Market Based Policies
Technical Work Group

Summary List of Pending Priority Policy Options for Analysis

	Policy Option	GHG Reductions ($MMtCO_2e$)			Net Present Value 2009–2025 (Million $)	Cost-Effective-ness ($/t$CO_2$e)	Level of Support
		2015	2025	Total 2009–2025			
MBP-1	Greenhouse gas cap and trade – economy wide						Pending
	25% below 2002		117			-$13.40	
	30% below 2002		128			-$5.10	
	35% below 2002		139			$3.70	
MBP-2	Carbon tax	*Not Yet Quantified*					Pending
MBP-3	Michigan Joins Chicago Climate Exchange	*Not Yet Quantified*					Pending
MBP-4	Fiscal policies (merged with MBP-6)						
MBP-5	Carbon credit system (considered within MBP-1)						
MBP-6	Market advisory group	*Not Quantifiable*					Pending
MBP-7	Cost analysis (incorporated into all policies)						

$MMtCO_2e$ – million metric tons carbon dioxide equivalent $/t$CO_2$e = cost per ton carbon dioxide equivalent

Note: The numbering used to denote the pending priority draft policy options is for reference purposes only; it does not reflect prioritization among these important draft policy options. Negative numbers indicate cost savings.

The Market Based Policies (MBP) Technical Work Group (TWG) is recently formed and has not developed descriptions for all of its pending policy options. What follows is a memorandum on the status of this group's work on option MBP-1 and draft descriptions of MBP-3 and MBP-6.

Results of the MBP Technical Work Group meeting/conference call on November 17 will be discussed at the Council meeting. Changes from that meeting are not reflected in this document which was posted prior to the call.

MBP-1 Cap-and-Trade

Policy Description

A cap-and-trade system works by setting an overall limit on emissions and either selling or distributing, at no cost, emissions "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, those sources that are able to reduce their emissions at a lower cost than the allowance price may do so and sell unused allowances to those who cannot achieve reductions as cost-effectively. In a system where allowances are initially sold, cost-effective emissions reductions reduce the number of allowances that must be purchased. Either way, cap-and-trade creates a financial incentive for emitters to continually seek out new emission-reducing technologies and cut their emissions as much as possible. By creating a market for the allowances, regulated entities have the choice of either purchasing allowances or directly reducing emissions and, as a result, resources are directed to the most cost-effective emissions reduction investments. To achieve overall emissions reductions over time, programs gradually lower the emissions "cap" by reducing the total number of available allowances.

Perhaps the best known example of cap-and-trade 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)[1] and proposed by several U.S.-based initiatives including the Northeast Regional Greenhouse Gas Initiative (RGGI),[2] the Western Climate Initiative (WCI),[3] and the Midwestern Regional Greenhouse Gas Reduction Accord.[4]

Michigan is actively participating in the development of the Midwestern Regional Greenhouse Gas Reduction 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 Michigan should support in these regional negotiations.

These preliminary recommendations do not represent the unanimous advice of the TWG. At least one member of the TWG does not support a cap and trade program, but instead prefers a carbon tax as a more efficient and less complex approach to GHG emissions mitigation.

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1 http://ec.europa.eu/environment/climat/emission.htm

2 http://www.rggi.org

3 http://www.westernclimateinitiative.org

4 http://midwesternaccord.org/

Policy Design

The cap-and-trade policy is designed and analyzed to work in concert with non-cap-and-trade policies and measures. The integration of other policies serves to reduce compliance costs and ease attainment of goals and caps. Emissions 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 cap-and-trade modeling. As a result, the expected operation of the cap-and-trade 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 cap-and-trade program depends largely on how it is structured. Key design parameters are discussed separately below.

Geographic Scope: The Market Based Policies TWG encourages national action in the implementation of a cap and trade program for the regulation of greenhouse gas 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 cap and trade program. The benefits of the cap and trade 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 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. This would include electricity generation; industrial sources; fossil fuel extraction, processing and transportation; transportation; residential and commercial fuel use; waste management; agriculture and forestry. It is recognized that some sectors may not be appropriate for regulation under a cap and trade program, and others may be appropriate but might 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.

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 has 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 emissions 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 very difficult to measure emissions 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 Market Based Policies TWG 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 it generates revenues which 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 TWG agrees that the *value* represented by the allowance should benefit the consumer. 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 consumer or ratepayer. Examples include tax reductions or direct payments, perhaps directed largely for the benefit of low income consumers. Another use could be public investments in end-use energy efficiency, providing both energy cost and emissions 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 TWG recognizes that the matter of allowance distribution is complex. Determining the most appropriate means of assuring 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 cap-and-trade 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 cap-and-trade programs' cap cannot be reduced and also qualify as an offset credit under any other cap-and-trade 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 TWG 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 TWG 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.

At least one member expressed the concern that if the program allowed 100% compliance with offsets, then in-sector emissions 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: Cap-and-trade 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'.

The general consensus within the TWG is that multiple price mitigation mechanisms are desirable, however concern was expressed by one member that a crude safety valve price cap would have the effect of undermining the emissions cap and would be unacceptable.

- *Banking*—Banking allows permit holders to withhold unneeded allowances from the market, or from surrender for emissions compliance, without expiration. A banked allowance may be used in any compliance period beyond the issuance period without penalty. Banking is seen as a means of mitigating market volatility by allowing holders to hold onto allowances (thereby mitigating supply) when prices are low and to use or sell them (thereby mitigating demand) when prices are high.
  - *Recommendation:* TBD
- *Borrowing*—Borrowing of allowance permits emitters to release excess tons of GHGs in the current compliance period in return for greater reductions in a future compliance period.
  - *Recommendation:* TBD
- *Safety Valve*—A safety valve is a program feature designed to limit or moderate the cost of allowances for the purpose of ensuring that the program will not have an unacceptable impact on consumer costs. Safety valves can be as direct and conceptually simple as an allowance price cap or as indirect as the RGGI's stepped expansion of offset opportunities triggered by allowance prices[5]. The safety valve can be used in conjunction with other tools to mitigate price volatility (such as banking and borrowing). It should be noted that hitting the safety valve price cap effectively converts the cap-and-trade program into a carbon tax at that price.
  - *Recommendation:* TBD

Reporting: (Recommendation TBD)

Leakage: Leakage occurs when, in response to program incentives, utilities choose to either increase out-of region fossil-based power purchases or investors choose to construct new generation units in unregulated border jurisdictions. In either case, both the environmental benefits and in-state investment are lost. It is noted that in a national program, leakage is not an issue. Leakage can be addressed through careful design of the point-of-regulation, as in the First Jurisdiction Deliverer (FJD) plan in WCI. FJD requires compliance from any generator within

[5] The Western Climate Initiative employs banking, offsets and three-year compliance periods to mitigate allowance prices but does not have a 'safety valve'.

the region plus any entity that imports fossil-based power from outside the WCI region.[6] (Recommendation TBD)

Trial Period: (Recommendation TBD)

Early Actions: (Recommendation TBD)

Goals: (Recommendation TBD)

Timing: (Recommendation TBD)

Parties Involved: (Recommendation TBD)

Other:

Implementation Mechanisms

The MGA Accord Partners are developing both a proposed design and model rule for the implementation of the regional cap-and-trade 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. (Recommendation TBD)

Related Policies/Programs in Place

There are no cap-and-trade programs in place to reduce GHG emissions in Michigan. Michigan has participated in the U.S. EPA SO_2 cap-and-trade program as well as the NOx program. Related GHG cap-and-trade programs are the Northeast's Regional Greenhouse Gas Initiative and the Western Climate Initiative. RGGI is scheduled to begin operating on January 1, 2009 and WCI is planned to begin on January 1, 2012.

Type(s) of GHG Reductions

TBD – [as approved by the TWG]

Estimated GHG Reductions and Costs or Cost Savings

The complete modeling results and analysis are attached as Annex 1. Two sector coverage scenarios were examined: power sector only and economy-wide. The economy-wide analysis includes all sectors except agriculture, forestry and waste management. All analyses include all MGA Partners: Iowa, Illinois, Kansas, Michigan, Minnesota, and Wisconsin, and the Canadian Province of Manitoba. Full results are contained in Annex 1.

Given that the MGA has not yet recommended GHG reduction goals the analysis assumed that the Michigan goals are applied to all MGA Partners. Since the Michigan goals are currently

[6] The Regional Greenhouse Gas Initiative does not address the issue of leakage within the program design. RGGI 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.

stated as a range (between 25% and 35% below 2002 levels in 2025) the analysis examines three goals for the region: 25%, 30% and 35% below 2002 levels in 2025.

