Appendix G
Recommendations for Market-Based Policies

Summary List of MCAC Policy Recommendations

No.	Policy Recommendations		GHG Reductions ($MMtCO_2e$)			Net Present Value 2009–2025 (Million $)	Cost-Effective-ness ($/tCO_2e$)	Level of Support
			2020	2025	Total 2009–2025			
MBP-1	Cap and Trade	20% below 2005 by 2020 (*Free-Granting Allowances*)[1]	92.48				–$25.83	Unanimous
		20% Below 2005 by 2020 (*Auctioning Allowances)*[2]	92.48				–$19.33	
MBP-3	Michigan Joins Chicago Climate Exchange		*Not Quantified*					Unanimous
MBP-6	Market Advisory Group		*Not Quantifiable*					Unanimous

Note: The numbering used to denote the policy recommendation is for reference purposes only; it does not reflect prioritization among these important recommendations.

[1] These results include mitigation costs, including payments or revenues resulting from the purchase or sale of allowances between Michigan emitters and out-of-state Midwestern Governors Association (MGA) partners.

[2] These results include mitigation costs but do not include payments to the state by Michigan emitters for the purchase of allowances at auction. The cost and revenue implications of distribution of allowances by auction can be found in Table G-1-2 and Annex G-1.

MBP-1. Cap and Trade

Policy Description

A cap-and-trade (C&T) system works by setting an overall limit on emissions and either selling or distributing, at no cost, emission "allowances," or permits, to regulated entities or sources. These regulated entities must periodically surrender enough allowances to match their reported emissions or face a penalty. In a system that freely grants allowances, sources that can reduce their emissions at a lower cost than the allowance price may do so and may sell unused allowances to sources that cannot achieve reductions as cost-effectively. In a system where allowances are initially sold, cost-effective emission reductions reduce the number of allowances that must be purchased. Either way, C&T creates a financial incentive for emitters to continually seek out new emission-reducing options and cut their emissions as much as possible. With the creation of a market for the allowances, regulated entities have the choice of either purchasing allowances or directly reducing emissions. As a result, resources are directed to the most cost-effective emission reduction investments. To achieve overall emission reductions over time, programs gradually lower the emissions "cap" by reducing the total number of available allowances.

Perhaps the best-known example of a C&T program is the U.S. Environmental Protection Agency (EPA) program to cut sulfur dioxide (SO_2) emissions from power plants. Established under the 1990 Clean Air Act Amendments, this program successfully proved the emissions trading concept by achieving dramatic, cost-effective reductions. More recently, the trading approach has been applied to greenhouse gas (GHG) emissions by the European Union (EU)[3] and has been proposed by several U.S.-based initiatives, including the Northeast Regional Greenhouse Gas Initiative (RGGI),[4] the Western Climate Initiative (WCI),[5] and the Midwestern Regional Greenhouse Gas Reduction Accord (Midwestern Accord).[6]

Michigan is actively participating in the development of the Midwestern Accord. The policy issues confronting the Midwestern Accord partners will need to be evaluated regionally and by each partner jurisdiction, and then negotiated until agreement is reached. These recommendations are offered to advise Michigan on the key program design features that it should support in these regional negotiations.

Policy Design

The C&T policy is designed and analyzed to work in concert with non-C&T policies and measures. The integration of other policies serves to reduce compliance costs and ease attainment of goals and caps. Emission reductions, costs, and cost savings from many of these other measures help Michigan comply with the cap; they also serve as a basis for the C&T. As a

[3] http://ec.europa.eu/environment/climat/emission.htm

[4] http://www.rggi.org

[5] http://www.westernclimateinitiative.org

[6] http://midwesternaccord.org/

result, the expected operation of the C&T program is integrated with other policies and policy recommendations, and is not presented as a stand-alone program.

Ultimately the pollution-cutting performance of a C&T program depends largely on how it is structured. Key design parameters are discussed separately below.

Geographic Scope

The Michigan Climate Action Council (MCAC) encourages national action in the implementation of a C&T program for the regulation of GHG emissions. In lieu of national action, or in advance of future action, Michigan should continue to participate in and encourage the development of the Midwestern Accord program.

Michigan should not seek to create its own one-state C&T program. The benefits of the C&T program are greatest when the market has access to a large number of low-cost mitigation options. Compliance costs will generally rise as the geographic scope of the program shrinks. In addition, the smaller the program's geographic scope, the greater is the concern for "leakage" and within-region versus out-of-region competition.

Sector Coverage

It is recommended that the program have the broadest possible sector coverage as soon as possible to include the maximum possible number of low-cost mitigation and sequestration options. This would include electricity generation; industrial sources; fossil fuel extraction, processing, and transportation; transportation fuels; and residential and commercial fuel supply. The transportation fuels and residential and commercial fuel supply sectors would most likely have to be regulated upstream of the actual point of emissions. The regulated entity in the transportation and residential and commercial sectors may need to be the fuel blender, distributor, or importer. It is recognized that some sectors may not be appropriate for regulation under a C&T program, and others may be appropriate but may need to be phased-in over time. Some sectors or sources deemed inappropriate for regulation may still be included in the program through the use of offset credits, such as agriculture, forestry, and some aspects of waste management. Consideration should also be given to applying other mechanisms, such as a carbon tax, to the small subset of sources within agriculture, forestry, and waste management (AFW) that are neither regulated under the C&T program nor included within that program as available for offset purposes.

When deciding which sectors should be regulated and when, consideration should be given to:

- *Data quality*—Sectors or sources with incomplete or unreliable historic emissions data or those for whom GHG emission or related fuel consumption data have not been reported would be difficult to effectively regulate. Michigan should identify sectors and sources that are appropriate for regulation and begin collecting the necessary source data in advance of regulation to ensure that emission caps are properly set and compliance can be measured and enforced.
- *Emissions reduction potential*—Emissions from some sectors contribute relatively little to Michigan's "footprint," and may be disproportionately difficult to document and regulate. Sectors with low reduction potential should be evaluated for inclusion from the standpoint of administrative burden or other appropriate concern.

- *Data reliability*—Sectors or sources with emissions that are very difficult to measure may be exempt from regulation out of a concern for the uncertain reliability of compliance measurements. Some agriculture and forestry sources, for example, present a significant challenge to those seeking an accepted, consistent, and verifiable measurement of emissions.

Allowance Value and Distribution

The MCAC represents a diversity of views on the issue of allowance distribution. Some members believe that the free allocation of allowances to covered entities is the best and most appropriate way to minimize costs to ratepayers, consumers, and businesses. Other members believe that auctioning allowances is the most equitable and simplest distribution method, and generates revenues that can be applied in a variety of ways to promote emission reductions and protect consumers from the impact of higher energy prices. Some members believe that a combination of free allocation and auctioning would be the best approach, particularly at the beginning of the program.

Regardless of distribution method, the MCAC agrees that the *value* represented by the allowance should benefit the residents of Michigan. In the electricity sector, for example, regulated utilities would be required to pass the value of a freely granted allowance (whether used or sold) onto the ratepayer through rate setting. Freely granted allowances for unregulated electric sector sources could be distributed to regulated load-serving entities, once again relying upon rate setting to direct the economic benefit to the ratepayer. In a full or partial auction system, the revenues from the sale of the allowances could be applied in a variety of ways to benefit the residents. Examples include tax reductions or direct payments, perhaps directed largely for the benefit of low-income consumers. Other uses could include investments in energy- or climate-related technological transformation and research and development, or public investments in end-use energy efficiency, providing both energy cost and emission reduction benefits. Another suggestion for the use of auction revenues is public investment to mitigate the cost of industry and worker transition.

Given the broad sector coverage recommended here, the MCAC recognizes that the matter of allowance distribution is complex. Determining the most appropriate means of ensuring that consumers realize the economic benefit from the value of the allowance will require careful study. Distribution methods or rules may need to vary across and within sectors to ensure value is directed to the benefit of consumers and recognize the multiplicity of concerns for intra- and inter-regional competition, particularly within the industrial sector.

Offsets

Regulated sources can comply with the C&T program in three ways: they can reduce emissions directly, they can acquire and surrender allowances sufficient to cover their emissions, or they can invest in qualifying offset projects and surrender offset credits. Offset projects are undertaken voluntarily and generate revenue for the project owner through the sale of offset credits, which are equivalent to government-issued allowances. Emission reductions from regulated sources are therefore not eligible as offset projects; otherwise these reductions would be double counted, once for the benefit of the regulated source under the cap, and again for the benefit of the offset purchaser. To ensure the integrity of the emissions cap, offset projects reduce emissions or sequester carbon from uncapped, out-of-sector projects that are recognized by the program as qualifying for allowance credit. In most cases, any emissions included under any C&T program's cap cannot be reduced and also qualify as an offset credit under any other

C&T program. Offsets provide an incentive for low-cost investments in uncapped emission reductions as an alternative to higher-cost, in-sector reductions or allowance purchases.

The MCAC agrees that offsets should be part of the program, and that given reasonable assurances that the offsets would have integrity, no geographic limitations should be imposed. The MCAC also recommends that Michigan should take the lead in developing the standards and protocols for verifiable forestry-based offsets.

There was not agreement on whether the use of offset credits should be limited or unlimited. Some members supported unlimited use of offsets, citing the compliance cost mitigation benefits. Others expressed the concern that if the program allowed 100% compliance with offsets, then in-sector emission reductions would not take place. In addition, placing limits on the use of offsets would encourage the transition to new technologies within the capped sectors.

Price Mitigation Mechanisms

C&T programs often feature one or more allowance price mitigation mechanisms to provide regulated sources compliance flexibility and smooth inherent market instability, especially in the early years of the program. A good example is offsets, which serve multiple purposes, including allowance price mitigation. Other program design features that provide compliance flexibility and mitigate allowance prices include allowance banking, allowance borrowing, and allowance price caps or "safety valves." Policymakers are encouraged to further investigate and consider these mechanisms in the development of the C&T program.

Reporting

The MCAC endorses the Midwestern Governors Association (MGA) draft recommendation for participation in and use of The Climate Registry (TCR), or a similar registry that is widely deployed and recognized, as the basis for a reporting program.

Leakage

Leakage occurs when, in response to program incentives (e.g., emission caps), utilities choose to increase out-of-region fossil-based power purchases or investors choose to construct new generation units in unregulated border jurisdictions. Leakage can also occur in the manufacturing sector where sources subject to GHG reduction requirements move to jurisdictions with lesser or no GHG reduction requirements, including areas outside the United States. In either case, both the environmental benefits and in-state investment are lost. Under a national program, leakage for utilities becomes a minor issue, but remains a major issue for carbon-intensive manufacturing that can relocate to areas with less stringent environmental requirements. Leakage for the power sector can be addressed through careful design of the point-of-regulation, as in the First Jurisdiction Deliverer (FJD) plan in the WCI. FJD requires compliance from any generator within the region, plus any entity that imports fossil-based power from outside the WCI region.[7] The MGA draft recommendation also proposes the use of FJD. The MCAC recognizes that in any regional program leakage is a serious concern and must be considered, evaluated, and addressed.

[7] While RGGI does not address the issue of leakage within the program design, it recognizes the issue and will monitor inter-regional contracts and purchases to assess whether leakage is occurring. RGGI has indicated that if leakage proves to be a serious issue, action will be taken to address it.

Trial Period

The MCAC recommends that the program include a trial period to allow the program and the regulated community to adjust to the requirements.

Early Actions

Early actions are investments in mitigation measures that predate the program. Because these programs typically take years to design and implement, there is a concern that sources will delay mitigation investments until the program begins to ensure that they earn proper credit. Any delay in mitigation works contrary to the purpose of the program, so most programs offer some form of hold-harmless feature to protect early actors from suffering a penalty as a result of their actions, or an incentive to recognize or encourage these early actions. The MCAC recommends that the C&T program award tradable allowance or offset credits for early actions taken after a threshold date that are verifiable and meet standards comparable to those applied to offsets.

Goals: Reductions resulting from complementary policies and measures plus those realized through the C&T program should be designed to achieve the Michigan and MGA regional goals.

Timing: The MCAC recommends that the first compliance period of the C&T program begin on January 1, 2012, and that the regional cap and state allocation budgets be designed to support the regional goal, as stated above, in 2020.

Parties Involved: Potentially regulated entities in covered sectors, all MGA partner jurisdictions, the MGA, TCR.

Other: None.

Implementation Mechanisms

The Midwestern Accord partners are developing both a proposed design and a model rule for the implementation of the regional C&T program. The model rule will be developed with opportunity for regional public comment, but once completed, possibly in the third quarter of 2009, each partner state and province will have to follow its own procedures to adopt the rule for that jurisdiction. In some or all cases, enabling legislation will be needed to authorize the adoption of the rule. In cases where enabling legislation is not required, legislators may still wish to enact legislation encouraging or limiting the state's participation.

Related Policies/Programs in Place

There are no C&T programs in place to reduce GHG emissions in Michigan. Michigan has participated in the U.S. EPA SO_2 C&T program as well as the oxides of nitrogen ozone season trading program. Related GHG C&T programs are RGGI and WCI. RGGI began operating on January 1, 2009, and WCI is planned to begin on January 1, 2012. The Chicago Climate Exchange (CCX), a voluntary carbon trading program described in MBP-3, includes Michigan-based companies and institutions among its members.

Type(s) of GHG Reductions

All six statutory GHGs (carbon dioxide [CO_2], methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride)

Estimated GHG Reductions and Costs or Cost Savings

The complete modeling results and analysis are attached as Annex G-1. The methodology used to develop the marginal cost curves of states/provinces and the general assumptions adopted in the simulations may be found in Annex G-3. Specific data and methods used for the development of the Michigan cost curve can be found in Annex G-2.

The MGA partners include six U.S. states: Iowa, Illinois, Kansas, Michigan, Minnesota, and Wisconsin; and one Canadian province: Manitoba. MGA has recently announced its draft goals and timing for the C&T program: to reduce GHG emissions by 15%, 20%, or 25% below 2005 levels in 2020. In Annex G-1 of this appendix, we simulated these three alternative MGA goals for 2020. We also examined an alternative set of goals based on the MCAC tentative target for 2025: to reduce GHGs by 25%–35% from the 2002 emissions level in 2025. In this analysis, we applied three alternative MCAC 2025 goals (25%, 30%, and 35% below the 2002 level) to all the MGA partners to study the cost implications of a C&T program in 2025.

For the purpose of informing MCAC recommendations, we analyzed two sectoral coverage scenarios in our simulations:

- Assuming economy-wide coverage (except AFW), and
- Assuming only the power sector is covered.

In each of the two above sectoral coverage scenarios, we applied the set of MGA goals and the set of MCAC goals to the total emissions from the C&T covered sectors. Full results are given in Annex G-1.

We also analyzed two alternative allowance distribution cases: a 100% free-granting case and a 100% auction case, both throughout the MGA region. In the auction case:

- We assumed there would be no permit trading among the partners.[8]
- According to the Coase theorem,[9] in equilibrium, each partner will choose to mitigate the same level of emissions as in a permit trading market, and will buy allowances for its remaining emissions from the auctioneer.
- The auction price would be the same level as the equilibrium price in a permit trading market.
- The auction revenues can be used ("recycled") for a variety of public purposes, such as to fund research and development in clean energy technologies, subsidize business expenditures on mitigation, and reduce various taxes. However, the impacts of recycling those revenues are not included in the simulation below.

Since the MCAC has adopted the mid-point MGA goal as the recommendation, and given that this policy recommends the economy-wide (excluding AFW) sector coverage approach, these results are presented below for both the 100% auction and the free-granting assumptions for

[8] In reality, a secondary market will develop and permits will be bought and sold. This assumption is made to facilitate modeling and analysis.

[9] The Coase theorem, named for economist Ronald H. Coase, states that when trade in an externality is possible and there are no transaction costs, bargaining will lead to an efficient outcome, regardless of the initial allocation of property rights.

initial allowance distribution. Full results of all goals, scenarios, and cases can be found in Annex G-1 of this appendix.

In the C&T simulations for the recommended goal (20% below 2005 levels for 2020), the permit price in the trading market would be $35.35 per metric ton of carbon dioxide equivalent (tCO_2e) emissions in 2020 for the economy-wide (excluding AFW) case.

The emission reductions from the C&T covered sources within Michigan under the economy-wide C&T program are expected to be 103.32 million (MM) tCO_2e in 2020. Since Michigan is expected to be a permit seller in the market in any of the sectoral coverage scenarios, the emission reductions undertaken by the in-state C&T covered sources would exceed the reduction requirement indicated by the state emission caps. Michigan sources would sell the surplus permits earned through over compliance to the other MGA partners and gain a profit.

The economy-wide simulation (excluding the AFW sectors) results, including both the free-granting case and the auction case, with the three alternative MGA 2020 GHG reduction goals and the three alternative MCAC 2025 goals, are presented in Tables G-A1-1 to G-A1-12 in Annex G-1 of this appendix. The power sector-only C&T simulation results are presented in Tables G-A1-13 to G-A1-24.

Free-Granting Case

In all the free-granting simulation cases, if we compare the net cost for each state/province after trading with the before-trading mitigation cost, we find that all states/province are better off as a result of participating in trading, since all the post-trading net costs are smaller than the pre-trading net costs. The gains from trading are shown in the Cost Saving column in the results tables. Compared with the pre-trading situation, Michigan can achieve cost savings of $193 million in 2020 in the economy-wide C&T program. Table G-1-1 gives the economy-wide results for the Michigan free-granting case. Full results are presented in Annex G-1.

Table G-1-1. 100% Free-granting results for Michigan—economy-wide (excluding AFW) program

Michigan-Only Economy-wide (Excluding AFW); Assuming Free Grant of Allowances	Before Trading Mitigation Cost (million $)	After Trading			Cost Savings (million $)	Permits Traded ($MMtCO_2e$)[a]	Emissions Reduction With Trading		Emission Reduction Goal (percent from BAU)
		Mitigation Cost (million $)	Trading Payments/ Revenues (million $)	Net Payment/ Revenue + Cost (million $)			($MMtCO_2e$)	(percent from BAU)	
With MGA goal 20% below 2005 levels by 2020	–$2,195	–$1,788	–$601	–$2,389	–$193	–17	92.48	35.3	28.81

[a] Represents number of permits bought or sold.

BAU = business as usual; AFW = agricultural, forestry and waste management; MCAC = Michigan Climate Action Council;; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Table G-1-1 Column Head Key

"Before Trading Mitigation Cost" means the net cost or net cost savings (negative numbers) to reduce GHG emissions from Michigan sources, including any savings, such as those resulting from reduced fuel or electricity purchases, assuming all reductions necessary to meet the stated goal are made.
"After Trading Mitigation Cost" means the net cost or net cost savings (negative numbers) to reduce GHG emission reductions from Michigan sources, including any savings, such as those resulting from reduced fuel purchases, assuming a regional cap-and-trade program is in place.
"After Trading Payment/Revenue" means the total payments by or revenues to Michigan sources resulting from the purchase or sale, respectively, of emission allowances through the cap-and-trade program. Negative numbers mean Michigan sources will sell more allowances in the market than they purchase.
"After Trading Net Payment/Revenue and Cost" is the total cost of or cost savings (negative numbers) from in-state mitigation plus allowance purchases and sales.
"Cost Savings" is the "Before Trading Mitigation Cost" less the "After Trading Net Payment/Revenue and Cost."
"Permits Traded" is the net number of allowances purchased or sold by sources within Michigan. Negative numbers mean Michigan has a relatively large number of low-cost mitigation options and will be a net importer of mitigation investment capital and a net exporter of allowances.
"Emissions Reduction with Trading ($MMtCO_2e$)" means the tons of CO_2e that will be mitigated in Michigan as a result of the trading program.
"Emission Reduction With Trading (percent from BAU)" means the expected percentage reduction from in-state business-as-usual emissions in the target year. Percent reductions in excess of the "Emission Reduction Goal (percent from BAU)" in the next column mean Michigan sources will "overcomply" in order to sell allowances to out-of-state sources at a profit.
"Emission Reduction Goal (percent from BAU)" means the target year business-as-usual emission reductions necessary to meet the goal.

