Appendix B

Modifications to the *AEO2003* Reference Case

Introduction

To analyze the Climate Stewardship Act of 2003 (S.139), the Energy Information Administration (EIA) used an updated version of the *Annual Energy Outlook 2003* (*AEO2003*) reference case. The *AEO2003* reference case was updated to incorporate revised expectations about near-term trends in natural gas prices and to reflect recent changes in corporate average fuel economy (CAFE) standards, as discussed in Chapter 2. In addition, Senators McCain and Lieberman explicitly requested that EIA update the projection for electricity generating capacity, taking into account capacity additions made since *AEO2003* was completed (November 2002). The capacity changes are summarized in Chapter 2, and a more in-depth analysis is provided below.

The *AEO2003* reference case was generated using EIA's National Energy Modeling System (NEMS). S.139 proposes a detailed program for greenhouse gas emissions monitoring and control and contains provisions that are either subject to varying interpretation or are intended to be defined after enactment of the bill. Based on EIA's interpretation of S.139, modifications were made in NEMS to allow modeling of its specific provisions. This appendix describes (1) the electric generating capacity updates made in the *AEO2003* reference case, and (2) other key modeling changes that were implemented to address the provisions of S.139 related to greenhouse gases other than carbon dioxide (non-CO_2 gases).

Electric Generating Capacity Updates

Within NEMS, only planned units that are reported as "under construction" are automatically included as being built during the forecast horizon. NEMS forecasts the construction of additional unplanned capacity by type as needed to meet future demand.

For *AEO2003*, the information on planned generating units was based predominantly on 2001 data from company filings on Form EIA-860, "Annual Electric Generator Report," which provides information for both utility and nonutility generators. The EIA-860 data were supplemented by a second data source, the NewGen database developed by Platts Database,[196] which is updated on a monthly basis. The NewGen database was used to update the EIA-860 information for more recent changes in plant operating status.

Based on new information available as of the end of March 2003, planned electric generating capacity was updated for the S.139 analysis. Additional units were represented as planned capacity in the S.139 reference case if they were reported as under construction in the NewGen database and as planned in the EIA-860 inventory.

Table B.1 shows the incremental units represented in the S.139 reference case that were not included in *AEO2003*. About 24 gigawatts of additional planned capacity was reported as being under construction as of March 2003. The additional capacity included about 16 gigawatts of natural-gas-fired combined-cycle plants, 4.6 gigawatts of gas-fired turbines, 2 gigawatts of dual-fired combined-cycle units, and 1.4 gigawatts of dual-fired turbines and internal combustion units, several renewable units, and a relatively small coal-fired unit.[197]

Table B.2 summarizes the total planned capacity included in NEMS for the years 2002-2005 in the S.139 reference case. Total planned capacity in the S.139 reference case is 122 gigawatts, most of it completed in 2002 and 2003. Estimates of total planned capacity, including units under construction and in earlier

[196] NewGen Data and Analysis, Platts Database (Boulder, CO, March 2003).

[197] The fact that the 24 gigawatts of additional capacity was not included as planned capacity in *AEO2003* does not invalidate the *AEO2003* forecasts, because NEMS projects additional new capacity as needed to meet demand (primarily natural-gas-fired units in the time frame of the forecast).

stages of planning, are much higher. For example, the latest version of NewGen reports 178 gigawatts of new planned capacity between April 2003 and December 2005. However, because 101 gigawatts of units have already been cancelled and because of the likelihood of further cancellations, only planned units that are under construction are included in the reference case.

Table B.1. Incremental Planned Net Summer Capacity Since Completion of *AEO2003** (megawatts)

North American Electric Reliability Council Region	2002	2003	2004	Total
East Central Area Reliability Coordination Agreement	888	1,137	528	2,553
Electric Reliability Council of Texas	371	922		1,293
Mid-Atlantic Area Council	2,221	739	149	3,109
Mid-America Interconnected Network	1,511	150		1,661
Mid-Continent Area Power Pool	302	38	38	378
New York	76	1,038		1,114
New England	703			703
Florida Reliability Coordinating Council	592	543		1,135
Southeastern Electric Reliability Council	637	5,114		5,751
Southwest Power Pool				0
Northwest Power Pool	438		1	438
Rocky Mountain Power Area	298	2,723		3,021
California	454	1,895	479	2,827
Total	**8,490**	**14,299**	**1,195**	**23,984**

*As of March 2003.
Source: Energy Information Administration, Form EIA-860, "Annual Electric Generator Report," (2002 preliminary) and NewGen Data and Analysis, Platts Database (Boulder, CO, November 2002).

Table B.2. Total Planned Additions of Net Summer Capacity Included In NEMS Through 2005* (gigawatts)

North American Electric Reliability Council Region	2002	2003	2004	2005	Total
East Central Area Reliability Coordination Agreement	9,606	4,685	994		15,285
Electric Reliability Council of Texas	5,772	2,517	688	121	9,099
Mid-Atlantic Area Council	4,826	3,339	874	48	9,087
Mid-America Interconnected Network	6,012	218			6,230
Mid-Continent Area Power Pool	841	580	110	48	1,578
New York	634	1,569			2,203
New England	3,680	253	0		3,934
Florida Reliability Coordinating Council	4,856	1,805	1,832		8,492
Southeastern Electric Reliability Council	16,462	13,607	519		30,587
Southwest Power Pool	7,158	2,012			9,171
Northwest Power Pool	2,721	953	71	168	3,914
Rocky Mountain Power Area	5,008	6,845	1,112	45	13,008
California	2,722	3,846	1,126	857	8,550
Alaska	752				752
Hawaii	60				60
Total	**71,110**	**42,230**	**7,325**	**1,286**	**121,951**

*As of March 2003.
Source: Energy Information Administration, Form EIA-860, "Annual Electric Generator Report," (2002 preliminary) and NewGen Data and Analysis, Platts Database (Boulder, CO, March 2003).

Overview of NEMS Cap and Trade Methodology

Emissions Calculations

The principal source of U.S. greenhouse gas emissions is fossil fuel combustion. These emissions depend on the carbon content of the fuel and the fraction of the fuel consumed in combustion, as reflected in fuel-specific emission factors in NEMS. The emission factors are multiplied by the fuel-specific energy consumption to calculate carbon dioxide emissions. The emission factor for coal is the highest and for natural gas the lowest among the fossil fuels, with petroleum falling about midway between coal and natural gas.

Carbon dioxide emitted by renewable sources is omitted from the emissions calculation. Biogenic carbon dioxide emissions are considered to be balanced by the carbon dioxide sequestration that occurred in its creation, and, by convention, are taken as zero. A portion of the carbon dioxide in nonfuel use of energy, such as for asphalt and petrochemical feedstocks, is assumed to be sequestered in the product and not released to the atmosphere.

While some of the other greenhouse gas emissions are related to energy activities, estimating those emissions based on economic factors is outside the scope of NEMS. As a result, baseline emissions of gases other than energy-related carbon dioxide were obtained from the U.S. Environmental Protection Agency (EPA), along with their marginal abatement cost curves (MACs), to estimate emissions under the provisions of S.139.

