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Global Climate Change: Reducing Greenhouse Gases — How Much from What Baseline?

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Summary

At the Kyoto meeting on Global Climate Change, the United States agreed to reduce emissions of six greenhouses gases. Specifically, under the terms of the Kyoto Protocol, from a baseline of 1990 for Carbon dioxide (CO_2), Methane (CH_4), and Nitrous Oxide (N_2O), and of 1995 for Hydrofluorocarbons (HFCs), Perfluoro-carbons (PFCs), and Sulfur Hexafluoride (SF_6), the U.S. committed to reduce by 7% the average annual tons of carbon equivalent released during the 5-year period 2008-2012.

Projecting the reductions that would be required *if* the U.S. were to ratify the treaty is difficult. While emissions of CO_2 are fairly well established and account for about 85% of total carbon equivalent emissions, emissions of the other gases, especially N_2O, are more uncertain. Once the baselines are set, uncertainties in factors affecting sources of emissions—e.g., the rate of economic growth, changes in energy prices, the rate at which nuclear facilities are retired, and the rate of adoption of energy-efficient technologies — will have to be overcome in determining the actual magnitude of the reductions required. And uncertainties in how some reductions might be accomplished under the Agreement — e.g., the extent of emissions trading among different countries and whether and how to account for "sinks" that sequester carbon — affects assumptions about how (and at what cost) reductions will actually be achieved.

Given these uncertainties, it is not surprising that a range of estimates emerges from various studies making different assumptions on these variables. The U.S. has prepared a *Climate Action Report* specifically to address these issues. Based on its baseline of 1,596 million metric tons of carbon equivalent (MMTCE), this report estimates that to meet its Kyoto commitment the U.S. will have to reduce emissions in 2010 by 462 MMTCE, or 23.7% from "business as usual" emissions that would occur then. Projections of CO_2 emissions by other studies suggest reductions necessary to meet the Kyoto Agreement vary from 21% to over 30% from "business as usual" 2010 emission levels. These high and low projections differ only in assumptions about CO_2 emissions. None of the estimates quantitatively integrates the full range of potential variables that could affect CO_2 and other greenhouse gas emissions in the future, which include economic growth, electricity restructuring, electricity demand, and technological change and penetration, among others.

The reviewed estimates of the reduction necessary to meet the commitment — i.e., the reduction below "business as usual" emissions projected for 2008-2010 — range from approximately 390 to 660 MMTCE. Even ignoring numerous uncertainties, then, there remains a ~70% difference from the lower to higher reduction projected necessary to achieve the target. To comply with the higher compared to the lower estimate would represent a substantial escalation of effort and makes estimating potential costs difficult. In short, projecting future greenhouse gas emissions, the amount that they might have to be reduced if the U.S. ratifies the Kyoto agreement, and potential costs, are all fraught with considerable uncertainty.

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At the Kyoto meeting on Global Climate Change, the United States agreed to reduce emissions of greenhouses gases.[1] Specifically, under the terms of the Kyoto Protocol, the United States committed that over the 5-year period 2008-2012, it would reduce its average annual net carbon-equivalent emissions of 6 gases by 7% below specified baseline years.[2] The gases and the baseline years are as follows:

Greenhouse Gas	**Baseline Year**
Carbon dioxide (CO_2)	1990
Methane (CH_4)	1990
Nitrous Oxide (N_2O)	1990
Hydrofluorocarbons (HFCs)	1995
Perfluorocarbons (PFCs)	1995
Sulfur Hexafluoride (SF_6)	1995

If the U.S. were to ratify the Kyoto Agreement, what would this commitment mean for the U.S.? What reductions would be required? Ascertaining the reductions necessary is a prerequisite to determining how the reductions might be achieved and what the impacts of those efforts might be.