The simulation results illustrate the implications of an economy-wide cap-and-trade policy (excluding the AFW sector). First, it shows that when the GHG reduction goal increases from 25%, to 30%, to 35% below 2002 levels in 2025, the equilibrium allowance (permit) price in the trading market increases from $94.04/tCO2e to $115.80/tCO2e, and to $140.06/tCO2e, respectively. The C&T simulations for the case where only the power sector is covered yield lower equilibrium permit prices than the economy-wide cap-and-trade simulations. The permit prices for the former are $59.44/tCO2e to $74.80/tCO2e, and to $93.01/tCO2e with respect to the three alternative Michigan 2025 goals.

The emission reductions from the cap-and-trade covered sources within Michigan under the economy-wide C&T program are expected to be 117.85 MMtCO2e, 128.23 MMtCO2e, and 138.99 MMtCO2e in 2025 corresponding to the three Michigan goals. In the power sector only simulations, the emission reductions of Michigan are 58.16 MMtCO2e, 63.28 MMtCO2e, and 68.81 MMtCO2e, respectively, in 2025. Since Michigan is expected to be a permit seller in the market in both of the two sectoral coverage scenarios, the emission reductions undertaken by the in-state cap-and-trade covered sources would exceed the reduction requirement indicated by the state emission caps. Michigan would sell the surplus permits to the other MGA partners and gain a profit.

The total net cost to Michigan for participating in the MGA cap-and-trade program is the sum of its mitigation cost and trading cost. Tables 1 to 6 in Annex 1 present detailed results of the costs of Michigan in 2025. The cost-effectiveness of the cap-and-trade policy can be computed by dividing the total net cost (mitigation cost plus trading cost) by all the emission reductions undertaken by Michigan. For the economy-wide simulations, the cost-effectiveness is -$13.4/tCO2e, -$5.1/tCO2e, and $3.7/tCO2e with respect to the three 2025 goals. For the power sector only simulations, the cost-effectiveness is -$10.5/tCO2e, -$6.0/tCO2e, and -$1.6/tCO2e, respectively.

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 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. The approximation methods we adopted are described in the next section "Quantification Methods".

GHG Mitigation Options Data Sources:

1. 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.

2. 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. Preliminary Quantification Analysis of Mitigation Options from the ES, RCI, and TLU TWGs of Michigan.

Emissions Inventory and Forecast Data Sources:

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

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

3. 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.

4. 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 Cap and Trade 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[7]. Partners that have 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 its own abatement cost plus the cost of permits. Partners that have 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 its 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 price. This ensures minimization of total net compliance costs for each partner and minimization of total abatement cost for the cap-and-trade program as a whole.[8]

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:

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

[8] 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.

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 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.

Figure 1 and Figure 2 in Annex 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 transactions costs.
- Marginal cost curves do not distinguish between producer vs. consumer allocation of permits.

For the basic model:

- Offsets are not included.
- No safety valve (permit price limit) is included.
- Banking and borrowing are not considered.
- These features can be included in advanced versions.

Key Uncertainties

TBD – [as needed and approved by the TWG]

Additional Benefits and Costs

TBD – [as needed and approved by the TWG]

Feasibility Issues

TBD – [as needed and approved by the TWG]

Status of Group Approval

Pending – [until MCAC moves to final agreement]

Level of Group Support

TBD – [blank until MCAC moves to final agreement]

Barriers to Consensus

TBD – [blank until final vote by the MCAC]

MBP-2 Carbon Tax

NOTE: This is a working draft that has not yet been endorsed by the TWG.

Policy Description

A carbon tax or fee is another method used to place a value or disincentive on greenhouse gas emissions. There are three primary types of carbon taxes: the revenue neutral tax, revenue generating tax, and a hybrid tax. The revenue neutral tax is simply used to send a price signal (disincentive), and the money raised is eventually given back to the taxpayers. The revenue generating tax is collected and then redistributed to offer incentives for deploying renewable energy and increased energy efficiency. The hybrid carbon tax returns a certain percentage of revenues back in the form of tax breaks and retains the rest to be redistributed as incentives for deploying more renewable energy.

The concept of a national carbon tax has gained strong support from individuals like New York Mayor Michael Bloomberg, former Vice President Al Gore and former Duke Energy CEO Paul Anderson. A report filed by the Congressional Budget Office in February 2008, came out strongly in favor of a national carbon tax over other methods for placing a value on greenhouse emissions. The report cited transparency, ease of implementation and relatively low cost of implementation as reasons to support a carbon tax.

Despite all of the documented benefits, a carbon tax has not generated as much support as a cap and trade system. It can be argued that the lack of broad support for a carbon tax is due in part to the word tax within its terminology. Conversely, the term cap and trade avoids the word tax even though it is essentially an alternative method for achieving the same goals.

Given the negativity associated with the word "tax," the MCAC recommends referring to this type of program as a Carbon Emissions Fee and Rebate Program (Carbon Fee-Rebate program).[9] The change in language is important because the term "tax" implies you are going to pay into a government coffer with no expectation of ever getting your money back. The term "rebate" more accurately reflects what typically occurs in such programs.

Policy Design

It is recommended that a comprehensive carbon fee-rebate program be pursued only in the absence of a cap-and-trade program.

As recommended in MBP-1, a cap and trade program needs to be regional or preferably national in scope, and should be economy-wide, that is, as broad as feasible. In the event the cap and trade program is not economy-wide, a Michigan carbon fee-rebate program could be used to impose a fair and equitable carbon fee on non-participating carbon emitters.

In this scenario and by regional agreement among Michigan and its neighboring states, Michigan could consider a carbon fee-rebate program to be applied to those sectors not covered by the cap-

[9] Carbon Emissions Fee-Rebate is only a working title for this program

and-trade program, where this is prudent and feasible. Examples could include transportation, residential, commercial, and agriculture sources not covered by a cap and trade program.

MCAC recommends against requiring any cap-and-trade regulated source to also be subject to a carbon tax on fuel.

If a revenue generating or a hybrid carbon emissions fee and rebate program is selected, revenues from the program would be used as determined by state legislatures, and could include:

- Mitigate the cost of the tax
- Promote energy efficiency/conservation
- Promote renewable energy
- Promote enable research
- Provide worker and business transition to new skills

To minimize administrative burdens, the carbon emissions fees could be applied in the same manner and at the same point as existing fuel taxes.

In the event a national carbon tax program or a national or regional cap-and-trade program is enacted that covers sources within sectors previously subject to the carbon tax, the Michigan (Regional) carbon tax should be adjusted to assure equity.

Revenue Neutral
As its name implies, a revenue neutral program is not designed to generate revenue for a governing body, but to create a disincentive for energy markets with regard to GHG emissions. Under such program, the fee is collected upstream and most or all of the costs are passed along to consumers. The revenue is then returned to consumers through reductions in payroll or other Such a "tax shift" establishes a cost for emissions without imposing additional cost burdens to energy consumers.

For instance, in British Columbia's revenue-neutral model, the tax/fee is collected upstream and the costs are passed along to consumers. The revenue is then returned to taxpayers through reductions in other provincial taxes. So while BC citizens pay in, the rebate mitigates any significant costs for the average consumer. Such a system could even be geared to create a positive cash flow for lower income citizens who typically consume lower amounts of energy.[10]

Revenue Generating

Under the revenue generating approach, the carbon fee-rebate program would be applied in the same manner and at the same point as existing fuel taxes in Michigan, with the goal of minimizing administrative burdens on both the state and the regulated entities.

The carbon tax/emissions rebate program would be deployed in those sectors of the economy not participating in the cap and trade program. Revenues could be used to create incentives in specific sectors. For instance, a fee could be imposed on carbon emissions from a sector not participating in the cap and trade program, and revenues used for incentive rebates back to that sector for specific efforts that reduce carbon emissions. While the cost to consumers would be higher with a revenue generating program of this nature, it creates a dual incentive to reduce carbon emissions for covered sectors.

[10] Carbon Tax Center, The. http://www.carbontax.org/issues/softening-the-impact-of -carbon-taxes/

Hybrid

A hybrid program retains elements of both revenue generating and revenue neutral programs.

For example, a hybrid carbon tax was adopted by Denmark in 1992. Under this system, all of Denmark's taxes are returned to industry in one of two ways: 60% of the revenue is returned in the form of lower taxes for companies signing voluntary agreements to reduce carbon emissions. The process of rebating or returning revenues helped Denmark avoid losing economic competitiveness. The other 40% of revenues are earmarked and returned to industry in the form of investment subsidies for environmental initiatives.[11]

Because most of the costs are being given back to industry, the net impact on the end consumer is reduced but not fully eliminated.

Goals:

- Near-term (2015): _______MMtCO2e mitigated at a projected fee of ___ per ton.
- Long-term (2025): _______MMtCO2e mitigated at a projected fee of ___ per ton.

Timing: Implementation of the carbon tax should be carried out in conjunction with the cap-and-trade.