To the extent possible, greenhouse gas emissions for covered and noncovered entities were calculated separately. The coverage assumptions and derivation of the emissions caps used in NEMS are discussed in the following sections.

Simulating the Allowance Market

With the cap and trade system envisioned under S.139, a market for emissions allowances arises. Simulating this allowance market is relatively straightforward. The emission allowances required for a given amount of energy-related carbon dioxide can be calculated using the emissions factors and energy consumption. Similarly, the cost of the allowance is added to the price of each fossil fuel in proportion to its carbon emissions, on a dollar per British thermal unit (Btu) basis. While S.139 includes a mechanism to allocate some portion of emissions allowances at no cost to the entity, the tradable nature of allowances implies that the allowance price represents an opportunity cost of emissions. As a result, the allowance price applies to all covered emissions sources, regardless of the initial allocation of allowances.

As the allowance price changes and feeds through to fossil energy prices, the demand for energy changes, as do the corresponding carbon dioxide emissions. For other greenhouse gases, NEMS calculates emissions reductions in covered sectors based on the exogenous marginal abatement cost curves. The emissions abatement at the current market price is subtracted from the baseline emissions to obtain the resulting emissions for the covered sources.

Simulating Alternative Compliance and the Emissions Offset Market

S.139 provides a financial incentive for noncovered entities to obtain credits for their registered reductions in emissions. Noncovered entities can sell allowance credits to covered entities as offsets. However, the bill limits the percentage of allowances that a covered entity may obtain from noncovered entities, from other countries, and from borrowing. The basic limits are 15 percent in Phase I (2010 to 2015) and 10 percent in Phase II. As an incentive for early action, entities may be allowed to satisfy up to 20 percent of their emissions limit from offsets during Phase I, provided they reach their Phase II limit by 2010. All eligible entities are assumed to take advantage of these alternate compliance provisions, and a fraction are assumed to get the early action bonus. For analytical purposes, an effective Phase I limit of 16 percent is assumed,[198] taking into account the extra offset potential available for early action participants.

The alternative compliance provisions of the bill are simulated in NEMS as a separate market for offset credits, interacting with the allowance market. Emissions reduction opportunities from noncovered entities, biological sequestration, and international sources are simulated using MACs, constrained by the overall percentage limits on alternate compliance. Given the constraint, the offset market typically clears at a lower price than the allowance market, suggesting that economical emissions reductions are forgone in the noncovered sectors.

NEMS varies the price of allowances in a goal-directed, iterative process until the covered emissions reach the annual cap as adjusted for the availability of offsets. An allowance price and offset price are determined as the model solves for the energy market equilibrium. A solution is obtained for a single projection year, and then NEMS advances to the next projection year.

Modeling of Allowance Price Expectations

As NEMS solves one year at a time, the results in subsequent years depend in part on prior years' results and the capital stock decisions simulated. Some capital stock decisions in NEMS depend on energy price expectations. When simulating an emissions cap in NEMS, it is assumed that future allowance prices are taken into account for these decisions. The future allowance prices are incorporated in the energy price expectations so that simulated capital decisions reflect the future allowance prices in project costs. NEMS solves for a convergence of the expected path of allowance prices and the realized prices that fulfill the emissions limits.

In a run with converged expectations, the capital stock decisions simulated in NEMS with forward-looking expectations reflect the projected allowance costs. Obviously, this foresight modeling technique does not account for the inevitable decisions that would be made based on over- or under-predictions of expected allowance cost. It represents an optimistic solution for capacity decisions, but one that is internally consistent with the economic factors simulated.

The banking provisions of S.139 provide a mechanism to help prevent losses that might occur on the basis of inaccurate expectations of allowance costs. In particular, decisions based on overestimates of future allowance costs are mitigated by an entity's ability to sell excess emission allowances. While borrowing of allowances is limited by interest penalties, the potential for borrowing provides some protection for underestimating allowance costs as well.

Modeling of the Allowance Banking Provisions

With the allowance banking provisions of S.139, covered entities do not have to meet a particular emissions goal in each year. Instead, they may choose to overcomply and bank allowances for future use. While the banking of allowances is allowed, borrowing of allowances is limited in the bill. An entity may be granted permission to borrow against its own future emission reductions, but only if it shows it has a project underway to achieve those reductions. In addition, borrowed allowances must be returned in excess of those borrowed at a rate of 10 percent per year. The interest penalty and the strict requirements suggest that, in aggregate, borrowing will be minimal.

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[198] The issue of how much of the covered sector market would undertake actions prior to 2010 to meet 1990 greenhouse gas emission levels is debatable. However, assuming that in each sector all of the entities that reduce emissions in 2010 achieve 1990 emissions goals, then that estimate provides an upper bound on the number of entities that could achieve 1990 levels before 2010. For example, using this approach, the electric power sector, the most price-responsive market, yielded a 41 percent participation rate. If the electric power sector were representative of the entire covered entity market, then the percentage offsets allowed in 2010 to 2015 would have been 17 percent (41 percent of the difference between 20 percent offsets and 15 percent offsets). However, the non-electric power markets are much less likely to participate, reducing the calculated market increase for offset purchases to 16 percent.

While banking of allowances is allowed to begin in 2010, the bill provides entities with an incentive for early action emission reductions. Entities that register early action reductions receive a corresponding increase in their allocations of free emissions allowances in Phase I. This provision is implemented such that the total number of allowances issued in Phase I does not change, only their allocation to covered entities.

With allowance banking, the decisions to buy, sell, and hold allowances will depend both on the current and anticipated allowance prices. The allowance price trajectory is assumed to be smoothed through expectations and arbitrage. If allowance prices were expected to grow rapidly in the future, high levels of early reductions and banking (overcompliance) would tend to occur, as the cost of those reductions would be expected to be recoverable in the future. This was the case in the sulfur dioxide trading program under the Clean Air Act Amendments of 1990. However, the buildup of high levels of banked allowances would then tend to lower expectations of prospective carbon prices and moderate banking of allowances.

With perfect banking decisions, the idealized solution is characterized by a price growth at an aggregate discount rate, such that the present value of the expected allowance price is constant. For this analysis, a discount rate equal to the real after-tax cost of capital in the electricity sector was assumed, as the most important capital decisions driving the emissions market are expected to take place in that sector.

The banking provisions are expected to smooth out the potential price spikes that might otherwise occur at the start of Phase I and Phase II. The incentive to bank excess allowances during Phase I is that the Phase II cap (starting in 2016) is more stringent than the Phase I cap. The Phase II cap is based on 1990 emission levels, while the Phase I cap is based on year 2000 emissions. In addition, the Phase II percentage limit on offset purchases is lower, which by itself makes the Phase II cap more difficult to meet. As a result, there is an incentive to build up a bank of allowances during Phase I, and then to deplete the balance gradually in Phase II. Once the bank balance drops to zero, no further incentives to accumulate bank balances exist, and the cost of an allowance will increase no faster than the assumed discount rate.

