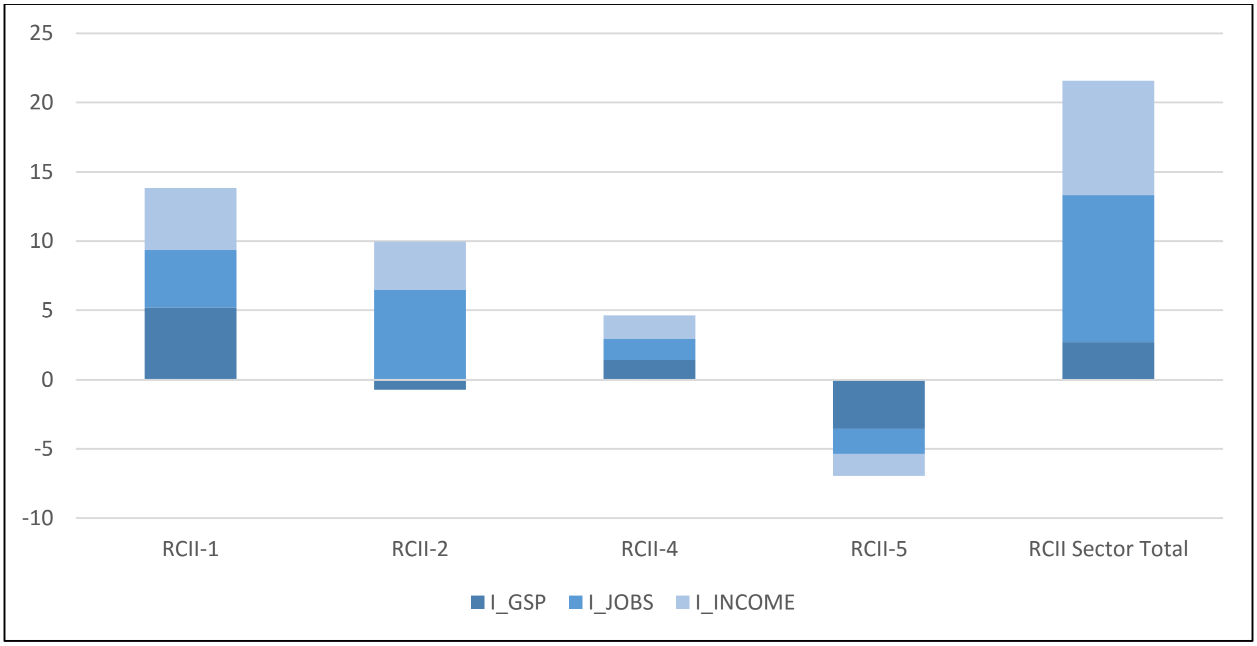


Figure IV-31 RCII Macroeconomic Impacts, Average Annual

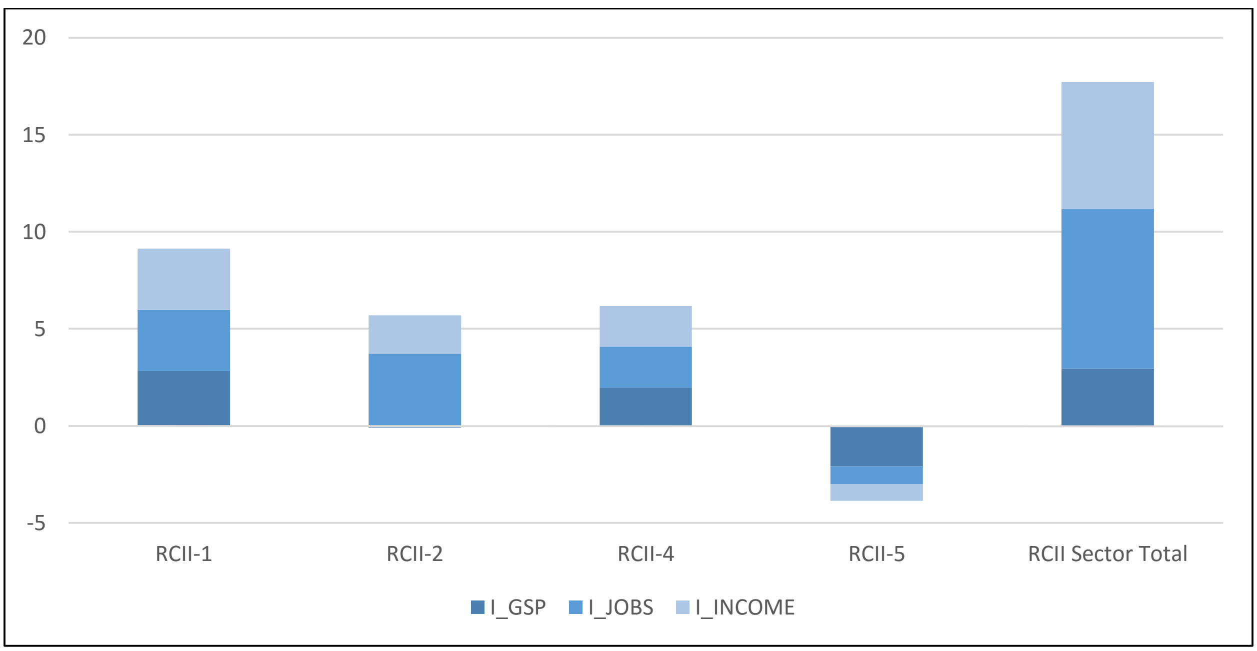
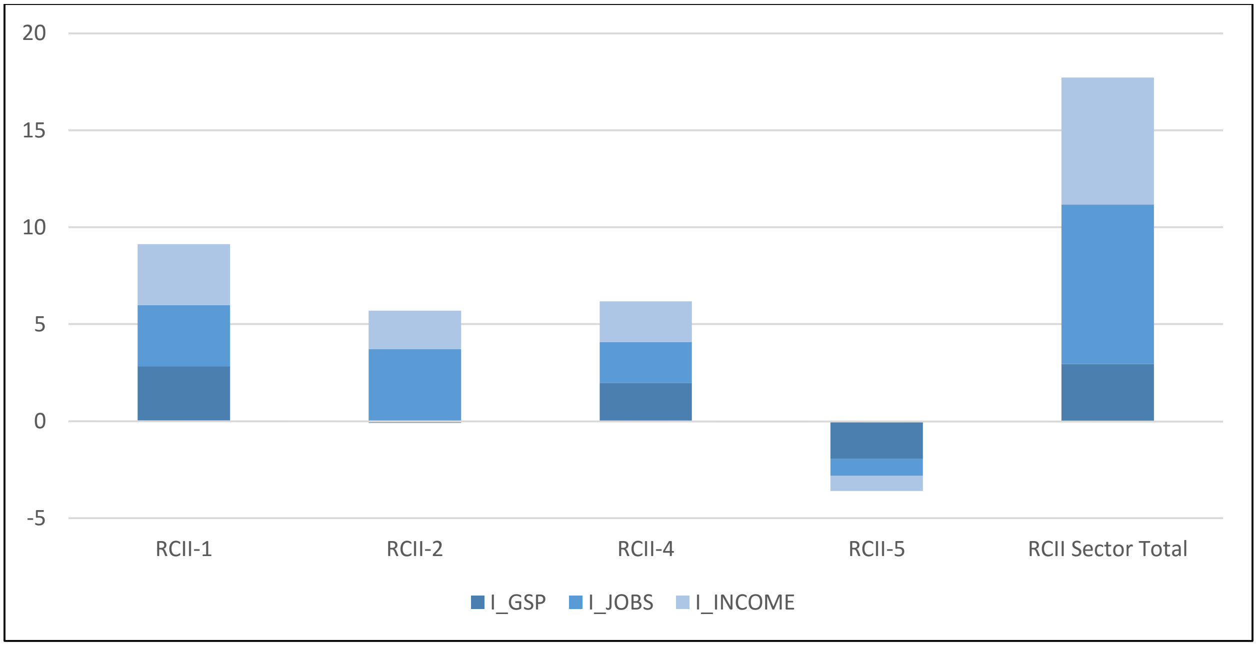


Figure IV-32 RCII Macroeconomic Impacts, 2016-2030



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 2016-2030 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 effectively 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 IV-33 RCII GSP Impacts ($2015 MM)

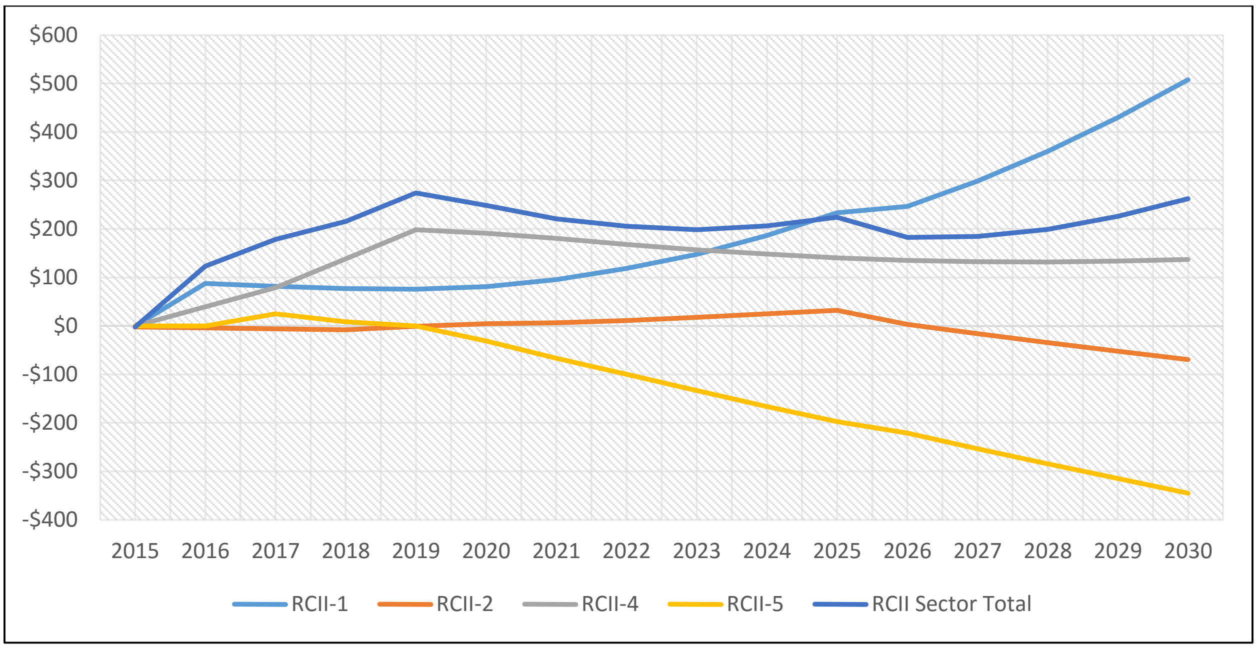


Figure IV-34 RCII Employment Impacts (Jobs)

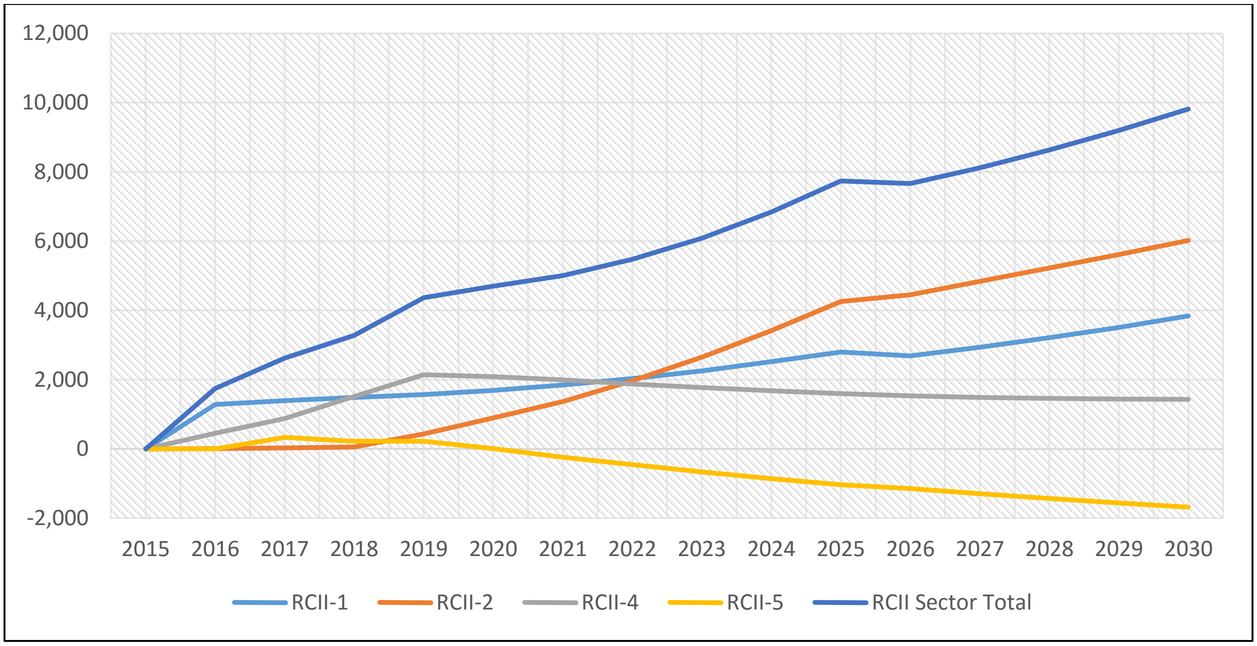
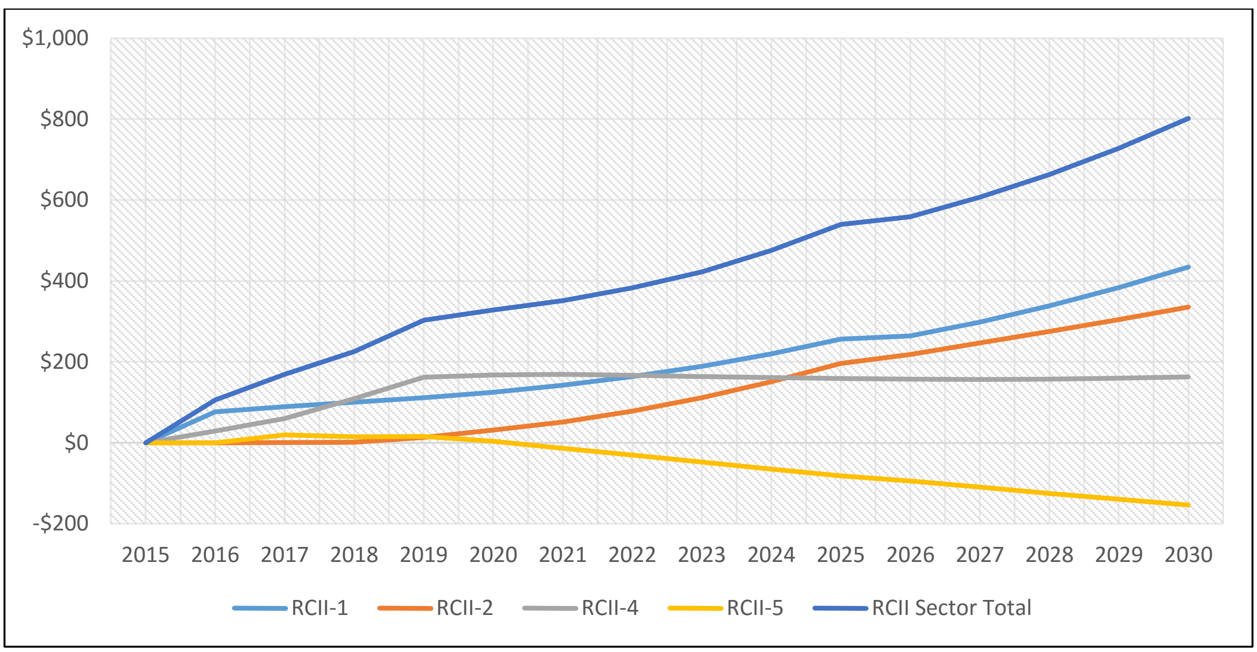


Figure IV-35 RCII Income Impacts ($2015 MM)



Graphs below show macroeconomic impacts on GSP, personal income, and employment in the final year (2030), in average (2016-2030) and in cumulative (2016-2030).

Figure IV-36 RCII GSP Impacts, Average Annual ($2015 MM)

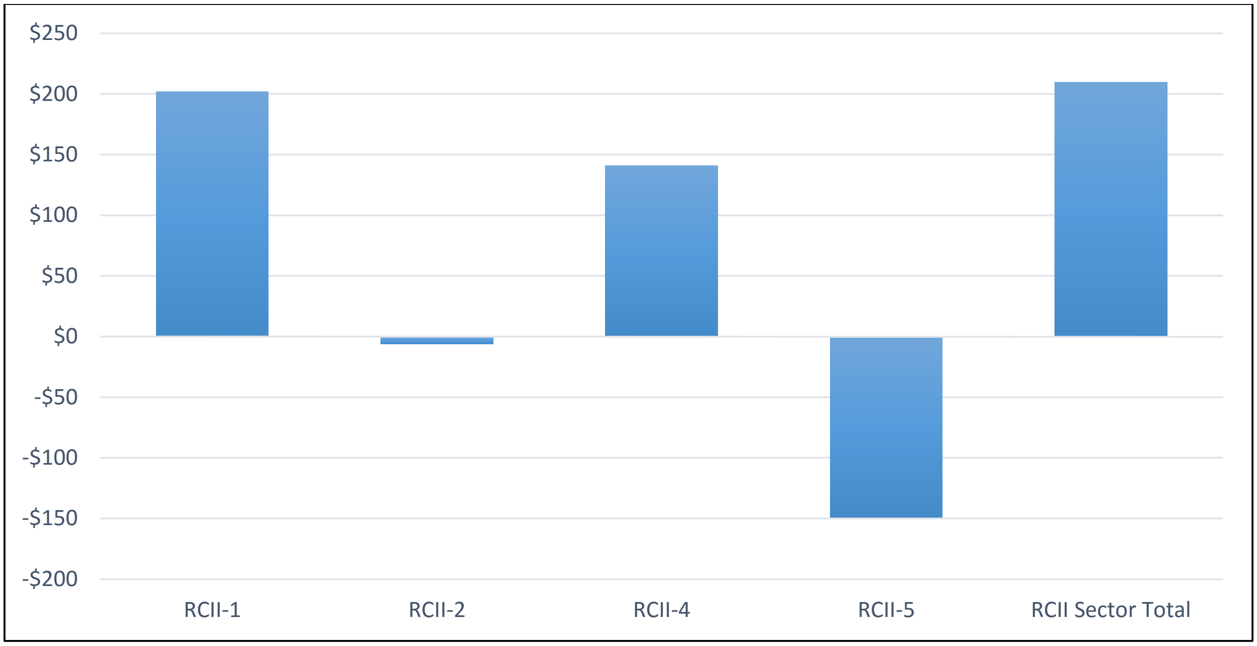


Figure IV-37 RCII GSP Impacts, 2016-2030 ($2015 MM)

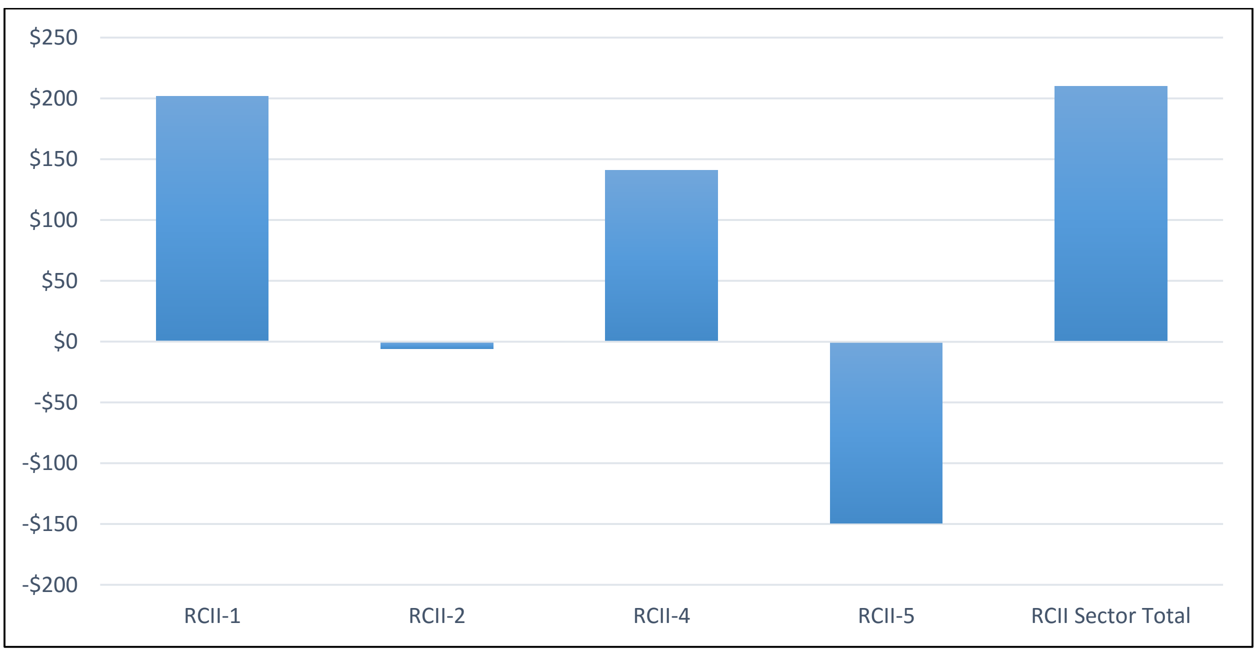


Figure IV-38 RCII GSP Impacts, Year 2030 ($2015 MM)

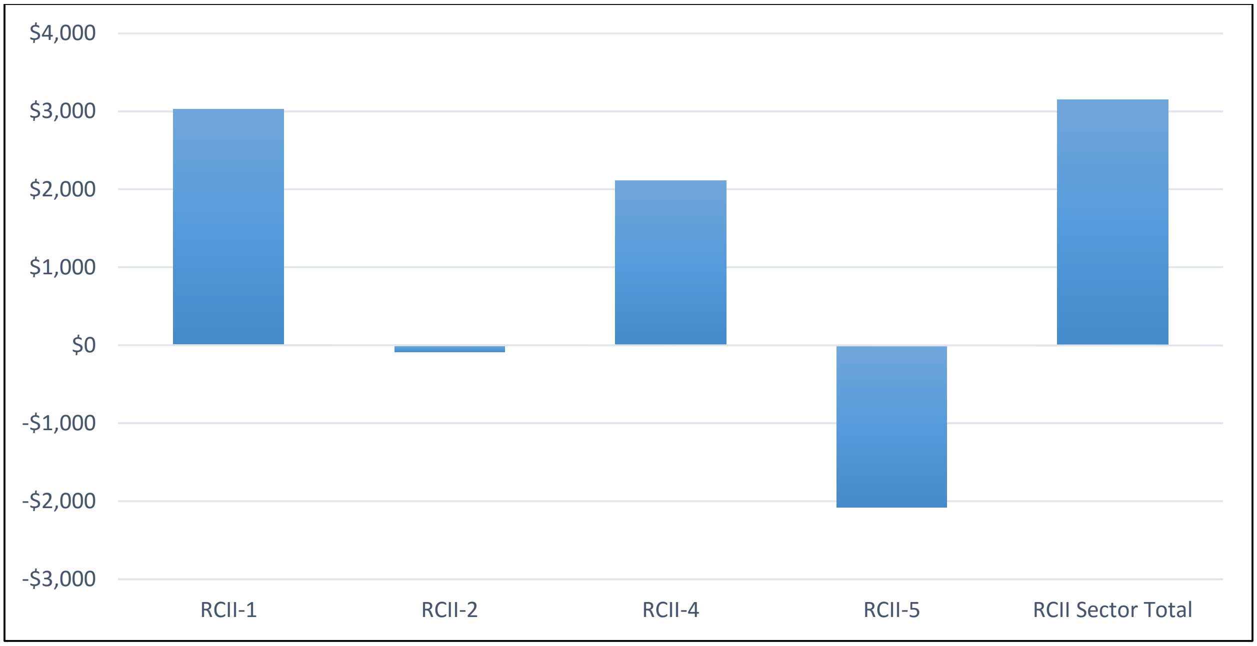


Figure IV-39 RCII Employment Impacts, Average Annual (Jobs)

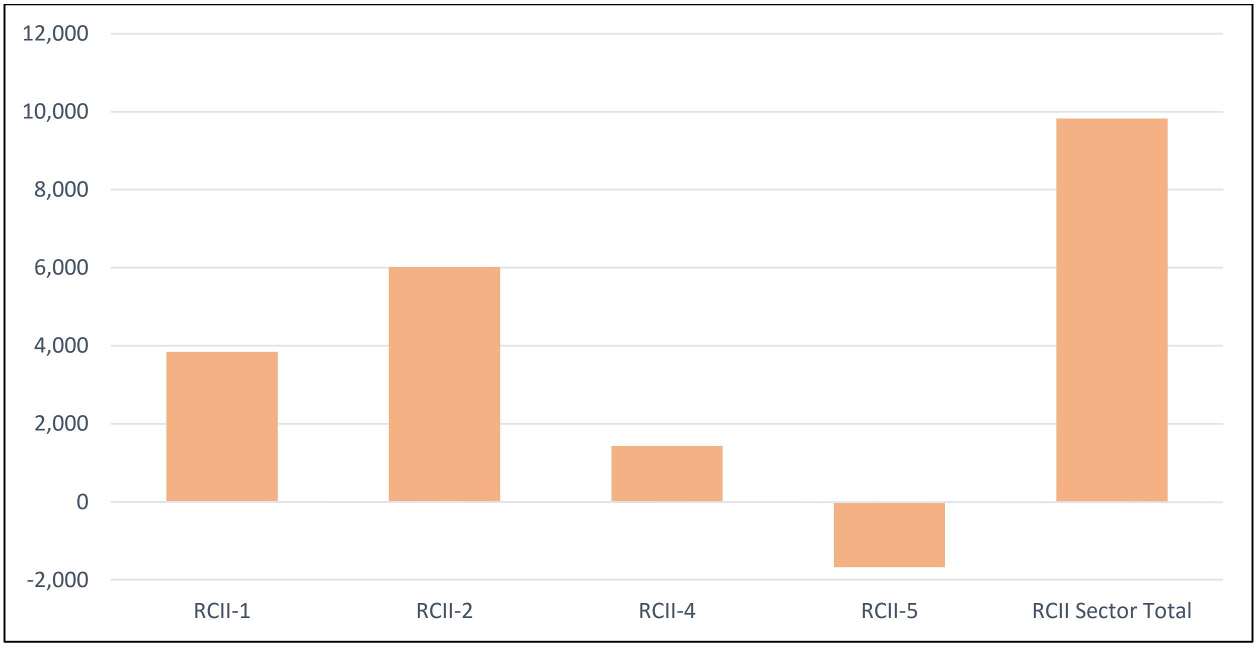


Figure IV-40 RCII Employment Impacts, 2016-2030 (Job Years)

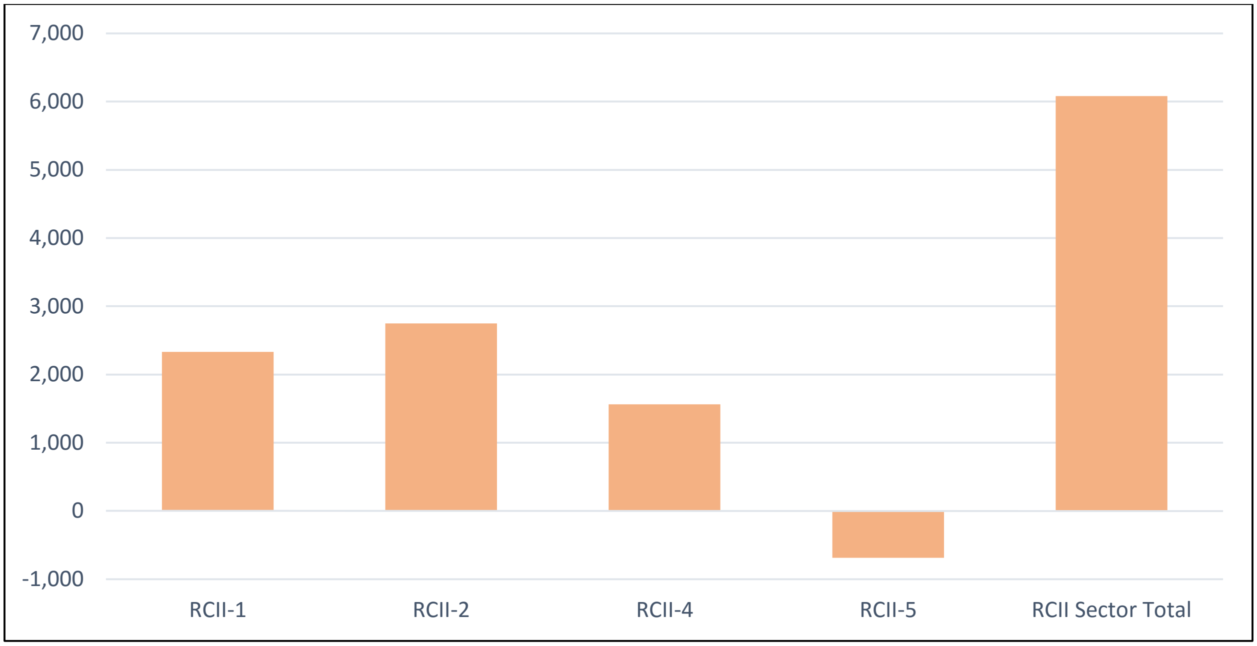


Figure IV-41 RCII Employment Impacts, Year 2030 (Jobs)

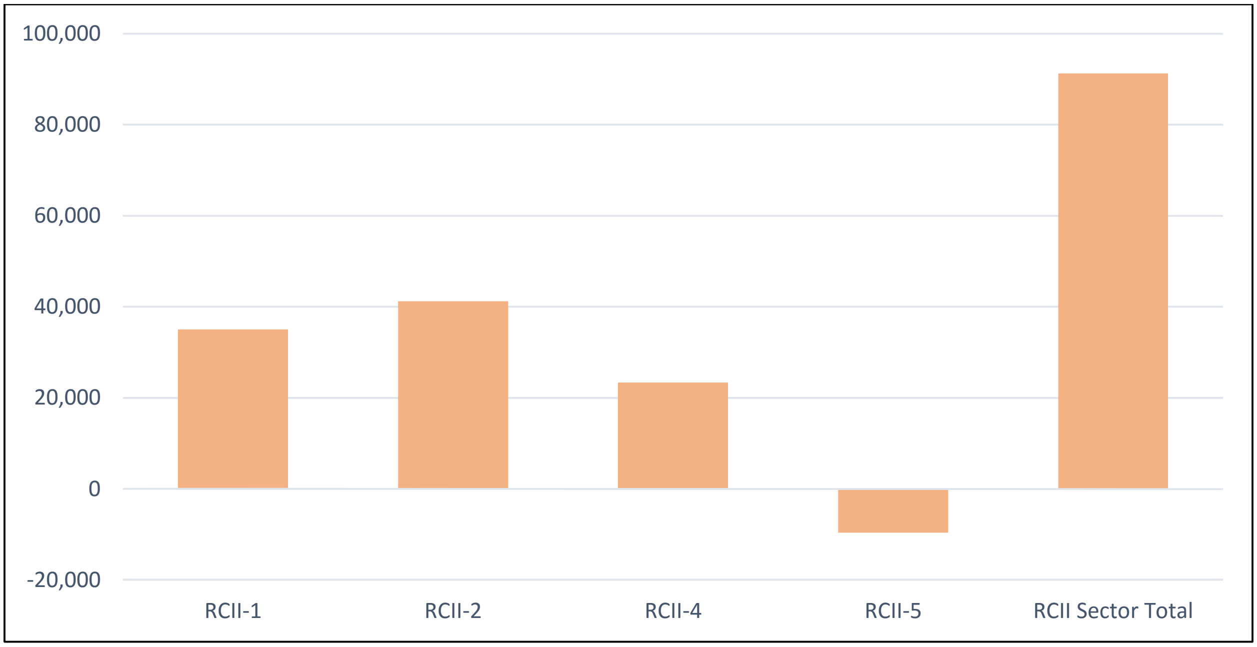


Figure IV-42 RCII Income Impacts, Average Annual ($2015 MM)

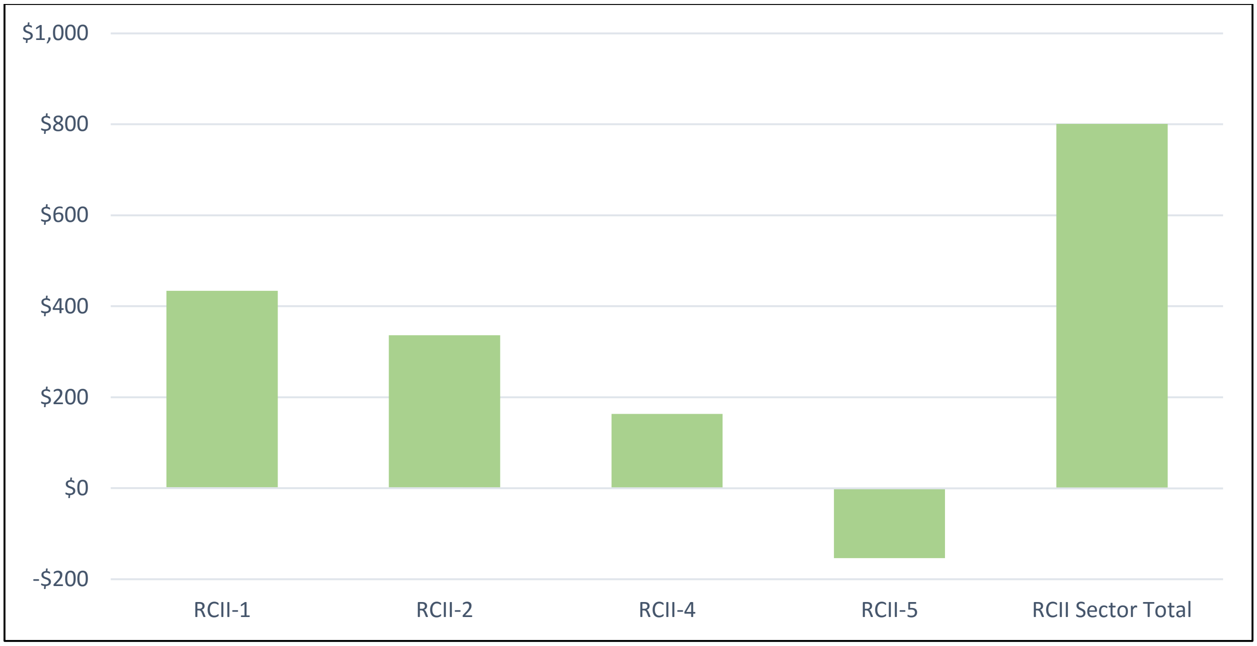


Figure IV-43 RCII Income Impacts, 2016-2030 ($2015 MM)

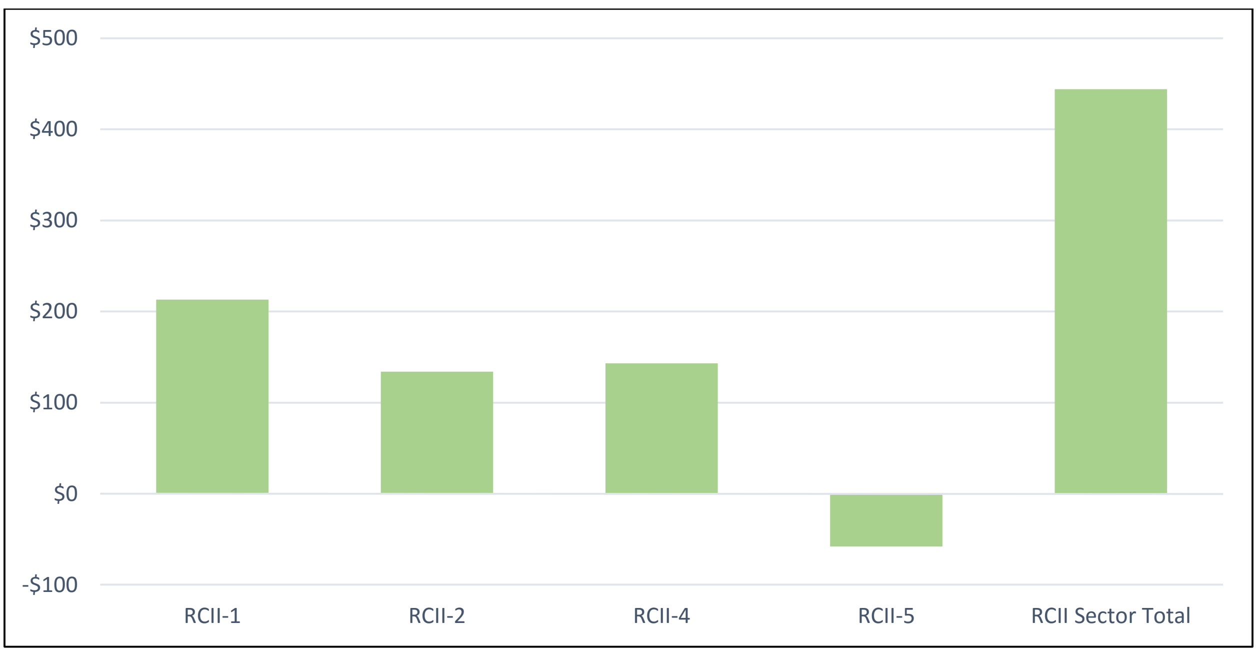
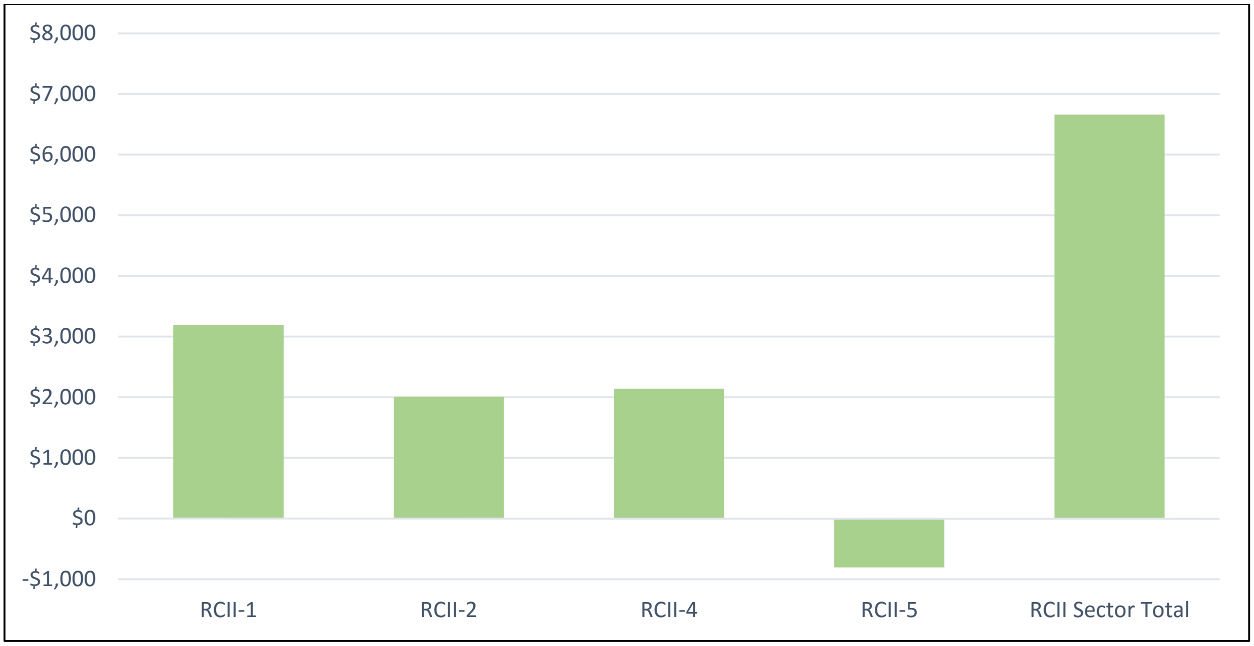


Figure IV-44 RCII Income Impacts, Year 2030 ($2015 MM)



3. Transportation & Land Use

The Transportation and Land Use (TLU) sector covers all forms of transportation, both passenger and freight (air, rail, marine vessel, and on-road vehicles). The sector contributed 22% of the state's total greenhouse gas (GHG) emissions in 2010 and is expected to contribute about the same in 2030 (21%). Of the transportation subsectors, the on-road subsector contributes the most GHG emissions (about 85% of the sector-level emissions in 2010). Key drivers of GHG emissions for the sector include: vehicle-miles traveled by Minnesota drivers; the fuel economy of vehicles on Minnesota roadways; and the carbon content of fuels used by Minnesota vehicles.

Strategies that can be employed to achieve both GHG reductions and positive economic impacts include: increases in fuel economy across the Minnesota vehicle fleet; shifting passenger trips from vehicles to lower emissions modes of travel (e.g. light rail, bus, carpooling, bikes, and pedestrian modes); developing more compact urban areas that reduce commute distances; and the use of lower carbon and locally-sourced transportation fuels.

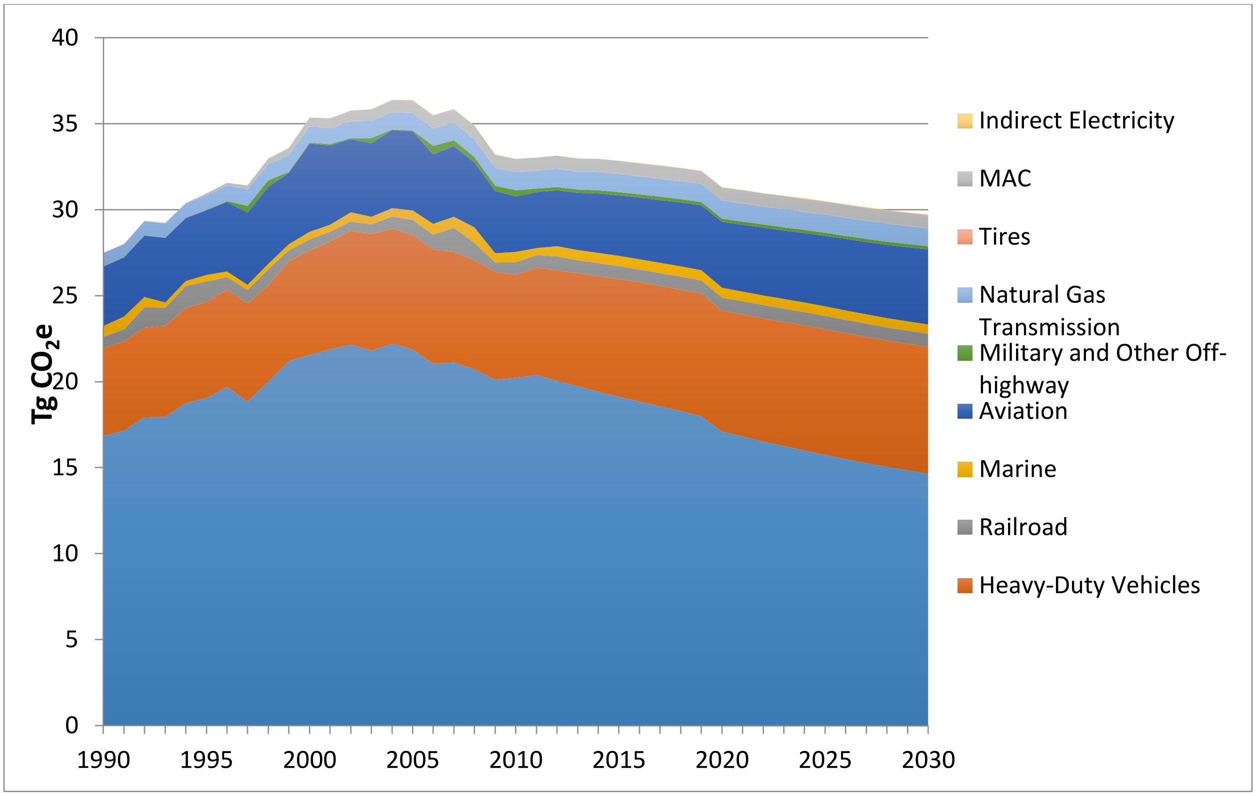
Baseline and Emissions Sources

Figure below provides a summary of the TLU GHG baseline. Emissions are dominated by light- and heavy-duty on-road vehicles. These vehicles are fueled primarily by gasoline and diesel; however, all fuels are included in the chart below (excluded are indirect emissions associated with electricity consumption in vehicles). Small contributions are made from fuel combustion in the rail, marine, aviation, military, and other off-road fuel sectors. Natural gas transmission contributions are shown to grow substantially after 2010. These come from methane (CH_4)

leaks from transmission systems. Tire wear produces carbon dioxide (CO_2) emissions, as that synthetic material breaks down (emission levels are too small to show up in the chart). Finally, mobile air conditioning (MAC) losses of refrigerants make up the rest of the baseline emissions.