Parties Involved:

Other:

Implementation Mechanisms

TBD – [as approved by the TWG]

Related Policies/Programs in Place

TBD – [as approved by the TWG]

Type(s) of GHG Reductions

TBD – [as approved by the TWG]

Estimated GHG Reductions and Costs or Cost Savings

TBD – [as approved by the TWG]

Data Sources: [TBD, as approved by the TWG]

Quantification Methods: [e.g., Full life cycle analysis with supply/demand equilibrium adjustments on TWG approval]

Key Assumptions: [TBD, as approved by the TWG]

[11] Prasad, Monica, "Taxation as a Regulatory Tool," (paper presented at the Tobin Conference Workshop on Regulation, February, 2008, Yulee, Fla.).

Key Uncertainties

TBD – [as needed and approved by the TWG]

Additional Benefits and Costs

TBD – [as needed and approved by the TWG]

Feasibility Issues

TBD – [as needed and approved by the TWG]

Status of Group Approval

Pending – [until MCAC moves to final agreement]

Level of Group Support

TBD – [blank until MCAC moves to final agreement]

Barriers to Consensus

TBD – [blank until final vote by the MCAC]

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 greenhouse gases (GHGs), with offset projects worldwide.

CCX Members are leaders in greenhouse gas (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 (FINRA, formerly NASD). The founder, Chairman and CEO 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 emitting Members make a voluntary but legally binding commitment to meet annual GHG emission reduction targets. Those who reduce below the targets have surplus allowances to sell or bank; 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 of CO2 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.

Goals of CCX:

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

Benefits of Membership:

- Be prepared: mitigate financial, operational and reputational risks
- Reduce emissions using the highest compliance standards with third party verification
- Prove concrete action on climate change to shareholders, rating agencies, customers and citizens
- Establish a cost-effective, turnkey emissions management system
- Drive policy developments based on practical, hands-on experience

- Gain leadership recognition for taking early, credible and binding action to address climate change
- Establish early track record in reductions and experience with growing carbon and GHG market

NOTE: Various Michigan-based businesses are members of the 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 greenhouse gas 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 are energy usage in office buildings and transportation.
- Join the Chicago Climate Exchange (CCX)[12] which requires a six (6) percent reduction in GHG emissions from state governmental sources between a baseline of 1998-2000 and 2010, and possibly additional reductions beyond 2010 under Phase 3.

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

Timing: TBD – [as approved by the TWG]

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 was unable to meet associated GHG reductions.

Alternately, membership and compliance may present opportunities for new revenues (for example, 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 Legislature in this process needs to be made accordingly. The states of Illinois and New Mexico have joined the CCX. Example: The State of Illinois joined by Executive Order 11 of 2006 (see web link; http://www.illinois.gov/gov/execorder.cfm?eorder=54

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

Related Policies/Programs in Place

None, however the state of Michigan, under Executive Directive 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 compliment the voluntary GHG reduction commitments required as part of being a member of the CCX.

Specifically, all state buildings under the Department of Management 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 a energy use and purchases ending fiscal year ending September 30, 2002.

In addition, the Midwestern Governors Association GHG Accord (Participating States and Provinces: Illinois, Iowa, Kansas, Manitoba, Michigan, Minnesota, and Wisconsin Observer States: Indiana, Ohio, South Dakota) to establish a Midwestern Greenhouse Gas Reduction Program (hereafter Program) to reduce GHG emissions in member states through the following actions:

1. Establish GHG reduction targets and timeframes consistent with those of MGA member states and provinces; and

2. Develop a market-based and multi-sector cap-and-trade mechanism to help achieve GHG reduction targets; and

3. Join The Climate Registry to enable tracking, management and crediting for entities that reduce GHG emissions; and

4. 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: Michigan Department of Environmental Quality (MDEQ) participates on the Steering Committee for the development of The Climate Registry, 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 Indian tribes have already signed on to join The Climate Registry. For more information about The Climate Registry go to http://www.theclimateregistry.org/.

Type(s) of GHG Reductions

TBD – [as approved by the TWG]

Estimated GHG Reductions and Costs or Cost Savings

TBD – [as approved by the TWG]

Data Sources: [TBD, as approved by the TWG]

Quantification Methods: [e.g., Full life cycle analysis with supply/demand equilibrium adjustments on TWG approval]

Key Assumptions: [TBD, as approved by the TWG]

Key Uncertainties

TBD – [as needed and approved by the TWG]

Additional Benefits and Costs

TBD – [as needed and approved by the TWG]

Feasibility Issues

TBD – [as needed and approved by the TWG]

Status of Group Approval

Pending – [until MCAC moves to final agreement]

Level of Group Support

TBD – [blank until MCAC moves to final agreement]

Barriers to Consensus

TBD – [blank until final vote by the MCAC]

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 cap-and-trade 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 cap-and-trade program. Minnesota also considered a similar panel of experts to evaluate GHG policies, and recommended a similar panel of experts at the Midwest Governor's Accord regional level.

Michigan has unique economic, social and legislative structures that separate the state from implementing specific policies verbatim that California or Minnesota have adopted in relation to GHG. However, Michigan can benefit from a multi-disciplinary approach when looking at how current and future polices will affect the overall physical and economic environment in our state. The Market Based Advisory Technical Working Group recommends to the MCAC the creation of a formal Market Advisory Group, appointed by the governor or appropriate agency head and approved by the Legislature, and working in support of the Department of Environmental Quality. The advisory group would hold regular meetings and have defined responsibilities, to include looking at the economic feasibility of implementing GHG reduction policies. In addition to offering expert advice on the design of market-based policies, the group 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 policy makers on the design of any future compliance programs to manage GHG emissions. The Market Advisory Group would consist of economists, actuaries, scientists, policy advisors, academics, attorneys, planners, engineers, as well as members of the public. It 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 impact of policy on GHG emissions on an on-going basis. The appointment of a Market Advisory Group 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: TBD

Parties Involved: The Market Advisory Group should be composed of individuals with particular expertise in key areas, such as economics, markets, climate science and policy, attorney, planners, actuaries, engineers, academics as well as in other jurisdictions or for other pollutants, key covered sectors, and finance. Involved parties beyond those represented on the group would include a very wide range of stakeholders from the regulated community, environmental community, all levels of government and the general public.

Other: The Market Advisory Group should encourage public comment throughout its deliberations.

Implementation Mechanisms

Authority of the MAG

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

MAG membership and governance

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

Tri-annually, the MAG would conduct elections. The MAG 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 workplan with milestones and otherwise conduct itself under processes used by business to assure the timely and high quality delivery its recommendations.

Budget

The MAG would conduct its analyses and make its recommendations on an on-going 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 would be posted on the Internet.

The MAG would annually summarize its activities to policymakers and to the public via the Internet.

It would hold quarterly meetings open to the public to describe progress on its work plan.

Related Policies/Programs in Place

TBD – [as needed and approved by the TWG]

Type(s) of GHG Reductions

TBD – [as approved by the TWG]

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

TBD – [as needed and approved by the TWG]

Additional Benefits and Costs

TBD – [as needed and approved by the TWG]

Feasibility Issues

TBD – [as needed and approved by the TWG]

Status of Group Approval

Pending – [until MCAC moves to final agreement]

Level of Group Support

TBD – [blank until MCAC moves to final agreement]

Barriers to Consensus

TBD – [blank until final vote by the MCAC]

Annex 1

Preliminary Analysis of MGA Cap and Trade in 2025

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November 1, 2008

Analysis Approach

This summary presents the preliminary simulation results of Midwestern Governors Association (MGA) Cap and Trade (C&T) Program. For the detailed specification 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 the summary "Modeling of Cap and Trade Programs" by Adam Rose and Dan Wei.

The MGA partners include six U.S. states: Iowa, Illinois, Kansas, Michigan, Minnesota, and Wisconsin; and one Canadian province: Manitoba. Thus far, the MGA has not decided on the C&T goal. Therefore, we used the Michigan Climate Action Council (MCAC) tentative goal for year 2025 as the GHG reduction target for all the MGA partners in the simulations. The 2025 MCAC GHG reduction goal for year 2025 is a 25% to 35% reduction from the 2002 emissions level. In the analysis, we simulated three scenarios of three alternative 2025 targets (25%, 30%, and 35% below 2002 level) using our model.

Since the committee is still discussing which sectors are going to be modeled in the MGA Cap and Trade Program, we analyzed two sectoral coverage scenarios in our preliminary simulations:

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

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

The economy-wide (excluding AFW) C&T simulation results with the three alternative MCAC 2025 GHG reduction goals are presented in Tables 1 to 3. The power sector only C&T simulation results with the three alternative MCAG goals are presented in Tables 4 to 6. The simulations assume that the permits, or allowances, are 'grandfathered' as opposed to sold at auction.

In each results table, 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. The next three columns (columns 3 to 5) show the mitigation cost, trading cost, and net cost (the sum of mitigation cost and trading cost) after the partners enter the C&T Program. Partners that have 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. Partners that have 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 selling permits. Next, the difference in the net cost between the before trading and after trading situations is presented in the Cost Saving column (column 6). The next two columns (columns 7 and 8) show the permits purchased/sold by each partner and the emissions reduced by in-state mitigation activities in quantity terms. The last two columns (columns 9 and 10) compare the emission reductions in percentage terms with and without trading for each partner, respectively.

