An Overview of the Cap and Trade Model

Rose-Zhang Permit Trading Model

- Purpose: Simulate basic features of cap & trade systems (and related policy refinements) to determine emission & cost implications
  - Extensive prior applications (Global, EU, US regions, RGGI, and MGA)
  - Flexible & transparent framework
  - Readily accommodates data refinements & updates
  - Readily accommodates simple & complex designs

R-Z Model Features

- Based on sound economic principles
- Main inputs (for each entity)
  - emission levels
  - marginal mitigation costs
  - initial permit allocations
- Main outputs (for each entity)
  - GHG emission reductions before and after permit trading
  - pre-trading mitigation costs
  - post-trading mitigation costs
  - cost savings
  - permit purchases/sales (volume & value)
  - permit price

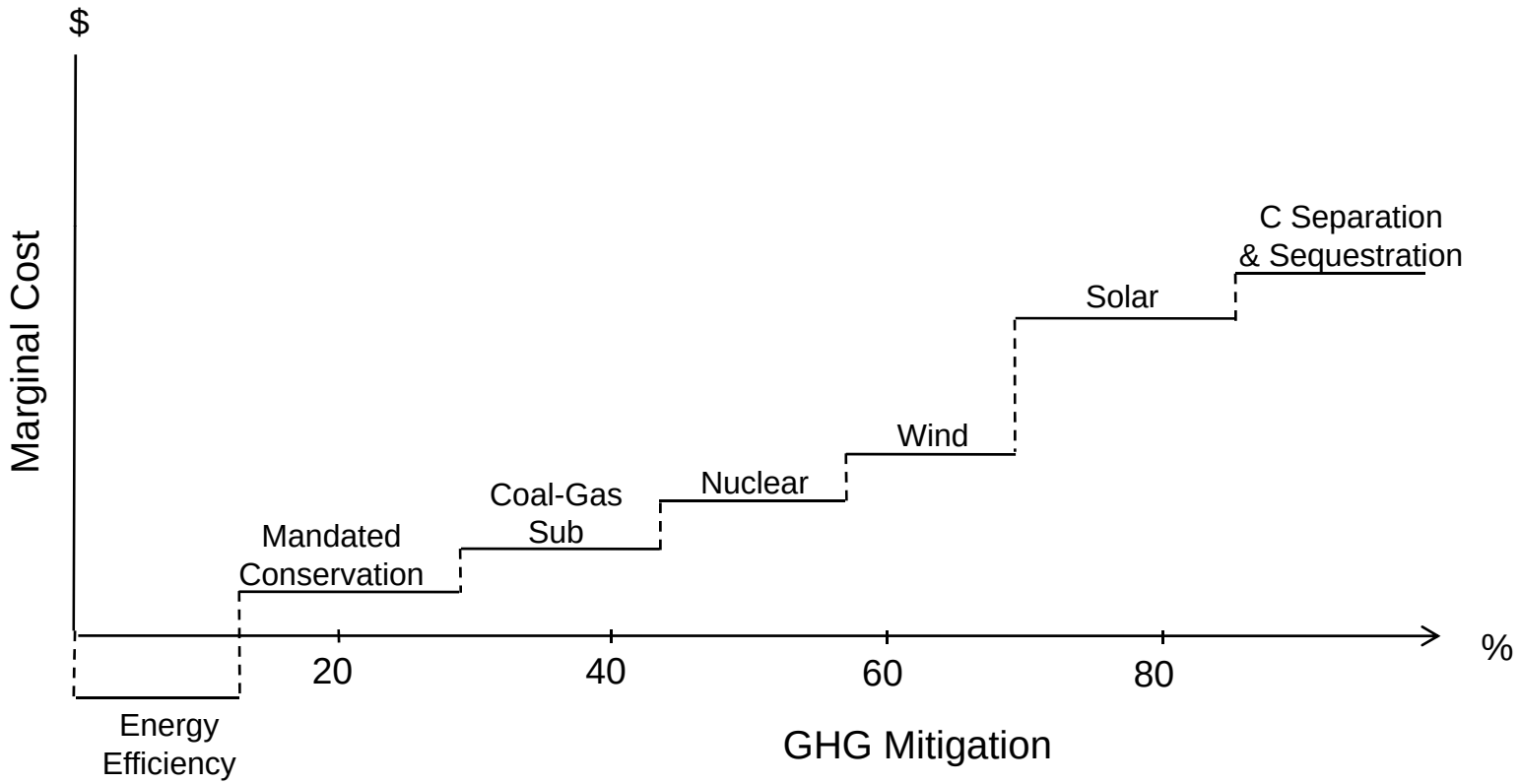
Evaluation Of Permit Trading Flexibility

(All entries represent departure from CO2 mitigation only unless otherwise indicated)

Study/Application	**How**	**What**	**Where**
Rose-Oladosu (2002) U.S.	Sequestration Permit price 64% lower	Methane Permit price 23% lower	
Stevens-Rose (2002) Global			Global trading Cost savings 85%
Springer (2003) Global		Methane and nitrous oxide Permit price 25-49% lower	From Annex I trading to global trading Average permit price 67% Lower
Zhang (2004) Global			From Annex I trading to global trading Permit price 76 - 79% lower
Akimoto et al. (2004) Global	Sequestration CO_2 shadow price 32% lower		
IPCC (2001) Global			Global trading Marginal abatement costs 29 - 78% lower
Rose-Zhang (2004) U.S.			National trading Cost savings 41%