Auction Case

In the auction case, there would be no permit trading among states. In equilibrium, each state will choose to mitigate the same level of emission as it would in a permit trading market, but each partner would buy allowances for its remaining emissions from the auctioneer. The auction price would be the same level as the equilibrium price in a permit trading market. For the economy-wide program, the auction payments would be approximately $6 billion in 2020. These auction costs are not real resource costs to society; rather, they are transfer payments from one entity (the regulated source) to another (the state). In our analysis, the impacts of recycling the auction revenues through government investment in new efficiency technologies, direct efficiency investments, tax relief or other measures are not included. Table G-1-2 gives the economy-wide results for the Michigan auction case. Full results are given in Annex G-1.

Table G-1-2. 100% Auction results for Michigan – economy wide (excluding AFW) program

Michigan Only Economy-wide (Excluding AFW); Assuming Auction of Allowances	Total BAU Emissions in 2020 ($MMtCO_2e$)	Emission Reduction Undertaken by Michigan Sources[a]		Emission Allowances Bought From Auctioneer ($MMtCO_2e$)	Auction Payment[b] by Emitters/ Revenue to the State (million $)	Mitigation Cost (million $)	Total Payments and Costs (million $)
		(percent from BAU)	($MMtCO_2e$)				
With MGA goal 20% below 2005 levels by 2020	261.99	35.3	92.48	169.51	$5,992	–$1,788	$4,205

[a] In equilibrium, each state will choose to mitigate the same level of emissions as in a permit trading market.

[b] The auction price would be the same level as the equilibrium price in a permit trading market.

BAU = business as usual; AFW = agricultural, forestry and waste management; MGA = Midwestern Governors Association; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Table G-1-2 Column Head Key

"Total BAU Emissions in 2020 ($MMtCO_2e$)" means total Michigan business-as-usual emissions from all covered sources in the year corresponding to the goal.
"Emission Reduction Undertaken by Michigan Sources (percent from BAU)" means the in-state emission reductions in the goal year expressed as a percentage of business-as-usual emissions.
"Emission Reduction Undertaken by Michigan Sources ($MMtCO_2e$)" means the in-state emission reductions in the goal year expressed in million metric tons of CO_2 equivalent.
"Emission Allowances Bought From Auctioneer ($MMtCO_2e$)" means the number of allowances that will be purchased by Michigan sources at auction.
"Auction Payment by Emitters/Revenue to the State" means total payments by Michigan sources for the purchase of allowances as shown in "Emission Allowances Bought From Auctioneer ($MMtCO_2e$)." This also represents the total revenues to the state of Michigan from the sale of these allowances.
"Mitigation Cost" means the net cost of or cost savings (negative numbers) from total expenditures for GHG emission reductions from Michigan sources, less savings, such as those resulting from reduced fuel purchases.
"Total Payments and Costs" means the total of Mitigation Costs and Auction Payments made by all sources in Michigan.

Data Sources:

Marginal cost curves for states/province are developed directly: (1) on the basis of assessment of state-level actions developed through the stakeholder processes in Minnesota, Iowa, and Michigan (developed on the basis of reduction potentials and mitigation costs of individual policy options presented in Center for Climate Strategies [CCS] final (or draft) climate change action reports for these three states); or (2) by approximation methods for the other states and province based on cost curves from states with direct data. Currently, no direct cost curve data are available for Midwestern partners other than Minnesota, Iowa, and Michigan. The marginal cost curves of Manitoba and Wisconsin are approximated based on Minnesota data. The cost

curve of Kansas is approximated based on Iowa data. The cost curve of Illinois is approximated based on Michigan data. The approximation methods we adopted are described in the Quantification Methods section following this section.

GHG Mitigation Options Data Sources:

Minnesota Climate Change Advisory Group. 2008. *Minnesota Climate Change Advisory Group Final Report: A Report to the Minnesota Legislature*. http://www.mnclimatechange.us/MCCAG.cfm.

Iowa Climate Change Advisory Council. 2008. Quantification analysis of mitigation options from the EEC, CRE, TLU, and AFW Subcommittees.

3. Michigan Climate Action Council. 2008. Quantification analysis of mitigation options from the ES, RCI, and TLU TWGs of Michigan.

Emissions Inventory and Forecast Data Sources:

For Manitoba: L. Williams and S. Roe. 2008. "Task 0 State-Provincial GHG Summaries Tech Memo 1-31-08.doc" and associated Excel workbooks.

For Iowa, Minnesota, Michigan, and Kansas: Final or Draft Inventory and Forecast Analysis by CCS.

World Resources Institute. 2007. *Illinois Greenhouse Gas Emissions Inventory and Projections*. Prepared for the Illinois Climate Change Advisory Group. http://www.epa.state.il.us/air/climatechange/documents/07-02-22/il-emissions-overview-v5.pdf.

World Resources Institute. 2007. *Wisconsin Greenhouse Gas Emissions Inventory and Projections*. Prepared for the Wisconsin Task Force on Global Warming. http://dnr.wi.gov/environmentprotect/gtfgw/documents/WRI-WI_Inventory_Final.pdf.

Quantification Methods:

The MGA partners' C&T simulations use a nonlinear programming model of emission allowance trading. This model is based on the well-established principles of the ability of unrestricted permit trading to achieve a cost-effective allocation of resources in the presence of externalities.[10] Partners with relatively high mitigation costs will accomplish only part of their reduction obligation by their own mitigation activities, and will cover their remaining obligations by purchasing permits in the market. The compliance costs of these partners are equal to their own abatement cost plus the cost of permits. Partners with relatively low costs will have the incentive to mitigate more than their reduction targets indicate, so that they can sell their surplus permits to other partners at a profit. For these partners, compliance costs are equal to their own abatement cost minus the revenues from selling permits. The nonlinear programming model requires equalization of the marginal cost of all trading participants with the equilibrium permit

[10] See, e.g., T. Tietenberg (2007), "Tradable Permits in Principle and Practice," in J. Freeman and C. Kolstad (eds.), *Moving to Markets: Lessons from Twenty Years of Experience*. New York: Oxford University Press.

price. This ensures minimization of total net compliance costs for each partner and minimization of total abatement cost for the C&T program as a whole.[11]

For states with the state climate change action plans developed, the marginal abatement cost curves are based on the reduction potential and mitigation cost or saving data of individual options that are quantitatively analyzed by the stakeholder process. We used the following approximation methods to develop marginal abatement cost curves for states and Manitoba without direct data at present.

One of the adjacent states for which direct reduction and cost data are available is selected as the reference. We assume that the list of mitigation options for the adjacent state (state A) is applicable to the state without direct data (state B). Second, for state B, the estimated cost or cost savings per unit GHG removed for each option is assumed to be at the same level as that of state A. Third, the mitigation potentials of each option are assumed to be proportional to the total mitigation potential in each state; this requires that each option be adjusted by the ratio of emissions from the relevant sector of the two states. For example, if the emissions from the power sector are 50 $MMtCO_2e$ and 100 $MMtCO_2e$ in state A and state B, respectively, the mitigation potentials of the Energy Supply options for state A are multiplied by a factor of 2 (100/50 = 2) for application to state B.

Figure G-A3-1 and Figure G-A3-2 in Annex G-1 show the economy-wide (excluding AFW sector) and power sector only marginal cost curves for all the MGA partner states and Manitoba.

Key Assumptions:

All emissions considered are consumption-based and are gross emissions (excluding sinks).

- Marginal cost curves embody direct mitigation costs only.
- Marginal cost curves do not include various transaction costs.
- Marginal cost curves do not distinguish between producer versus consumer allocation of permits.

For the basic model:

Offsets, safety valve (permit price limit), and banking and borrowing are not included. These features can be included in advanced versions:

- Free allocation to grandfathered sources and auction of all allowances.

Key Uncertainties

A number of design variables (including the reduction targets, sectoral coverage, allocation methods, flexibility mechanisms, and level of complementary measures) can affect the simulation results, such as permit prices, in-state mitigation volume, trading volume, and cost savings from joining the C&T program. The uncertainties should be evaluated by the Market

[11] See, for example, B. Stevens and A. Rose (2002), "A Dynamic Analysis of the Marketable Permits Approach to Global Warming Policy: A Comparison of Spatial and Temporal Flexibility," *Journal of Environmental Economics & Management* 44(1):45–69; A. Rose, T. Peterson, and Z. Zhang (2006), "Regional Carbon Dioxide Permit Trading in the United States: Coalition Choices for Pennsylvania," *Penn State Environmental Law Review* 14(2):203–229.

Advisory Group described in MBP-6 to better understand the costs and benefits of a C&T program in Michigan.

As noted in the quantification methods and in Annex G-1, cost curves for Manitoba, Wisconsin, Kansas and Illinois were approximated from comparable states for which data are available. While these approximations are generally useful for this type of analysis, they are not as reliable as results based on state-specific action plans. The trading flows and costs would most likely change somewhat if state-specific data were to be used.

Additional Benefits and Costs

As noted above, the C&T analysis does not consider the price paid by those purchasing allowances at auction as a "cost" in the program. The analysis does not consider any benefits or value derived from the use of those revenues by the state for the purposes recommended in the Allowance Value and Distribution section under Policy Design, or any other use.

Feasibility Issues

As noted in the discussion.

Status of Group Approval

Approved.

Level of Group Support

Unanimous.

Barriers to Consensus

None.

MBP-3. Chicago Climate Exchange

Policy Description

The Chicago Climate Exchange (CCX), launched in 2003, is the world's first and North America's only active voluntary, legally binding integrated trading system to reduce emissions of all six major GHGs, with offset projects worldwide.

CCX members are leaders in GHG management and represent all sectors of the global economy, as well as public-sector innovators. Reductions achieved through CCX are the only reductions made in North America through a legally binding compliance regime, providing independent, third-party verification by the Financial Industry Regulatory Authority (formerly the National Association of Securities Dealers). The founder, Chairman, and Chief Executive Officer of CCX is economist and financial innovator Dr. Richard L. Sandor, who was named a Hero of the Planet by *TIME Magazine* in 2002 for founding CCX, and in 2007 as the "father of carbon trading."

CCX members make a voluntary but legally binding commitment to meet annual GHG emission reduction targets. Those who reduce emissions below the targets have surplus allowances to sell or bank, while those who emit above the targets comply by purchasing CCX Carbon Financial Instrument® (CFI®) contracts. The states of New Mexico and Illinois are members of CCX.

The commodity traded at CCX is the CFI contract, each of which represents 100 metric tons (t) of CO_2 equivalents. CFI contracts are comprised of Exchange Allowances and Exchange Offsets. Exchange Allowances are issued to emitting members in accordance with their emission baseline and the CCX Emission Reduction Schedule. Exchange Offsets are generated by qualifying offset projects.

The goals of CCX are to:

- Facilitate the transaction of GHG allowance trading with price transparency, design excellence, and environmental integrity.
- Build the skills and institutions needed to cost-effectively manage GHGs.
- Facilitate capacity building in both public and private sectors to facilitate GHG mitigation.
- Strengthen the intellectual framework required for cost-effective and valid GHG reduction.
- Help inform the public debate on managing the risk of global climate change.

The benefits of CCX membership are:

- Being prepared to mitigate financial, operational and reputational risks.
- Reducing emissions using the highest compliance standards with third-party verification.
- Proving concrete action on climate change to shareholders, rating agencies, customers, and citizens.
- Establishing a cost-effective, turnkey emissions management system.

- Driving policy developments based on practical, hands-on experience.
- Gaining leadership recognition for taking early, credible, and binding action to address climate change.
- Establishing an early track record in reductions and experience with the growing carbon and GHG market.

NOTE: Various Michigan-based businesses are members of CCX, including Ford Motor Company, Dow Corning, Steelcase, DTE Energy, Smurfit-Stone, Knoll Inc., DuPont, and Michigan State University. In addition, the states of Illinois and New Mexico are also members of CCX.

Policy Design

- Leading by example—Michigan will inventory and quantify all GHG emissions from sources that result from state government operations and are under the control of state government. Typically speaking, state government's primary sources of GHG emissions are energy use in office buildings and transportation.
- Michigan will join CCX,[12] which requires a 6% reduction in GHG emissions from state governmental sources between a baseline of 1998–2000 and 2010, and possibly additional reductions beyond 2010 under CCX Phase 3 requirements.

Goals: Emission reductions from state operations consistent with CCX Phase 2 requirements.

Timing: Michigan should consider joining CCX in 2009 and achieving the 2020 reduction goal. If there is insufficient time to achieve this reduction, Michigan should join in 2009 or 2010 and participate beginning with Phase 3.

Parties Involved: Governor Granholm and Executive Office staff, various executive departments and agencies, Michigan legislature.

Other: Contracts for GHG reductions are legally binding and extend for multiple years. To the degree that compliance with those contracts imposes a cost on the state, the legislature would be obligated to appropriate the necessary funds to purchase credits if the state of Michigan were unable to meet associated GHG reductions.

Alternately, membership and compliance may present opportunities for new revenues (for example, offset credits for biological sequestration on state forest lands), which would be under the jurisdiction of the legislature through the budget-setting process.

Implementation Mechanisms

The MCAC suggests the state of Michigan join the CCX by issuance of an Executive Order though the Governor's office. A determination of the necessity for involving the Michigan

[12] See http://www.chicagoclimatex.com/.

legislature in this process needs to be made accordingly. Illinois and New Mexico have joined the CCX. (Illinois joined by Executive Order 11 of 2006 [see http://www.illinois.gov/gov/execorder.cfm?eorder=54.])

Related Policies/Programs in Place

No related policies or programs are in place Michigan. However the state, under Executive Directive No. 2007-22 (http://www.michigan.gov/gov/0,1607,7-168-36898-180298--,00.html), has committed to reducing the carbon footprint of state government by reducing energy consumption and furthering efficiency efforts in fleet management, green procurement, and recycling. This effort would complement the voluntary GHG reduction commitments required as part of being a member of CCX.

Specifically, all state buildings under the Department of Management and Budget and other state agencies under the executive branch have a goal of achieving 10% reduction in energy use by December 31, 2008, and a further goal of 20% reduction in grid-based energy purchases by December 31, 2015, when compared to energy use and purchases ending fiscal year ending September 30, 2002.

In addition, the Midwestern Accord[13] plans to establish a Midwestern Greenhouse Gas Reduction Program (hereafter Midwestern GHG Program) to reduce GHG emissions in member states through the following actions:

- Establish GHG reduction targets and time frames consistent with those of MGA member states and provinces;
- Develop a market-based and multi-sector C&T mechanism to help achieve GHG reduction targets;
- Join TCR to enable tracking, management of, and crediting for entities that reduce GHG emissions; and
- Develop and implement other associated mechanisms and policies as needed to achieve the GHG reduction targets, such as a low-carbon fuel standard and regional incentives and funding mechanisms.

NOTE: The Michigan Department of Environmental Quality (MDEQ) participates on the Steering Committee for the development of TCR, a multi-state program designed to be an essential piece of infrastructure for the development of state and federal climate change programs. Thirty-nine states and the District of Columbia in the United States, six states in Mexico, nine Canadian provinces, and three Native American tribes have already signed on to join TCR. More information about TCR is available at http://www.theclimateregistry.org/.

Type(s) of GHG Reductions

CO_2.

[13] Midwestern Accord participating states and provinces: Illinois, Iowa, Kansas, Manitoba, Michigan, Minnesota, and Wisconsin; observer states: Indiana, Ohio, South Dakota.

Estimated GHG Reductions and Costs or Cost Savings

This policy has not been quantified. However, MDEQ analysis indicates that achievement of the 2010 CCX goal is possible with the successful implementation of Executive Directive No. 2007-22.

Data Sources: Not applicable.

Quantification Methods: Not applicable.

Key Assumptions: Not applicable.

Key Uncertainties

The CCX Phase 3 goals are not known. Therefore it is not possible to judge the costs and benefits of achieving them.

Additional Benefits and Costs

Additional benefits include those identified under 'Benefits of Membership' in the Policy Description section of this recommendation. Additional costs may be an issue if Michigan fails to achieve the contractually required reductions. In this event, the state legislature would be obligated to purchase or sponsor offset credits or projects. It is also possible that with or without the need for offset credits, Michigan could invest in state offset projects and sell the credits through the CCX mechanism and generate additional revenues.

Feasibility Issues

Given that several other states have already joined CCX, no feasibility issues have been identified.

Status of Group Approval

Approved.

Level of Group Support

Unanimous.

Barriers to Consensus

None.

MBP-6. Market Advisory Group

Policy Description

The MCAC is tasked with considering potential state and multi-state actions to mitigate and adapt to climate change in various sectors, including energy supply, energy efficiency and conservation, industrial process and waste management, transportation and land use, and agriculture and forestry, as well as advising state and local government on measures to address climate change.

GHG policies have broad-based impacts and implications. As a result, it is helpful to look at current and future policies from several viewpoints. Some states have looked at forming groups of experts to help them evaluate both the intended and unintended consequences of GHG policies. For example, California has formed a Market Advisory Committee (MAC) to help formulate a GHG C&T system in the state. The California MAC has proposed a set of guiding principles and has developed an initial set of recommendations for a California C&T program. Minnesota also considered a similar panel of experts to evaluate GHG policies, and recommended a similar panel of experts at the Midwestern Accord regional level.

Michigan has unique economic, social, and legislative structures that separate the state from implementing specific policies verbatim that California or Minnesota has adopted in relation to GHG emission reduction. However, Michigan can benefit from a multidisciplinary approach when looking at how current and future polices will affect the overall physical and economic environment in the state. The Market-Based Policies (MBP) Technical Work Group (TWG) recommends to the MCAC the creation of a formal Market Advisory Group (MAG), appointed by the Governor or appropriate agency head and approved by the state legislature, and working in support of the MDEQ. The MAG would hold regular meetings and have defined responsibilities, to include examining the economic feasibility of implementing GHG reduction policies. In addition to offering expert advice on the design of market-based policies, the MAG would catalog current policies and laws in state and local government, assess how each contributes to or reduces GHGs, and provide guidance to the state's policymakers on the design of any future compliance programs to manage GHG emissions. The MAG would consist of economists, actuaries, scientists, policy advisors, academics, attorneys, planners, engineers, as well as members of the public, all of whom would serve without pay.

Policy Design

Goals: This recommendation consists of current and future policy evaluation and guidance to help evaluate and assess the economic, social, and environmental impacts of policy on GHG emissions on an ongoing basis. The appointment of a MAG is recommended to provide analysis and guidance for this purpose. It should possess scientific, economic, and legal expertise to provide an experts' review of policies and programs.

Timing: The MAG should be in place in advance of the start of a regional or national C&T program, preferably before the end of 2009 to take maximum advantage of the MAG’s input.

Parties Involved: The MAG should be composed of individuals with particular expertise in key areas, such as economics, markets, climate science and policy, law, planning, statistics, engineering, and academia, as well as in other jurisdictions or for other pollutants, key covered sectors, and finance. Involved parties beyond those represented in the MAG would include a very wide range of stakeholders from the regulated community, environmental community, all levels of government, and the general public.

Other: The MAG should encourage public comment throughout its deliberations.