Following each of the six Cap and Trade results tables, the basic data used in the simulation are summarized in the Data Tables. The data tables present the 2025 baseline emissions, the emission budget (capped emissions), and reduction target in percentage terms relative to the 2025 baseline level of the C&T covered sectors in the first three numerical columns. The last column in the data tables show the autarkic (each state's own) marginal mitigation cost level for each state/province to meet the emission budget.

Figure 1 shows the economy-wide (excluding AFW) marginal cost curves for all the states and province included in this study. Figure 2 shows the marginal cost curves of the power sector. The Appendix presents in detail how we developed the marginal cost curve for Michigan.

Summary of the findings from the preliminary Cap and Trade simulations:

1. The factors that have the greatest influence on all simulations are the absolute levels and the 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.

2. 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 their net cost of mitigation activities.

3. 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 those designed directly for the electricity supply sector and those in the RCI sectors that contribute to the reduction of electricity consumption. When the GHG reduction goal increases from 25%, to 30%, to 35% below 2002 levels the equilibrium permit price in the trading market increases from \$94.04/tCO2e to \$115.80/tCO2e, and to \$140.06/tCO2e, correspondingly,

in the economy-wide (excluding AFW) C&T simulations; and increases from $59.44/tCO2e to $74.80/tCO2e, and to $93.01/tCO2e, correspondingly, in the power sector-only C&T simulations.

4. In all the simulation cases, Michigan is the third biggest permit seller in the market, and Kansas is the biggest seller. Minnesota is the biggest permit buyer in the market, followed by Wisconsin.

5. In all the simulation cases, if we compare the net after trading mitigation cost with the before trading cost for each state/province, 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 Savings column in the result tables. Compared with the pre-trading situation, Michigan can reduce its net costs (mitigation cost plus permit sales revenue) and achieve savings of $141 to $157 millions in 2025 in the economy-wide (excluding AFW) C&T Program; and $26 to $60 millions in the power sector only C&T Program.

Please note these are the preliminary simulation results. They are subject to change when we obtain updated quantification analysis results for individual mitigation options from the other TWGs.

TABLE 1. ECONOMY-WIDE (EXCLUDING AFW) EMISSION TRADING SIMULATION AMONG MGA PARTNERS IN YEAR 2025
(with MCAC goal 25% below 2002 levels by 2025)

(million dollars or otherwise specified)

State	Before Trading	After Trading			Cost Difference	Permits Traded	Emission Reduction w/ Trading		Emission Reduction Goal
	Mitigation Cost	Mitigation Cost	Trading Cost[a]	Net Cost		(million tCO_2)	(million tCO_2)	(percent from BAU)	(percent from BAU)
IA	202	1,728	-2,154	-426	-628	-22.91	76.60	64.31	45.08
IL	191	-381	542	161	-30	5.76	129.32	40.93	42.75
KS	-80	1,738	-3,101	-1,364	-1,283	-32.98	77.27	72.76	41.71
MB	5	-133	115	-18	-24	1.22	8.95	45.01	51.15
MI	**-1,422**	**-394**	**-1,185**	**-1,579**	**-157**	**-12.60**	**117.85**	**42.88**	**38.30**
MN	6,226	-377	3,205	2,828	-3,399	34.08	43.19	25.92	46.37
WI	4,461	-446	2,578	2,132	-2,328	27.42	41.60	27.77	46.07
Total	9,583	1,734	0	1,734	-7,849	68.48[b]	494.79	42.93	42.93

[a] Permit Price = $94.04/ton$CO_2$e.
[b] Represents number of permits bought or sold.

DATA TABLE
(with MCAC goal 25% below 2002 levels by 2025)

State	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 (million tCO_2e)	GHG Mitigation Goal in 2025 (relative to BAU emissions)	Autarkic Marginal Mitigation Cost (dollars per tCO_2e)
IA	119.1	65.4	45.08%	42.9
IL	316.0	180.9	42.75%	104.7
KS	106.2	61.9	41.71%	24.9
MB	19.9	9.7	51.15%	133.3
MI	**274.8**	**169.6**	**38.30%**	**69.5**
MN	166.6	89.4	46.37%	304.8
WI	149.8	80.8	46.07%	272.6
Total	1,152.4	657.7	42.93%	

TABLE 2. ECONOMY-WIDE (EXCLUDING AFW) EMISSION TRADING SIMULATION AMONG MGA PARTNERS IN YEAR 2025
(with MCAC goal 30% below 2002 levels by 2025)

(million dollars or otherwise specified)

State	Before Trading	After Trading			Cost Difference	Permits Traded	Emission Reduction w/ Trading		Emission Reduction Goal
	Mitigation Cost	Mitigation Cost	Trading Cost[a]	Net Cost		(million tCO_2)	(million tCO_2)	(percent from BAU)	(percent from BAU)
IA	407	2,473	-2,973	-499	-906	-25.67	83.72	70.29	48.74
IL	1,590	836	717	1,553	-38	6.19	140.93	44.60	46.56
KS	35	2,381	-4,055	-1,674	-1,709	-35.02	83.43	78.57	45.59
MB	99	-60	136	76	-23	1.17	9.64	48.50	54.41
MI	**-515**	**693**	**-1,352**	**-659**	**-144**	**-11.68**	**128.23**	**46.66**	**42.41**
MN	8,172	48	4,166	4,214	-3,958	35.98	47.24	28.35	49.94
WI	6,043	-49	3,361	3,312	-2,731	29.02	45.39	30.30	49.67
Total	15,831	6,322	0	6,322	-9,509	72.37[b]	538.59	46.73	46.73

[a] Permit Price = \$115.80/tonCO_2e.
[b] Represents number of permits bought or sold.

DATA TABLE
(with MCAC goal 30% below 2002 levels by 2025)

State	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 (million tCO_2e)	GHG Mitigation Goal in 2025 (relative to BAU emissions)	Autarkic Marginal Mitigation Cost (dollars per tCO_2e)
IA	119.1	61.1	48.74%	51.1
IL	316.0	168.9	46.56%	128.0
KS	106.2	57.8	45.59%	31.2
MB	19.9	9.1	54.41%	156.2
MI	**274.8**	**158.3**	**42.41%**	**91.4**
MN	166.6	83.4	49.94%	349.8
WI	149.8	75.4	49.67%	314.8
Total	1,152.4	613.8	46.73%	

TABLE 3. ECONOMY-WIDE (EXCLUDING AFW) EMISSION TRADING SIMULATION AMONG MGA PARTNERS IN YEAR 2025
(with MCAC goal 35% below 2002 levels by 2025)

(million dollars or otherwise specified)

State	Before Trading	After Trading			Cost Difference	Permits Traded	Emission Reduction w/ Trading		Emission Reduction Goal
	Mitigation Cost	Mitigation Cost	Trading Cost[a]	Net Cost		(million tCO_2)	(million tCO_2)	(percent from BAU)	(percent from BAU)
IA	648	3,307	-3,901	-594	-1,242	-27.85	90.27	75.78	52.40
IL	3,285	2,381	864	3,245	-40	6.17	153.02	48.43	50.38
KS	177	3,061	-5,073	-2,012	-2,190	-36.22	88.76	83.59	49.48
MB	208	32	154	186	-22	1.10	10.36	52.13	57.67
MI	**652**	**2,068**	**-1,557**	**511**	**-141**	**-11.12**	**138.99**	**50.58**	**46.53**
MN	10,401	605	5,264	5,869	-4,532	37.59	51.60	30.96	53.52
WI	7,856	471	4,249	4,720	-3,137	30.34	49.46	33.01	53.26
Total	23,228	11,925	0	11,925	-11,303	75.19[b]	582.47	50.54	50.54

[a] Permit Price = $140.06/ton$CO_2$e.
[b] Represents number of permits bought or sold.

