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Kyoto Testimony

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Main Kyoto Report

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What Does the Kyoto Protocol Mean to U.S. Energy Markets and the U.S. Economy?

A Briefing Paper on the
Energy Information Administration's Analysis and Report

Prepared for
the Committee on Science, U.S. House of Representatives

October 1998

Completed Kyoto Report

Economic Effects of a Complex Agreement Depend on Many Assumptions

The Kyoto Protocol, negotiated by more than 160 nations in December 1997, aims to reduce net emissions of certain greenhouse gases (primarily carbon dioxide (CO_2)). Each of the participating developed countries must decide how to meet its respective reduction goal during a five-year period (2008-2012); but specific ground rules remain to be worked out at future negotiating sessions. The next meeting is in Buenos Aires (November 1998).

In a study entitled *Impacts of the Kyoto Protocol on U.S. Energy Markets and Economic Activity*, the Energy Information Administration (EIA), an independent statistical and analytical agency in the U.S. Department of Energy, has projected that meeting the U.S. targets under the Protocol will call for significant market adjustments:

- Reductions in CO_2 emissions will result in between 18 and 77 percent less coal use than projected in the EIA Reference Case in 2010, particularly affecting electricity generation, and between 2 and 13 percent less petroleum use, mainly affecting transportation.
- Energy consumers will need to use between 2 and 12 percent more natural gas in 2010 and between 2 and 16 percent more renewable energy, and extend the operating life of existing nuclear units.
- To achieve these ends via market-based means, average delivered energy costs (in inflation-adjusted 1996 dollars) must be between 17 and 83 percent higher than projected in 2010.
- The amount prices must rise is uncertain. Accounting procedures and international trading rules for greenhouse gases are not finalized. Forecasting technological change and public response to it under various pricing scenarios is an inexact science. The more stringent the need for domestic

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emission reductions, however, the more costly the adjustment process will be.

EIA undertook this study in response to a request by the Chairman and Ranking Minority Member of the House Committee on Science that it analyze impacts of the Protocol (which the President has not yet submitted to the U.S. Senate for ratification) on U.S. energy use, prices, and the general economy in the 2008-2012 time frame. That is when this country is supposed to reach an average level of net greenhouse gas emissions 7 percent lower than they were in 1990--having shown demonstrable progress toward that goal by 2005. At the Committee's request, EIA assumed that actions begin in 2005.

EIA was asked to do the study for several reasons. More than 80 percent of the human-originated greenhouse gas emissions are energy-related. EIA's National Energy Modeling System (NEMS) is perhaps the most complete, integrated, regional computer model available to simulate all elements of U.S. energy supply and demand in the context of the full U.S. macroeconomy. NEMS presents year-by-year projections over a 20-year horizon, accounting for capital stock turnover and the availability and penetration of specific energy-consuming technologies. Its annual "Reference Case" assumes no change from existing laws and regulations, and so it provides a base from which to evaluate policy options or alternative assumptions.

EIA analyzed six cases to investigate the uncertain range of impacts which could result from the Kyoto Protocol. Differences among the cases analyzed arise from three facts: 1) The Protocol gives credit for "CO_2- equivalent" reductions in five gases other than CO_2--methane, nitrous oxide, and three synthetic gases--as well as for certain actions that take carbon out of the atmosphere (such as preserving or extending forests); 2) participating developed countries are allowed to sell excess "permits" (e.g., because of economic problems since 1990 in the participating countries of the former Soviet Union, they may have about 165 million metric tons of carbon permits easily available); and 3) support for effective programs in other countries can earn permits. Details of this last process (called "Joint Implementation" among developed countries and the "Clean Development Mechanism," or CDM, for developing countries) are unsettled.