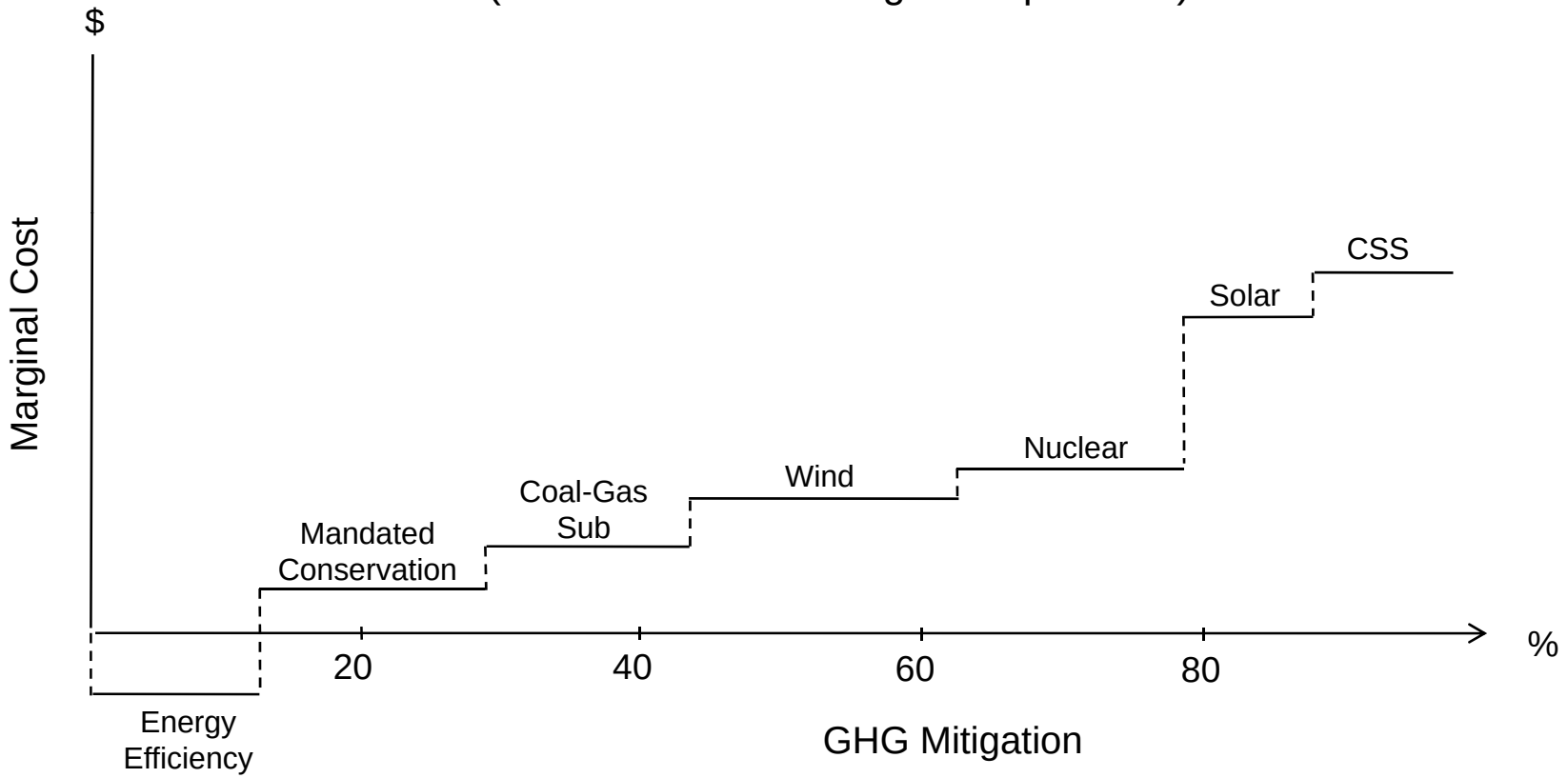
Sample Cost Curve

Figure 1. Marginal Costs of GHG Mitigation



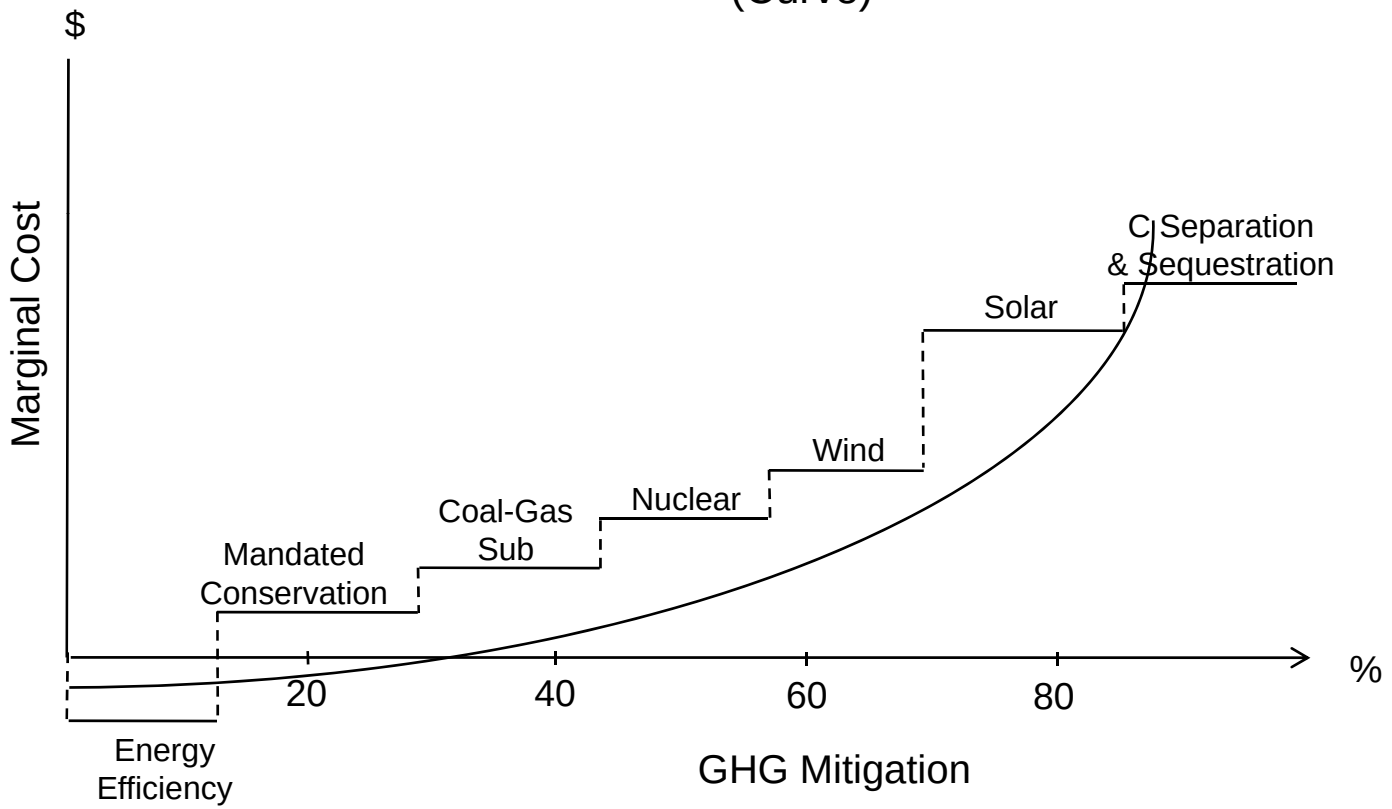
Sample Cost Curve

Figure 2. Marginal Costs of GHG Mitigation
(Wind at lower cost & greater potential)



Sample Cost Curve

Figure 3. Marginal Costs of GHG Mitigation (Curve)



Development of the Marginal Cost Curve for Iowa

Table A1. GHG Mitigation Options of Iowa

Sector	Climate Mitigation Actions	Estimated 2020 Annual GHG Reduction Potential (MMtCO2e)	Estimated Cost or Cost Savings per ton GHG Removed	GHG Reduction Potential as Percentage of 2020 Baseline Emissions[1]	Cumulative GHG Reduction Potential	Weights (add-up to 100)
TLU-7	Fuel Efficient Operations for Light Duty Vehicles	0.65	-$90.00	0.45%	0.45%	0.60
EEC-11	Rate Structures and Technologies To Promote Reductions	0.06	-$16.12	0.04%	0.49%	0.06
EEC-3	Financial Mechanisms for Energy Efficiency	0.98	-$15.97	0.68%	1.18%	0.91
EEC-1	Demand-Side Management (DSM)/Energy Efficiency Programs for Electricity	8.11	-$15.87	5.64%	6.81%	7.50