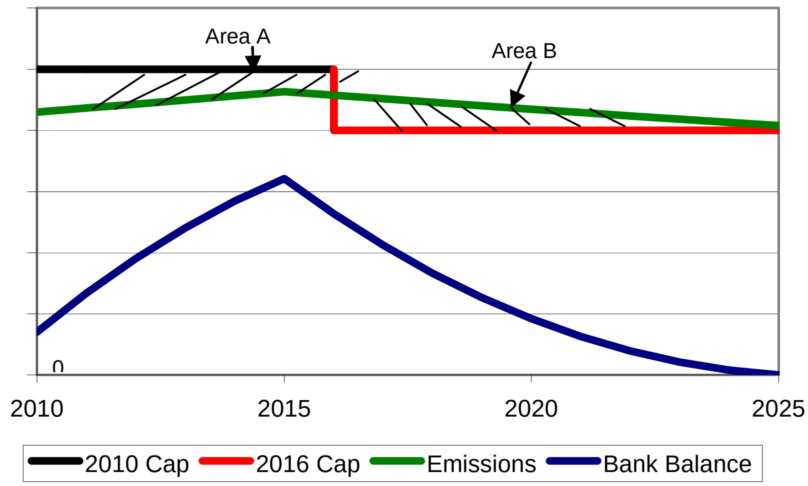
Short-term and long-term factors influence the economics of allowance banking. In the short term, the capital stock is largely fixed. This limits the ability of firms to respond quickly to fluctuations in allowance prices. In the long term, firms may acquire new capital stock to respond to emissions allowance costs. NEMS reflects these factors through explicit simulations of energy-using capital stock investment decisions and by modeling the economic behavior as constrained by available equipment, building structures, and transportation systems. With the relatively smooth price growth associated with allowance banking, firms are able to respond effectively to the long-term emissions reductions without undue disruptions. Without allowance banking, large price changes are more likely to occur as a result of short-term rigidities associated with the fixed capital stock.

In NEMS, the allowance bank balance is assumed to return to zero in some future year, say 2025. The objective of the solution algorithm is to determine the starting allowance price growing at the discount rate, with no annual constraint on emissions during the banking period. The initial price is varied such that the accumulated bank balance in the target year reaches zero. After the target year, emissions are constrained at the Phase II cap (adjusted for offset purchases), and the allowance price needed on a year-by-year basis to meet the cap is determined, subject to a maximum price increase per year equal to the discount rate.

An idealized solution to this procedure is illustrated in Figure B.1, where emissions are plotted along with the emissions caps. The hatched Area A represents the amount of early overcompliance used to build an allowance bank balance. Area B represents the amount of undercompliance and depletion of that bank balance. Areas A and B would be equalized by 2025 (the end of the projection horizon). There is little or no borrowing in aggregate, and the final balance in the target year, 2025, is zero.

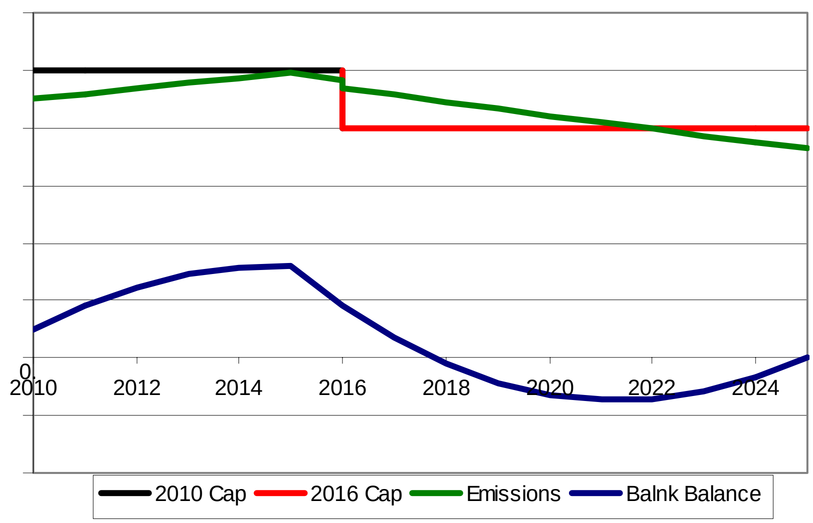
Based on the results in the solution with an assumed target year, the target year for the zero bank balance may be changed. If allowance prices drop significantly after the banking period ends, or borrowing occurs (as shown in Figure B.2), the target year is reassigned to an earlier year and the procedure is repeated. If prices continue to rise faster than the discount rate after the bank balance drops to zero, or if aggregate borrowing occurs in subsequent years, the target year is reassigned to a later year. Consequently, the target year for the end of the allowance banking may differ across the scenarios run for this study. For most scenarios, however, the target year for the end of banking is 2023.

Figure B.1. Illustration of Allowance Banking (emissions)



Source: Energy Information Administration, Office of Integrated Analysis and Forecasting.

Figure B.2. Illustration of Trail Solution With Borrowing—Requires Earlier Target Year (emissions)



Source: Energy Information Administration, Office of Integrated Analysis and Forecasting.

Derivation of Marginal Abatement Cost Curves

Although NEMS is a detailed energy-economy model of United States and uses consumer behavior to develop detailed projections of energy consumption, energy prices, macroeconomic activity, and carbon dioxide emissions, it does not include economic or behavioral models to estimate the other greenhouse gases covered in S.139. *For this study*, a set of exogenous assumptions on projected emissions and MACs was used to analyze S.139.[199] *For the S.139 study*, an exogenous set of curves was incorporated to reflect assumptions about the potential for reductions in other greenhouse gases as a function of allowance prices.

The MACs, along with the associated baseline projections of the emissions, were obtained from the EPA's Office of Air and Radiation. EPA provided EIA with MACs as developed in several recent studies.[200,201,202] At EIA's request, the EPA's business-as-usual (BAU) projections and MACs were extended to 2025. The EPA BAU projections and MACs were used in this analysis because they are the only consistent and relatively complete source for such emission estimates.

While using MACs for emissions of non-CO_2 gases provides a more complete emissions accounting for analyzing S.139, the use of MACs as a proxy for more detailed modeling is an issue. MACs are simplified, reduced-form representations of emissions compliance potential as a function of a single variable, the allowance price. This contrasts with the detailed energy and macroeconomic models in NEMS that simulate behavioral responses, technology choice, and capital stock accounting in great detail. Modeling the determinants of the other greenhouse gases on a similar scale was not feasible.

As an alternative, a relatively simple approach of using exogenous MACs was deemed the best alternative *for this study*. The approach is also justified based on the relative size of the impacts from these other emissions sources in the covered sectors compared to energy-related carbon dioxide. In addition, the potential impact of most of these sources in the noncovered sectors is constrained by the bill's limits on credits from alternative compliance sources. To the extent the MACs misrepresent the cost of reducing emissions from these alternative sources, the primary effect will be on the offset price, with little impact on the overall economic analysis of the bill.

The exogenous MAC curves are treated as four classes:

(1) Emissions from non-CO_2 greenhouse gases from domestic covered sectors
(2) Emissions of non-CO_2 greenhouse gases from domestic uncovered sectors
(3) Carbon Sequestration (agriculture and forestry), domestic
(4) International greenhouse gases and sequestration.