GHG emissions are shown to decline during the forecast period. This is brought about primarily through an increase in the on-road vehicle fleet's efficiency as a result of the federal corporate average fuel economy (CAFE) standards, as well as efficiency standards for heavy duty vehicles.

Figure IV-45 TLU Sector GHG Baselines



CSEO Policy Options

There were four policies developed for the TLU sector. These are detailed in Appendix F.3 and are summarized as follows:

TLU-1. Transportation Pricing

Transportation pricing can reduce GHG 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, which all seek to modify the costs of driving to change transportation behaviors:

- TLU-1A Pay-as-you-go Insurance: Provides incentives for automotive insurance companies to institute pay-as-you-go insurance pricing. This would convert an existing fixed cost for insurance into a per-mile variable cost. This policy option would therefore incentivize a reduction in vehicle miles traveled (VMT) without increasing costs on Minnesota drivers.
- TLU-1B Carbon Tax: This policy option looks at the impacts of assessing a $30 per ton societal cost for each ton of carbon. This amounts to a tax of $0.24 per gallon for E10 gasoline. This carbon tax policy option also rebates to low income households and to address equity issues.
- TLU-1C Fuel Tax: This policy option examines the impact of a 6.5% statewide wholesale fuel sales tax on gross gasoline and special fuel (including diesel) purchases. This strategy is designed to provide both funding for roads and bridges in Minnesota, and potential greenhouse gas emissions reductions.

TLU-2. Improve Land Development and Urban Form

Land use patterns and population density can have a significant impact on transportation and residential energy consumption. This policy option seeks to 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 VMT and GHG emissions 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 emissions from buildings. Also, greater concentration and more compact urban form can economize on infrastructure expansion, which can further reduce GHG emissions from transportation.

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. This policy option examines the VMT, fuel consumption and cost impacts of denser development within the seven-county Minneapolis-St. Paul Metropolitan area.

TLU-3. Metropolitan Council Draft 2040 Plan

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; and increased availability of multimodal travel options. This policy option examines the VMT, fuel consumption and cost impacts of the 2040 TPP, particularly with regard to expanded transit use within the seven county Metro area.

TLU-4. Zero Emission Vehicle Standard

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. 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.

As adoption of EVs increases in Minnesota and other parts of the country we will have better information about their integration on of EVs with renewable energy policies 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 two scenarios with bookend numbers:

- 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; and
- EVs with 100% renewable energy from wind and solar power.

Direct and Indirect Policy Option Impacts

Overview

The tables below provide a summary of the microeconomic analysis of Climate Solutions & Economic Opportunities (CSEO) policies in the Transportation and Land Use (TLU) sector. Table IV-10 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 GHG reductions for 2020 and 2030 in teragrams (Tg) of carbon dioxide equivalent reductions (CO_2e), as well as the cumulative reductions through 2030 (1 Tg is equal to 1 million metric tons). 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

The second summary, Table IV-11, above 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) Economic Impacts

Table IV-12 below provides a summary of the expected impacts of TLU 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 IV-10 TLU 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 Tg	2030 Tg	$TgCO_2e$	$TgCO_2e$	$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 Draft 2040 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.

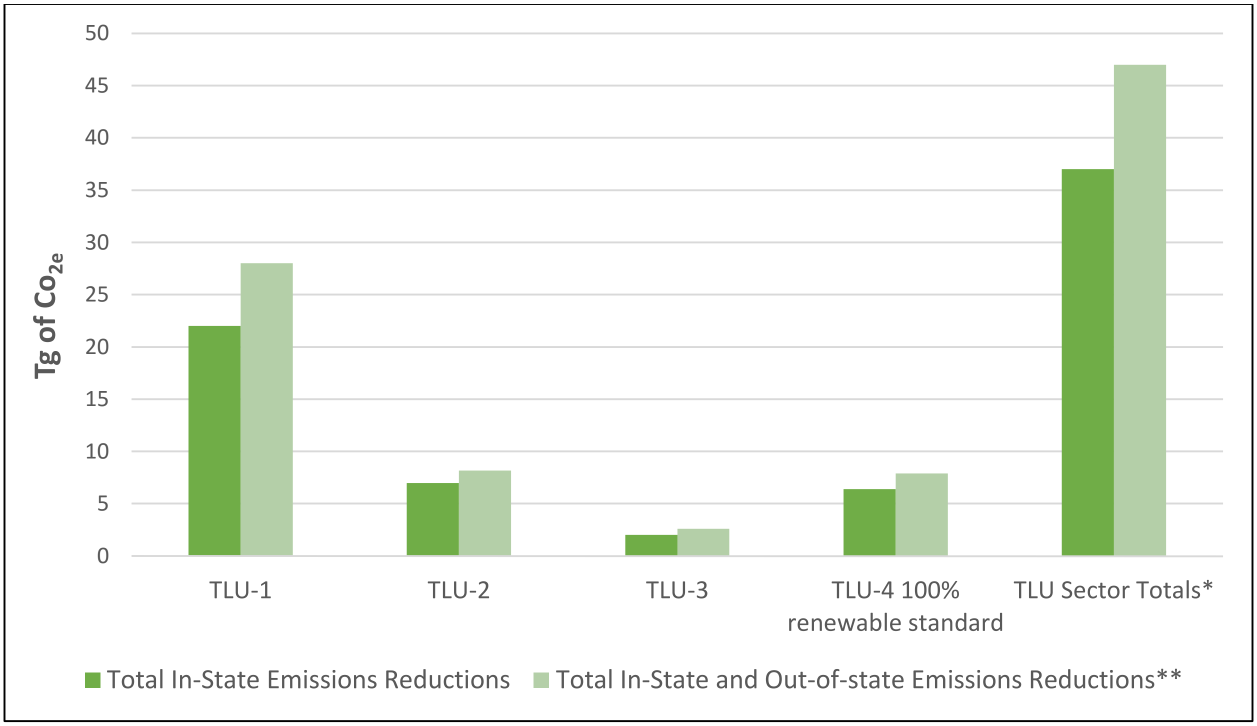
Table IV-11 TLU Policy Options, Intra-Sector Interactions & Overlaps

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 Tg	2030 Tg	$TgCO_2e$	$TgCO_2e$	$Million	$/$tCO_2e$
TLU-1	Transportation Pricing -	1.5	2.0	21	28	$2,718	$97.30

	Total						
	- 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 Draft 2040 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 AG-4 and AG-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 IV-46 TLU Policies GHG Emissions Abatement, 2016-2030



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 IV-12 Macroeconomic Impacts of TLU Policies

Macroeconomic (Indirect) Impacts Results									
Scenario	GSP[a] ($2015 MM)			Employment[b] (Individual)			Personal Income[c] ($2015 MM)		
	Year 2030[d]	Average (2016-2030)[e]	Cumulative (2016-2030)[f]	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)
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**

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 IV-47 Net Job Creation for TLU Policies and TLU Sector by Ascending Order, 2016-2030

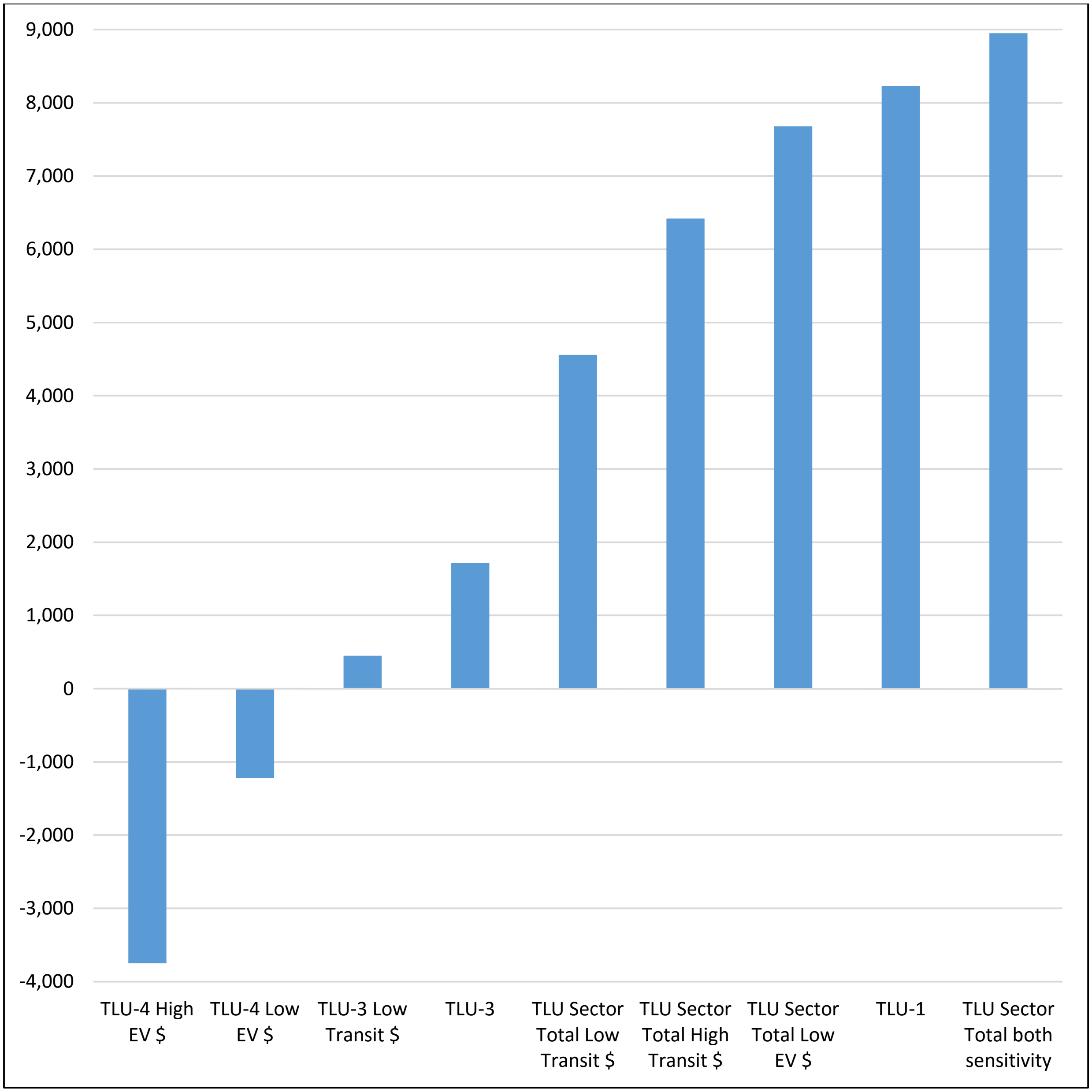
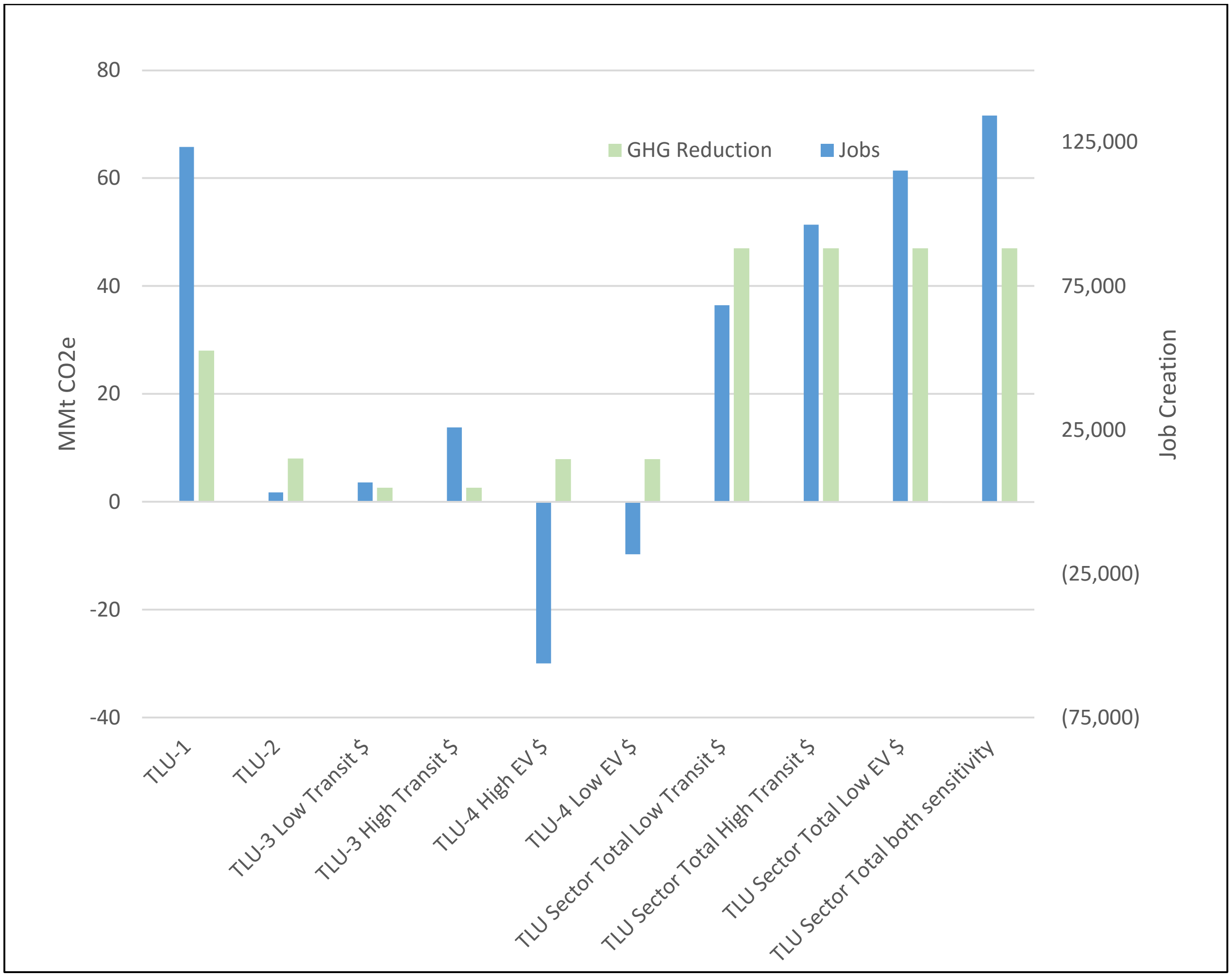


Figure below summarizes a potential for job creation and GHG emissions abatement of TLU sector policies on the same graph. This allows for a simultaneous assessment of performance of individual CSEO options against two crucial environmental and economic indicators.

Figure IV-48 Job Gains and GHG Reduction by TLU Policy Recommendations, 2016-2030



Macroeconomic Indicators

Graphs below present the overall macroeconomic impacts of each policy in the TLU sector, as well as the sector-level impacts, by using the Macroeconomic Impact Index. The index is a blended score indicating overall macroeconomic impact of a policy or a set of policies on GSP, income and employment. In this project, the three variables are weighted equally, and indexed based on the maximum value among all the policies. I_GSP, I_Jobs, and I_Income represent the index score for GSP, Jobs and Income, respectively.

Figure IV-49 TLU Macroeconomic Indicators, 2030

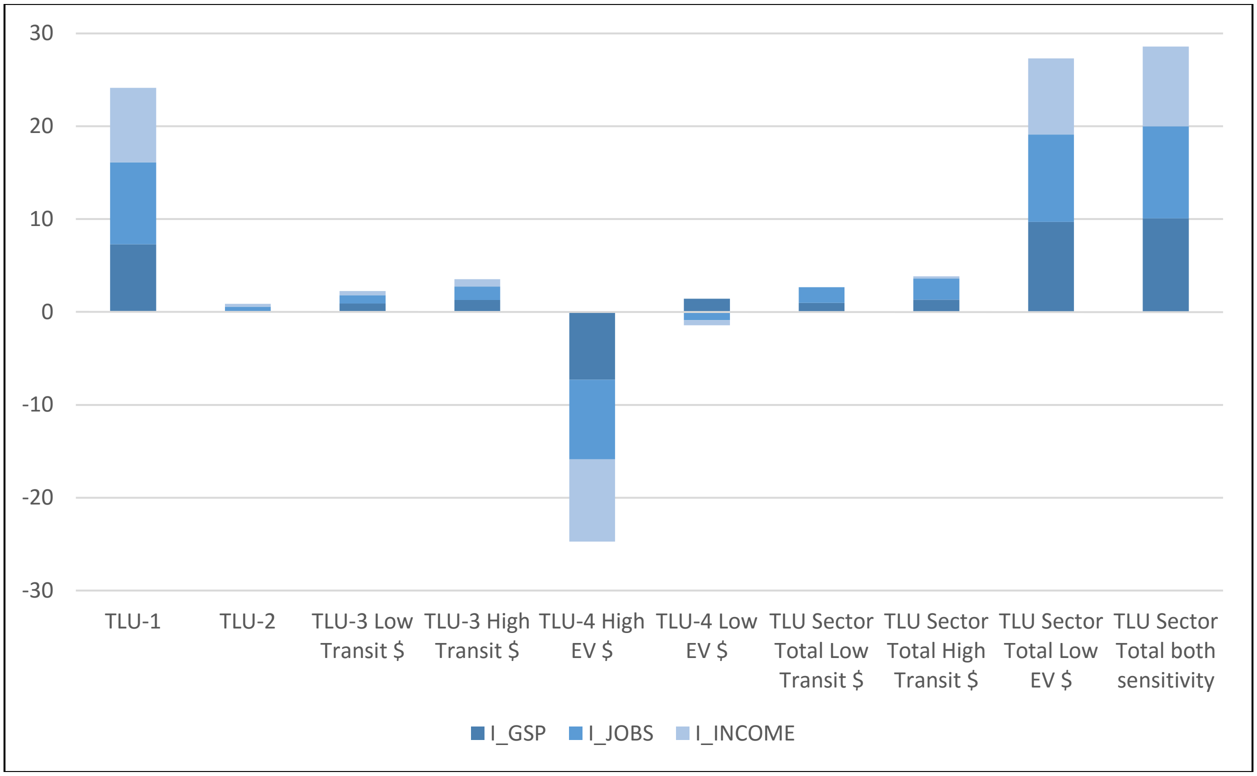


Figure IV-50 TLU Macroeconomic Indicators, 2016-2030 Average Annual

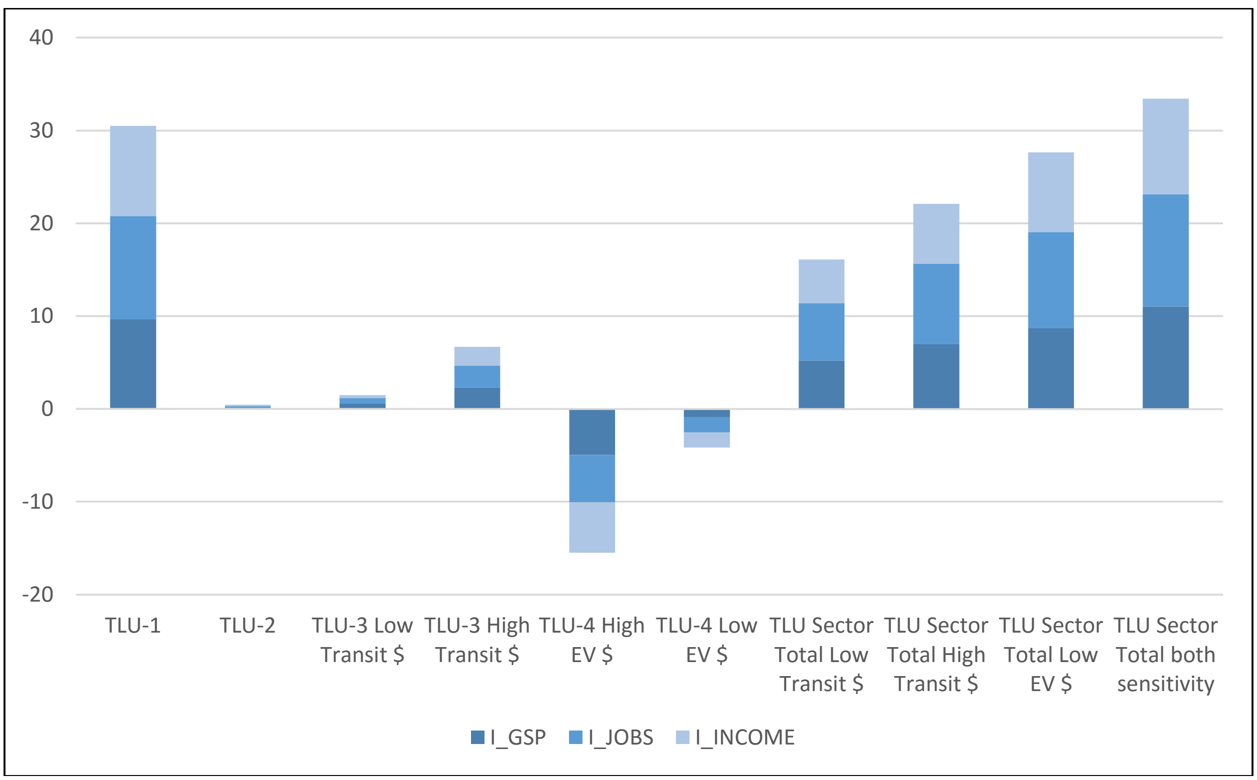
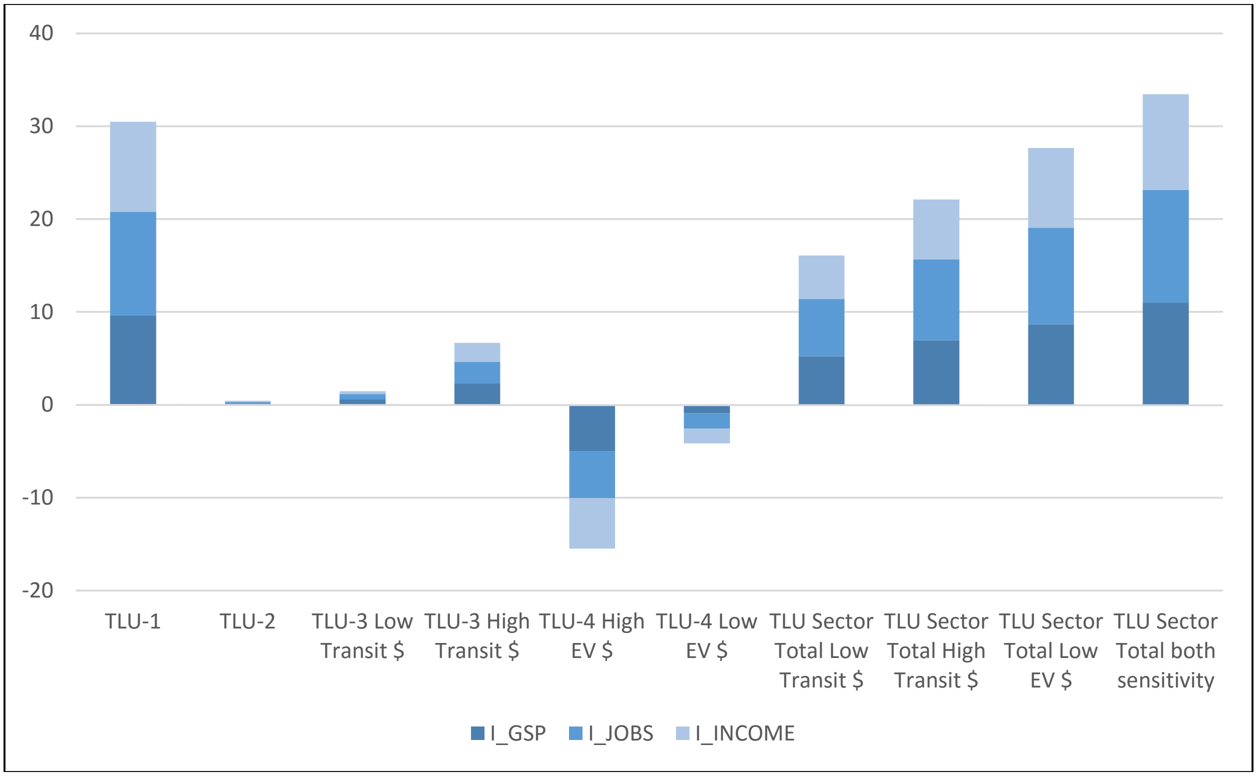


Figure IV-51 TLU Macroeconomic Indicators, 2016-2030



Graphs below show the trend of TLU policy macroeconomic impacts during the year 2015 to the year 2030.

Figure IV-52 TLU GSP Impacts ($2015 MM)

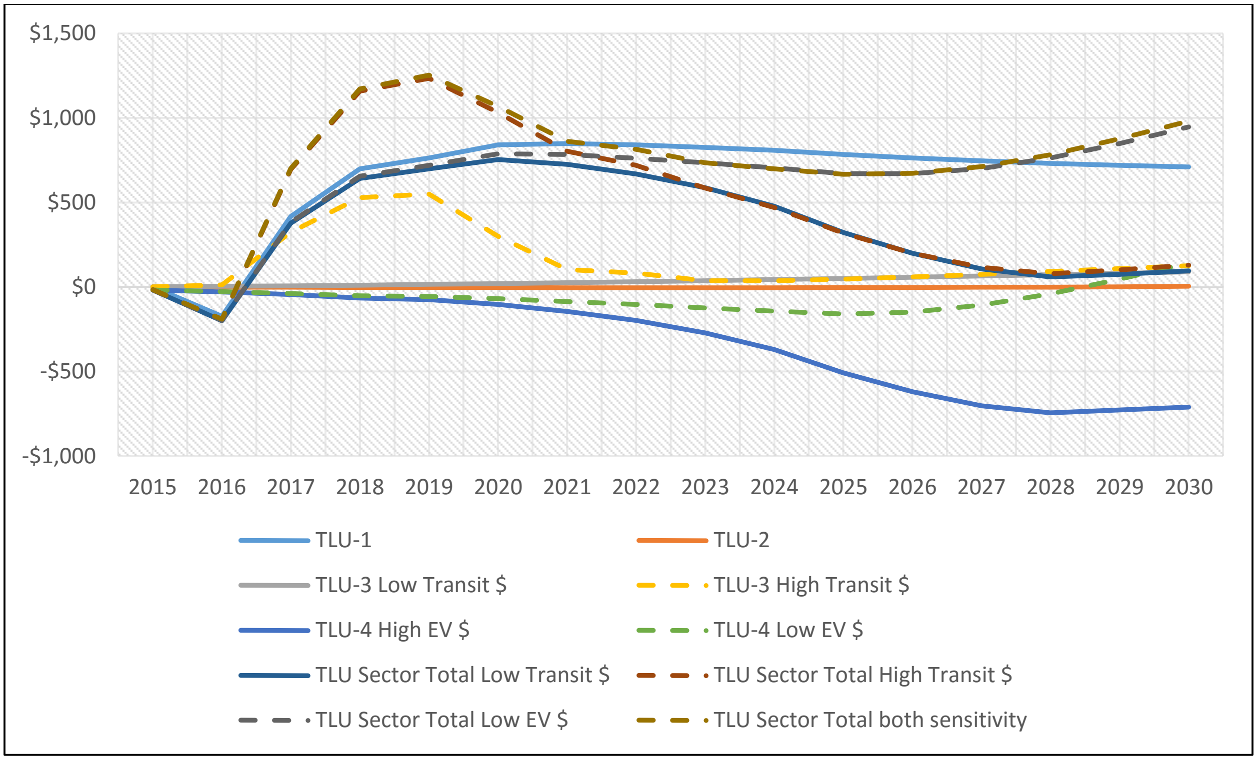


Figure IV-53 TLU Income Impacts ($2015 MM)

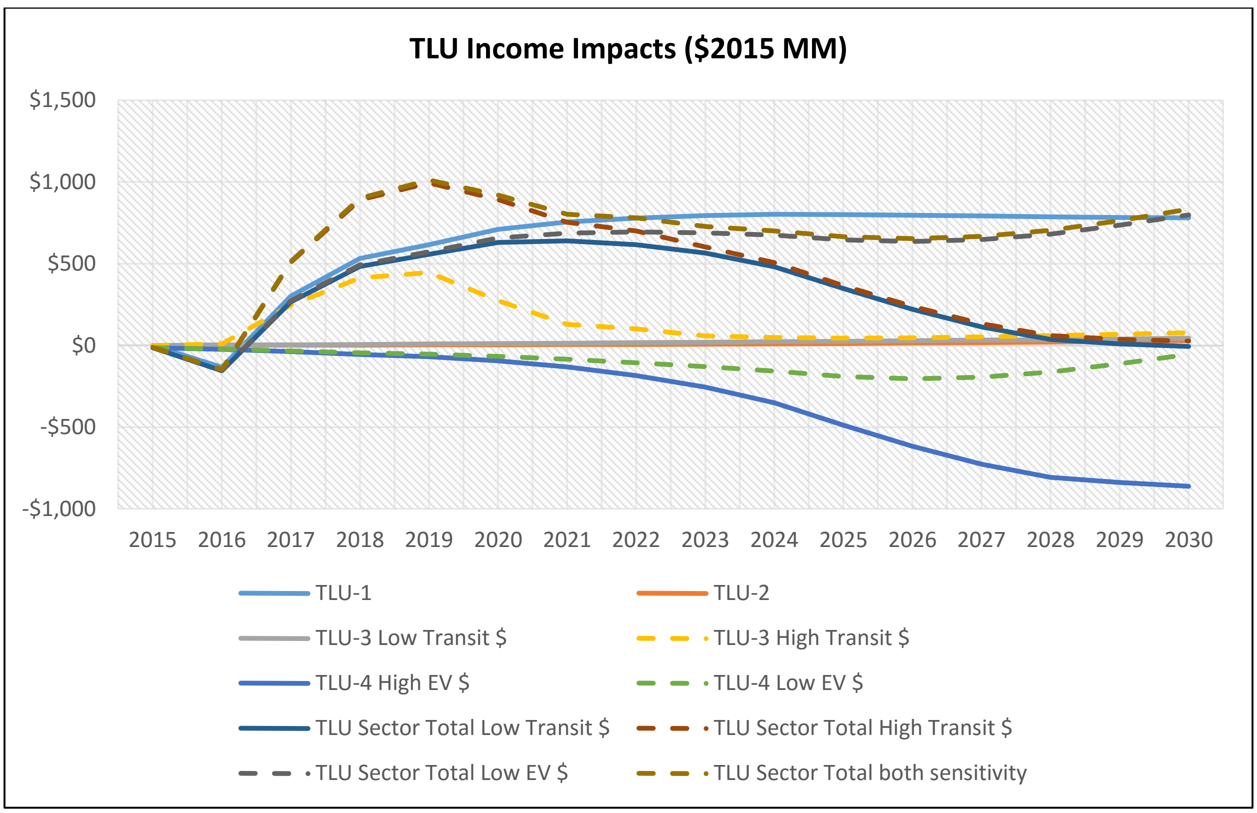
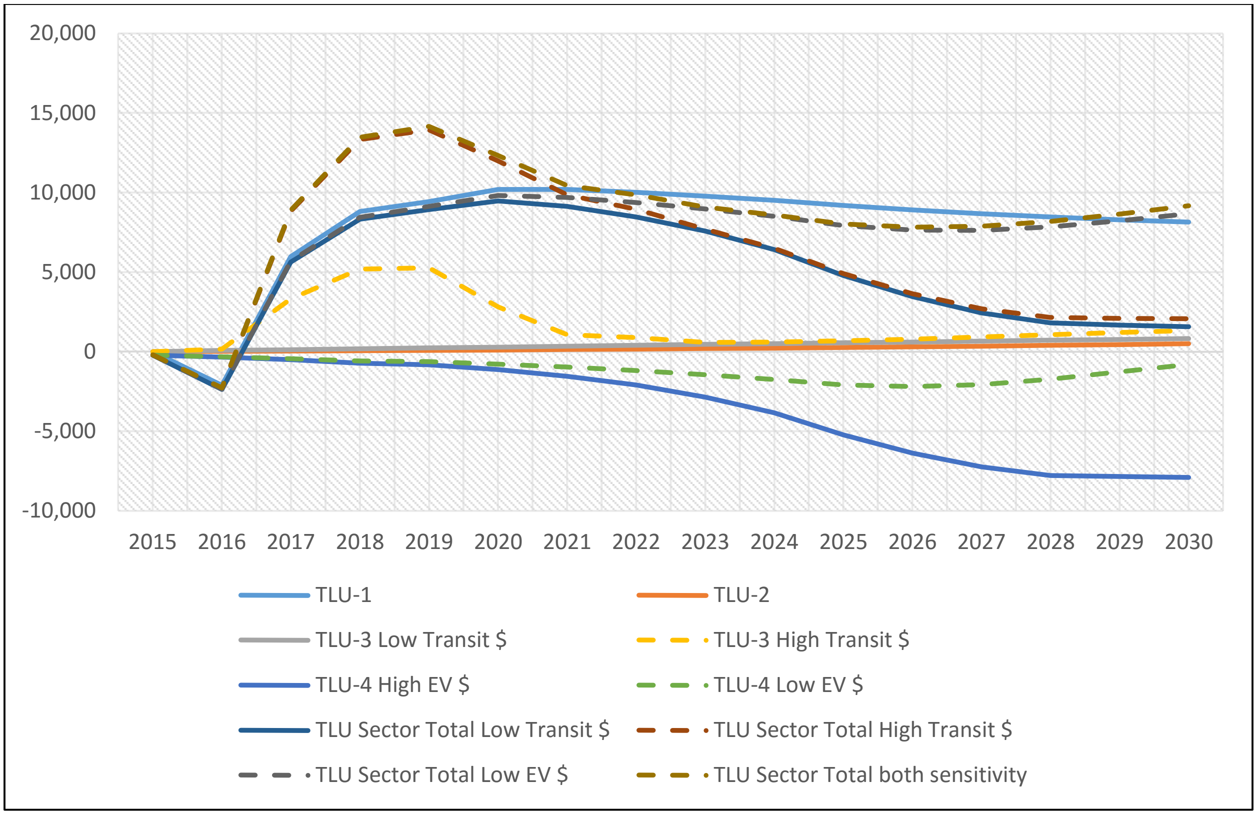


Figure IV-54 TLU Employment Impacts (Jobs)



Graphs below show macroeconomic impacts on GSP, personal income, and employment in the final year (2030), average (2016-2030) and cumulative (2016-2030). Lighter color indicates sensitivity scenarios.

Figure IV-55 TLU GSP Impacts, Average Annual ($2015 MM)

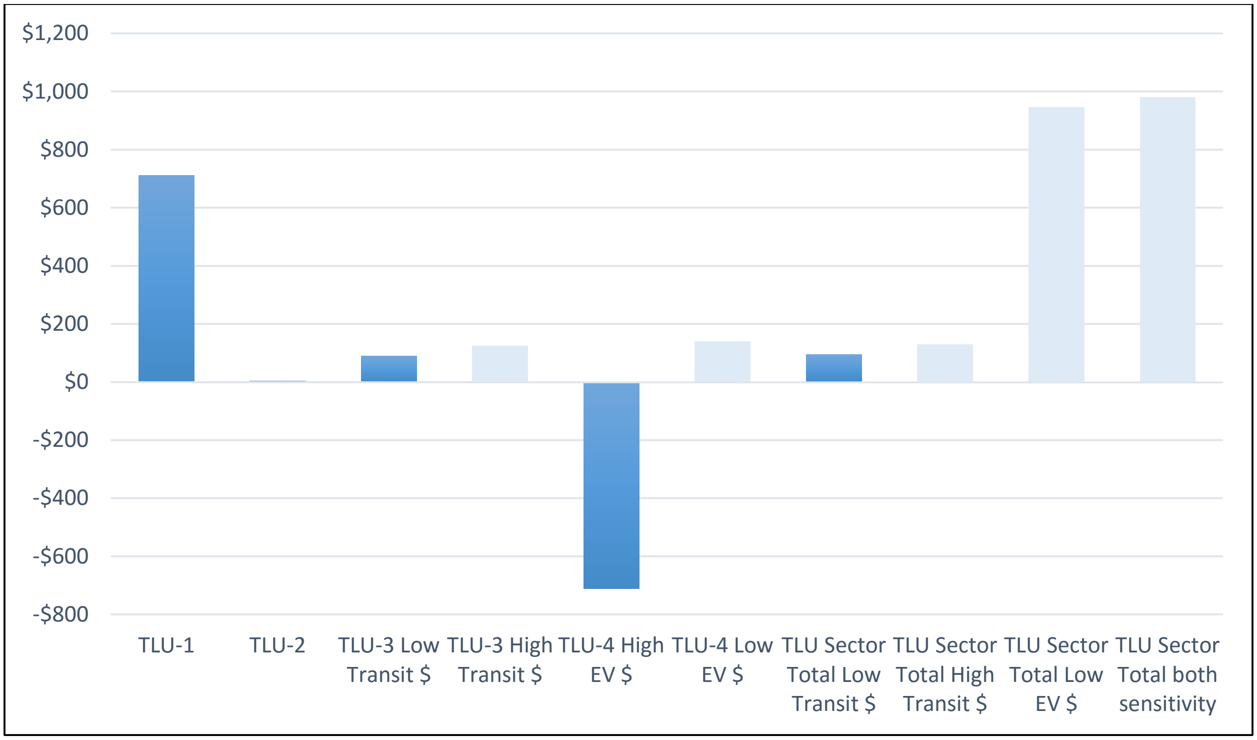


Figure IV-56 TLU GSP Impacts, 2016-2030 ($2015 MM)

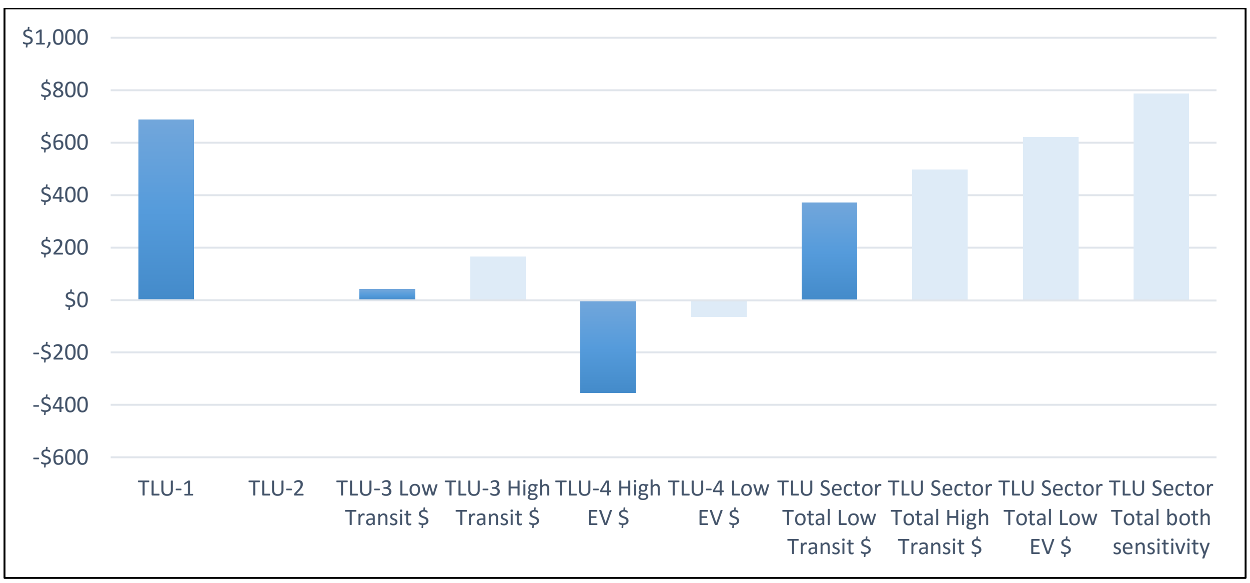


Figure IV-57 TLU GSP Impacts, Year 2030 ($2015 MM)

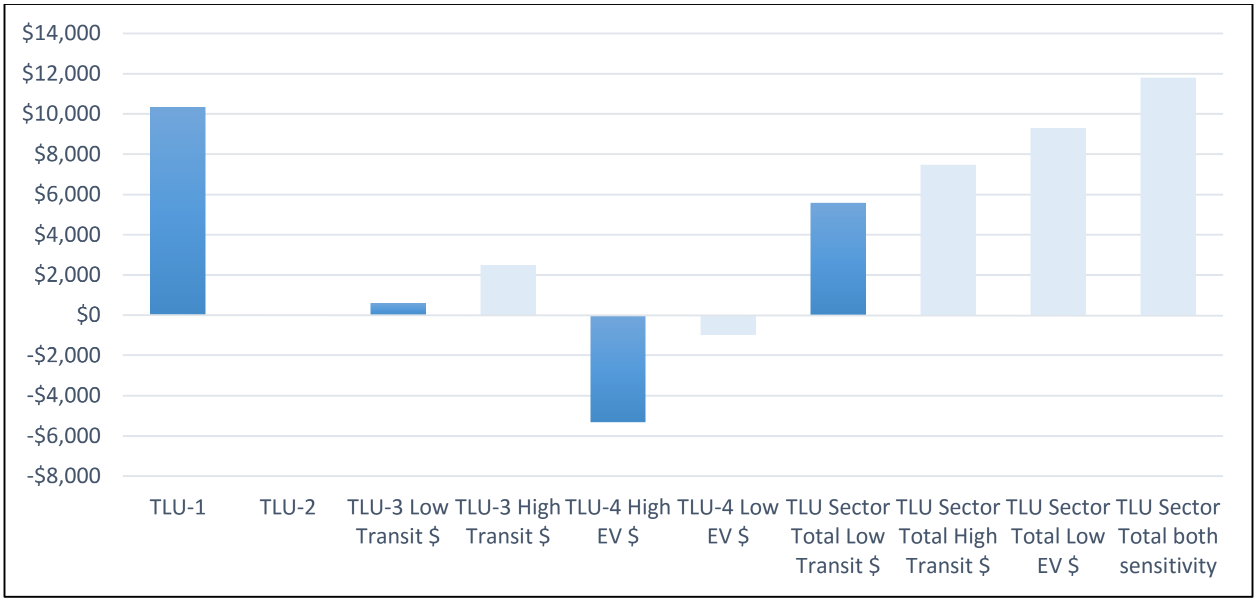


Figure IV-58 TLU Employment Impacts, 2016-2030 Average Annual (Jobs)