EEC-5	Incentive Mechanisms for Achieving Energy Efficiency	3.24	-$15.46	2.25%	9.06%	2.99
EEC-6	Promotion and Incentives for Improved Design and Construction in the Private Sector	0.08	-$14.41	0.06%	9.12%	0.07
CRE-4a	Decarbonization Fund	0.00	-$14.31	0.00%	9.12%	0.00
EEC-8	Focus on Specific Residential Market Segments	0.90	-$13.77	0.63%	9.74%	0.83
EEC-4	Improved Building Codes for Energy Efficiency	0.55	-$13.52	0.38%	10.12%	0.50
AFW-8	Waste Management Strategies	4.10	-$8.00	2.85%	12.97%	3.79
EEC-2	Demand-Side Management (DSM) Energy Efficiency Programs for Natural Gas	2.37	-$1.23	1.65%	14.62%	2.19
EEC-9	Midwestern Governors Association Energy Security and Climate Stewardship Platform	0.00	$0.00	0.00%	14.62%	0.00
AFW-9	Landfill Methane Energy Programs	0.78	$0.80	0.54%	15.16%	0.72
AFW-4	Encourage Large-Scale Manure/Methane Management Capture Utilization	2.64	$3.00	1.83%	17.00%	2.44
AFW-6	Cellulosic Fuel Incentives	9.79	$3.50	6.80%	23.80%	9.05

