Carbon Abatement With Economic Growth: A National Strategy

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1. Introduction and Summary

The risk of catastrophic global climate disruption from human activities could be mitigated if atmospheric CO_2 concentrations are stabilized at approximately 450 parts per million, about 60 percent above pre-industrial concentrations. This requires keeping total global carbon emissions within 500 billion tons over the 21st century, rather than the 1,400 billion tons towards which the world is now headed. Achieving this goal would require that annual global carbon emissions from fossil fuels be at least halved from its current 6 million tons instead of tripled by the end of the century, and that deforestation is halted. This requires that global annual per-capita carbon emissions decrease from today's 1 ton to less than 0.3 tons, whereas with business-as-usual per-capita emissions will grow to almost 2 tons, notwithstanding growing populations and economies. For U.S., which currently emits about one-fourth of the global total at almost 6 tons per-capita, this implies a twenty-fold decrease in carbon intensity and more than ten-fold decrease in emissions over the century, if national emissions converged during the century to equal per-capita limits under a global climate stabilization path. Whatever burden sharing approach is adopted, it is clear that the U.S. will have to radically reduce its carbon emissions over the next several decades.

This paper presents the results of a study showing that the U.S. could dramatically reduce its greenhouse gas emissions over the next two decades while the economy continues to grow.[1] It examines a set of policies to increase energy efficiency, accelerate adoption of renewable energy, reduce air pollution, and shift to less carbon-intensive fuels. The policies are targeted within and across sectors – residential and commercial buildings, industrial facilities, transportation, and power generation. They include incentives, standards, codes, market mechanisms, regulatory reform, research and development, public outreach, technical assistance and infrastructure investment.

Together with steps to reduce emissions of non-CO_2 greenhouse gases and land-based CO_2 emissions, and the acquisition of a limited amount of allowances internationally, this portfolio of policies would allow the U.S. to meet its obligations under the Kyoto Protocol, reducing its GHG emissions to 7 percent below 1990 levels by 2010, with far greater reductions by 2012. It would bring overall economic *benefits* to the US, since lower fuel and electricity bills would more than pay the costs of technology innovation and program implementation. In 2010, the annual savings would exceed costs by $50 billion, and by 2020 by approximately $135 billion. At the same time, jobs, GDP and incomes would increase, and pollutant emissions would decrease.

Energy use in buildings, industries, transportation, and electricity generation was modeled for this study using the U.S. Department of Energy, Energy Information Administration's National Energy Modeling System (NEMS). The NEMS model version, data and assumptions employed in this study were those of EIA's (Energy Info Admin.) *Annual Energy Outlook*[2], which also formed the basis for the Base Case. We refined the NEMS model with advice from EIA, based on their ongoing model improvements, and drawing on expertise from colleagues at Union of Concerned Scientists, the National Laboratories and elsewhere.

Table 1 provides summary results on overall energy and greenhouse gas impacts and economic impacts of the policy set for the *Base Case* and *Climate Protection Case* for 2010 and 2020. The policies cause reductions in primary energy consumption that reach 11 percent by 2010 and 30 percent in 2020, relative to the Base Case in those years, through increased efficiency and greater adoption of cogeneration of heat and power (CHP).

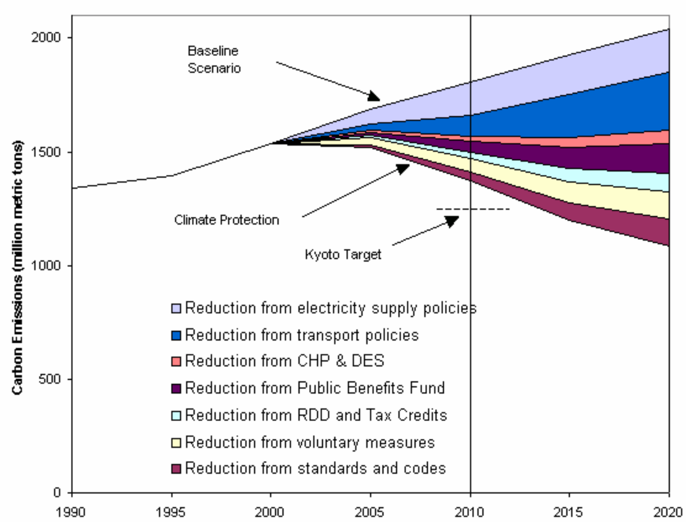
Table 1: Summary of Results

	1990[3]	2010 Base Case	2010 Climate Protection	2020 Base Case	2020 Climate Protection
End-use Energy (Quads)	63.9	86.0	76.4	97.2	72.6
Primary Energy (Quads)	84.6	114.1	101.2	127.0	89.4
Renewable Energy (Quads)					
Non-Hydro	3.5	5.0	10.4	5.5	11.0
Hydro	3.0	3.1	3.1	3.1	3.1
Net GHG Emissions (MtCe/yr)	1,648	2,204	1,533	-----	-----
Energy Carbon	1,338	1,808	1,372	2,042	1,087
Land-based Carbon	-----	-----	-58	-----	-----
Non-CO_2 Gases	310	397	279	-----	-----
International Trade	-----	-----	-60	-----	-----
Net Savings[4]					
Cumulative present value (billion$)	------	------	$105	------	$576
Levelized annual (billion$/year)	------	------	$13	------	$49
Levelized annual per household ($/year)	------	------	$113	------	$375
Macro-economic Impacts (Changes in Year)[5]					
GDP (billions$)	-----	-----	23.2	-----	43.9
Jobs	-----	-----	0.7	-----	1.3
Wages/Compensation($household)	-----	-----	220	-----	400

Relative to today's levels, use of non-hydro renewable energy roughly triples by 2010 in the Climate Protection Case, owing to a Renewable Portfolio Standard (RPS), whereas in the Base Case it increases by less than 50 percent. Given the entire set of policies, non-hydro renewable energy doubles relative to the Base Case in 2010, accounting for about 10 percent of total primary energy supplies. The absolute amount of renewables does not increase substantially between 2010 and 2020 because the 10 % RPS electric sector targets in 2010 give the same absolute amount as the 20% in 2020 since demand declines sharply owing to the efficiency policies. A more aggressive renewables policy for the 2010-2020 period could be considered.[6]

The reductions in energy-related carbon emissions are even more dramatic than the reductions in energy consumption, because of the shift toward lower-carbon fuels and renewable energy. Carbon emissions have already risen by over 15 percent since 1990, and in the Base Case will rise a total of 35 percent by 2010, in stark contrast to the 7 percent emissions *reduction* that the U.S. negotiated at Kyoto. In the Climate Protection case, the U.S. promptly begins to reduce energy-related carbon emissions, and by 2010 emissions are only 2.5 percent above 1990 levels, and by 2020, emissions are well below 1990 levels. Relative to the Base case, the 2010 reductions[7] amount to 436 MtC/yr.

Figure 1: Reductions in Energy-related Carbon Emissions, Displayed by Major Policy Group



Land-based activities, such as forestry, land-use, and agriculture, yield another 58 MtC/yr of reductions. Methane emissions are also reduced, through measures aimed at landfills, natural gas production and distribution systems, mines, and livestock husbandry. The potent fluorine-containing greenhouse gases are reduced by substituting with non-greenhouse gases, implementing alternative cleaning processes in the semiconductor industry, reducing leaks, and investing in more efficient gas-using equipment. In total, the Climate Protection case adopts reductions of these other greenhouse gases equivalent to 118 MtC/yr by 2010.

Together the reduction measures for energy-related carbon (436 MtC/yr), land-based carbon (58 MtC/yr), and non-carbon gases (118 MtCe/yr) amount to 612 MtCe/yr of reductions in 2010. Through these measures, the U.S. is able to accomplish the vast majority of its emissions reduction obligation under the Kyoto Protocol through domestic actions. This leaves the United States slightly shy of its Kyoto target, with only 60 MtC/yr worth of emissions allowances to procure from other countries though the "flexibility mechanisms" of the Kyoto Protocol – (Emissions Trading, Joint Implementation, and the Clean Development Mechanism). The Climate Protection case assumes that the U.S. will take steps to ensure that allowances procured through these flexibility mechanisms reflect legitimate mitigation activity. In particular, we assume that U.S. restrains its use of so-called "hot air" allowances, i.e., allowances sold by countries that negotiated excessively high Kyoto targets.