Implementation Mechanisms

Authority of the MAG

To advise policymakers, such as the MDEQ, Michigan Public Service Commission, Michigan Economic Development Corporation, Attorney General's office, state legislature, and Governor on GHG policies, potential negative and positive impacts on the environment, public health, the economy, and the well-being of the citizens of Michigan, and to recommend policies to optimize the benefits and reduce the costs of the policies in the future.

MAG Membership and Governance

The governor would appoint 11 persons for 3-year staggered renewable terms without pay, with technical experience in such areas as: finance; sources of emissions, such as the mobile sources; electricity generation and transmission; industrial sources; carbon credit trading firms; public health, and resource-based economics and econometric modeling. At least one person appointed by the Governor would represent the public at large. All appointments would be subject to legislative advice and consent.

MAG members would be allowed to include other experts from the public and private sectors as necessary to conduct its analyses and make its recommendations.

The MAG would conduct elections tri-annually. It would be organized with a Chair, Vice Chair, and Secretary-Treasurer; take action as needed by a majority vote of its appointed members; establish a budget and work plan with milestones; and otherwise conduct itself under processes used by business to ensure the timely and high-quality delivery its recommendations.

Budget

The MAG would conduct its analyses and make its recommendations on an ongoing basis, with financial resources provided by legislative appropriations.

Reporting

The MAG would provide its recommendations orally or in writing to policymakers. These would reflect comments from the members of the public and private sectors that the MAG agreed to accept. The MAG would explain its rationale for accepting and not accepting comments when it finalized recommendations. Copies of final recommendations and the rationale for accepting/not accepting comments would be posted on the Internet.

The MAG would annually summarize its activities to policymakers and the public via the Internet, and would hold quarterly meetings open to the public to describe progress on its work plan.

Related Policies/Programs in Place

Any market-based GHG regulatory program, such as the MGA C&T program.

Type(s) of GHG Reductions

Principally CO_2 but other GHGs as well, if they are regulated under the adopted market-based program.

Estimated GHG Reductions and Costs or Cost Savings

This policy is not quantified.

Data Sources: Not applicable.

Quantification Methods: Not applicable.

Key Assumptions: Not applicable.

Key Uncertainties

None.

Additional Benefits and Costs

None.

Feasibility Issues

None.

Status of Group Approval

Approved.

Level of Group Support

Unanimous.

Barriers to Consensus

None.

Annex G-1

Analysis of MGA Cap and Trade in 2020 and 2025

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December 25, 2008

This summary presents the simulation results of Midwestern Governors Association (MGA) Cap and Trade (C&T) Program. For the detailed specifications of our policy design model, the methodology we used to develop the marginal cost curves of states/provinces, and the general assumptions we adopted in the simulations, please refer to Annex G-3, "Modeling of Cap and Trade Programs."

The MGA partners include six U.S. states: Iowa, Illinois, Kansas, Michigan, Minnesota, and Wisconsin; and one Canadian province: Manitoba. MGA has recently announced its draft goals and timing for the C&T program: to reduce greenhouse gas (GHG) emissions by 15%, 20%, and 25% below 2005 levels in 2020. In the following C&T analysis, we simulate these three alternative MGA goals for 2020. We also examine an alternative and much more stringent set of goals based on the Michigan Climate Action Council (MCAC) tentative target for 2025: to reduce GHGs by 25%–35% from the 2002 emissions level in 2025. In this analysis, we apply three alternative MCAC 2025 goals (25%, 30%, and 35% below the 2002 level) to all the MGA partners to study the cost implications of a C&T program in 2025.

For the purpose of informing committee recommendations, we analyzed two sectoral coverage scenarios in our simulations:

- Assuming economy-wide coverage (except for agriculture, forestry, and waste), and
- Assuming only the power sector is covered.

In each of the two sectoral coverage scenarios, we applied the set of MGA goals and the set of MCAC goals to the total emissions from the C&T covered sectors. Our model is sufficiently flexible to accommodate any sectoral coverage strategy in future analyses.

We also analyzed two alternative allowance distribution cases: a 100% free-granting case and a 100% auction case, both throughout the MGA region. In the auction case:

- We assumed there will be no permit trading among the partners.[14]
- According to the Coase Theorem, in equilibrium, each partner will choose to mitigate the same level of emissions as in a permit trading market, and will buy allowances for its remaining emissions from the auctioneer.
- The auction price will be the same level as the equilibrium price in a permit trading market.

[14] In reality, a secondary market will develop and permits will be bought and sold. This assumption is made to facilitate modeling and analysis.

- The auction revenues can be used ("recycled") to fund research and development in clean energy technologies, subsidize business expenditures on mitigation, and reduce various taxes. However, the impacts of recycling those revenues are not included in the simulation below.

The economy-wide simulation (excluding the Agriculture, Forestry, and Waste Management [AFW] sectoral) results, including both the free granting case and the auction case, with the three alternative MGA 2020 GHG reduction goals and the three alternative MCAC 2025 goals, are presented in Tables G-A1-1 to G-A1-12. The power sector-only C&T simulation results are presented in Tables G-A1-13 to G-A1-24.

In each results table for the free granting case, the second column shows the mitigation cost for each partner to achieve the reduction target before it enters the C&T Program—i.e., the cost of each state's own mitigation activities to achieve the reduction goal. Negative numbers in this column indicate overall cost savings for a given state. Columns 3 to 5 show the mitigation cost, trading cost, and net cost (the sum of the mitigation and trading costs) after the partners enter the C&T Program. Partners with relatively high mitigation costs will accomplish only part of their reduction obligation through their own mitigation activities, and will cover their remaining obligations by purchasing permits in the market. Partners with relatively low costs will have the incentive to mitigate more than their reduction targets indicate, so that they can sell their surplus permits to other partners at a profit. In the Trading Cost column, negative numbers represent revenues from the sale of permits. Column 6, Cost Saving, presents the difference in the net cost before and after permit trading. Columns 7 and 8 show the permits purchased/sold by each partner and the emissions reduced by in-state mitigation activities in millions of metric tons of carbon dioxide equivalent ($MMtCO_2e$). Finally, columns 9 and 10 compare the emission reductions in percentage terms with and without trading, respectively, for each partner.

In each results table of the auction case, the second column shows the business as usual (BAU) emissions level in the target year. Columns 3 and 4 present the emission reductions undertaken by the partners in both percentage and quantity terms. Column 5 presents the emission allowances the partners choose to purchase from the auctioneer (which is the difference between the numbers in column 2 and the numbers in column 4). Column 6 indicates the auction payment for each partner (or the auction revenue collected by the government), which is the product of the numbers in columns 5 and the price of allowances. Column 7 presents the mitigation cost. The last column shows the total net expenditure, which is the sum of the auction payment (column 6) and the mitigation cost (column 7). Note that the auction cost is not a real resource cost (i.e., resources are not being used up), but is rather a transfer from emitters to the government.

Following the simulation results tables, the basic data used in the simulation are summarized. These data tables present the 2020 (or 2025) baseline emissions, the emission budget (capped emissions), the reduction target in percentage terms relative to the 2020 (or 2025) baseline level of the C&T covered sectors, and the internal marginal mitigation cost level for each state/province to meet the emission budget.

Figures G-A1-1 and G-A1-2 show the 2020 and 2025 economy-wide (excluding AFW) marginal cost curves for all the states and province included in this study. Figures G-A1-3 and G-A1-4 show the 2020 and 2025 marginal cost curves of the power sector. This annex presents in detail how we developed the 2025 marginal cost curves for Michigan.

Summarizing the findings from the C&T simulations:

- The factors that have the greatest influence on all simulations are the absolute and relative levels of the marginal mitigation cost curves. The former has the greatest influence on the potential for cost savings, while the latter has the greatest influence on the extent of permit trading across trading states/provinces, including whether each state/province is a permit buyer or seller.
- For some of the MGA partners, the total net cost of achieving the carbon emission caps under the C&T Program is negative. This means that compliance with the caps will result in overall cost savings. In some cases, this result is due to the existence of an extensive range of cost-saving options, such as improvements in energy efficiency. In other cases, this happens to the permit selling partners, which indicates that the revenue the sellers gain in the permit market more than offsets the costs they spend on mitigation activities.
- In general, the power sector-only C&T simulations yield lower equilibrium permit prices than the economy-wide (excluding AFW) C&T simulations. This is mainly because, in the power sector-only analysis, all mitigation options that contribute to the emission reductions from electric power generation are counted, including not only those designed directly for the electricity supply sector, but also those in the residential, commercial, and industrial (RCI) sectors that contribute to the reduction of electricity consumption. Please note although we include both the supply-side and demand-side options in the power sector mitigation cost curve, the MCAC and MGA reduction goals are only applied to the total emissions from the power sector in the power sector-only runs—i.e., the power sector does not have the obligation to reduce emissions generated from the other economic sectors.
- In the C&T simulations for the MGA goals, the permit prices in the trading market are \$21.23/tCO_2e, \$35.35/tCO_2e, and \$50.82/tCO_2e for the economy-wide (excluding AFW) runs, respectively, corresponding to the 15%, 20%, and 25% reduction goals below 2005 levels for 2020. The permit prices for the power sector-only runs are \$13.25/tCO_2e, \$17.25/tCO_2e, and \$22.24/tCO_2e, respectively.
- The MCAC GHG reduction goals are much more stringent compared with the MGA goals. In the simulations for the MCAC goals, with the GHG reduction target increases from 25%, to 30%, and to 35% below the 2002 level, the equilibrium permit price in the trading market increases from \$74.99/tCO_2e to \$93.25/tCO_2e, and to \$113.52/tCO_2e, correspondingly, in the economy-wide (excluding AFW) C&T simulations; and increases from \$38.34/tCO_2e to \$49.03/tCO_2e, and to \$62.39/tCO_2e, correspondingly, in the power sector-only C&T simulations.
- In the economy-wide simulation cases with the MGA reduction goals, Michigan is the biggest permit seller in the market in the first simulation, and the second-biggest seller in the second and third simulations. In the power sector-only simulations, Michigan is the biggest seller in the first simulation, and third-biggest seller in the second and third simulations. Minnesota is the biggest permit purchaser in the market, followed by Wisconsin.
- In the economy-wide simulation cases with the MCAC reduction goals, Michigan is the second-biggest permit seller in the first simulation, and third-biggest seller in the second and third simulations; while in the power sector-only simulations, Michigan is the third-biggest permit seller in all runs. In all the cases, Kansas is the biggest seller. Minnesota is again the biggest permit buyer in the market, followed by Wisconsin.

- In all the simulation cases, if we compare the net cost for each state/province after trading with the before-trading mitigation cost, we find that all states/province are better off as a result of participating in trading, since all the post-trading net costs are smaller than the pre-trading net costs. The gains from trading are shown in the Cost Saving column in the result tables. Compared with the pre-trading situation, Michigan can achieve cost savings of $187–$207 million in 2020 in the economy-wide C&T Program following the MGA reduction goals; and $69–$157 million in the power sector-only C&T Program. Michigan can reduce its net costs (mitigation cost plus permit sales revenue) and achieve savings of $344–$394 million in 2025 in the economy-wide (excluding AFW) C&T Program following the MCAC reduction goals, and $70–$115 million in the power sector-only C&T Program.

In the auction cases, there would be no permit trading among states. In equilibrium, each state would choose to mitigate the same level of emission as it would in a permit trading market, but each partner would buy allowances for its remaining emissions from the auctioneer. The auction price would be the same level as the equilibrium price in a permit trading market. For the economy-wide program, the auction payments range from $16.35 to $34.54 billion in the MGA goal simulations, and from $49.24 to $64.61 billion in the MCAC goal simulations. For the power sector-only program, the auction payments range from $4.20 to $6.22 billion in the MGA goal simulations, and from $9.97 to $14.06 billion in the MCAC goal simulations. These auction costs are not real resource costs to society, but are simply transfer payments from one entity to another. Our analysis does not include the impacts of recycling the auction revenues through government investment in new efficiency technologies, direct efficiency investments, tax relief, or other measures.

Economy-wide Cap-and-Trade Simulations

Table G-A1-1. Economy-wide (excluding AFW) emission trading simulation among MGA partners in 2020

(With MGA goal **15% below 2005** levels by 2020, assuming **free grant** of allowances; million dollars or otherwise specified)

State/ Province	Before Trading	After Trading			Cost Saving	Permits Traded	Emission Reduction w/ Trading		Emission Reduction Goal
	Mitigation Cost	Mitigation Cost	Trading Payments/ Revenues[a]	Net Payment/ Revenue + Cost		($MMtCO_2$)	($MMtCO_2$)	(percent from BAU)	(percent from BAU)
IA	–$397	–$289	–$144	–$432	$36	–6.77	41.33	37.44	31.31
IL	–$2,401	–$2,317	–$96	–$2,413	$12	–4.55	89.46	30.15	28.62
KS	–$237	–$76	–$259	–$334	$98	–12.18	39.60	40.07	27.75
MB	–$79	–$200	$47	–$153	$74	2.23	4.98	29.15	42.20
MI	**–$2,263**	**–$2,085**	**–$385**	**–$2,470**	**$207**	**–18.13**	**81.95**	**31.28**	**24.36**
MN	$604	–$1,006	$444	–$562	$1,166	20.93	25.62	16.57	30.11
WI	$345	–$1,013	$392	–$621	$966	18.46	24.83	17.93	31.27
Total	**–$4,427**	**–$6,985**	**$0**	**–$6,985**	**$2,558**	**37.08[b]**	**307.77**	**28.55**	**28.55**

[a] Permit price = $21.23/$tCO_2e$.

[b] Represents number of permits bought or sold.

AFW = agriculture, forestry, and waste management sectors; BAU = business as usual; MGA = Midwestern Governors Association; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Table G-A1-2. Economy-wide (excluding AFW) emission trading simulation among MGA partners in 2020

(With MGA goal **15% below 2005** levels by 2020, assuming **auction** of allowances)

State/ Province	Total BAU Emissions in 2020 ($MMtCO_2$)	Emission Reduction Undertaken by Michigan Sources[a]		Emission Allowances Bought from Auctioneer ($MMtCO_2$)	Auction Payment by Emitters/ Revenue to the State (million $)[b]	Mitigation Cost (million $)	Total Payments and Costs (million $)
		(percent from BAU)	($MMtCO_2$)				
IA	110.39	37.44	41.33	69.06	$1,466	–$289	$1,177
IL	296.69	30.15	89.46	207.23	$4,400	–$2,317	$2,083
KS	98.82	40.07	39.60	59.22	$1,257	–$$76	$1,181
MB	17.09	29.15	4.98	12.11	$257	–$200	$57
MI	**261.99**	**31.28**	**81.95**	**180.04**	**$3,822**	**–$2,085**	**$1,738**
MN	154.59	16.57	25.62	128.97	$2,738	–$1,006	$1,732
WI	138.44	17.93	24.83	113.61	$2,412	–$1,013	$1,399
Total	**1,078.01**	**28.55**	**307.77**	**770.24**	**$16,352**	**–$6,985**	**$9,367**

[a] In equilibrium, each state will choose to mitigate the same level of emissions as in a permit trading market.

[b] The auction price would be the same level ($21.23/$tCO_2e$) as the equilibrium price in a permit trading market.

AFW = agriculture, forestry, and waste management sectors; BAU = business as usual; MGA = Midwestern Governors Association; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Table G-A1-3. Economy-wide (excluding AFW) emission trading simulation among MGA partners in 2020

(With MGA goal **20% below 2005** levels by 2020, assuming **free grant** of allowances; million dollars or otherwise specified)

State/ Province	Before Trading	After Trading			Cost Saving	Permits Traded	Emission Reduction w/ Trading		Emission Reduction Goal
	Mitigation Cost	Mitigation Cost	Trading Payments/ Revenues[a]	Net Payment/ Revenue + Cost		($MMtCO_2$)	($MMtCO_2$)	(percent from BAU)	(percent from BAU)
IA	–$334	–$58	–$371	–$429	$96	–10.51	49.53	44.87	35.35
IL	–$2,111	–$1,993	–$126	–$2,119	$8	–3.55	100.93	34.02	32.82
KS	–$202	$183	–$608	–$425	$222	–17.20	48.83	49.41	32.00
MB	–$21	–$186	$82	–$104	$84	2.32	5.48	32.05	45.60
MI	**–$2,195**	**–$1,788**	**–$601**	**–$2,389**	**$193**	**–17.00**	**92.48**	**35.30**	**28.81**
MN	$1,592	–$928	$866	–$61	$1,653	24.51	28.40	18.37	34.22
WI	$1,168	–$939	$758	–$181	$1,349	21.45	27.44	19.82	35.31
Total	**–$2,102**	**–$5,708**	**$0**	**–$5,708**	**$3,606**	**44.71[b]**	**353.08**	**32.75**	**32.75**

[a] Permit price = $35.35/$tCO_2e$.

[b] Represents number of permits bought or sold.

AFW = agriculture, forestry, and waste management sectors; BAU = business as usual; MGA = Midwestern Governors Association; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Table G-A1-4. Economy-wide (excluding AFW) cap-and-trade simulation among MGA partners in 2020

(with MGA goal **20% below 2005** levels by 2020, assuming **auction** of allowances)

State/ Province	Total BAU Emissions in 2020 ($MMtCO_2$)	Emission Reduction Undertaken by Michigan Sources[a]		Emission Allowances Bought From Auctioneer ($MMtCO_2$)	Auction Payment by Emitters/ Revenue to the State (million $)[b]	Mitigation Cost (million $)	Total Payments and Costs (million $)
		(percent from BAU)	($MMtCO_2$)				
IA	110.39	44.87	49.53	60.86	$2,151	–$58	$2,093
IL	296.69	34.02	100.93	195.76	$6,920	–$1,993	$4,927
KS	98.82	49.41	48.83	49.99	$1,767	$183	$1,951
MB	17.09	32.05	5.48	11.61	$410	–$186	$224
MI	**261.99**	**35.30**	**92.48**	**169.51**	**$5,992**	**–$1,788**	**$4,205**
MN	154.59	18.37	28.40	126.19	$4,461	–$928	$3,533
WI	138.44	19.82	27.44	111.00	$3,924	–$939	$2,985
Total	**1,078.01**	**32.75**	**353.08**	**724.93**	**$25,626**	**–$5,708**	**$19,918**

[a] In equilibrium, each state will choose to mitigate the same level of emissions as they would do in a permit trading market.

[b] The auction price would be the same level ($33.35/$tCO_2e$) as the equilibrium price in a permit trading market.

AFW = agriculture, forestry, and waste management sectors; BAU = business as usual; MGA = Midwestern Governors Association; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Table G-A1-5. Economy-wide (excluding AFW) emission trading simulation among MGA partners in 2020

(With MGA goal **25% below 2005** levels by 2020, assuming **free grant** of allowances; million dollars or otherwise specified)

State/ Province	Before Trading	After Trading			Cost Saving	Permits Traded	Emission Reduction w/ Trading		Emission Reduction Goal
	Mitigation Cost	Mitigation Cost	Trading Payments/ Revenues[a]	Net Payment/ Revenue + Cost		($MMtCO_2$)	($MMtCO_2$)	(percent from BAU)	(percent from BAU)
IA	–$239	$280	–$708	–$428	$188	–13.93	57.41	52.01	39.39
IL	–$1,627	–$1,483	–$149	–$1,633	$6	–2.94	112.77	38.01	37.02
KS	–$146	$546	–$1,091	–$545	$399	–21.48	57.30	57.98	36.25
MB	$50	–$164	$121	–4$3	$93	2.38	6.00	35.10	49.00
MI	**–$1,957**	**–$1,322**	**–$822**	**–$2,144**	**$187**	**–16.18**	**103.32**	**39.44**	**33.26**
MN	$2,837	–$800	$1,417	$617	$2,220	27.88	31.37	20.29	38.33
WI	$2,207	–$819	$1,233	$414	$1,793	24.26	30.23	21.83	39.36
Total	**$1,125**	**–$3,761**	**$0**	**–$3,761**	**$4,886**	**51.58[b]**	**398.40**	**36.96**	**36.96**

[a] Permit price = $50.82/$tCO_2e$.