EIA's six cases cover a range of reductions in energy-linked carbon emissions from an annual average of 122 million metric tons below the expected baseline emissions (1990+24% Case) to 542 million metric tons (1990-7% Case) in 2008-2012. In the 1990+24% Case, domestic actions may furnish about one-fifth of all reductions, with the rest coming from international activities (including trading), offsets of other gases, and carbon sinks in the U.S., while the 1990+9% Case assumes that nearly 60 percent of the reductions result from such domestic initiatives as fuel-switching, improved technology, and cutbacks in energy use. EIA did not separately calculate the contributions of international activities, offsets or sinks for any case. The 1990-3% Case assumes all reductions are from domestic actions, with a 4 percentage point contribution from sinks and offsets from other gases. In the 1990-7% case, all reductions must come from domestic energy-related reductions.

The Kyoto Protocol does not specify targets for greenhouse gases after the period 2008-2012. At the Committee's request, EIA held the target for energy-related carbon emissions in the commitment period constant to 2020, the end of the forecast horizon. Targets following the 2008-2012 period will be a topic at future negotiating sessions.

To reduce carbon emissions, EIA assumes that a "carbon price" is added to the price of delivered energy fuels based on their carbon content. For example, coal prices rise more than petroleum and natural gas prices; and the cost of generating electricity from non-carbon-emitting nuclear and renewable fuels is not increased due to the carbon price. Although electricity does not have the carbon price directly added to it, its price is increased due to the higher cost of fossil fuels used for generation.

The price increases encourage a reduction in the use of energy services (heating, lighting, and travel, for example), the adoption of more energy-efficient equipment, and a shift to less carbon-intensive fuels. The carbon price reflects the amount fossil fuel prices in the U.S., adjusted for the carbon content of the fuel, must rise to achieve the removal of the last ton of carbon emissions that meets the carbon reduction target in each case.

In most of the cases, the carbon price peaks early in the 2008-2012 period, reaching between $67 and $348 per metric ton in 2010, and then declines as energy markets adjust and more efficient, new technologies become available and gradually penetrate the market. In the least stringent reduction cases, the increase is more gradual throughout the period because less severe reductions need to be made. Looking at average carbon prices over the commitment period 2008 to 2012 shows how the cost of compliance increases with increasingly stringent targets.

Differences in the cost of energy will affect the outlook for U.S. jobs, consumer prices, investment, technical change, and economic growth. Whenever use of a factor of production such as energy is restricted, economic performance falls for some period of time, the price of energy and other goods and services rises, and consumption and employment decline. Hence the various cases affect the national economy to varying degrees.

Electricity and Coal Industries Face Major Adjustments

Well over one-third of all primary energy consumed by the United States today goes into producing and delivering electricity. At the point of use, electricity can be highly efficient; and there are certain end uses where fuel substitution is not feasible. More than one-half of all U.S. electricity generated in 1997 was produced from coal--a fuel that emits more carbon dioxide during combustion than any other fossil fuel. Thus, electricity production and consumption is likely to be a major focus in meeting Kyoto targets, accounting for between two-thirds and three-fourths of the domestic carbon reductions in 2010 in the various cases examined. Historically, this industry has responded when relative fuel prices have changed.

Because coal is the most carbon-intensive of the fossil fuels, delivered prices for coal are affected by carbon prices more than other fuel prices. They are between 153 and 800 percent higher in 2010. The various cases studied for show prices for electricity between 20 and 86 percent higher in all end-use sectors, reflecting both the increased fuel costs and the incremental capital investments for non-coal generating capacity--either by traditional utilities or by non-utility generators in an increasingly restructured industry. The price rise for electricity is moderated somewhat by the fact that fuel is only part of the cost of generating electricity and that the cost of generation from renewables and nuclear power are unaffected by carbon prices. Neither of these fuels, however, can replace significant amounts of coal in the

2008-2012 timeframe. By 2020, non-hydro renewables (chiefly wind turbines, biomass in advanced technological applications, and to a lesser extent, geothermal facilities) penetrate the market in a significant way--providing as much as one-fifth of generation at the highest carbon prices. While hydroelectric dams have accounted for four-fifths of the renewable energy used for U.S. electricity production to date, the expansion of hydroelectric capacity is capital-intensive and is likely to meet with environmental objections; thus little additional hydroelectric capacity is expected. The bulk of the substitution for coal generation would be natural gas, because of its lower carbon content and the high efficiency of gas-fired combined cycle plants.