The set of policies in the *Climate Protection* Case also reduces criteria air pollutants that cause or aggravate human health problems, and adversely affect agriculture, forests, water resources, and buildings. The policies would significantly reduce energy-related emissions as summarized in Table 2. Sulfur oxide emissions would decrease the most – by half in 2010 and by nearly 75 percent in 2020. The other pollutants are reduced between 7 and 16 percent by 2010, and between 17 and 29 percent by 2020, relative to *Base* case levels in those years.

Table 2: Impact of Policies on Air Pollutant Emissions

	1900	2010 Base Case	2010 Climate Protection	2020 Base Case	2020 Climate Protection
CO	65.1	69.8	63.8	71.8	59.8
NOx	21.9	16.5	13.9	16.9	12.0
SO2	19.3	12.8	6.2	12.7	3.3
VOC	7.7	5.5	5.1	5.9	4.9
PM-10	1.7	1.5	1.3	1.6	1.3

The complete Climate Protection package provides net economic benefits to the U.S., while improving public health and the environment. In dramatically reducing energy consumption, the Climate Protection strategy reduces our dependence on insecure energy supplies and positions the U.S. as a supplier of innovative and environmentally superior technologies and practices.

Far from being the economically crippling burden that some allege and others fear, ratifying the Kyoto Protocol and ambitiously reducing greenhouse gas emissions could initiate a national technological and economic renaissance with cleaner energy, industrial processes and products in the coming decades. In the U.S, we therefore face an important challenge. We can be followers, leaving other more forward-looking countries to assume the global leadership in charting a sustainable path. Or we can embrace the opportunity to usher in a technological and environmental transition, providing world markets with the advanced and clean energy technologies needed to sustain the new century's economic growth.

2. Energy Policies

Analyses of the investment costs and energy savings of policies to promote energy efficiency and co-generation in the residential, commercial, and industrial sectors and efficiency for light duty vehicles, were taken primarily from the American Council for an Energy Efficient Economy.[8] Analyses of avoided energy, costs and emissions, pollutant emissions caps, renewable energy, and other transportation modes followed the approaches taken in Bernow *et al.*[9] Below we group these policies into the particular sector where they take effect, and describe the key assumptions made concerning the technological impacts of the individual policies. Unless otherwise indicated, each of the policies is assumed to start in 2003.

In evaluating the avoided energy, costs and emissions of these policies we relied primarily on the U.S. Department of Energy's NEMS model, data and assumptions. We adapted the Energy Information Administration's 2001 Reference Case Forecast[10] to create a slightly revised "Base Case." Our policies build on those included in this Base Case forecast (i.e., we avoid taking credit for emissions reductions, costs, or savings already included in the EIA 2001 Reference Case).

2.1 Policies in the Buildings and Industrial Sectors

Carbon emissions from fuel combustion in residential and commercial buildings account for about 10 percent of U.S. greenhouse gas emissions, while emissions from the industrial sector account for another 20 percent. When emissions associated with the electricity consumed are counted, these levels reach over 35 percent for buildings and 30 percent for industry. We analyzed a set of policies that include new building codes, new appliance standards, tax incentives for the purchase of high efficiency products, a national public benefits fund, expanded research and development, voluntary agreements and support for combined heat and power.

Building codes

Building energy codes require all new residential and commercial buildings to be built to a minimum level of energy efficiency that is cost-effective and technically feasible. "Good practice" residential energy codes, defined as the 1992 (or a more recent) version of the Model Energy Code (now known as the International Energy Conservation Code), have been adopted by 32 states.[11] "Good practice" commercial energy codes, defined as the ASHRAE 90.1 model standard, have been adopted by 29 states.[12] However, the Energy Policy Act of 1992 (EPAct) requires all states to adopt a commercial building code that meets or exceeds ASHRAE 90.1, and requires all states to consider upgrading their residential code to meet or exceed the 1992 Model Energy Code.

This policy assumes that DOE enforces the commercial building code requirement in EPAct and that states comply. We also assume that relevant states upgrade their residential energy code to either the 1995 or 1998 Model Energy Code either voluntarily or through the adoption of a new federal requirement. Furthermore, we assume that the model energy codes are significantly improved during the next decade and that all states adopt mandatory codes that go beyond current "good practice" by 2010. To quantify the impact of these changes, we assume a 20 percent energy savings in heating and cooling in buildings in half of new homes and commercial buildings.

New Appliance and Equipment Efficiency Standards

The track record for electricity efficiency standards is impressive, starting with the National Appliance Energy Conservation Act of 1987 and continuing through the various updates that were enacted in early 2001 for washers, water heaters, and central air conditioners. These standards have removed the most inefficient models from the market, while still leaving consumers with a diversity of products. An analysis of Department of Energy figures by the American Council for an Energy Efficient Economy, estimates nearly 8 percent of annual electricity consumption will be saved in 2020 due to standards already enacted[13]. However, many appliance efficiency standards haven't kept pace with either legal update requirements or technological advances. The Department of Energy is many years behind its legal obligation to regularly upgrade standards for certain appliances to the "maximum level of energy efficiency that is technically feasible and economically justified."

In this study, we assume that the government upgrades existing standards or introduces new standards for several key appliances and equipment types: distribution transformers, commercial air conditioning systems, residential heating systems, commercial refrigerators, exit signs, traffic lights, *torchiere* lighting fixtures, ice makers, and standby power consumption for consumer electronics. We also assume the higher energy efficiency standards for residential central air conditioning and heat pumps than was allowed by the Bush Administration. These are all measures that can be taken in the near term, based on technologies that are available and cost-effective.

Tax Incentives

A wide range of advanced energy-efficient products have been proven and commercialized, but have not yet become firmly established in the marketplace. A major reason for this is that conventional technologies get "locked-in"; they benefit from economies of scale, consumer awareness and familiarity, and already existing infrastructure that make them more able to attract consumers, while alternatives are overlooked though they could be financially viable once mass-produced and widely demonstrated.

In this study, we include initial tax incentives for a number of products. For consumer appliances, we considered a tax incentive of $50 to $100 per unit. For new homes that are at least 30 percent more efficient that the Model Energy Code, we considered an incentive of up to $2,000 per home; for commercial buildings with at least 50 percent reduction in heating and cooling costs relative to applicable building codes, we applied an incentive equal to $2.25 per square foot. Regarding building equipment such as efficient furnaces, fuel cell power systems, gas-fired heat pumps, and electric heat pump water heaters, we considered a 20 percent investment tax credit. Each of these incentives would be introduced with a sunset clause, terminating them or phasing them out in approximately five years, so as to avoid their becoming permanent subsidies. Versions of all of the tax incentives considered here have already been introduced into bills before the Senate and/or House[14].

National Public Benefits Fund

Electric utilities have historically funded programs to encourage more efficient energy-using equipment, assist low-income families with home weatherization, commercialize renewables, and undertake research and development (R&D). Such programs have typically achieved electricity bill savings for households and businesses that are roughly twice the program costs [15]. Despite the proven effectiveness of such technologies and programs, increasing price competition and restructuring have caused utilities to reduce these "public benefit" expenditures over the past several years. In order to preserve such programs, fifteen states have instituted public benefits funds that are financed by a small surcharge on all power delivered to consumers.

This study's policy package includes a national level public benefits fund (PBF) fashioned after the proposal introduced by Sen. Jeffords (S. 1369) and Rep. Pallone (H. 2569) in the 106th Congress. The PBF would levy a surcharge of 0.2 cents per kilowatt-hour on all electricity sold, costing the typical residential consumer about $1 per month. This federal fund would provide matching funds for states for approved public benefits expenditures. In this study, the PBF is allocated to several different programs directed at improvements in lighting, air conditioning, motors, and other cost-effective energy efficiency improvements in electricity-using equipment.