[b] Represents number of permits bought or sold.

AFW = agriculture, forestry, and waste management sectors; BAU = business as usual; MGA = Midwestern Governors Association; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Table G-A1-6. Economy-wide (excluding AFW) cap-and-trade simulation among MGA partners in 2020

(With MGA goal **25% below 2005** levels by 2020, assuming **auction** of allowances)

State/ Province	Total BAU Emissions in 2020 ($MMtCO_2$)	Emission Reduction Undertaken by Michigan Sources[a]		Emission Allowances Bought From Auctioneer ($MMtCO_2$)	Auction Payment by Emitters/ Revenue to the State (million $)[b]	Mitigation Cost (million $)	Total Payments and Costs (million $)
		(percent from BAU)	($MMtCO_2$)				
IA	110.39	52.01	57.41	52.98	$2,693	$280	$2,973
IL	296.69	38.01	112.77	183.92	$9,347	–$1,483	$7,863
KS	98.82	57.98	57.30	41.52	$2,110	$546	$2,656
MB	17.09	35.10	6.00	11.09	$564	–$164	$400
MI	**261.99**	**39.44**	**103.32**	**158.67**	**$8,064**	**–$1,322**	**$6,742**
MN	154.59	20.29	31.37	123.22	$6,262	–$800	$5,462
WI	138.44	21.83	30.23	108.21	$5,499	–$819	$4,680
Total	**1,078.01**	**36.96**	**398.40**	**679.61**	**$34,538**	**–$3,761**	**$30,777**

[a] In equilibrium, each state will choose to mitigate the same level of emissions as they would do in a permit trading market.

[b] The auction price would be the same level ($50.82/$tCO_2e$) as the equilibrium price in a permit trading market.

AFW = agriculture, forestry, and waste management sectors; BAU = business as usual; MGA = Midwestern Governors Association; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Data table G-A1-D1

(Economy-wide C&T with MGA goal 15%, 20%, and 25% below 2005 levels by 2020)

State/ Province	2020 BAU Gross Emissions of the C&T Covered Sectors (Consumption-based) ($MMtCO_2e$)	Emissions Cap for the C&T Covered Sectors in 2020 ($MMtCO_2e$)			GHG Mitigation Goal in 2020 (relative to BAU emissions)			Autarkic Marginal Mitigation Cost ($/tCO_2e$)		
		15% below 2005	20% below 2005	25% below 2005	15% below 2005	20% below 2005	25% below 2005	15% below 2005	20% below 2005	25% below 2005
IA	110.4	75.8	71.4	66.9	31.31%	35.35%	39.39%	10.8	17.6	24.8
IL	296.7	211.8	199.3	186.9	28.62%	32.82%	37.02%	15.9	30.9	46.9
KS	98.8	71.4	67.2	63.0	27.75%	32.00%	36.25%	5.6	10.7	16.1
MB	17.1	9.9	9.3	8.7	42.20%	45.60%	49.00%	89.9	110.3	132.1
MI	**262.0**	**198.2**	**186.5**	**174.9**	**24.36%**	**28.81%**	**33.26%**	**–1.2**	**13.0**	**28.1**
MN	154.6	108.0	101.7	95.3	30.11%	34.22%	38.33%	136.0	175.3	217.2
WI	138.4	95.1	89.6	84.0	31.27%	35.31%	39.36%	129.0	165.8	205.1
Total	**1,078.0**	**770.2**	**724.9**	**679.6**	**28.55%**	**32.75%**	**36.96%**			

BAU = business as usual; C&T = cap and trade; MGA = Midwestern Governors Association; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $/tCO_2e$ = dollars per metric tons of carbon dioxide equivalent.

Table G-A1-7. Economy-wide (excluding AFW) emission trading simulation among MGA partners in 2025

(With MCAC goal **25% below 2002** levels by 2025, assuming **free grant** of allowances; million dollars or otherwise specified)

State/ Province	Before Trading	After Trading			Cost Saving	Permits Traded	Emission Reduction w/ Trading		Emission Reduction Goal
	Mitigation Cost	Mitigation Cost	Trading Payments/ Revenues[a]	Net Payment/ Revenue + Cost		($MMtCO_2e$)	($MMtCO_2e$)	(percent from BAU)	(percent from BAU)
IA	–$240	$817	–$1,501	–$684	$444	–20.02	73.71	61.89	45.08
IL	–$843	–$710	–$135	–$845	$2	–1.80	136.89	43.32	42.75
KS	–$200	$1,086	–$2,124	–$1,038	$838	–28.33	72.62	68.39	41.71
MB	$156	–$188	$215	$27	$129	2.87	8.30	41.75	56.18
MI	**–$1,885**	**–$631**	**–$1,597**	**–$2,229**	**$344**	**–21.30**	**126.56**	**46.05**	**38.30**
MN	$6,226	–$686	$2,830	$2,144	$4,082	37.74	39.53	23.72	46.37
WI	$4,461	–$736	$2,313	$1,577	$2,883	30.85	38.18	25.48	46.07
Total	**$7,675**	**–$1,047**	**$0**	**–$1,047**	**$8,722**	**69.65[b]**	**495.79**	**43.02**	**43.02**

[a] Permit price = $74.99/$tCO_2e$.

[b] Represents number of permits bought or sold.

AFW = agriculture, forestry, and waste management sectors; BAU = business as usual; MCAC = Michigan Climate Action Council; MGA = Midwestern Governors Association; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Table G-A1-8. Economy-wide (excluding AFW) cap-and-trade simulation among MGA partners in 2025

(With MCAC goal **25% below 2002** levels by 2025, assuming **auction** of allowances)

State/ Province	Total BAU Emissions in 2025 ($MMtCO_2$)	Emission Reduction Undertaken by Michigan Sources[a]		Emission Allowances Bought From Auctioneer ($MMtCO_2$)	Auction Payment by Emitters/ Revenue to the State (million $)[b]	Mitigation Cost (million $)	Total Payments and Costs (million $)
		(percent from BAU)	($MMtCO_2$)				
IA	119.11	61.89	73.71	45.40	$3,404	$817	$4,222
IL	315.98	43.32	136.89	179.09	$13,430	–$710	$12,721
KS	106.19	68.39	72.62	33.57	$2,517	$1,086	$3,604
MB	19.88	41.75	8.30	11.58	$868	–$188	$680
MI	**274.82**	**46.05**	**126.56**	**148.26**	**$11,118**	**–$631**	**$10,487**
MN	166.64	23.72	39.53	127.11	$9,532	–$686	$8,846
WI	149.82	25.48	38.18	111.64	$8,372	–$736	$7,636
Total	**1,152.44**	**43.02**	**495.79**	**656.65**	**$49,243**	**–$1,047**	**$48,196**

[a] In equilibrium, each state will choose to mitigate the same level of emissions as they would do in a permit trading market.

[b] The auction price would be the same level ($74.99/$tCO_2e$) as the equilibrium price in a permit trading market.

AFW = agriculture, forestry, and waste management sectors; BAU = business as usual; MCAC = Michigan Climate Action Council; MGA = Midwestern Governors Association; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Table G-A1-9. Economy-wide (excluding AFW) emission trading simulation among MGA partners in 2025

(With MCAC goal **30% below 2002** levels by 2025, assuming **free grant** of allowances; million dollars or otherwise specified)

State/ Province	Before Trading	After Trading			Cost Saving	Permits Traded	Emission Reduction w/ Trading		Emission Reduction Goal
	Mitigation Cost	Mitigation Cost	Trading Payments/ Revenues[a]	Net Payment/ Revenue + Cost		($MMtCO_2$)	($MMtCO_2$)	(percent from BAU)	(percent from BAU)
IA	–$78	$1,379	–$2,085	–$706	$627	–22.36	80.41	67.51	48.74
IL	$135	$318	–$186	$132	3	–2.00	149.12	47.19	46.56
KS	–$100	$1,615	–$2,845	–$1,231	$1,131	–30.51	78.93	74.33	45.59
MB	$261	–$136	$264	$128	$133	2.83	8.92	44.87	59.11
MI	**–$1,304**	**$299**	**–$1,966**	**–$1,667**	**$363**	**–21.08**	**137.64**	**50.08**	**42.41**
MN	$8,172	–$391	$3,747	$3,356	$4,816	40.18	43.04	25.83	49.94
WI	$6,043	–$459	$3,073	$2,613	$3,430	32.95	41.46	27.68	49.67
Total	**$13,129**	**$2,626**	**$0**	**$2,626**	**$10,503**	**73.96[b]**	**539.52**	**46.82**	**46.82**

[a] Permit price = $93.25/$tCO_2e$.

[b] Represents number of permits bought or sold.

AFW = agriculture, forestry, and waste management sectors; BAU = business as usual; MCAC = Michigan Climate Action Council; MGA = Midwestern Governors Association; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Table G-A1-10. Economy-wide (excluding AFW) cap-and-trade simulation among MGA partners in 2025

(With MCAC goal **30% below 2002** levels by 2025, assuming **auction** of allowances)

State/ Province	Total BAU Emissions in 2025 ($MMtCO_2$)	Emission Reduction Undertaken by Michigan Sources[a]		Emission Allowances Bought From Auctioneer ($MMtCO_2$)	Auction Payment by Emitters/ Revenue to the State (million $)[b]	Mitigation Cost (million $)	Total Payments and Costs (million $)
		(percent from BAU)	($MMtCO_2$)				
IA	119.11	67.51	80.41	38.70	$3,608	$1,379	$4,988
IL	315.98	47.19	149.12	166.86	$15,560	$318	$15,878
KS	106.19	74.33	78.93	27.26	$2,542	$1,615	$4,157
MB	19.88	44.87	8.92	10.96	$1,022	–$136	$886
MI	**274.82**	**50.08**	**137.64**	**137.18**	**$12,792**	**$299**	**$13,092**
MN	166.64	25.83	43.04	123.60	$11,525	–$391	$11,134
WI	149.82	27.68	41.46	108.36	$10,104	–$459	$9,645
Total	**1,152.44**	**46.82**	**539.52**	**612.92**	**$57,154**	**$2,626**	**$59,780**

[a] In equilibrium, each state will choose to mitigate the same level of emissions as they would do in a permit trading market.

[b] The auction price would be the same level ($93.25/$tCO_2e$) as the equilibrium price in a permit trading market.

AFW = agriculture, forestry, and waste management sectors; BAU = business as usual; MCAC = Michigan Climate Action Council; MGA = Midwestern Governors Association; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Table G-A1-11. Economy-wide (excluding AFW) emission trading simulation among MGA partners in 2025

(With MCAC goal **35% below 2002** levels by 2025, assuming **free grant** of allowances; million dollars or otherwise specified)

State/ Province	Before Trading	After Trading			Cost Saving	Permits Traded	Emission Reduction w/ Trading		Emission Reduction Goal
	Mitigation Cost	Mitigation Cost	Trading Payments/ Revenues[a]	Net Payment/ Revenue + Cost		($MMtCO_2$)	($MMtCO_2$)	(percent from BAU)	(percent from BAU)
IA	$119	$2,027	–$2,757	–$730	$849	–24.29	86.70	72.79	52.40
IL	$1,337	$1,620	–$287	$1,332	$5	–2.53	161.72	51.18	50.38
KS	$26	$2,194	–$3,633	–$1,440	$1,465	–32.01	84.55	79.62	49.48
MB	$380	–$69	$313	$245	$135	2.76	9.57	48.14	62.03
MI	**–$531**	**$1,469**	**–$2,394**	**–$925**	**$394**	**–21.09**	**148.97**	**54.20**	**46.53**
MN	$10,401	$0	$4,809	$4,809	$5,592	42.36	46.82	28.10	53.52
WI	$7,856	–$94	$3,950	$3,856	$4,000	34.79	45.00	30.04	53.26
Total	**$19,589**	**$7,147**	**$0**	**$7,147**	**$12,442**	**77.38[b]**	**583.33**	**50.62**	**50.62**

[a] Permit price = $113.52/$tCO_2e$.

[b] Represents number of permits bought or sold.

AFW = agriculture, forestry, and waste management sectors; BAU = business as usual; MCAC = Michigan Climate Action Council; MGA = Midwestern Governors Association; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Table G-A1-12. Economy-wide (excluding AFW) cap-and-trade simulation among MGA partners in 2025

(With MCAC goal **35% below 2002** levels by 2025, assuming **auction** of allowances)

State/ Province	Total BAU Emissions in 2025 ($MMtCO_2$)	Emission Reduction Undertaken by Michigan Sources[a]		Emission Allowances Bought From Auctioneer ($MMtCO_2$)	Auction Payment by Emitters/ Revenue to the State (million $)[b]	Mitigation Cost (million $)	Total Payments and Costs (million $)
		(percent from BAU)	($MMtCO_2$)				
IA	119.11	72.79	86.70	32.41	$3,679	$2,027	$5,706
IL	315.98	51.18	161.72	154.26	$17,511	$1,620	$19,131
KS	106.19	79.62	84.55	21.64	$2,457	$2,194	$4,650
MB	19.88	48.14	9.57	10.31	$1,170	–$69	$1,102
MI	**274.82**	**54.20**	**148.97**	**125.85**	**$14,287**	**$1,469**	**$15,756**
MN	166.64	28.10	46.82	119.82	$13,602	$0	$13,601
WI	149.82	30.04	45.00	104.82	$11,899	–$94	$11,805
Total	**1,152.44**	**50.62**	**583.33**	**569.11**	**$64,605**	**$7,147**	**$71,752**

[a] In equilibrium, each state will choose to mitigate the same level of emissions as they would do in a permit trading market.

[b] The auction price would be the same level ($113.52/$tCO_2e$) as the equilibrium price in a permit trading market.

AFW = agriculture, forestry, and waste management sectors; BAU = business as usual; MCAC = Michigan Climate Action Council; MGA = Midwestern Governors Association; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Data table G-A1-D2

(Economy-wide C&T with MCAC goal 25%, 30%, and 35% below 2002 levels by 2025)

State/ Province	2025 BAU Gross Emissions of the C&T Covered Sectors (Consumption-based) ($MMtCO_2e$)	Emissions Cap for the C&T Covered Sectors in 2025 ($MMtCO_2e$)			GHG Mitigation Goal in 2025 (relative to BAU emissions)			Autarkic Marginal Mitigation Cost ($/$tCO_2e$)		
		25% below 2002	30% below 2002	35% below 2002	25% below 2002	30% below 2002	35% below 2002	25% below 2002	30% below 2002	35% below 2002
IA	119.1	65.4	61.1	56.7	45.08%	48.74%	52.40%	33.2	41.1	49.6
IL	316.0	180.9	168.9	156.8	42.75%	46.56%	50.38%	72.4	90.2	109.3
KS	106.2	61.9	57.8	53.6	41.71%	45.59%	49.48%	21.3	27.3	33.8
MB	19.9	8.7	8.1	7.5	56.18%	59.11%	62.03%	169.3	192.3	216.8
MI	**274.8**	**169.6**	**158.3**	**146.9**	**38.30%**	**42.41%**	**46.53%**	**43.4**	**59.6**	**77.1**
MN	166.6	89.4	83.4	77.5	46.37%	49.94%	53.52%	304.8	349.8	398.2
WI	149.8	80.8	75.4	70.0	46.07%	49.67%	53.26%	272.6	314.8	360.0
Total	**1,152.4**	**656.7**	**612.9**	**569.1**	**43.02%**	**46.82%**	**50.62%**			

BAU = business as usual; C&T = cap and trade; MCAC = Michigan Climate Action Council; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $/$tCO_2e$ = dollars per metric tons of carbon dioxide equivalent.

Power Sector-Only Cap-and-Trade Simulations

Table G-A1-13. Power sector emission trading simulation among MGA partners in 2020

(With MGA goal **15% below 2005** levels by 2020, assuming **free grant** of allowances; million dollars or otherwise specified)

State/ Province	Before Trading	After Trading			Cost Saving	Permits Traded	Emission Reduction w/ Trading		Emission Reduction Goal
	Mitigation Cost	Mitigation Cost	Trading Payments/ Revenues[a]	Net Payment/ Revenue + Cost		($MMtCO_2$)	($MMtCO_2$)	(percent from BAU)	(percent from BAU)
IA	$80	$181	–$123	$57	$22	–9.30	21.90	47.13	27.11
IL	–$885	–$947	$50	–$897	$12	3.75	46.95	36.47	39.38
KS	$103	$176	–$82	$94	$9	–6.18	18.52	38.10	25.38
MB	–$38	–$50	–$3	–$53	$15	–0.22	0.57	94.89	57.50
MI	**–$919**	**–$898**	**–$179**	**–$1,076**	**$157**	**–13.48**	**43.89**	**38.98**	**27.01**
MN	$635	–$509	$186	–$322	$957	14.07	12.74	17.05	35.89
WI	$326	–$518	$151	–$367	$693	11.37	12.18	19.72	38.13
Total	**–$700**	**–$2,565**	**$0**	**–$2,565**	**$1,865**	**29.19[b]**	**156.75**	**33.11**	**33.11**

[a] Permit price = $13.25/$tCO_2$e.

[b] Represents number of permits bought or sold.

BAU = business as usual; MGA = Midwestern Governors Association; $MMtCO_2$e = million metric tons of carbon dioxide equivalent.

Table G-A1-14. Power sector emission trading simulation among MGA partners in 2020

(With MGA goal **15% below 2005** levels by 2020, assuming **auction** of allowances)

State/ Province	Total BAU Emissions in 2020 ($MMtCO_2$)	Emission Reduction Undertaken by Michigan Sources[a]		Emission Allowances Bought From Auctioneer ($MMtCO_2$)	Auction Payment by Emitters/ Revenue to the State (million $)[b]	Mitigation Cost (million $)	Total Payments and Costs (million $)
		(percent from BAU)	($MMtCO_2$)				
IA	46.47	47.13	21.90	24.57	$326	$181	$506
IL	128.76	36.47	46.95	81.81	$1,084	–$947	$137
KS	48.62	38.10	18.52	30.10	$399	$176	$575
MB	0.60	94.89	0.57	0.03	$0	–$50	–$50
MI	**112.57**	**38.98**	**43.89**	**68.68**	**$910**	**–$898**	**$12**
MN	74.68	17.05	12.74	61.94	$821	–$509	$312
WI	61.77	19.72	12.18	49.59	$657	–$518	$139
Total	**473.47**	**33.11**	**156.75**	**316.72**	**$4,197**	**–$2,565**	**$1,631**

[a] In equilibrium, each state will choose to mitigate the same level of emissions as they would do in a permit trading market.

[b] The auction price would be the same level ($13.25/$tCO_2$e) as the equilibrium price in a permit trading market.

BAU = business as usual; MGA = Midwestern Governors Association; $MMtCO_2$e = million metric tons of carbon dioxide equivalent.