Furthermore, demand for industrial steam coal and metallurgical coal is also reduced because of a shift to natural gas in industrial boilers and a reduction in industrial output.

Because domestic coal consumption is between 18 and 77 percent lower in 2010 in the carbon reduction cases, there would be ripple effects on the industry. For example, even though total coal production drops, the average price per ton for coal at the minemouth in 2010 is between 3 and 28 percent higher than the Reference Case price. This is because a larger share of production would come from higher-cost Eastern coal mines, which tend to serve the remaining markets. Carbon prices raise the cost of rail transportation (involved now in delivering two-thirds of all coal) and make Western coal less competitive. The production of Western coal is discouraged further by the reduced size of the market and the reduced profitability of investing in new coal mines (which have been mostly in the West).

For the past two decades or so, the number of coal miners in this country has been declining by nearly 6 percent per year, primarily as a result of improved labor productivity (especially in large Western surface mines). Without taking the Kyoto Protocol in consideration, the Reference Case already projects a further employment drop of more than 15 percent--leaving only about 69,000 U.S. coal miners by 2010. In the carbon reduction cases, between 10,000 and 43,000 more jobs could be lost. Some of these job losses could be offset by growth in employment in the natural gas and renewable industries.

While no new nuclear power plants are considered in these cases, extending the licenses of existing plants is projected to become more economical with higher carbon prices. In more stringent carbon reduction cases, most existing nuclear plants are operated through 2020, in contrast to the Reference Case outlook that projected about half of the nuclear plants would be retired by that time.

Although reduced demand for electricity and improved efficiency in its generation can contribute to reducing carbon emissions from electricity generation, fuel-switching accounts for most of the reductions. In the short run, power suppliers would increase their use of less carbon-intensive plants, including steam plants that use oil and gas to heat their boilers. Much more efficient and cost-effective combined-cycle systems increase their share as new capacity is added.

All Sectors Need to Adjust; Motor Vehicles Face Main Non-Electric Impact

EIA assumes that carbon prices would be imposed at the point of consumption--

raising the "delivered" prices of both primary fuels and electricity across the board. Because various fuels face different price increases (based on their different carbon contents), all end-use sectors will not be affected identically. History has shown that residential, commercial, industrial, and transportation users of energy react differently to price changes.

As energy costs rise, all consumers tend to use less. In the broadest terms, the required carbon reductions could prompt the nation to lower "energy intensity" (the quantity of energy consumed per dollar of Gross Domestic Product) as much as three times faster between 2005 and 2010 than in the Reference Case. The rate of decline slows after 2010 reaching a decline rate from 1.4 to 1.7 percent for the 2005 to 2020 period. In the Reference Case, energy intensity declines at 0.9 percent per year.

In all cases, consumers have a price incentive to reduce their demand for energy services, to switch to lower-carbon energy sources, and to invest in more energy-efficient technologies. A number of more efficient and lower-carbon technologies for electricity generation become economically available as the carbon price raises fossil-fuel prices. Those who produce and sell electricity are likely to respond vigorously to higher fuel prices because this industry has long been accustomed to factoring future energy prices into investment choices; and competition is becoming keener because of ongoing regulatory reforms. By contrast, residential consumers tend to respond less to fuel prices, paying more attention to other factors (such as style, familiarity, convenience).