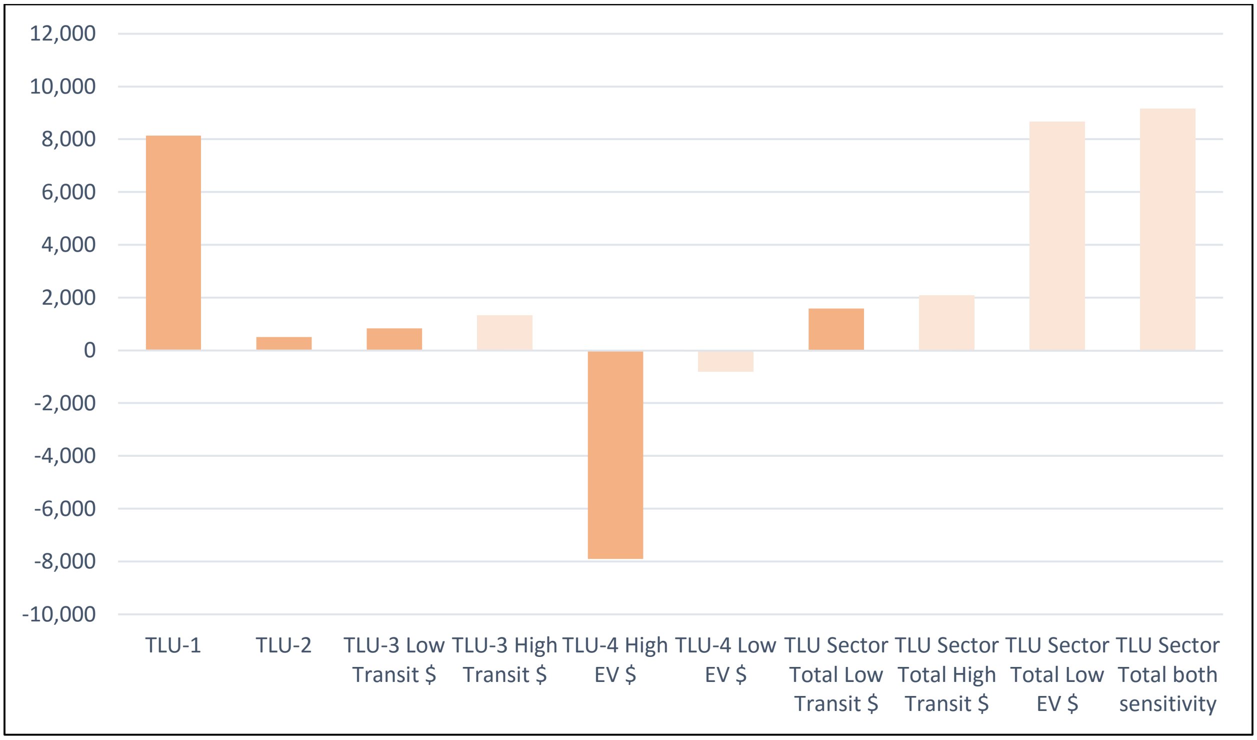


Figure IV-59 TLU Employment Impacts, 2016-2030 (Job Years)

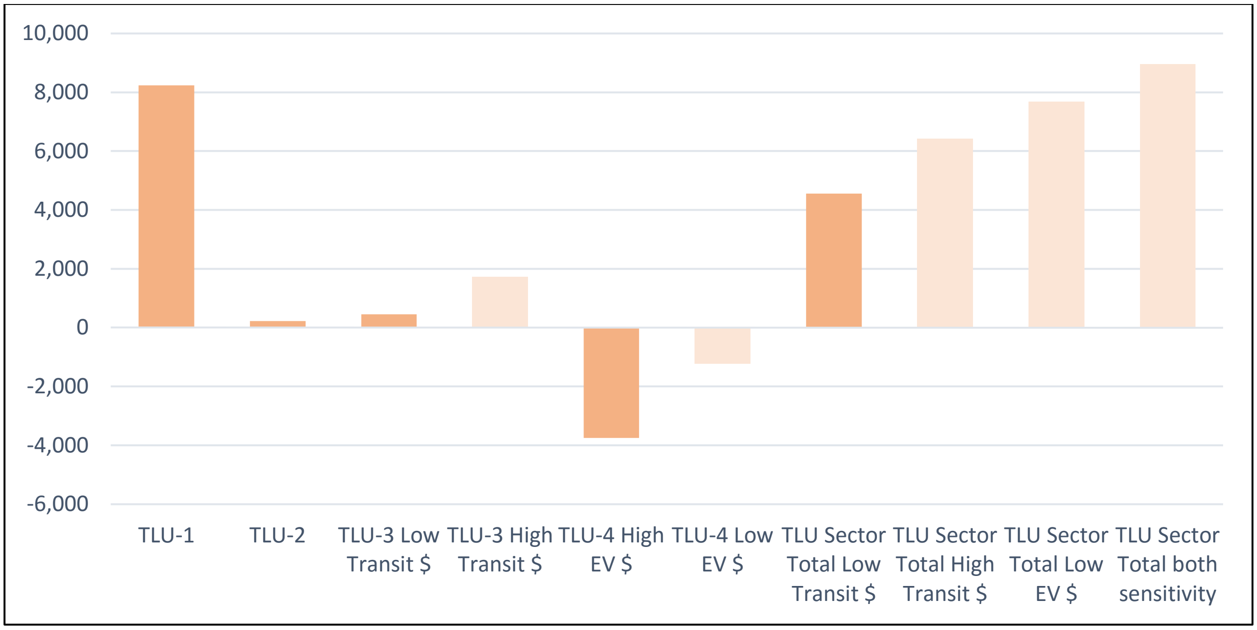


Figure IV-60 TLU Employment Impacts, Year 2030 (Jobs)

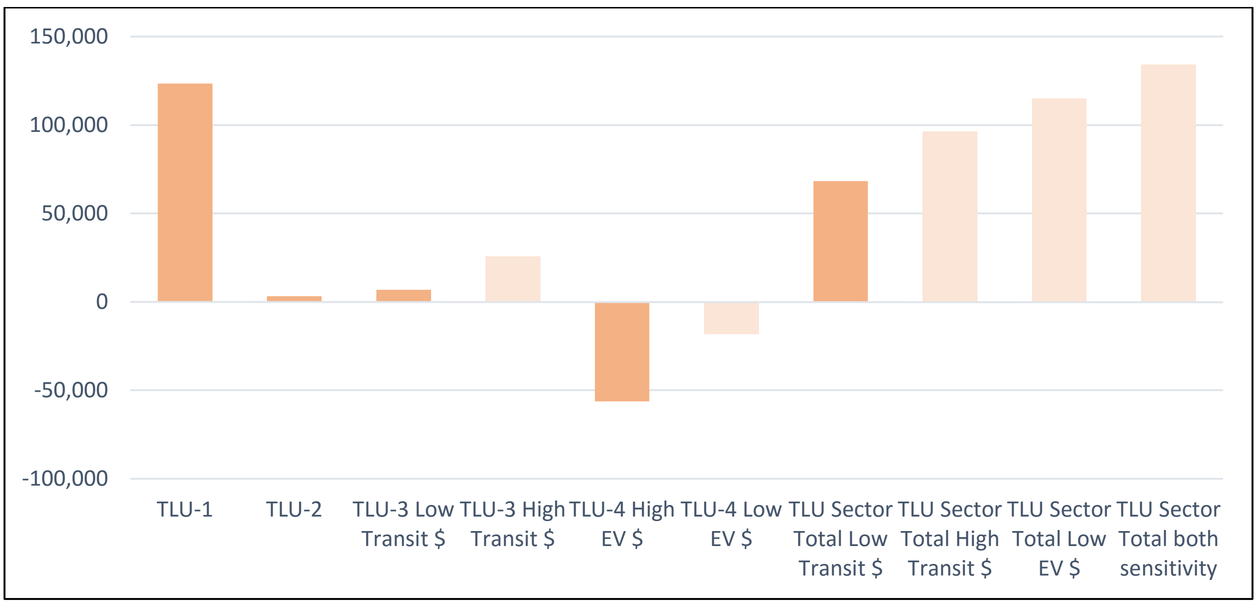


Figure IV-61 TLU Income Impacts, 2016-2030 Average Annual ($2015 MM)

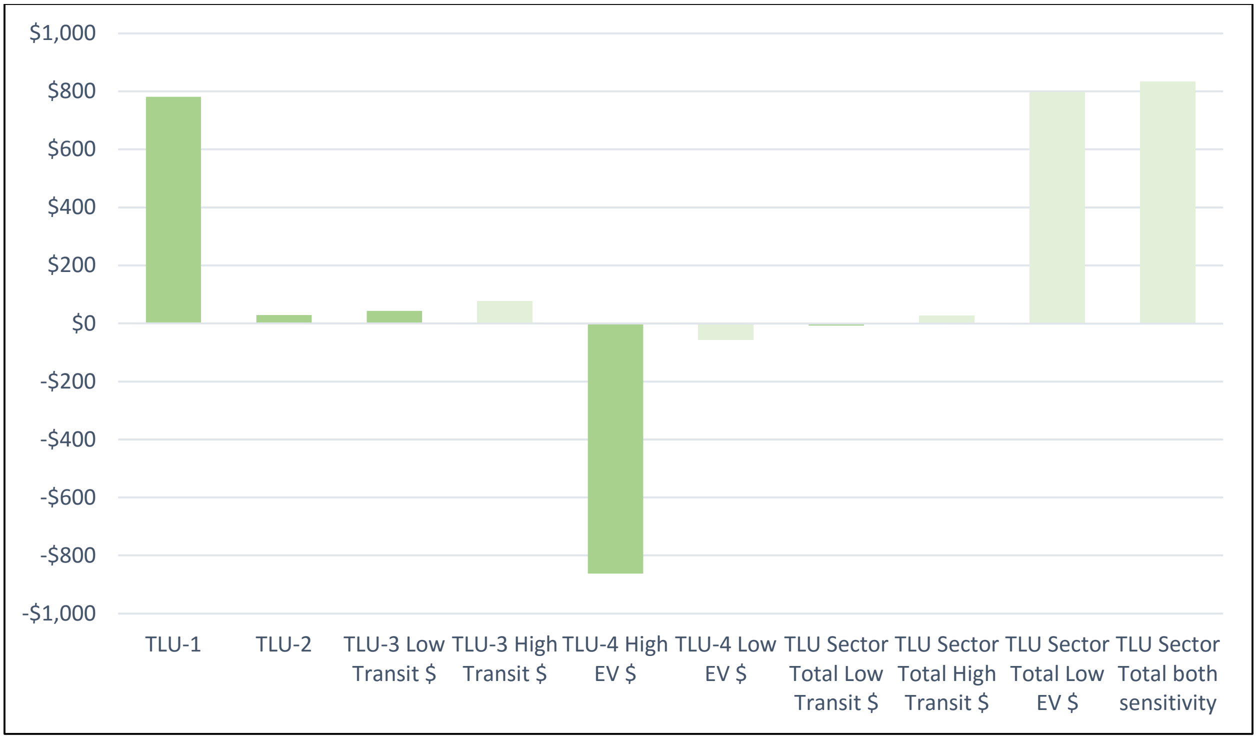


Figure IV-62 TLU Income Impacts, 2016-2030 ($2015 MM)

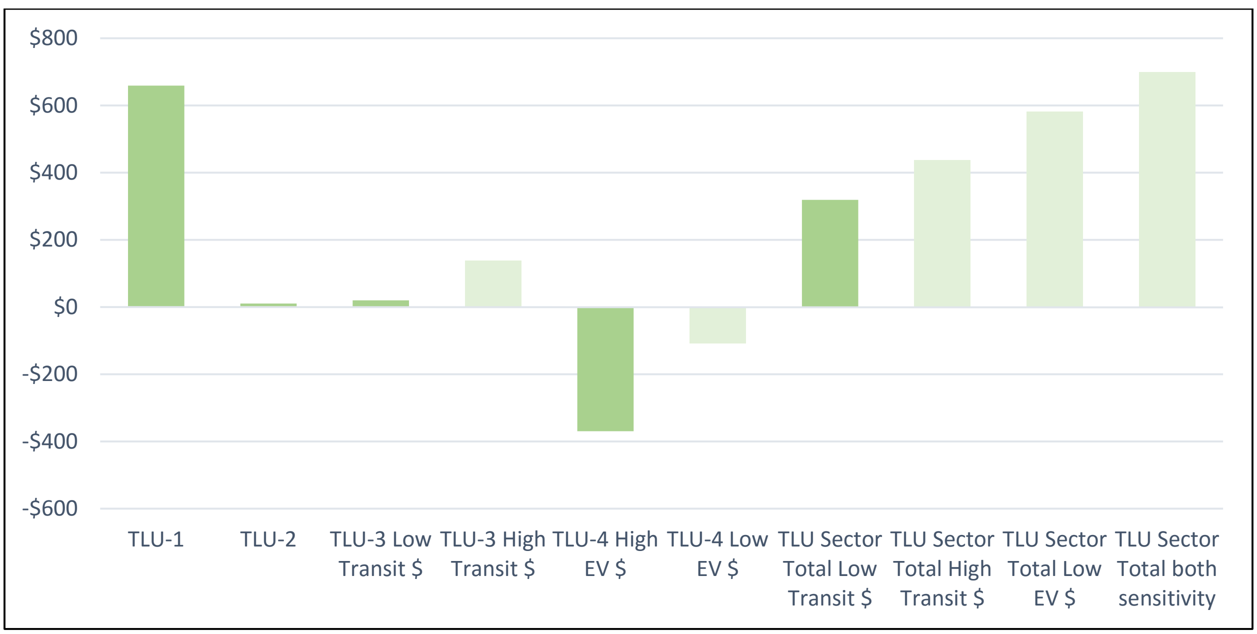
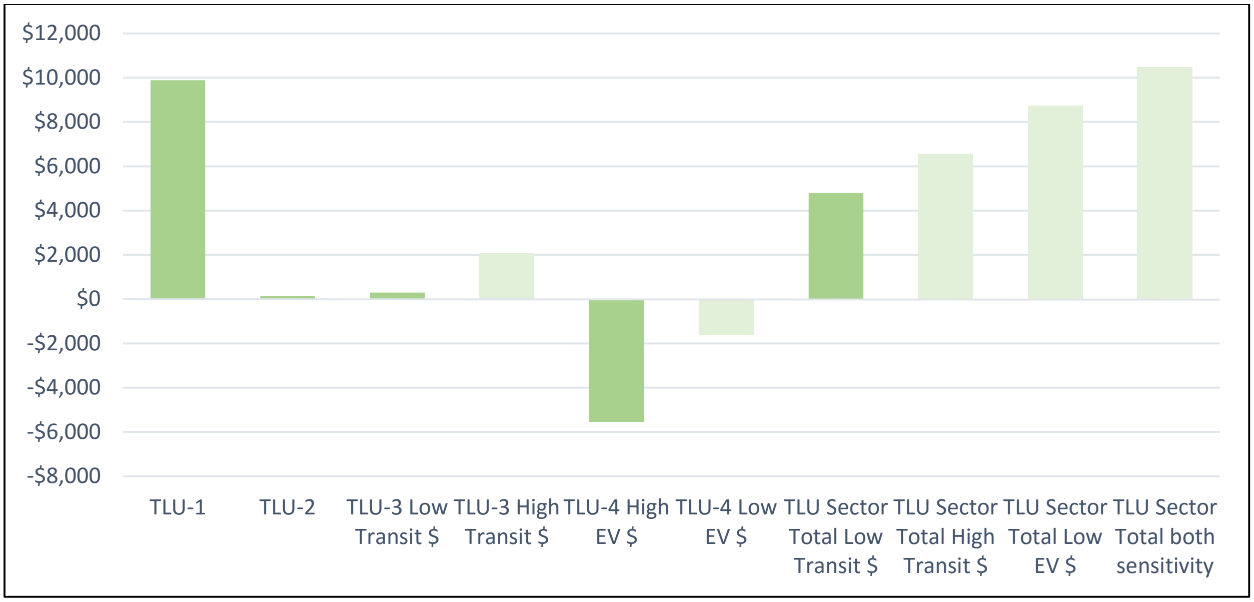


Figure IV-63 TLU Income Impacts, Year 2030 ($2015 MM)



4. Agriculture

The Agriculture sector addresses emissions sources in two primary subsectors: crop production and livestock management. This sector is important to the state's economy and is also a significant greenhouse gas (GHG) contributor (15% of Minnesota's emissions in 2010 and about 16% of Minnesota's emissions expected in 2030). Key drivers to GHG emissions include: nutrient inputs and fuel requirements for primary crops (e.g., corn, wheat and soybeans); livestock populations and manure management methods (especially for ruminant animals, such as dairy cattle); cultivation of soils with high organic carbon content; and crop residue management methods (including agricultural burning).

Strategies that could reduce GHG emissions and provide positive economic benefits include: nutrient management (e.g., reducing commercial nitrogen fertilizer inputs to Minnesota's crops); use of cover cropping or shifting annual crops to perennial cropping systems; use of improved manure management methods, such as anaerobic digestion; and production of advanced biofuels, along with programs to incentivize their use within the state.

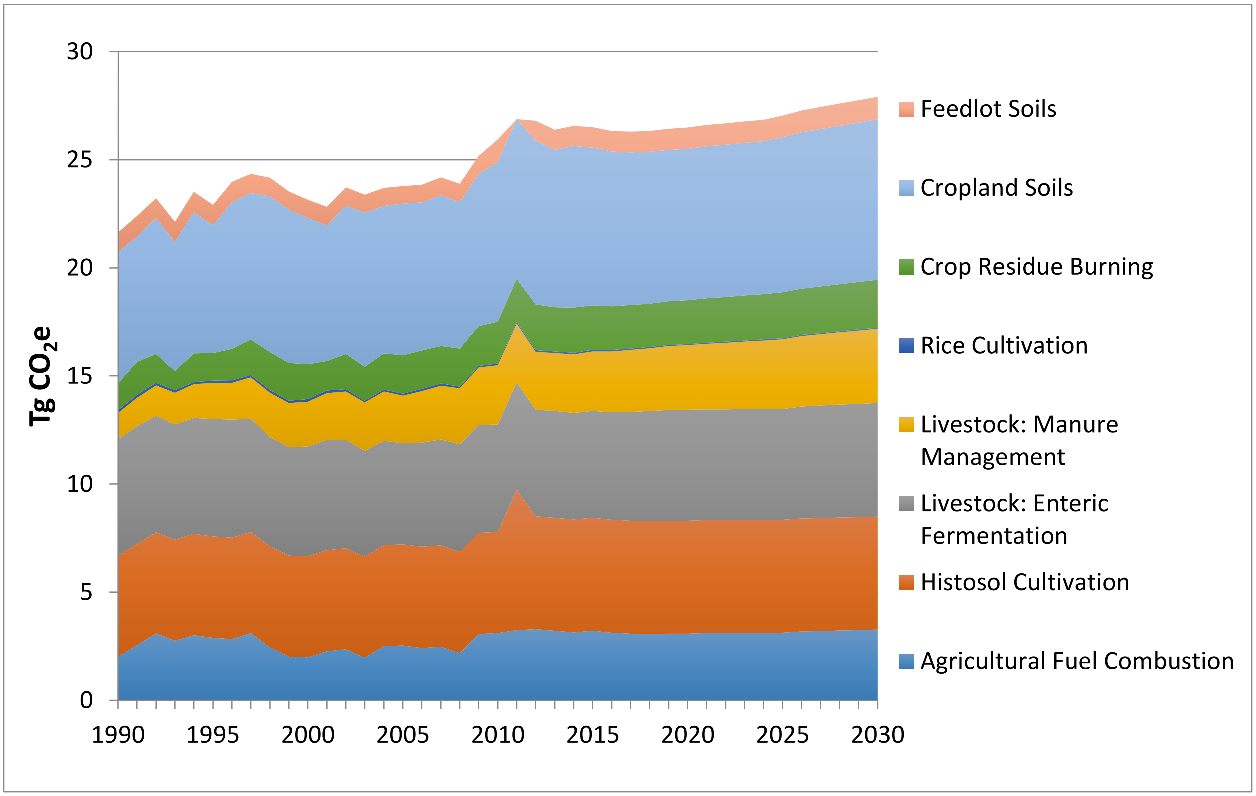
Baseline and Emissions Sources

The GHG baseline for the Agriculture sector is provided in Figure IV-57 below. Sources include: manure management and enteric fermentation in the livestock management subsector (methane [CH_4] and N_2O); synthetic and organic nitrogen inputs to crop and feedlot soils (N_2O), energy use (e.g., CO_2/CH_4/N_2O from diesel combustion); and soil management (e.g. CO_2 losses from cultivation of soils with high levels of soil carbon or "histosols"). See Chapter II for more information on the contribution of the Agriculture sector to the State's GHG baseline.

In Minnesota, key contributing sources from the crop production subsector and include nitrogen (N) inputs to soils, soils management (e.g. tillage practices, including histosol cultivation), and fuel use. The recent peak shown in Figure IV-57 for histosol cultivation stems from the adoption of GHG estimates developed for the US national inventory. Those estimates, along with the historical estimates, are multi-year in nature; placing these estimates into an annual time-series can produce peaks such as this that should not be construed as being derived actual annual estimates. Both enteric fermentation (methane emissions from the digestion systems of ruminant animals, primarily cattle) and manure management emissions are also key contributing source sectors.

Forecasted emissions for the agricultural sector are shown to increase slightly through 2030. These increases are mainly driven by expected future increases in fuel combustion and N application to produce Minnesota's primary crops: corn, soybeans, and wheat.

Figure IV-64 Agriculture Sector GHG Baseline



It is also important to note that the Agriculture (A) sector, along with the Forestry and Other Land Use (FOLU) and Waste Management (WM) sectors, can act as bio-energy feedstock sources that can reduce GHG emissions in other sectors (e.g., solid biomass for reductions of fossil fuel use in the Energy Supply [ES] and Residential, Commercial, Institutional and Industrial [RCII] sectors), liquid biofuels (mainly for reductions of fossil fuel use in the Transportation and Land Use [TLU] sector), and biogas for reductions across all sectors. In-state production of biofuels also produces important positive economic impacts. The CSEO Policy options described in the next section were selected to address some of the most important opportunities for emissions reduction and economic growth.

CSEO Policy Options

There were five Policy options developed for the Agriculture sector. These are detailed in Appendix F-4 and are summarized as follows:

AG-1. Nutrient Management in Agriculture

The nitrogen in inorganic and organic fertilizer, manure and plant-based, is the primary GHG contributor to nitrous oxide emissions during crop production. When vegetation does not fully use N 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 N use, reducing nitrate leaching into groundwater and surface water and N_2O emissions. This policy option includes further development, refinement and implementation of N 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).

A number of different approaches (policy option implementation mechanisms) can be applied to achieve gains in NUE. Policy Option AG-1 isn't prescriptive as to which will be used and at what levels; however, for the purposes of policy option impacts assessment a series of possible mechanisms was applied. These included: a 40 lb. N/acre reduction in fertilizer application following application of manure or N-fixing legumes; use of nitrification or urease inhibitors; and use of precision agriculture (e.g., variable rate timing of N application, global positioning system based yield monitoring, and enhanced soil sampling).

AG-2. Soil Carbon Management: Increased Use of Cover Crops

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 three 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.

AG-2 is the first of two policy options that address soil carbon management; the second is AG-3 below. 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 grown on a significant number of acres, would fall into this category as well.

AG-3. Soil Carbon Management: Increased Conversion of Row Crops to Perennial Crops

This policy option seeks to achieve beyond business as usual (BAU) levels of conversion of row crops to perennial crops (grasses and legumes) for forage hayland, grazing, or biofuels production. These conversions will serve to increase carbon storage in agricultural soils and biomass and potentially reductions in fuel and fertilizer consumption. 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.

AG-4. Advanced Biofuels Production

This policy option includes 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 as compared to fossil-based sources, and thus their use provides net GHG reductions.

While the policy option does not specify which biofuels should be produced, total GHG reductions should achieve a minimum 50% improvement over the use of fossil fuels (e.g., gasoline or diesel). For the purposes of impacts analysis, a combination of ethanol production methods were assessed that could meet the level of carbon intensity required (cellulosic and energy beet production methods). This policy option has a direct linkage to Policy Option AG-5 below.

AG-5. In-State Biofuel Consumption (Support of the Existing Biofuels Statute)

This policy option addresses biofuels consumption and the combined AG-4/AG-5 policy options are often referred to in this report as the "biofuels package." From an emissions perspective, GHG reductions for biofuels production in Minnesota would not be achieved, unless these fuels were consumed in-state, thereby offsetting the use of fossil fuels. Exported fuels would serve to reduce emissions in other states; so the ability of Policy Option AG-4 to assist Minnesota to meet its goals would be limited without some assurance that the advanced biofuels would be consumed in-state.

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. 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 as produced from Policy Option AG-4 addressing advanced biofuels production.

Direct and Indirect Policy Option Impacts

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 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 teragrams (Tg) of carbon dioxide equivalent reductions (CO_2e), as well as the cumulative reductions through 2030 (1 Tg is equal to 1 million metric tons). 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 IV-13 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 above 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 IV-14 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) Economic Impacts of Agriculture Policies

Table IV-15 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 IV-13 Agriculture 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 Tg	2030 Tg	$TgCO_2e$	$TgCO_2e$	$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 IV-14 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 Tg	2030 Tg	$TgCO_2e$	$TgCO_2e$	$Million	$/$tCO_2e$
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)**

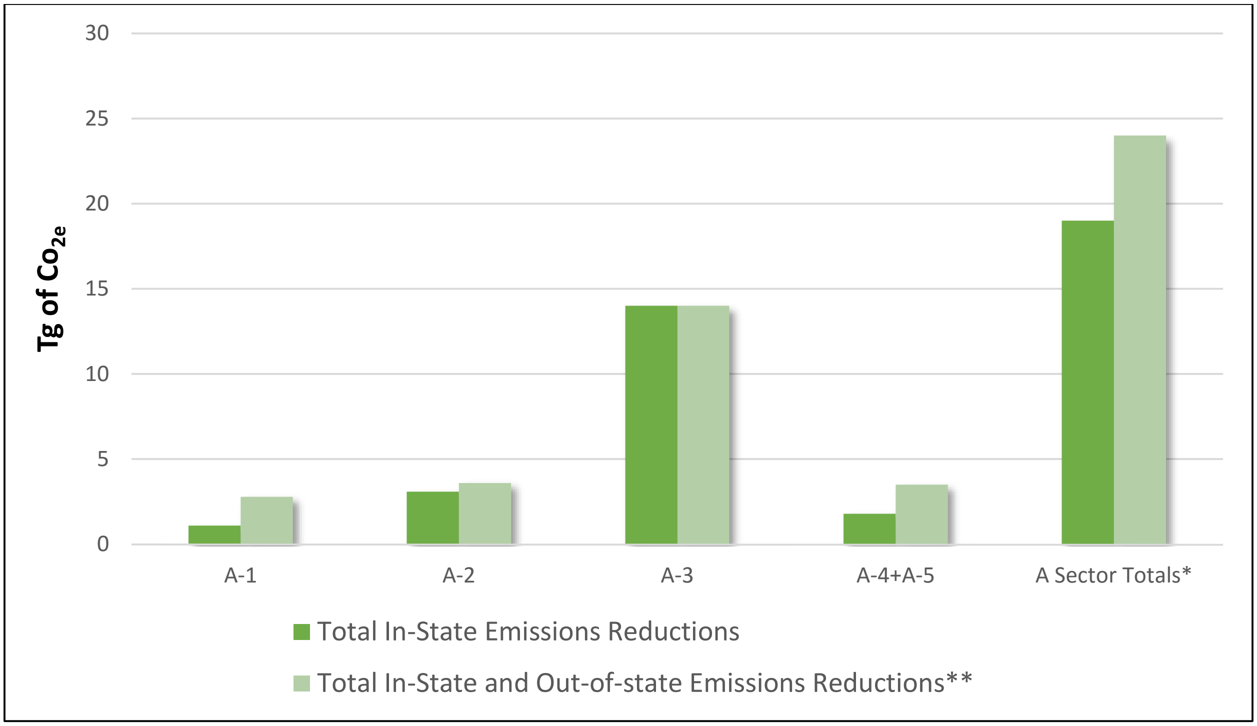
Notes:
[a] In-state (Direct) GHG Reductions.
[b] Total (Direct and Indirect) GHG Reductions.
[c] Net Present Value of fully implemented policy option using 2014 dollars ($2014).
[d] Cost effectiveness values include full energy-cycle GHG reductions, including those occurring out of State. Dollars expressed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

Table IV-15 Macroeconomic (Indirect) Impacts of Agriculture Policies

Macroeconomic (Indirect) Impacts Results									
Scenario	GSP[a] ($2015 MM)			Employment[b] (Individual)			Personal Income[c] ($2015 MM)		
	Year 2030[d]	Average (2016-2030)[e]	Cumulative (2016-2030)[f]	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)
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 2016-2030 time period.

Figure IV-65 AG Policies GHG Emissions Abatement, 2016-2030



Notes:

* All Policies Total's comprise emissions reductions achieved by Ag 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.

Figure IV-66 Net Job Creation for AG Policies and AG Sector by Ascending Order, 2016-2030

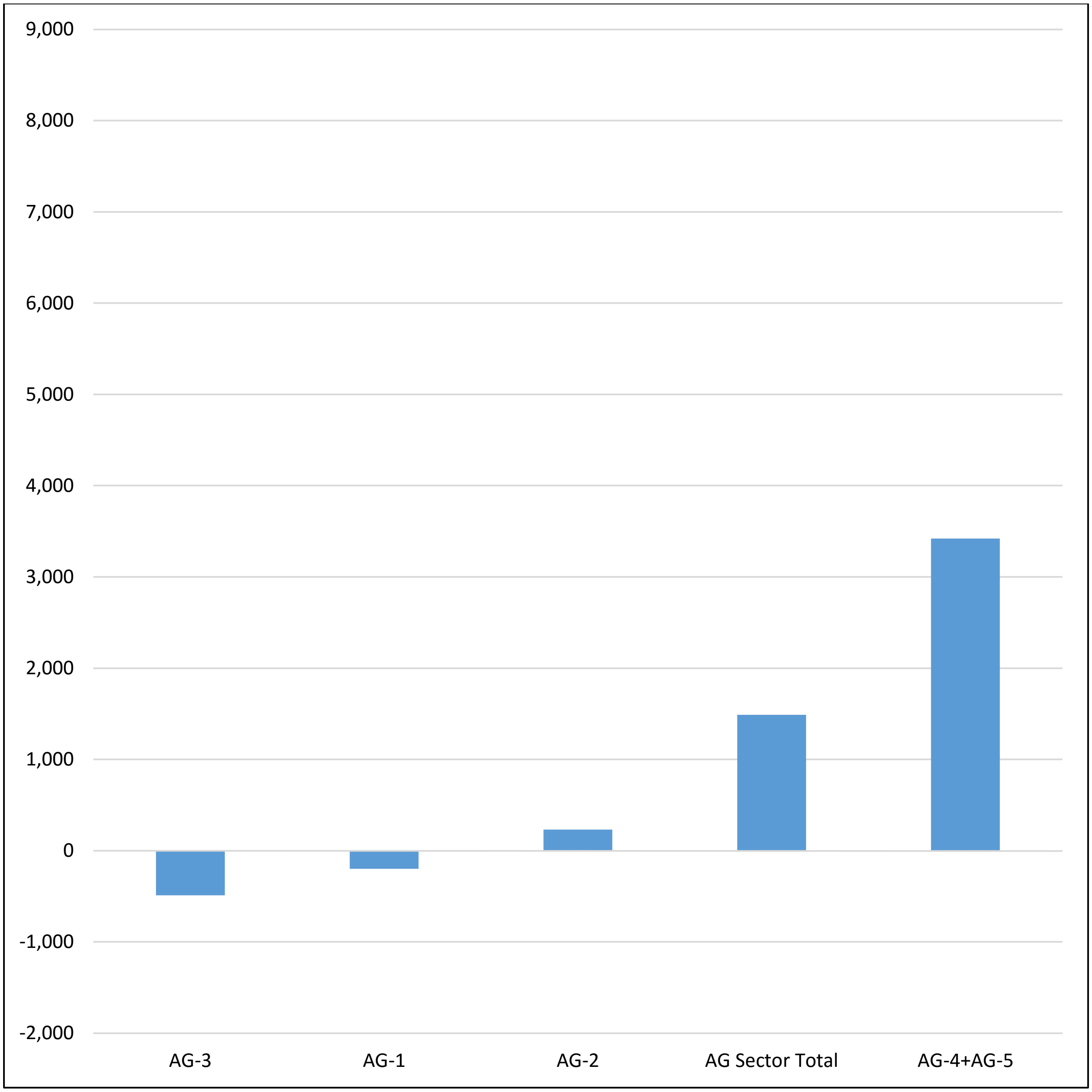
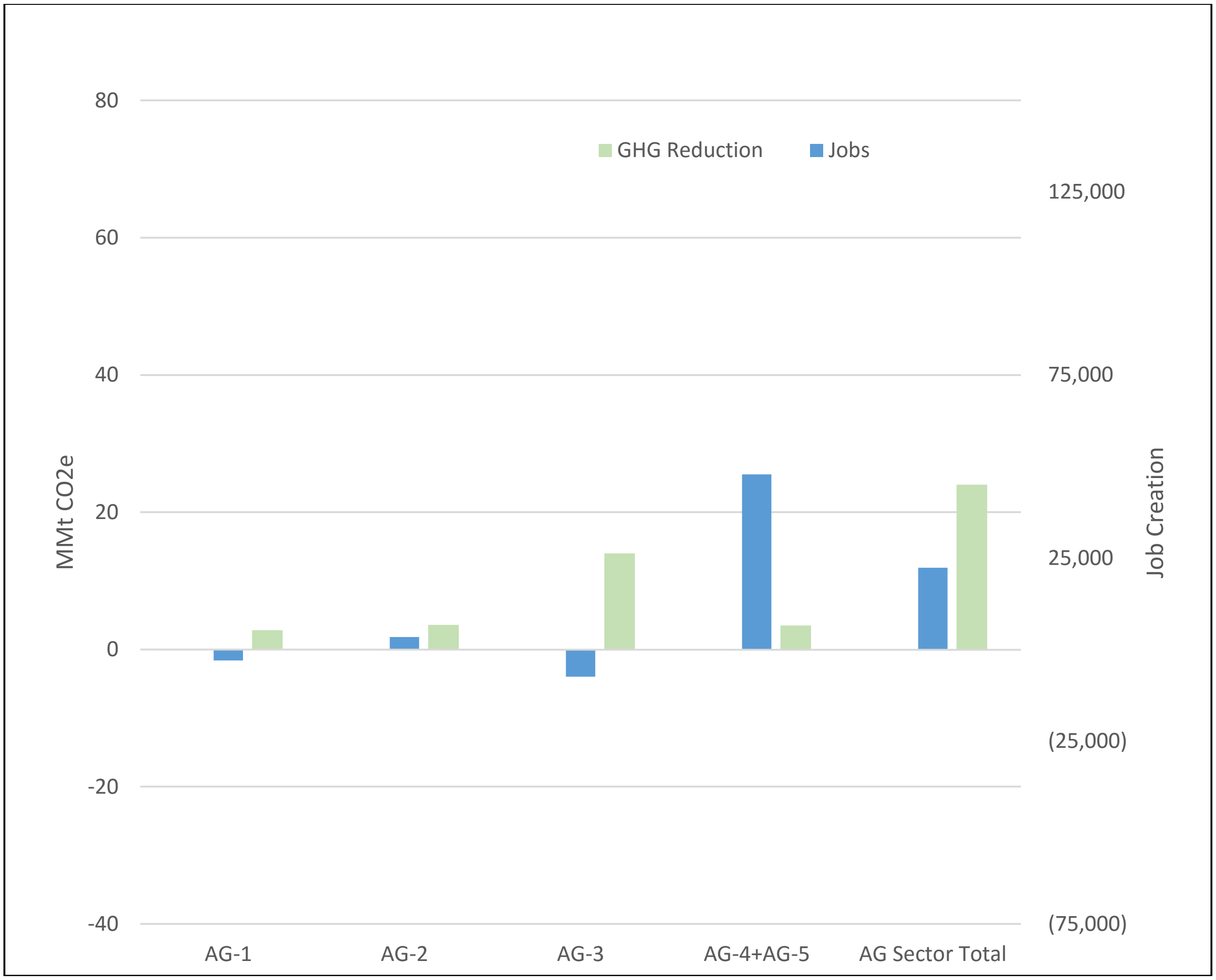


Figure below summarizes a potential for job creation and GHG emissions abatement of AG sector policies on the same graph. This allows for a simultaneous assessment of performance of individual CSEO options against two crucial environmental and economic indicators.

Figure IV-67 Job Gains and GHG Reduction by AG Policy Recommendations, 2016-2030



Sector level index

Graphs below present the overall macroeconomic impacts of each policy in Ag sector, as well as the sector-level impacts, by using the Macroeconomic Impact Index. The index is a blended score indicating an overall macroeconomic impact of a policy or a set of policies on GSP, income and employment. In this project, the three variables are weighted equally, and indexed based on the maximum value among all the policies. I_GSP, I_Jobs, and I_Income represent the index score for GSP, Jobs and Income, respectively.

Figure IV-68 AG Macroeconomic Indicators, 2030

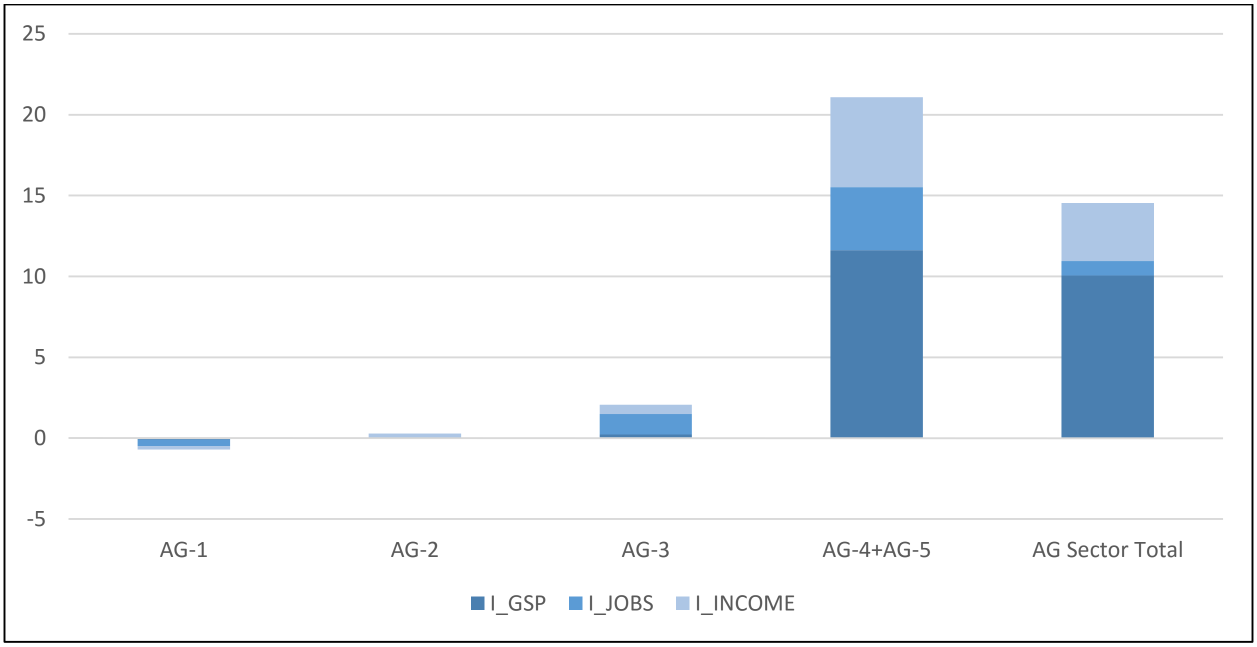


Figure IV-69 AG Macroeconomic Indicators Average Annual

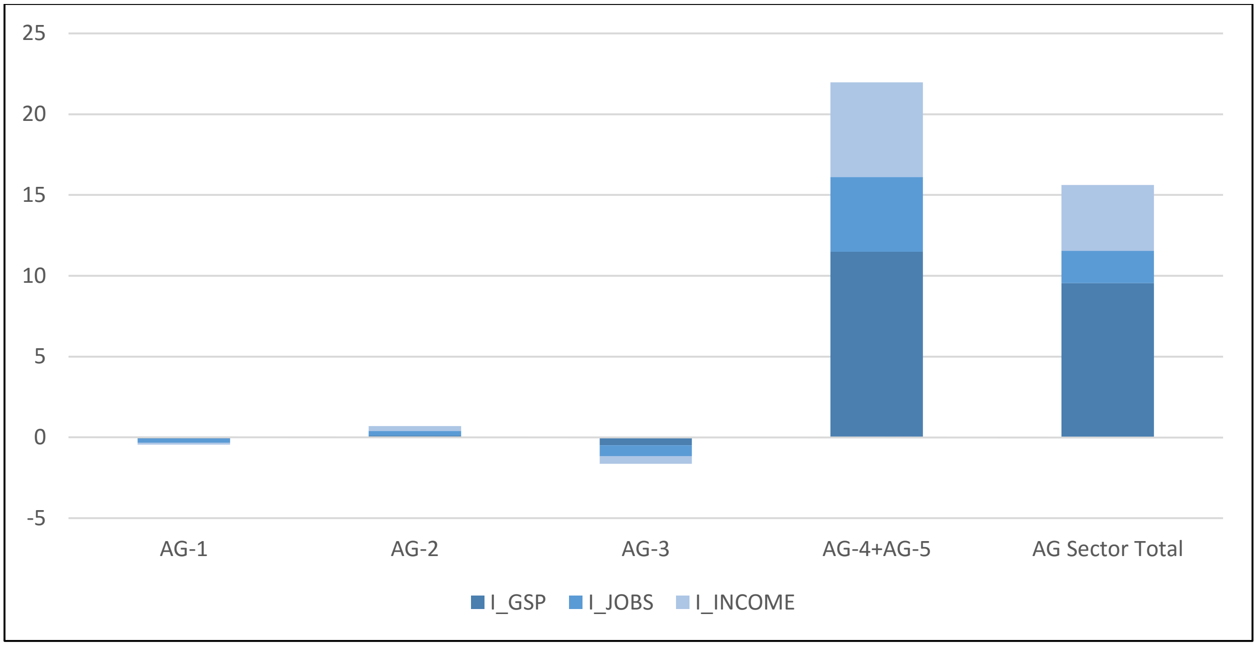
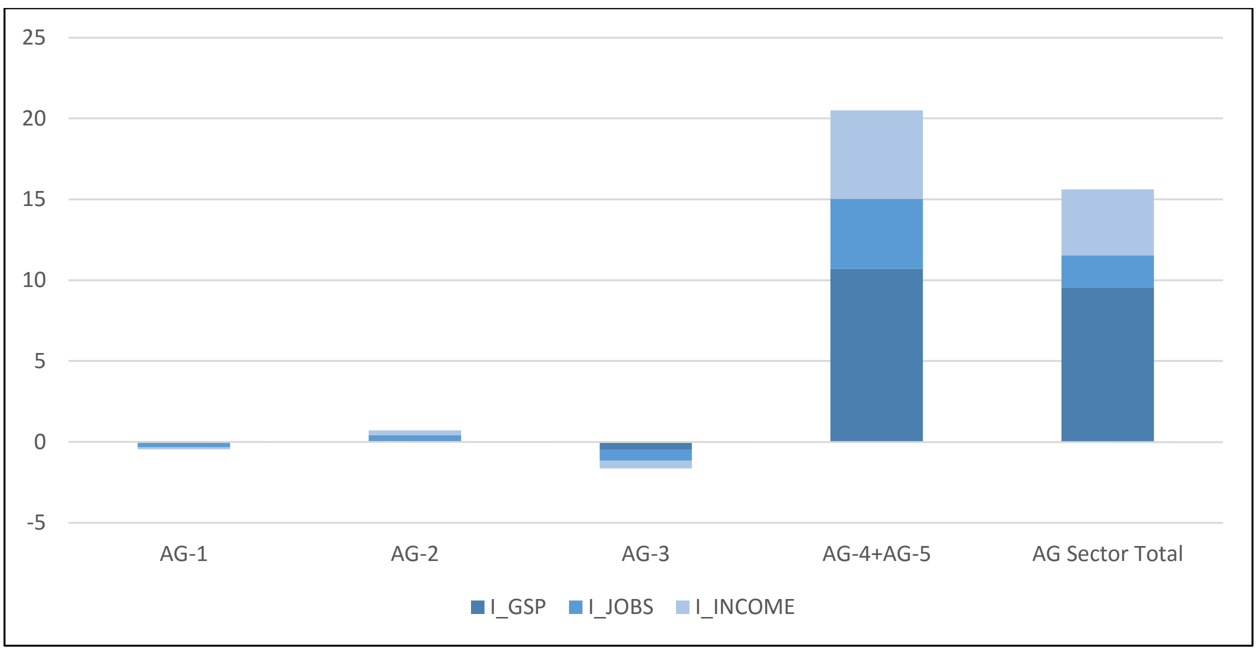


Figure IV-70 AG Macroeconomic Indicators, 2016-2030



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 IV-71 AG GSP Impacts ($2015 MM)