Expand Federal Funding for Research and Development in Energy Efficient Technologies

Federal R&D funding for energy efficiency has been a spectacularly cost-effective investment. The DOE has estimated that the energy savings from 20 of its energy efficiency R&D programs has been roughly $30 billion so far – more than three times the federal appropriation for the entire energy efficiency and renewables R&D budget throughout the 1990s.[16]

Tremendous opportunities exist for further progress in material-processing technologies, manufacturing processing, electric motors, windows, building shells, lighting, heating/cooling systems, and super-insulation, for example. The EPA's *Energy Star* programs have also saved large amounts of energy, building on the achievements of R&D efforts and ushering efficient products into the marketplace. By certifying and labeling efficient lighting, office equipment, homes and offices, *Energy Star* has helped foster a market transformation toward much more efficient products and buildings. Currently, roughly 80 percent of personal computers, 95 percent of monitors, 99 percent of printers, and 65 percent of copiers sold are Energy Star certified.[17] In light of these successes, EPA should be allocated the funds to broaden the scope of its Energy Star program, expanding to other products (refrigerators, motors) and building sectors (hotels, retailers), and the vast market of existing buildings that could be retrofitted. In this study, we assume that increased funding to expand research and development efforts in industry (e.g., motors) buildings (e.g., advanced heating/cooling), and transport (e.g., more fuel efficient cars and trucks) will lead to more energy-savings products becoming commercially available.

Support for Co-generation

Cogeneration (or, combined heat and power – CHP) is a super-efficient means of co-producing two energy-intensive products that are usually produced separately – heat and power. The technical and economical value of CHP has been widely demonstrated, and some European countries rely heavily on CHP for producing power and providing heat to industries, businesses, and households. The thermal energy produced in co-generation can also be used for (building and process) cooling or to provide mechanical power.

While CHP already provides about 9 percent of all electricity in the US, there are considerable barriers to its wider cost-effective implementation[18]. Environmental standards should be refined to recognize the greater overall efficiency of CHP systems, for example by assessing facility emissions on the basis of fuel input, rather than useful energy output. Non-uniform tax standards discourage CHP implementation in certain facilities. Moreover, utility practices are generally highly hostile to prospective CHP operators, through discriminatory pricing and burdensome technical requirements and costs for connecting to the grid.

In this study, we include policies that would establish a standard permitting process, uniform tax treatment, accurate environmental standards, and fair access to electricity consumers through the grid. Such measures would help to unleash a significant portion of the enormous potential for CHP. In this study we assumed 50 GW of new CHP capacity by 2010, and an additional 95 GW between 2011 and 2020. With electricity demand reduced by the various energy efficiency policies adopted in this study, co-generated electricity reaches 8 percent of total remaining electricity requirements in 2010 and 36 percent in 2020.

2.2 Policies in the Electric Sector

A major goal for U.S. energy and climate policy is to dramatically reduce carbon and other pollutant emissions from the electric sector, which is responsible for more than one-third of all U.S. greenhouse gas emissions. We analyzed a set of policies in the electric sector that include standards and mechanisms to help overcome existing market barriers to investments in technologies that can reduce emissions. The three policies -- a renewable portfolio standard, a cap on pollutant emissions, and a carbon cap and trade system -- are described below.

Renewable Portfolio Standard

A Renewable Portfolio Standard (RPS) is a flexible, market-oriented policy for accelerating the introduction of renewable resources and technologies into the electric sector. An RPS sets a schedule for establishing a minimum amount of renewable electricity as a fraction of total generation, and requires each generator that sells electricity to meet the minimum either by producing that amount of renewable electricity in its mix or acquiring credits from generators that exceed the minimum. The market determines the portfolio of technologies and geographic distribution of facilities that meet the target at least cost. This is achieved by a trading system that awards credits to generators for producing renewable electricity and allows them to sell or purchase these credits. Thirteen states – Arizona, Connecticut, Hawaii, Iowa, Maine, Massachusetts, Minnesota, Nevada, New Jersey, New Mexico, Pennsylvania, Texas, and Wisconsin – already have RPSs, and Senator Jeffords introduced a bill in the 106th Congress (S. 1369) to establish a national RPS.

In this study, we have applied an RPS that starts at a 2 percent requirement in 2002, grows to 10 percent in 2010, and to 20 percent in 2020, after all efficiency policies are included. Wind, solar, geothermal, biomass, and landfill gas are eligible renewable sources of electricity, but environmental concerns exclude municipal solid waste (owing to concerns about toxic emissions from waste-burning plants) and large-scale hydro (which, in any event, need not be treated as an emerging energy technology as it already supplies nearly 10 percent of the nation's electricity supply).

We also here tighten the existing SO_2 cap so as to reduce sulfur emissions to roughly 40 percent of current levels by 2010 and one third of current levels by 2020. We also impose a cap-and-trade system on NO_x emissions in the summertime, when NO_x contributes more severely to photochemical smog. This system expands the current cap and trade program, which calls on 19 states to meet a target in 2003 that then remains constant, to include all states with a cap that is set first in 2003 but decreases in 2010, relative to 1999 levels. The cap results in a 25 percent reduction of annual NO_x emissions by 2003, and a 50 percent reduction by 2010.

Carbon Cap-And-Trade Permit System

This study introduces a cap-and-trade system for carbon in the electric sector; with the cap set to achieve progressively more stringent targets over time, starting in 2003 at 2 percent below current levels, increasing to 12 percent below current by 2010 and 30 percent below by 2020. Restricting carbon emissions from electricity generation has important co-benefits, including reduced emissions of SO_2 and NO_x, as discussed above, fine particulate matter, which is a known cause of respiratory ailments, and mercury, which is a powerful nervous system toxin and already contaminates over 50,000 lakes and streams in the US. A progressively more stringent target also reduces demand for coal, and hence mining-related pollution of streams and degradation of landscapes and terrestrial habitats.

In the SO_2, NO_x, and CO_2 trading systems, permits are distributed through an open auction, and the resulting revenues can be returned to households (e.g., through a tax reduction or as a rebate back to households). Recent analyses suggest that an auction is the most economically efficient way to distribute permits, meeting emissions caps at lower cost than allocations based on grandfather allowances or equal per kWh allowances[19]. Implementing such auctions for the electric sector will also clear the way for an economy-wide approach in future years based on auctioning. In this study, the price of auctioned carbon permits reaches $100 per metric ton carbon.

While not specifically targeted by the trading programs, the operators of the 850 old "grand-fathered" coal plants built before the Clean Air Act of 1970, which emit 3-5 times as much pollution per unit of power generated than newer coal power plants, will likely retire these plants rather than face the cost of purchase the large amount of credits necessary to keep them running. When the Clean Air Act was adopted, it was expected that these dirty power plants would eventually be retired. However, utilities are continuing to operate these plants beyond their design life, and have in fact increased their output over the last decade. By subjecting these old plants to the same requirements as newer facilities, as has been done or is being considered in several states including Massachusetts and Texas, operators would be obliged to modernize the old plants or to retire them in favor of cleaner electric generation alternatives.

2.3 Policies in the Transport Sector

Another goal for U.S. energy and climate policy is to reduce carbon emissions from the transport sector, which is responsible for about one-third of all U.S. greenhouse gas emissions. We analyzed a set of policies in the transportation sector that include improved efficiency (light duty vehicles, heavy duty trucks and aircraft), a full fuel-cycle GHG standard for motor fuels, measures to reduce road travel, and high-speed rail (HSR).

Strengthened CAFE Standards

Today's cars are governed by fuel economy standards that were set in the mid-1970s. The efficiency gains made in meeting those standards have been entirely wiped out by increases in population and driving, as well as the trend toward gas-guzzling SUVs. When the fuel economy standards were implemented, light duty trucks only accounted for about 20 percent of vehicle sales. Light trucks now account for nearly 50 percent of new vehicle sales; this has brought down the overall fuel economy of the light duty vehicle fleet, which now stands at its lowest average fuel economy since 1981. If the fuel economy of new vehicles had held at 1981 levels rather than tipping downward, American vehicle owners would be importing half a million fewer barrels of oil each day.

We introduce in this study a strengthened Corporate Average Fuel Economy (CAFE) standard for cars and light trucks, along with complementary market incentive programs. Specifically, fuel economy standards for new cars and light trucks rise from EIA's projected 25.2 mpg for 2001 to 36.5 mpg in 2010, continuing to 50.5 mpg by 2020. This increase in vehicle fuel economy would save by 2020 approximately twice as much oil as could be pumped from Arctic National Wildlife Refuge oil field over its entire 50-year lifespan[20]. Based on assessments of near-term technologies for conventional vehicles, and advanced vehicle technologies for the longer-term, we estimate that the 2010 CAFE target can be met with an incremental vehicle cost of approximately $855, and the 2020 CAFE target with an incremental cost of $1,900. To put these incremental costs in perspective, they are two to three times less than the fuel savings at the gasoline pump over the vehicle's lifetime[21].