Table G-A1-15. Power sector emission trading simulation among MGA partners in 2020

(With MGA goal **20% below 2005** levels by 2020, assuming **free grant** of allowances; million dollars or otherwise specified)

State/ Province	Before Trading	After Trading			Cost Saving	Permits Traded	Emission Reduction w/ Trading		Emission Reduction Goal
	Mitigation Cost	Mitigation Cost	Trading Payments/ Revenues[a]	Net Payment/ Revenue + Cost		($MMtCO_2$)	($MMtCO_2$)	(percent from BAU)	(percent from BAU)
IA	$98	$272	–$230	$42	$56	–13.34	27.93	60.10	31.40
IL	–$776	–$911	$103	–$808	$32	5.99	49.30	38.29	42.94
KS	$126	$286	–$195	$91	$35	–11.30	25.77	53.00	29.77
MB	–$40	–$50	–$4	–$54	$14	–0.21	0.57	95.30	60.00
MI	**–$946**	**–$865**	**–$186**	**–$1,051**	**$105**	**–10.79**	**46.03**	**40.89**	**31.30**
MN	$1,119	–$502	$284	–$218	$1,337	16.44	13.18	17.65	39.66
WI	$676	–$512	$228	–$284	$960	13.21	12.59	20.38	41.77
Total	**$256**	**–$2,283**	**$0**	**–$2,283**	**$2,539**	**35.64[b]**	**175.37**	**37.04**	**37.04**

[a] Permit price = $17.25/$tCO_2e.

[b] Represents number of permits bought or sold.

BAU = business as usual; MGA = Midwestern Governors Association; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Table G-A1-16. Power sector emission trading simulation among MGA partners in 2020

(With MGA goal **20% below 2005** levels by 2020, assuming **auction** of allowances)

State/ Province	Total BAU Emissions in 2020 ($MMtCO_2$)	Emission Reduction Undertaken by Michigan Sources[a]		Emission Allowances Bought From Auctioneer ($MMtCO_2$)	Auction Payment by Emitters/ Revenue to the State (million $)[b]	Mitigation Cost (million $)	Total Payments and Costs (million $)
		(percent from BAU)	($MMtCO_2$)				
IA	46.47	60.10	27.93	18.54	$320	$272	$592
IL	128.76	38.29	49.30	79.46	$1,371	–$911	$459
KS	48.62	53.00	25.77	22.85	$394	$286	$680
MB	0.60	95.30	0.57	0.03	$0	–$50	–$50
MI	**112.57**	**40.89**	**46.03**	**66.54**	**$1,148**	**–$865**	**–$283**
MN	74.68	17.65	13.18	61.50	$1,061	–$502	$559
WI	61.77	20.38	12.59	49.18	$848	–$512	$337
Total	**473.47**	**37.04**	**175.37**	**298.10**	**$5,142**	**–$2,283**	**$2,860**

[a] In equilibrium, each state will choose to mitigate the same level of emissions as they would do in a permit trading market.

[b] The auction price would be the same level ($17.25/$tCO_2e) as the equilibrium price in a permit trading market.

BAU = business as usual; MGA = Midwestern Governors Association; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Table G-A1-17. Power sector emission trading simulation among MGA partners in 2020

(With MGA goal **25% below 2005** levels by 2020, assuming **free grant** of allowances; million dollars or otherwise specified)

State/ Province	Before Trading	After Trading			Cost Saving	Permits Traded	Emission Reduction w/ Trading		Emission Reduction Goal
	Mitigation Cost	Mitigation Cost	Trading Payments/ Revenues[a]	Net Payment/ Revenue + Cost		($MMtCO_2$)	($MMtCO_2$)	(percent from BAU)	(percent from BAU)
IA	$118	$380	–$375	$5	$113	–16.84	33.43	71.93	35.69
IL	–$628	–$855	$172	–$683	$55	7.74	52.15	40.50	46.51
KS	$151	$416	–$352	$64	$87	–15.82	32.43	66.69	34.16
MB	–$41	–$50	–$4	–$55	$14	–0.20	0.57	95.77	62.50
MI	**–$935**	**–$814**	**–$190**	**–$1,004**	**$69**	**–8.54**	**48.61**	**43.18**	**35.60**
MN	$1,700	–$491	$416	–$75	$1,775	18.70	13.74	18.39	43.43
WI	$1,094	–$502	$333	–$169	$1,263	14.96	13.09	21.18	45.41
Total	**$1,460**	**–$1,916**	**$0**	**–$1,916**	**$3,376**	**41.40[b]**	**194.01**	**40.98**	**40.98**

[a] Permit price = $22.24/$tCO_2e$.

[b] Represents number of permits bought or sold.

BAU = business as usual; MGA = Midwestern Governors Association; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Table G-A1-18. Power sector emission trading simulation among MGA partners in 2020

(With MGA goal **25% below 2005** levels by 2020, assuming **auction** of allowances)

State/ Province	Total BAU Emissions in 2020 ($MMtCO_2$)	Emission Reduction Undertaken by Michigan Sources[a]		Emission Allowances Bought From Auctioneer ($MMtCO_2$)	Auction Payment by Emitters/ Revenue to the State (million $)[b]	Mitigation Cost (million $)	Total Payments and Costs (million $)
		(percent from BAU)	($MMtCO_2$)				
IA	46.47	71.93	33.43	13.04	$290	$380	$670
IL	128.76	40.50	52.15	76.61	$1,704	–$855	$849
KS	48.62	66.69	32.43	16.19	$360	$416	$776
MB	0.60	95.77	0.57	0.03	$1	–$50	–$50
MI	**112.57**	**43.18**	**48.61**	**63.96**	**$1,422**	**–$814**	**$608**
MN	74.68	18.39	13.74	60.94	$1,355	–$491	$865
WI	61.77	21.18	13.09	48.68	$1,083	–$502	$581
Total	**473.47**	**40.98**	**194.01**	**279.46**	**$6,215**	**–$1,916**	**$4,299**

[a] In equilibrium, each state will choose to mitigate the same level of emissions as they would do in a permit trading market.

[b] The auction price would be the same level ($22.24/$tCO_2e$) as the equilibrium price in a permit trading market.

BAU = business as usual; MGA = Midwestern Governors Association; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Data table G-A1-D3

(Power sector C&T with MGA goal 15%, 20%, and 25% below 2005 levels by 2020)

State/ Province	2020 BAU Gross Emissions of the C&T Covered Sectors (Consumption-based) ($MMtCO_2e$)	Emissions Cap for the C&T Covered Sectors in 2020 ($MMtCO_2e$)			GHG Mitigation Goal in 2020 (relative to BAU emissions)			Autarkic Marginal Mitigation Cost ($/tCO_2e$)		
		15% below 2005	20% below 2005	25% below 2005	15% below 2005	20% below 2005	25% below 2005	15% below 2005	20% below 2005	25% below 2005
IA	46.5	33.9	31.9	29.9	27.11%	31.40%	35.69%	8.7	9.6	10.5
IL	128.8	78.1	73.5	68.9	39.38%	42.94%	46.51%	19.7	28.0	36.8
KS	48.6	36.3	34.1	32.0	25.38%	29.77%	34.16%	10.5	11.4	12.4
MB	0.6	0.3	0.2	0.2	57.50%	60.00%	62.50%	–87.9	–85.0	–81.9
MI	**112.6**	**82.2**	**77.3**	**72.5**	**27.01%**	**31.30%**	**35.60%**	**–9.3**	**–1.7**	**6.4**
MN	74.7	47.9	45.1	42.2	35.89%	39.66%	43.43%	155.4	188.8	224.4
WI	61.8	38.2	36.0	33.7	38.13%	41.77%	45.41%	140.8	170.5	202.1
Total	**473.5**	**316.7**	**298.1**	**279.5**	**33.11%**	**37.04%**	**40.98%**			

BAU = business as usual; C&T = cap and trade; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $/tCO_2e$ = dollars per metric tons of carbon dioxide equivalent.

Table G-A1-19. Power sector emission trading simulation among MGA partners in 2025

(With MCAC goal **25% below 2002** levels by 2025, assuming **free grant** of allowances; million dollars or otherwise specified)

State/ Province	Before Trading	After Trading			Cost Saving	Permits Traded	Emission Reduction w/ Trading		Emission Reduction Goal
	Mitigation Cost	Mitigation Cost	Trading Payments/ Revenues[a]	Net Payment/ Revenue + Cost		($MMtCO_2$)	($MMtCO_2$)	(percent from BAU)	(percent from BAU)
IA	$116	$604	–$962	–$358	$474	–25.09	47.52	92.60	43.72
IL	–$190	–$747	$434	–$314	$123	11.31	68.47	47.49	55.34
KS	$155	$692	–$986	–$295	$450	–25.72	47.86	91.06	42.12
MB	–$57	–$66	–$9	–$75	$17	–0.22	0.72	95.71	66.07
MI	**–$976**	**–$726**	**–$320**	**–$1,046**	**$70**	**–8.35**	**62.24**	**51.52**	**44.61**
MN	$4,413	–$561	$1,072	$511	$3,902	27.97	17.96	21.53	55.06
WI	$2,414	–$577	$771	$193	$2,220	20.10	16.92	24.65	53.92
Total	**$5,875**	**–$1,382**	**$0**	**–$1,382**	**$7,257**	**59.38[b]**	**261.70**	**50.16**	**50.16**

[a] Permit price = $38.34/$tCO_2e$.

[b] Represents number of permits bought or sold.

BAU = business as usual; MGA = Midwestern Governors Association; MCAC = Michigan Climate Action Council; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Table G-A1-20. Power sector emission trading simulation among MGA partners in 2025

(With MCAC goal **25% below 2002** levels by 2025, assuming **auction** of allowances)

State/ Province	Total BAU Emissions in 2025 ($MMtCO_2$)	Emission Reduction Undertaken by Michigan Sources[a]		Emission Allowances Bought From Auctioneer ($MMtCO_2$)	Auction Payment by Emitters/ Revenue to the State (million $)[b]	Mitigation Cost (million $)	Total Payments and Costs (million $)
		(percent from BAU)	($MMtCO_2$)				
IA	51.32	92.60	47.52	3.80	$146	$604	$749
IL	144.17	47.49	68.47	75.70	$2,902	–$747	$2,155
KS	52.56	91.06	47.86	4.70	$180	$692	$872
MB	0.75	95.71	0.72	0.03	$1	–$66	–$65
MI	**120.80**	**51.52**	**62.24**	**58.56**	**$2,245**	**–$726**	**$1,519**
MN	83.41	21.53	17.96	65.45	$2,509	–$561	$1,949
WI	68.67	24.65	16.92	51.75	$1,984	–$577	$1,406
Total	**521.68**	**50.16**	**261.70**	**259.98**	**$9,968**	**–$1,382**	**$8,586**

[a] In equilibrium, each state will choose to mitigate the same level of emissions as they would do in a permit trading market.

[b] The auction price would be the same level ($38.34/$tCO_2e$) as the equilibrium price in a permit trading market.

BAU = business as usual; MCAC = Michigan Climate Action Council; MGA = Midwestern Governors Association; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Table G-A1-21. Power sector emission trading simulation among MGA partners in 2025

(With MCAC goal **30% below 2002** levels by 2025, assuming **free grant** of allowances; million dollars or otherwise specified)

State/ Province	Before Trading	After Trading			Cost Saving	Permits Traded	Emission Reduction w/ Trading		Emission Reduction Goal
	Mitigation Cost	Mitigation Cost	Trading Payments/ Revenues[a]	Net Payment/ Revenue + Cost		($MMtCO_2$)	($MMtCO_2$)	(percent from BAU)	(percent from BAU)
IA	$136	$690	–$1,234	–$544	$680	–25.17	49.54	96.52	47.47
IL	$91	–$502	$489	–$12	$103	9.98	74.10	51.40	58.32
KS	$179	$797	–$1,282	–$485	$664	–26.15	50.31	95.73	45.97
MB	–$59	–$66	–$10	–$76	$18	–0.21	0.72	96.44	68.33
MI	**–$859**	**–$514**	**–$429**	**–$942**	**$83**	**–8.74**	**67.10**	**55.54**	**48.31**
MN	$5,322	–$506	$1,432	$926	$4,396	29.20	19.21	23.04	58.05
WI	$3,037	–$529	$1,034	$506	$2,531	21.09	18.04	26.27	56.99
Total	**$7,847**	**–$629**	**$0**	**–$629**	**$8,475**	**60.28[b]**	**279.03**	**53.49**	**53.49**

[a] Permit price = $49.03/ton$CO_2e$.

[b] Represents number of permits bought or sold.

BAU = business as usual; MCAC = Michigan Climate Action Council; MGA = Midwestern Governors Association; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Table G-A1-22. Power sector emission trading simulation among MGA partners in 2025

(With MCAC goal **30% below 2002** levels by 2025, assuming **auction** of allowances)

State/ Province	Total BAU Emissions in 2025 ($MMtCO_2$)	Emission Reduction Undertaken by Michigan Sources[a]		Emission Allowances Bought From Auctioneer ($MMtCO_2$)	Auction Payment by Emitters/ Revenue to the State (million $)[b]	Mitigation Cost (million $)	Total Payments and Costs (million $)
		(percent from BAU)	($MMtCO_2$)				
IA	51.32	96.52	49.54	1.78	$88	$690	$778
IL	144.17	51.40	74.10	70.07	$3,435	–$502	$2,934
KS	52.56	95.73	50.31	2.25	$110	$797	$907
MB	0.75	96.44	0.72	0.03	$1	–$66	–$65
MI	**120.80**	**55.54**	**67.10**	**53.70**	**$2,633**	**–$514**	**$2,119**
MN	83.41	23.04	19.21	64.20	$3,147	–$506	$2,641
WI	68.67	26.27	18.04	50.63	$2,482	–$529	$1,954
Total	**521.68**	**53.49**	**279.03**	**242.65**	**$11,897**	**–$629**	**$11,268**

[a] In equilibrium, each state will choose to mitigate the same level of emissions as they would do in a permit trading market.

[b] The auction price would be the same level ($49.03/$tCO_2e$) as the equilibrium price in a permit trading market.

BAU = business as usual; MCAC = Michigan Climate Action Council; MGA = Midwestern Governors Association; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Table G-A1-23. Power sector emission trading simulation among MGA partners in 2025

(With MCAC goal **35% below 2002** levels by 2025, assuming **free grant** of allowances; million dollars or otherwise specified)

State/ Province	Before Trading	After Trading			Cost Saving	Permits Traded	Emission Reduction w/ Trading		Emission Reduction Goal
	Mitigation Cost	Mitigation Cost	Trading Payments/ Revenues[a]	Net Cost		($MMtCO_2$)	($MMtCO_2$)	(percent from BAU)	(percent from BAU)
IA	$157	$750	–$1,519	–$769	$926	–24.34	50.63	98.65	51.22
IL	$413	–$143	$487	$344	$69	7.80	80.56	55.88	61.29
KS	$205	$871	–$1,590	–$718	$923	–25.48	51.67	98.30	49.83
MB	–$60	–$66	–$12	–$78	$18	–0.20	0.73	97.18	70.59
MI	**–$703**	**–$208**	**–$611**	**–$819**	**$115**	**–9.79**	**72.61**	**60.11**	**52.00**
MN	$6,333	–$420	$1,882	$1,462	$4,871	30.17	20.75	24.88	61.05
WI	$3,733	–$453	$1,362	$910	$2,824	21.84	19.41	28.26	60.06
Total	**$10,079**	**$332**	**$0**	**$332**	**$9,747**	**59.81[b]**	**296.35**	**56.81**	**56.81**

[a] Permit price = $62.39/$tCO_2e$.

[b] Represents number of permits bought or sold.

BAU = business as usual; MCAC = Michigan Climate Action Council; MGA = Midwestern Governors Association; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Table G-A1-24. Power sector emission trading simulation among MGA partners in 2025

(With MCAC goal **35% below 2002** levels by 2025, assuming **auction** of allowances)

State/ Province	Total BAU Emissions in 2025 ($MMtCO_2$)	Emission Reduction Undertaken by Michigan Sources[a]		Emission Allowances Bought From Auctioneer ($MMtCO_2$)	Auction Payment by Emitters/ Revenue to the State (million $)[b]	Mitigation Cost (million $)	Total Payments and Costs (million $)
		(percent from BAU)	($MMtCO_2$)				
IA	51.32	98.65	50.63	0.69	$43	$750	$793
IL	144.17	55.88	80.56	63.61	$3,969	–$143	$3,826
KS	52.56	98.30	51.67	0.89	$56	$871	$927
MB	0.75	97.18	0.73	0.02	$1	–$66	–$64
MI	**120.80**	**60.11**	**72.61**	**48.19**	**$3,007**	**–$208**	**$2,799**
MN	83.41	24.88	20.75	62.66	$3,909	–$420	$3,489
WI	68.67	28.26	19.41	49.26	$3,074	–$453	$2,621
Total	**521.68**	**56.81**	**296.35**	**225.33**	**$14,058**	**$332**	**$14,391**

[a] In equilibrium, each state will choose to mitigate the same level of emissions as they would do in a permit trading market.

[b] The auction price would be the same level ($62.39/$tCO_2e$) as the equilibrium price in a permit trading market.

BAU = business as usual; MCAC = Michigan Climate Action Council; MGA = Midwestern Governors Association; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

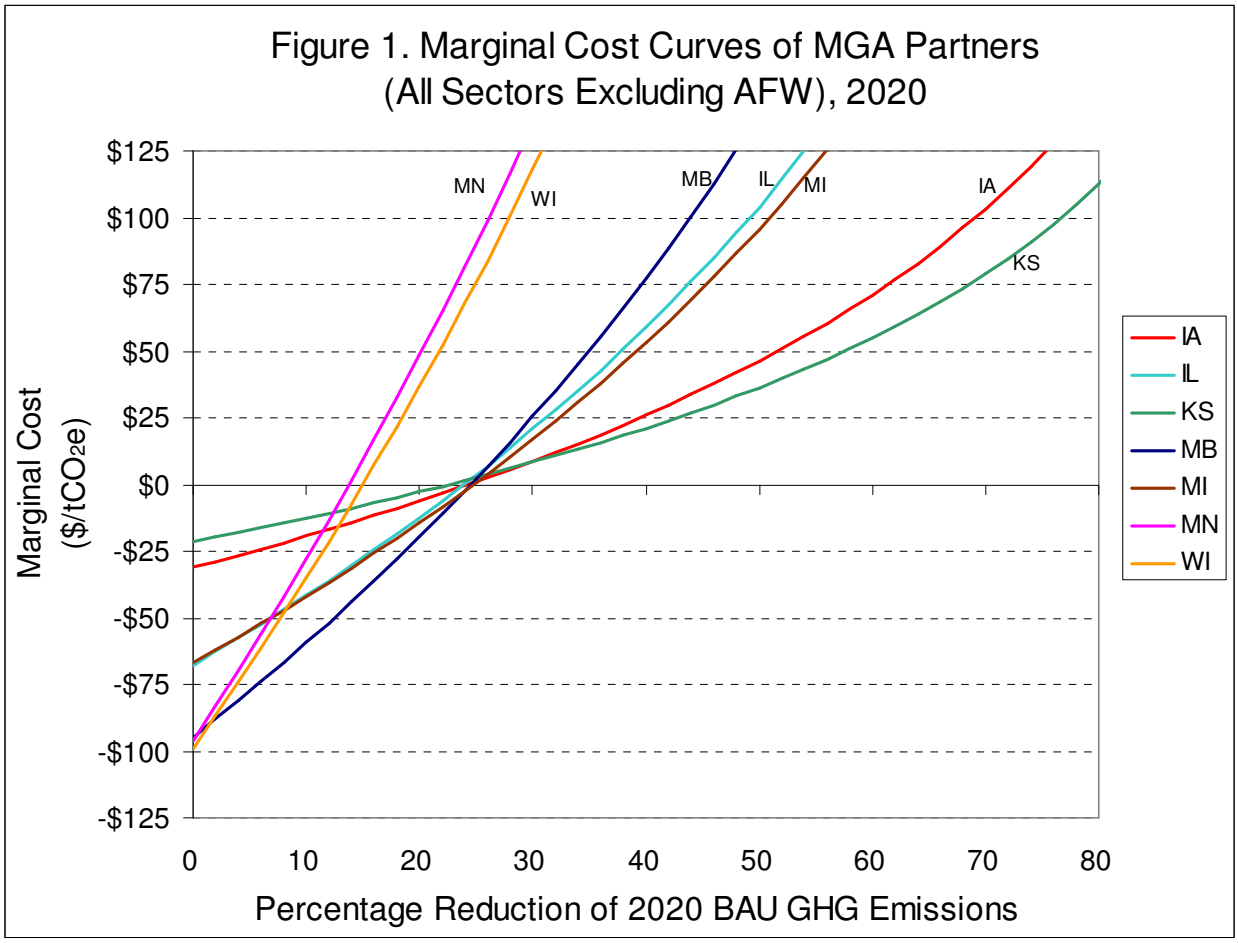
Data table D-A1-D4

(Power sector C&T with MCAC goal 25%, 30%, and 35% below 2002 levels by 2025)

State/ Province	2025 BAU Gross Emissions of the C&T Covered Sectors (Consumption-based) (million tCO_2e)	Emissions Cap for the C&T Covered Sectors in 2025 ($MMtCO_2e$)			GHG Mitigation Goal in 2025 (relative to BAU emissions)			Autarkic Marginal Mitigation Cost ($/$tCO_2e$)		
		25% below 2002	30% below 2002	35% below 2002	25% below 2002	30% below 2002	35% below 2002	25% below 2002	30% below 2002	35% below 2002
IA	51.3	28.9	27.0	25.0	43.72%	47.47%	51.22%	9.6	10.6	11.7
IL	144.2	64.4	60.1	55.8	55.34%	58.32%	61.29%	60.7	70.3	80.5
KS	52.6	30.4	28.4	26.4	42.12%	45.97%	49.83%	11.3	12.3	13.4
MB	0.8	0.3	0.2	0.2	66.07%	68.33%	70.59%	-79.5	-75.6	-71.4
MI	120.8	66.9	62.4	58.0	44.61%	48.31%	52.00%	21.9	30.4	39.6
MN	83.4	37.5	35.0	32.5	55.06%	58.05%	61.05%	345.8	383.8	424.7
WI	68.7	31.6	29.5	27.4	53.92%	56.99%	60.06%	278.9	312.6	348.8
Total	**521.7**	**260.0**	**242.7**	**225.3**	**50.16%**	**53.49%**	**56.81%**			

BAU = business as usual; C&T = cap and trade; MCAC = Michigan Climate Action Council; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $/$tCO_2e$ = dollars per metric tons of carbon dioxide equivalent.