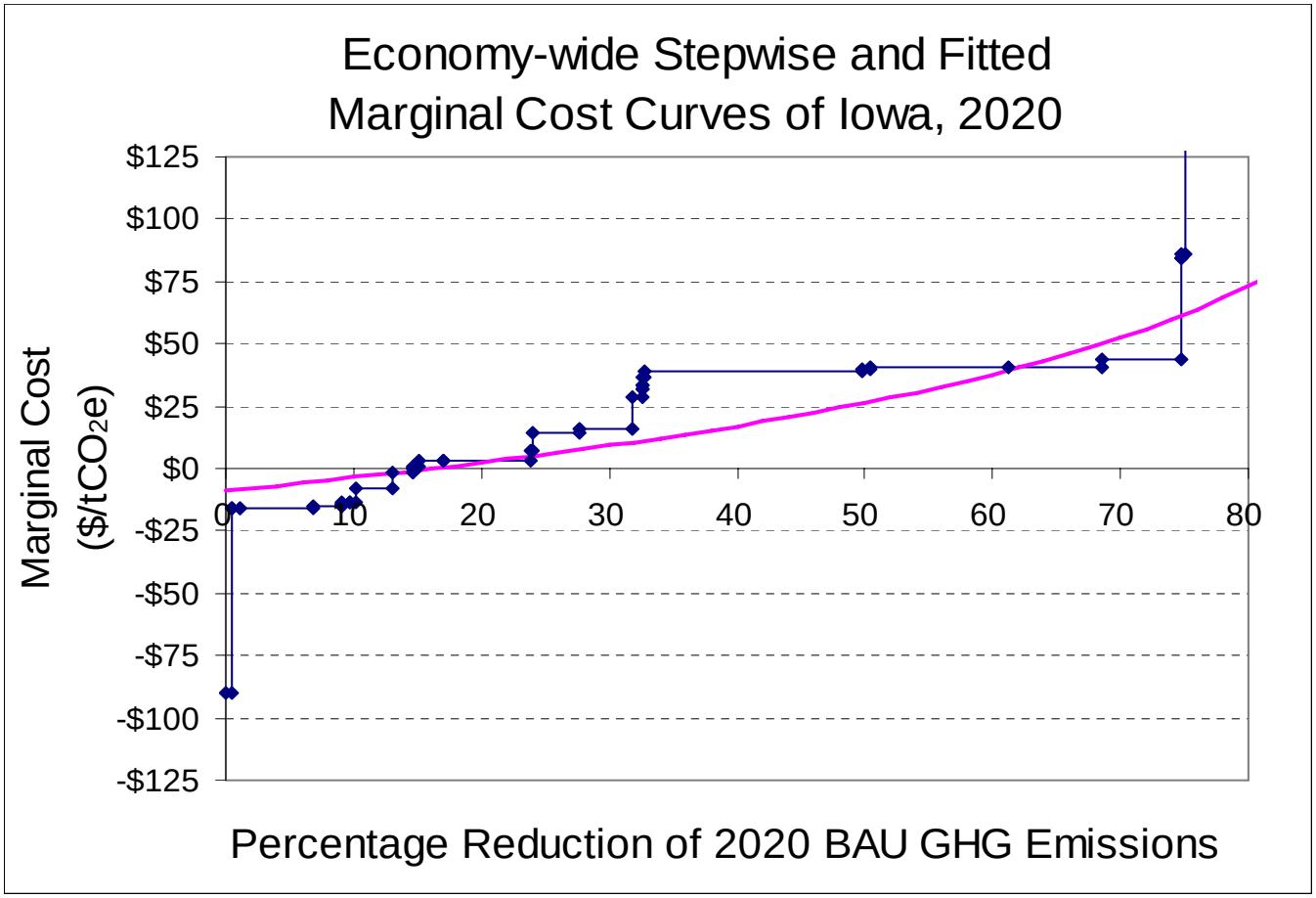
Table A1 (cont). GHG Mitigation Options of Iowa

Sector	Climate Mitigation Actions	Estimated 2020 Annual GHG Reduction Potential (MMtCO2e)	Estimated Cost or Cost Savings per ton GHG Removed	GHG Reduction Potential as Percentage of 2020 Baseline Emissions[1]	Cumulative GHG Reduction Potential	Weights (add-up to 100)
EEC-13	Government Lead-by-Example: Improved Design and Construction in New and Existing State and Local Government Buildings	0.36	$7.10	0.25%	24.05%	0.33
TLU-10	Fuel Strategies	5.19	$14.00	3.61%	27.66%	4.80
CRE-12	Combined Heat and Power	6.05	$15.69	4.21%	31.86%	5.59
AFW-7	Improved On-Farm (or First Point of Purchase) Energy Use and Efficiency	1.02	$29.00	0.71%	32.57%	0.94
CRE-8	Support for Grid-based Renewable Energy & Development	0.13	$31.98	0.09%	32.67%	0.12
CRE-5	Performance Standards	0.00	$33.65	0.00%	32.67%	0.00
CRE-11	Distributed Generation/Co-generation	0.06	$36.23	0.04%	32.71%	0.06
CRE-2	Technology Initiatives, including Renewables	24.54	$38.72	17.05%	49.76%	22.68
CRE-13	Pricing strategies to promote renewable energy and/or CHP	1.05	$39.61	0.73%	50.49%	0.97
AFW-3	Expanded Use of Agriculture and Forestry Biomass Feedstocks for Electricity, Heat or Steam Production	15.36	$41.00	10.68%	61.17%	14.20
AFW-5	Land Management to Promote Sequestration Benefits	10.60	$41.00	7.37%	68.54%	9.80
CRE-7	Policies Related to Nuclear Power	8.85	$43.90	6.15%	74.69%	8.18
TLU-5	Adopt Best Workplaces for Commuters in Iowa	0.02	$84.00	0.01%	74.70%	0.02
AFW-1	Nutrient Management	0.64	$86.00	0.44%	75.15%	0.59
TLU-3	Expand and Improve Transit Infrastructure	0.05	$483.00	0.03%	75.18%	0.05