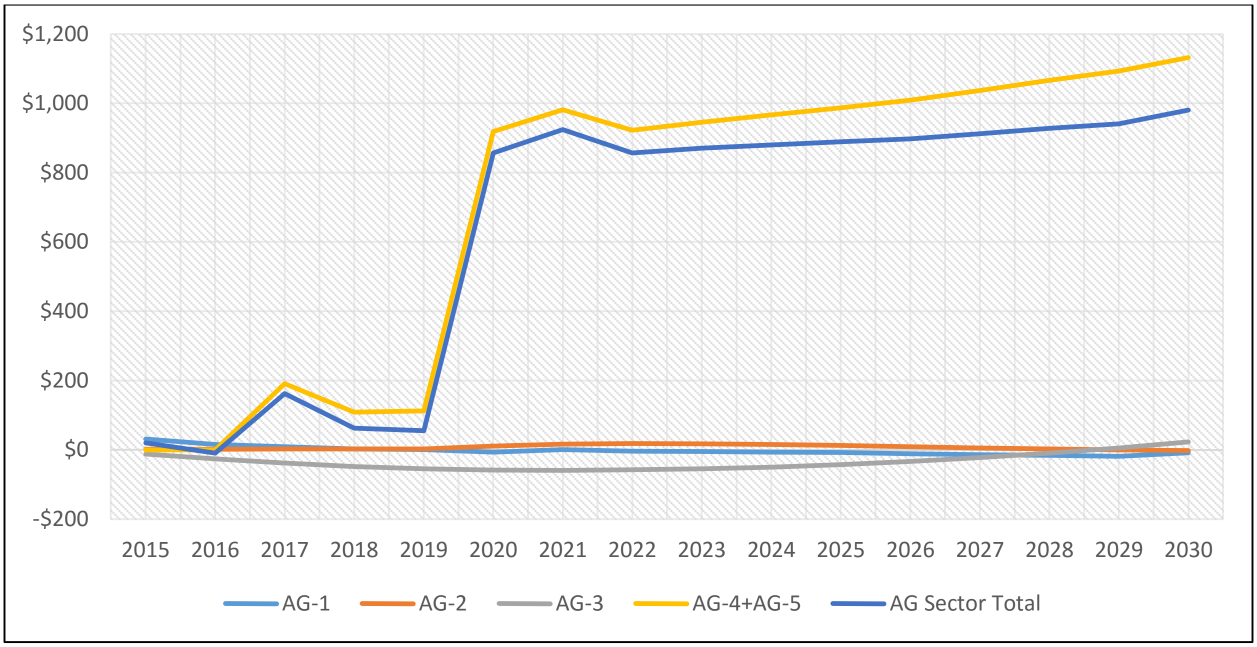


Figure IV-72 AG Employment Impacts (Jobs)

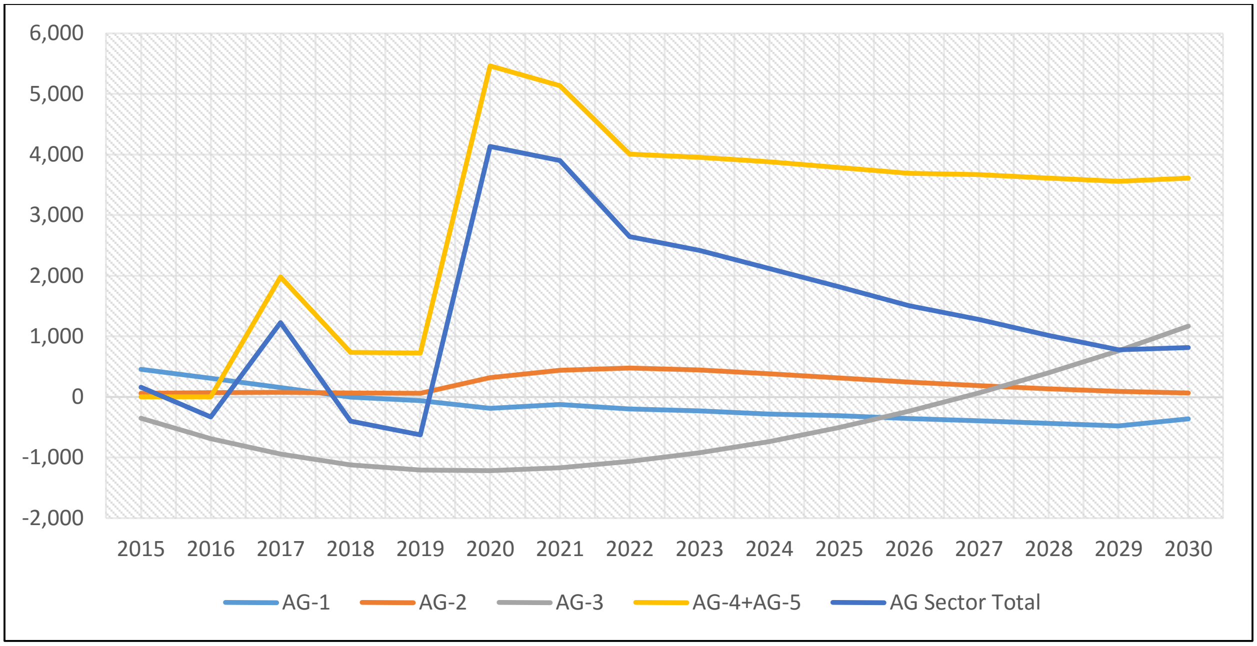
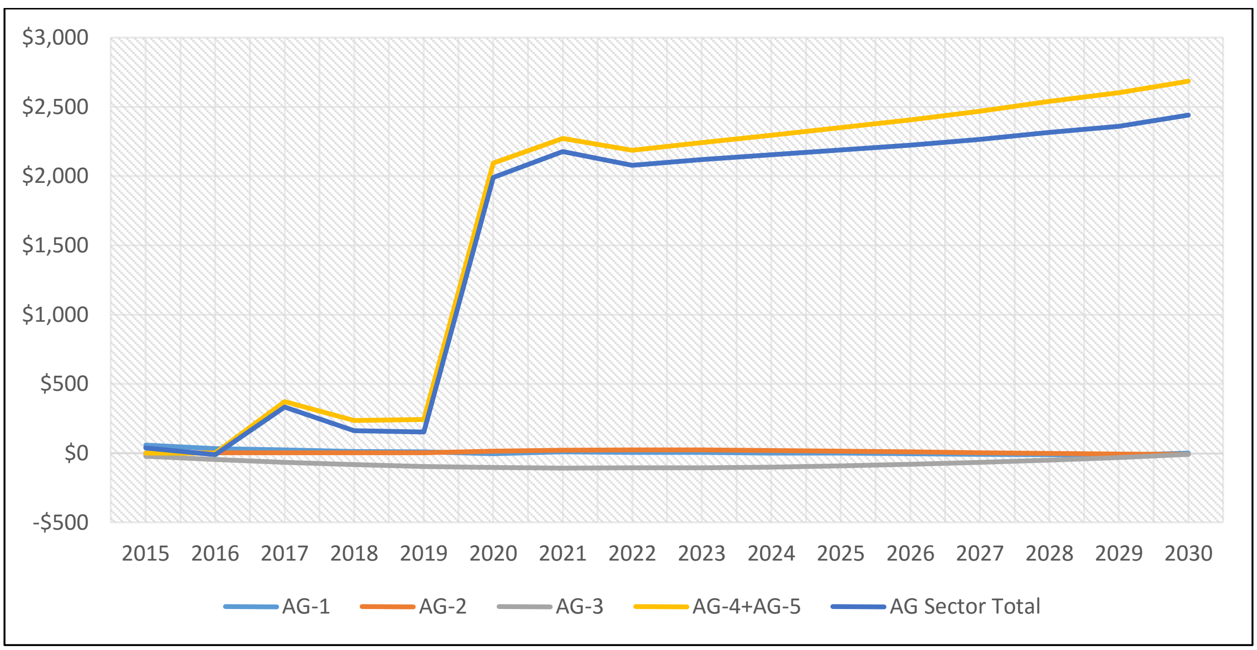


Figure IV-73 AG Income Impacts ($2015 MM)



Graphs below show macroeconomic impacts on GSP, personal income, and employment in the final year (2030), in average (2016-2030) and cumulative (2016-2030).

Figure IV-74 AG GSP Impacts, 2016-2030 Average Annual ($2015 MM)

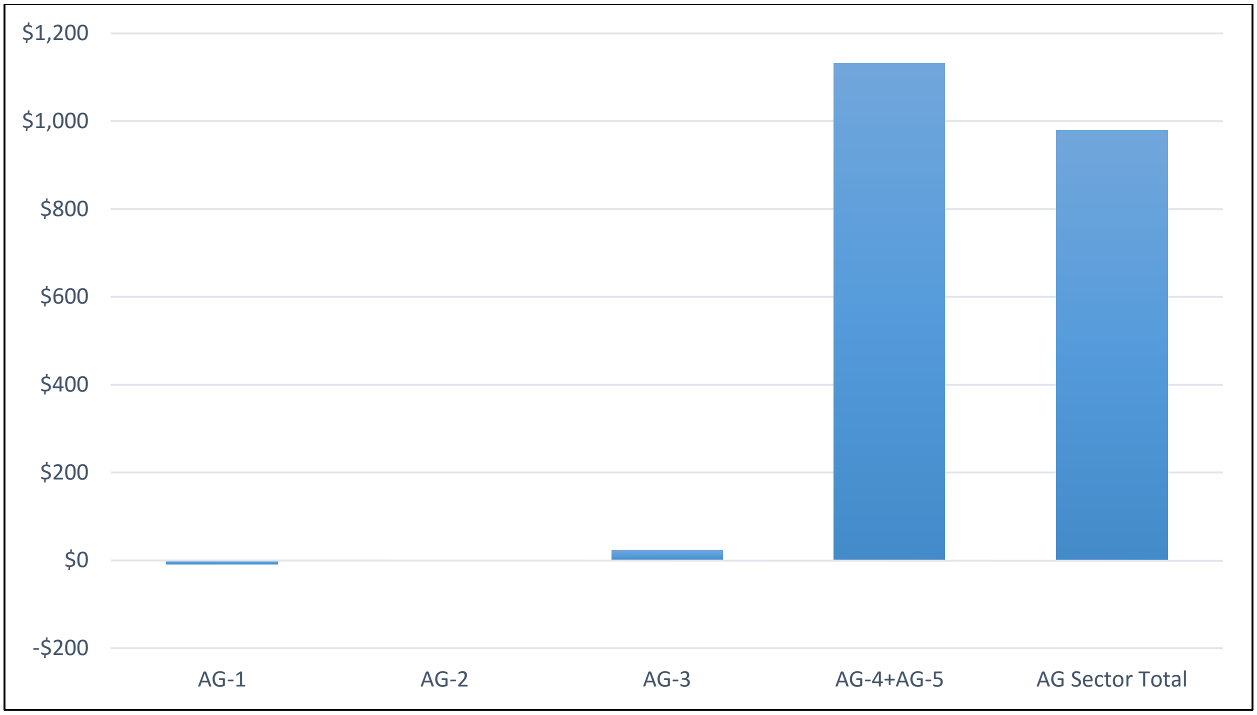


Figure IV-75 AG GSP Impacts, 2016-2030 ($2015 MM)

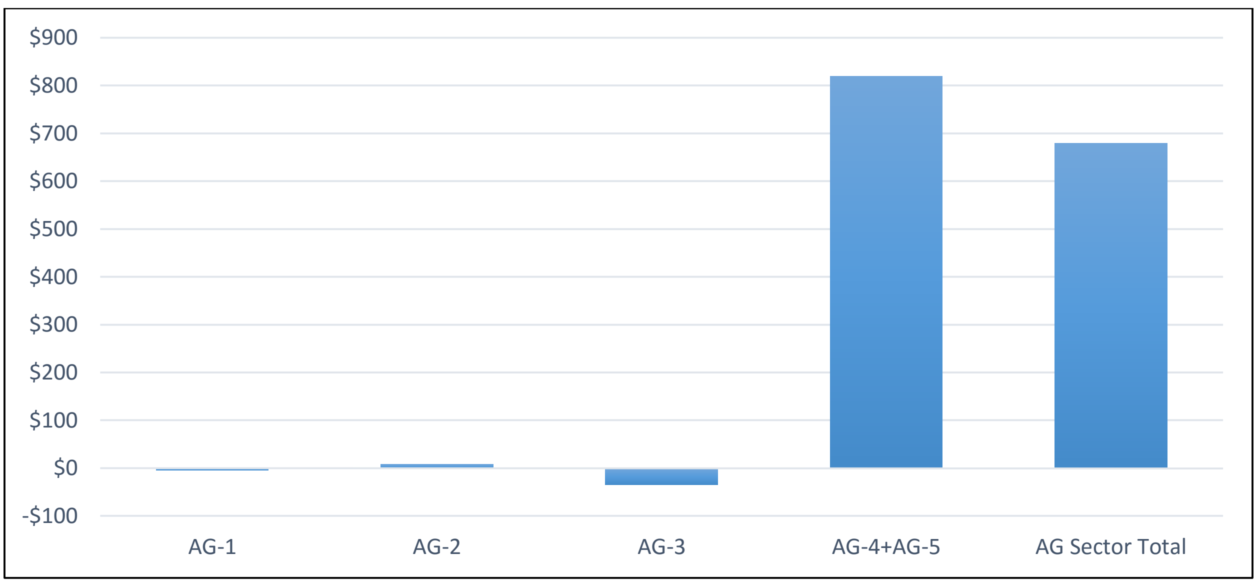


Figure IV-76 AG GSP Impacts, 2016-2030 Average Annual ($2015 MM)

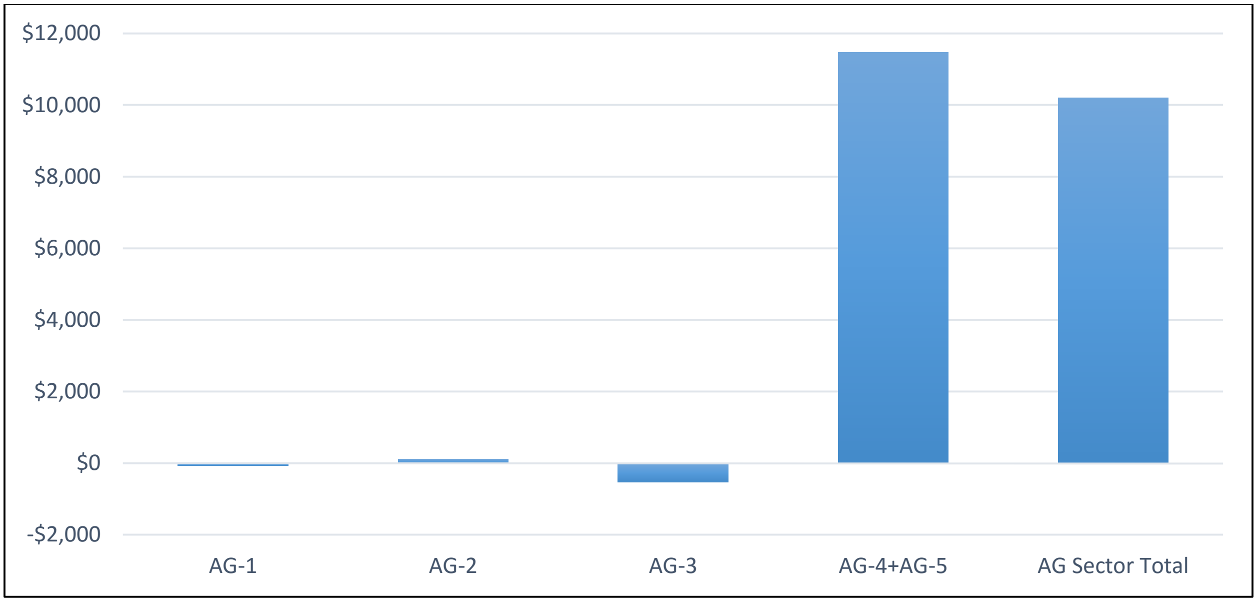


Figure IV-77 AG Employment Impacts, Average Annual (Jobs)

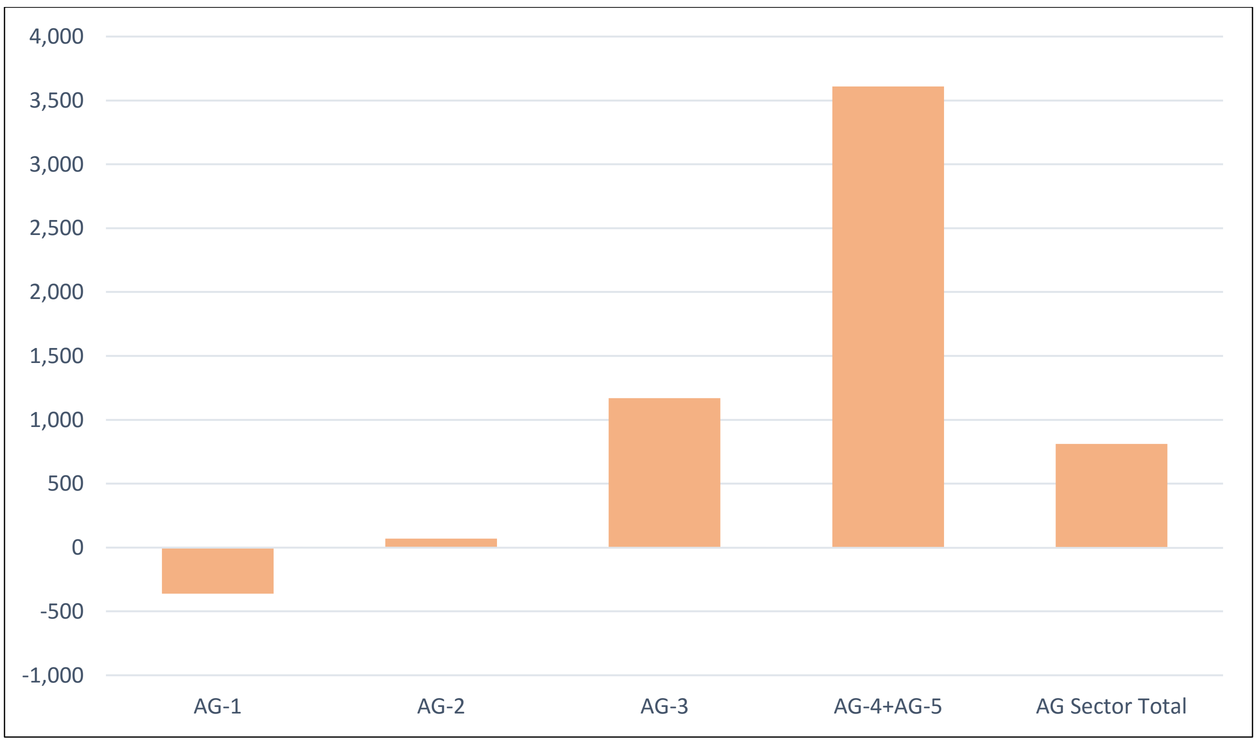


Figure IV-78 AG Employment Impacts, 2016-2030 (Job Years)

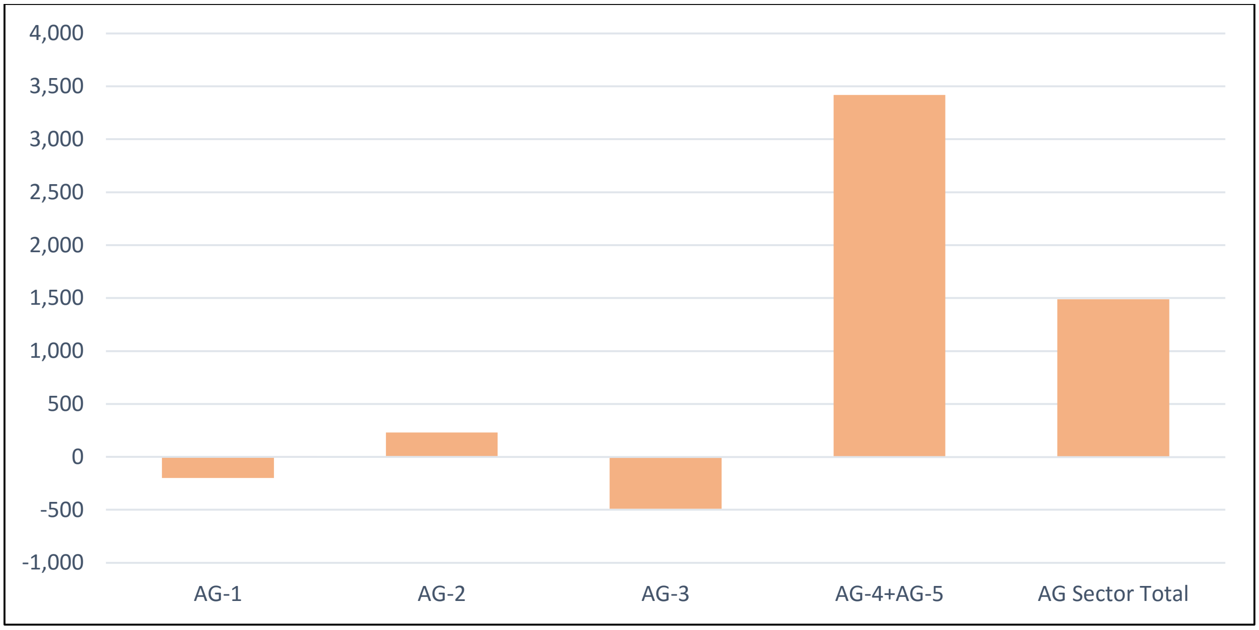


Figure IV-79 AG Employment Impacts, Year 2030 (Jobs)

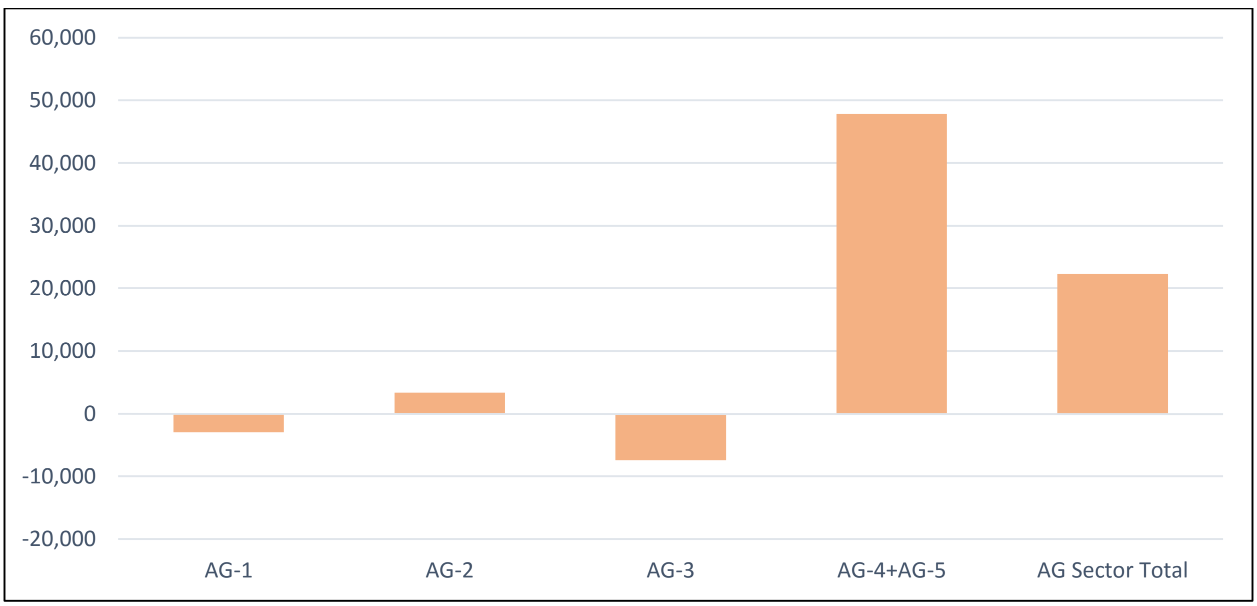


Figure IV-80 AG Income Impacts, Average Annual ($2015 MM)

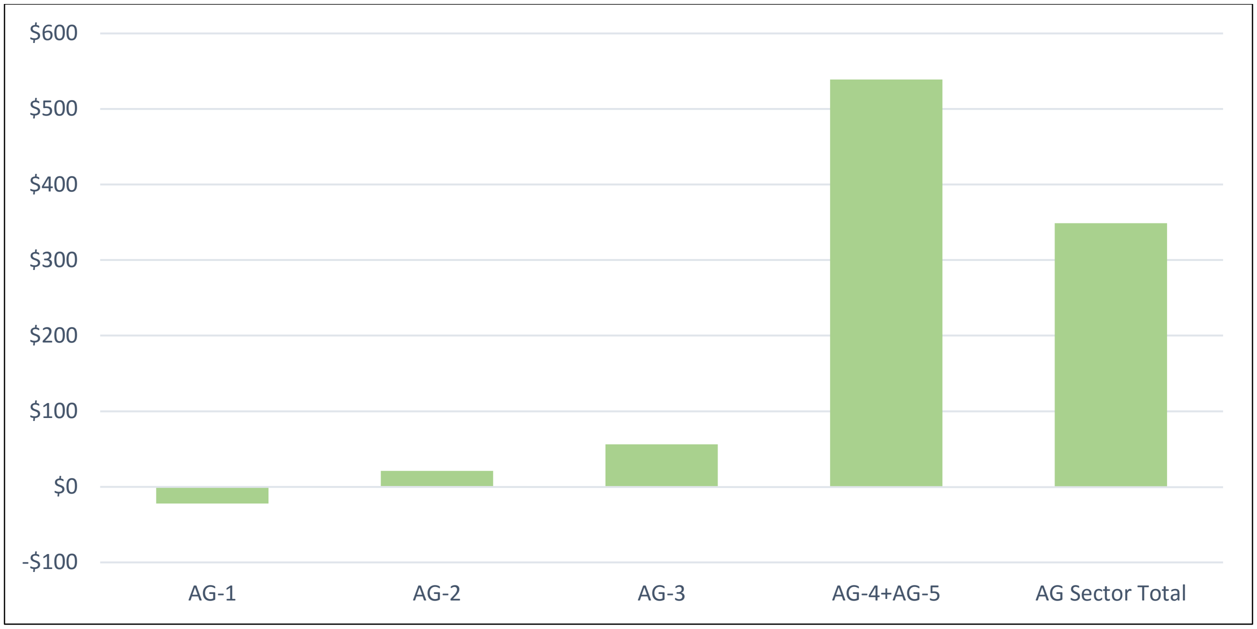


Figure IV-81 AG Income Impacts, 2016-2030 ($2015 MM)

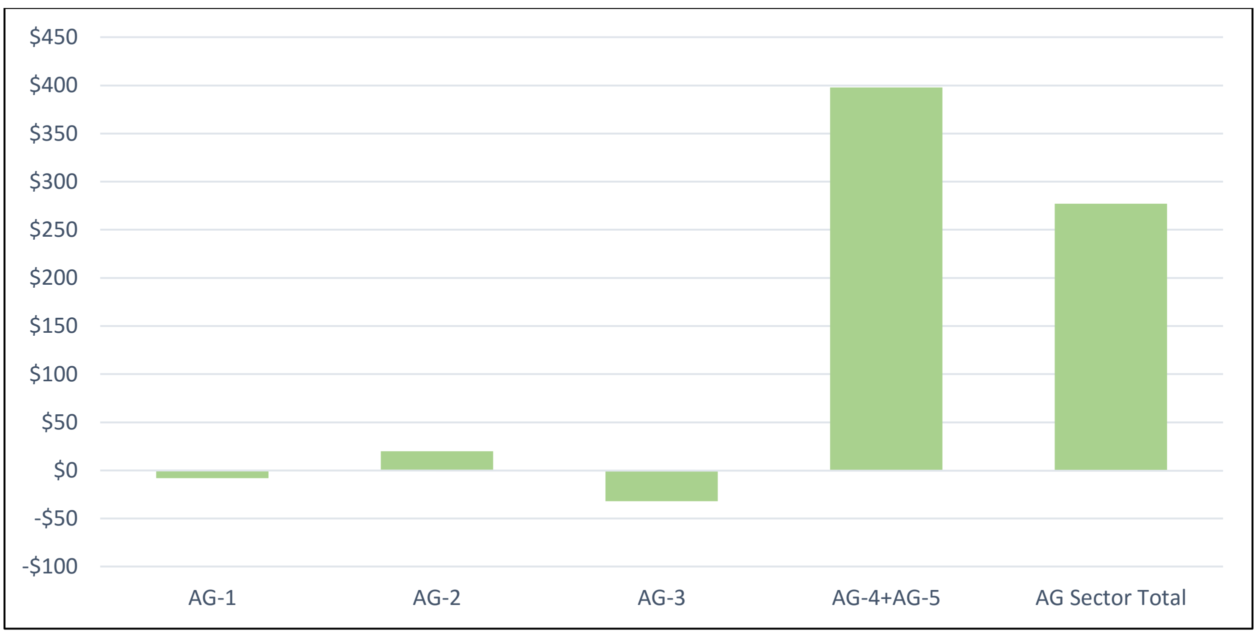
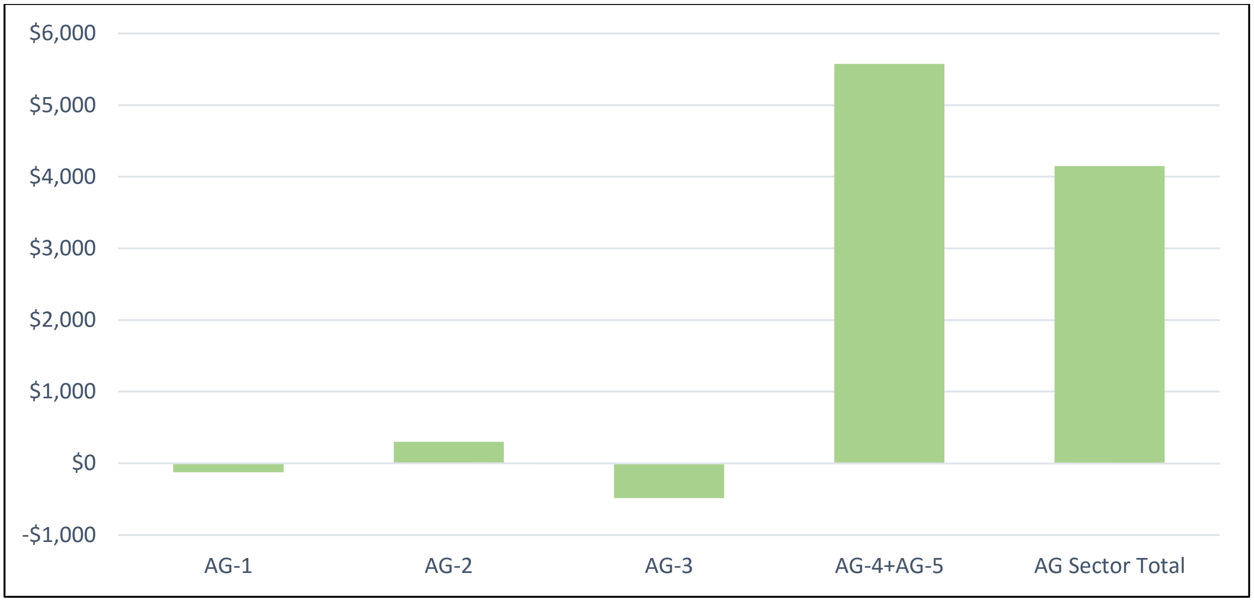


Figure IV-82 AG Income Impacts, Year 2030 ($2015 MM)



5. Forestry & Other Land Use

The Forestry and Other Land Use (FOLU) sector primarily addresses carbon sequestration in forested and urban areas (i.e. "sinks" of carbon dioxide [CO_2]). Additionally, there are sources of greenhouse gases (GHG) in this sector, including wildfires and prescribed burns, and importantly methane emissions from wetlands (an uncertain, but potentially significant source). When wetland methane emissions are included, the sector becomes a net source of GHG emissions. Contributions to state-level emissions are about eight percent in 2010 and are expected to be about five percent in 2030. Key drivers to carbon sequestration rates and GHG emissions include: coverage of rural forested areas; the health, age and species make-up of these forests; health and coverage of urban forests; wildfire; and the coverage of wetlands.

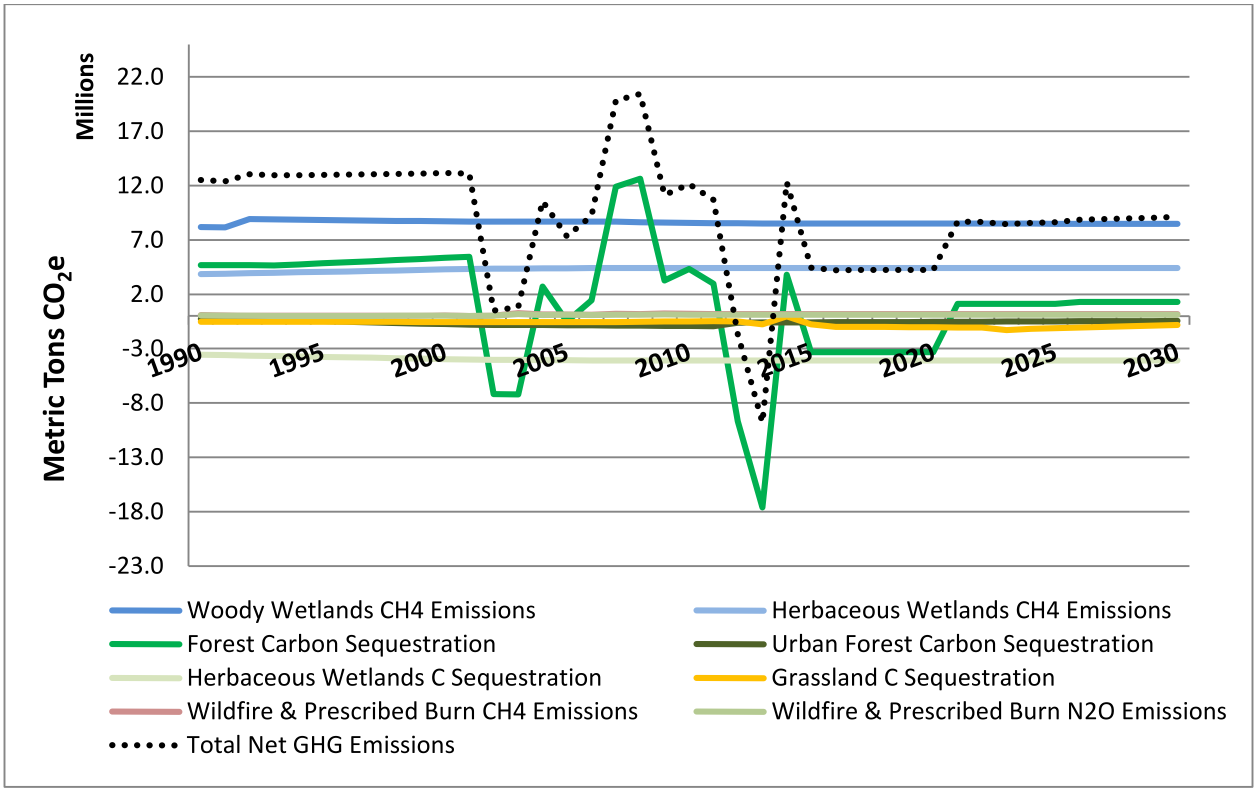
Strategies that could be employed to reduce emissions/enhance sinks and produce economic benefits include: recovery of damaged and degraded forestland; reforestation/afforestation; maintenance and/or expansion of urban forests; biomass utilization for energy or durable wood products; and tree planting programs in rural forests to improve forest productivity.

FOLU Baseline and Emissions Sources

The FOLU sector is primarily composed of net carbon sequestration across the different land uses in Minnesota. Energy use and the associated GHG emissions within the FOLU sector are captured within the Residential, Commercial, Institutional, and Industrial (RCII) sector (e.g. forest industries, rangeland, and urban forest management). There are also a small number of other non-energy related GHG sources addressed. These include methane (CH_4) releases from wetlands, CH_4 and nitrous oxide (N_2O) emissions from wildfires, and N_2O emissions from "settlement soils" (deriving from non-farm fertilizer application to urban soils). For more detail on FOLU emission sources and their contribution to the overall baseline inventory, see Chapter II and Appendix C.

Figure IV-74 below provides the FOLU GHG baseline. Carbon sequestration estimates are based on land area for a given land use and its annual sequestration rate. As these values vary from year to year, the net sequestration for a given year may be negative (net sequestration) or positive (net emissions). Urban forests, wetlands, and grasslands were net GHG sinks in all years, but these sinks are small compared to CO_2 losses from forests (in most years) and CH_4 emissions from wetlands.

Figure IV-83 FOLU Sector GHG Baseline



The addition of wetland emissions in the baseline creates a much different picture from previous sector baselines (e.g., the 2008 Minnesota baseline used in the state action plan). As shown with the dotted line in Figure IV-83, the net emissions are now positive in nearly all years of the baseline. As further described in Appendix C, these CH_4 emissions carry a high level of uncertainty.

The other key factor that drives the large changes shown in forest carbon (C) sequestration rates is the level of annual disturbance from: insects/disease, fire, and weather events. Periods with high levels of disturbance lead to large shifts in carbon sequestration levels. The Minnesota FOLU forecast anticipates higher levels of disturbance in the future, especially from insects/disease, in the post-2030 timeframe.

CSEO Policy Options

Four policy options were developed for the FOLU sector. The initial CSEO set also included FOLU-1 (Protection of Peatlands/Wetlands). However, due to a current high level of uncertainty around the net GHG impacts associated with these lands, and the associated efficacy of any GHG management intervention, policy options addressing wetlands were dropped from further development (pending a better understanding of the underlying carbon dynamics of MN's wetlands). The remaining four policy options are detailed in Appendix F.5 and are summarized as follows:

FOLU-2. Manage for Highly Productive Forests

Additional thinning of commercial stands did not increase forest carbon sequestration in our assessment of direct GHG impacts. Therefore, further development of the policy option toward a final CSEO recommendation was not conducted.

FOLU-3. Community Forests

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 and provide energy savings through shade and windbreaks. Trees also provide numerous other economic, environmental, and public health benefits. This policy option would strengthen community forests across the state by increasing and maintaining the overall tree canopy cover of community forests to 40% by 2050.

FOLU-4. Tree Planting: Forest Ecosystems

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 likely will increase. Since younger forests accumulate carbon more quickly than do older forests, 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.

FOLU-5. Conservation on Private Lands

Permanent vegetation in natural ecosystems and agricultural systems sequester more carbon than do rowcrops. 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.

Direct and Indirect Policy Option Impacts

Table IV-16 below provides the direct "stand-alone" policy option impacts for the FOLU sector (see Section III-A above for a discussion of "stand-alone" versus integrated impacts). On a stand-alone basis, the complete set of FOLU policy options is expected to produce GHG reductions of 1.6 $TgCO_2e$ in 2020 and 2.7 $TgCO_2e$ in 2030. As with all results, these presume that the policy options will be fully implemented as designed (see Appendix F.5 for details on the design of each policy option). On a cumulative basis, the FOLU policy options are expected to reduce GHG emissions by 36 $TgCO_2e$ through 2030.

Table IV-16 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 Tg	2030 Tg	$TgCO_2e$	$TgCO_2e$	$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 TgCO_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 TgCO2e; 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 TgCO2e; NPV = $1,304; 2085 CE = $53

Table IV-17 FOLU Policy Options, Intra-Sector Interactions

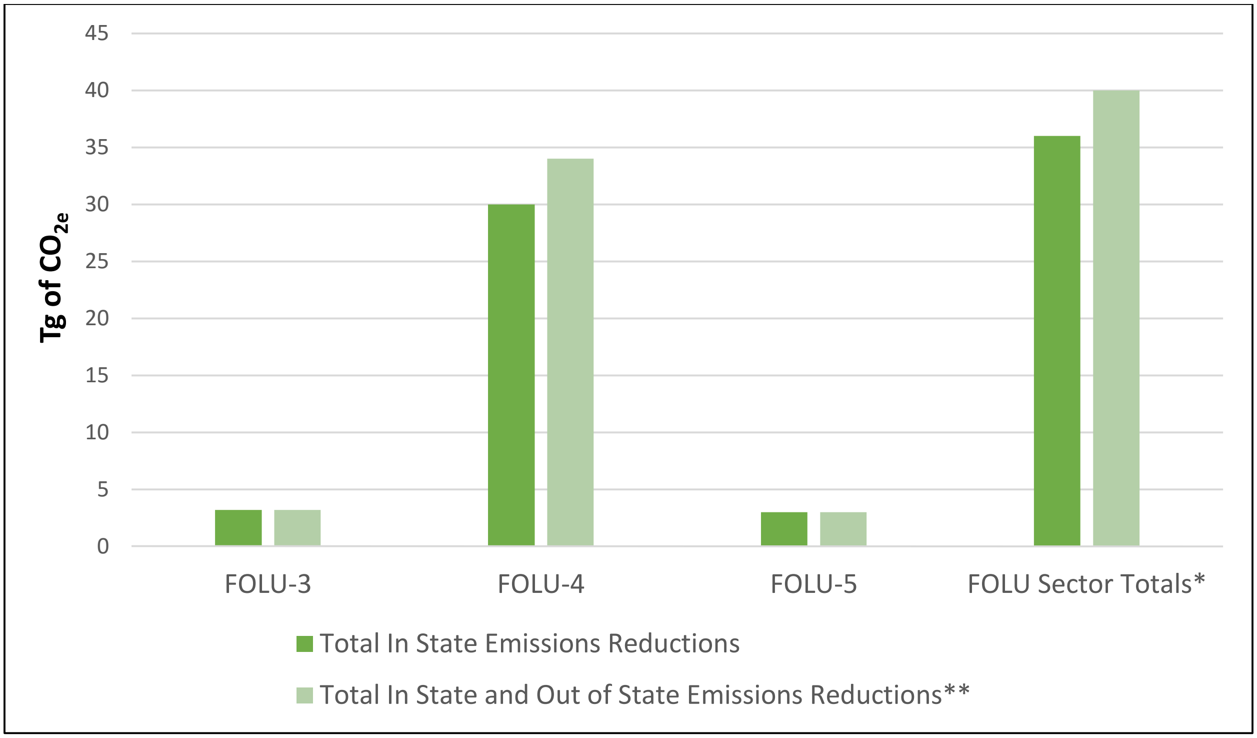
Intra-Sector Interactions & Overlaps Adjusted Results							
Policy Option ID	Policy Option Title	GHG Reductions				Costs	
		Annual[a]		2030 Cumulative[a]	2030 Cumulative[b]	Net Cost[c] 2015-2030	Cost Effectiveness[d]
		2020 Tg	2030 Tg	TgCO_2e	TgCO_2e	$Million	$/t$CO_2$e
FOLU-2.	Manage for Highly Productive 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.
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 IV-18 Macroeconomic Impacts of FOLU Policies

Macroeconomic (Indirect) Impacts Results									
Scenario	GSP[a] ($2015 MM)			Employment[b] (Individual)			Personal Income[c] ($2015 MM)		
	Year 2030[d]	Average (2016-2030)[e]	Cumulative (2016-2030)[f]	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)
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 farms lose income (FOLU-5 low income)	-$114	-$87	-$1,301	-1,350	-1,060	-15,900	-$3	$67	$1,010
FOLU-5 farms keep income (FOLU-5 keep income)	-$75	-$59	-$883	-920	-720	-10,750	$117	$144	$2,157
FOLU Sector Total Farms Lose Income (FOLU Sector Total Low Income)	**$258**	**$264**	**$3,961**	**2,940**	**2,910**	**43,610**	**$446**	**$409**	**$6,135**
FOLU Sector Total Farms Keep Income (FOLU Sector Total Keep Income)	**$294**	**$290**	**$4,345**	**3,340**	**3,220**	**48,340**	**$567**	**$486**	**$7,292**

Figure IV-84 FOLU Policies GHG Emissions Abatement, 2016-2030



Notes:
* All Policies Total's comprise emissions reductions achieved by Ag 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.

Forestry and Other Land Use Sector Overview

The tables above 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 teragrams (Tg) of carbon dioxide equivalent reductions (CO_2e), as well as the cumulative reductions through 2030 (1 Tg is equal to 1 million metric tons). 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.