The emissions and MACs for category 1 were used to estimate covered emissions under the bill. Within this category, there is no limit on reductions specified in the bill and the allowances for these emissions

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[199] EIA has no plans to develop behavioral models of sequestration or domestic or international marginal abatement curves. Because the estimates of MACs are exogenous to NEMS, highly uncertain, and scenario dependent, use of such curves in future studies will require further review and adjustment.

[200] U.S. Environmental Protection Agency, Office of Air and Radiation, *U.S. Methane Emissions 1990-2020: Inventories, Projections, and Opportunities for Reductions,* EPA_30-R-99-013 (September 1999), http://www.epa.gov/ghginfo/pdfs/07-complete.pdf; and *Addendum to the U.S. Methane Emissions 1990-2020: Update for Inventories, Projections, and Opportunities for Reductions* ((December 2001), http://www.epa.gov/ghginfo/pdfs/final_addendum2.pdf.

[201] U.S. Environmental Protection Agency, Office of Air and Radiation, *U.S. High GWP Gas Emissions 1990-2010: Inventories, Projections, and Opportunities for Reductions* (June 2001), EPA 000-F-97-000, http://www.epa.gov/ghginfo/pdfs/gwp_gas_emissions_6_01.pdf.

[202] U.S. Environmental Protection Agency, Office of Air and Radiation, *U.S. Adipic Acid and Nitric Acid N_2O Emissions 1990-2020: Inventories, Projections and Opportunities for Reductions* (December 2001), http://www.epa.gov/ghginfo/pdfs/adipic.pdf.

can be considered along with allowances for carbon dioxide emissions as a single market with unlimited trading.

Reductions in a noncovered entity's emissions, potential carbon sequestration, and international emission reductions are included to reflect the bill's alternative compliance provisions. Allowance credits may be obtained from these noncovered entities subject to the restrictions outlined in Chapter 1. The allowance credits from noncovered entities are commonly referred to as offsets. Offsets are capped at 15 percent and 10 percent limits of emissions from covered sectors for Phase I and Phase II, respectively.[203] The price at which offsets sell is also determined within the overall NEMS solution process.

The MACs were adjusted slightly, because the curves reflect abatement options available with negative costs. The availability of abatement options with negative costs suggests that imperfect information, transactions costs, and other factors limiting the adoption of the abatement options are not adequately reflected in the cost curves. The abatement curves were shifted such that the negative portions would become available at $1 per ton carbon equivalent while leaving the rest of the curve unchanged.

Table B.3 presents a summary of the assumed domestic MACs for gases from covered sectors (excluding energy-related CO_2), along with the associated baseline emissions projection for non-CO_2 gases from covered sectors. This table represents the combined response to allowance costs for the high GWP gases, coal-related methane emissions, and a portion of nitrous oxide emissions from adipic and nitric acid production. The price/quantity points on the curve within a year are constructed from the points in the table by linear interpolation. Curves for intervening years are also derived by interpolation.

Table B.3. Domestic Marginal Abatement Costs for Non-CO_2 Covered Gases (reductions in million metric tons carbon equivalent)

Allowance Price (2001 dollars per metric ton carbon equivalent)	2005	2010	2015	2020	2025
	BAU Emissions				
$0	206	233	269	314	373
	Emission Reductions				
$1	11.1	12.2	14.6	17.9	21.3
$10	27.2	30.6	37.5	47.4	60.6
$20	38.2	43.4	54.2	70.0	91.9
$30	39.7	44.9	55.4	70.8	92.8
$40	43.4	49.0	61.1	78.9	103.9
$50	44.9	51.0	63.5	81.9	107.8
$75	47.1	53.4	66.6	86.1	113.5
$100	47.3	53.6	66.7	86.2	113.6
$125	47.8	54.2	67.7	87.5	115.4
$150	49.0	55.7	69.7	90.3	119.3
$175	50.2	57.2	71.6	92.9	123.0
$200	50.3	57.2	71.7	93.0	123.1

Sources: U.S. Environmental Protection Agency, Office of Air and Radiation, *U.S. Methane Emissions 1990-2020: Inventories, Projections, and Opportunities for Reductions,* EPA_30-R-99-013 (September 1999), http://www.epa.gov/ghginfo/pdfs/07-complete.pdf; *Addendum to the U.S. Methane Emissions 1990-2020: Update for Inventories, Projections, and Opportunities for Reductions (*(December 2001), http://www.epa.gov/ghginfo/pdfs/final_addendum2.pdf; *U.S. High GWP Gas Emissions 1990-2010: Inventories, Projections, and Opportunities for Reductions* (June 2001), EPA 000-F-97-000, http://www.epa.gov/ghginfo/pdfs/gwp_gas_emissions_6_01.pdf; and *U.S. Adipic Acid and Nitric Acid N_2O Emissions 1990-2020: Inventories, Projections and Opportunities for Reductions* (December 2001), http://www.epa.gov/ghginfo/pdfs/adipic.pdf.

[203] The 15 percent limit is adjusted to 16 percent in this analysis to account for those entities qualifying for a bonus limit of 20 percent for early participation.

The assumed MACs for non-CO_2 emissions in the *noncovered* sectors are presented in Tables B.4 and B.5. Table B.4 includes reduction opportunities in natural gas operations and small landfills. The carbon sequestration MACs (Table B.5 and Figure B.3) are derived from the Forest and Agricultural Sector Optimization Model (FASOM-GHG), in consultation with the EPA.[204,205] Carbon sequestration from biofuel use is not incorporated in the agricultural offset curves in order to avoid double counting of carbon dioxide reductions from the use of biomass energy for power generation, which is already reflected in NEMS.

The quantities from domestic agricultural offsets that are available for reduction at every price in the MAC are adjusted downward by 50 percent, consistent with a previous EPA study for Senators Smith, Voinovich, and Brownback.[206] The pricing and availability of agricultural offsets are deemed to be more uncertain than those for other domestic non-CO_2 offsets because of limited information, an inability to measure or verify the data, and administrative costs.[207] Further, the quantity of offsets from other non-CO_2 gases in the uncovered sector is quite small, as shown in Table B.4. Their adjustment downward by 50 percent would change the demand for these offsets by, at most, 25 million metric tons. The impact on the offset price is expected to be small, based on the remaining offset curves. No impact is expected on the domestic covered entity allowance price because of the limits set on the use of offsets and sequestration in the bill.