[1] Iowa 2020 projected consumption-based gross GHG emission level is 143.87 Million Metric Tons of CO2e.

Notes:

1. The numbers presented here are preliminary. They are subject to change when we obtain updated quantification analyses for individual mitigation options from the Subcommittees.
2. Only options that are quantitatively analyzed for reduction potential and cost/savings are included in the cost curve development.
3. The overlaps between options within the EEC sector and within the CRE sector have been adjusted. It is assumed that there are no overlaps between AFW options. The overlaps within the TLU sector and the overlaps between sectors have not been adjusted at the time of this preliminary analysis.


Economy-wide Stepwise and Fitted
Marginal Cost Curves of Iowa, 2020
Marginal Cost
($/tCO2e)
$125
$100
$75
$50
$25
$0
-$25
-$50
-$75
-$100
-$125
0
10
20
30
40
50
60
70
80
Percentage Reduction of 2020 BAU GHG Emissions

Sample Outputs
(multi-state cap and trade)

TABLE 2. ECONOMY-WIDE EMISSION TRADING SIMULATION AMONG MGA PARTNERS IN YEAR 2020
(with MGA goal 20% below 2005 levels by 2020)

(million dollars or otherwise specified)

State	Before Trading	After Trading			Cost Saving	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	21	254	-301	-47	68	-15.22	61.99	43.09	32.51
IL	-2,515	-2,870	249	-2,621	106	12.61	89.04	27.34	31.21
KS	-72	140	-301	-160	88	-15.21	51.40	43.28	30.47
MB	-286	-269	-62	-332	46	-3.16	11.15	45.80	32.81
MI	-2,577	-2,758	138	-2,620	44	6.97	72.58	26.47	29.01
MN	-1,158	-1,264	89	-1,175	17	4.50	57.25	30.55	32.95
WI	-975	-1,304	188	-1,116	140	9.52	39.22	26.30	32.68
Total	-7,563	-8,071	0	-8,071	508	33.59[b]	382.63	31.28	31.28

[a] Permit Price = \$19.76/tonCO_2e.
[b] Represents number of permits bought or sold.

Sample Outputs
(Minnesota only cap and trade)

Emission Trading Simulation Among Four Sectors in Minnesota, 2025
(with the 2025 emission cap as 30% below the 2005 level)

(million dollars or otherwise specified)

State	Before Trading	After Trading[a]			Cost Saving	Permits Traded	Emission Reduction After Trading		Emission Reduction Cap
	Mitigation Cost	Mitigation Cost	Trading Cost	Net Cost		(million tCO_2e)	(million tCO_2e)	(percent from BAU)	(percent from BAU)
Power Sector	2,653	-692	1,141	449	2,203	17.42	24.14	30.38	52.31
Transportation Sector	-68	216	-457	-241	173	-6.98	20.71	52.06	34.51
Other	928	-9	584	575	352	8.92	24.97	31.80	43.16
Sequestration	0	272	-1,268	-996	996	-19.36	19.36	n.a.	n.a.
Total	3,512	-213	0	-213	3,725	26.35[b]	89.18	45.10	45.10

[a] Permit Price = \$65.48/tonCO_2e.
[b] Represents number of permits bought or sold.

Policy Refinements

- Production-based vs. Consumption-based allocation
- Economic sector (emitter) disaggregation
- Offsets
- Flexibility
  - how (e.g., sequestration)
  - what (e.g., CO2, methane, nitrous oxides, SFCs)
  - where (e.g., alternative configurations of states)
  - when (e.g., permit banking & borrowing)

Potential Permit Trading Anomalies

- Participants as a whole gain from flexibility
- However, individual states may not because new entrants:
  - may raise the permit price
  - may undercut existing states' permit sales
  - may be able to exercise monopoly power
  - may increase inequities

Preliminary Analysis of MGA Cap and Trade and Carbon Tax for Iowa in 2020

MGA Cap and Trade

Assumptions:

- Geographic Coverage:
  - Seven MGA partners: Iowa, Illinois, Kansas, Michigan, Minnesota, Wisconsin, and Manitoba.
- Sector Coverage:
  - All economic sectors.
- Emission Reduction Target:
  - Three preliminary short term (2020) goals recommended to the Midwestern Greenhouse Gas Reduction Accord Advisory Group by the Target-Setting, Data and Reporting Subgroup: 15, 20, and 25% below 2005 levels by 2020.
- Emission permits are assumed to be grandfathered
- Consumption-based gross emissions are used

MGA Cap and Trade

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*.
  2. Iowa Climate Change Advisory Council. 2008. Preliminary Quantification Analysis of Mitigation Options by the EEC, CRE, TLU, and AFW Subcommittees.