Intra-Sector Interactions & Overlaps Adjustments

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.

Indirect Economic Impacts of FOLU Policies

Table IV-19 below provides a summary of the expected impacts on jobs and economic growth during the CSEO planning period.

Table IV-19 Macroeconomic Impacts of FOLU Policies

Macroeconomic (Indirect) Impacts Results									
Scenario	GSP ($2015 MM)			Employment (Individual)			Personal Income ($2015 MM)		
	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)
FOLU Sector Total Low Income	**$258**	**$264**	**$3,961**	**2,940**	**2,910**	**43,610**	**$446**	**$409**	**$6,135**
FOLU Sector Total Keep Income	**$294**	**$290**	**$4,345**	**3,340**	**3,220**	**48,340**	**$567**	**$486**	**$7,292**

<u>Modeling Framework and Assumptions</u>

For the purposes of macro-economic analysis of CSEO policies, Regional Economic Models, Inc. (REMI) software was used. 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 principal data sources for macro-economic modeling are microeconomic quantifications results of direct costs and savings of individual policy options. However, these inputs are also supplemented with additional data and assumptions that were made internally, based on research and expert judgement, when certain cost/savings or other conditions pertaining to policy option implementation where not specified in micro economic analysis.

REMI model used in this analysis was specifically built for the state of Minnesota, and incorporates "Standard Regional Control", which is a baseline forecast of the state' economy and demography.

Figure IV-85 Net Job Creation for FOLU Policies and FOLU Sector by Ascending Order, 2016-2030

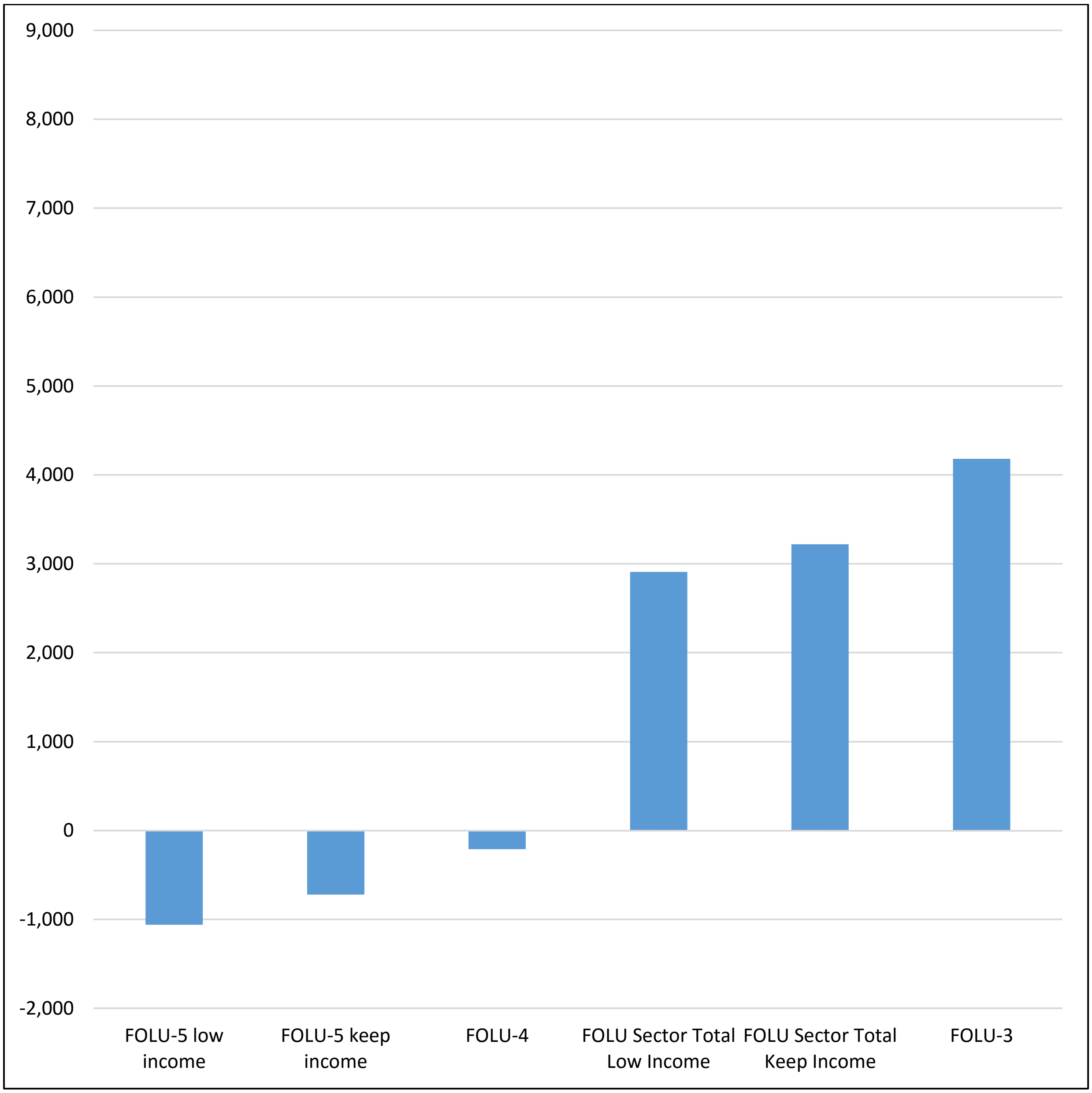
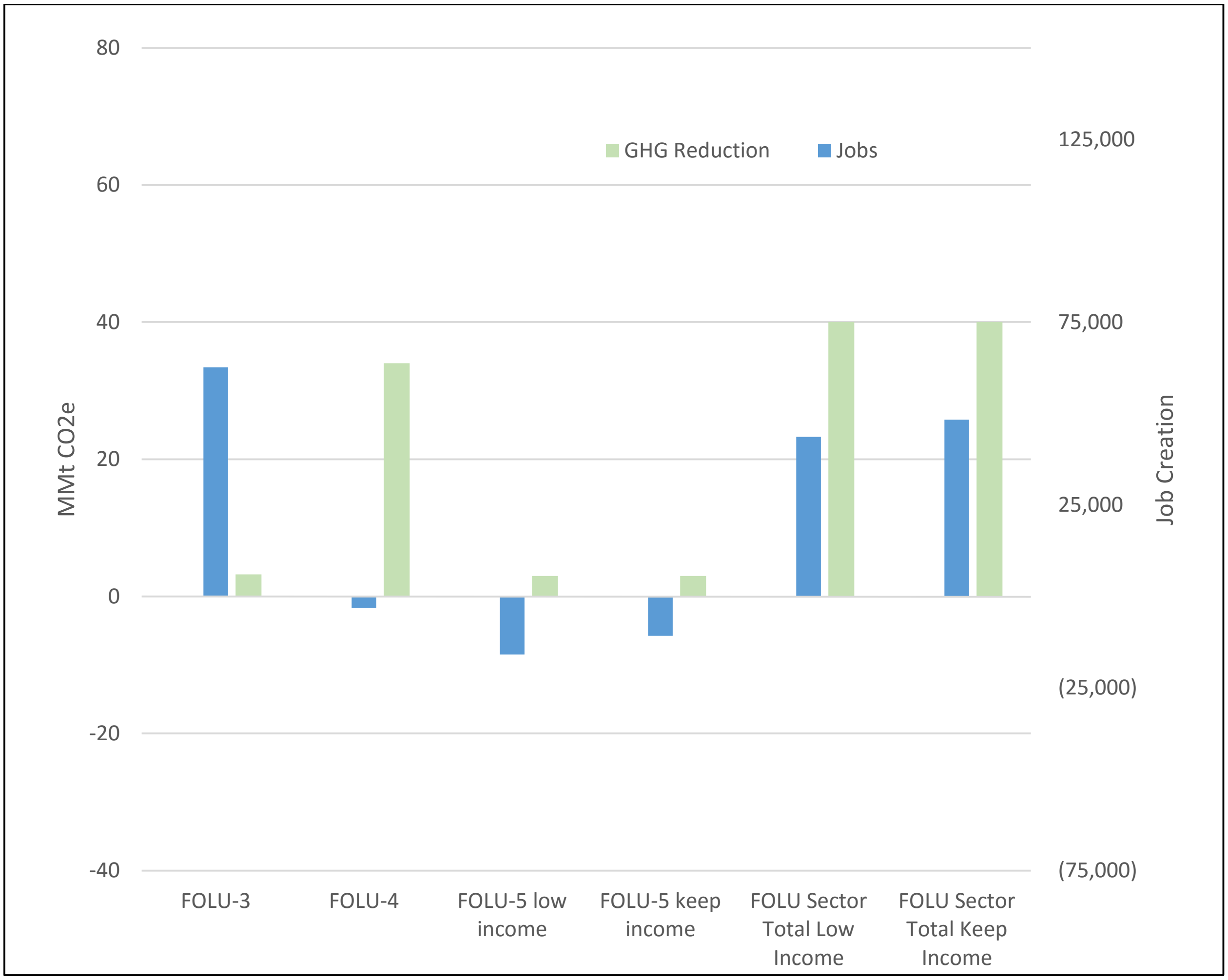


Figure below summarizes a potential for job creation and GHG emissions abatement of FOLU sector policies on the same graph. This allows for a simultaneous assessment of performance of individual CSEO options against two crucial environmental and economic indicators.

Figure IV-86 Job Gains and GHG Reduction by FOLU Policy Recommendations, 2016-2030



Macroeconomic index

Graphs below present the overall macroeconomic impacts of each policy in ES sector, as well as the sector-level impacts, by using the Macroeconomic Impact Index. The index is a blended score indicating an overall macroeconomic impact of a policy or a set of policies on GSP, income and employment. In this project, the three variables are weighted equally, and indexed based on the maximum value among all the policies in the project. I_GSP, I_Jobs, and I_Income represent the index score for GSP, Jobs and Income, respectively.

Figure IV-87 FOLU Macroeconomic Indicators, Year 2030

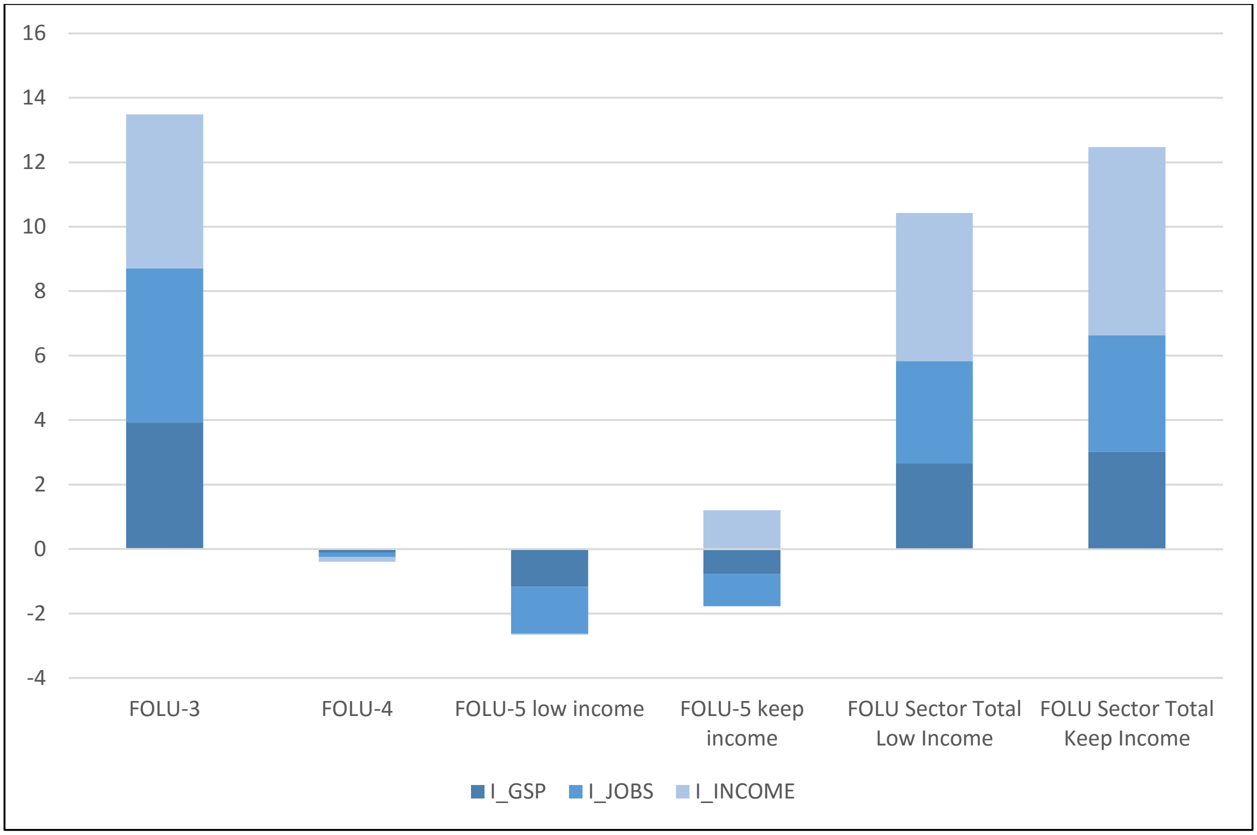


Figure IV-88 FOLU Macroeconomic Indicators, Average Annual

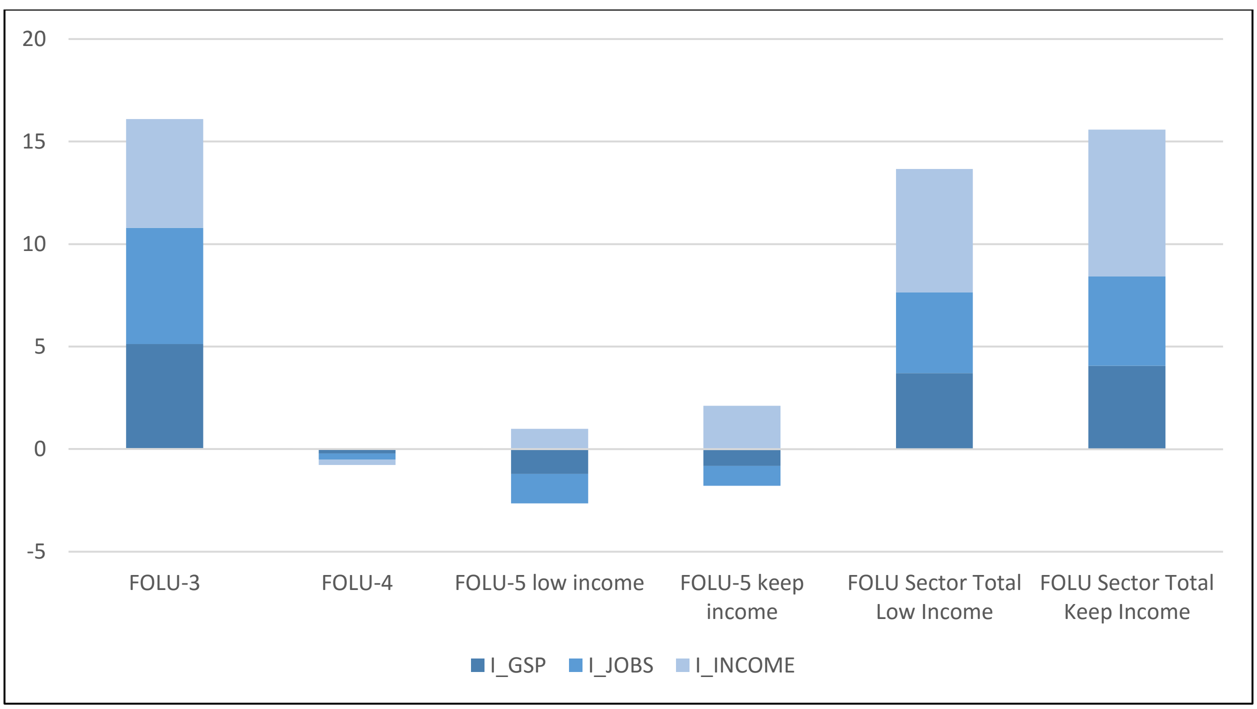
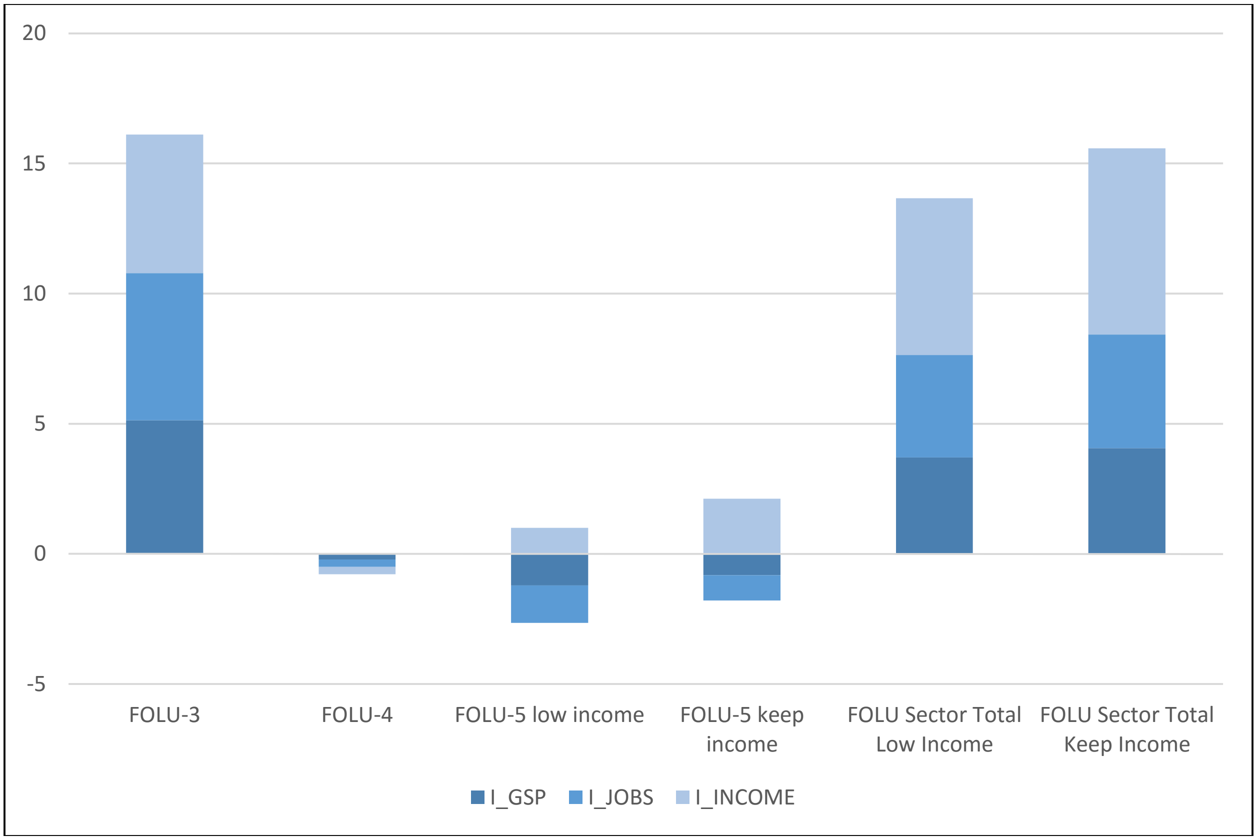


Figure IV-89 FOLU Macroeconomic Indicators, 2016-2030



Graphs below show the trend of FOLU policy macroeconomic impacts during the year 2015 to the year 2030.

Figure IV-90 . FOLU GSP Impacts ($2015 MM)

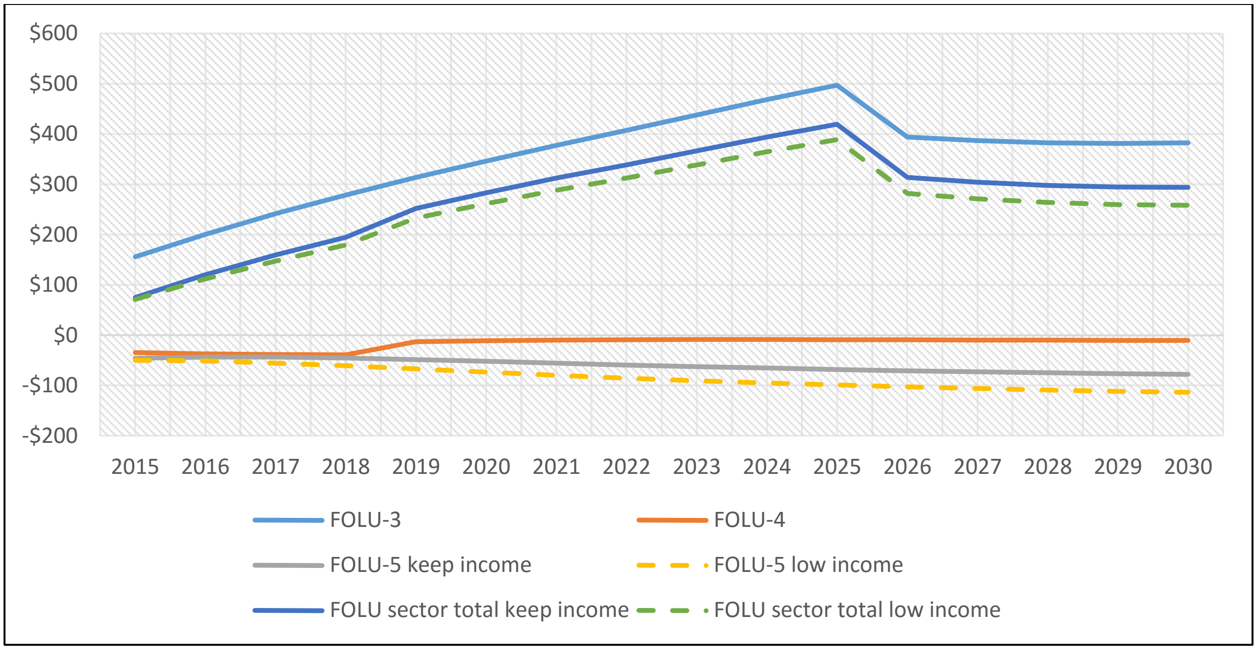


Figure IV-91 FOLU Income Impacts ($2015 MM)

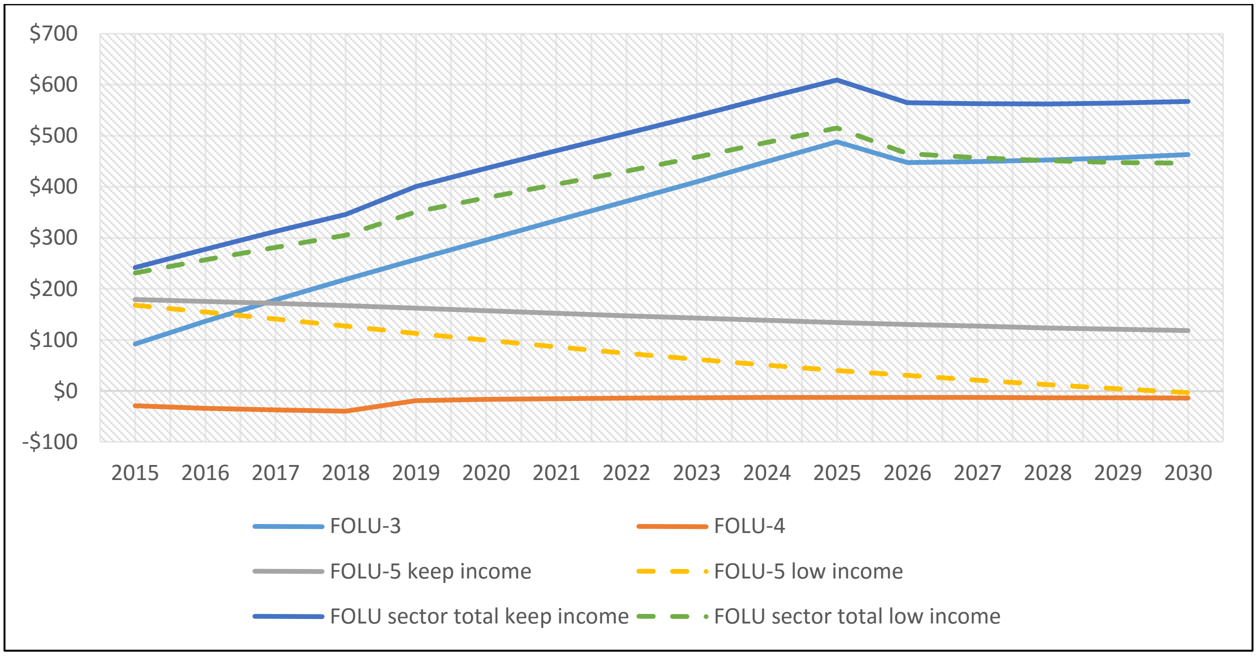
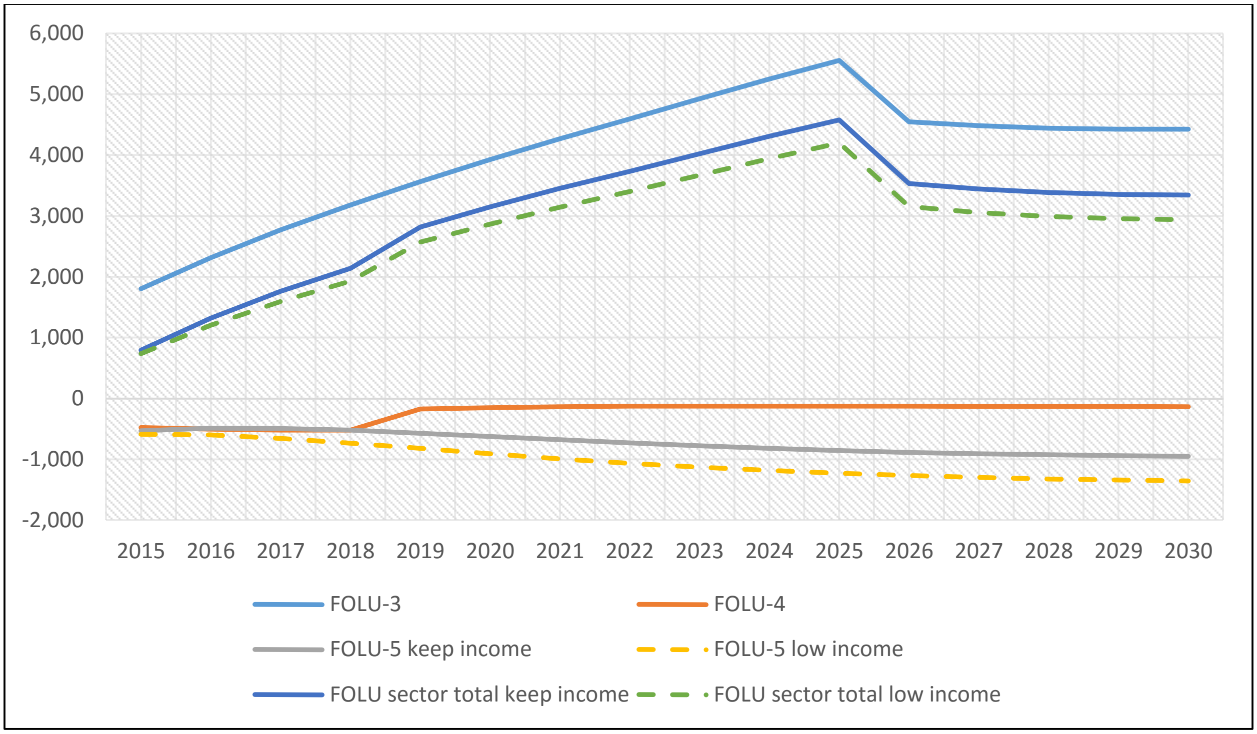


Figure IV-92 FOLU Employment Impacts (Jobs)



Graphs below show macroeconomic impacts on GSP, personal income, and employment in the final year (2030), in average (2016-2030) and in cumulative (2016-2030). Light color means sensitivity scenarios.

Figure IV-93 FOLU GSP Impacts, Average Annual ($2015 MM)

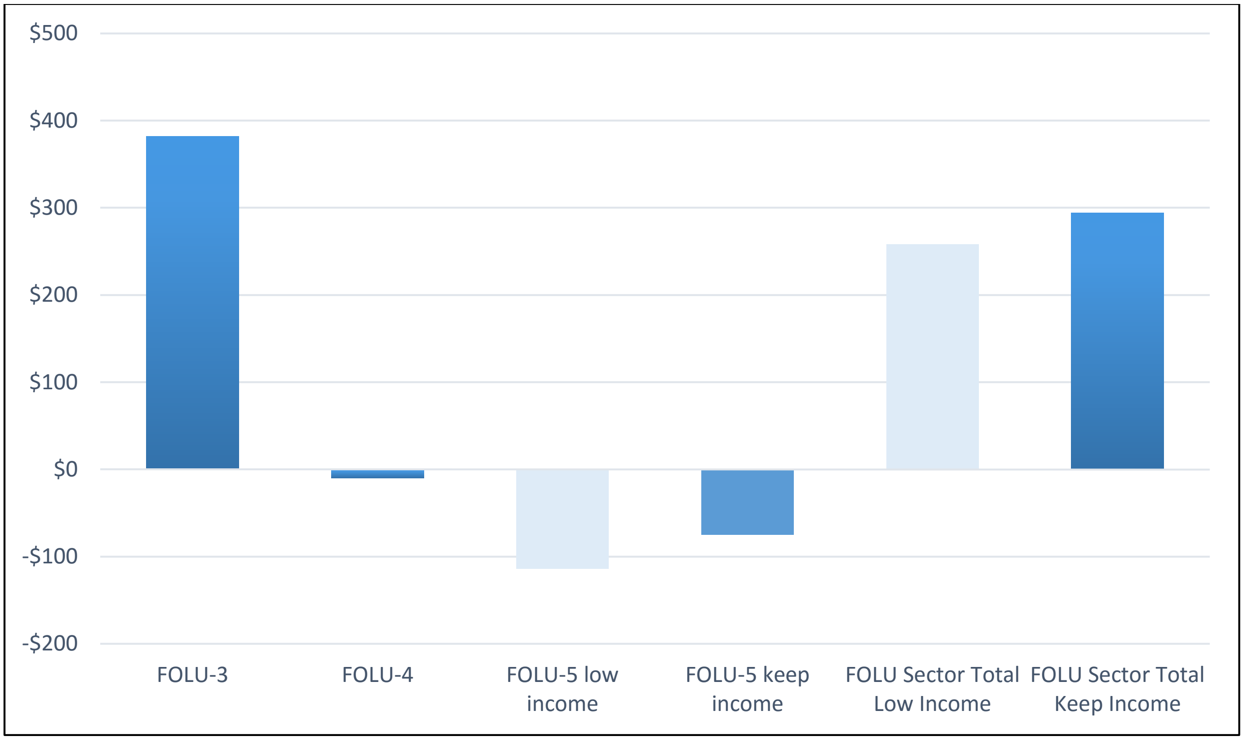


Figure IV-94 FOLU GSP Impacts, 2016-2030 ($2015 MM)

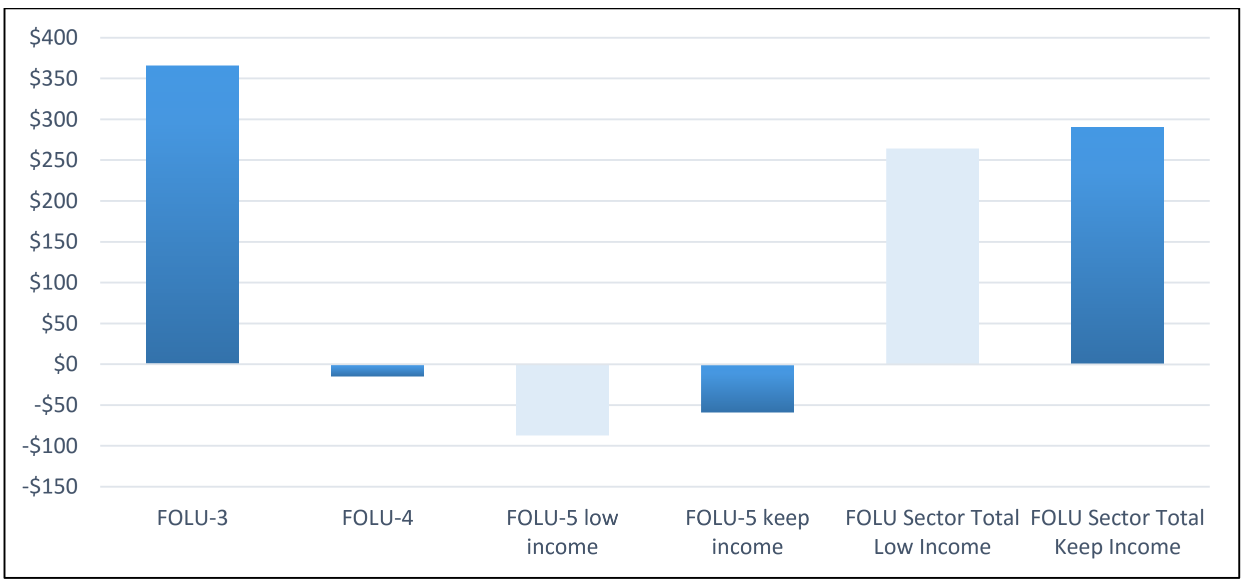


Figure IV-95 FOLU GSP Impacts, Year 2030 ($2015 MM)

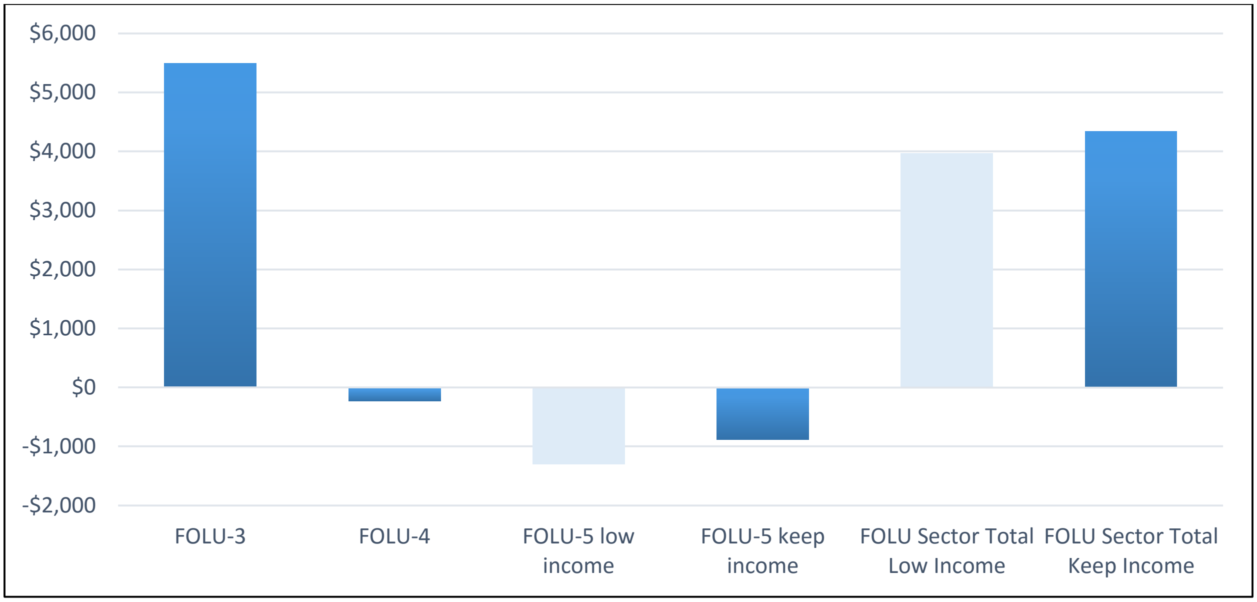


Figure IV-96 FOLU Employment Impacts, Average Annual (Jobs)

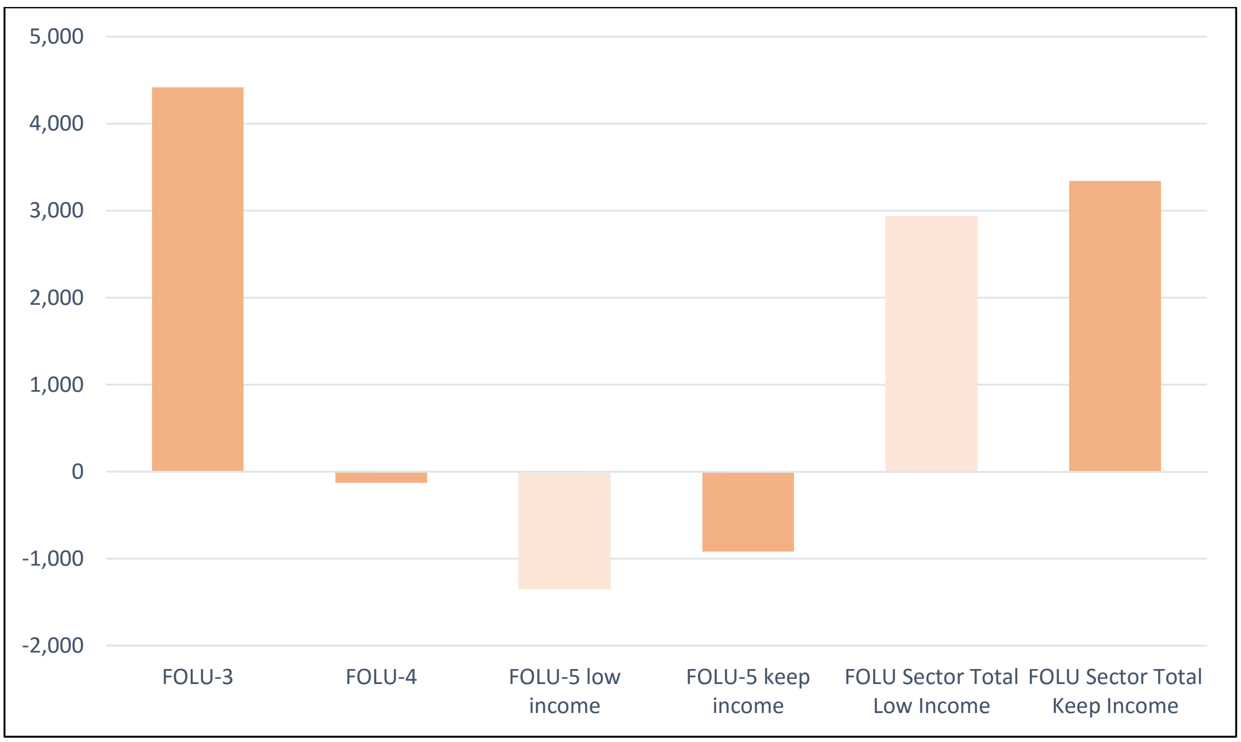


Figure IV-97 FOLU Employment Impacts, 2016-2030 (Job Years)

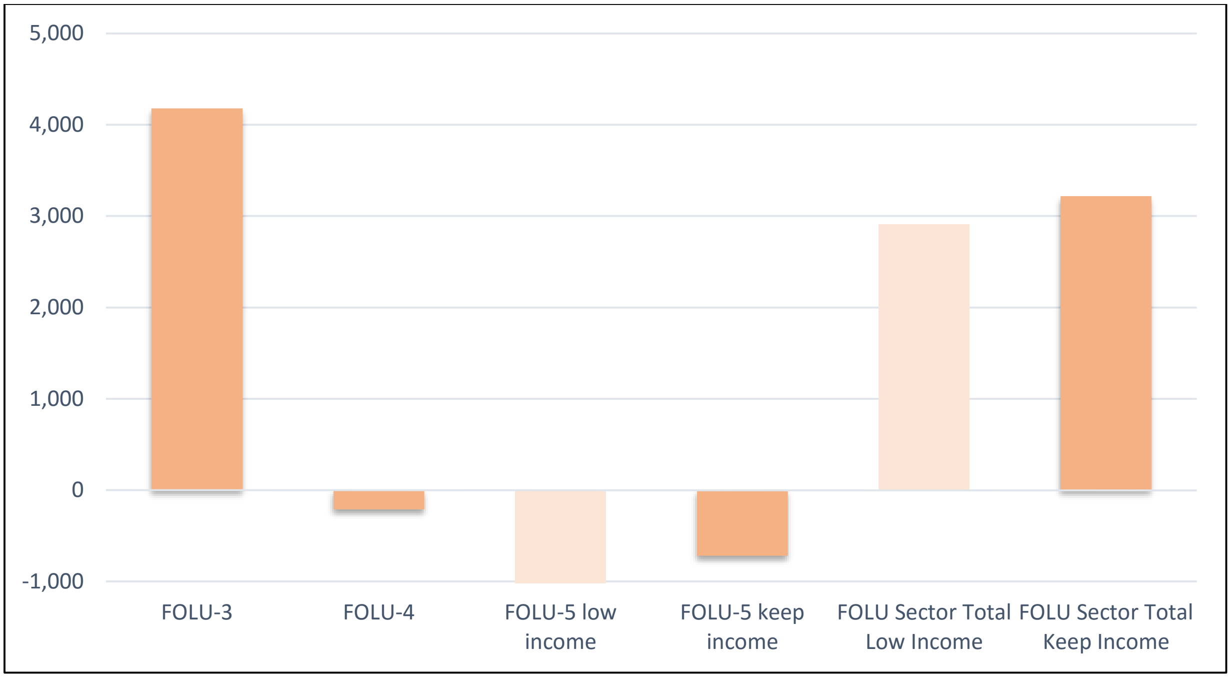


Figure IV-98 FOLU Employment Impacts, Year 2030 (Jobs)

Figure IV-99 FOLU Income Impacts, 2016-2030 Average Annual ($2015 MM)

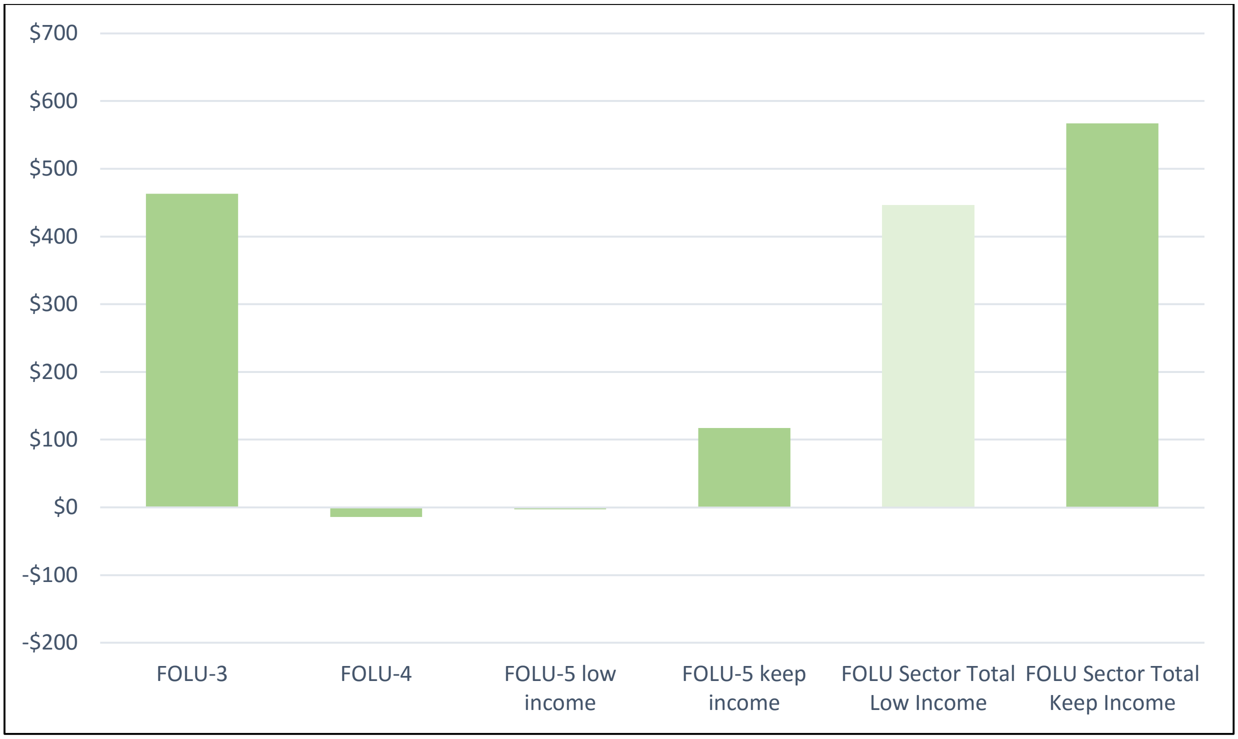
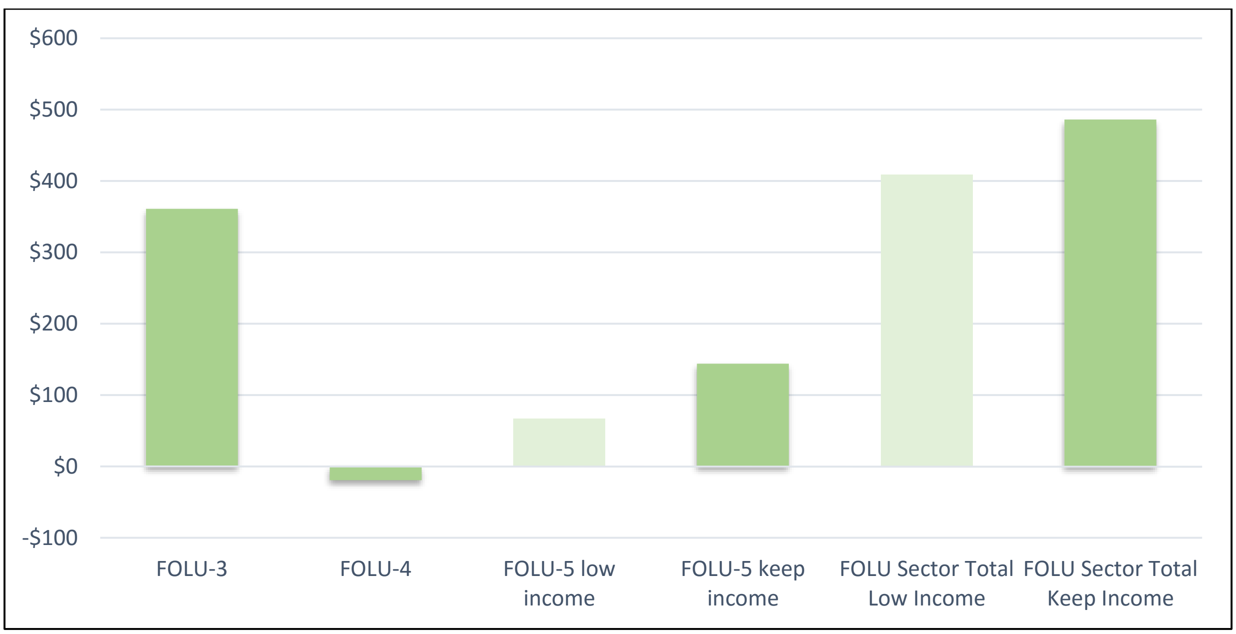


Figure IV-100 FOLU Income Impacts, 2016-2030 ($2015 MM)



6. Waste Management

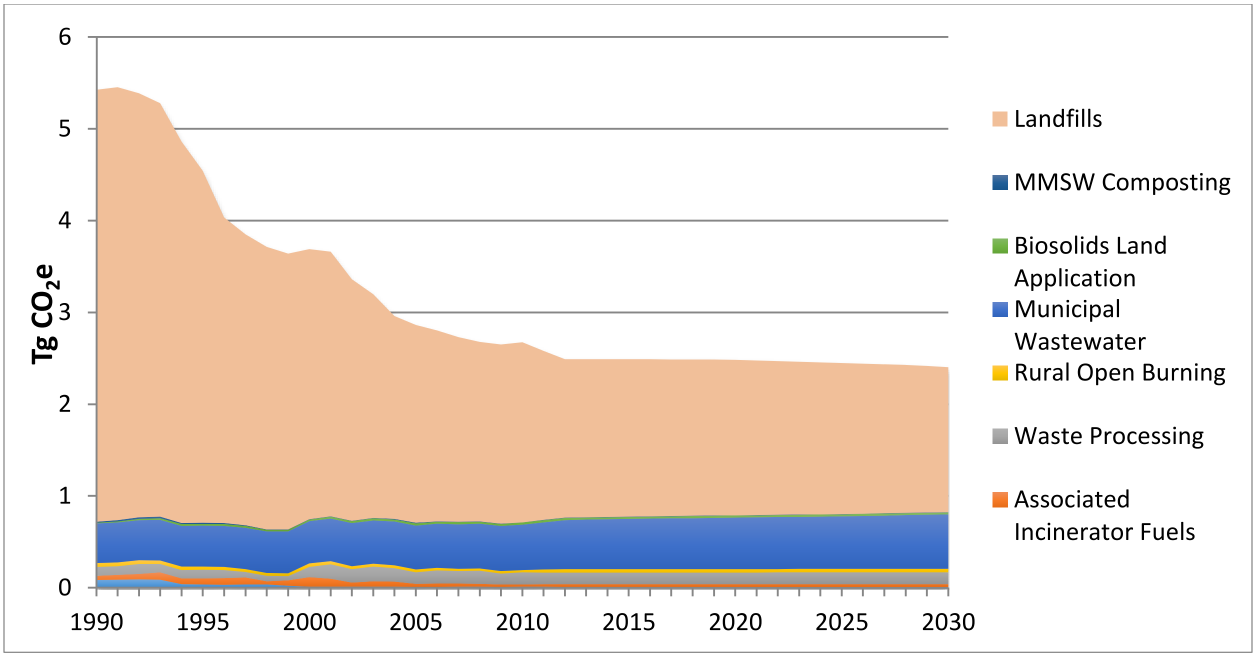
The Waste Management (WM) sector includes two subsectors: solid waste management and wastewater treatment. Key sources include landfills and municipal wastewater treatment. The sector contributed less than two percent of Minnesota's emissions in 2010 and is expected to contribute about 1.5% in 2030. Note that some solid waste is exported from Minnesota for management, and those emissions are not included in these Minnesota totals. Also, it is important to note that the most significant opportunities for greenhouse gas (GHG) reduction from solid waste management involve reducing emissions that occur upstream from the point of waste generation (i.e. during manufacturing and transport of packaging and products that end up in the waste stream). Most of these emissions would occur outside of the state. Also, wastewater treatment plants consume large amounts of energy (mainly electricity); and those emissions are reported under the Energy Supply (ES) sector.