Improving Efficiency of Freight Transport

We also consider policies to improve fuel economy for heavy-duty truck freight transport, which accounts for approximately 16 percent of all transport energy consumption. A variety of improvements such as advanced diesel engines, drag reduction, rolling resistance, load reduction strategies, and low friction drivetrains offer opportunities to increase the fuel economy of freight trucks.

To accelerate the improvement in heavy duty truck efficiency, we have considered measures that expand R&D for heavy duty diesel technology, vehicle labeling and promotion, financial incentives to stimulate the introduction of new technologies, efficiency standards for medium- and heavy-duty trucks, and fuel taxes and user-fees calibrated to eliminate the existing subsidies for freight trucking. Together, it is estimated that these policies could bring about a fuel economy improvement of 6 percent by 2010, and 23 percent by 2020, relative to today's trucks.

Improving Efficiency of Air Travel

Air travel is the quickest growing mode of travel, and far more energy intensive than vehicle travel. One passenger mile of air travel today requires about 1.7 times as much fuel as vehicle travel.[22] We consider here policies for improving the efficiency of air travel, including R&D in efficient aircraft technologies, fuel consumption standards, and a revamping of policies that subsidize air travel through public investments.

We assume that air travel efficiency improves by 23 percent by 2010, and 53 percent by 2020. This is in contrast to the Base Case where efficiency increases by 9 percent by 2010 and 15 percent by 2020, owing to a combination of aircraft efficiency improvements (advanced engine types, lightweight composite materials, and advanced aerodynamics), increased load factor, and acceleration of air traffic management improvements[23]. We assume that air travel can reach 82 seat-miles per gallon by 2020 from its current 51.

Greenhouse Gas Standards for Motor Fuels

Transportation in the U.S. relies overwhelmingly on petroleum-based fuels, making it a major source of GHG emissions. We introduce here a full fuel-cycle GHG standard for motor fuels, similar in concept to the RPS for the electric sector. The standard is a cap on the average GHG emissions from gasoline, and would be made progressively more stringent over time. Fuel suppliers would have the flexibility to meet the standard on their own or by buying tradable credits from other producers of renewable or low-GHG fuel.

The policy adopted in this study requires a 3 percent reduction in the average national GHG emission factor of fuels used in light duty vehicles in 2010, increasing to a 7 percent reduction by 2020. The policy would be complemented by expanded R&D, market creation programs, and financial incentives. Such a program would stimulate the production of low-GHG fuels such as cellulosic ethanol and biomass- or solar-based hydrogen.

For this modeling study, we assume that most of the low-GHG fuel is provided as cellulosic ethanol, which can be produced from agricultural residues, forest and mill wastes, urban wood wastes, and short rotation woody crops[24]. As cellulosic ethanol can be co-produced along with electricity, in this study we assume that electricity output reaches 10 percent of ethanol output by 2010 and 40 percent by 2020[25]. Due to the accelerated development of the production technology for cellulosic ethanol, we estimate that the price falls to $1.4 per gallon of gasoline equivalent by 2010 and remains at that price thereafter[26].

Improving Alternative Modes to Reduce Vehicle Miles Traveled

The amount of travel in cars and light duty trucks continues to grow due to increasing population and low vehicle occupancy. Between 1999 and 2020, the rate of growth in vehicle miles traveled is projected to increase in the Base Case by about 2 percent per year. The overall efficiency of the passenger transportation system can be significantly improved through measures that contain the growth in vehicle miles traveled through land-use and infrastructure investments and pricing reforms to remove implicit subsidies for cars, which are very energy intensive.

We assume that these measures will primarily affect urban passenger transportation and result in a shift to higher occupancy vehicles, including carpooling, vanpooling, public transportation, and telecommuting. We consider that the level of reductions of vehicle miles traveled that can be achieved by these measures relative to the Base Case are 8 percent by 2010 and 11 percent by 2020.

High-Speed Rail

High-speed rail (HSR) offers an attractive alternative to intercity vehicle travel and short distance air travel. In both energy cost and travel time, high-speed rail may be competitive with air travel for trips of roughly 600 miles or less, which account for about one-third of domestic air passenger miles traveled. Investments in rail facilities for key inter-city routes (such as the Northeast corridor between Washington and Boston, the East cost of Florida between Miami and Tampa, and the route linking Los Angeles and San Francisco) could provide an acceptable alternative and reduce air travel in some of the busiest flight corridors[27].

In this analysis we have taken the DOT's recent estimates of the potential high-speed rail ridership which, based on projected mode shifts from air and automobile travel in several major corridors of the US, reaches about 2 billion passenger miles by 2020[28]. While this level of HRS ridership provides relatively small energy and carbon benefits by 2020, it can be viewed as the first phase of a longer-term transition to far greater ridership and more advanced, faster and efficient electric and MAGLEV systems in the ensuing decades.

2.4 Summary Results

Table 3 summarizes the carbon reductions and the net costs (generally net benefits) of each energy policy through 2010 and 2020. Carbon reductions reach 436 MtC in 2010 (about 24 percent below the Base Case in that year) and 954 MtC in 2020 (about 47 percent below the Base Case in that year). The costs were computed by discounting and summing the incremental annualized capital costs, administrative costs, incremental O&M and fuel costs, and subtracting the discounted O&M and fuel cost savings, using a 5 percent real discount rate. Overall the net savings achieved by the demand policies more than offset the net costs for the electric supply policies. The Climate Protection policy package as a whole results in cumulative net savings of $91 billion 2025 for both states.

Table 3. Carbon reductions, net costs, and cost per saved carbon in 2010 and 2020						
	2010			2020		
	Carbon Savings	Cumulative Net Cost (present value)	Cost of saved carbon	Carbon Savings	Cumulative Net Cost (present value)	Cost of saved carbon
	MtC/yr	billion (1999)$	(1999)$ per tC	MtC/yr	billion (1999)$	(1999)$ per tC
Buildings & Industry Sectors						
Appliance standards	29	-$24	-$315	86	-$84	-$256
Building Codes	7	-$5	-$353	30	-$23	-$244
Voluntary measures	61	-$50	-$229	118	-$112	-$179
Research and design	21	-$18	-$257	71	-$53	-$186
Public Benefits Fund	50	-$29	-$224	134	-$101	-$187
Tax Credits	4	-$4	-$292	11	-$8	-$152
CHP and DES	21	-$53	-$611	59	-$151	-$554
subtotal	**193**	**-$183**	**-$301**	**509**	**-$533**	**-$242**
Electric Sector						
RPS; NOx/Sox Cap and Trade;						
Carbon Cap and Trade						
subtotal	**147**	**$140**	**$258**	**190**	**$258**	**$188**
Transport Sector						
Vehicle Travel Reductions	29	-$50	-$496	37	-$126	-$495
LDV efficiency improvements	38	-$19	-$270	136	-$149	-$296
HDV efficiency improvements	8	-$3	-$179	33	-$22	-$214
Aircraft efficiency improvements	10	-$3	-$106	28	-$14	-$129
Greenhouse Gas Standards	11	$7	$227	22	$25	$237
subtotal	**95**	**-$68**	**-$272**	**255**	**-$286**	**-$265**
TOTAL	436	-$111	-$80	954	-$561	-$121

It is important to note that the large net savings achieved by the energy efficiency policies create the "economic space" into which policies for fuel shifting to low emissions and renewable energy resources and technologies and step, while retaining overall net economic benefits. Rather than limiting policies to those with net benefits at the margin, this approach takes the longer view, by bringing cutting edge options into early use, thereby inducing technology learning and setting the stage for the deeper carbon reductions for which they will be needed in the future, while getting deeper carbon and emissions reductions in the near term.