Projecting the required reductions is a two-step process. First, emissions of the six greenhouse gases in their specified baseyear must be calculated in order to determine the targeted emission levels — i.e., 7% below baseyear level. This calculation is complicated because the existing 1990/1995 data for the six greenhouse gases are of uneven quality. While data for energy-related emissions of CO_2 are fairly

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[1]On the Agreement, see Susan R. Fletcher, *Global Climate Change Treaty: Summary of the Kyoto Protocol*, CRS Report 98-2, December 22, 1997; on the science and policy of global climate change, see Wayne A. Morrissey and John R. Justus, *Global Climate Change*, CRS Issue Brief 89005. For the Protocol, see http://www.UNFCCC.DE/

[2]Technically, the net carbon-equivalent emissions of the 6 greenhouse gases for the 5-year period 2008-2012 are not to exceed 5 times 93% of the baseline emissions. Kyoto Protocol, Article 3(1). This is equivalent to the *average annual emission load* during the 5 year period being 7% below the baseline.

robust, emissions data for the remaining five gases are less certain. Uncertainties also arise in comparing the relative global warming effects of the several gases, which involves converting them to metric tons of "carbon equivalents."

Second, because the Kyoto Agreement caps greenhouse gas emissions below current levels, emissions growth that would have normally occurred up through the 2008-2012 time period must be offset in order to maintain the reduction. This requirement introduces numerous uncertainties into the calculations, including:

- Growth rates for the six greenhouse gases will be influenced by economic factors that are difficult to project into the future;
- Fossil fuel consumption (the major source of CO_2 emissions) will be influenced by energy policy considerations, including development of non-carbon based substitutes, deployment of energy efficient technologies, and other factors such as the future of the nuclear industry. Like economic factors, these factors are difficult to predict in lieu of a discrete climate change policy;
- Net effects of post-1990 human-induced activities that influence carbon sinks, such as forestry practices, will affect necessary reduction requirements in the 2008-2012 period;
- The Kyoto Agreement establishes mechanisms for achieving reductions jointly among nations. In effect, the inventory of emissions from which any one nation can achieve reductions is international. This does not influence the amount of reductions the U.S. would be required to accomplish; however, it offers the opportunity for the U.S. to achieve some portion of its reductions in other countries. Thus the actual amount by which greenhouse gases would be reduced within the U.S. will be influenced by any bilateral agreements through which U.S. interests sponsor emission reductions in other countries (and how much other countries seek reductions in the U.S.).

The Kyoto Baseline

The first step in calculating the reductions required to meet the Kyoto Agreement begins with estimating baseline year emissions. From this baseline, the mandated emissions limit can be calculated. This is no easy task.

The 1997 Submission of the United States of America Under the United National Framework Convention on Climate Change, the *Climate Action Report* (*CAR*),[3] contains U.S. emissions data relied upon during the Kyoto negotiations. **Table 1** depicts the baseline emissions as reported by the *CAR*. Carbon dioxide accounts for about 85% of the greenhouse effect of the 6 greenhouse gases; about 98% of this CO_2 comes from fossil fuel combustion. Fuel use data, which are relatively robust, provide

[3]Office of Global Climate Change, *Climate Action Report*, 1997 Submission of the United States of America Under the United Nations Framework Convention on Climate Change (Department of State Publication 10496, July 1997).

the primary source for estimating historical CO_2 emissions. Emissions estimates for the other gases, especially N_2O, are considerably less certain.[4]

Table 1. U.S. Baseline Year Greenhouse Gas Emissions

Greenhouse Gas	**Baseline Year**	**Emissions** (MMTCE)
Carbon dioxide (CO_2)	1990	1,353
Methane (CH_4)	1990	170
Nitrous Oxide (N_2O)	1990	36
Hydrofluorocarbons (HFCs)	1995	21
Perfluorocarbons (PFCs)	1995	8
Sulfur Hexafluoride (SF_6)	1995	8
Total		1,596

Source: *Climate Action Report*, p. 56. (Note: Emissions from burning international bunker fuel are excluded; for the U.S., this was about 22 MMTCE for 1995 [p. 60].)

These may not be the final figures. Before the next Conference of the Parties, scheduled for Buenos Aires in November, 1998, the Kyoto Protocol requires each Party to the Agreement "to provide ... data to establish its level of carbon stocks in1990 and to enable an estimate to be made of its changes in carbon stocks in subsequent years" (Article 3(4)). Methodologies for emissions estimates are to be those accepted by the Intergovernmental Panel on Climate Change and approved by the Conference of the Parties (Article 5 of the Protocol); guidelines for preparing information necessary to demonstrate compliance with the Protocol are to be adopted by the first session of the Conference of Parties to the Protocol (Article 7). To assure that all countries are using credible and comparable means of estimating emissions, the baseline estimates will be subject to review by "expert review teams" created under the Protocol (Article 8(2)).