Strategies for GHG reduction and positive economic impacts include: source reduction (reduced waste generation) and re-use; enhanced recycling; composting; landfill gas to energy; and wastewater treatment plant energy efficiency and renewable energy programs.

WM Baseline and Emissions Sources

Figure below provides the WM GHG baseline for Minnesota. It includes landfill methane (CH_4) emissions, CH_4 and nitrous oxide (N_2O) emissions from composting, N_2O emissions from land application of wastewater treatment plant biosolids, CH_4/N_2O from municipal wastewater treatment, $CO_2/CH_4/N_2O$ emissions from rural (open) burning of municipal solid waste (MSW), waste processing, and $CO_2/CH_4/N_2O$ from combustion of auxiliary fuels during waste incineration and the incineration of those wastes. MSW that is used for the purposes of generating electricity (refuse derived fuel) is accounted for in the ES sector.

Figure IV-101 WM Sector GHG Baseline



Notes: This chart excludes ~1TgCO_2 that is sequestered annually in construction and demolition landfills. MMSW = mixed MSW.

Historically, the WM sector emissions were dominated by landfill CH_4, which occurs during the anaerobic decomposition of MSW. However, over time, a combination of factors has lowered these emissions even though levels of waste generation have increased over time. These factors include: more waste being emplaced in modern landfills with landfill gas (LFG) collection and control; some waste being exported for management outside of the state; organic components of the waste stream being diverted to other management methods (e.g., composting); diversion of solid waste for use in waste to energy plants (emissions addressed in the ES sector); and higher levels of recycling and re-use.

As shown in Figure IV-101, even after factoring in expected future diversion of MSW via re-use and recycling, GHG emissions levels are expected to remain relatively constant through the forecast period. Landfill CH_4 is expected to remain the dominant contributor to *direct* in-state GHG emissions, followed by CH_4/N_2O emissions from municipal wastewater treatment. The term *direct* here is emphasized, because from a materials management perspective, there is often much more in the way of GHG emissions embedded in waste materials, than there is in the eventual management of those materials. The current Minnesota baseline does not present these embedded emissions (as most of these likely occur out-of-state or could be double-counted with those from other sectors, like Industry); however, a consumption-based accounting approach would provide estimates for these embedded (or "upstream") emissions. Through policy option interventions such as source reduction and re-use, these often substantial emissions can be reduced, although those reductions may occur outside of the

State's boundaries. This type of thinking has been applied in the selection and design of CSEO solid waste management policy options presented in the next section.

CSEO Policy Options

Three policy options were developed for the WM sector. These are detailed in Appendix F.6 and are summarized as follows:

WM-1. Wastewater Treatment - Energy Efficiency

This policy option addresses opportunities for energy conservation within wastewater treatment plants (WWTPs). The conservation mandate is technology agnostic to allow for flexibility. The policy option design calls for a state-wide reduction in energy usage from WWTPs of 25% by 2025. Most plants that have not already undertaken significant energy efficiency retrofits can find cost savings energy efficiency (EE) measures in the form of more efficient aeration equipment and higher efficiency blowers and pumps.

WM-2. Front-End Waste Management: Source Reduction

Front-end solid waste management (SWM) technologies promote reduction of the 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, re-use, 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 along with WM-3 below represent a continuation of the AFW-7 policy option from the 2008 MCCAG report. Following that report in 2008, the 2014 Legislature codified a 75% total recycling goal that combines conventional dry recycling and composting, food-rescue, and food-to-animals for the seven Metro counties. 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%. The overall goal of WM-2 is to achieve a zero percent per capita increase in waste generation per capita by 2020 and a three percent decrease by 2025.

WM-3. Front-End Waste Management - Re-Use, Composting & Recycling

This policy option represents the second component of the MSW policy option package for improving front-end waste management in MN. The goal of this policy option is to achieve a total recycling rate, including composting of 75% by 2025. This assumes that no additional waste is diverted from current levels of waste to energy (WTE) generation. MN achieved a recycling rate (including organics recycling) of over 49% in 2012.

Direct and Indirect Policy Option Impacts

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 teragrams (Tg) of carbon dioxide equivalent reductions (CO_2e), as well as the cumulative reductions through 2030 (1 Tg is equal to 1 million metric tons). 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 IV-22 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 IV-20 WM 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	2030 Cumulative[b]	Net Costs[c] 2015-2030	Cost Effectiveness[d]
		2020 Tg	2030 Tg	$TgCO_2e$	$TgCO_2e$	$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)**

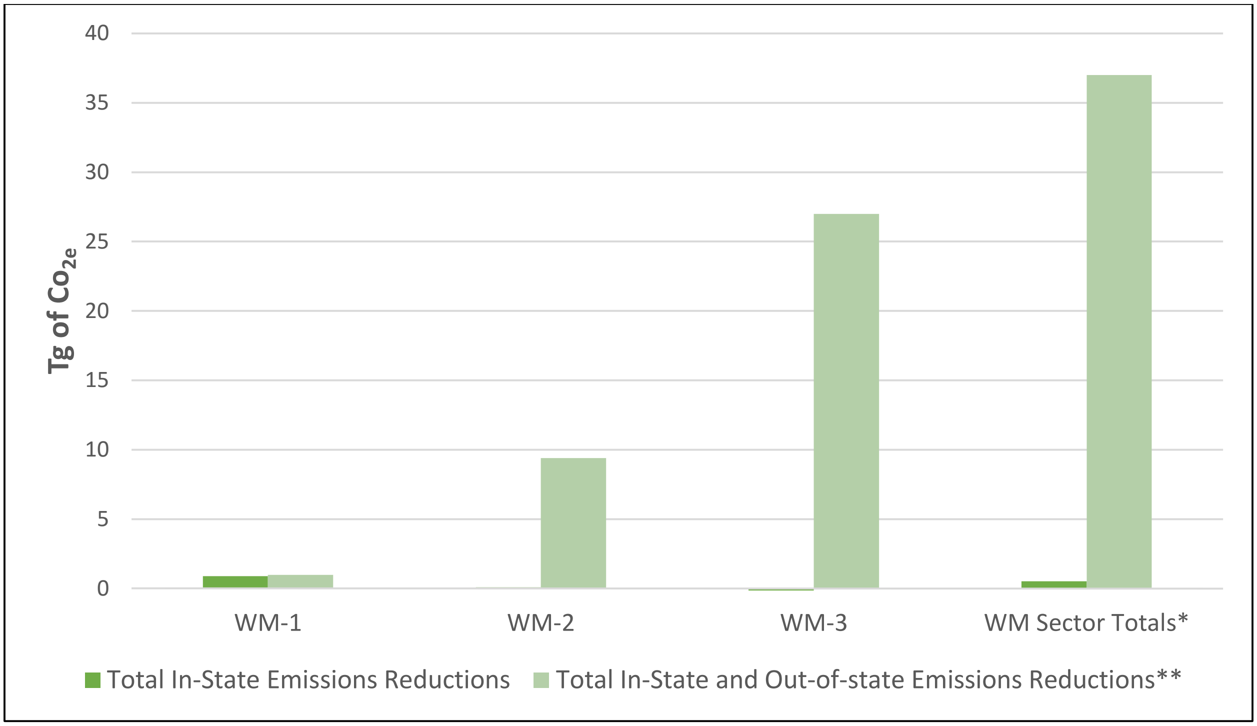
Notes:
[a] In-state (Direct) GHG Reductions.
[b] Total (Direct and Indirect) GHG Reductions.
[c] Net Present Value of fully implemented policy option using 2014 dollars ($2014).
[d] Cost effectiveness values include full energy-cycle GHG reductions, including those occurring out of state. Dollars expressed in $2014.
[e] Assumes full implementation of WM-2.

Table IV-21 WM 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 Tg	2030 Tg	$TgCO_2e$	$TgCO_2e$	$Million	$/tCO₂e
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 IV-102 WM Policies GHG Emissions Abatement, 2016-2030



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 IV-22 Macroeconomic Impacts of WM Policy Options

Macroeconomic (Indirect) Impacts Results									
Scenario	GSP[a] ($2015 MM)			Employment[b] (Individual)			Personal Income[c] ($2015 MM)		
	Year 2030[d]	Average (2016-2030)[e]	Cumulative (2016-2030)[f]	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)
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 2016-2030 time period.

Figure IV-103 Net Job Creation for WM Policies and WM Sector by Ascending Order, 2016-2030

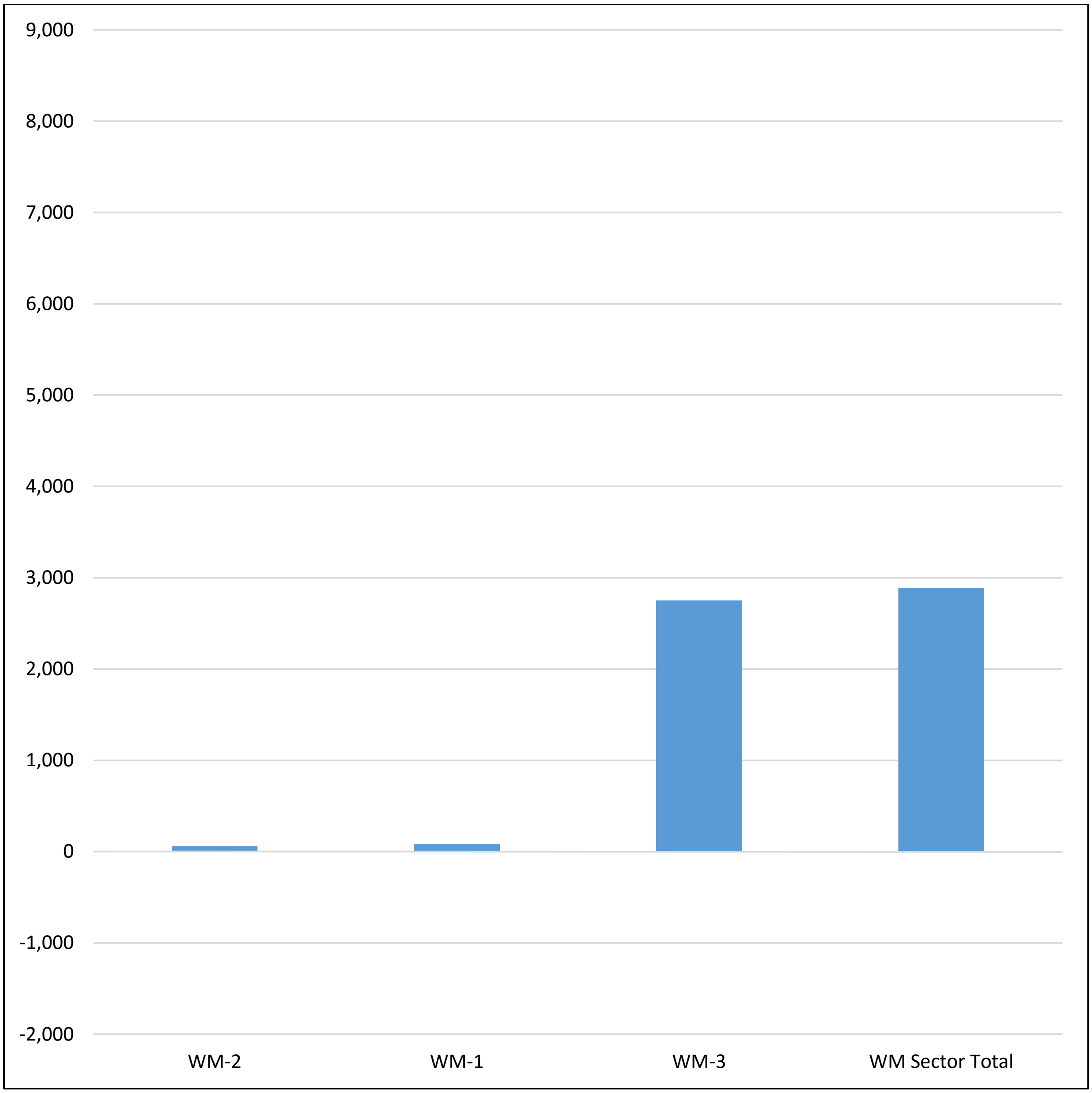
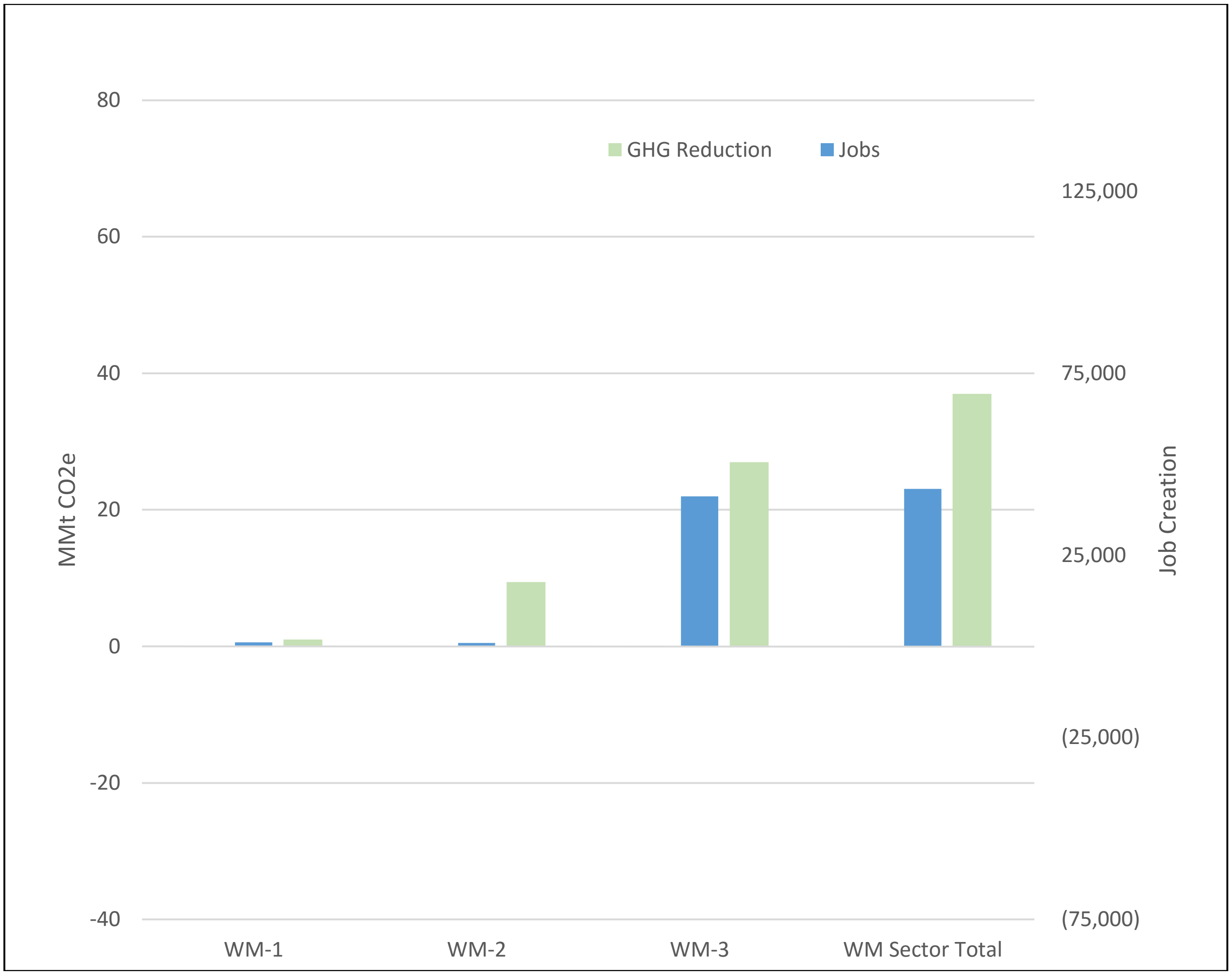


Figure below summarizes a potential for job creation and GHG emissions abatement of WM sector policies on the same graph. This allows for a simultaneous assessment of performance of individual CSEO options against two crucial environmental and economic indicators.

Figure IV-104 Job Gains and GHG Reduction by WM Policy Recommendations, 2016-2030



Macroeconomic Impacts

Graphs below present the overall macroeconomic impacts of each policy in WM sector, as well as the sector-level impacts, by using the Macroeconomic Impact Index. The index is a blended score indicating overall macroeconomic impact of a policy or a set of policies on GSP, income and employment. In this project, the three variables are weighted equally, and indexed based on the maximum value among all the policies. I_GSP, I_Jobs, and I_Income represent the index score for GSP, Jobs and Income, respectively.

Figure IV-105 WM Macroeconomic Indicators, 2030

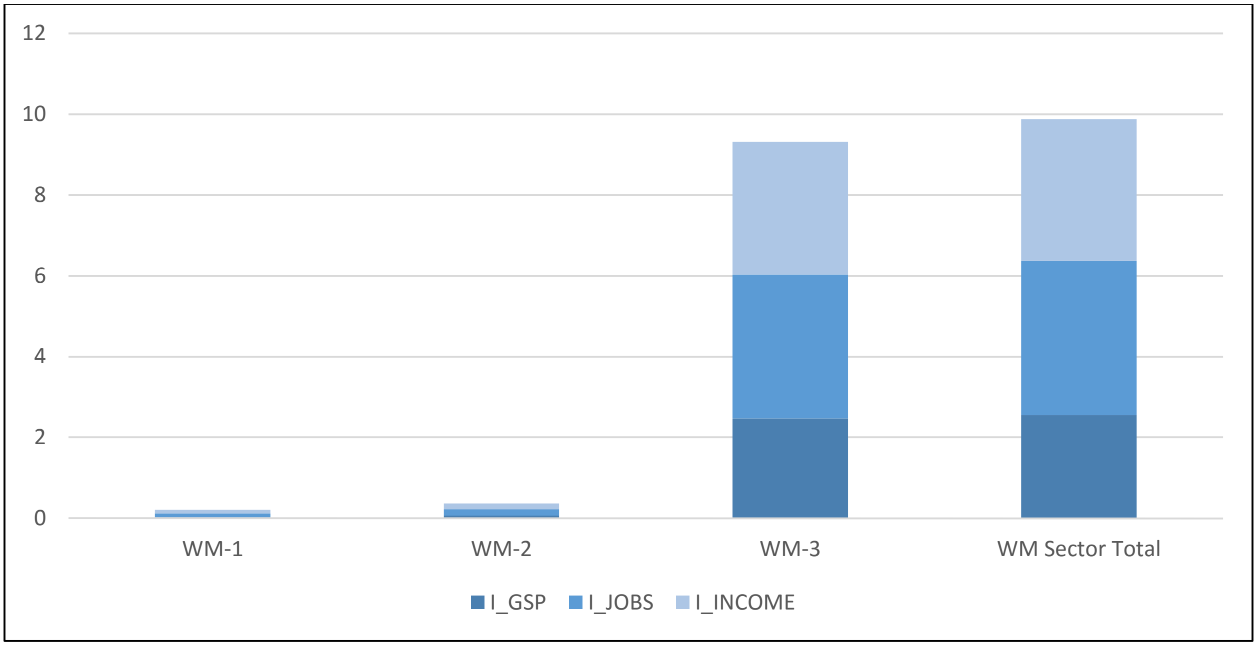


Figure IV-106 WM Macroeconomic Indicators, Average Annual

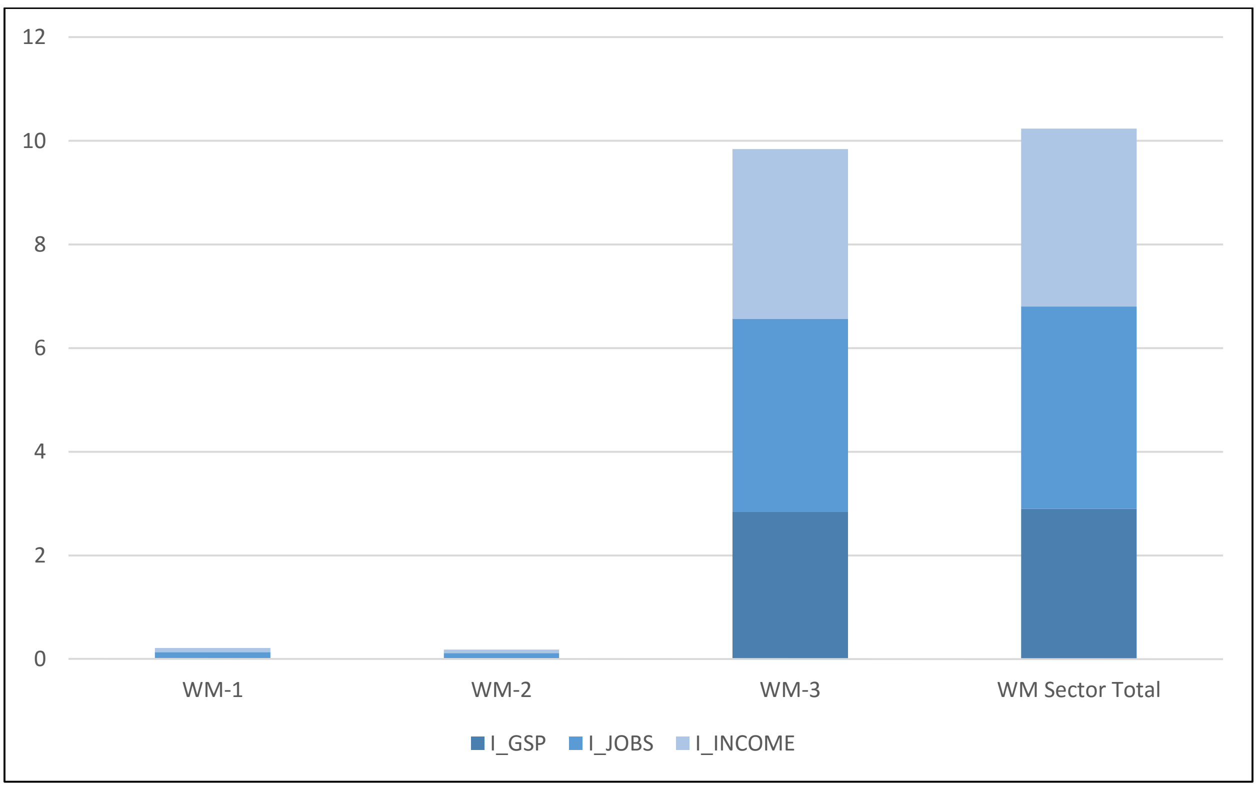
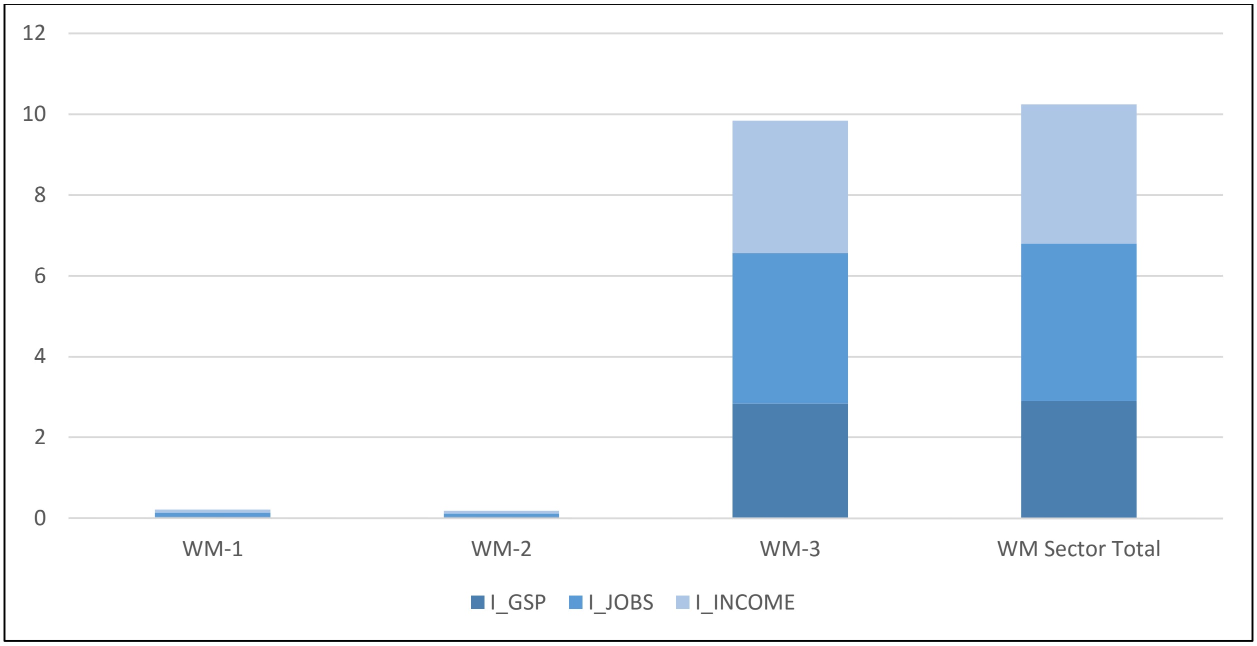


Figure IV-107 WM Macroeconomic Indicators, 2016-2030



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 IV-108 WM GSP Impacts ($2015 MM)

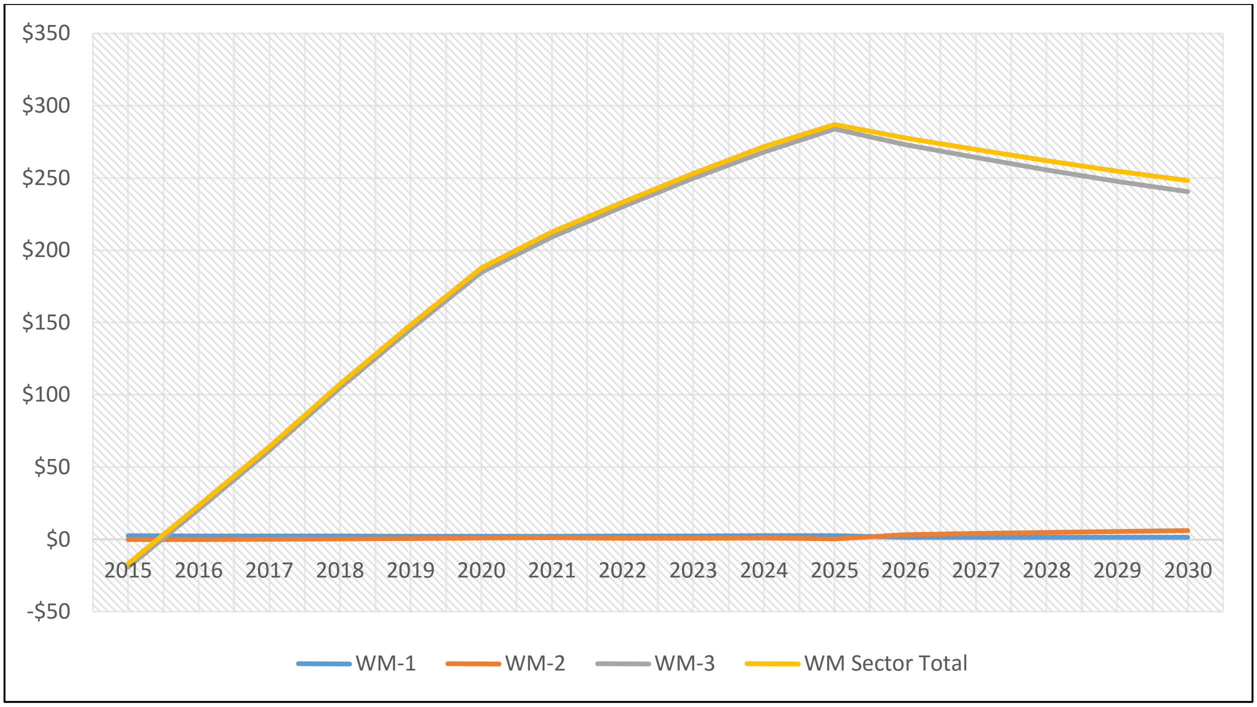


Figure IV-109 WM Employment Impacts (Jobs)

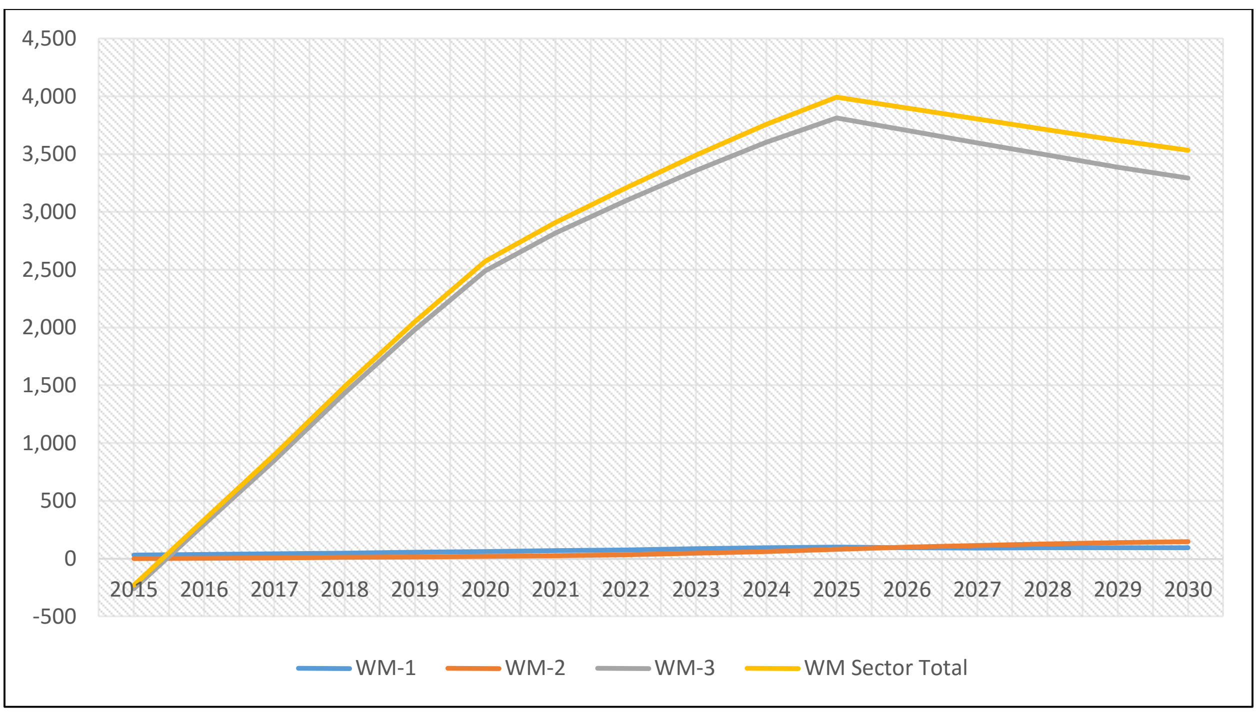
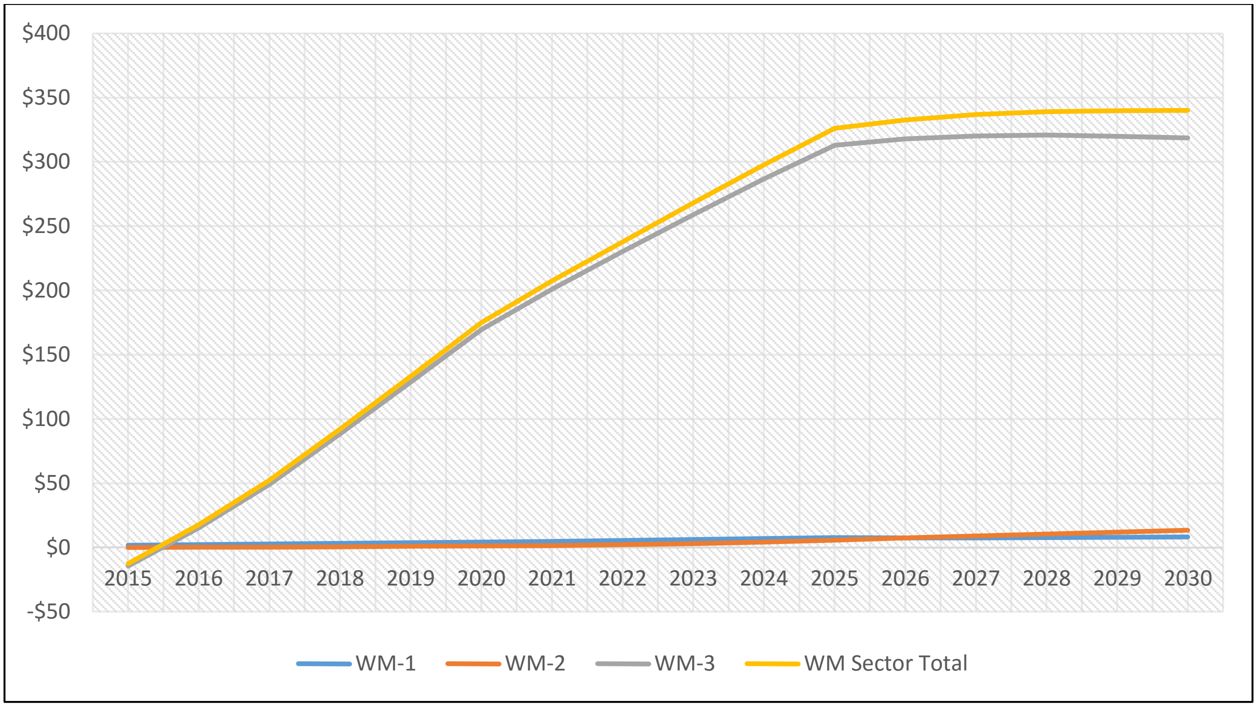


Figure IV-110 WM Income Impacts ($2015 MM)



Graphs below show macroeconomic impacts on GSP, personal income, and employment in the final year (2030), in average (2016-2030) and in cumulative (2016-2030).