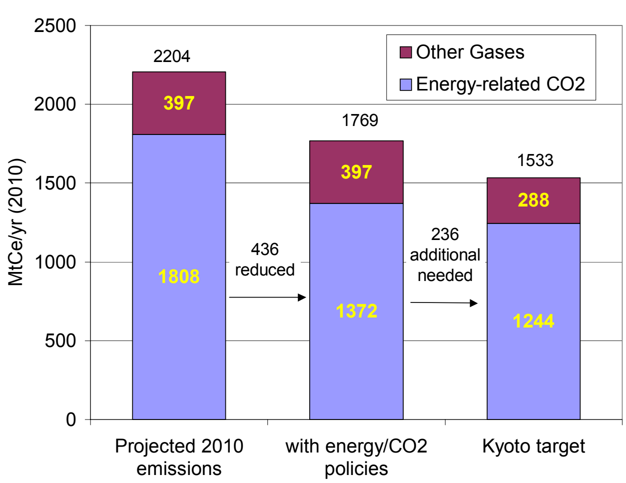
3. Achieving Kyoto

Energy-related CO_2 emissions are the predominant source of U.S. greenhouse gas emissions for the foreseeable future, and their reduction is the central and ultimate challenge for protecting the climate. Yet, with its delayed and weak emissions mitigation policies heretofore, the U.S. may not be able to rely solely on energy sector policies and technologies to meet its Kyoto obligation of emissions 7 percent reduction below 1990 levels with no net economic cost. As our analysis has shown, such efforts, if aggressively pursued, would slow our growth in energy sector CO_2 emissions from a projected 35 percent to 2.5 percent above 1990 levels by 2010 and still achieve a small net economic benefit. This would be a major accomplishment, but would still leave us 128 MtC/yr short of achieving a target of 1244 MtC/yr by 2010, if the Kyoto target were confined only to the domestic energy sector. A tighter carbon cap for the electric sector could increase domestic energy-related emission reductions to meet the Kyoto requirement, but this would incur incremental costs that could eliminate the net benefit and lead to a modest overall net cost.

Of course, there is more to the Kyoto agreement. The Kyoto targets cover six gases – methane (CH_4), nitrous oxide (N_2O), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), sulfur hexafluoride (SF6) and carbon dioxide. The use of these gases is currently growing, due to the ongoing substitution of ozone depleting substances (ODS) with HFCs, and to a lesser extent, to growth in CH_4 emissions from livestock and coal and natural gas systems, in N_20 from fertilizer use, and in PFC emissions from semiconductor manufacture[29].

The U.S. commitment requires emissions of all six gases, in aggregate, to be reduced to 7 percent below their baseline levels.[30] When all of the six "Kyoto gases" are considered, baseyear emissions amount to 1680 MtCe/yr, making the -7 percent Kyoto reduction target equal to 1533 MtCe/yr, as shown in the third column of Figure 2. The projected 2010 emissions for all six gases is 2204 MtCe/yr (first column), thus the total required reduction is expected to be 672 MtCe/yr. The energy-CO_2 policies described in the previous sections yield 436 MtCe/yr in reductions by 2010 (second column), leaving the U.S. with 236 MtCe/yr additional reductions to achieve from other policies and measures.

Figure 2: Projected Emissions, 2010, All Gases



The Kyoto agreement provides us with several options for obtaining the additional 236 MtCe/yr of reductions. Two of these options involve domestic reductions: the control of non-CO_2 gases ("multi-gas control") and the use of "sinks" or biotic sequestration, through the land use, land use change and forestry options allowed under the Protocol. The other options involve obtaining credits and allowances from international sources. Under the Kyoto Protocol, countries can purchase credits and allowances through the Clean Development Mechanism (CDM), Joint Implementation, or Emissions Trading (ET) to offset domestic emissions exceeding our 7 percent reduction target. This section examines how we might meet the Kyoto target through the use of these options, and what the costs and other implications might be.

3.1 Domestic Options

Article 3.3/3.4 and Sinks

GHG emissions and removals from land use and land use change and forestry (LULUCF) are a subject of great controversy and scientific uncertainty. The Kyoto Protocol treats LULUCF activities in two principal categories: afforestation, reforestation, and deforestation under Article 3.3, and "additional human-induced activities" such as forest and cropland management under Article 3.4. Different interpretations of these two articles can have widely varying impacts on the US reduction commitment.[31] For instance, the US estimate of business-as-usual forest uptake during the first commitment period is 288 MtCe/yr. If fully credited as an Article 3.4 activity, this uptake could provide credit equal to more than 40% of the US reduction requirement, with no actual mitigation effort. However, the vast majority of countries do not interpret the Protocol as allowing credit for business-as-usual offsets, and therefore believe they should be excluded.

Since our analysis was conducted prior to the July 2001 COP6bis meetings in Bonn, we based our LULUCF analysis on the "consolidated negotiating text" issued by Jan Pronk, President of COP6, in the weeks prior to the meeting.[32] The so-called "Pronk text" reflected an attempted compromise among various parties on a number of contentious issues, and was the basis for the final COP6bis outcome on LULUCF issues.[33] The Pronk text capped total US crediting from Article 3.4 activities and afforestation and reforestation projects in the CDM and JI at roughly 58 MtCe/yr.[34] Domestic forest management activities would be subject to an 85% discount. Thus, if one assumes the US estimate above, the Pronk rules would result in 42 MtCe/yr of essentially zero-cost credit for forest management activities that are expected to occur anyway.[35] In addition, agricultural management (e.g. no-till agriculture, grazing land management, revegetation) would be allowed under a net-net accounting approach that would allow the US to count another expected 10 MtCe/yr of business-as-usual, i.e. zero-cost, credit towards the cap. In sum, the Pronk proposal translates to 52 MtCe/yr of "free" carbon removals, and another 6 MtCe/yr that could be accrued through new domestic forest or agricultural management activities.[36]

Based on a recent summary of LULUCF cost estimates, we assumed that the 6MtCe/yr of "new" offsets allowable under the Pronk text would be purchased for $10/tCe.[37] A total of 58 MtCe/yr of LULUCF credit would therefore be available to help meet the reduction requirement of 236 MtCe/yr remaining after having adopted the energy-related CO_2 policies described above.

The net result of our analysis is slightly different than the implications of the COP6bis agreement. The agreement would allow approximately 28MtCe/yr of existing forest management, up to 16MtCe/yr of reforestation/afforestation through the CDM, and an unlimited amount of new Article 3.4 forest and agricultural management activities.[38] The difference is that the US would receive fewer "free" credits from business-as-usual activity, would need to pay a bit for domestic and CDM projects to reach the 58 MtCe/yr of assumed LULUCF activity modeled here. However, the US would no longer be capped with respect to the generation of further Article 3.4 offsets, potentially offering an expanded pool of lower cost reduction opportunities than modeled here.

Multi-gas Control

Multi-gas control is a fundamental aspect of the Protocol, and its potential for lowering the overall cost of achieving Kyoto targets has been the subject of several prominent studies (Reilly et al., 1999 and 2000). Table 4 shows baseline and projected emission levels for the non-CO_2 gases.[39]

Table 4: Baseline and Projected Emissions for the Non-CO_2 Kyoto Gases (MtCe/yr)

Gas	Base Year (1990/95)	7% Below Base Year	Projected 2010	Reductions Required[(a)]	Sources
Methane	170	158	186	28	(USEPA 1999)
Nitrous Oxide	111	103	121	18	(Reilly et al. 1999b; USEPA 2001a)
High GWP Gases (HFC, PFC, SF6)	29	27	90	63	(USEPA 2000)
Total	310	288	397	109	

(a) These are the reductions that would be needed if each gas were independently required to be 7 percent below its base year level.

Methane emissions are expected to grow by only 10 percent from 1990 to 2010, largely because of increased natural gas leakage and venting (due to increased consumption), enteric fermentation and anaerobic decomposition of manure (due to increased livestock and dairy production). Methane from landfills, which accounted for 37 percent of total methane emissions in 1990, are expected to decline slightly as a consequence of the Landfill Rule of the Clean Air Act[40], which requires all large landfills to collect and burn landfill gases.

Several measures could reduce methane emissions well below projected levels. USEPA estimates that capturing the methane from landfills not covered by the Landfill Rule, and using it to generate electricity, is economically attractive at enough sites to reduce projected landfill emissions by 21 percent.[41] At a cost of $30/tCe, the number of economically attractive sites increases sufficiently that 41 percent of landfill emissions can be reduced. Similarly, USEPA has constructed methane reduction cost curves for reducing leaks and venting in natural gas systems, recovering methane from underground mines, using anaerobic digesters to capture methane from manure. and reducing enteric fermentation by changing how livestock are fed and managed.