- 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 for each of the three states prepared by CCS.
  3. For Illinois and Wisconsin: World Resources Institute. 2007. *GHG Emissions Inventory and Projections,* prepared for the Illinois Climate Change Advisory Group and the Wisconsin Task Force on Global Warming.

MGA C&T Simulation Results

— with MGA goal 15% below 2005 levels by 2020

TABLE 1. ECONOMY-WIDE EMISSION TRADING SIMULATION AMONG MGA PARTNERS IN YEAR 2020
(with MGA goal 15% below 2005 levels by 2020)

(million dollars or otherwise specified)

State	Before Trading	After Trading			Cost Saving	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	-37	3	-45	-42	5	-4.42	45.13	31.37	28.30
IL	-2,896	-2,981	62	-2,919	23	6.03	81.64	25.07	26.92
KS	-108	-49	-78	-127	19	-7.63	38.65	32.54	26.12
MB	-274	-284	-33	-317	43	-3.18	10.15	41.69	28.61
MI	-2,837	-2,840	2	-2,837	0	0.23	67.14	24.48	24.57
MN	-1,320	-1,351	26	-1,326	5	2.50	51.40	27.42	28.76
WI	-1,224	-1,352	66	-1,286	62	6.46	36.01	24.15	28.48
Total	-8,695	-8,854	0	-8,854	158	15.23[b]	330.12	26.98	26.98

[a] Permit Price = \$10.24/tonCO_2e.
[b] Represents number of permits bought or sold.

MGA C&T Simulation Results

— with MGA goal 15% below 2005 levels by 2020

DATA TABLE
(with MGA goal 15% below 2005 levels by 2020)

State	2020 BAU Gross Emissions (Consumption-based) (million tCO_2e)	Emissions Cap in 2020 (million tCO_2e)	GHG Mitigation Goal in 2020 (relative to 2020 BAU emissions)	Autarkic Marginal Mitigation Cost (dollars per tCO_2e)
IA	143.9	103.2	28.30%	8.0
IL	325.7	238.0	26.92%	18.0
KS	118.8	87.7	26.12%	5.2
MB	24.3	17.4	28.61%	-16.1
MI	274.2	206.8	24.57%	10.6
MN	187.4	133.5	28.76%	14.3
WI	149.1	106.7	28.48%	29.7
Total	1,223.4	893.3	26.98%	

MGA C&T Simulation Results

— with MGA goal 20% below 2005 levels by 2020

TABLE 2. ECONOMY-WIDE EMISSION TRADING SIMULATION AMONG MGA PARTNERS IN YEAR 2020
(with MGA goal 20% below 2005 levels by 2020)

(million dollars or otherwise specified)

State	Before Trading	After Trading			Cost Saving	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	21	254	-301	-47	68	-15.22	61.99	43.09	32.51
IL	-2,515	-2,870	249	-2,621	106	12.61	89.04	27.34	31.21
KS	-72	140	-301	-160	88	-15.21	51.40	43.28	30.47
MB	-286	-269	-62	-332	46	-3.16	11.15	45.80	32.81
MI	-2,577	-2,758	138	-2,620	44	6.97	72.58	26.47	29.01
MN	-1,158	-1,264	89	-1,175	17	4.50	57.25	30.55	32.95
WI	-975	-1,304	188	-1,116	140	9.52	39.22	26.30	32.68
Total	-7,563	-8,071	0	-8,071	508	33.59[b]	382.63	31.28	31.28

[a] Permit Price = \$19.76/tonCO_2e.
[b] Represents number of permits bought or sold.

MGA C&T Simulation Results

— with MGA goal 20% below 2005 levels by 2020

DATA TABLE
(with MGA goal 20% below 2005 levels by 2020)

State	2020 BAU Gross Emissions (Consumption-based) (million tCO_2e)	Emissions Cap in 2020 (million tCO_2e)	GHG Mitigation Goal in 2020 (relative to 2020 BAU emissions)	Autarkic Marginal Mitigation Cost (dollars per tCO_2e)
IA	143.9	97.1	32.51%	11.1
IL	325.7	224.0	31.21%	36.7
KS	118.8	82.6	30.47%	8.6
MB	24.3	16.4	32.81%	-8.2
MI	274.2	194.7	29.01%	32.3
MN	187.4	125.7	32.95%	27.4
WI	149.1	100.4	32.68%	49.7
Total	1,223.4	840.8	31.28%	

MGA C&T Simulation Results

— with MGA goal 25% below 2005 levels by 2020

TABLE 3. ECONOMY-WIDE EMISSION TRADING SIMULATION AMONG MGA PARTNERS IN YEAR 2020
(with MGA goal 25% below 2005 levels by 2020)