For the U.S., some adjustments to the **Table 1** figures are likely. For CO_2 the changes are likely to be small; for example, Department of Energy data result in a slightly higher figure for U.S. CO_2 emissions. However, for the other gases, the revisions could be more substantial. The Protocol also requires that further studies of greenhouse gas emissions and removals be undertaken and incorporated in any future commitments for reducing greenhouse gases beyond the 2008-2012 target.

[4]For example, it is possible that the nitrous oxide data contained in the *CAR* could be off by as much as a factor of three.

Based on the figures in **Table 1**, under the Kyoto agreement, the U.S. would be committed to emitting no more than 1,484 MMTCE annually on average during 2008-2012. This represents a reduction of 112 MMTCE annually below 1990 levels.

Projecting Emissions in 2008-2012

While the 1990/1995 baseline for the greenhouse gases contains uncertainties, those figures will be effectively frozen once the U.S. submits for review its compliance information as required by Articles 7 and 8. The reductions that will be required of the U.S. to meet its commitment under the Protocol will be the difference between 5 times 93% of the 1,596 MMTCE baseline (based on the emissions estimates from the 1997 *U.S. Climate Action Report*) and what would be "business as usual emissions" for the period 2008-2012. Estimating those "business as usual emissions" for 2008-2012 introduces the most uncertainty into the calculation of the reductions necessary to meet the terms of the Kyoto Protocol.

If emissions increase, the reductions required will be more than the 7% that would be required if average annual emissions during 2008-2010 were the same as for the base-years. But already, by 1995, emissions of the three 1990 baseyear greenhouse gases — CO_2, CH_4, and N_2O — had increased 9.5%. If the U.S. had reduced its 1995 emissions of these three gases to the level required by the Kyoto Protocol (7% below the baseline), the U.S. would have had to reduce its actual 1995 emissions of greenhouse gases by 155 MMTCE, or 9.4%.

But this 1995 calculation is based on historical data: the comparable calculation for 2008-2012 involves projections of substantial uncertainty. Such projections depend on a number of crucial assumptions involving economic activity and growth, interest rates, energy consumption, consumer behavior, technological change, policy interventions and their effectiveness, and others.

The *CAR* Projections

The 1997 *Climate Action Report* projects greenhouse gas emissions for the years 2000, 2005, 2010, and 2020. For evaluating the impact of the Kyoto Protocol, the 2010 projection falls in the middle of the target period. The projections presume continued funding support for the Administration's Climate Change Action Programs comparable to the 1997 levels approved by Congress.[5] The projected 2010 greenhouse emissions are shown in **Table 2** (the report discusses uncertainties,[6] but does not indicate potential error bars for these point estimates).

Based on the projection that net emissions will be 1,946 MMTCE in 2010, the average reduction necessary for the U.S. to meet its Kyoto commitment would be 462 MMTCE per year, or 23.7% below the "business as usual" emissions projected. This

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[5]The *Climate Action Report* discusses this and other variables affecting projections, pp. 117-124.

[6] The *Climate Action Report* discusses uncertainties, pp. 127-130.

calculation does not include any net, human-induced change in U.S. carbon sinks from afforestation, reforestation, and deforestation that could affect the 2010 reduction estimate.

Sensitivity Analysis

Inevitably, such projections depend on assumptions. Other analyses result in different projections. At the current time, virtually all alternative analyses focus on CO_2 emissions, the largest component of greenhouse gases.

Economic Variables. The Energy Information Administration (EIA) publishes a projection of U.S. energy production and consumption annually, including projected CO_2 emissions from energy-related activities. The *Annual Energy Outlook 1998* projects carbon emissions for energy use under three economic growth scenarios. **Table 3** substitutes the EIA CO_2 projections (with its 1990 baseline adjusted to *CAR* estimate) for the *CAR* projection, while retaining the *CAR* projections for the other 5 greenhouse gases.