We have used a similar USEPA study to estimate the emissions reductions available for the high GWP gases.[42] Table 1 shows that the high-GWP gases, while only a small fraction of baseline emissions (first column), are expected to rise so rapidly that they will account for majority of net growth in non-CO_2 emissions relative to the 7 percent reduction target (last column). In many applications, other gases can be substituted for HFCs and PFCs, new industrial process can implemented, leaks can be reduced, and more efficient gas-using equipment can be installed. For instance, minor repairs of air conditioning and refrigeration equipment could save an estimated 6.5 MtCe/yr in HFC emissions by 2010 at cost of about $2/tCe. New cleaning processes for semiconductor manufacture could reduce PFC emissions by 8.6 MtCe/yr by 2010 at an estimated cost of about $17/tCe. In all, USEPA identified 37 measures for reducing high GWP gases, a list which is likely to be far from exhaustive given the limited experience with and data on abatement methods for these gases.

The major source of nitrous oxide in the U.S. is the application of nitrogen fertilizers, which results in about 70 percent of current emissions. Given the tendency of farmers to apply excess fertilizer to ensure good yields, effective strategies for N2O abatement from cropping practices has thus far been elusive. Thus, aside from measures to reduce N2O from adipic and nitric acid production (amounting to less than one MtCe/yr), and from mobile sources as a result of transportation policies (see below), we have not included a full analysis of N2O reduction opportunities[43].

Relying largely on recent USEPA abatement studies[44], we developed the cost curve for reducing non-CO_2 gases depicted in Figure 2 below.[45] In addition to what is covered in the USEPA studies, we assumed that:

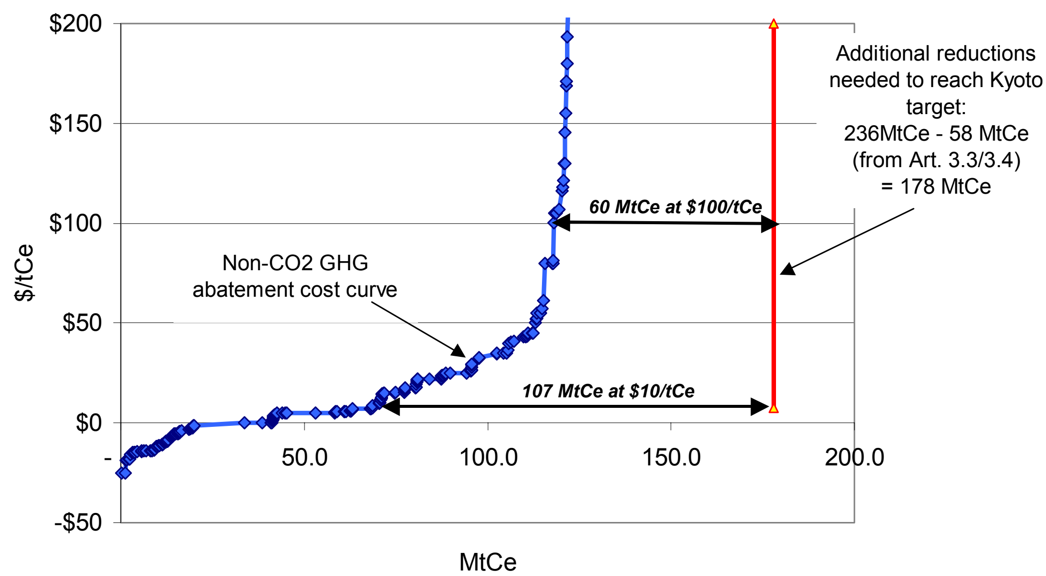
- Only 75 percent of the 2010 technical potential found in the USEPA studies would actually be achieved, and that policies and programs needed to promote these measures would add a transaction cost of $5/tCe.
- The savings in 2010 fossil fuel use resulting from the policies and measures implemented in the energy sector will yield corresponding benefits for several categories of non-CO_2 emissions. In particular, we assumed that a) reduced oil use in the transport sector (down 14 percent) will lead to a proportional decrease in N2O emissions from mobile sources[46]; b) reduced natural gas demand (down 13 percent) will result in proportionately fewer methane emissions from leaks and venting; and c) reduced coal production (down 49 percent) will lead to decreased underground mining and its associated emissions. [47]

Figure 3 shows that domestic options, taken together, are insufficient to reaching the Kyoto target. The line on the left is the “supply curve” of non-CO_2 abatement options, and the line on the right is the reduction requirement after both energy-related and Article 3.3/3.4 sinks are accounted for. Under current conditions (only 9 years left until 2010), the supply of remaining domestic options appears insufficient to satisfy demand. This gap ranges from 107 MtCe/yr at $10/tCe to 60 MtCe/yr at $100/tCe as shown. Therefore, to meet our Kyoto obligations, we are now in a situation of looking to the international market to fill this gap.

3.2 International Options

The Kyoto Protocol creates two principal types of greenhouse gas offsets in the international market: the purchase of surplus allowances from countries that are below their Kyoto targets and the creation of carbon credits through project-based mechanisms, CDM and JI.

Figure 3: Non-CO2 GHG Emissions Reductions, Cost and Potential, 2010



Emissions Allowance Trading/Hot Air

The combination of emission targets based on circa 1990 emissions and the subsequent restructuring and decline of many economies in transition (EITs) means that these countries could have a large pool of excess emissions allowances, typically referred to as "hot air" (see Appendix B). We assume that hot air will constitute no more than 50 percent of all international trading, and we assume a maximum availability of 200 MtCe/yr, based on a recent analysis.[48]

CDM and JI

CDM and JI projects, can be an important part of a comprehensive climate policy, providing they truly contribute to sustainable development in the host countries and create genuine, additional GHG benefits. It is reasonable to expect that the U.S. government and other stakeholders will want to develop the CDM and JI market in order to involve developing countries, engage in technology transfer, develop competitive advantages, and prepare for future commitment periods.

Similarly, the possibility of limited crediting lifetimes, or discounting of carbon reductions in future projects years, as proposed by some, could increase the effective cost per tCe. In a recent analysis, Bernow *et al*. (2000) illustrated how different approaches to standardizing baselines could lead to differences in additional power sector activity (tCe) of a factor of 4. These types of considerations are rarely included in CDM/JI analyses, either bottom-up or top-down.

Given the small differences between the two different approaches, we adopt the top-down results of the GTEM model,[49] since they provide a fuller CDM curve, include multiple gases, and provide a cost curve for JI investments as well.

3.3 Combining the Options

There are two ways to combine the available options to meet our Kyoto target. We can prioritize which options to rely on more heavily, based on their strategic advantages and co-benefits, as we have done for energy/CO_2 policies. Or we can simply seek lowest-cost solution for the near-term. A long-term climate policy perspective argues for the former approach. For example, rules and criteria for JI, and especially CDM, should be designed so that additionality, sustainability, and technology transfer are maximized. Ideally, our cost curves for CDM and JI would reflect only investments that are consistent with those criteria. However, our current ability to reflect such criteria in quantitative estimates of CDM and JI potential is limited.[50]

It is possible to model priority investment in the domestic reductions of non-CO_2 gases by implementing some measures that are higher cost than the global market clearing carbon price. Just as energy/CO_2 measures like a Renewable Portfolio Standard can be justified by the technological progress, long-term cost reductions, other co-benefits that they induce, so too can some non-CO_2 measures. While we have not attempted to evaluate specific policies for non-CO_2 gases as we have for CO_2, we have picked a point on the non-CO_2 cost curve, \$100/tCe, to reflect an emphasis on domestic action. At \$100/tCe, domestic non-CO_2 measures can deliver 118 MtCe/yr of reductions, still about 60 MtCe/yr short of the Kyoto goal, to which we must turn to the international market.

To model the global emissions trading market, we used the CDM/JI cost curves, and hot air assumptions described above, together with assumptions regarding the demand for credits and allowances from all Annex B parties.[51] This model yields market-clearing prices and quantities for each of the three principal flexible mechanisms: CDM, JI, and ET/hot air.[52] The results are shown in Table 5.