(million dollars or otherwise specified)

State	Before Trading	After Trading			Cost Saving	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	98	643	-755	-112	210	-24.75	77.60	53.94	36.73
IL	-1,863	-2,667	565	-2,102	239	18.52	97.13	29.82	35.51
KS	-19	440	-673	-233	214	-22.04	63.39	53.37	34.81
MB	-290	-243	-97	-340	50	-3.19	12.19	50.10	37.01
MI	-2,046	-2,608	401	-2,207	161	13.14	78.55	28.65	33.44
MN	-888	-1,105	184	-921	32	6.04	63.56	33.92	37.14
WI	-597	-1,216	375	-841	244	12.28	42.74	28.66	36.89
Total	-5,606	-6,756	0	-6,756	1,151	49.98[b]	435.16	35.57	35.57

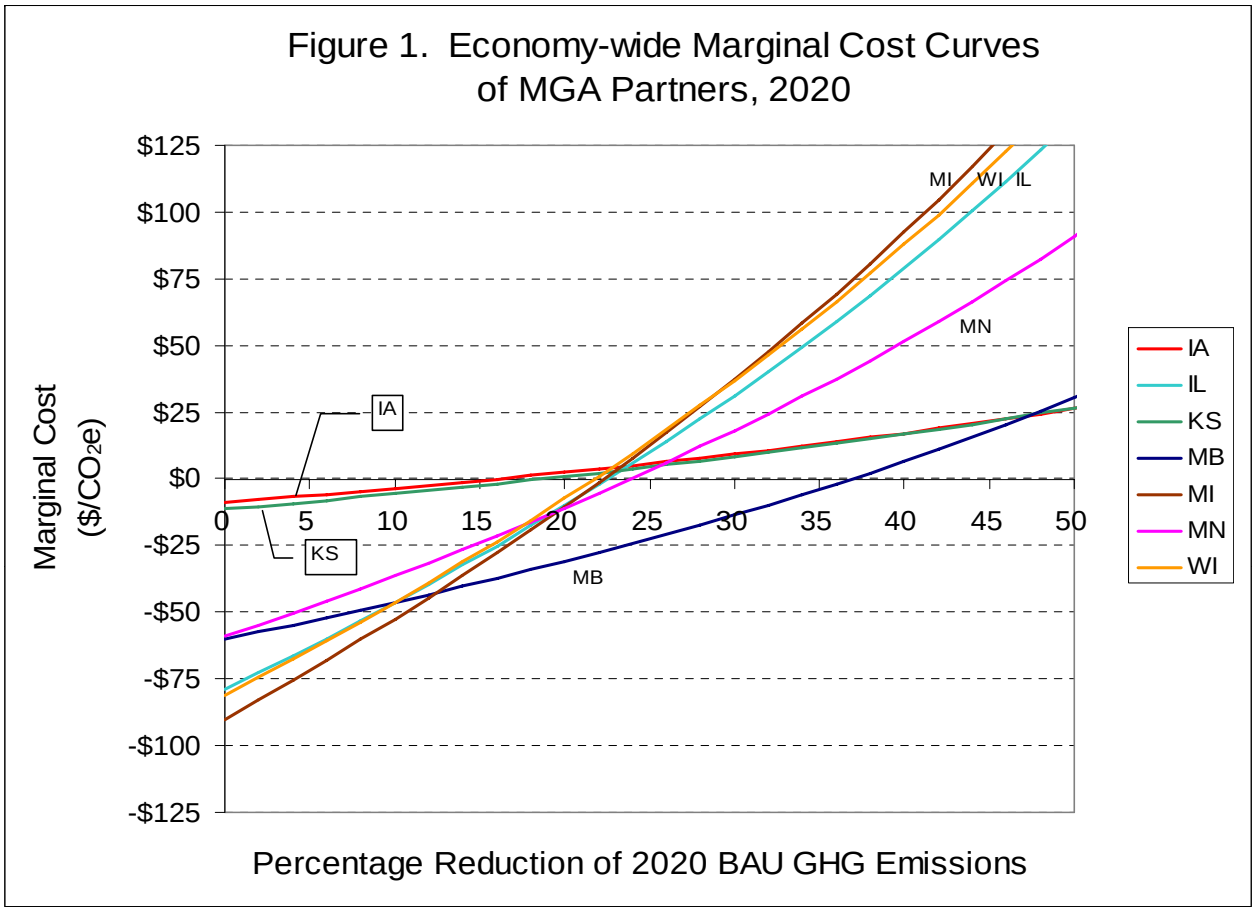
[a] Permit Price = \$30.51/tonCO_2e.
[b] Represents number of permits bought or sold.