Table 2. Projected 2010 U.S. Greenhouse Gas Emissions — *CAR* Data

Greenhouse Gas	Baseline Year Emissions (MMTCE)	2010 Emissions (MMTCE)
Carbon dioxide (CO_2)	1,353	1,669
Methane (CH_4)	170	152
Nitrous Oxide (N_2O)	36	34
Hydrofluorocarbons (HFCs)	21	91
Perfluorocarbons (PFCs)	8	
Sulfur Hexafluoride (SF_6)	8	
Total	1,596	1,946

Source: *Climate Action Report*, p. 111

Using EIA's low economic growth scenario, projected total greenhouse gas emissions are about the same as *CAR's* point estimate (just 1% higher), while the reference case and high growth projections are considerably higher, implying greater reductions to meet the Kyoto commitment. For its reference case, EIA's projections would result in an average annual reduction of 577 MMTCE, or 28% below the 1990/1995 baseline, to meet the target in 2010. Under the high economic growth case, the U.S. emission reduction from the 1990/1995 baseline necessary to meet the target would be 657 MMTCE, or 30.7%, while under the low growth case it would be 487 MMTCE, or 24.7%.

Energy Policy Variables. EIA also conducts sensitivity analysis on several energy policy variables that could affect future energy production, consumption, and emissions. Three of these variables include: (1) the rate of development and penetration of energy efficient technologies, (2) trends in electricity demand, and (3) retirement of nuclear capacity. Using the reference case to freeze the economic variables, EIA varies these energy policy factors to determine how they would affect energy consumption, production, and emissions. With respect to CO_2 emissions, EPA projects:

- If energy efficient technologies are developed faster and penetrate markets more quickly than the reference case, 79 additional MMTCE would be saved in 2010. Conversely, if technological development and use stalls at 1998 levels, EIA estimates that 2010 emissions would be 31 MMTCE higher than the reference case[7];
- If electricity demand rises faster than anticipated, as might happen if electricity restructuring reduces prices, EIA estimates that 2010 emissions would be 29 MMTCE higher than for the reference case[8];
- If nuclear facilities (which displace carbon-emitting fossil fuel facilities) are held in service longer than assumed in the reference case, EIA estimates that 42 additional MMTCE would be saved in 2010; conversely, if nuclear facilities are retired faster than anticipated (as might happen if electricity restructuring reduces electricity prices) EIA estimates that 2010 emissions would be 15 MMTCE higher than assumed in the reference case.[9]

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[7] *EIA*, p. 193.

[8] *EIA*, p. 195.

[9] Interpolated from *EIA*, p. 55.

Table 3. Projected 2010 U.S. Greenhouse Gas Emissions — EIA CO_2 Data for Three Economic Growth Scenarios

Greenhouse Gas	Baseline Year Emissions (MMTCE)	2010 Emissions (MMTCE)
Carbon dioxide (CO_2)	1,353	High growth: 1,864 Reference: 1,784 Low growth: 1,694
Methane (CH_4)	170	152
Nitrous Oxide (N_2O)	36	34
Hydrofluorocarbons (HFCs)	21	91
Perfluorocarbons (PFCs)	8	
Sulfur Hexafluoride (SF_6)	8	
Total	1,596	High growth: 2,141 Reference: 2,061 Low growth: 1,971

Source: Energy Information Administration, *Annual Energy Outlook 1998*, with projections through 2020, DOE/EIA-0383(98) (December 1997), p. 152 [adjusted to equate to *CAR* baseline].

Thus EIA finds that the uncertainties injected by energy policy variables are comparable to the uncertainties resulting from economic variables.