DATA TABLE
(with MCAC goal 35% below 2002 levels by 2025)

State	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 (million tCO_2e)	GHG Mitigation Goal in 2025 (relative to BAU emissions)	Autarkic Marginal Mitigation Cost (dollars per tCO_2e)
IA	119.1	56.7	52.40%	59.8
IL	316.0	156.8	50.38%	153.1
KS	106.2	53.6	49.48%	37.9
MB	19.9	8.4	57.67%	180.8
MI	**274.8**	**146.9**	**46.53%**	**115.0**
MN	166.6	77.5	53.52%	398.2
WI	149.8	70.0	53.26%	360.0
Total	1,152.4	570.0	50.54%	

TABLE 4. POWER SECTOR EMISSION TRADING SIMULATION
AMONG MGA PARTNERS IN YEAR 2025
(with MCAC goal 25% below 2002 levels by 2025)

(million dollars or otherwise specified)

State	Before Trading	After Trading			Cost Difference	Permits Traded	Emission Reduction w/ Trading		Emission Reduction Goal[c]
	Mitigation Cost	Mitigation Cost	Trading Cost[a]	Net Cost		(million tCO_2)	(million tCO_2)	(percent from BAU)	(percent from BAU)
IA	112	809	-1,563	-755	-867	-26.30	48.74	94.97	43.72
IL	883	-299	888	589	-293	14.94	64.85	44.98	55.34
KS	154	917	-1,638	-721	-875	-27.56	49.70	94.55	42.12
MB	-57	-66	-14	-79	-22	-0.23	0.73	97.03	66.07
MI	**-585**	**-356**	**-254**	**-610**	**-26**	**-4.27**	**58.16**	**48.15**	**44.61**
MN	4,413	-441	1,516	1,075	-3,338	25.51	20.42	24.48	55.06
WI	2,414	-471	1,065	594	-1,819	17.92	19.11	27.83	53.92
Total	7,333	94	0	94	-7,240	58.37[b]	261.70	50.16	50.16

[a] Permit Price = $59.44/ton$CO_2$e.
[b] Represents number of permits bought or sold.
[c] Power sector only

DATA TABLE
(with MCAC goal 25% below 2002 levels by 2025)

State	2025 BAU Gross Emissions of Power Sector (Consumption-based) (million tCO_2e)	Emissions Cap for Power Sector in 2025 (million tCO_2e)	GHG Mitigation Goal in 2025 (relative to BAU emissions)	Autarkic Marginal Mitigation Cost (dollars per tCO_2e)
IA	51.3	28.9	43.72%	11.3
IL	144.2	64.4	55.34%	100.1
KS	52.6	30.4	42.12%	12.8
MB	0.8	0.3	66.07%	-79.5
MI	**120.8**	**66.9**	**44.61%**	**47.6**
MN	83.4	37.5	55.06%	345.8
WI	68.7	31.6	53.92%	278.9
Total	521.7	260.0	50.16%	

TABLE 5. POWER SECTOR EMISSION TRADING SIMULATION AMONG MGA PARTNERS IN YEAR 2025
(with MCAC goal 30% below 2002 levels by 2025)

(million dollars or otherwise specified)

State	Before Trading	After Trading			Cost Difference	Permits Traded	Emission Reduction w/ Trading		Emission Reduction Goal[c]
	Mitigation Cost	Mitigation Cost	Trading Cost[a]	Net Cost		(million tCO_2)	(million tCO_2)	(percent from BAU)	(percent from BAU)
IA	135	900	-1,927	-1,027	-1,162	-25.76	50.13	97.67	47.47
IL	1,342	104	989	1,093	-248	13.23	70.85	49.15	58.32
KS	181	1,019	-2,026	-1,006	-1,187	-27.08	51.25	97.50	45.97
MB	-59	-65	-16	-82	-23	-0.22	0.73	97.73	68.33
MI	**-345**	**-13**	**-368**	**-381**	**-37**	**-4.92**	**63.28**	**52.39**	**48.31**
MN	5,322	-325	1,965	1,640	-3,682	26.27	22.15	26.55	58.05
WI	3,037	-368	1,383	1,015	-2,021	18.49	20.64	30.06	56.99
Total	9,613	1,253	0	1,253	-8,361	57.99[b]	279.03	53.49	53.49

[a] Permit Price = $74.80/ton$CO_2$e.
[b] Represents number of permits bought or sold.
[c] Power sector only

DATA TABLE
(with MCAC goal 30% below 2002 levels by 2025)

State	2025 BAU Gross Emissions of Power Sector (Consumption-based) (million tCO_2e)	Emissions Cap for Power Sector in 2025 (million tCO_2e)	GHG Mitigation Goal in 2025 (relative to BAU emissions)	Autarkic Marginal Mitigation Cost (dollars per tCO_2e)
IA	51.3	27.0	47.47%	12.6
IL	144.2	60.1	58.32%	113.6
KS	52.6	28.4	45.97%	14.2
MB	0.8	0.2	68.33%	-75.6
MI	**120.8**	**62.4**	**48.31%**	**60.0**
MN	83.4	35.0	58.05%	383.8
WI	68.7	29.5	56.99%	312.6
Total	521.7	242.7	53.49%	

TABLE 6. POWER SECTOR EMISSION TRADING SIMULATION AMONG MGA PARTNERS IN YEAR 2025
(with MCAC goal 35% below 2002 levels by 2025)

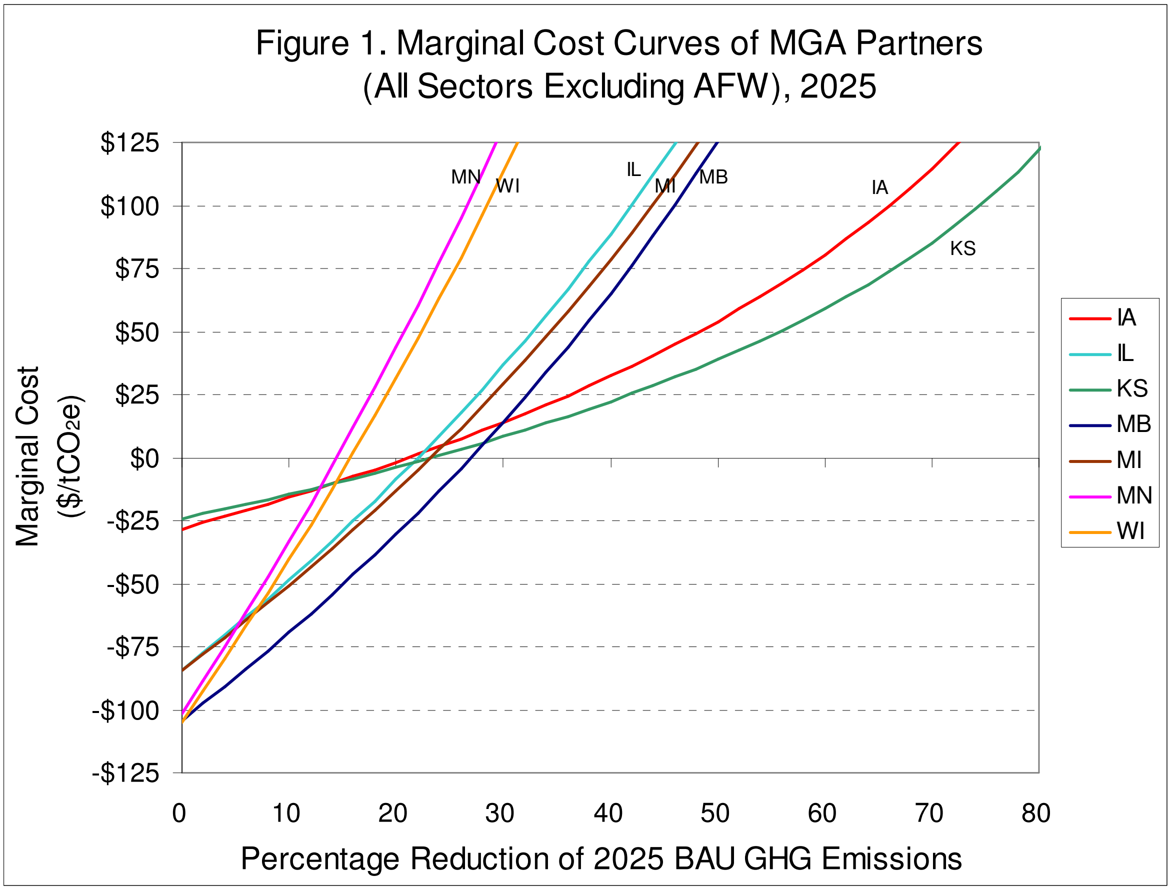
(million dollars or otherwise specified)

State	Before Trading	After Trading			Cost Difference	Permits Traded	Emission Reduction w/ Trading		Emission Reduction Goal[c]
	Mitigation Cost	Mitigation Cost	Trading Cost[a]	Net Cost		(million tCO_2)	(million tCO_2)	(percent from BAU)	(percent from BAU)
IA	161	959	-2,284	-1,324	-1,485	-24.55	50.84	99.07	51.22
IL	1,859	651	1,021	1,672	-186	10.97	77.39	53.68	61.29
KS	211	1,085	-2,404	-1,319	-1,530	-25.85	52.04	99.01	49.83
MB	-60	-65	-19	-84	-24	-0.21	0.74	98.35	70.59
MI	**-48**	**450**	**-558**	**-108**	**-60**	**-6.00**	**68.81**	**56.96**	**52.00**
MN	6,333	-158	2,491	2,333	-4,000	26.79	24.13	28.94	61.05
WI	3,733	-221	1,753	1,532	-2,201	18.85	22.40	32.62	60.06
Total	12,190	2,702	0	2,702	-9,488	56.61[b]	296.35	56.81	56.81

[a] Permit Price = $93.01/ton$CO_2$e.
[b] Represents number of permits bought or sold.
[c] Power sector only