Figure IV-111 WM GSP Impacts, Average Annual ($2015 MM)

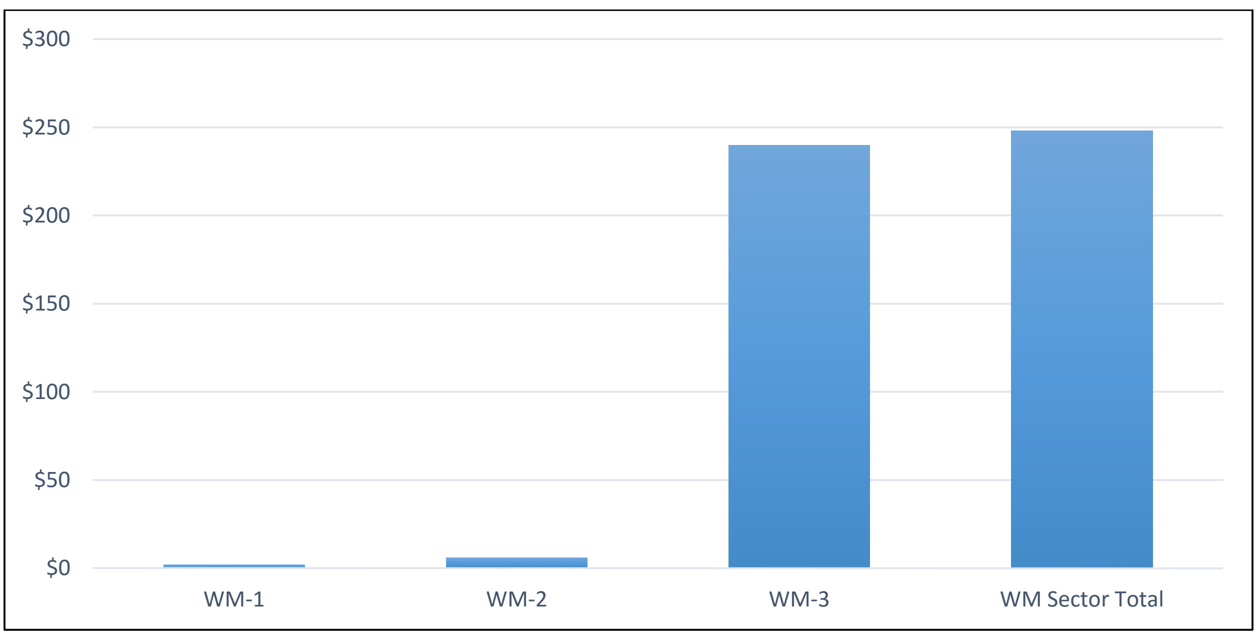


Figure IV-112 WM GSP Impacts, 2016-2030 ($2015 MM)

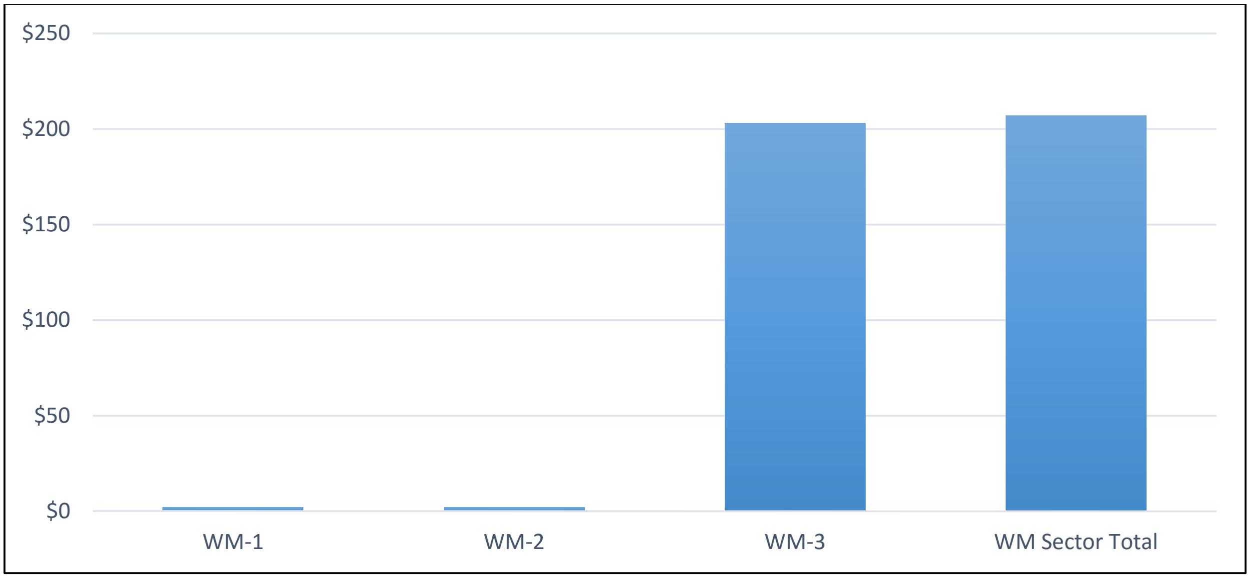


Figure IV-113 WM GSP Impacts, Year 2030 ($2015 MM)

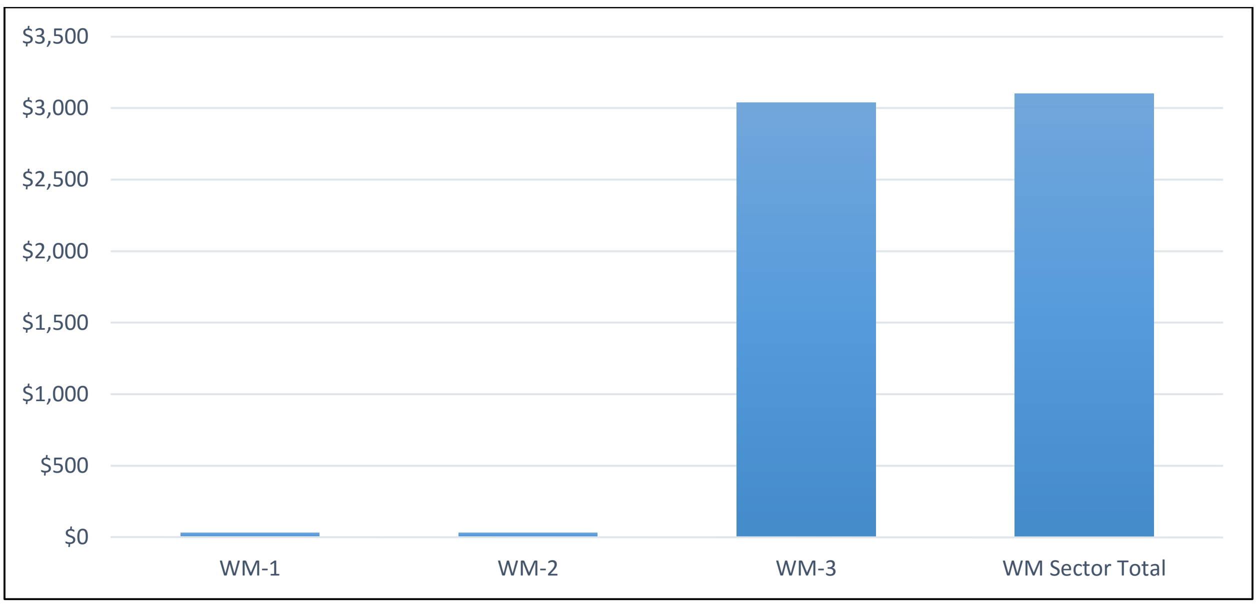


Figure IV-114 WM Employment Impacts, Average Annual (Jobs)

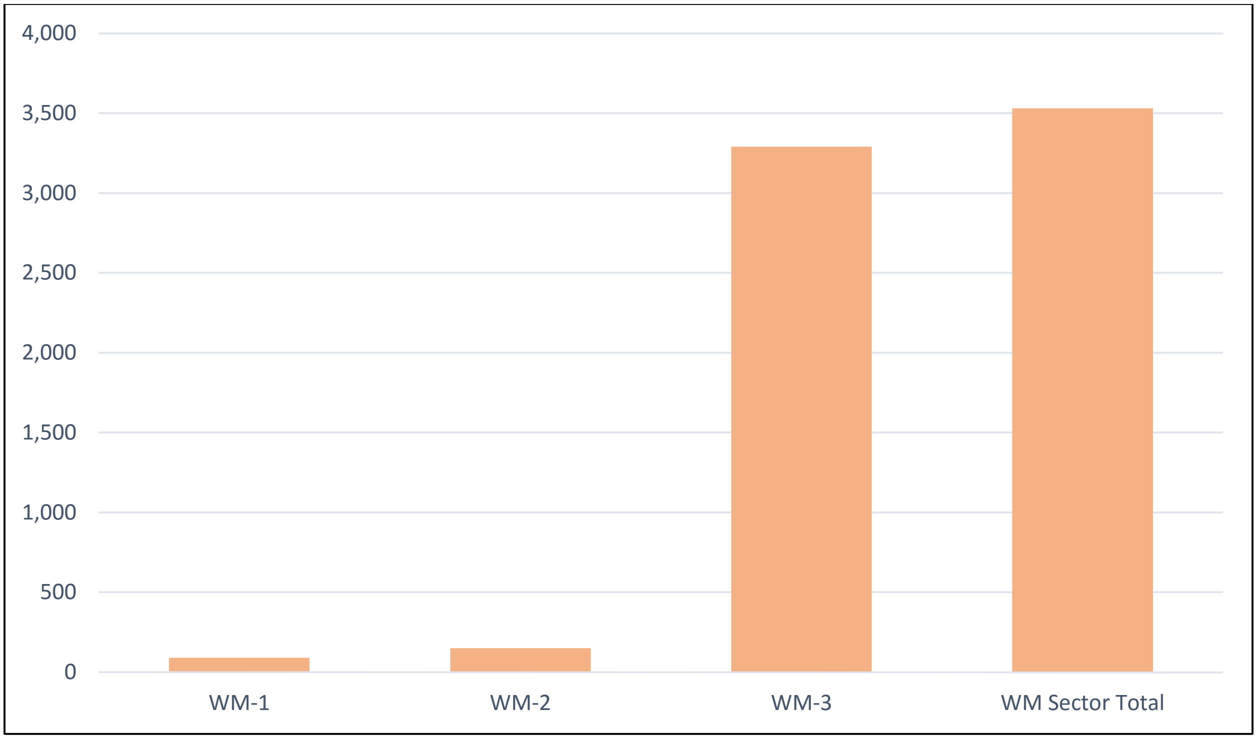


Figure IV-115 WM Employment Impacts, 2016-2030 (Job Years)

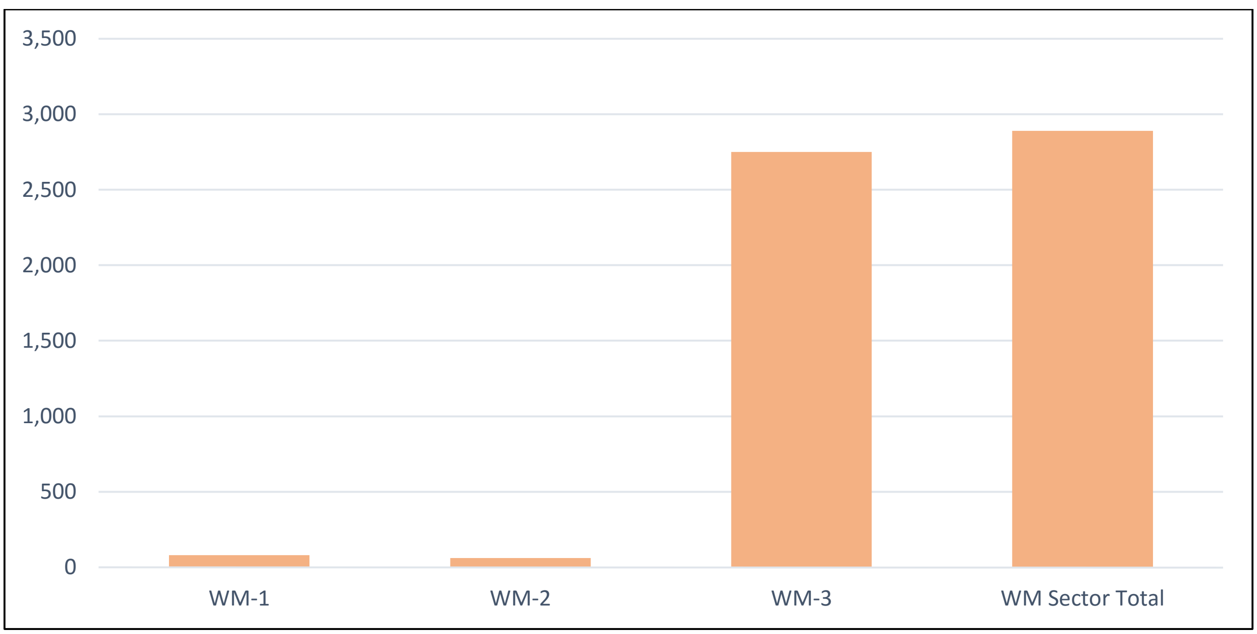


Figure IV-116 WM Employment Impacts, Year 2030 (Jobs)

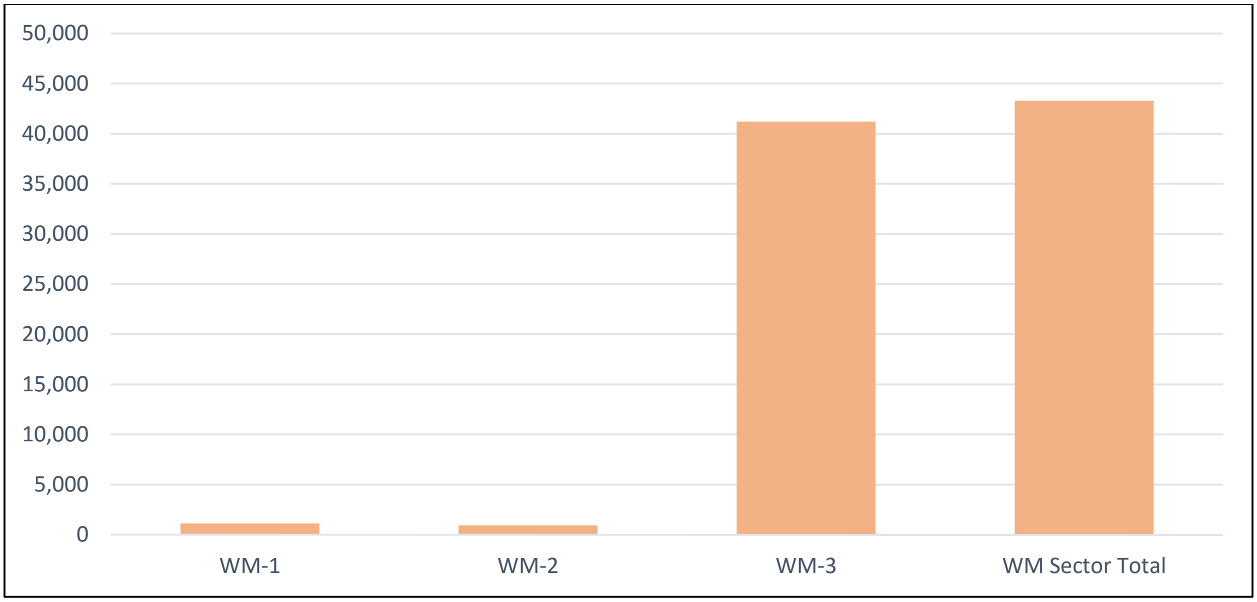


Figure IV-117 WM Income Impacts, Average Annual ($2015 MM)

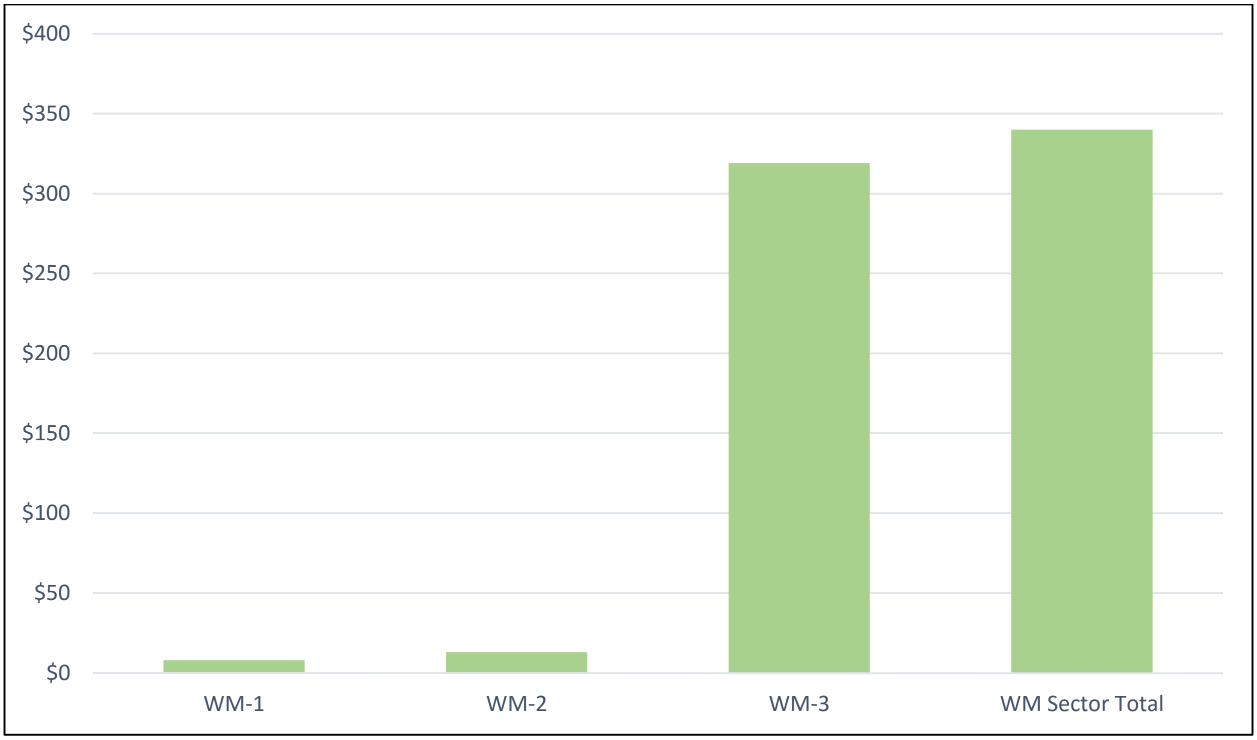


Figure IV-118 WM Income Impacts, 2016-2030 ($2015 MM)

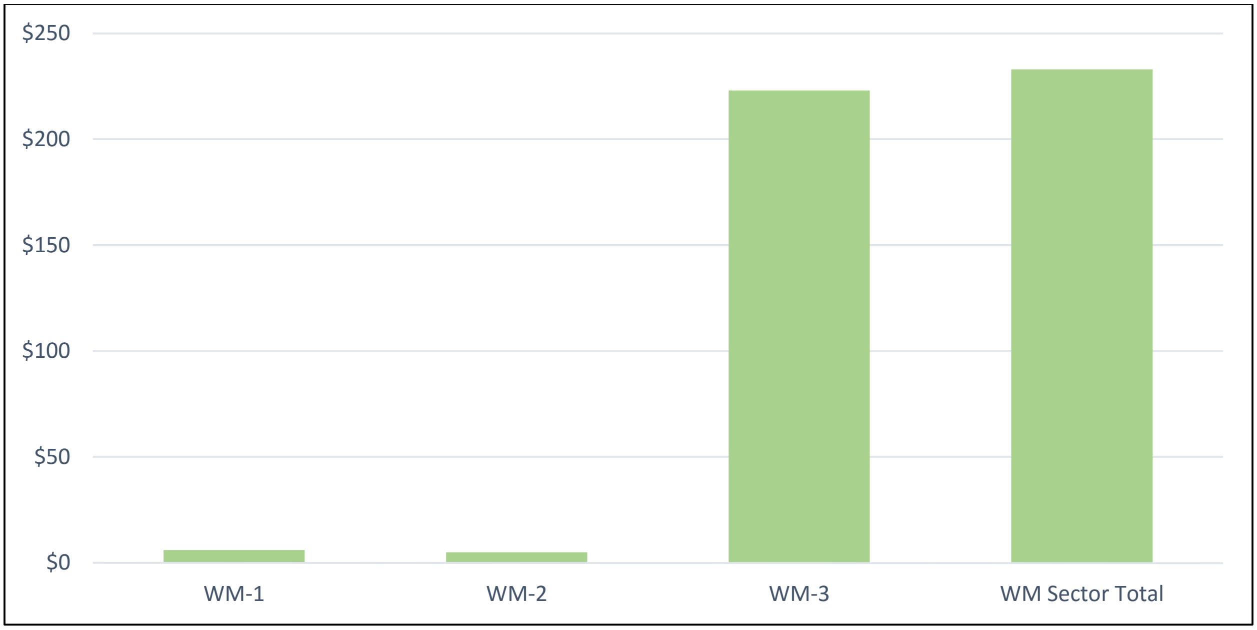
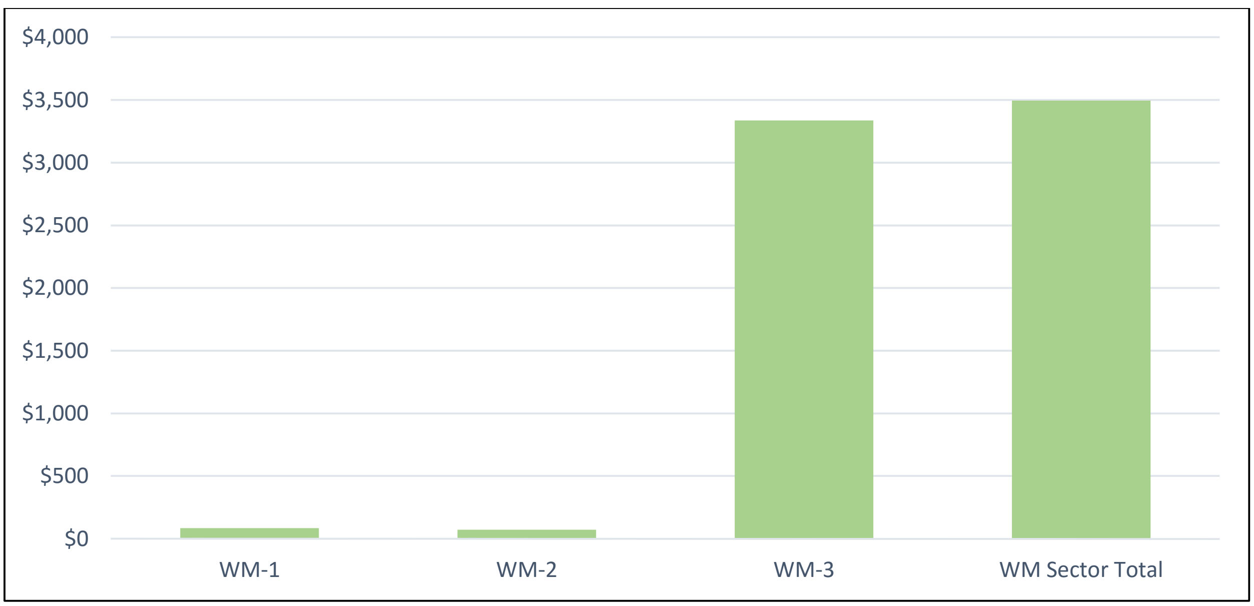


Figure IV-119 WM Income Impacts, Year 2030 ($2015 MM)



Chapter V. Additional Assessments

Policy Option Impacts on EPA Clean Power Plan Compliance

Background

This section analyzes the potential capacity of Minnesota to comply with the EPA Clean Power Plan's emissions limitations under the Clean Air Act Section 111(d) by implementing all the CSEO policies with electricity system impacts. To achieve Clean Power Plan compliance, Minnesota must impose emissions limitations on the affected electricity generation units (EGUs) through standards of performance[6]. CSEO policies that affect electric utility system behavior in Minnesota and neighboring states, either by changing electricity supply fuel composition or by changing the demand for electricity, are: ES 1 and 2, RCII 1,2 and 4, FOLU-3 and WM-1. Additionally, there are polices that cause marginal increase in electricity demand: Agriculture policy 4, WM 2 and WM 3.

An evaluation of how the policies contribute to meeting the Clean Power Plan's target provides an additional perspective on the total value of the proposed policies, and place them more completely in the current national regulatory context.

Policies of greatest interest to Minnesota are Energy Supply (ES) sector and Residential, Commercial, Industrial, and Institutional (RCII) sector policies. ES and RCII policies together account for about 73% of the total GHG reductions achieved by the entire package of CSEO policies against the business as usual scenario (BAU), and thus are considered crucial for the state of Minnesota. As Appendices of this report show, these policies are not only cost effective in terms of greenhouse gas (GHG) emissions abatement but also capable in most cases of resulting in negative net present values (NPVs), which indicates that they save more money than they cost over the projected implementation period (2015-2030).

Results of Policy Options Impacts on 111(d) Compliance

Baseline and GHG Reduction

For the purposes of this analysis, Center for Climate Strategies' (CCS) 3E Planning Synthesis Module tool was used, while utilizing input data both from EPA's Emissions & Generation Resource Integrated Database (eGRID) from 2012[7] and Minnesota Pollution Control Agency (MPCA)[8].

---

[6] Environmental Protection Agency. (2015, October 23). Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units; Final Rule. *80*. 14, Retrieved from https://www.gpo.gov/fdsys/pkg/FR-2015-10-23/pdf/2015-22842.pdf

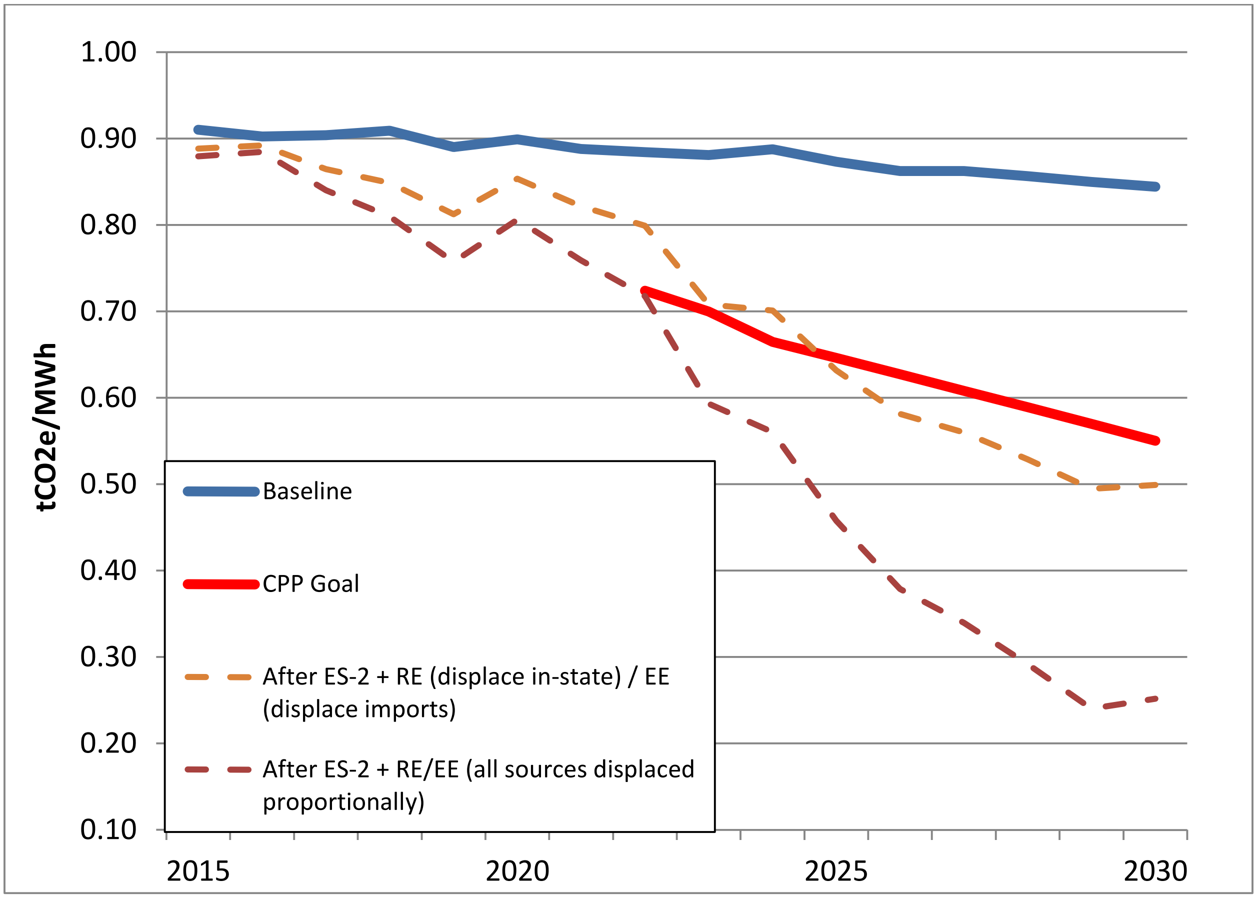
[7] Environmental Protection Agency. (2015, October 29). eGRID. Retrieved from http://www.epa.gov/energy/egrid

[8] More details on this analytical approach are provided in **Quantification Methods** section in Appendix F-7.

Two distinct scenarios for how the CSEO policies will offset MN electricity generation sources were analyzed; these include:

- All source offset proportionally – assumes that 111(d) units will be offset in the same proportion as the proportion of 111(d) unit generation to the total ES baseline (including imports). For example, in 2015 111(d) sources generate 60% of the total electricity consumed in MN, so 60% of emission reductions from RE/EE measures are allocated to 111(d) sources.
- ES-1 (RE) offsets in-state sources; EE policies offset imports - assumes that ES-1 will offset in-state sources (111(d) sources offset proportionally to total in-state generation), and EE will offset imports before offset in-state sources. In other words, no reductions from EE measures will be allocated to 111(d) sources until reductions from those policies exceed electricity imports.

Figure V-1 Emissions for 111(d) Applicable Units Under a Rate-Based Approach



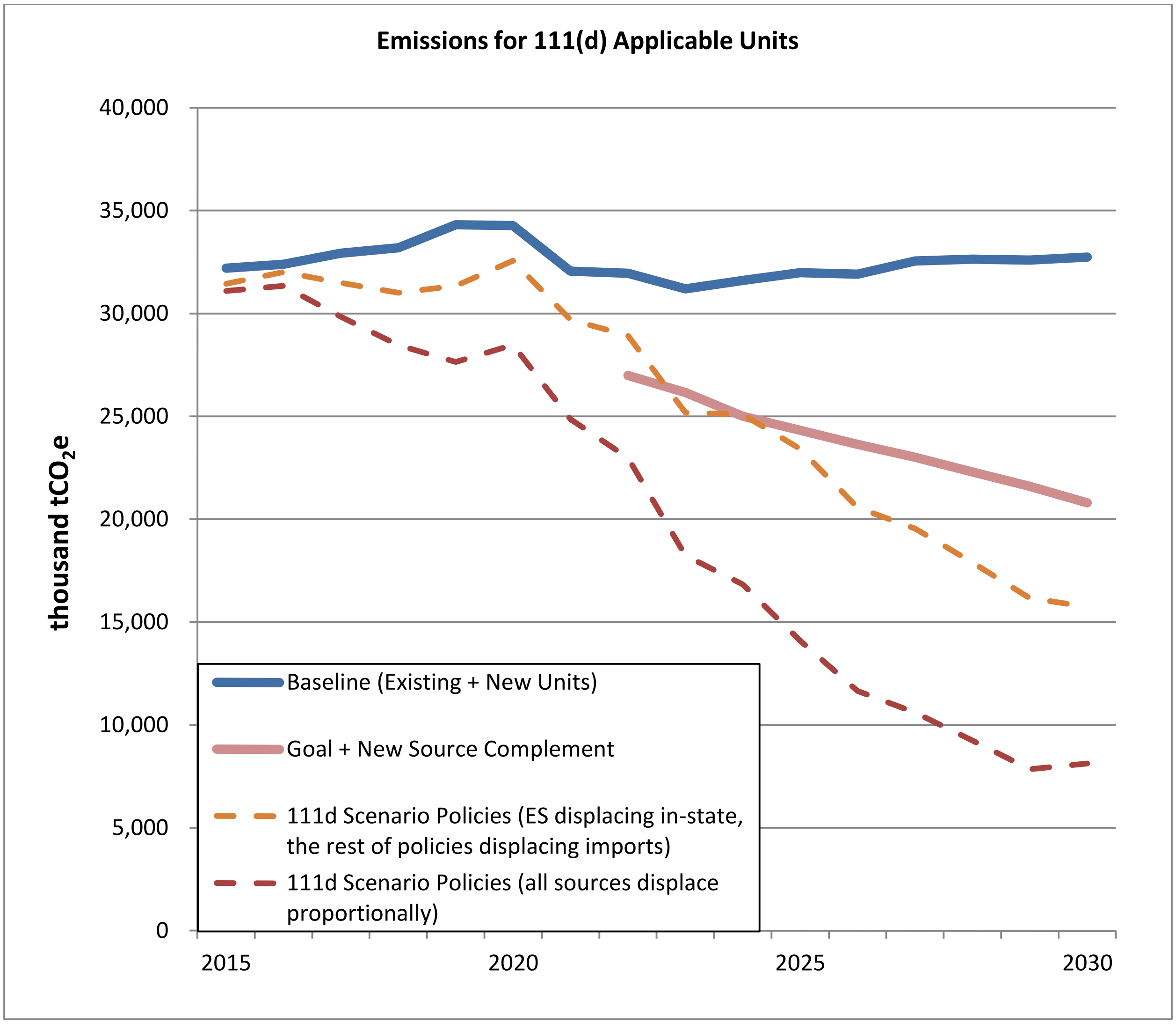
Notes:
Clean Power Plan (referred to as 111d in graph) Scenarios include comprehensive effects of CSEO policy options that affect electricity supply and demand, adjusted as necessary, including: ES-1, ES-2, RCII-1, RCII-2, RCII-4, TLU-2, FOLU-3, WM-1, WM-2, WM-3 and AG-4/AG-5.

The dashed lines present CSEO policy impacts under two geographic displacement scenarios on a mass-basis for the overall MN electricity sector CO_2 emissions. Rate based evaluations are available in the report and appendices.

The blue solid line presents an estimated MN CO_2 and energy baseline, using marginal resource mix assumptions provided by MPCA.

The red solid line presents Clean Power Plan goal calculated for Minnesota, expressed as mass-based CO_2 emissions pathway.

Figure V-2 Emissions for 111(d) Applicable Units Under a Mass-Based Approach



Notes:

Clean Power Plan (referred to as 111d in graph) Scenarios include comprehensive effects of CSEO policy options that affect electricity supply and demand, adjusted as necessary, including: ES-1, ES-2, RCII-1, RCII-2, RCII-4, TLU-2, FOLU-3, WM-1, WM-2, WM-3 and AG-4/AG-5.

The dashed lines present CSEO policy impacts under two geographic displacement scenarios on a mass-basis for the overall MN electricity sector CO_2 emissions. Rate based evaluations are available in the report and appendices.

The blue solid line presents an estimated MN CO_2 and energy baseline, using marginal resource mix assumptions provided by MPCA.

The red solid line presents Clean Power Plan goal calculated for Minnesota, expressed as mass-based CO_2 emissions pathway.

The two graphs above show both compliance and non-compliance pathways modeled under different assumptions pertaining to what electricity will be displaced by implementing CSEO policies: in-state generated electricity, out-of-state electricity imports, or both with different ratios (detailed explanation of these crucial assumptions is provided under “quantification methods” section in the Appendix F-7). The first graph shows the changes in the average state emissions rate of the existing 111(d) applicable electricity generation fleet in Minnesota as a result of introduction of zero emission, renewable sources, and the demand side energy efficiency measures. This is consistent with the EPA’s approach to calculating state specific emission rate goals based on averaging of subcategory specific emissions performs rates[9].

The second graph shows changes in the total amount of annual CO_2 emissions from 111(d) applicable MN generation (mass-based approach with the source complement) as a result of implementing CSEO policies that affect electricity supply and demand. EPA establishes equivalency between this mass-based and rate-based targets, and both are derived from the application of best system for emissions reductions (BSER)[10]. As a result of BSER application, the expected emissions limits in each year are quantified for the interim period (2022-2029) and the final period (2030 and beyond). These limits are shown in both graphs as solid red line (for the rate-based approach) and the solid orange line (for the mass-based approach). Solid blue lines represent Minnesota’s electricity sector baseline, estimated using marginal electricity resource mix and other relevant assumptions provided by MPCA.

Both graphs indicate that two policy scenarios (light green and brown colors) that combine all the mentioned CSEO policies realized under different displaced electricity assumptions, enable the Minnesota to comply with the goals set by the Clean Power Plan in the final compliance period, while one of them (ES + EE policies-all sources offset proportionally) establishes compliance even during the interim period. This is also true under the mass-based (with new source complement) approach. At the same time, if the state decides not to implement these policies, the compliance gap between Clean Power Plan goal and the baseline remains large (estimated baseline emissions in 2030 are 32,766,605 tCO2e, whereas the estimated Clean Power Plan target for that year is 20,573,680 tCO2e), assuming the state continues with business as usual only.

Table V-1 and Table V-2 below are quantitative translation of the above graphs. Table V-1 represents the rate-based case (this time we express the emission rates in lbs CO2e/MWh the same way EPA does in its final rule) and Table V-2 contains the outcomes for the mass-based

---

[9] Environmental Protection Agency. (2015, October 23). Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units; Final Rule. *80*. 161. Retrieved from https://www.gpo.gov/fdsys/pkg/FR-2015-10-23/pdf/2015-22842.pdf

[10] Environmental Protection Agency. (2015, October 23). Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units; Final Rule. *80*. 6. Retrieved from https://www.gpo.gov/fdsys/pkg/FR-2015-10-23/pdf/2015-22842.pdf

case. The years chosen are: the assumed beginning of the policy implementation period (2015), the middle of the Clean Power Plan interim period (2025), and the beginning of the Plan's final period (2030). Scenarios ES-2 + RE/EE (all sources offset proportionally) and ES-2 + RE (offset in-state) / EE (offset imports) both individually allow Minnesota to achieve compliance with the EPA's 111(d) rule targets for the state in the final period. This is true whether the state opts for the state rate-based or the mass-based approach.

Table V-1 Forecasted Emission Rates for Baseline, Clean Power Plan Goal Scenario, and Different CSEO Policy Scenarios

Scenarios	Units	Year		
		2015	2025	2030
Baseline (Existing Units)	lbs CO2e/MWh	2,007	1,925	1,861
CPP Goal	lbs CO2e/MWh		1,424	1,213
After ES-2	lbs CO2e/MWh	2,007	1,599	1,547
After ES-2 + ES-1 (RE, all sources offset proportionally)	lbs CO2e/MWh	1,973	1,453	1,337
After ES-2 + RE/EE (all sources offset proportionally)	lbs CO2e/MWh	1,939	1,009	555
After ES-2 + RE (offset in-state) / EE (offset imports)	lbs CO2e/MWh	1,959	1,392	1,100

Notes:

- Acronym "EE" means "energy efficiency" and comprises all the policies that reduce demand for electricity on the grid to various degrees, among other actions and economic impacts they cause. As noted in the first page of this chapter, these are all RCII policies, TLU-2, FOLU-3, AG-4, WM-1, WM-2 and WM-3.
- The cell reserved for CPP scenario emission rate for 2015 is intentionally left empty, since the CCP compliance period starts in 2022.

Table V-2 Forecasted Mass-based Emissions for Baseline, Clean Power Plan Goal Scenario, and Different CSEO Policy Scenarios

Scenarios	Units	Year		
		2015	2025	2030
Baseline (Existing + New Units)	tCO2e	32,208,028	31,981,444	32,746,153
Mass Goal + New Source Complement	tCO2e		24,320,241	20,803,024
After ES-2	tCO2e	32,208,532	26,750,241	27,514,962
After ES-2 + ES-1 (RE, all sources offset proportionally)	tCO2e	31,662,881	24,391,627	24,026,089
After ES-2 + RE/EE (all	tCO2e	31,092,564	14,103,026	

sources offset proportionally)				8,126,943
After ES-2 + RE (offset in-state) / EE (offset imports)	tCO2e	31,441,561	23,424,943	15,746,795

Notes:
tCO2e are metric tons of CO_2 equivalent.
Acronym "EE" means "energy efficiency" and comprises all the policies that reduce demand for electricity on the grid to various degrees, among other actions and economic impacts they cause. As noted in the first page of this chapter, these are all RCII policies, TLU-2, FOLU-3, AG-4, WM-1, WM-2 and WM-3.
The cell reserved for Clean Power Plan scenario emission-based value for 2015 is intentionally left empty, since the Clean Power Plan compliance period starts in 2022.

Cost effectiveness

The aggregate cost effectiveness (CE) value for the scenario "ES-2 + RE/EE (all sources offset proportionally)" was calculated to be -$2.0/ton CO_2 e. This scenario comprises all the CSEO policies that affect electricity generation and emissions (ES-1 and 2, RCII -1,2 and 4, TLU-2, WM-1 ,2 and 3, FOLU-3, and AG-4/AG-5 policies) within the confines of the Section 111(d) rule, Clean Power Plan (CPP). The negative sign indicates that the package of CSEO policies that allow Minnesota to comply with the CPP, when implemented, achieve net cost savings of $2 per ton of CO_2 e they reduce over the modeling period.

As explained in Appendix E, Policy Quantifications Principles Guidelines, the CE metric for each policy is calculated by dividing its NVP values with its cumulative GHG reductions achieved by that policy, which produces values expressed in $/ ton of CO_2 e. For the purposes of CPP compliance, only the electricity system related GHG reductions for each policy achieves are derived, and then those values are used to calculate CPP related cost effectiveness. Individual policy CE values used in this section for the calculation of the aggregate CE related to compliance with CPP are different then the total CEs of each policy, which consider all GHG reductions each policy achieves (not just those related to the electricity system and 111(d) rule limitations).

The contribution of each policy to complying with the CPP (expressed as a percentage of the total contribution) are shown in the table below.

Table V-3 Contribution of Individual Policies to Complying with 111(d) (in %)

ES-2	17.41
ES-1	22.94
RCII-1	23.36
RCII-2	21.13
RCII-4	12.15

TLU-2	2.10
FOLU-3	0.96
WM-1	0.38
AG-4/AG-5	N/A
WM-2	N/A
WM-3	N/A

Table above shows that ES and RCII polices achieve the greatest reduction in GHG emissions related to affected EGUs and have the greatest contribution to Minnesota CPP compliance. Since AG-4/AG-5, WM-2 and WM-3 policies increase the demand for electricity and increase the electricity system emissions (to a small extent), for those policies the contribution calculation is not applicable as a GHG reduction but is included in net effects within the sectors.

Macroeconomic Impacts of CPP Set of Policies

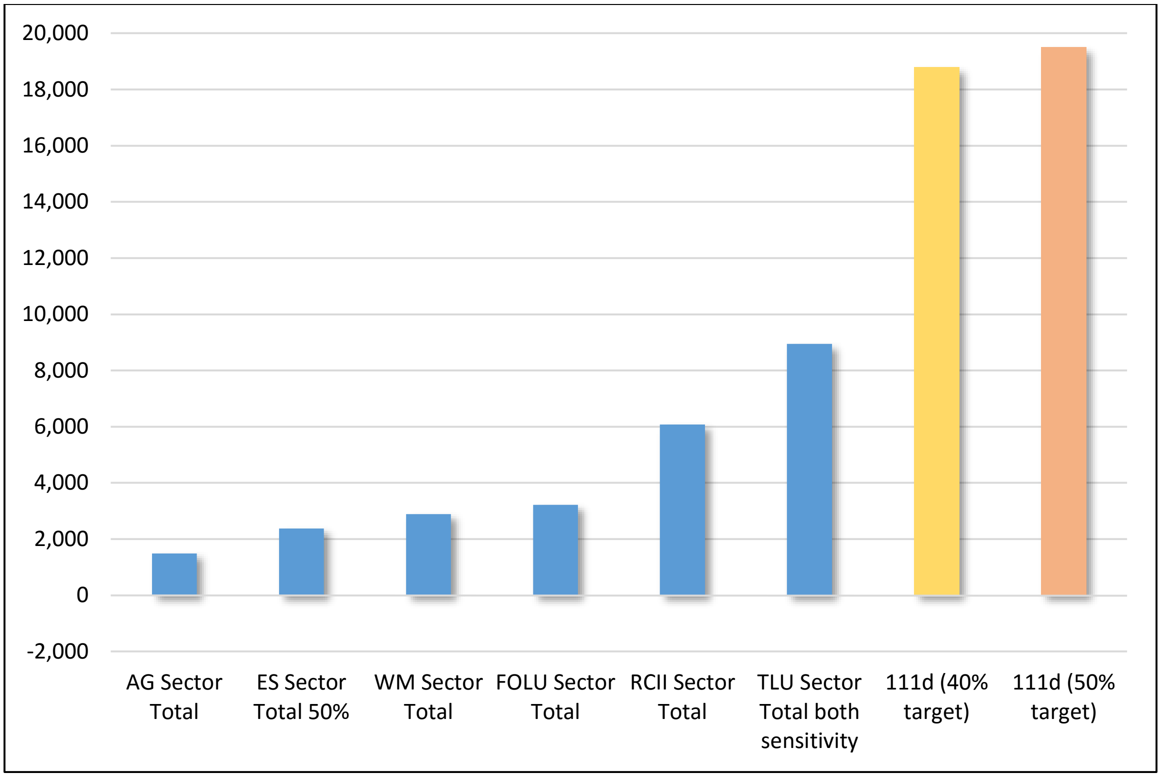
In addition to macroeconomic analyses of individual options, CCS utilized the Regional Economic Models, Inc. (REMI) PI+ software to also assess potential macroeconomic impacts of the package of CSEO options relevant to compliance with the CPP. Table below summarizes the results of that analysis. It shows estimated CPP policy package's impact on GSP, employment and total earned income in the state.

Table V-4 Macroeconomic (Indirect) Impacts of Clean Power Plan

Macroeconomic (Indirect) Impacts Results									
Scenario	Gross State Product (GSP, $2015 Millions)			Employment (Full & Part-Time Jobs)			Income Earned ($2015 Millions)		
	Year 2030[d]	Average (2016-2030)[e]	Cumulative (2016-2030)[f]	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)
CPP (ES-1 40%)	$2,669	$ 1,831	$ 27,463	26,480	18,796	281,940	$2,605	$ 1,604	$ 24,063
CPP (ES-1 50%)	$2,894	$ 1,914	$ 28,716	28,140	19,507	292,610	$2,798	$ 1,672	$ 25,078

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 2016-2030 time period.

Figure V-3 Average Annual Jobs Impact of 111(d) Scenarios vs. Sector Impacts



Macroeconomic index

Graphs below present the overall macroeconomic impacts of the set of CSEO policies relevant to the compliance with the CPP.

The overall economic impact from each scenario is expressed by 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 2016-2030 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 remains visible as differently-shaded segments of that line.