Another analysis, prepared by the Interlaboratory Working Group on Energy-Efficient and Low-Carbon Technologies (IWG) focuses on technology development and penetration and its potential impact on projected 2010 CO_2 emissions (see **Table 4**). To examine the potential for technology development to reduce CO_2 emissions, the analysis compares a "business as usual" case (based on EIA's 1997 reference case assumptions) with an efficiency case that assumes that 35% of cost-effective efficiency is captured. As stated by the report: "The general philosophy of the efficiency case is that it reduces, but does not eliminate, various market barriers and lags to the adoption of cost-effective energy efficient technology."[10]

[10]Interlaboratory Working Group on Energy Efficient and Low-Carbon Technologies [Oak Ridge National Laboratory, Lawrence Berkeley National Laboratory, Argonne National Laboratory, National Renewable Energy Laboratory, Pacific Northwest National Laboratory, *Scenarios of U.S. Carbon Reductions*, p. 1.2
http://www.ornl.gov/ORNL/Energy_Eff/CON444/labweb.htm

Table 4. Projected 2010 U.S. Greenhouse Gas Emissions — Interlaboratory Working Group CO_2 Data for Energy Efficient Scenario

Greenhouse Gas	Baseline Year Emissions (MMTCE)	2010 Emissions (MMTCE)
Carbon dioxide (CO_2)	1,353	Business as Usual: 1,717 High Efficiency: 1,597
Methane (CH_4)	170	152
Nitrous Oxide (N_2O)	36	34
Hydrofluorocarbons (HFCs)	21	91
Perfluorocarbons (PFCs)	8	
Sulfur Hexafluoride (SF_6)	8	
Total	1,596	Business as Usual: 1,994 High Efficiency: 1,874

Source: Interlaboratory Working Group on Energy Efficient and Low-Carbon Technologies, *Scenarios of U.S. Carbon Reductions*, p. 1.6. [Adjusted to equate to *CAR* baseline.]

This group's "business as usual" baseline is somewhat lower than the EIA's 1998 "reference case," and a bit higher (plus 2.5%) than the *CAR* point estimate for 2010. The "business as usual" reduction estimate for 2010 resulting from this scenario would be 510 MMTCE per year, or 25.6% below the baseline to achieve the Kyoto target. However, under the group's "efficiency case," emissions drop substantially and are less than the *CAR's* point projection; in this case, the reductions necessary for the U.S. to meet its Kyoto commitment in 2010 would be 390 MMTCE, or 21% below the 1990/1995 baseline.

Carbon Sequestration Variables. A country's contribution to greenhouse gases not only consists of direct emissions but also is influenced by activities that affect carbon sinks — processes that remove and sequester carbon from the atmosphere. Activities that affect sinks include farming and forestry practices. A positive net growth of trees removes carbon from the atmosphere; clearing forests typically releases carbon. A nation's emission reduction commitment can be affected by net changes in sinks. According to the Protocol, "The net changes in greenhouse gas emissions from sources and removals by sinks resulting from direct human-induced land-use change and forestry activities, limited to afforestation, reforestation, and deforestation since 1990, measured as verifiable changes in stocks ... shall be used to meet" the 2008-2012 commitments (Article 3(3)). Also, revised methods of accounting for "removals in the agricultural soil and land-use change and forestry categories" may be approved by the November 1998 Conference of Parties and be

applied in meeting the 2008-2012 commitment, if the activities took place after 1990 (Article 3(4)).

The 1997 *U.S. Climate Action Report* estimates that in 1990 carbon sequestration represented a sink of 125 MMTCE and projects a slight decline in the future. However, the estimates are uncertain and may not reflect the way the Protocol ultimately assesses sinks. In estimating reductions necessary to meet the Kyoto commitment, a net increase in human-induced carbon sequestration from forestry practices between 1990 and 2008-2012 would be subtracted from emissions during the period, thereby reducing the amount of actual emissions that will have to be curtailed. Conversely, net negative sequestration from forestry practices would be added to the emissions that will have to be reduced.

Scope of Reductions: Other Considerations

In discussing the emission reductions required under the Kyoto agreement, there is a tendency to focus on domestic emissions of CO_2, which account for 85% of U.S. greenhouse gas emissions and for which the data are the best. However, it is important to remember that the Kyoto Agreement involves 6 gases, not 1. Also, as the Agreement is international in terms of the emissions inventory available, the U.S. can seek reduction opportunities through bilateral trading and joint implementation. These considerations do not affect the amount of carbon-equivalent emissions that U.S. would be obligated to reduce; however, they can influence where some of those reductions may occur, and how much they would cost.