DATA TABLE
(with MCAC goal 35% below 2002 levels by 2025)

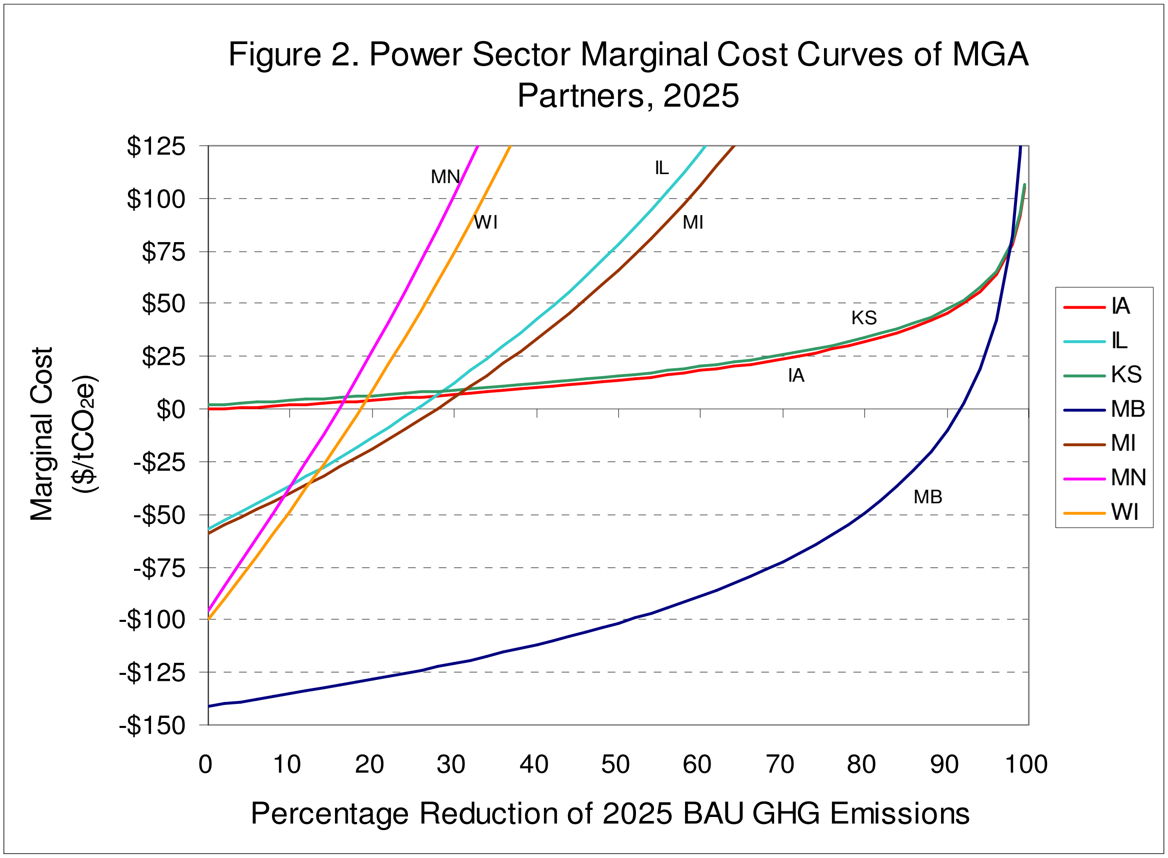
State	2025 BAU Gross Emissions of Power Sector (Consumption-based) (million tCO_2e)	Emissions Cap for Power Sector in 2025 (million tCO_2e)	GHG Mitigation Goal in 2025 (relative to BAU emissions)	Autarkic Marginal Mitigation Cost (dollars per tCO_2e)
IA	51.3	25.0	51.22%	14.1
IL	144.2	55.8	61.29%	128.0
KS	52.6	26.4	49.83%	15.6
MB	0.8	0.2	70.59%	-71.4
MI	**120.8**	**58.0**	**52.00%**	**73.3**
MN	83.4	32.5	61.05%	424.7
WI	68.7	27.4	60.06%	348.8
Total	521.7	225.3	56.81%	



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 Draft State Climate Change Action Plan of Iowa. The marginal cost curve of MI is developed based on the preliminary quantification analysis results for individual mitigation options provided by the ES, RCI, and TLU TWGs.

2. 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.

3. 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.



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 Draft State Climate Change Action Plan of Iowa. The marginal cost curve of MI is developed based on the preliminary 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.

Data Sources:

GHG Mitigation Options Data:

1. 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.

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

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

Emissions Inventory and Forecast Data:

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

2. For Iowa, Michigan, and Kansas: Draft Inventory and Forecast Analysis by CCS.

3. 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.

4. 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.

Background: Development of Marginal Cost Curve for Michigan

1. 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 ES, RCI, and TLU TWGs. Table 1 presents the list of options that have been analyzed by the TWGs in a quantitative manner (please note these are only preliminary analysis results, they are subject to change with the undergoing concurrent stakeholder process).

Table A1. GHG Mitigation Options of Michigan (All Sectors Excluding AFW)

Sector	Climate Mitigation Actions	Estimated 2025 Annual GHG Reduction Potential (MMtCO2e)	Estimated Cost or Cost Savings per ton GHG Removed	GHG Reduction Potential as Percentage of 2025 Baseline Emissions	Cumulative GHG Reduction Potential	Weights (add-up to 100)
TLU-6	Land Use Planning and Incentives	0.430	-$189.00	0.16%	0.16%	0.35
TLU-2	Eco Driver Program	2.600	-$187.00	0.95%	1.10%	2.14
TLU-5	Congestion Mitigation	0.180	-$81.00	0.07%	1.17%	0.15
ES-13	Combined Heat and Power (CHP) standards, incentives and/or barrier removal	0.030	-$60.53	0.01%	1.18%	0.02
TLU-3	Truck Idling Policies	0.870	-$54.00	0.32%	1.50%	0.72
RCI-4	Adopt More Stringent Building Codes for Energy Efficiency	9.700	-$35.23	3.53%	5.03%	7.99
RCI-7	Promotion and Incentives for Improved Design and Construction in the Private Sector	0.000	-$31.00	0.00%	5.03%	0.00
RCI-2	Existing Buildings Energy Efficiency Incentives, Assistance, Certification, and Financing	53.800	-$28.00	19.58%	24.60%	44.34
RCI-1	Utility Demand-Side Management for Electricity and Natural Gas	0.000	-$18.00	0.00%	24.60%	0.00
ES-10	Co-Fired Coal Facility	0.132	$1.76	0.05%	24.65%	0.11
ES-6	New Nuclear Power	4.688	$2.31	1.71%	26.36%	3.86
ES-1	Renewable Portfolio Standard	17.727	$4.45	6.45%	32.81%	14.61
ES-11	Power plant replacement, EE and repowering	4.965	$8.21	1.81%	34.61%	4.09
TLU-1	Promote Low-Carbon Fuel Use in Transportation	6.700	$10.00	2.44%	37.05%	5.52
TLU-8	Increase Rail Capacity, and Address Rail Freight System Bottlenecks	0.190	$35.00	0.07%	37.12%	0.16
ES-12	Distributed renewable energy incentives, barrier removal, and development issues including grid access	2.154	$64.10	0.78%	37.90%	1.78
RCI-8	Net Metering for Distributed Generation	1.625	$74.65	0.59%	38.49%	1.34
RCI-6	Incentives to Promote Renewable Energy Systems Implementation	14.708	$121.55	5.35%	43.85%	12.12
TLU-7	Transit and Travel Options	0.540	$185.00	0.20%	44.04%	0.45
TLU-4	Advanced Vehicle Technology	0.300	$2,198.00	0.11%	44.15%	0.25

[1] Michigan 2025 projected consumption-based gross GHG emission level excluding AFW sector is 274.82 Million Metric Tons of CO_2e.

In Table A1, Column 3 of the table presents the estimated 2025 annual GHG reduction potential for each option, with reduction potentials translated into percentages of the 2025 BAU emissions level of the 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 cheapest option. Column 6 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.

Based on the data presented in Table A1, the stepwise marginal cost function of Michigan in 2025 is first drawn in Figure A1. The horizontal axis represents the percentage of GHG emissions 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 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 23% of 2025 baseline emissions in Michigan.