Figure G-A1-1. Marginal cost curves of MGA partners (all sectors, excluding AFW), 2020



Note:

1. The marginal cost curves of MN and IA are developed based on mitigation options data in the Minnesota (MN) State Climate Change Action Plan and the State Climate Change Action Plan of Iowa (IA), respectively. The marginal cost curve of Michigan (MI) is developed based on the quantification analysis results for individual mitigation options provided by the Energy Supply (ES), Residential, Commercial, and Industrial, and Transportation and Land Use Technical Work Groups.

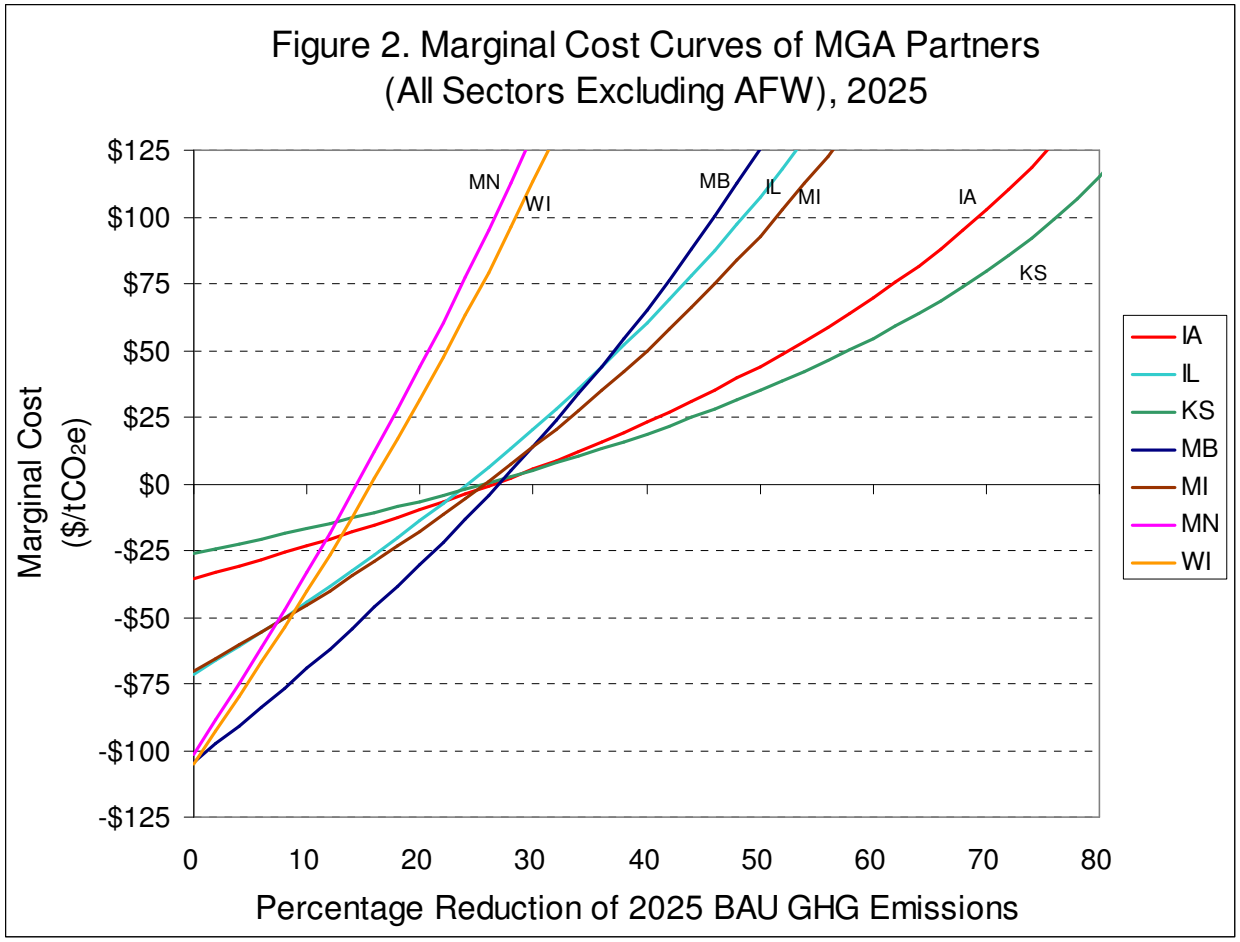
2. The quantification data for MI and MN are for 2025. The mitigation cost data for options of MI and MN are adjusted to 2020 based on the assumption of 2% annual technical improvement or innovation rate. In other words, we use the same reduction potential (in percentage terms) for individual options in 2020 as in 2025, and assume the cost per ton of CO_2e reduction would be about $(1+2\%)^5$ higher in 2020 than in 2025.

3. The marginal cost curves of Manitoba (MB) and Wisconsin (WI) are approximated based on MN data. The cost curve of Kansas (KS) is approximated based on IA data. The cost curve of Illinois (IL) is approximated based on MI data.

4. We adopted the following assumptions when we developed the cost curve for one state based on the data from one of its adjacent states. We assumed that the list of mitigation options for the adjacent state (state A) is applicable to the state without direct data (state B). Second, for state B, the estimated cost or cost savings per unit of GHG removed for each option is assumed to be at the same level as that of state A. Third, the mitigation potentials of each option are assumed to be proportional to the total mitigation potential in each state; this requires that each option be adjusted by the ratio of emissions from the relevant sector of the two states. For example, if the emissions from the power sector are 50 $MMtCO_2e$ and 100 $MMtCO_2e$ in state A and state B, respectively, the mitigation potentials of the ES options for state A are multiplied by a factor of 2 (100/50 = 2) for application to state B.

AFW = agriculture, forestry, and waste management sectors; BAU = business as usual; GHG = greenhouse gas; MGA = Midwestern Governors Association; $/tCO$_2$e = dollars per metric tons of carbon dioxide equivalent.

Figure G-A1-2. Marginal cost curves of MGA partners (all sectors, excluding AFW), 2025



Note: 1. The marginal cost curves of MN and IA are developed based on mitigation options data in the Minnesota State Climate Change Action Plan and the State Climate Change Action Plan of Iowa, respectively. The marginal cost curve of MI is developed based on the quantification analysis results for individual mitigation options provided by the ES, RCI, and TLU TWGs.

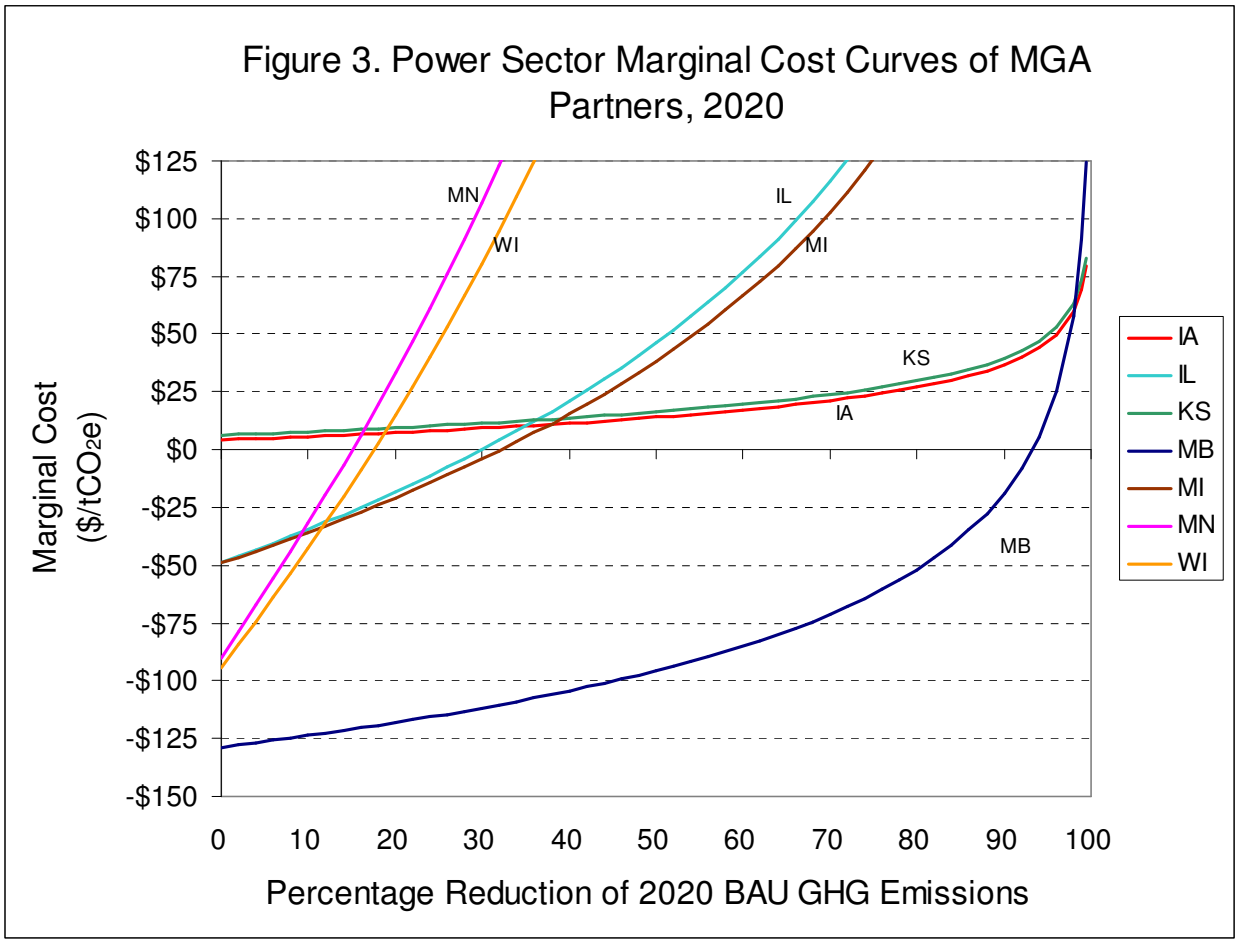
2. The quantification data for Iowa are for the Year 2020. The mitigation cost data for options of IA are adjusted to the Year 2025 based on the assumption of 2% annual technical improvement or innovation rate. In other words, we use the same reduction potential (in percentage terms) for individual options in year 2025 as in year 2020, and assumed the cost per ton of CO_2e reduction would be about $(1+2\%)^5$ lower in year 2025 than in year 2020.

3. The marginal cost curves of MB and WI are approximated based on MN data. The cost curve of KS is approximated based on IA data. The cost curve of IL is approximated based on MI data.

4. The following assumptions are adopted when we develop the cost curve for one state based on the data from one of its adjacent states. We assume that the list of mitigation options for the adjacent state (state A) is applicable to the state without direct data (state B). Second, for state B, the estimated cost or cost savings per unit GHG removed for each option is assumed to be at the same level as that of state A. Third, the mitigation potentials of each option are assumed to be proportional to the total mitigation potential in each state; this requires that each option be adjusted by the ratio of emissions from the relevant sector of the two states. For example, if the emissions from the power sector are 50 MMtCO2e and 100 MMtCO2e in state A and state B, respectively, the mitigation potentials of the ES options for state A are multiplied by a factor of 2 (100/50=2) for application to state B.

AFW = agriculture, forestry, and waste management sectors; BAU = business as usual; GHG = greenhouse gas; MGA = Midwestern Governors Association; $/tCO$_2$e = dollars per metric tons of carbon dioxide equivalent.

Figure G-A1-3. Power sector marginal cost curves of MGA partners, 2020



Note: 1. The power sector marginal cost curves of the states are developed based on the reduction potential and mitigation cost/saving data of individual options that contribute to the emission reductions from power sector. These options not only include those designed directly for the electricity supply sector (such as promotion of renewable energy utilization, repowering existing plants, etc.), but also include options in RCI sectors that contribute to the reduction of electricity consumption (e.g., energy efficiency appliances, building codes, etc.). Also, for those options that apply to the use of both electricity and other fuel types, the emission reduction potentials are adjusted by multiplying the percentage of electricity consumption to total energy consumption in the RCI sector. RCI options that relate entirely to reduction of other fossil fuels consumption (such as gas, oil) are not included in the power sector cost curve development.

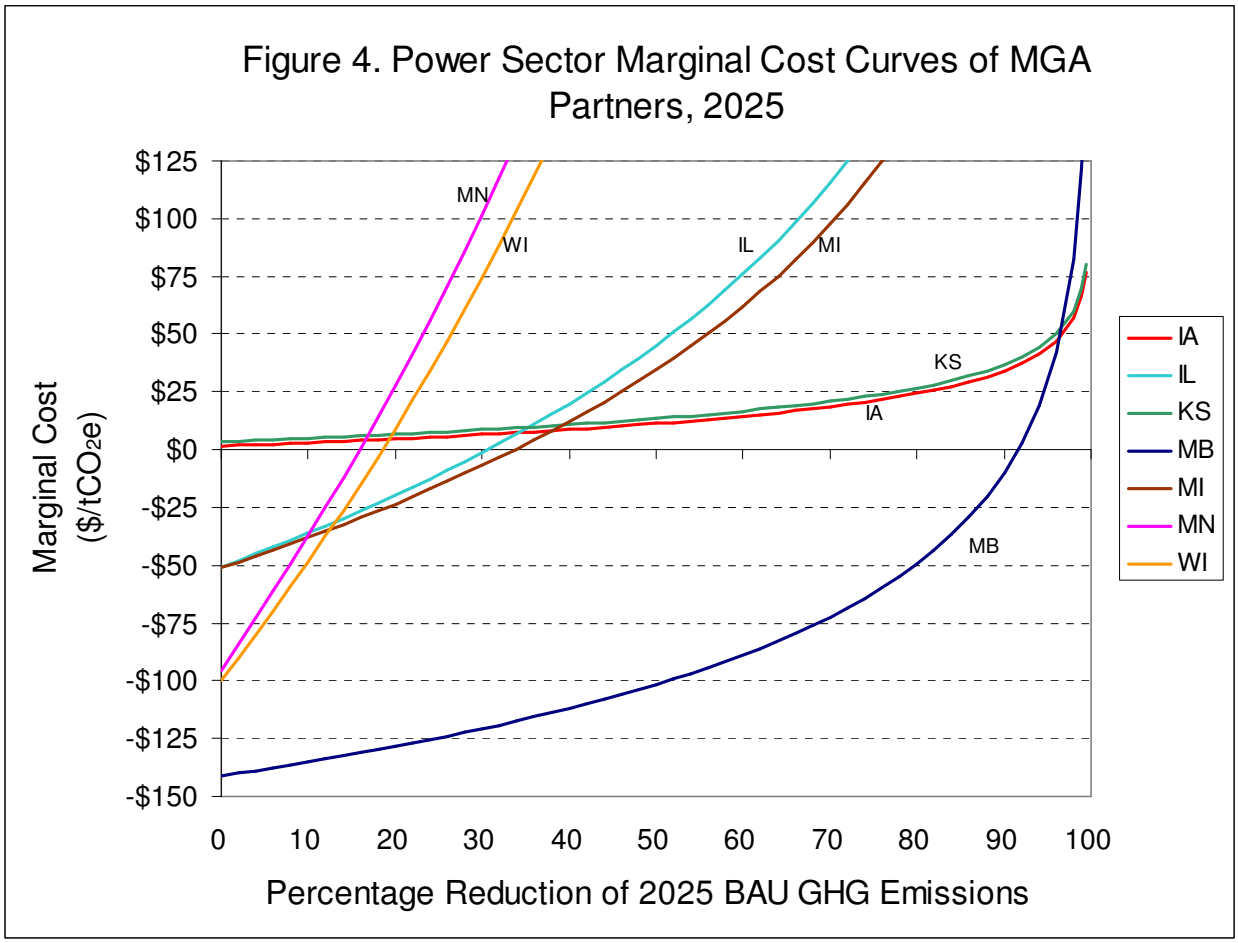
2. The marginal cost curves of MN and IA are developed based on mitigation options data in the Minnesota State Climate Change Action Plan and the State Climate Change Action Plan of Iowa, respectively. The marginal cost curve of MI is developed based on the quantification analysis results for individual mitigation options provided by the ES and RCI TWGs.

3. The marginal cost curves of MB and WI are approximated based on MN data. The cost curve of KS is approximated based on IA data. The cost curve of IL is approximated based on MI data.

4. The following assumptions are adopted when we develop the cost curve for one state based on the data from one of its adjacent states. We assume that the list of mitigation options for the adjacent state (state A) is applicable to the state without direct data (state B). Second, for state B, the estimated cost or cost savings per unit GHG removed for each option is assumed to be at the same level as that of state A. Third, the mitigation potentials of each option are assumed to be proportional to the total mitigation potential in each state; this requires that each option be adjusted by the ratio of emissions from the relevant sector of the two states.

BAU = business as usual; GHG = greenhouse gas; MGA = Midwestern Governors Association; $/tCO$_2$e = dollars per metric tons of carbon dioxide equivalent.