Reducing Emissions from Six Gases, Not One

While the 5 non-CO_2 gases account for only about 15% of U.S. greenhouse gas emissions, their impact on required reductions cannot be ignored. The *Climate Action Report* indicates that emissions of all 5 increased from 1990 to 1995. Any increase means that even greater reductions will probably come from CO_2 — with most of the impact of achieving those reductions falling on those burning fossil fuels. Of particular concern are HFCs and PFCs; while their present contribution to greenhouse gas emissions is small, their use has been growing rapidly, especially HFCs, which are replacing chlorofluorocarbons (CFCs) that are being phased out under the Montreal Protocol because they deplete stratospheric ozone. Unless effective means are developed to contain or eliminate these emissions, CO_2 emitting sources may bear an even greater share of the committed reductions than would otherwise be the case.

As suggested earlier, data on the five non-CO_2 gases are of considerably less quality than for energy-related CO_2 emissions, and their conversion to carbon equivalents entails some uncertainty. With the U.S. required to provide final estimates this year for its 1990/1995 baseline, this situation could lead to some significant problems. If the U.S. underestimates 1990/1995 emissions of these gases, the growth trend to 2008-2012 could be artificially increased because of the depressed baseline. This would result in additional reductions being required. In contrast, if the U.S. overestimates 1990/1995 emissions of these gases, the growth trend to 2008-2012 could be artificially reduced because of the inflated baseline. This would result

in less required reductions (though failing to meet the spirit of the commitment). As previously noted, these baseline estimates will be subject to review by "expert review teams" created under the Protocol.

Emissions Trading Mechanisms

Any consideration of the domestic impacts of reducing greenhouse gas emissions under the Kyoto Agreement has to take into account the potential under the Agreement for some of those reductions to be accomplished elsewhere.[11] The Kyoto agreement does not require the U.S. to reduce its domestic emissions by a specific amount; rather, it requires the U.S. to reduce emissions from any certified source in a manner that results in the reduction requirement being met.

The Protocol establishes three mechanisms that expand the inventory of reduction opportunities.

Under article 4, the Protocol authorizes Annex I Parties[12] "to fulfill their commitments under Article 3 jointly" — in effect, this allows one country to emit greenhouse gases in excess of its commitment to the degree another country's emissions are lower than its commitment. Parties proposing joint fulfillment of commitments must formally notify the secretariat of their intent when they ratify or otherwise approve the Protocol.

Under article 6 of the Protocol, any Annex I Party "may transfer to, or acquire from, any other such Party emission reduction units resulting from projects aimed at reducing anthropogenic emissions by sources or enhancing anthropogenic removals by sinks of greenhouse gases in any sector of the economy...." The protocol spells out conditions for such emissions trading, including a requirement that it only "be supplemental to domestic actions for the purposes of meeting commitments...." The November 1998 Conference of Parties in Buenos Aires is to elaborate on guidelines for implementing this article with respect to verification and reporting. Parties can authorize private entities, such as corporations, to engage in emissions trades under this article.

Under article 12, the Protocol defines a "clean development mechanism" by which Annex I countries can gain credit for post-2000 emissions reductions achieved by assisting nonAnnex I countries in sustainable development activities that reduce emissions or enhance carbon sinks. Such "joint implementation" emissions reductions must be real and measurable; the November 1998 Conference of the Parties is to "elaborate modalities and procedures with the objective of ensuring transparency, efficiency and accountability through independent auditing and verification of project activities."

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[11] *Global Climate Change: Market-Based Strategies to Reduce Greenhouse Gases*, CRS Issue Brief 97057.

[12] Annex I Parties — listed in an Annex to the 1992 U.N. Framework Convention on Climate Change (FCCC) — include the "developed" nations and the former soviet economies; the U.S. is an Annex I Party. Each Annex I Party that has an assigned target for greenhouse gas emissions is listed, with its target, in Annex B of the Kyoto Protocol.

These "emissions trading" mechanisms offer the possibility that actual domestic greenhouse gas reductions will be less than the amount required to meet the U.S. commitment. If so, the impact of reductions will be different than if the U.S. met its full commitment through reducing emissions within its borders. The amount of reductions that can be shifted elsewhere is unclear, but nonetheless, may offer the possibility of avoiding some of the higher cost/higher impact reductions that otherwise would have occurred domestically. That the rules for "emissions trading" opportunities are not yet final and the ultimate share of reductions that might be shifted out of the country is uncertain adds a further degree of uncertainty in evaluating actual domestic reductions and their impacts.