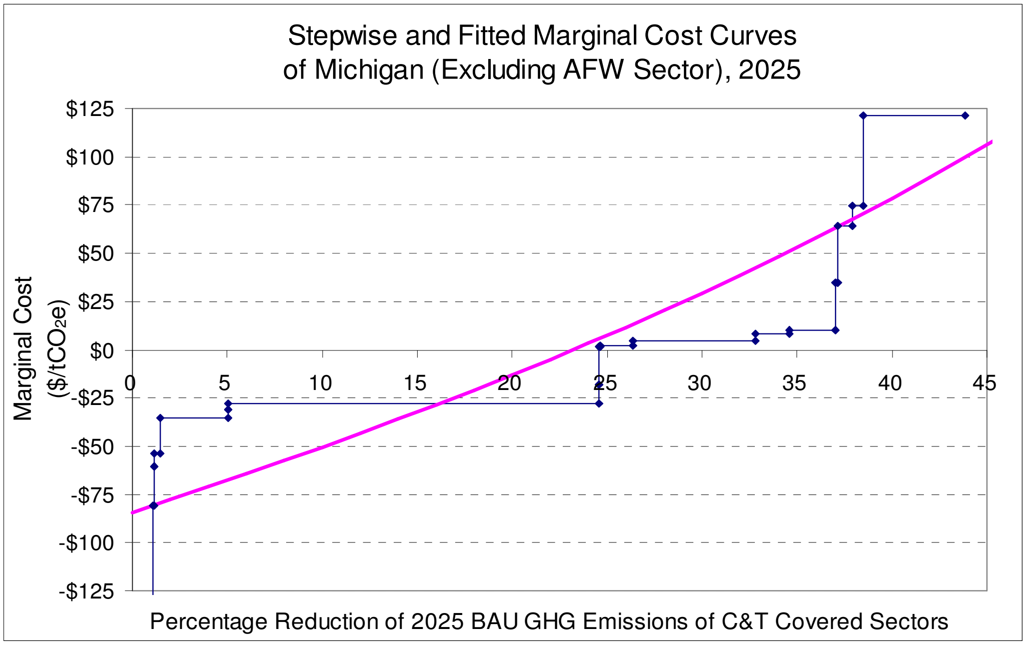
Next, we fit a smooth curve through the data using regression analysis (also see Figure A1). We weight each policy option based on its GHG mitigation potential to give relatively greater influence to those options that have the potential for higher levels of application, and thereby should improve the accuracy of the estimation. This fitted curve is then used in our C&T analysis model.

The fitted curve shown in Figure A1 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; *a* and *b* are parameters.

Figure A1. Stepwise and Fitted Marginal Cost Curve of Michigan (Excluding AFW Sector), 2025



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:

$$MC = -84.18 - 318.20 \times \ln(1 - R)$$

The fitted curve has an intercept with the Y-axis at MC = -$84.18. The curve increases to MC=0 at the emission reduction level of 23%, 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.

2. Power Sector only Marginal Cost Curve

The policy options we used to develop the power sector marginal cost curve not only include 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 to total energy consumption in the RCI sector. RCI options that relate entirely to reduction of other fossil fuels consumption (e.g., gas, oil) are not included in the cost curve development. Table A2 presents the list of options of Michigan used to develop the power sector cost curve.

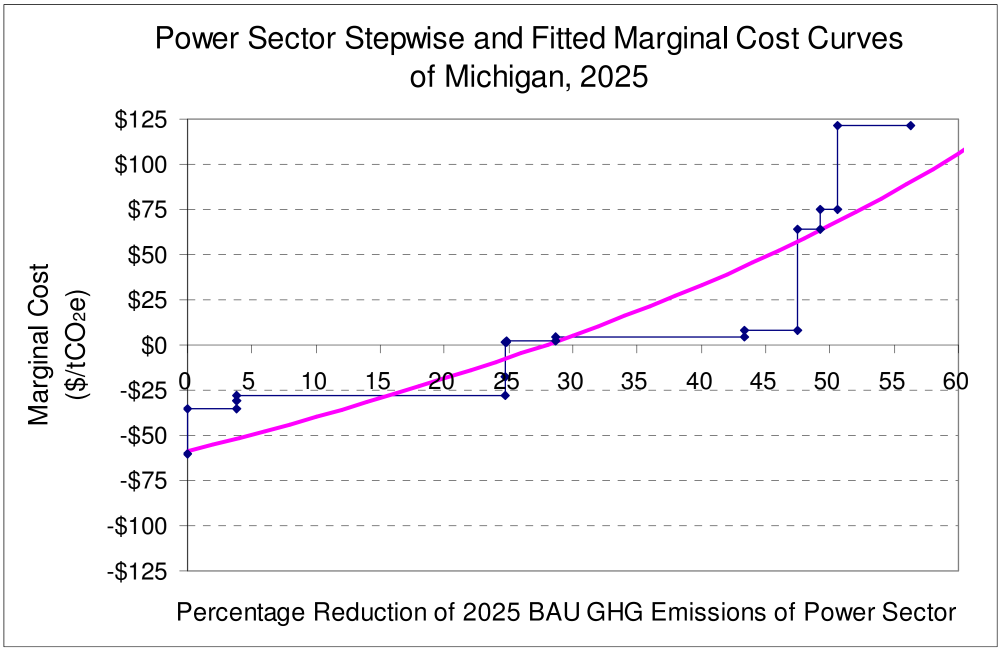
Table A2. GHG Mitigation Options of Michigan (for Power Sector)

Sector	Climate Mitigation Actions	Estimated 2025 Annual GHG Reduction Potential (MMtCO2e)	Estimated Cost or Cost Savings per ton GHG Removed	GHG Reduction Potential as Percentage of 2025 Baseline Emissions	Cumulative GHG Reduction Potential	Weights (add-up to 100)
ES-13	Combined Heat and Power (CHP) standards, incentives and/or barrier removal	0.030	-$60.53	0.02%	0.02%	0.04
RCI-4	Adopt More Stringent Building Codes for Energy Efficiency	4.554	-$35.23	3.77%	3.79%	6.69
RCI-7	Promotion and Incentives for Improved Design and Construction in the Private Sector	0.000	-$31.00	0.00%	3.79%	0.00
RCI-2	Existing Buildings Energy Efficiency Incentives, Assistance, Certification, and Financing	25.261	-$28.00	20.91%	24.71%	37.12
RCI-1	Utility Demand-Side Management for Electricity and Natural Gas	0.000	-$18.00	0.00%	24.71%	0.00
ES-10	Co-Fired Coal Facility	0.132	$1.76	0.11%	24.81%	0.19
ES-6	New Nuclear Power	4.688	$2.31	3.88%	28.70%	6.89
ES-1	Renewable Portfolio Standard	17.727	$4.45	14.67%	43.37%	26.05
ES-11	Power plant replacement, EE and repowering	4.965	$8.21	4.11%	47.48%	7.30
ES-12	Distributed renewable energy incentives, barrier removal, and development issues including grid access	2.154	$64.10	1.78%	49.26%	3.17
RCI-8	Net Metering for Distributed Generation	1.625	$74.65	1.35%	50.61%	2.39
RCI-6	Incentives to Promote Renewable Energy Systems Implementation	6.906	$121.55	5.72%	56.33%	10.15

[1] Michigan 2025 projected consumption-based power sector gross CO2 emission level is 120.8 Million Metric Tons CO2e.

Following the same methodology as described above, the power sector stepwise and fitted marginal cost curves of Michigan for year 2025 are developed and presented in Figure A2. The specification of the power sector fitted marginal cost curve is: $MC = -58.84 - 180.10 \times \ln(1 - R)$

Figure A2. Power Sector Stepwise and Fitted Marginal Cost Curve of Michigan, 2025



Annex 2

Modeling of Cap and Trade Programs

by

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November 2008

I. 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. 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 non-linear 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), ten EPA regions covering all states of the U.S, Midwestern Governors Association (MGA) region, Minnesota internal state trading, Western Climate Initiative (WCI), and Pacific Rim states and countries (see Rose et al., 1998; Rose and Zhang, 2004; Rose et al., 2006; 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 own abatement cost plus the cost of permits, whereas for selling states (or sectors), compliance costs are equal to 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 vs. 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:

- 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

II. DEVELOPMENT OF MARGINAL COST CURVES

Many states have developed State 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 CO_2 that can be reduced (this is specified in terms of a cost-effectiveness, including the possibility of cost savings per unit 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 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.

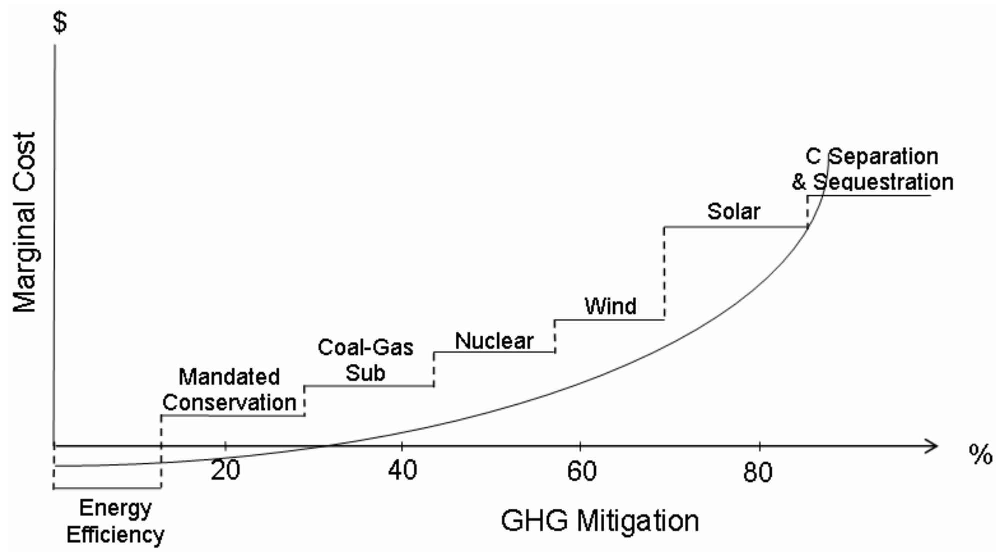

Figure 1. Illustrative Marginal Cost Step Function and Curve for GHG Mitigation

Prior CCS analysis for Minnesota can serve as an example of the construction of the mitigation marginal cost curve. Table 1 presents 8 example climate mitigation options out of the 37 options analyzed in a quantitative manner 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 BAU emissions 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.