Table B.4. Marginal Abatement Costs for Domestic Non-CO_2 Offsets in Noncovered Sectors (reductions in million metric tons carbon equivalent)

Allowance Price (2001 dollars per metric ton carbon equivalent)	2005	2010	2015	2020	2025
			BAU Emissions		
$0	154	155	155	153	151
			Emission Reductions		
$1	14.7	18.6	19.9	21.2	21.2
$10	24.5	24.3	24.3	24.3	24.2
$20	31.3	29.5	29.1	28.6	28.4
$30	38.8	35.9	34.4	32.9	32.8
$40	42.3	40.0	38.1	36.2	36.0
$50	44.9	43.4	41.3	39.2	38.9
$75	49.8	49.9	47.5	45.2	44.9
$100	50.2	50.6	48.4	46.2	45.8
$125	51.2	51.6	49.6	47.5	47.2
$150	51.4	51.8	49.8	47.8	47.5
$175	51.5	51.9	50.0	48.1	47.8
$200	51.6	52.0	50.1	48.3	47.9

Sources: U.S. Environmental Protection Agency, Office of Air and Radiation, *U.S. Methane Emissions 1990-2020: Inventories, Projections, and Opportunities for Reductions,* EPA_30-R-99-013 (September 1999), http://www.epa.gov/ghginfo/pdfs/07-complete.pdf; *Addendum to the U.S. Methane Emissions 1990-2020: Update for Inventories, Projections, and Opportunities for Reductions (*(December 2001), http://www.epa.gov/ghginfo/pdfs/final_addendum2.pdf; *U.S. High GWP Gas Emissions 1990-2010: Inventories, Projections, and Opportunities for Reductions* (June 2001), EPA 000-F-97-000, http://www.epa.gov/ghginfo/pdfs/gwp_gas_emissions_6_01.pdf; and *U.S. Adipic Acid and Nitric Acid N_2O Emissions 1990-2020: Inventories, Projections and Opportunities for Reductions* (December 2001), http://www.epa.gov/ghginfo/pdfs/adipic.pdf.

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204 D.M. Adams, R.J. Alig, J.M. Callaway, and B.A. McCarl, *The Forest and Agricultural Sector Optimization Model (FASOM): Model Structure and Policy Application*s, USDA Forest Service Report PNW-RP-495 (1996).

205 B.A. McCarl and U.A Schneider, "Greenhouse Gas Mitigation in U.S. Agriculture and Forestry," *Science Magazine* (December 2001), http://www.sciencemag.org/cgi/content/full/294/5551/2481.

206 http://www.epa.gov/air/oaq_caa.html.

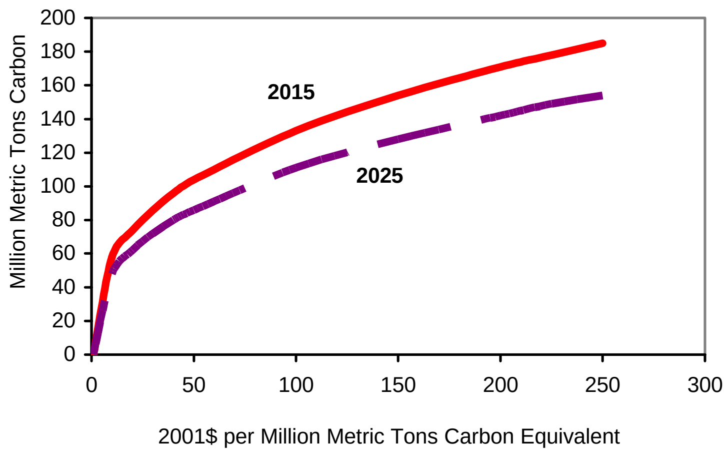
207 It can be argued that all domestic offsets should be reduced by 50 percent as was done by EPA in its study for Senators Smith, Voinovich, and Brownback. Since the quantities of offsets available from domestic non-agricultural sources are small and prices are sharply rising, this study does not reduce the non-CO_2 abatement quantities.

Table B.5. Marginal Abatement Costs for Carbon Sequestration in Domestic Agriculture and Forestry (reductions in million metric tons carbon equivalent)

Allowance Price (2001 dollars per metric ton carbon equivalent)	2005	2010	2015	2020	2025
$1	0	0	0	0	0
$10	0	57	58	59	48
$20	0	73	74	76	62
$30	0	84	86	88	72
$40	0	94	96	98	80
$50	0	101	104	106	86
$100	0	130	133	136	111
$150	0	151	154	157	128
$200	0	167	171	174	142
$225	0	174	178	182	149
$250	0	181	185	189	154

Notes: The reductions shown are relative to a case with no carbon allowance value. Offset curves exclude biofuels, which are represented endogenously in NEMS.
Source: U.S. Environmental Protection Agency, FASOM Reduced Form Model, excluding biofuels use.

Figure B.3. Agricultural Sequestration Curve



Source: Energy Information Administration, Office of Integrated Analysis and Forecasting.

S.139 provisions severely limit the sources and quantities of international offsets that qualify for purchase by U.S. entities. The bill asserts that international offsets may only be purchased from countries that have established certified greenhouse gas emission reduction programs.[208] To date, only a portion of the Annex B countries qualify. Further restricting United States access to inexpensive sequestration offsets is the Marrakech Accord which limits the total quantity of sequestration offsets that Annex B (without the U.S.) may register and use to about 70 million metric tons per year.

While the methodology used to develop the international MAC for United States use applies to the entire Annex B group, not counting the United States, information from EPA was only adequate to characterize

[208] Under S.139, Section 312, Compliance, Part (b)(1)(B), international allowances may be permitted for use if and only if three conditions are simultaneously met, the most important of which is that "… the other nation has adopted enforceable limits on its greenhouse gas emissions which the tradable allowances were issued to implement." The major developing countries of China, Mexico, South Korea, India, and Brazil have no binding obligations to limit or reduce emissions under the UNFCCC or the Kyoto Protocol. Consequently, the only avenue that the United States has to access international allowances is through a subset of Annex B countries that meet the three criteria of S.139.

the MACs for Annex I countries,[209] excluding the United States. (Annex B countries include Annex I countries plus Lithuania, Slovenia, Croatia, and the Ukraine.) However, those excluded from this analysis only account for about 4 percent of Annex B and are unlikely to significantly affect the offset prices from this market. It is possible to try and develop a better estimate for Annex B emissions for the baseline but the problem remains that our study had no known source for non-CO_2 MACs for Lithuania, Slovenia, Croatia and the Ukraine. We expect that had such an estimate been available, it would have lowered the cost of international offsets derived from additional "hot air," primarily from the Ukraine. Future work by the EPA on developing MACs for all of Annex B would allow a more complete analysis.

The Annex I countries are assumed to adhere to their Kyoto Protocol targets through 2025. The greenhouse gas emission targets of the Kyoto Protocol were used to develop the aggregate emission targets through 2025 for Annex I countries without U.S. participation. Energy Modeling Forum (EMF) 21 assumptions[210] on the availability of non-CO_2 offsets were used to estimate the offset MACs available to Annex I countries without U.S. participation. The Marrakech Accords,[211] also known as the Seventh Conference of the Parties of the United Nations Framework Convention on Climate Change (COP 7 of the UNFCCC), were used to limit the quantity of agricultural/forestry offsets available to this international group to about 70 million metric tons per year, which were assumed to be available at $15 per ton carbon equivalent.[212] Any price at or below $25 per ton carbon equivalent would produce the same international offset curve from Annex I for U.S. use. Pacific Northwest Laboratories provided the MAC and the baseline projection for energy-related carbon dioxide for Annex I countries from its Second Generation Model (SGM).[213] It was assumed that an additional 130 million metric tons of offsets would be available each year from the Clean Development Mechanism (CDM)[214] at $15 per ton carbon. Since the Annex I countries have already demonstrated an interest in "real" greenhouse gas emission control by limiting the use of sequestration/forestry to about 70 million metric tons, a CDM limit of nearly twice the sequestration limit appears to be consistent with the Annex I countries' determination to reduce greenhouse gas emissions. The difference between the Annex I baseline and the target determines the year-by-year reductions necessary. Subtraction of the reductions from the MAC provides the MAC available for U.S. use.