Thus, while the emissions trading mechanisms of the Protocol do not reduce the emissions reduction that the U.S. would have to achieve, those mechanisms offer the opportunity to shift impacts of some of the reduction to other countries where, presumably, the costs (which would be borne by U.S. interests) may be less.

Reduction Uncertainties

Table 5 depicts the range of reduction requirements implied by the analyses reviewed above. As can be seen from **Table 5**, the projected reductions necessary by 2008-2010 to meet the Kyoto Agreement vary from over 30% (EIA's high economic growth scenario) to 21% (Interlaboratory Working Group's high energy efficiency case) below "business as usual" emissions. These high and low projections, which bracket the *Climate Action Report's* point estimate, differ only in assumptions about CO_2 emissions: the high projection is 16.7% higher than the low one; they vary from the *Climate Action Report's* by +11.7% to -4.3%.

Table 5. Projected 2010 Reduction Requirements to Achieve the Kyoto Accord

Projection	Projected Net Greenhouse Gas Emissions 2010 MMTCE	Kyoto Reduction Requirement	
		MMTCE	%
CAR	1,946	462	23.7
EIA			
High growth	2,141	657	30.7
Reference	2,061	577	28
Low Growth	1,971	487	24.7
IWG			
Business as Usual	1,974	510	25.6
Efficiency Case	1,874	390	21

None of the estimates integrates the full range of potential variables that could affect CO_2 emissions in the future — economic growth, electricity restructuring, electricity demand, and technological change and penetration. Thus these estimates do not include all the uncertainties about CO_2 emissions. And for net emissions, none of these estimates explore the uncertainties inherent in the baseline estimates and variables affecting projections of the other 5 greenhouse gases covered by the Kyoto Agreement. The likely impact of various uncertainties on future emissions/reduction needs is summarized in **Table 6**. In short, projecting future emissions and the amount that emissions might have to be reduced to comply with the Kyoto agreement is fraught with considerable uncertainty.

The reviewed estimates of the reduction necessary to meet the commitment — i.e., the reduction below "business as usual" emissions projected for 2008-2010 — range from approximately 390 to 660 MMTCE. Even ignoring numerous uncertainties, then, there remains a ~70% difference from the lower to higher reduction projected necessary to achieve the target. To comply with the higher compared to the lower estimate would represent a substantial escalation of effort and makes estimating potential costs difficult.[13]

[13]Larry Parker and John Blodgett, *Climate Change: Three Policy Perspectives*, CRS Report 94-816 (1994).

Table 6. Selected Uncertainties in Projected Reduction Requirements

Variable introducing uncertainty	Impact on Future Greenhouse Gas Emissions/Reductions Required		
Baseline			
Baseline revised:			
upward	– [= less emissions, less reductions]		
down	+ [= more emissions, more reductions]		
Economic Assumptions for Projecting Emissions/Reductions in 2008-2010			
	Change from "business as usual"	EIA estimate MMTCE	IWG estimate MMTCE
Economic growth:			
higher than expected	+	+80	
lower than expected	–	– 90	
Energy Policy Assumptions			
Energy efficient technologies:			
adopted faster than expected	–	– 79	– 120
adopted slower than expected	+	+31	
Energy prices (e.g., electricity, gasoline):			
decline	+	+29	
rise	–		
Nuclear facilities retire:			
faster than expected	+	+15	
slower than expected	–	– 42	
Sinks			
Sinks:			
Human-induced sequestration drops	+		
Human-induced sequestration up	–		
Non-CO_2 Greenhouse Gases			
Netting all 6 greenhouse gases:			
Emission uncertainties narrow:			
higher than expected in 2010	+		
lower than expected in 2010	–		
HFCs, PFCs & SF_6 emissions:			
grow faster than expected	+		
grow slower than expected	–		
Emissions Trading			
"Emissions Trading" opportunities:	no change in emissions, but:		
Many opportunities taken	reduce domestic reductions/costs		
Few opportunities materialize	less reductions exported		