Based on the data presented in Table 1, the stepwise marginal cost function for Minnesota in 2025 is first drawn in Figure 2. The horizontal axis represents the percentage of GHG emissions 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 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 2). We weight each policy option based on its GHG mitigation potential to give relatively greater influence to those 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.

Table 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.

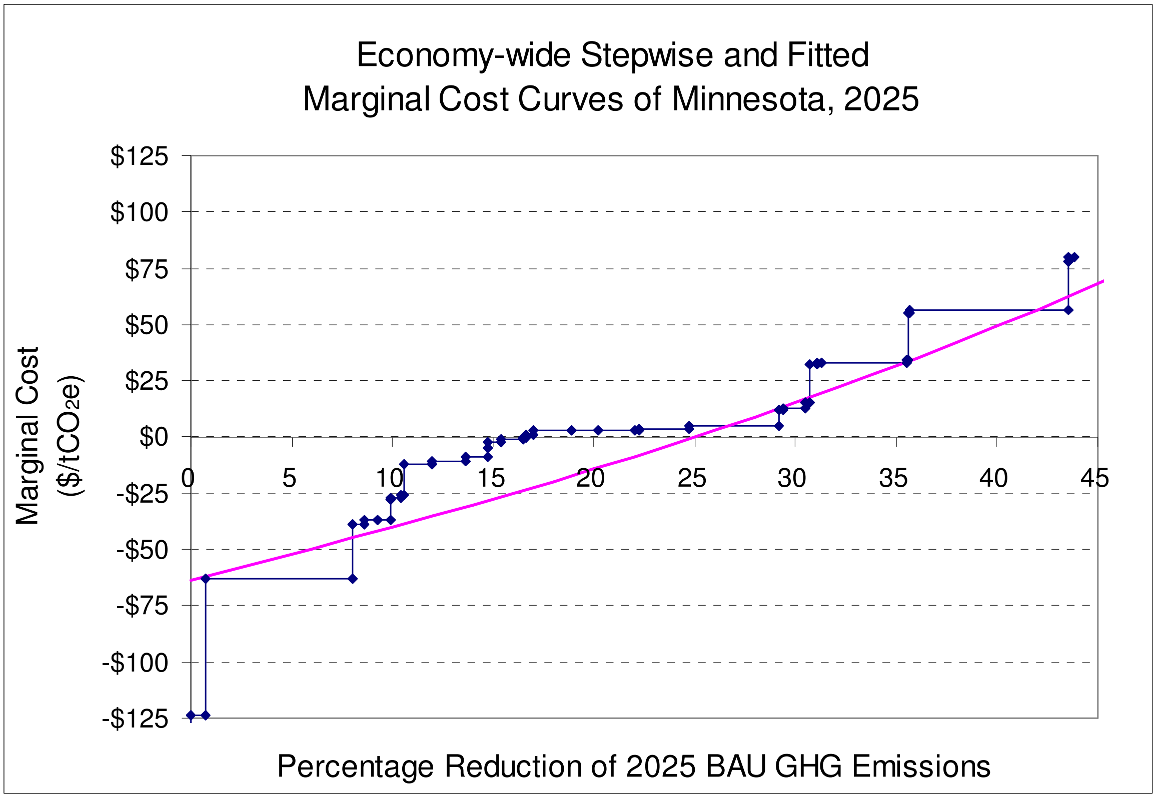

Figure 2. Stepwise and Fitted Marginal Cost Curve of Minnesota, 2025

The fitted curve shown in Figure 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; *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; 1994). As the emission reductions increase along the X axis, the cost to reduce one additional unit of emission increase 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.

III. 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 (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6) — 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 vs. 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 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, etc.), but also include options in RCI sectors that contribute to the reduction of electricity consumption (e.g., demand-side management, 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.
- The target year we used for the MGA C&T analysis is Year 2025. The mitigation policy options of Iowa are analyzed for Year 2020. Therefore, we adjusted the mitigation cost data of Iowa to year 2025 based on the assumption of 2% annual technical improvement or innovation rate. In other words, we used the same reduction potential numbers for individual options in year 2025 as in year 2020 for Iowa, and assumed the cost per ton of CO_2e reduction being about $(1+2\%)^5$ lower in year 2025 than in year 2020.
- For state that lacks direct cost data, the cost curve is approximated based on the data of one of its adjacent state 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 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 $MMtCO_2e$ 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.

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.

IV. 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 total net compliance costs for each state and minimization of total abatement costs for the region as a whole. For selling states (high cost states), they will reduce emissions up to the point where their marginal cost equals the prevailing market permit price, and accomplish their remaining reduction responsibility by purchasing available permits in the market. For purchasing states (low cost states), they would have the incentive to do more than their reduction targets indicate, so that they can sell their surplus permits on the open market to obtain 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):[13]

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

where MC_i is the marginal cost of abatement for state i, R_i is the percentage of greenhouse gas abatement undertaken by state i in million tons of carbon dioxide equivalent (MMtCO2e), 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:

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

[13] The shape of the cost function for mitigating carbon 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 carbon emissions among a number of economic modeling studies that he surveyed (a type of meta-analysis). Nordhaus (1994) used an analytical model to further derive a logarithmic relationship between the marginal costs and the percentage reduction.

where E_i is each state's gross (unabated) emissions in MMtCO2e. 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 autarkic 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 it an incentive to undertake abatement and sell permits to those 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 emissions permits available for sale in a given regional trading coalition TS, is:

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

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 emissions permits in the region is equal to the total supply:

$$TD = TS \qquad (8)$$

Substituting 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:

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

We solve the model by minimizing total abatement costs of all states $\sum_i TC_i$ subject to Eq. (4), (6), and (9), using GAMS, an algebraic modeling system for linear, nonlinear, and integer programming problems (Brooke et al., 1996).[14] 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 follows 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).

[14] 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.

REFERENCES

Brooke, A., Kendrick, D., and Meeraus, A. 1996. *GAMS: A User's Guide.* Redwood City, CA: Scientific Press.

Center for Climate Strategies (CCS). 2008. "Cap and Trade," Chapter 8 in *Minnesota Climate Change Action Plan*, Report to the Minnesota Climate Change Advisory Group.

Nordhaus, W.D. 1991. "The Cost of Slowing Climate Change: A Survey," *Energy Journal* 12: 35-67.

Nordhaus, W.D. 1994. *Managing the Global Commons*. Cambridge, MA: MIT Press.

Loeschel, A. and Zhang, Z.X. 2002. "The Economic and Environmental Implications of the U.S. Repudiation of the Kyoto Protocol and the Subsequent Deals in Bonn and Marrakech," *Weltwirtschaftlishes Archiv* 138(4): 711-46.

Rose, A. and Wei, D. 2008. "Greenhouse Gas Emissions Trading among Pacific Rim Countries: An Analysis of Policies to Bring Developing Countries to the Bargaining Table," *Energy Policy* 36: 1420-9.

Rose, A. and Zhang, Z.X. 2004. "Interregional Burden-Sharing of Greenhouse Gas Mitigation in the United States," *Mitigation and Adaptation Strategies for Global Change* 9(3): 477-500.

Rose, A., Peterson, T., and Zhang, Z.X. 2006. "Regional Carbon Dioxide Permit Trading in the United States: Coalition Choices for Pennsylvania," *Penn State Environmental Law Review* 14(2): 203-29.

Rose, A., Stevens, B. K., Edmonds, J., and Wise, M. 1998. "International Equity and Differentiation in Global Warming Policy," *Environmental and Resource Economics* 12(1): 25-51.

Stevens, B. and Rose, A. 2002. "A Dynamic Analysis of the Marketable Permits Approach to Global Warming Policy: A Comparison of Spatial and Temporal Flexibility," *Journal of Environmental Economics and Management* 44(1): 45-69.

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

Zhang, Z.X. 2000. "The Design and Implementation of an International Greenhouse Gas Emissions Trading Scheme," *Environment and Planning C: Government and Policy* 18(3): 321-337.