However, electricity prices, which are 20 to 86 percent higher than the reference case in 2010, are more than matched in percentage terms by the projected 25- to 147-percent rise in natural gas prices due to increased demand and the inclusion of the "carbon price." Thus, in end-uses where electricity competes with natural gas (such as home heating), the former becomes relatively more attractive. Although petroleum products, on average, contain more carbon than does natural gas, the price of natural gas would be increased by a greater percentage, in part because current prices for gasoline (a major end use of petroleum) incorporate Federal and State taxes. Also, lower world oil demand as a result of the Protocol would lower crude oil prices and offset part of the "carbon price" on oil products.

As prices for any factor of production increase, all goods and services reflect some cost increases they otherwise would not see. As higher energy prices are transmitted throughout the economy, people will react in part by buying less of everything. To some extent, this means U.S. industry and business must cope with smaller product demand, so that total output falls (thus cutting back further on emissions). In addition, industrial consumers of energy are prompted to replace existing facilities and adopt more efficient technology faster (assuming investment dollars are available), besides switching to less carbon-intensive fuels. The net result is an incremental gain in energy efficiency. If demand for energy-efficient products in the U.S. market should coincide with the appearance of new inventions and processes, a situation analogous to the rapid improvements and cost reductions in computers might occur. However, EIA does not include "breakthroughs" in end-use and generating technologies that are not yet on the drawing board because it is unlikely that they could be developed and penetrate rapidly enough to be significant in the 2008-2012 time period.

Higher fuel prices reduce total residential demand for energy, by promoting the installation of more efficient building shells, heating- and cooling- units, water heaters, and other end-use technologies, which results in larger carbon reductions than cutting back on miscellaneous items such as computers, TV sets, and VCRs. While total energy use by 2010 was projected at 184 million Btu per household in the Reference Case, it ranges between 145 and 173 million Btu in the six carbon reduction cases analyzed.

Space conditioning (heating, cooling, and ventilation) is the most significant energy use in the commercial sector, representing the best opportunity for reducing carbon emissions in the future. More efficient lighting and office equipment also contribute to carbon reductions (along with some modifications in the use of computer and telecommunications equipment). Total energy use per square foot of commercial floorspace in 2010 (206 thousand Btu in the Reference Case) is projected across the cases to drop to between 148 and 192 thousand Btu.

The U.S. transportation sector represents the single largest target for carbon reductions apart from electricity generation, because the transport sector is the biggest U.S. consumer of petroleum by far. A combination of more efficient vehicles and less travel would be needed across all modes. Total petroleum consumption in the transportation sector is between 2 and 16 percent lower in 2010 than in the Reference Case. Because of the impact of higher energy prices on the economy, there is less demand for air travel and freight shipment. In addition, airline fares are higher as a result of higher jet fuel prices, so air travel is between 1 and 18 percent lower. Consumption by aircraft is between 1 and 16 percent lower and freight trucks consume 1 to 6 percent less fuel.

Rising Price Could Level Off or Lower Gasoline Use

In approximately the past 25 years Americans have doubled the number of vehicle-miles traveled on U.S. streets and highways, increasing the average miles traveled per vehicle by about 12 percent. In the Reference Case, however, this rising trend is projected to slow modestly--even without the addition of a "carbon price" at the gasoline pump. Baby-boomers are aging, driving age population growth is slowing, miles driven by women are approaching a gender-equilibrium, and there are more older cars on the road (which typically are not driven as much as new cars). Historically, increases in gasoline prices have not done much to decrease the overall steady upward climb in motor fuel consumption.

Across the cases, the average price of gasoline increases by between 11 and 53 percent beyond the Reference Case price in 2010. In the 1990+24% Case, the average price of gasoline is only about 15 cents above 1996 prices in 2010 (1996 dollars). For the 1990+9% Case, the average price of gasoline peaks around 2008 at approximately 30 cents per gallon above where it was in 1996 ... and about 10 cents more than it was in 1990. In the 1990-3% Case, the average price of gasoline peaks at slightly more than $1.80 a gallon in 2009, while in the 1990-7% Case, it almost reaches $2.00 a gallon.