Figure V-4 Macroeconomic Indicators, Final Year 2030

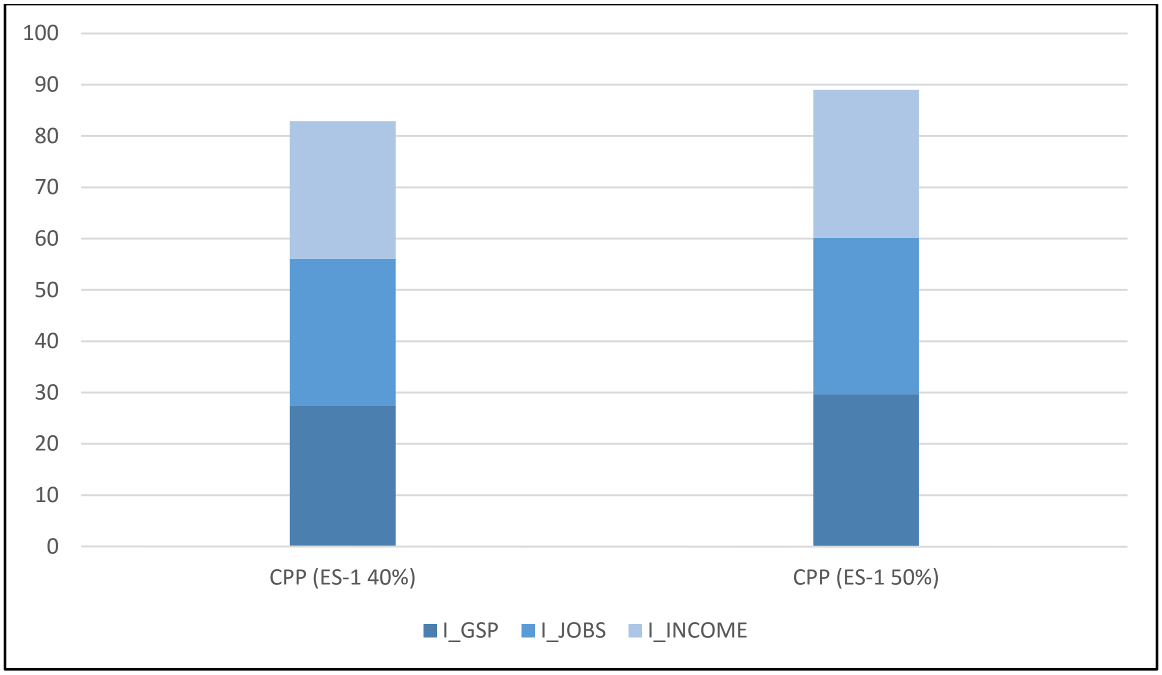


Figure V-5 Macroeconomic Indicators, 2016-2030

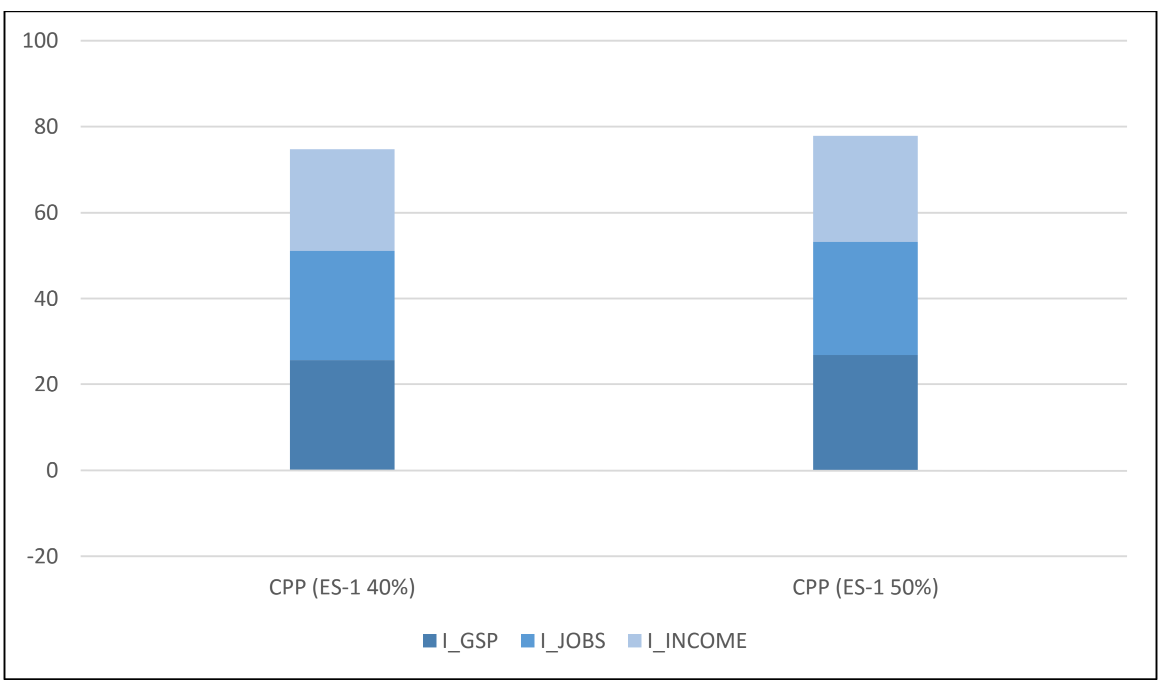
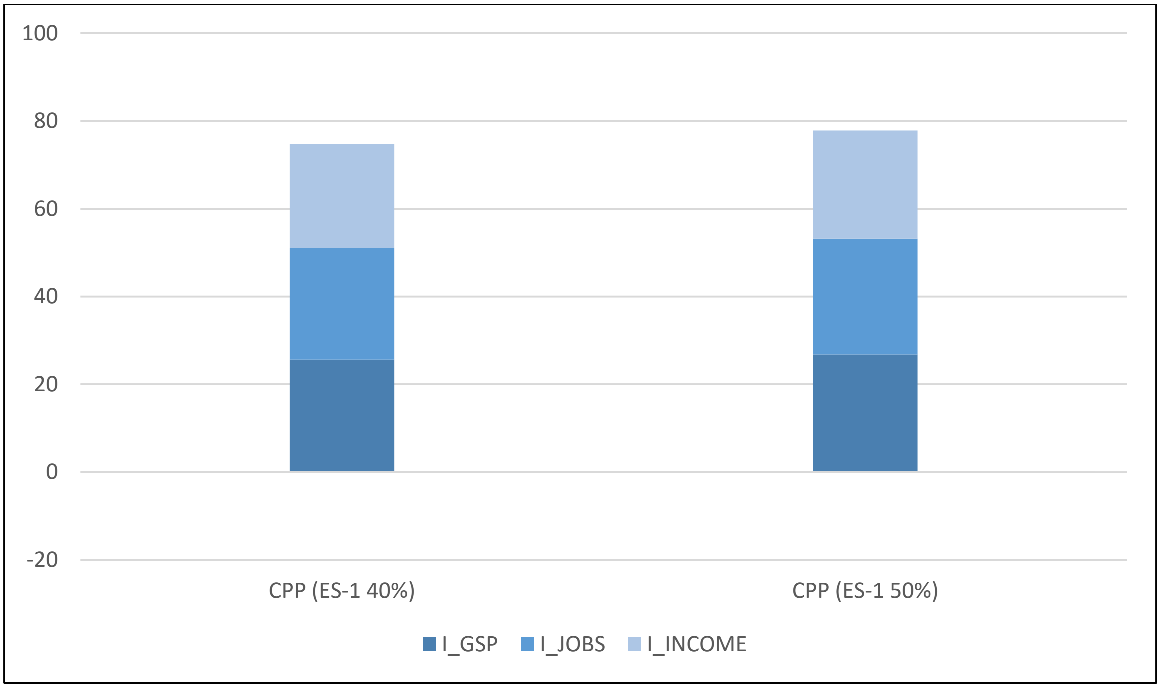


Figure V-6 Macroeconomic Indicators, Average Annual



Graphs below show the trend of CPP policies impacts during the year 2015 to the year 2030.

Figure V-7 CPP GSP Impacts ($2015 MM)

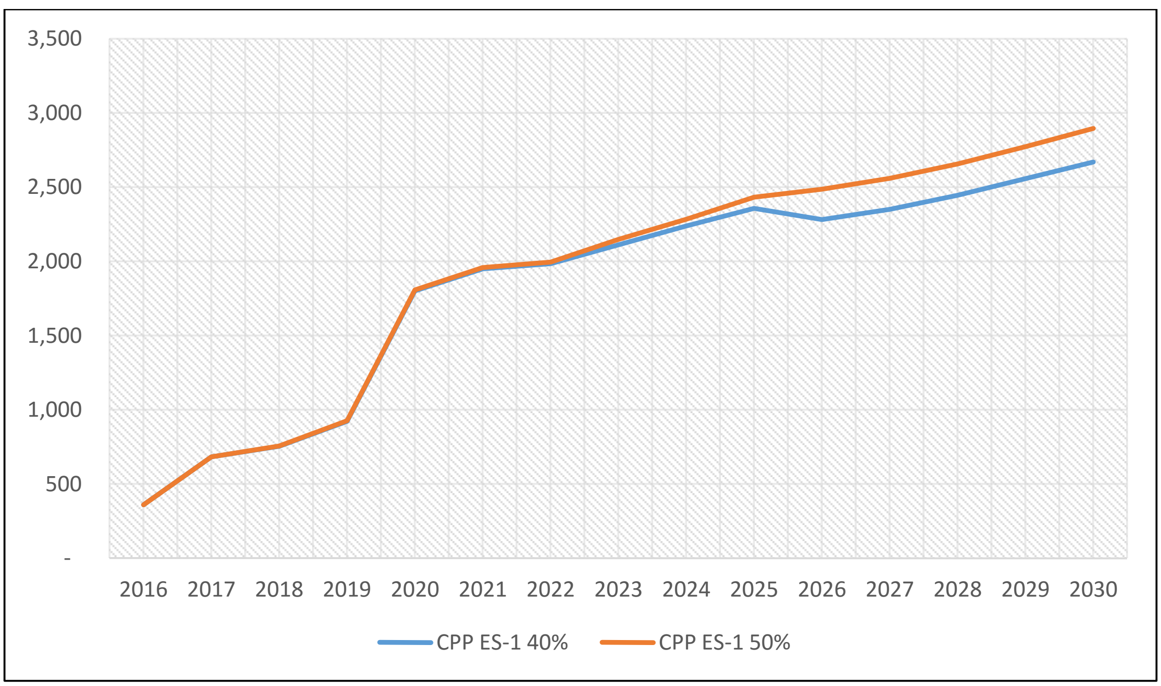


Figure V-8 CPP Employment Impacts 2016-2030 (Jobs)

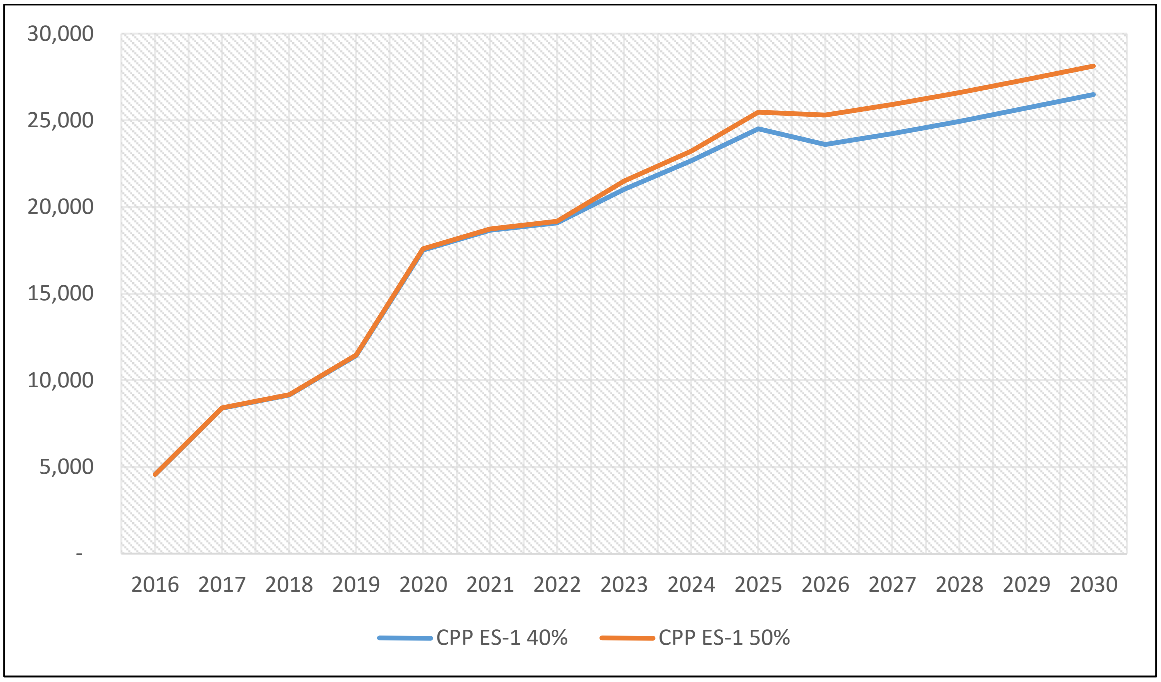
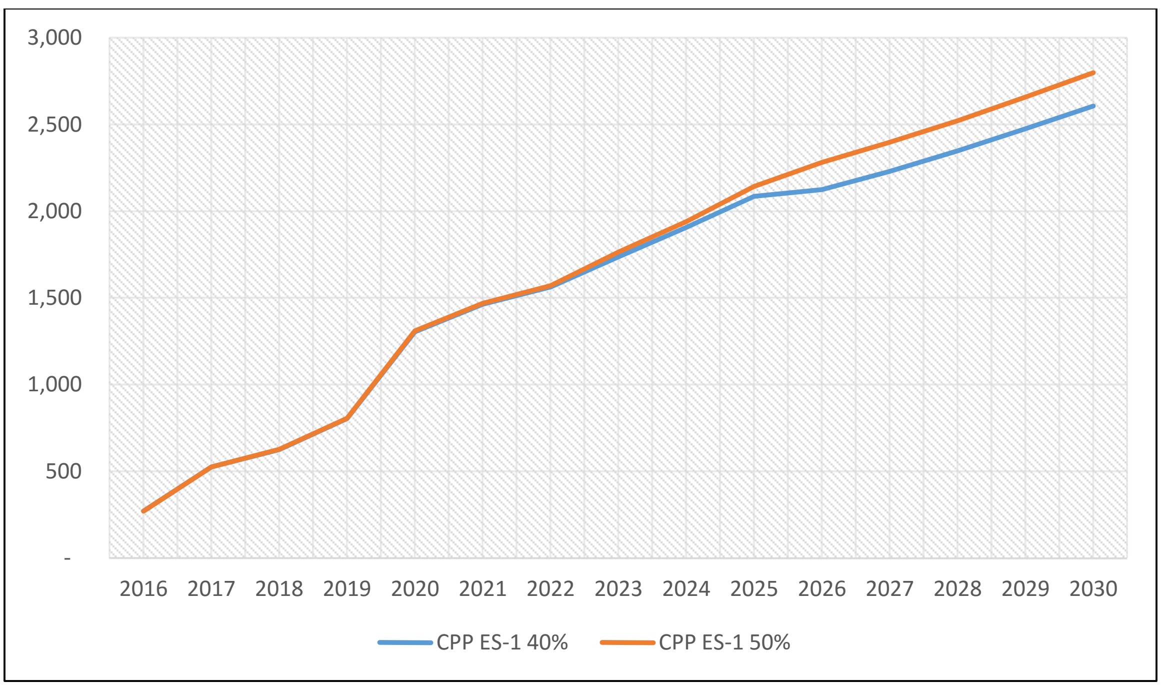


Figure V-9 CPP Income Impacts ($2015 MM)



Bar charts that follow show macroeconomic impacts of CPP policies on GSP, personal income, and employment in the final year (2030), average (2016-2030) and cumulative (2016-2030). Light color indicates sensitivity scenarios.

Figure V-10 CPP GSP Impacts, Year 2030 ($2015 MM)

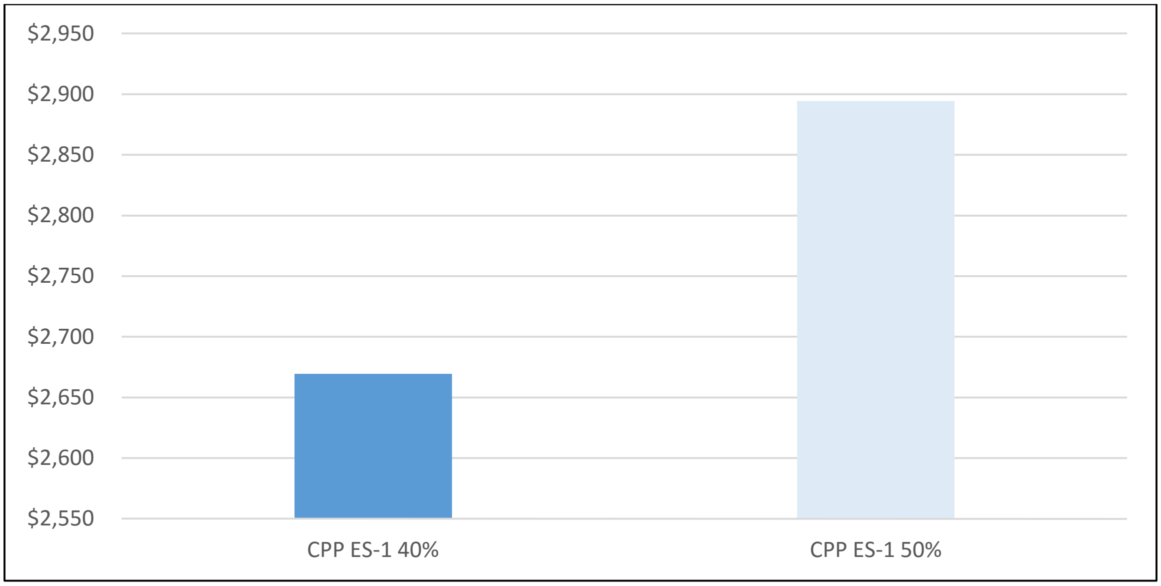


Figure V-11 CPP GSP Impacts, Average Annual ($2015 MM)

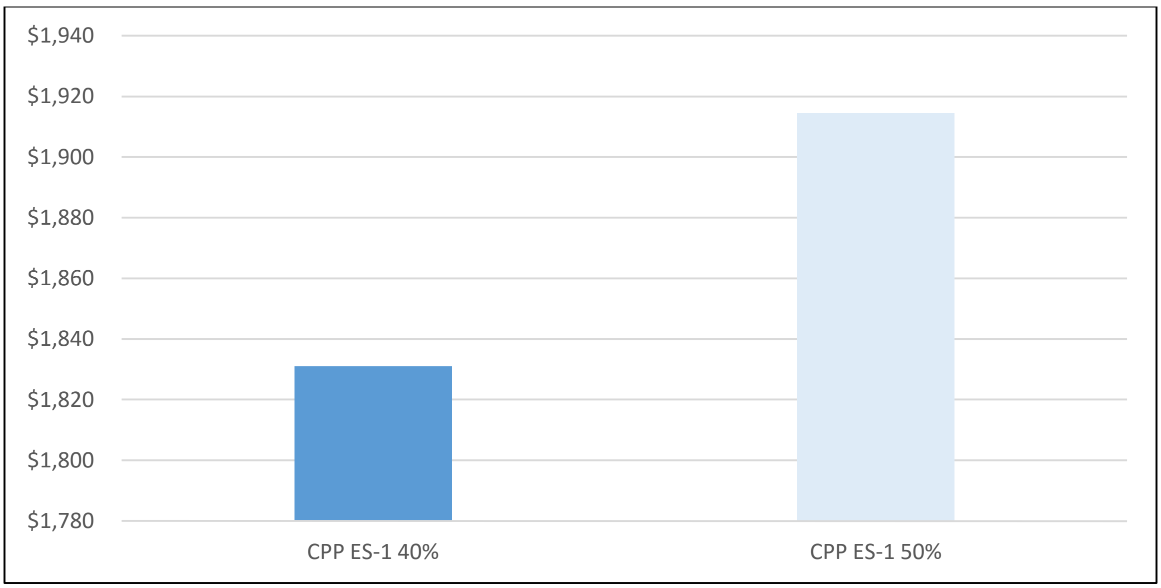


Figure V-12 CPP GSP Impacts, 2016-2030 ($2015 MM)

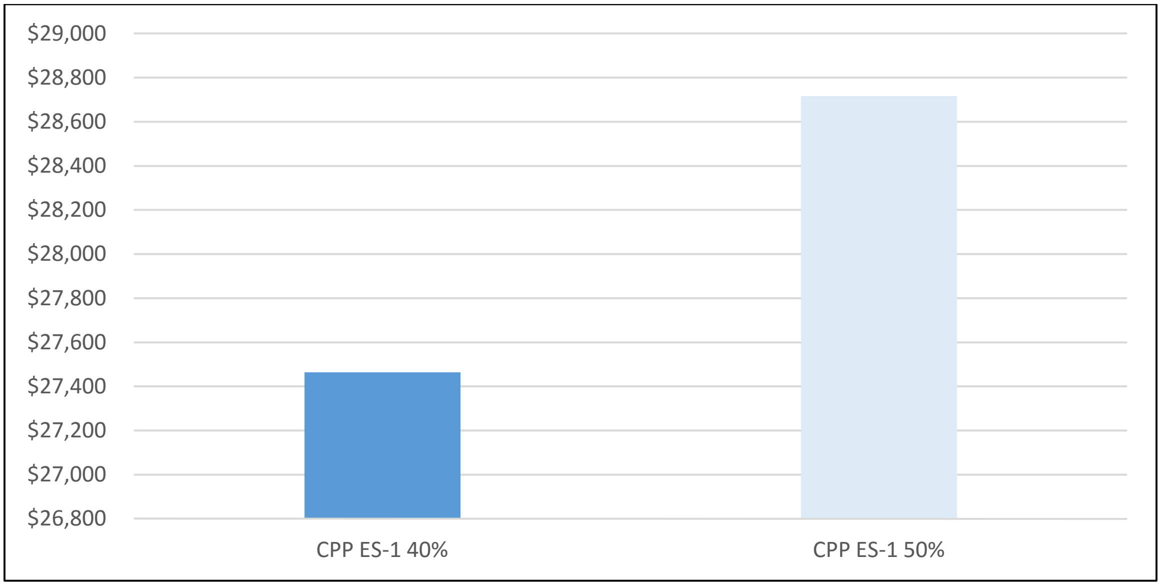


Figure V-13 CPP Employment Impacts, Year 2030 (Jobs)

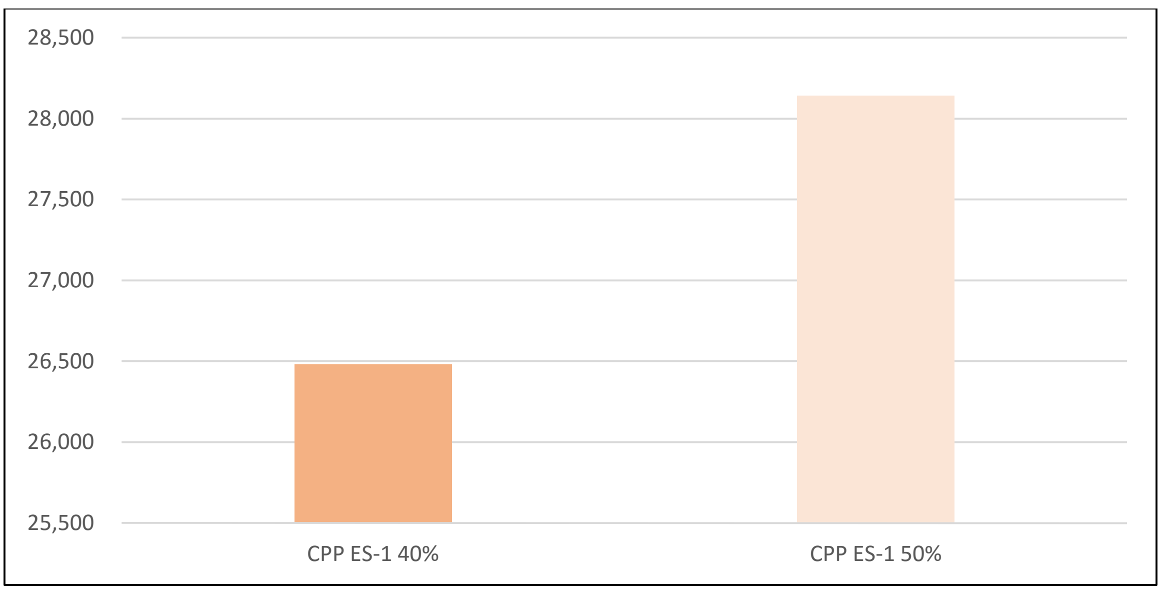


Figure V-14 CPP Employment Impacts, Average Annual (Jobs)

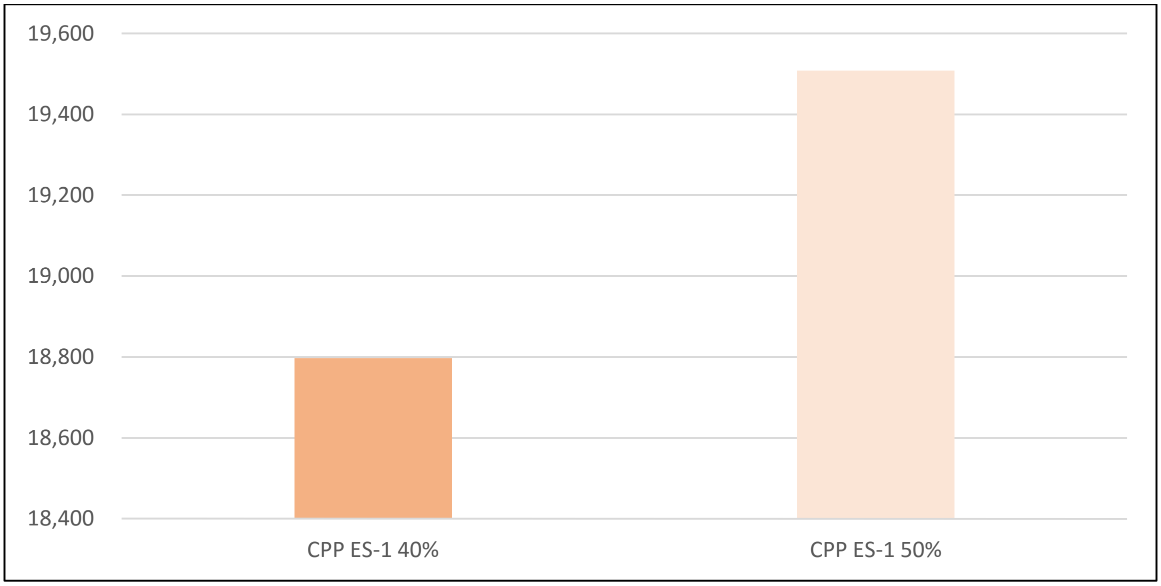


Figure V-15 CPP Employment Impacts, 2016-2030 (Job Years)

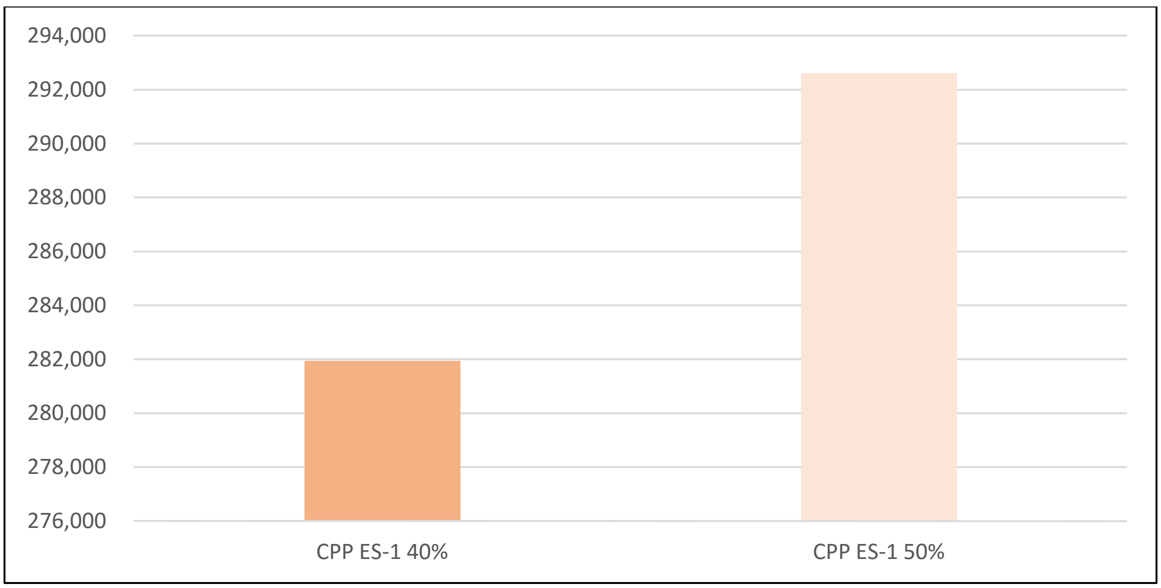


Figure V-16 CPP Income Impacts, Year 2030 ($2015 MM)

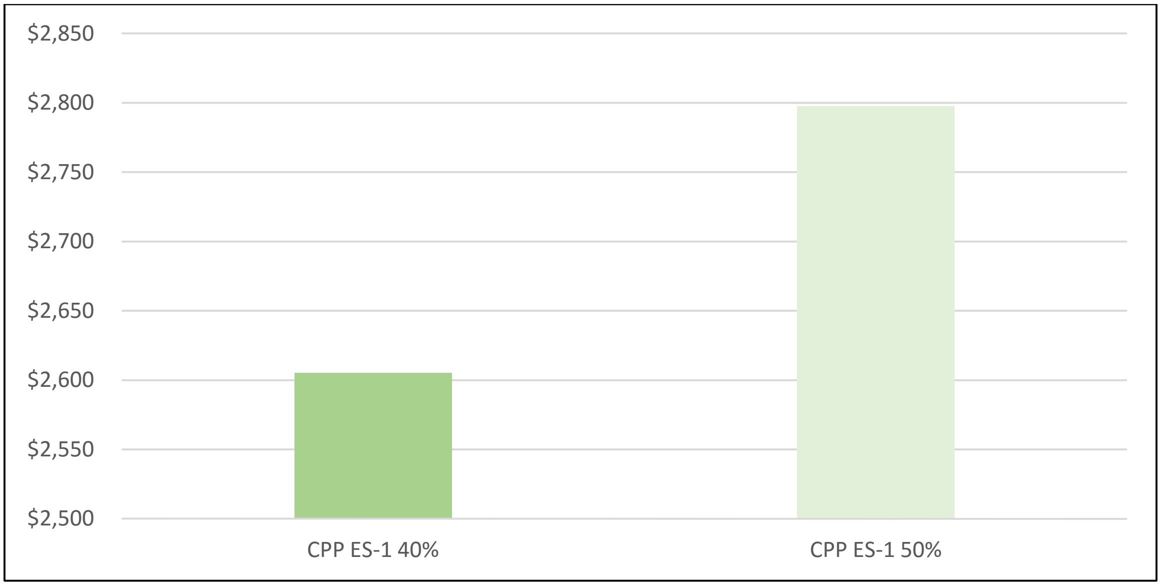


Figure V-17 CPP Income Impacts, Average Annual ($2015 MM)

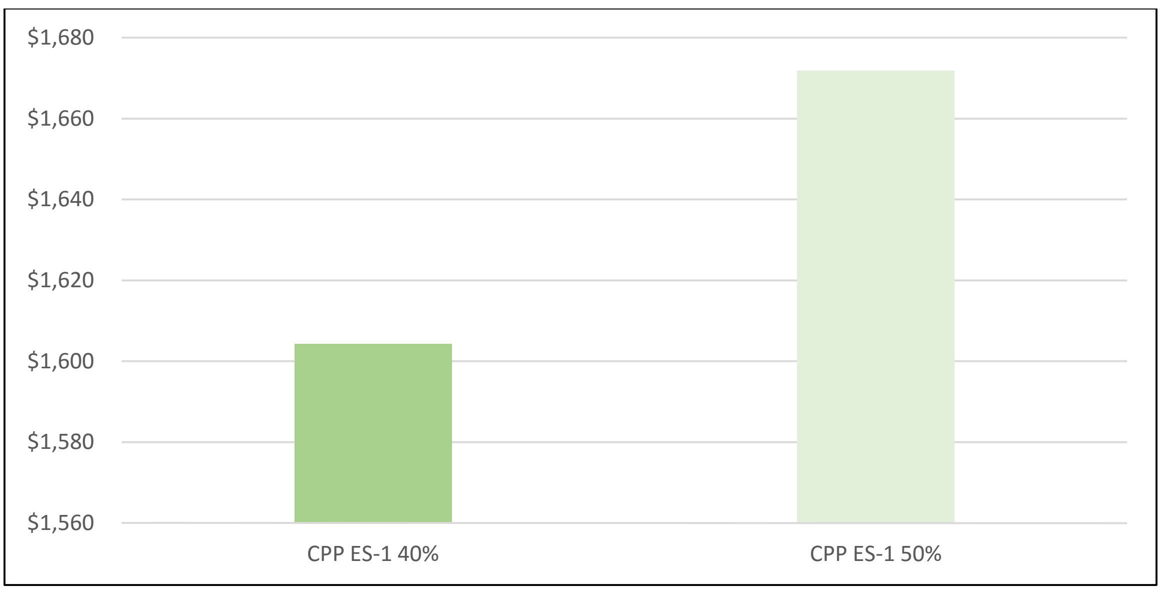
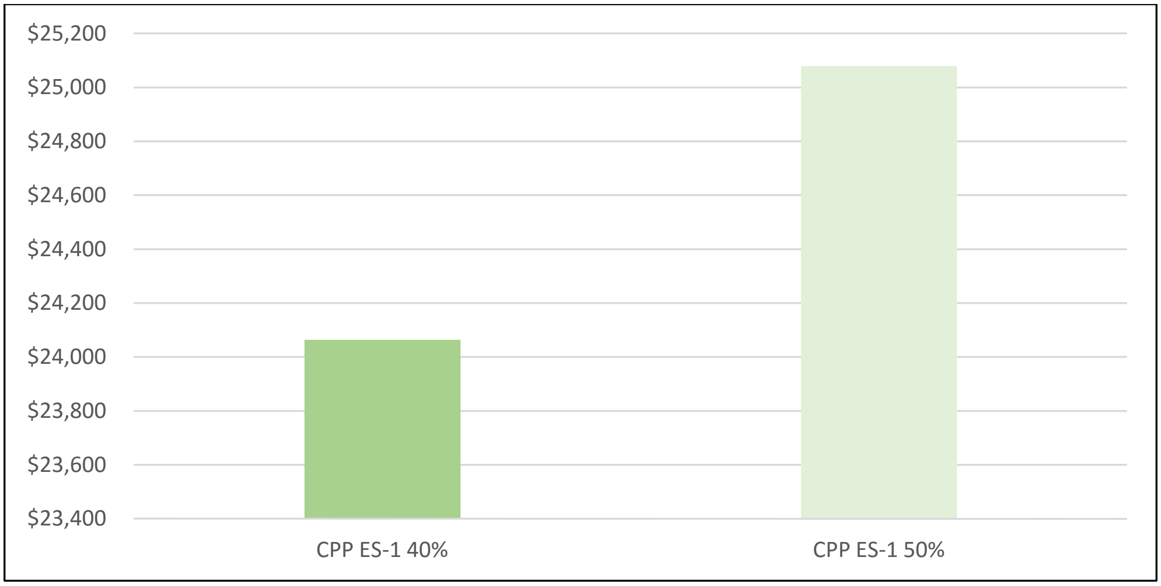


Figure V-18 CPP Income Impacts, 2016-2030 ($2015 MM)



Principal Drivers of Macroeconomic Changes

These Clean Power Plan Scenarios represent combinations of policies described in other chapters and their respective appendices. Policies evaluated under the 111(d) compliance analysis are ES 1 and 2, and EE policies, which comprise RCII 1, RCII-2, RCII-4, FOLU-3, TLU-2, AG-4, WM-1, WM-2 and WM-3. The principal drivers, consequently, are those described within those discussions of macroeconomic impact. Those influences (such as the cost-saving shift involved in ES-1 or the energy-efficiency impacts of the RCII policies) remain in place in the CPP analysis, which simply aggregates into a single scenario (with some integrations to represent the integrative effects identified in the microeconomic analysis) these policies and their major influences on the larger Minnesota economy.

Sectors Most Impacted by This Policy

The direct impacts from the individual policies that we saw before remain present, in general. The construction sector continues to grow rapidly, seeing large gains in size and in the number of people it employees. Chemical manufacturing, which captures the growth in biofuels production, remains a growing sector in the Clean Power Plan scenarios, as that biofuels production is just as present in the combined analysis as it was in the individual analysis.

By contrast, utilities still see smaller scale in demand, and thus require less inputs and labor to carry out their business. The Waste Management policies also bring direct reductions in the scale of the waste disposal sectors, as their goal of reducing and diverting the waste stream reduces the amount to be hauled, tipped and disposed in landfills.

The Clean Power Plan scenarios end up capturing most of the policies that produce significant savings to households and businesses, and a familiar profile of gains – reflecting the availability of more money in pocket and more capacity to spend on the part of households – appears. The greatest indirect gains in employment are in retail sales, health care, clothing and food service, as well as direct hiring by homes; gains in these are all solid indicators that money saved elsewhere has made itself useful in popular consumer-spending destinations. Educational, financial and other services focusing on longer-term returns to consumers also see significant gains, but are less labor-intensive per dollar, and so the job growth there is not as steep.

Businesses, likewise, show signs that their overall costs to operate fall under this scenario rather than rise. Gains in white collar fields, such as management and administrative support, indicate expansion that comes with lower overall costs. The combination of ES-1's reduction in costs to produce electricity along with the lower costs associated with efficiencies from the RCII sector and less demand for waste and other services drives a structural shift toward lower costs that even some less successful policies (such as ES-2, which raises utility costs to produce a bit) do not fully offset.

Policy Option Impacts on Adaptation

Climate adaptation and climate mitigation are closely linked, with many climate mitigation actions having climate adaptation impacts as well as reducing greenhouse gas emissions. The table below outlines some of the key climate adaptation benefits of the CSEO actions, in particular as these relate to Community and Ecosystem Resilience. The footnotes to the table provide some additional clarification about these adaptation benefits.

Table V-5 Community Resilience Co-Benefits of CSEO Policy Options

	Community Resilience Co-Benefits						
CSEO Category	Improve Extreme Weather Resilience	Increase Self-Sufficiency for Energy or Supply Chain Needs	Greater Economic Resilience with More $ Staying in Local Economy	Increase Water Availability/Reduce Drought Impacts	Reduce Need for Infra-structure Investment	Increase Use of Multi-Modal, Non-Motorized Pathways and Healthy Living Behaviors	Reduce Degradation of Air Quality and Other Urban Heat Island Impacts
Agriculture Sector							
AG-1 Nutrient management			X[23]				
AG-2 Healthy soils				X[1]			
AG-5 Biofuels		X	X				X
Forestry Management							

FOLU-1 Protect peat lands							
FOLU-2 Forest thinning		X[3]		X			
FOLU-3 Community forests	X			X	X[5,6]	X	X
FOLU-4 Disturbance response		X[3]		X			
FOLU-5 Conservation		X[8]					
Waste Sector							
WM-1 Water efficiency	X			X	X		
WM-2 Wastewater		X	X				
WM-3 Waste management	X	X	X				
Land Use and Transportation							
TLU-1a Pay as you drive						X	X[12]
TLU-1b Carbon Tax on fuels	X[13]					X	X[12]
TLU-1c Fuel sales tax	X[13]					X	X[12]
TLU-2 Metro densification					X	X	X[12]
TLU-3 Draft 2040 plan					X	X	X[12]
TLU-4 Electric vehicles	X[15]	X	X[16]				X[12]
Energy Supply Sector							
ES-1 Increase RES	X[18]	X[15]	X[15]	X[19]			X
ES-2 Coal plant retirement							X
ES-3 EPA Clean Power Plan	X	X	X		X		X
Demand Side Energy Efficiency							
RCII-1 CHP	X	X	X	X[19]	X[6,20]		X
RCII-2 Zero Energy Ready		X	X	X[21]	X[6]		X
RCII-4 Increase EE		X	X	X[21]	X[6]		X
RCII-5 Thermal renewables	X[15]	X[22]	X		X[6]		

Table V-6 Ecosystem Co-Benefits of CSEO Policy Options

	Ecosystem Co-Benefits					
CSEO Category	Improve Biodiversity/Wildlife Habitat and Resistance to Pests	Improve Surface/ Ground Water Quality	Reduce Soil Erosion	Increase Resilience of Ag and Forestry Production	Reduce Wildfires	Reduce Flooding
Agriculture Sector						

AG-1 Nutrient management	X[24]	X[24]		X[23]		
AG-2 Healthy soils	X[2]	X[1]	X[1]	X[1]		X[1]
AG-5 Biofuels						
Forestry Management						
FOLU-1 Protect peat lands	X	X			X	X
FOLU-2 Forest thinning	X	X	X	X[4]	X	
FOLU-3 Community forests	X	X	X			X
FOLU-4 Disturbance response	X	X	X	X[7]	X	
FOLU-5 Conservation	X	X	X	X[9]		X
Waste Sector						
WM-1 Water efficiency		X		X[10]		
WM-2 Wastewater						
WM-3 Waste management	X	X				
Land Use and Transportation						
TLU-1a Pay as you drive						
TLU-1b Carbon Tax on fuels						
TLU-1c Fuel sales tax						
TLU-2 Metro densification	X[14]	X				
TLU-3 Draft 2040 plan						
TLU-4 Electric vehicles		X[17]				
Energy Supply Sector						
ES-1 Increase RES		X		X	X[11]	
ES-2 Coal plant retirement		X				
ES-3 EPA Clean Power Plan				X		
Demand Side Energy Efficiency						
RCII-1 CHP		X		X	X[11]	
RCII-2 Zero Energy Ready		X				
RCII-4 Increase EE		X				
RCII-5 Thermal renewables					X[11]	

Notes:

1 Healthy soils with high organic carbon content have high infiltration rates and greater water holding capacities. These characteristics reduce runoff and soil erosion. Organic matter improves soil structure and makes it more resilient to erosive effects of wind and water.

2 Cover crops can reduce pest outbreaks by providing enhanced bio-control that promotes the growth and survival of beneficial insects.

3 Makes more woody biomass available for use in home and commercial heating.

4 Favors tree species expected to do better under changed climate conditions and improves overall forest health.

5 Urban forests can reduce stormwater management needs.

6 Reduces the need for expanding utility power generation, transmission and distribution systems due to reduced cooling loads, greater energy efficiency, more distributed generation, and/or increased renewable energy supplies.

7 Focuses on rapid restoration of productive capacity of forests following disturbance.

8 Grassland conservation is part of a cellulosic feed stock supply chain strategy.

9 Forest conservation reduces fragmentation and loss of capacity to manage forests, better enabling effective harvest and adaptation management - providing for sustainable long term fiber supply. Grassland conservation also provides for a forage reserve for livestock producers. Conserved lands can be accessed for emergency haying and grazing as floods and droughts impact other forage supplies.

10 Conserving groundwater resources through more efficient water use will better ensure the sustainability of water resources utilized for agricultural irrigation.

11 Some benefits of woody biomass use could include healthier forests through better, cost-effective forest management practices that mitigate the occurrence/severity of wildfires.

12 Research indicates that stronger urban heat island effects impact both higher density urban areas and lower density sprawling urban areas.

13 Given the many risks to infrastructure condition from extreme weather, more funds could be available to upgrade and maintain infrastructure thus reducing vulnerability.

14 More compact development would prevent or slow growth on the urban edge, thus preserving existing habitat.

15 Diversifying the fuel supply and increasing locally available renewables will result in improved resiliency during extreme weather events, disruption to fossil fuel distribution, or other emergencies.

16 Relying on electricity for a portion of our vehicle fleet will result in some of the fuel production being sourced from local renewable energy like solar and wind.

17 Vehicles with zero emissions will lead to fewer pollutants impacting water quality.

18 Wind or solar power generated as distributed generation on site, versus as electricity from the grid, increases resilience to extreme weather impacting the grid system.

19 Electricity generation at a utility-scale requires significant amounts of water for various parts of the energy production process including extraction, processing and cooling. More renewable energy and/or CHP systems can off-set some of the water requirements for current energy production.

20 Reduces demand on the water distribution system. (Many CHP systems require significantly less water for cooling purposes or are air cooled and can alleviate some of the water demand required for coal-fired generation.)

21 Measures such as low flow faucet aerators, water distribution system efficiency, condensing hot water heaters, industrial process efficiency, etc. can lead to reduced water consumption.

22 Renewable thermal energy can help mitigate volatility in both pricing and fuel supplies by reducing the state's reliance on conventional fuels, and also mitigate risks associated with fuel shortages due to tightened domestic supplies.

23 Proper nitrogen management through increased nitrogen use efficiency is an important factor in profitability and long term viability of crop production.

24 Increased nitrogen uptake by the crop will reduce nitrogen which would otherwise move into the environment and could have a negative impact on plants, animals, surface waters, and groundwater. Vigorous cropping systems also provide protection from pests.