Table 5: Reductions Available in 2010 Up From Various Sources (in MtCe)

	Domestic Options		International Trade			
	Non-CO_2 gases	Sinks	CDM	JI	Hot air (ET)	Total
Amount available at < or = \$0/tCe (MtCe)	41	52				93
Amount available at \$0-\$100 (MtCe)	77	6				83
Amount available at \$8 (MtCe)			30	6	25	60
Annual costs (\$Million)	\$1,783	\$60	\$235	\$48	\$196	\$2,322

The first row of the table shows that 93 MtCe/yr are available at net savings or no net cost, over half from the non-additional or "anyways" forest management and other Article 3.4 sinks activities implicit in the Pronk text. Another 77 MtCe/yr of non-CO_2 gas savings are available as we climb the cost curve from \$0-100/tC (second row). The net result is that nearly \$1.8 billion per year is invested in technologies and practices to reduce non-CO_2 GHG emissions by 118 MtCe/yr in 2010. Another \$60 million per year is directed toward the 6 MtCe/yr of expected additional sinks projects allowed under the Pronk proposal. The third row shows that of the 60 MtCe/yr of international trading, half comes from CDM projects, and much of the rest from hot air. The model we use estimates a market-clearing price of about $8/tCe for this 60 MtC/yr of purchased credits and allowance, amounting to a total annual cost of less than $500 million.[53]

In summary, of the 672 MtCe/yr in total reductions needed to reach Kyoto by 2010, nearly 65 percent comes from energy sector CO_2 reduction policies, 18 percent from domestic non-CO_2 gas abatement, 9 percent from domestic sinks, and 9 percent from the international market. The net economic benefits deriving from the energy-related carbon reductions reach nearly $50 billion/yr in 2010. The total annual cost for the 35 percent of 2010 reductions coming those last three options – non-CO_2 control, sinks, and international trading – is estimated at approximately $2.3 billion, making the total package a positive economic portfolio by a large margin. Had we taken the other approach noted at the beginning of the section – aiming for the lowest near-term compliance cost – we would rely more heavily on international trading. We modeled this scenario, and found that it would nearly double the amount of international trading, and lower the overall annual cost to $0.9 billion, and reduce the amount of non-CO_2 control by over 40 percent. This additional benefit is minor in comparison to the economic and environmental benefits of the entire policy portfolio.

4. Conclusions

This study shows that the United States can achieve its carbon reduction target under the Kyoto Protocol – 7 percent below 1990 levels for the first budget period of the Protocol. Relying on national policies and measures for greenhouse gas reductions, and accessing the flexibility mechanisms of the Kyoto Protocol for a small portion of its total reductions, the U.S. would enjoy net economic savings as a result of this Climate Protection package. Such action would lead to carbon emission reductions of about 24 percent by 2010 relative to the Base Case, bringing emissions to about 2.5 percent above 1990 levels. Furthermore, emissions of other pollutants would also be reduced, thus improving local air quality and public health.

Adopting these policies at the national level through legislation will not only help America meet its Kyoto targets but will also lead to economic savings for consumers, as households and businesses would enjoy annual energy bill reductions in excess of their investments. These net annual savings would increase over time, reaching nearly $113 per household in 2010 and $375 in 2020. The cumulative net savings would be about $114 billion (present value 1999$) through 2010 and $576 through 2020.

While implementing this set of policies and additional non-energy related measures is an ambitious undertaking, it represents an important transitional strategy to meet the long-term requirements of climate protection. It builds the technological and institutional foundation for much deeper long-term emission reductions needed for climate protection. Such actions would stimulate innovation and invention here in the U.S. while positioning the U.S. as a responsible international leader in meeting the global challenge of climate change.

[1] This study -- *The American Way to the Kyoto Protocol* (2001) -- was undertaken by Tellus Institute for World Wildlife Fund for Nature (WWF). "Important input to that study was provided on energy efficiency (by colleagues at American Council for an Energy-efficient Economy) and on renewable energy (by colleagues at Union of Concerned Scientists and other experts).

[2] EIA, 2001a. *Annual Energy Outlook 2001 with Projections to 2020.* U.S. Department of Energy, Washington D.C.

EIA, 2001b. *U.S. Carbon Dioxide Emissions from Energy Sources, 2000 Flash Estimate. U.S.* Department of Energy. http://www.eia.doe.gov/oiaf/1605/flash/sld001.htm

[3] Under Kyoto, the base year for three of the non-CO2 GHGs (HFCs, PFCs, SF6) is 1995, not 1990, and the 1995 levels for these emissions are reported here.

[4] Savings are in 1999 $. The 2010 savings include $2.3 billion costs per year ($9 billion cumulative through 2010) of non-energy related measures needed to meet the Kyoto target. Costs are not included in 2020 since these measures policies do not extend past 2010.

[5] Impacts were made using an I-O model, taking account of productivity trends, and assuming that there is otherwise less than full employment in those job/skill areas that would be required by the shifts from energy to other demands caused by the policies.

[6] ACEEE, 1999. *Meeting America's Kyoto Protocol Targets.* H. Geller, S. Bernow and W. Dougherty. Washington, D.C.: American Council for an Energy-Efficient Economy.

[7] Throughout this report we refer to U.S. emissions target for the year 2010 to mean the average of the five year period from 2008 to 2012.

[8] Same as ACEE, 1999.

[9] Bernow, S. K. Cory, W. Dougherty, M. Duckworth, S.Kartha and M. Ruth, 1999. *America's Global Warming Solutions.* Washington, D.C.: World Wildlife Fund.

[10] EIA, 2001a. *Annual Energy Outlook 2001 with Projections to 2020.* U.S. Department of Energy, Washington D.C.

EIA, 2001b. *U.S. Carbon Dioxide Emissions from Energy Sources, 2000 Flash Estimate. U.S.* Department of Energy. http://www.eia.doe.gov/oiaf/1605/flash/sld001.htm

[11] BCAP, 1999. *Status of State Energy Codes*. Washington, D.C.: Building Codes Assistance Project, Sept./Oct.

[12] Ibid

[13] Nadel, S. and H. Geller, 2001. *Smart Energy Policies: Saving Money and Reducing Pollutant Emissions though Greater Energy Efficiency.* American Council for and Energy-Efficient Economy, with Tellus Institute. Report No. E012. Washington, D.C.

[14] The bills include those introduced by Senators Murkowski and Lott (S.389); Bingaman and Daschle (S.596), Smith (S.207), Hatch (S.760), and Representative Nussle (H.R. 1316).

[15] Nadel, Steven and Marty Kushler. 2000. "Public Benefit Funds: A Key Strategy for Advancing Energy Efficiency." *The Electricity Journal*. Oct., pp. 74-84.

[16] EERE, 2000. *Scenarios for a Clean Energy Future*, Prepared by the Interlaboratory Working Group on Energy-Efficient and Clean-Energy Technologies, Washington, D.C.: U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy.

[17] EPA, 2001. "The Power of Partnerships, Climate Protection Partnerships Division, Achievements for 2000—In Brief." Washington, D.C.: U.S. Environmental Protection Agency.

Brown, Rich, Carrie Webber, and Jon Koomey, 2000. "Status and Future Directions of the ENERGY STAR Program," In *Proceedings of the 2000 ACEEE Summer Study on Energy Efficiency in Buildings*, 6.33–43. Washington, D.C.: American Council for an Energy-Efficient Economy.

[18] Elliott, R. N. and M. Spurr, 1999. *Combining Heat and Power: Capturing Wasted Energy.* Washington, D.C.:American Council for an Energy-Efficient Economy.

[19] Burtraw, D., K. Palmer, R. Barvikar and A. Paul, 2001. *The Effect of Allowance Allocation on the Costs of Carbon Emissions Trading.* Discussions Paper 01-30. Washington, D.C.: Resources for the Future.

[20] Assuming a mean value at a market price of oil of $20/barrel.

U.S. Geological Survey, 2001. Arctic National Wildlife Refuge, 1002 Area, Petroleum Assessment, 1998, Including Economic Analysis. Fact Sheet FS-028-01, April. (See also U.S. Geological Survey, 1999. The Oil and Gas Resource Potential of the Arctic National Wildlife Refuge 1002 Area, Alaska. USGS Open File Report 98-34.