Recent submissions for CDM credits to the United Nations have been refused, as reported by Reuters.[215] Excerpts from the article include:

> *"Don't expect miracles," Hans Jurgen Stehr, chairman of the executive board of the Clean Development Mechanism, told Reuters yesterday [on June 9, 2003] after announcing the results of the study…*
>
> *Twelve projects were presented to the U.N. body. The answer on each occasion was no.*

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[209] Annex I is composed of the 15 European Union countries plus Australia, Bulgaria, Canada, Czech Republic, Estonia, Hungary, Iceland, Japan, Latvia, Liechtenstein, Monaco, New Zealand, Norway, Poland, Romania, Russian Federation, Slovakia, Switzerland, and the United States. The United States is not a participant in the Marrakech Accords, which means that the proposed sequestration limit of 30 million metric tons carbon does not affect U.S. use of sequestration.

[210] The Energy Modeling Forum, sponsored by Stanford University, is a series of periodic seminars and workshops that examine important energy issues. EMF 21 concentrated on non-CO_2 greenhouse gas abatement strategies. See http://www.stanford.edu/group/EMF/group21/index.htm.

[211] http://unfccc.int/resource/docs/cop7/13.pdf

[212] The $15 per ton cost for CDM and sequestration is an assumption of this analysis. There is no good information to estimate such costs. For this analysis, any costs at or below $25 per ton would imply that these reductions would all be taken first and the residual amount of offsets left to the U.S. would remain unchanged. Previous global trading studies by PNNL and EMF suggest that such costs will range between $5 per ton to $25 per ton for Annex I because otherwise, less costly alternative Annex I reductions could be undertaken for the 2008-2020 period.

[213] Communication with Ron Sands, who operates the SGM model for EPA. These curves integrated the EMF 21 offset curves and the SGM baseline and MACs for carbon dioxide.

[214] The CDM allows Annex I countries to take emissions credits for projects that reduce emissions in non-Annex I countries, provided that the projects lead to measurable, long-term benefits.

[215] See http://www.planetark.org/dailynewsstory.cfm/newsid/21123/story.htm

The backers of three projects in Brazil, a landfill plant in South Africa, a wind farm in Jamaica and a project in South Korea will, however, be able to resubmit revised applications at the end of June. The backers in each case argued they would reduce the emissions of greenhouse gases such as carbon dioxide.

"We have to answer the question: why would this not have happened anyway," said Christine Zumkeller, coordinator of the U.N's cooperative mechanisms programme.

A country with many fast-flowing rivers could, for example, argue it is helping the planet by building hydroelectric plants instead of burning fossil fuels, but regulators say that may not be a legitimate argument if the fossil fuel plant was not a viable alternative in the first place.

The debate is likely to increase in coming years if the Kyoto Protocol takes effect and if a U.N. climate change summit in Milan in December agrees to give richer nations credits for planting trees that absorb carbon dioxide.

Since the only participants in these programs are Annex I countries, the uncertainty around the availability of international offsets is assumed to be equivalent to the uncertainty for domestic offsets from sequestration. That is, the remaining quantities of offsets available from participating Annex I countries were reduced by 50 percent. The resulting MAC for international offsets in the main case of this study is shown in Table B.6.

Table B.6. Marginal Abatement Costs for International Offsets (reductions in million metric tons carbon equivalent)

Offset Price (2001 dollars per metric ton carbon equivalent)	2010	2015	2020	2025
$10	0	0	0	0
$15	0	0	0	0
$20	0	0	0	0
$30	13	0	0	0
$40	31	0	0	0
$50	45	3	0	0
$75	81	48	23	3
$100	115	90	71	54
$125	146	129	116	102
$150	170	158	151	138
$175	193	186	183	171
$200	217	214	216	205
$225	263	266	275	265

Source: Communication with Ron Sands, who operates the SGM model for EPA, and adjustments made by EIA as described below.

Annex I Countries' Baseline and MAC Greenhouse Gas Emission Calculations

This section describes the methodology used to derive the baselines and the MAC's *for international offsets*. The Annex I energy-related international carbon emission estimates and the associated MAC for carbon are taken from the SGM model developed by Pacific Northwest Laboratories, as provided by Ron Sands.[216] Although EIA has international energy-related carbon emission projections, EIA does not have associated MACs. The SGM results were used to maintain consistency of the baseline carbon emissions with the appropriate MAC. It is assumed that the SGM definition of Annex I includes Lithuania, Slovenia, Croatia, and Ukraine because, according to documentation provided, Annex I appears to be the sum of OECD, EEU, and FSU, and those four countries would be included in EEU and FSU. This means that the SGM definition of Annex I is actually Annex B. However, EMF21 provides baseline emissions and MAC data for non-CO_2 gases for Annex I countries. In order to derive consistent baseline and MAC

[216] Ron Sands email to Joseph Beamon dated March 27, 2003.

emission profiles for all greenhouse gas emissions for Annex B, EIA adopted the following methodology. The rates of change of carbon dioxide emissions of the FSU and EE were used as the rates of change for these four countries (Lithuania, Slovenia, Croatia, and Ukraine) and were applied to the most recent historical year emission data to estimate the total greenhouse gas emissions from these countries over the 2000-2025 time frame. The baseline emissions for these four countries, including the SGM projection of U.S. carbon dioxide emissions and MAC, were subtracted from the Annex B greenhouse gas baseline to derive BAU and MAC projections for Annex I excluding the United States.

Baseline carbon dioxide emissions of EEU and FSU countries are projected to decline from 1,319 million metric tons carbon equivalent in 1990 to 1,285 million metric tons carbon equivalent in 2025 according to PNNL's SGM model. The projected annual growth rates for carbon dioxide emissions are calculated in 5-year intervals from these data (Table B.7). For Lithuania and Slovenia only 1990 greenhouse gas emissions data are available from the United Nations (UN),[217] and the derived growth rates are applied to the 1990 emissions. For Croatia and Ukraine, 1990 and 1995 greenhouse gas emissions data are available, and the growth rates are applied beginning in 1995 to estimate the projected greenhouse gas emissions through 2025 (Table B.8). These four countries are estimated to have greenhouse gas emissions of 279 million metric tons carbon equivalent in 1990 and 239 million metric tons carbon equivalent in 2025.