Figure G-A1-4. Power sector marginal cost curves of MGA partners, 2025



Note: 1. The power sector marginal cost curves of the states are developed based on the reduction potential and mitigation cost/saving data of individual options that contribute to the emission reductions from power sector. These options not only include those designed directly for the electricity supply sector (such as promotion of renewable energy utilization, repowering existing plants, etc.), but also include options in RCI sectors that contribute to the reduction of electricity consumption (e.g., energy efficiency appliances, building codes, etc.). Also, for those options that apply to the use of both electricity and other fuel types, the emission reduction potentials are adjusted by multiplying the percentage of electricity consumption to total energy consumption in the RCI sector. RCI options that relate entirely to reduction of other fossil fuels consumption (such as gas, oil) are not included in the power sector cost curve development.

2. The marginal cost curves of MN and IA are developed based on mitigation options data in the Minnesota State Climate Change Action Plan and the State Climate Change Action Plan of Iowa, respectively. The marginal cost curve of MI is developed based on the quantification analysis results for individual mitigation options provided by the ES and RCI TWGs.

3. The marginal cost curves of MB and WI are approximated based on MN data. The cost curve of KS is approximated based on IA data. The cost curve of IL is approximated based on MI data.

4. The following assumptions are adopted when we develop the cost curve for one state based on the data from one of its adjacent states. We assume that the list of mitigation options for the adjacent state (state A) is applicable to the state without direct data (state B). Second, for state B, the estimated cost or cost savings per unit GHG removed for each option is assumed to be at the same level as that of state A. Third, the mitigation potentials of each option are assumed to be proportional to the total mitigation potential in each state; this requires that each option be adjusted by the ratio of emissions from the relevant sector of the two states.

BAU = business as usual; GHG = greenhouse gas; MGA = Midwestern Governors Association; $/tCO$_2$e = dollars per metric tons of carbon dioxide equivalent.

References

GHG Mitigation Options Data

Iowa Climate Change Advisory Council. 2008. Quantification Analysis of Mitigation Options From the EEC, CRE, and TLU Subcommittees of Iowa.

Michigan Climate Action Council. 2008. Quantification Analysis of Mitigation Options From the ES, RCI, and TLU TWGs of Michigan.

Minnesota Climate Change Advisory Group. 2008. *Minnesota Climate Change Advisory Group Final Report: A Report to the Minnesota Legislature*. http://www.mnclimatechange.us/MCCAG.cfm.

Emissions Inventory and Forecast Data

For Iowa, Michigan, and Kansas: Inventory and Forecast Analysis by the Center for Climate Strategies.

For Manitoba: Williams and Roe. 2008. "Task 0 State-Provincial GHG Summaries Tech Memo 1-31-08.doc" and associated Excel workbooks.

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Annex G-2

Development of Marginal Cost Curves for Michigan

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Economy-wide (Excluding AFW) Marginal Cost Curve

The marginal cost curve of Michigan is developed based on the reduction potential and mitigation cost/saving data of individual options that are quantitatively analyzed by the Energy Supply (ES), Residential, Commercial, and Industrial (RCI), and Transportation and Land Use (TLU) Technical Work Groups (TWGs). Table G-A2-1 presents the list of options that have been quantitatively analyzed by the TWGs.

Table G-A2-1. GHG mitigation options of Michigan (all sectors excluding AFW)

Recommendation No.	Climate Mitigation Actions	Estimated 2025 Annual GHG Reduction Potential ($MMtCO_2e$)	Estimated Cost or Cost Savings per Ton GHG Removed	GHG Reduction Potential as Percentage of 2025 Baseline Emissions[1]	Cumulative GHG Reduction Potential	Weights (add-up to 100)
TLU-6	Land Use Planning and Incentives	0.430	–$189.00	0.16%	0.16%	0.38
TLU-2	Eco-Driver Program	2.200	–$176.00	0.80%	0.96%	1.96
TLU-3	Truck Idling Policies	0.760	–$85.00	0.28%	1.23%	0.68
TLU-5	Congestion Mitigation	0.180	–$81.00	0.07%	1.30%	0.16
RCI-4	Adopt More Stringent Building Codes for Energy Efficiency	9.700	–$35.00	3.53%	4.83%	8.64
RCI-7	Promotion and Incentives for Improved Design and Construction in the Private Sector	0.000	–$31.00	0.00%	4.83%	0.00
RCI-2	Existing Buildings Energy Efficiency Incentives, Assistance, Certification, and Financing	53.800	–$28.00	19.58%	24.40%	47.94
ES-3	Energy Efficiency Portfolio Standard	14.600	–$19.00	5.31%	29.72%	13.01
RCI-1	Utility Demand-Side Management for Electricity and Natural Gas	0.000	–$19.00	0.00%	29.72%	0.00
ES-13	Combined Heat and Power (CHP) Standards, Incentives	0.500	$4.09	0.18%	29.90%	0.45

Recommendation No.	Climate Mitigation Actions	Estimated 2025 Annual GHG Reduction Potential ($MMtCO_2e$)	Estimated Cost or Cost Savings per Ton GHG Removed	GHG Reduction Potential as Percentage of 2025 Baseline Emissions[1]	Cumulative GHG Reduction Potential	Weights (add-up to 100)
	and/or Barrier Removal					
ES-11	Power Plant Replacement, EE, and Repowering	2.000	$9.40	0.73%	30.63%	1.78
ES-10	Technology-Focused Initiatives (Biomass Co-firing, Energy Storage, Fuel Cells, Etc.), Including Research, Development, & Demonstration--Co-firing at 10%	0.500	$10.70	0.18%	30.81%	0.45
TLU-1	Promote Low-Carbon Fuel Use in Transportation	5.900	$16.00	2.15%	32.96%	5.26
ES-6	New Nuclear Power	6.300	$25.98	2.29%	35.25%	5.61
RCI-6	Incentives To Promote Renewable Energy Systems Implementation	0.000	$27.00	0.00%	35.25%	0.00
TLU-8	Increase Rail Capacity, and Address Rail Freight System Bottlenecks	0.190	$35.00	0.07%	35.32%	0.17
ES-1	Renewable Portfolio Standard and Distributed Generation "Carve-Out"	14.600	$48.00	5.31%	40.63%	13.01
TLU-7	Transit and Travel Options	0.540	$185.00	0.20%	40.83%	0.48
TLU-4	Advanced Vehicle Technology	0.030	$1,458.00	0.01%	40.84%	0.03

[1] Michigan 2025 projected consumption-based gross GHG emission level excluding the AFW sector is 274.82 $MMtCO_2e$.

Note: The emission reduction potentials shown in the table are the values after overlap adjustment (both within sectors and across sectors).

$MMtCO_2e$ = million metric tons of carbon dioxide equivalent; EE = energy efficiency; ES = Energy Supply; GHG = greenhouse gas; RCI = Residential, Commercial, and Industrial; TLU = Transportation and Land Use.

In Table G-A2-1, Column 3 of the table presents the estimated 2025 annual greenhouse gas (GHG) reduction potential for each option, with reduction potentials translated into percentages of the 2025 business as usual (BAU) emissions level of the cap and trade (C&T) covered sectors in Column 5. The estimated cost or cost saving per ton of GHG removed by each option in 2025 is presented in Column 4. The options are listed in ascending order in terms of cost, beginning with the lowest-cost (including cost-savings) option. Column 6 lists the cumulative GHG

reduction potentials of the policy options. The last column presents the proportion of GHG mitigation contributed by each option.

Based on the data presented in Table G-A2-1, the stepwise marginal cost function of Michigan in 2025 is first drawn in Figure G-A2-1. The horizontal axis represents the percentage of GHG emission reduction, and the vertical axis represents the marginal cost or savings of mitigation. In the figure, each horizontal segment represents an individual mitigation option. The width of the segment indicates the GHG emission reduction potential of the option in percentage terms. The height of the segment relative to the x-axis shows the average cost (saving) of reducing one metric ton of GHG with the application of the option. The figure indicates that, collectively, the reduction potential of options from all economic sectors can avoid about 40% of 2025 baseline emissions in Michigan.

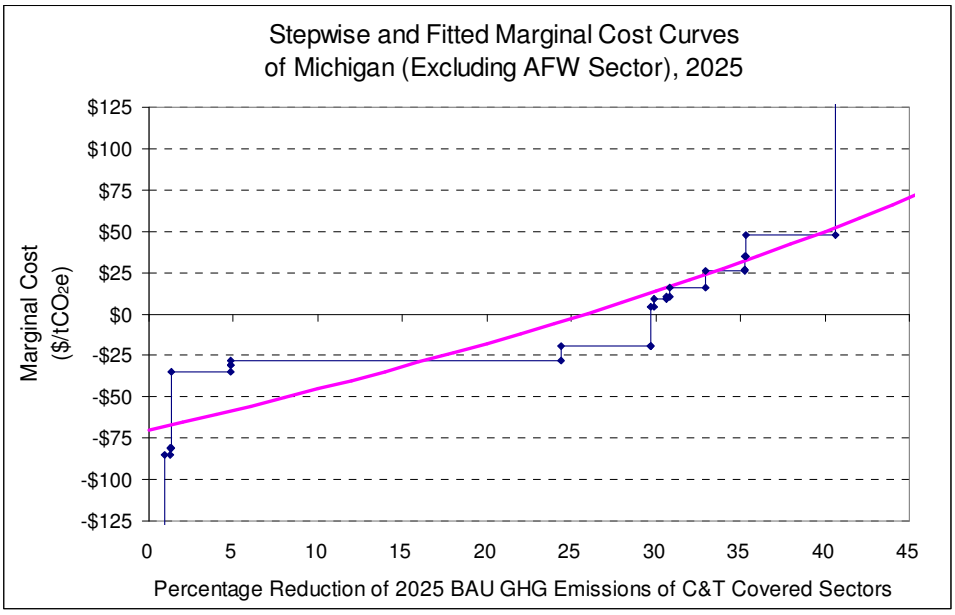
Next, we fit a smooth curve through the data using regression analysis (also see Figure G-A2-1). We weight each policy option based on its GHG mitigation potential to give relatively greater influence to options that have the potential for higher levels of application, and thereby should improve the accuracy of the estimation. This fitted curve is then used in our C&T analysis model.

The fitted curve shown in Figure G-A2-1 has the following functional form:

$$MC = a + b \times \ln(1 - R)$$

where MC is the marginal cost; R is the percentage reduction of GHG emissions; and a and b are parameters.

Figure G-A2-1. Stepwise and fitted marginal cost curve of Michigan (excluding AFW sector), 2025



AFW = Agriculture, Forestry, and Waste Management; BAU = business as usual; C&T = cap and trade; GHG = greenhouse gas.

The logarithmic functional form utilized here is consistent with theoretical expectations and empirical findings on diminishing returns of emission control (Nordhaus, 1994). As the emission reductions increase along the x-axis, the cost to reduce one additional unit of emission increases at an accelerating rate; in other words, it exhibits diminishing returns.

The economy-wide (excluding AFW) marginal cost curve of Michigan has the following specification:

$$MC = -70.13 - 235.15 \times \ln(1 - R)$$

The fitted curve has an intercept with the y-axis at MC = –$70.13. The curve increases to MC = 0 at the emission reduction level of 25.8%, which indicates that Michigan has cost-saving mitigation potentials (such as energy efficiency) up to that level of the 2025 BAU emissions of the C&T covered sectors.

Power Sector-Only Marginal Cost Curve

The policy options we used to develop the power sector marginal cost curve include not only those designed directly for the electricity supply sector, but also those in the RCI sectors that contribute to the reduction of electricity consumption. The emission reduction potentials of these options are adjusted by multiplying the percentage of electricity consumption by total energy consumption in the RCI sectors. RCI options that relate entirely to reduction of other fossil fuel consumption (e.g., gas, oil) are not included in the cost curve development. Table G-A2-2 presents the list of options Michigan used to develop the power sector cost curve.

Table G-A2-2. GHG mitigation options of Michigan (for power sector)

RecommendationsNo.	Climate Mitigation Actions	Estimated 2025 Annual GHG Reduction Potential ($MMtCO_2e$)	Estimated Cost or Cost Savings per ton GHG Removed	GHG Reduction Potential as Percentage of 2025 Baseline Emissions[1]	Cumulative GHG Reduction Potential	Weights (add-up to 100)
RCI-4	Adopt More Stringent Building Codes for Energy Efficiency	4.949	–$35.00	4.10%	4.10%	6.98
RCI-7	Promotion and Incentives for Improved Design and Construction in the Private Sector	0.000	–$31.00	0.00%	4.10%	0.00
RCI-2	Existing Buildings Energy Efficiency Incentives, Assistance, Certification, and Financing	27.452	–$28.00	22.72%	26.82%	38.72
ES-3	Energy Efficiency Portfolio Standard	14.600	–$19.00	12.09%	38.91%	20.59
RCI-1	Utility Demand-Side Management for Electricity and	0.000	–$19.00	0.00%	38.91%	0.00

RecommendationsNo.	Climate Mitigation Actions	Estimated 2025 Annual GHG Reduction Potential ($MMtCO_2e$)	Estimated Cost or Cost Savings per ton GHG Removed	GHG Reduction Potential as Percentage of 2025 Baseline Emissions[1]	Cumulative GHG Reduction Potential	Weights (add-up to 100)
	Natural Gas					
ES-13	Combined Heat and Power (CHP) Standards, Incentives and/or Barrier Removal	0.500	$4.09	0.41%	39.32%	0.71
ES-11	Power Plant Replacement, EE, and Repowering	2.000	$9.40	1.66%	40.98%	2.82
ES-10	Technology-Focused Initiatives (Biomass Co-firing, Energy Storage, Fuel Cells, Etc.), Including Research, Development, & Demonstration--Co-firing at 10%	0.500	$10.70	0.41%	41.39%	0.71
ES-6	New Nuclear Power	6.300	$25.98	5.22%	46.61%	8.89
RCI-6	Incentives To Promote Renewable Energy Systems Implementation	0.000	$27.00	0.00%	46.61%	0.00
ES-1	Renewable Portfolio Standard and Distributed Generation "Carve-Out"	14.600	$48.00	12.09%	58.69%	20.59

[1] Michigan 2025 projected consumption-based power sector gross CO_2 emission level is 120.8 $MMtCO_2e$.

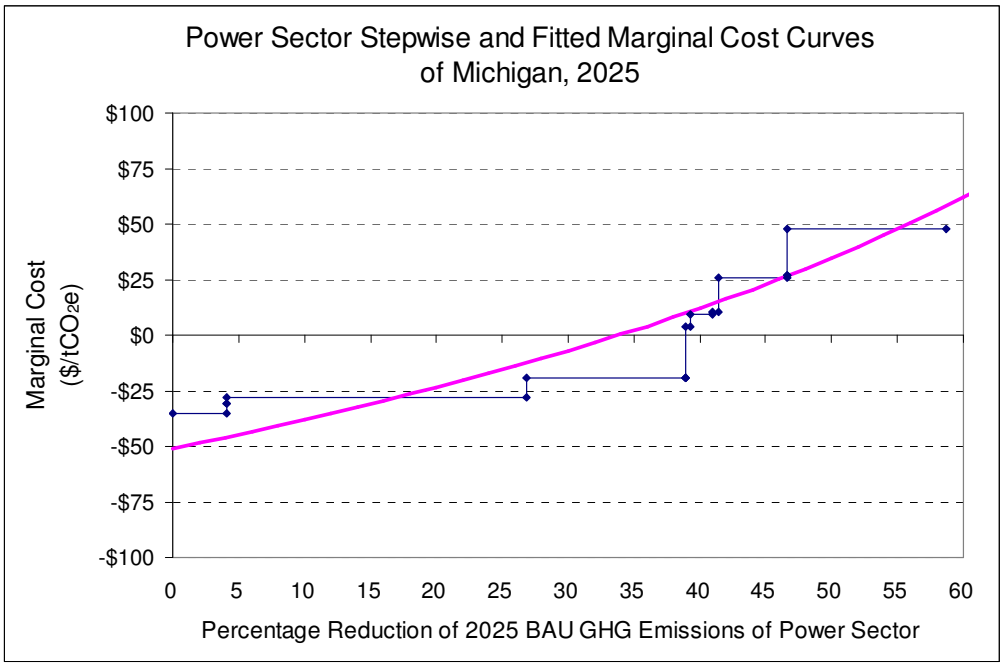
Note: The emission reduction potentials shown in the table are the values after overlap adjustment (both within sectors and across sectors).

$MMtCO_2e$ = million metric tons of carbon dioxide equivalent; EE = energy efficiency; ES = Energy Supply; GHG = greenhouse gas; RCI = Residential, Commercial, and Industrial.

Following the same methodology as described above, the power sector stepwise and fitted marginal cost curves of Michigan for 2025 are developed and presented in Figure G-A2-2. The specification of the power sector fitted marginal cost curve is:

$$MC = -50.98 - 123.36 \times \ln(1 - R)$$

Figure G-A2-2. Power sector stepwise and fitted marginal cost curve of Michigan, 2025



$/tCO$_2$e = dollars per metric ton of carbon dioxide equivalent; BAU = business as usual; GHG = greenhouse gas.

Reference

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Annex G-3

Modeling of Cap-and-Trade Programs

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November 2008

Introduction of the Cap-and-Trade Model

A cap-and-trade (C&T) system has many desirable features for implementing pollution emission reductions. The cap limits emissions, while the trading ensures that the reduction will be achieved at the lowest possible cost (economic efficiency). The initial allocation of permits can be used to address issues of fairness (equity).

The model we use for the C&T analysis has been previously developed and successfully applied to simulate the workings of interregional (and international) C&T systems. It is based on established economic principles (equilibrium and optimization). The model can be solved either as a system of simultaneous equations or as a nonlinear programming model. It has been applied to the analysis of C&T associated with the Kyoto Protocol, emissions trading within the European Union, the Regional Greenhouse Gas Initiative (RGGI), 10 U.S. Environmental Protection Agency EPA regions covering all U.S. states, the Midwestern Governors Association (MGA) region, Minnesota internal state trading, the Western Climate Initiative (WCI), and Pacific Rim states and countries (see Rose et al., 1998 and 2006; Rose and Zhang, 2004; Center for Climate Strategies (CCS), 2008; Rose and Wei, 2008).

This model is based on the ability of unrestricted permit trading to achieve a cost-effective allocation of resources in the presence of externalities (see, e.g., Tietenberg, 2007). For permit purchasing states (or sectors), compliance costs are equal to their own abatement plus the cost of permits, whereas for selling states (or sectors), compliance costs are equal to their own abatement cost minus the revenues from selling permits. The model can readily be adapted to include such alternative design features as variations in sector and source coverage, implications of the cap on emission reduction requirements over time, offsets, variations on auctioning, upstream versus downstream application, borrowing and banking, and any explicit constraints on the permit price or trading (see Stevens and Rose, 2002; CCS, 2008). With a few modifications, the same model can also be used to simulate a carbon tax.

The model yields the following general results:

- Greenhouse gas (GHG) emission reductions (abatement and sequestration) for each entity (sector and/or state) before and after permit trading.
- Cost (or cost savings) of GHG emission reductions for each trading entity before and after trading.
- Number of permits traded (bought and sold) by each entity.
- Equilibrium permit price.
- Cost savings for each entity of joining the C&T program.

- Auction revenues if the allowances are auctioned among trading entities instead of grandfathered.

The model uses the following inputs (all the input data are collected from the state's climate change action plans):

- Projections of baseline GHG emissions for each trading entity.
- Caps on GHG emissions for each entity (translated from the state reduction goals in target years).
- Marginal cost curve of GHG emission reduction for each entity based on the cost of all relevant mitigation/sequestration options.