[21] Assuming a retail price of gasoline of $1.50/gallon, a 10-year life of the vehicle, and 12,000 miles per year.

[22] Assuming typical load factors of 0.33 for autos and 0.6 for air.

[23] Lee, J.J., S.P. Lukachko, L.A. Waitz and A. Schaefer, 2001. "Historical and Future Trends in Aircraft Performance, Cost and Emissions." Forthcoming in *Annual Review of Energy and the Environment*, Vol 26. November.

Office of Technology Assessment, 1994. *Saving Energy in U.S. Transportation*, OTA-ETI-589, Washington, D.C.

Interlaboratory Working Group, 2000. *Scenarios for a Clean Energy Future.*Argonne National Laboratory, the National Renewable Energy Laboratory, Lawrence Berkeley National Laboratory, Oak Ridge National Laboratory and Pacific Northwest National Laboratory. Commissioned by DOE Office of Energy Efficiency and Renewable Energy. http://www.ornl.gov/ORNL/Energy_EFF/CEF.htm.

[24] Walsh, M., B. Perlack, D. Becker, A. Turhollow and R. Graham, 1997. *Evolution of the Fuel Ethanol Industry: Feedstock Availability and Price. Biofuels Feedstock* Development Program. Oak Ridge, TN: Oak Ridge National Laboratory.

Walsh, M., R. Perlack, D. Becker, A. Turhollow, D. Ugarte, D. Becker and R. Graham, S. Slinsky and D. Ray, 1999. *Biomass Feedstock Availability in the United States: Draft*. Oak Ridge National Laboratory. Oak Ridge Tennessee. April.

[25] Lynd., L. 1997. "Cellulosic Ethanol Technology in Relation to Environmental Goals and Policy Formulation." in J. DeCicco and M. DeLucchi, eds., *Transportation, Energy and Environment: How Far Can Technology Take Us?* Washington, D.C.: American Council for an Energy-Efficient Economy.

[26] Interlaboratory Working Group, 2000, same as above.

[27] USDOT 1997 U.S. Department of Transportation, 1997. *High-Speed Ground Transportation for America.* Federal Railroad Administration. Washington, D.C.

[28] USDOT 1997, same as above.

[29] USEPA, 2001. "The Power of Partnerships, Climate Protection Partnerships Division, Achievements for 2000—In Brief." Washington, D.C.: U.S. Environmental Protection Agency.

[30] These gases can be controlled interchangeably, using 100 year Global Warming Potentials (GWP), so long as the total carbon-equivalents (C_e) are reduced to 93 percent of their baseline levels. In contrast to the main three gases (CO2, CH4, and N2O), which have a 1990 base year, the high GWP gases have a base year of 1995.

[31] For instance, different accounting methods and rules have been considered regarding: a) what constitutes a forest; b) which biotic pools and lands are counted; c) which activities are considered eligible for crediting under Article 3.4; and d) uncertainties in measuring above and below ground carbon stocks.

[32] See "Consolidated negotiating text proposed by the President", as revised June 18, 2001, FCCC/CP/2001/2/Rev.1, http://www.unfccc.int/resource/docs/cop6secpart/02r01.pdf

[33] See FCCC/CP/2001/L.7. Review of the implementation of commitments and of other provisions of the Convention. Preparations for the first session of the Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol (Decision 8/CP.4). Decision 5/CP.6. Implementation of the Buenos Aires Plan of Action.

[34] The Pronk text, along with the COP6bis agreement, prohibits first commitment period crediting of CDM projects that avoid deforestation.

[35] This figure is drawn from the Annex Table 1 of the April 9 draft of the Pronk text, which adopts Pronk adopts the accounting approach for Article 3.3. activities suggested by the IPCC Special Report of LULUCF. This approach yields an Article 3.3 debit of 7 MtCe/yr from net afforestation, reforestation, and deforestation activity, which under the Pronk approach could be offset fully by undiscounted forest management activities. Thus the 42 MtCe/yr estimate is based on 85% x (288 – 7) MtCe/yr.

[36] The Pronk proposal also allowed this cap to be filled through afforestation and deforestation activities in the CDM.

[37] Missfeldt and Haites (2001) use a central estimate of 50 MtCe/year at $7.50/tCe for CDM afforestation and reforestation projects. They also assume the availability of 150 MtCe/year at $15/tCe for Article 3.4 sinks in Annex B countries. Note however that the Pronk 85% discount on forest management projects would, in principle, increase their cost accordingly (by 1/.15 or 6.7 times). However, given the relatively small quantity (6 MtCe) that could be purchased, lower cost opportunities in cropland management or the CDM should more than suffice.

[38] This figure is listed in a footnote to the agreement, since the US was not a party to it.

[39] USEPA (1999, 2000) expects voluntary Climate Change Action Plan (CCAP) activities to reduce 2010 methane and high GWP gas emissions by about 10 percent and 15 percent, respectively, reductions that are not included in their 2010 projections shown in Table 1. Instead these reductions are embodied in both their and our cost curves.

[40] USEPA, 1999, same as above.

[41] USEPA, 1999. *U.S. Methane Emissions 1990 – 2020: Inventories, Projections, and Opportunities for Reductions*, U.S. Environmental Protection Agency, Office of Air and Radiation, September . http://www.epa.gov/ghginfo.

[42]USEPA, 2000. *Estimates of U.S. Emissions of High-Global Warming Potential Gases and the Costs of Reductions*, Review Draft, Reid Harvey, U.S. Environmental Protection Agency, Office of Air and Radiation, March. http://www.epa.gov/ghginfo.

[43] USEPA, 2001b. Draft U.S. Nitrous Oxide Emissions 1990-2020: Inventories, Projections, and Opportunities for Reductions. EPA, Washington, DC, September, 2001.

[44] USPEA, 1999, 2000, 2001b, same as above.

[45] The result is a cost curve that is similar and more up-to-date than that used in widely cited multiple gas studies (Reilly et al, 1999a; Reilly et al, 1999b; EERE, 2000).

[46] A similar assumption is used by European Commission (1998). Approximately fifteen percent of N2O emissions are a byproduct of fuel combustion, largely by vehicles equipped with catalytic converters (USEPA, 2001a).

[47] We assume that coal production is a proportional to coal use (i.e. we ignore net imports/exports). USEPA expects that the marginal methane emissions rate will increase with production as an increasing fraction is expected to come from deeper underground mines (USEPA, 1999).

[48] Victor, David G., Nakicenovic, Nebojsa, and Victor, Nadejda, 2001, "The Kyoto Protocol Emission Allocations: Windfall Surpluses for Russia and Ukraine," Climatic Change **49** (3):263-277, May 2001.

[49] Grütter, J. 2001. *World Market for GHG Emission Reductions: An analysis of the World Market for GHG abatement, factors and trends that influence it based on the CERT model*. Prepared for the World Bank's National AIJ/JI/CDM Strategy Studies Program, March, 2001.

[50] We did briefly examine the potential contribution of a CDM fast track for renewables and efficiency, as embodied in the Pronk text. Applying the power sector CDM model developed by Bernow et al (2001), we found that a carbon price of $20/tCe would induce only 3 MtCe/yr of new renewable energy project activity by 2010. At a price of $100/tCe, this amount rises to 18 MtCe/yr. Given that a large technical potential for energy efficiency projects exists at low or negative cost per tCe, fast track efficiency projects (under 5 MW useful energy equivalents according to Pronk text) could significantly increase the amount available at lower costs.

[51] For the estimated demand for CDM, JI, and ET/hot air from other Annex 1 parties, we used a combination of EPPA and GTEM cost curves.[51] (Reilly et al, 1999b, and Ellerman and Decaux, 1998; Vrolijk and Grubb, 2000; Grutter, 2001).

[52] Our approach is similar to that used in a few other recent studies (Grutter, 2001; Haites, 2000; Missfeldt and Haites, 2001; Krause et al, 2001; Vrolijk and Grubb, 2000).

[53] The market clearing price is lower here than in other similar studies, due in large part to a much lower U.S. demand for international trade, which results from of our aggressive pursuit of domestic abatement options and the fact that we assume that domestic policies and investments should be done as a matter of sound energy and environmental policy (i.e. they are price-inelastic).