Table B.7. Baseline Carbon Dioxide Emissions for EEU and FSU Countries from SGM (million metric tons carbon equivalent)

Year	Baseline Emissions	Annual growth Rate (percent)
1990	1,319	
1995	894	-7.5
2000	815	-1.8
2005	979	3.7
2010	1,079	2.0
2015	1,167	1.6
2020	1,250	1.4
2025	1,285	0.6

Source: Historical data and projections from Ron Sands, PNNL, obtained using the SGM model.

Table B.8. Baseline Greenhouse Gas Emissions for Lithuania, Slovenia, Croatia, and Ukraine Using SGM Growth Rates (million metric ton carbon equivalent)

Year	Lithuania	Slovenia	Croatia	Ukraine	Total
1990	14	5	9	251	**279**
1995	9	4	6	147	**166**
2000	9	3	5	134	**151**
2005	10	4	7	161	**182**
2010	12	4	7	177	**200**
2015	12	5	8	192	**217**
2020	13	5	9	205	**232**
2025	14	5	9	211	**239**

Source: Historical data from "National Communications From Parties Included in Annex I to the Convention: Report on National Greenhouse Gas Inventory Data from Annex I Parties for 1990 to 2000", United Nations, October 11 2002, FCCC/SB/2002/INF.2, available at http://unfccc.int/program/mis/ghg/index.html (Table 4, page 10). Projections calculated using methodology described in this appendix.

[217] "National Communications From Parties Included in Annex I to the Convention: Report on National Greenhouse Gas Inventory Data from Annex I Parties for 1990 to 2000", United Nations, October 11 2002, FCCC/SB/2002/INF.2, available at http://unfccc.int/program/mis/ghg/index.html (Table 4, page 10).

In order to derive Annex I greenhouse gas emissions (excluding the United States) that are consistent with the Annex I MACs, the estimated BAU greenhouse gas emissions of these four countries were subtracted from the derived greenhouse gas emissions of Annex I excluding the United States. This calculation underestimates the BAU emissions from the Annex I countries excluding the United States by the quantity of non-CO_2 emissions for 1990, because the non-CO_2 emissions of these four countries are not included.[218] Using the rule of thumb that non-CO_2 emissions typically represent about 15 percent of total greenhouse gas emissions, the underestimate is expected to be about 40 million metric tons carbon equivalent (about 1 percent of Annex I greenhouse gas emissions excluding the United States) and well within the measurement error for 1990 reported data. This level of error was judged to be insignificant within the context of this analysis. With these adjustments, a consistent baseline and MAC were derived for Annex I countries.

The Kyoto Protocol targets for the Annex B countries excluding the United States are specified as percentages in the text of the Kyoto Protocol (Table B.9). These percentages were applied to the 1990 emissions[219] to derive the targets for Annex I countries excluding the United States. Since the Kyoto Protocol specifies that these targets have to be met in the 2008 to 2012 time frame, it is assumed that the targets are met in 2010. It is further assumed that the targets remain constant from 2010 onwards. The difference between the greenhouse gas baseline emissions and the Kyoto target represents the greenhouse gas emissions reductions that would be necessary to meet the Kyoto targets (Table B.10). The baseline emissions for Annex I were developed from SGM and EMF 21 information provided through EPA's contractors (Table B.11).

Table B.9: Kyoto Protocol 2010 National Emissions Targets (percent of 1990 emissions)

Annex B Country	Target	Annex B Country	Target
Australia	108	Lichtenstein	92
Austria	92	Lithuania	92
Belgium	92	Luxembourg	92
Bulgaria	92	Monaco	92
Canada	94	Netherlands	92
Croatia	95	New Zealand	100
Czech Republic	92	Norway	101
Denmark	92	Poland	94
Estonia	92	Portugal	92
Finland	92	Romania	92
France	92	Russian Federation	100
Germany	92	Slovakia	92
Greece	92	Slovenia	92
Hungary	94	Spain	92
Iceland	110	Sweden	92
Ireland	92	Switzerland	92
Italy	92	Ukraine	100
Japan	94	United Kingdom and Northern Ireland	92
Latvia	92	United States	93

Source: "Kyoto Protocol of the United Nations Framework Convention on Climate Change", available at http://unfccc.int/resource/docs/convkp/kpeng.pdf, Annex B, page 23.

[218] (Annex I + 4 other country) CO_2 + Annex I non-CO_2 - (4 other country CO_2 +non-CO_2) = Annex I total GHG – (4 other country non-CO_2 emissions).

[219] "National Communications From Parties Included in Annex I to the Convention: Report on National Greenhouse Gas Inventory Data from Annex I Parties for 1990 to 2000", October 11, 2002, FCCC/SB/2002/INF.2, available at http://unfccc.int/program/mis/ghg/index.html (Table 4, page 10).

Table B.10. Annex I Countries' Baseline Greenhouse Gas Emissions, Excluding the United States, Historical and Forecast (million metric tons carbon equivalent)

Year	Baseline Emissions	Kyoto Protocol Target	Reductions from Baseline Needed To Meet Kyoto Protocol Target
1990	3,188		
1995	2,906		
2000	2,875		
2005	3,109		
2010	3,299	2,898	401
2015	3,462	2,898	564
2020	3,605	2,898	707
2025	3,688	2,898	790

Sources: Energy Information Administration, Office of Integrated Analysis and Forecasting; Ron Sands, PNL; and The Energy Modeling Forum (EMF), sponsored by Stanford University. EMF is a series of periodic seminars that examine important energy issues. EMF21 concentrated on greenhouse gas abatement strategies. See http://www.stanford.edu/group/EMF/group21/index.htm.

Table B.11. Annex I Countries' Baseline Greenhouse Gas Emissions, Excluding the United States (million metric tons carbon equivalent)

GHG Gas	1990	1995	2000	2005	2010	2015	2020	2025
CO_2 (annex B)..	2,745	2,399	2,386	2,623	2,806	2,957	3,086	3,145
CH_4	472	437	402	405	407	419	431	443
N_2O	216	198	191	204	216	227	242	256
HGWP...	34	39	47	59	71	75	79	82
Lithuania, Slovenia, Croatia, Ukraine........	-279	-166	-151	-182	-200	-217	-232	-239
Total Annex I Baseline..........................	**3,188**	**2,906**	**2,875**	**3,109**	**3,299**	**3,461**	**3,605**	**3,688**

Note: Total greenhouse gas emissions from Annex I, excluding the United States, are the sum of emissions of carbon dioxide (CO_2), methane (CH_4), ntitrous oxide (N_2O), and non-CO_2 gases with high global warming potential (HGWP) minus emissions from Lithuania, Slovenia, Croatia, and the Ukraine. As noted, this sum understates Annex I baseline GHG emissions by the amount of non-CO_2 emissions from the four countries.
Sources: Ron Sands email to Joseph Beamon, March 27, 2003, for Annex I carbon emission projections and marginal abatement cost curves; EMF 21 assumptions for all other gases in Annex I. Note that since we were only interested in greenhouse gas emissions in Annex I excluding the United States, we used SGM results for all countries in Annex I to be consistent.