The addition of a "carbon price" is expected to reduce auto travel and increase the purchase of more efficient vehicles, reducing gasoline demand between 3 and 18 percent in 2010. Improvements in truck, auto, and plane efficiency are moderated by slow turnover rates. The stock of U.S. vehicles is so large that its average performance lags far behind advances in new car mileage. Increasing new car efficiency in 2010 by 1 to 6 miles per gallon above the 30.6 miles per gallon in the Reference Case improves the rating of the entire stock of light-duty vehicles by only about one mile per gallon or less.

EIA assumed that more than 50 fuel-saving technologies would be available to makers of light- duty vehicles during the period examined--ranging from electronic transmission controls to reduced cylinder friction; but a major uncertainty is whether consumers will purchase fuel efficient vehicles or continue the recent trend toward light trucks and sports utility vehicles. Some reversal is expected, particularly when the carbon price is relatively high. For example, in the 1990+9% case, the subcompact share of new car sales in 2010 is 19 percent compared to 12 percent in the Reference Case, reducing sales of compact, midsize, and large vehicles by 2 percentage points each. The annual increase in average horsepower ratings in the 1990+9% Case is about half that of the Reference Case.

The Reference Case foresaw sales of about 1.8 million alternative-fuel vehicles by 2010, but this number would not be affected much by imposition of a carbon price. While AFV's use less fuel than autos with gasoline engines, they are generally more expensive overall due to their higher vehicle prices.

Industrial Energy Efficiency, Already Rising, Would Further Improve

The industrial sector includes agriculture, mining, construction and manufacturing. Energy has represented a relatively small fraction of total production costs in most industries (ranging from less than 2 percent for the food industry to as much as 30 percent of production costs annually for the cement industry.) Consequently, the price of energy has not played a dominant role in recent years in improving industrial energy efficiency.

U.S. energy intensity (energy input per dollar GDP output) has been influenced by two factors in the U.S. economy. First, structural shifts have occurred where the mix of goods and services has shifted away from the production of energy intensive goods (e.g.,iron and steel) and toward services (e.g., telecommunications, entertainment). Second, technological improvements (e.g., continuous casting and electric arc furnaces) have impacted industrial efficiency. For more than a quarter century, the gradual migration of heavy industry and primary metals abroad, growth in the U.S. service sector and technological progress have combined to reduce U.S. energy intensity by about 1.4 percent annually.

The Reference Case projection embodies considerable improvement in energy intensity. Just as lower real prices for oil, gas, and electricity during the late 1980s lowered incentives for energy conservation, the higher prices projected in connection with meeting the Kyoto carbon emission reduction goals result in less energy consumed for each constant dollar of output produced. This analysis projects a replay of the early 1980s, when the cost of both energy and capital inputs were rising. Across the cases, about two-thirds of the projected reduction in industrial energy intensity is attributable to the structural effect (change in the mix of goods and services); the remaining one-third to increased energy efficiency.

In the carbon reduction cases, relative to the Reference Case in 2010, total carbon emissions from the industrial sector are between 7 and 28 percent lower. Part of this is due to lower U.S. industrial production because higher energy prices lower domestic demand and make U.S. exports relatively more expensive. In addition, industrial consumers are likely to replace existing capacity somewhat faster, invest in more efficient technology, and switch to less carbon-intensive fuels.

Energy Efficiency Could Improve in the Buildings Sectors With Rising Prices

Rapid development and adoption of new electrical devices--computers, telecommunications equipment, and other appliances--have expanded energy demand in the residential and commercial sectors. Increasing energy prices could lower total demand in the two sectors by between 7 and 25 percent in 2010.

Periods of increasing energy prices appear to have had little impact on commercial energy demand, as seen by comparing the price increases in the 1970s with the change in demand. Energy prices are only one factor in choices for buildings, appliances, and equipment in these sectors. How consumers react to higher prices by reducing the demand for energy services--less heating and cooling, reduced lighting, etc.--will be a major factor in lowering energy demand.