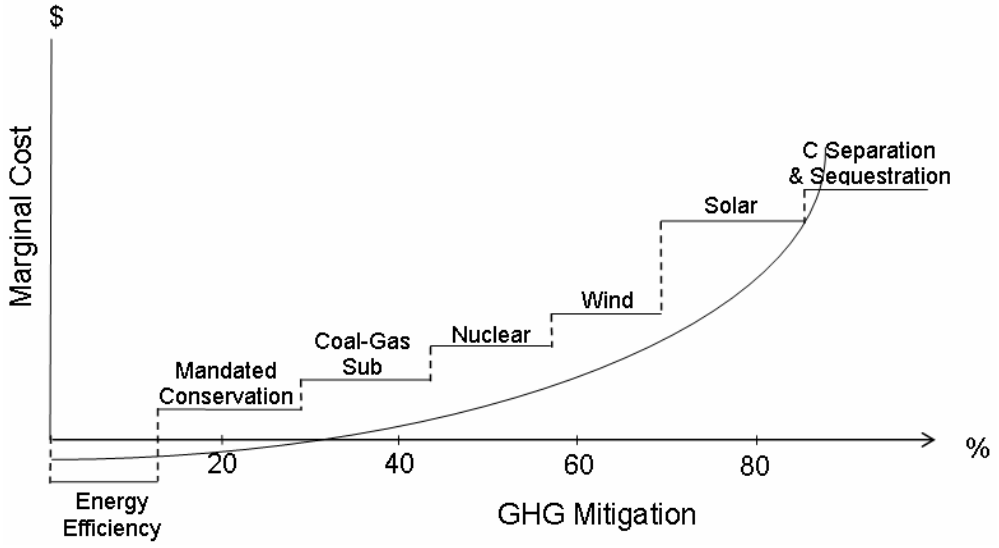
Development of Marginal Cost Curves

Many states have developed climate change action plans. The following data are collected for each applicable mitigation option (that has been quantitatively analyzed) in these states:

- The range of the mitigation option's application (maximum percentage of total emissions that can be reduced by the option).
- The cost per ton of carbon dioxide (CO_2) that can be reduced (this is specified in terms of a cost-effectiveness, including the possibility of cost savings per unit of GHG removed).

For each state, the mitigation options are then ordered from lowest cost to highest cost. A step function is developed based on the mitigation potential and cost per ton of CO_2 reduction for each policy option. Such a step function is illustrated in Figure G-A3-1. Next, a smooth curve is developed to fit the step function, which would be used as the marginal cost curve of the state in C&T policy analysis.

Figure G-A3-1. Illustrative marginal cost step function and curve for GHG mitigation



C = carbon; GHG = greenhouse gas.

Prior CCS analysis for Minnesota can serve as an example of the construction of the mitigation marginal cost curve. Table G-A3-1 presents 8 example climate mitigation options out of the 37 options analyzed quantitatively for Minnesota by CCS. Column 2 of the table presents the estimated 2025 annual GHG reduction potential for each option, with reduction potentials translated into percentages of the 2025 business as usual (BAU) emission level in Column 4. The estimated cost or cost saving per ton of GHG removed by each option in 2025 is presented in Column 3. The options are listed in ascending order in terms of cost, beginning with the cheapest option. Column 5 lists the cumulative GHG reduction potentials of the policy options listed in the table. The last column presents the proportion of GHG mitigation contributed by each option.

Table G-A3-1. GHG mitigation options of Minnesota

Climate Mitigation Actions	Estimated 2025 Annual GHG Reduction Potential ($MMtCO_2e$)	Estimated Cost or Cost Savings per ton GHG Removed	GHG Reduction Potential as Percentage of 2025 Baseline Emissions[1]	Cumulative GHG Reduction Potential	Weights (add-up to 100)
RCI-6. Non-Utility Strategies and Incentives To Encourage Energy Efficiency and Reduce GHG Emissions	1.3	–$37.00	0.65%	9.91%	1.48
AFW-1. Agricultural Crop Management--A. Soil Carbon Management	1.3	–$2.00	0.65%	15.42%	1.48
TLU-5. Climate-Friendly Transportation Pricing/Pay as You Drive	2.1	–$1.00	1.05%	16.46%	2.39
AFW-8. End of Life Waste Management Practices--A. Landfilled Waste Methane	0.73	$1.00	0.36%	16.98%	0.83
AFW-4. Expanded Use of Biomass Feedstocks for Electricity, Heat, or Steam Production	3.8	$3.00	1.90%	18.87%	4.32
ES-3. Efficiency Improvements, Repowering and other Upgrades to Existing Plants--Biomass co-firing	0.4	$12.00	0.20%	29.38%	0.46
AFW-5. Forestry Management Programs to Enhance GHG Benefits--A. Forestation	2.2	$13.00	1.11%	30.48%	2.50
ES-5. Renewable and/or Environmental Portfolio Standard	15.7	$56.40	7.83%	43.53%	17.86

[1] Minnesota 2025 projected consumption-based gross GHG emission level is 200.46 Million Metric Tons of CO_2e.

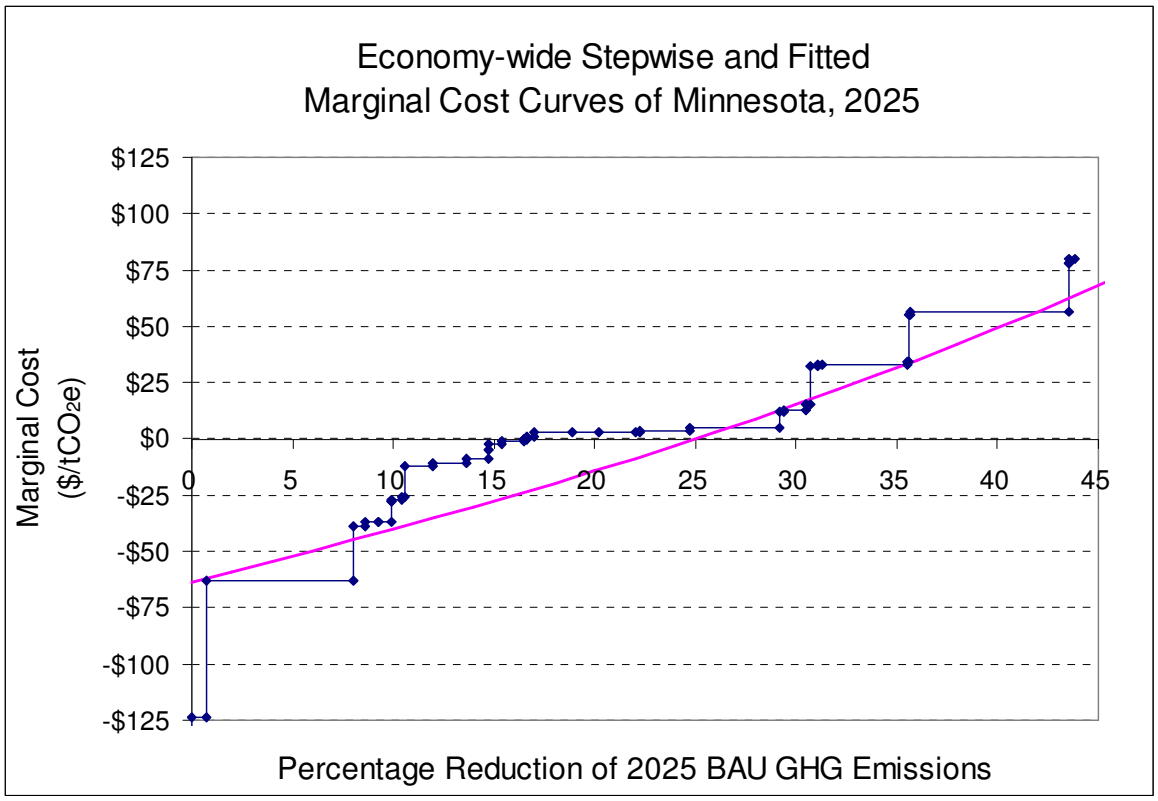
AFW = Agriculture, Forestry, and Waste Management; GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; EE = energy efficiency; ES = Energy Supply; GHG = greenhouse gas; RCI = Residential, Commercial, and Industrial; TLU = Transportation and Land Use.

Based on the data presented in Table G-A3-1, the stepwise marginal cost function for Minnesota in 2025 is first drawn in Figure G-A3-2. The horizontal axis represents the percentage of GHG emission reduction, and the vertical axis represents the marginal cost or cost savings of mitigation. In the figure, each horizontal segment represents an individual mitigation option. The width of the segment indicates the GHG emission reduction potential of the option in percentage terms. The height of the segment relative to the x-axis shows the average cost (saving) of reducing one metric ton of GHG with the application of the option. The figure indicates that, collectively, the reduction potential of options from all economic sectors can avoid

about 44% of 2025 baseline emissions in Minnesota. Our approach to develop the marginal cost curve based on state-specific climate change action plans directly includes any introduction of new emission reduction technologies (such as carbon capture and storage) of the state. Furthermore, sensitivity analyses of mitigation options, for example, to account for different learning and penetration effects or technological innovations, can be readily reflected in the cost curve by variations in the width (usually lengthening) and height (usually lowering), as well as the sequencing of the corresponding segments of the options.

Next, we fit a smooth curve through the data using statistical analysis (see Figure G-A3-2). We weight each policy option based on its GHG mitigation potential to give relatively greater influence to options that have the potential for higher levels of application, and thereby should improve the accuracy of the estimation. This fitted curve will then be used in our C&T analysis model.

Figure G-A3-2. Economy-wide and stepwise and fitted marginal cost curves of Minnesota, 2025



$/tCO2e = dollars per metric ton of carbon dioxide equivalent; BAU = business as usual; GHG = greenhouse gas.

The fitted curve shown in Figure G-A3-2 has the following functional form:

$$MC = a + b \times \ln(1 - R)$$

where MC is the marginal cost; R is the percentage reduction of GHG emissions; and a and b are parameters.

The logarithmic functional form utilized here is consistent with theoretical expectations and empirical findings on diminishing returns of emission control (Nordhaus, 1991 and 1994). As the emission reductions increase along the x-axis, the cost to reduce one additional unit of emission increases at an accelerating rate; in other words, it exhibits diminishing returns.

The marginal cost curve for Minnesota has the following specification:

$$MC = -63.37 - 220.25 \times \ln(1 - R)$$

The fitted curve has an intercept with the y-axis at MC = –$63.37. The curve increases to MC = 0 at the emission reduction level of 25%, which indicates that Minnesota has cost-saving mitigation potentials (such as energy efficiency) up to that level of the 2025 BAU emissions.

General Assumptions Adopted in the Analysis

The general assumptions we adopted in the C&T analysis and our modeling can be summarized as follows:

Emissions:

- All six GHGs—CO_2, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride—from the covered sectors are included in the analysis.
- The gross emissions (excluding forestry and agriculture soils sinks) are considered.

Marginal Cost Curves:

- Marginal cost curves embody direct mitigation costs only.
- Marginal cost curves do not include various transactions costs.
- Marginal cost curves do not distinguish between producer versus consumer allocation of permits.
- For analysis of C&T among power sectors, the power sector marginal cost curves of the states are developed based on the reduction potential and mitigation cost/saving data of individual options that contribute to the emission reductions from the power sector. These options not only include those designed directly for the electricity supply sector (such as promotion of renewable energy utilization, repowering existing plants, generation performance standards), but also include options in residential, commercial, and industrial (RCI) sectors that contribute to the reduction of electricity consumption (e.g., demand-side management, energy efficiency appliances, building codes). Also, for those options that apply to the use of both electricity and other fuel types, the emission reduction potentials are adjusted by multiplying the percentage of electricity consumption by total energy consumption in the RCI sectors. RCI options that relate entirely to reduction of other fossil fuels consumption (such as gas, oil) are not included in the power sector cost curve development.
- The target year we used for the Midwestern Governors Association C&T analysis is 2025. The mitigation policy options of Iowa are analyzed for 2020. Therefore, we adjusted the mitigation cost data of Iowa to 2025, based on the assumption of a 2% annual technical improvement or innovation rate. In other words, we used the same reduction potential

numbers for individual options in 2025 as in 2020 for Iowa, and assumed the cost per metric ton of CO_2 equivalent (CO_2e) reduction being about (1% + 2%)[5] lower in 2025 than in 2020.

- For state that lacks direct cost data, the cost curve is approximated based on the data of one of its adjacent states that has quantified cost data available. We assume that the list of mitigation options for the adjacent state (state A) is applicable to the state without direct data (state B). Second, for state B, the estimated cost or cost savings per unit of GHG removed for each option is assumed to be at the same level as of state A. Third, the mitigation potentials of each option are assumed to be proportional in each state; this requires that each option be adjusted by the ratio of emissions from the relevant sector of the two states. For example, if the emissions from the power sector are 50 million metric tons of CO_2 equivalent ($MMtCO_2e$) and 100 $MMtCO_2e$ in state A and state B, respectively, the mitigation potentials of the Energy Supply (ES) options for state A are multiplied by a factor of 2 (100/50=2) for application to state B.

Basic Model (can be included in advanced versions):

- Offsets are not included.
- No safety valve (permit price limit) is included.
- Recycling of auction revenues (or tax revenues in the carbon tax cases) is not analyzed in the simulations.
- Banking and borrowing are not considered.

Specification of the Cap-and-Trade Model

The C&T model is based on well-established principles of the ability of unrestricted permit trading to achieve a cost-effective allocation of resources in the presence of externalities (see, e.g., Tietenberg, 2007). Where a strict cap implies unique GHG emission reduction requirements, the individual state and overall regional optimization can be accomplished without explicit consideration of the benefits side of the ledger (i.e., it yields "efficiency without optimality"). Therefore, the model simply requires equalization of marginal costs of all entities with the equilibrium permit price (see Zhang, 2000; Loeschel and Zhang, 2002; Rose and Zhang, 2004). This ensures minimization of both total net compliance costs for each state and total abatement costs for the region as a whole. Purchasing (high-cost) states will reduce emissions up to the point where their marginal cost equals the prevailing market permit price, and will accomplish their remaining reduction responsibility by purchasing available permits in the market. Selling (low-cost) states have the incentive to do more than their reduction targets indicate, so that they can sell their surplus permits on the open market for a profit. For the region as a whole, permit sales and purchases cancel out, simplifying the overall objective functions.

We assume that the marginal abatement cost function for state *i* is of the logarithmic form, similar to Nordhaus (1994):[15]

[15] The shape of the cost function for mitigating CO_2 emissions has been studied extensively. For example, Nordhaus (1994) found that the logarithmic functional form provided the best fit for the estimates of the marginal costs of mitigating a specific amount of CO_2 emissions among a number of economic modeling studies that he surveyed (a type of meta-analysis). He used an analytical model to further derive a logarithmic relationship between the marginal costs and the percentage reduction.

$$MC_i = a_i + b_i \times \ln(1 - R_i) \qquad i = 1\ ,\ \ldots\ ,\ n \qquad (1)$$

where MC_i is the marginal cost of abatement for state i, R_i is the percentage of GHG abatement undertaken by state i in $MMtCO_2e$, and a_i and b_i are cost parameters. This functional form has the desired property of positive and increasing marginal cost for $b_i < 0$. When $a_i = 0$, the cost curve starts from the origin. When $a_i < 0$, the curve can show the cost-saving mitigation range of the state. These cost parameters also capture technological and other distinctions that cause mitigation costs to differ across regions. By integration, the total cost of abatement for region i, TC_i, is:

$$TC_i = \int_0^{R_i} \left[a_i \cdot R_i - b_i \cdot (1 - R_i) \cdot \ln(1 - R_i) - b_i \cdot R_i\right] \cdot E_i \qquad i = 1\ ,\ \ldots\ ,\ n \qquad (2)$$

where E_i is each state's gross (unabated) emissions in $MMtCO_2e$. Denoting the total required percentage reduction of emissions in region i in the absence of emissions trading as $\overline{R}_i$, the total abatement cost for each state in the absence of trading, $TC\overline{R}_i$, is calculated as:

$$TC\overline{R}_i = \int_0^{\overline{R}_i} \left[\left(a_i + b_i \cdot \ln(1 - r_i)\right) dr_i E_i\right] = \left[a_i \cdot \overline{R}_i - b_i \cdot (1 - \overline{R}_i) \cdot \ln(1 - \overline{R}_i) - b_i \cdot \overline{R}_i\right] \cdot E_i$$

$$i = 1\ ,\ \ldots\ ,\ n \qquad (3)$$

Emissions trading helps a region with relatively high marginal abatement cost to lower its compliance cost by avoiding the undertaking of their own actions. To minimize compliance costs, a purchasing state undertakes only some of its abatement requirement itself, $R_i E_i$, $\left(R_i E_i < \overline{R}_i E_i\right)$, up to the point where the marginal cost of doing so is equal to the endogenously determined permit price, P:

$$MC_i = a_i + b_i \times \ln(1 - R_i) = P \qquad i \in N \qquad (4)$$

where N is the set of all states.

The state meets the remaining demand, $\left(\overline{R}_i E_i - R_i E_i\right)$, via purchasing the "right to emit" at the regional market price, P. So, the total demand for emission permits of all purchasing states, TD, is:

$$TD = \sum_i \left(\overline{R}_i E_i - R_i E_i\right) \qquad i \in N \qquad (5)$$

On the other hand, for state j, with relatively low marginal cost, emissions trading provides an incentive to undertake abatement and sell permits to higher-cost states at the equilibrium permit price, P:

$$MC_j = a_j + b_j \times \ln(1 - R_j) = P \qquad j \in N \qquad (6)$$

The total amount of emission permits available for sale in a given regional trading coalition TS, is:

$$TS = \sum_j \left(R_j E_j - \overline{R}_j E_j \right) \qquad j \in N \tag{7}$$

The sum of total number of purchasing states *i* and total number of selling states *j* will be equal to *n*. At the equilibrium, the total demand for emission permits in the region is equal to the total supply:

$$TD = TS \tag{8}$$

Substituting Equation (Eq.) (5) and Eq. (7) into Eq. (8) and rearranging terms yields the condition that the total emissions actually abated equal the total emission abatement requirement:

$$\sum_i R_i E_i = \sum_i \overline{R}_i E_i \qquad i = 1, \ldots, n \tag{9}$$

We solve the model by minimizing total abatement costs of all states $\sum_i TC_i$ subject to Eqs. (4), (6), and (9), using GAMS (General Algebraic Modeling System), an algebraic modeling system for linear, nonlinear, and integer programming problems (Brooke et al., 1996).[16] The solution yields the equilibrium permit price (*P*), each state's own abatement after trading $(R_i E_i)$, and each state's marginal abatement cost (MC_i). Because we focus on unrestricted emissions trading, in equilibrium the marginal cost of abatement for each region is the same and is equal to the permit price, indicated in Eq. (4) and Eq. (6).

This completes the description of the general model by which the permit price, MC_i, and R_iE_i are determined endogenously in a competitive market. In the case where the permit price is set exogenously, as in the case of some auction-based C&T or the carbon tax cases, the situation becomes simpler because MC_i and hence R_iE_i follow suit. There is no need for Eqs. (5), (7), (8), and (9) because the total sales of selling states to purchasing states are not equal to the total purchases, except by chance (when the specified permit price equals the equilibrium price).

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[16] The market equilibrium solution of our model is unique, so the same solution could be obtained without optimizing. The reason why we specify an objective function is that we use GAMS/MINOS, a solver mainly for optimization problems. The minimization of the total cost is a logical choice for an objective in the case of "cost-effectiveness" analysis here (i.e., when a policy target is set and decision units seek to attain it at least cost). Had we used a software package that is specifically designed to solve a simultaneous equation system, then there would have been no need for an objective function.

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