Detailed Derivation of Marginal Abatement Curves

Data for the carbon dioxide MAC were obtained from SGM model results. Allowance prices were converted from 1990 dollars to 2001 dollars using a factor of 1.26 (Table B.12). The MACs for methane, nitrous oxide, and high-GWP gases were obtained from the EPA/EMF21 IMAC model results using a discount rate of 10 percent and a tax rate of 40 percent (Tables B.13, B.14, and B.15). An aggregated MAC for carbon dioxide, methane, nitrous oxide, and high-GWP gases was derived by summing the amounts at each price (Table B.16). To the aggregate MAC, an amount of 200 million metric tons carbon equivalent was added to represent agriculture and forestry sinks and CDM (70 million metric tons carbon equivalent for agriculture and forestry sinks and 130 million metric tons carbon equivalent for CDM). The 200 million metric tons carbon equivalent was added at $15 per metric ton carbon equivalent.[220] Table

[220] For purposes of this analysis, any price between $1 per ton and $20 per ton would have made absolutely no difference to the prices and quantities of international offsets offered for sale to the United States. Virtually all estimates *for limited use of international sequestration* fall in that $1 - $20 range. Greater precision was not required for purposes of this study.

B.16 is the summation of Tables B.12 through B.15 with the agriculture and forestry sinks and CDM adjustments.

Using the aggregate MAC, the reductions required to meet Kyoto Protocol targets in each year were subtracted from the MAC to provide an estimate of the offsets that might be available to the U.S. market. The aggregate remaining MAC was then reduced by a factor of 50 percent to represent uncertainties in the available amounts for U.S. offset markets. Table B.17 is the result of adjusting the aggregate MAC for Kyoto Protocol targets and applying the reductions. This exogenously derived MAC was used for this study. Table B.17 implies that the equilibrium price in 2010 for the Annex I countries excluding the United States is expected to be between $20 and $30 per metric ton carbon equivalent in 2010, between $40 and $50 per metric ton in 2015 and between $50 and $75 per metric ton in 2020 and 2025.

Table B.12. Carbon Dioxide Marginal Abatement Costs for Annex I Counties, Excluding the United States (reductions in million metric tons carbon equivalent)

Allowance Price (2001 dollars per metric ton carbon equivalent)	2010	2015	2020	2025
$0	0	0	0	0
$10	44	64	84	95
$15	62	89	117	130
$20	80	115	149	166
$30	114	162	210	232
$40	145	205	265	290
$50	174	244	314	342
$75	236	326	413	447
$100	295	400	499	539
$125	354	474	584	630
$150	400	529	649	696
$175	445	583	711	759
$200	490	637	774	823
$225	535	690	837	887

Source: Ron Sands, PNNL use of the Second Generation Model, provided to EIA staff via email.

Table B.13. Methane Marginal Abatement Costs for Annex I Counties, Excluding the United States (reductions in million metric tons carbon equivalent)

Allowance Price (2001 dollars per metric ton carbon equivalent)	2010	2015	2020	2025
$0	27	27	27	27
$10	42	42	43	43
$15	54	54	55	56
$20	65	66	67	68
$30	78	79	79	80
$40	81	82	83	84
$50	82	83	84	84
$75	90	91	92	94
$100	98	100	101	102
$125	100	102	103	105
$150	102	103	105	106
$175	102	104	106	107
$200	105	107	108	110
$225	148	151	154	157

Source: Energy Modeling Forum, EMF21. The Energy Modeling Forum, sponsored by Stanford University, is a series of periodic seminars that examine important energy issues. EMF21 concentrated on greenhouse gas abatement strategies. See http://www.stanford.edu/group/EMF/group21/index.htm.

Table B.14. Nitrous Oxide Marginal Abatement Costs for Annex I Counties, Excluding the United States (reductions in million metric tons carbon equivalent)

Allowance Price (2001 dollars per metric ton carbon equivalent)	2010	2015	2020	2025
$0	0	0	0	0
$10	19	19	20	20
$15	19	19	20	20
$20	19	19	20	20
$30	19	19	20	20
$40	19	19	20	20
$50	19	19	20	20
$75	19	19	20	20
$100	19	19	20	20
$125	19	19	20	20
$150	19	19	20	20
$175	19	19	20	20
$200	19	19	20	20
$225	19	19	20	20

Source: Energy Modeling Forum, EMF21. The Energy Modeling Forum, sponsored by Stanford University, is a series of periodic seminars that examine important energy issues. EMF21 concentrated on greenhouse gas abatement strategies. See http://www.stanford.edu/group/EMF/group21/index.htm.

Table B.15. Marginal Abatement Costs for Non-CO_2 Gases with High Global Warming Potential for Annex I Counties, Excluding the United States (reductions in million metric tons carbon equivalent)

Allowance Price (2001 dollars per metric ton carbon equivalent)	2010	2015	2020	2025
$0	5	7	9	11
$10	11	12	13	14
$15	13	16	18	21
$20	15	20	24	28
$30	16	21	26	31
$40	17	22	28	33
$50	17	23	28	33
$75	18	23	29	34
$100	18	24	30	36
$125	19	26	33	39
$150	21	28	36	43
$175	21	29	37	45
$200	22	30	38	46
$225	25	35	45	56

Source: Energy Modeling Forum, EMF21. The Energy Modeling Forum, sponsored by Stanford University, is a series of periodic seminars that examine important energy issues. EMF21 concentrated on greenhouse gas abatement strategies. See http://www.stanford.edu/group/EMF/group21/index.htm.

Table B.16. Aggregate Greenhouse Gas Marginal Abatement Costs for Annex I Counties, Excluding the United States and Adjusted for Agriculture and Forestry Sinks and CDM (reductions in million metric tons carbon equivalent)

Allowance Price (2001 dollars per metric ton carbon equivalent)	2010	2015	2020	2025
$0	32	34	36	39
$10	116	137	159	172
$15	348	379	410	427
$20	380	420	460	482
$30	427	481	535	563
$40	462	529	595	627
$50	492	569	645	680
$75	562	660	754	795
$100	630	743	850	898
$125	693	821	940	995
$150	742	880	1,009	1,066
$175	788	935	1,074	1,132
$200	835	992	1,140	1,199
$225	927	1,096	1,256	1,320

Source: Energy Information Administration, Office of Integrated Analysis and Forecadting. The results are the sum of the results from Tables B.11-B.14.

Table B.17. Aggregate Greenhouse Gas Marginal Abatement Costs for Annex I Counties, Excluding the United States and Adjusted for Agriculture and Forestry Sinks, CDM, Kyoto Protocol Targets, and a 50-Percent Reduction Factor (reductions in million metric tons carbon equivalent)

Allowance Price (2001 dollars per metric ton carbon equivalent)	2010	2015	2020	2025
$0	0	0	0	0
$10	0	0	0	0
$15	0	0	0	0
$20	0	0	0	0
$30	13	0	0	0
$40	31	0	0	0
$50	45	3	0	0
$75	81	48	23	3
$100	115	90	71	54
$125	146	129	116	102
$150	170	158	151	138
$175	193	186	183	171
$200	217	214	216	205
$225	263	266	274	265

Source: Energy Information Administration, Office of Integrated Analysis and Forecasting, using methodology described above.