MGA C&T Simulation Results

— with MGA goal 25% below 2005 levels by 2020

DATA TABLE
(with MGA goal 25% below 2005 levels by 2020)

State	2020 BAU Gross Emissions (Consumption-based) (million tCO_2e)	Emissions Cap in 2020 (million tCO_2e)	GHG Mitigation Goal in 2020 (relative to 2020 BAU emissions)	Autarkic Marginal Mitigation Cost (dollars per tCO_2e)
IA	143.9	91.0	36.73%	14.4
IL	325.7	210.0	35.51%	56.6
KS	118.8	77.4	34.81%	12.1
MB	24.3	15.3	37.01%	0.2
MI	274.2	182.5	33.44%	55.4
MN	187.4	117.8	37.14%	41.3
WI	149.1	94.1	36.89%	71.1
Total	1,223.4	788.3	35.57%	



Notes: 1. The marginal cost curve of MN is developed based on mitigation options data in the Minnesota State Climate Change Action Plan. The marginal cost curve of IA is developed based on the preliminary quantification analysis results for individual mitigation options provided by the EEC, CRE, TLU, and AFW Subcommittees.

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

Findings from the Preliminary MGA C&T Simulations

- 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.

- For all the MGA partners, the total cost of achieving the carbon emission caps is negative. This means that compliance with the caps will result in overall cost savings. This result is due to the existence of an extensive range of cost-saving options, such as improvements in energy efficiency.

- With the MGA GHG reduction goal increases from 15%, to 20%, and to 25% below 2005 level, the equilibrium permit price in the trading market increases from $10.24/tCO2e to $19.76/tCO2e, and to $30.51/tCO2e, respectively. The volume of permits traded among the partners also increase remarkably when the reduction goal gets more and more stringent (from 15.23 MMtCO2e in the 15% case to 49.98 MMtCO2e in the 25% case).

Findings from the Preliminary MGA C&T Simulations (cont)

- In the 15% reduction goal case, Kansas is the biggest permit seller in the market, followed by Iowa and Manitoba. Wisconsin is the biggest permit buyer in the market in this simulation case, closely followed by Illinois. In both the 20% and 25% reduction goal cases, Iowa is the biggest permit seller in the market and Kansas becomes the second biggest seller. On the buyer's side, in these two simulation cases, Illinois becomes the biggest permit purchaser.

- In all the three simulation cases, if we compare the net cost of each state/province after trading with the before trading mitigation cost, we find that all states/provinces are better off as a result of participating in trading, since all the post-trading net costs are smaller than the pre-trading costs. The gains from trading are shown in the Cost Saving column in the result tables. Compared with the pre-trading situation, Iowa can reduce its net costs (mitigation cost plus permit sales revenue) and achieve savings of $5 million, $68 million, and $210 million in 2020 depending on the MGA GHG reduction goal.

- The MGA carbon tax cases are equivalent to the cases of a cap and trade program when the allowances are fully auctioned. The tax rate is equal to the allowance price and so are the government revenue and mitigation levels by individual emitters.

Economy-wide Carbon Tax in Iowa

- Since we are simulating an economy-wide carbon tax, for any given tax rate, we can estimate reductions by the emission sources, as well as how much tax is paid for the emissions generated, by looking at the economy-wide marginal cost curve of Iowa alone.

- Five carbon tax scenarios for Iowa in 2020:
  - Tax rate for Iowa to achieve the MGA 15% goal
  - Tax rate for Iowa to achieve the MGA 20% goal
  - Tax rate for Iowa to achieve the MGA 25% goal
  - A given tax rate at $20/tCO2e
  - A given tax rate at $40/tCO2e

Iowa Carbon Tax Simulation Results

TABLE 4. SIMULATION RESULTS OF ECONOMY-WIDE CARBON TAX

Scenario	Tax Rate ($/tCO2e)	Emission Reduction[a]		Mitigation Cost (million dollars)	Amount of Emissions that Pay Carbon Tax (million tCO2e)	Payment on Carbon Tax (million dollars)	Net Cost (million dollars)[c]
		(percent from 2020 BAU)[b]	(million tCO_{2e})				
1	8.02	28.30%	40.72	-37.04	103.15	826.97	789.93
2	11.09	32.51%	46.77	20.74	97.10	1,077.18	1,097.92
3	14.38	36.73%	52.84	97.95	91.03	1,308.69	1,406.65
4	20	43.35%	62.37	261.25	81.50	1,629.95	1,891.20
5	40	61.77%	88.87	1,038.97	55.00	2,199.84	3,238.81

[a] In equilibrium, the emitter will choose to mitigate to the level where its marginal abatement cost equals the tax rate.
[b] Iowa 2020 BAU emissions level is 143.87 MMtCO2e.
[c] Sum of Mitigation Cost and Tax Payment.

Findings from the Preliminary Iowa Carbon Tax Simulations

- In Scenarios 1-3, the three MGA goals are translated to 28.30%, 32.51%, and 36.73% below the Iowa 2020 baseline emissions. In order to achieve these goals, the corresponding tax rate would be $8.02/tCO2e, $11.09/tCO2e, and $32.51/tCO2e, respectively.

- In Scenarios 4 and 5, when the tax rate is given at the level of $20/tCO2e and $40/tCO2e, the emission reductions that can be achieved in Iowa are 43.35% and 61.77%, respectively, below the 2020 baseline level, or 62.37 MMtCO2e and 88.87 MMtCO2e, respectively.

- Please note the tax revenue collected can be re-distributed to low-income consumers or directed to other greenhouse gas mitigation programs in the state, including R&D in new or improved fuels and technologies. However, in this study, we did not analyze the economic impacts associated with the revenue recycling.