Technology improvements could have the largest impact for space conditioning--heating, cooling, and ventilation--which is the most intensive use of energy in buildings, but the penetration of more efficient equipment is slowed by the gradual pace of stock turnover. Improved lighting technologies will also be important, as well as improvements in building shells--insulation and windows.

Standards on new buildings and some energy-using equipment have been important in dampening the growth in energy consumption, leaving less opportunity for future improvements. Energy demand by white goods--freezers, refrigerators, dishwashers, clothes washers and dryers, stoves--declines even in the Reference Case primarily due to past standards on refrigerators and freezers and one that becomes effective in 2001.

Shift Toward Natural Gas and Renewables Characterizes New Energy Mixes

In order to meet the Kyoto Protocol targets, the proportion of each fuel used in the United States is projected to change from that of the Reference Case. Because of the higher relative carbon content of coal and petroleum products, those two energy sources would be used less--placing more reliance on natural gas and renewable energy, and slowing the decline in nuclear power. Although petroleum use declines relative to the Reference Case in absolute terms, its percentage-share increases slightly because total energy demand is lower in the carbon reduction cases. Most petroleum is used in the transportation sector--where there are limited economic options for fuel substitution. As noted earlier, domestic coal consumption declines substantially, with most of the reduction coming in electricity generation.

Because of lower demand for petroleum in the United States and other developed countries committed to reducing greenhouse gas emissions, world oil prices in 2010 would be about 4 to 16 percent lower than they would have been without the effect of any "carbon price." At the same time, U.S. dependence on imported petroleum by 2010 would be lessened--from about 59 percent of all petroleum consumption in the Reference Case to as much as 53 percent.

More use of natural gas in electric generation is offset only partly by reductions from the end-use sectors. Although carbon emissions from burning natural gas are lower than from coal or petroleum, they are not zero. Later in the forecast period, natural gas starts to face stiffer competition from increasingly economic non-hydro renewables and, particularly in the more stringent carbon reduction cases, from refurbished existing nuclear power units. As a result, by 2020, natural gas use is highest in the 1990+9% Case.

Higher demand forces up the average wellhead price of gas, relative to the Reference Case--moderately by 2010 ($2.78 per thousand cubic feet for the 1990+9% Case, vs. $2.33 for the Reference Case) but considerably by 2020 ($3.71 vs. $2.62). Although the natural gas industry will be tested in meeting levels of production that may be required, sufficient resources are available. There is historic precedent for the necessary increases in drilling and pipeline capacity, but appropriate market incentives and careful planning will be needed.

Most of the increase in renewable energy sources is likely to occur in electricity generation, primarily with additions to wind energy systems and an increase in the use of biomass (wood, switch grass, and refuse); but the overall renewable contribution by 2008-2012 will remain small compared to traditional sources. If the market penetration of additional renewable technologies is enhanced by carbon pricing, however, the renewables' share of generation will continue to increase through 2020.

Output and Cost-of-Living Impacted During the Transition Period

Even though energy represents only about 7 percent of our Gross Domestic Product (GDP), it is a crucial factor in virtually all the goods and services we produce and consume. The effects of alternative carbon scenarios can be expressed in terms of their impacts on the economy as a whole (e.g., GDP, capital investment, prevailing interest rates, inflation rates) as well as their impacts on individual families and enterprises (e.g., increased expenditures on energy, disposable income).

When energy costs rise, other factors of production--including labor and capital--become relatively less expensive. Energy price increases encourage adjustments in which labor and capital are substituted for more expensive energy to the extent practicable. In the process however, some economic potential is lost. This reduces the "potential" GDP for the Nation. EIA calculates that such losses would range from $13 billion to $72 billion in 2010 (1992 dollars). In an economy today of over $7 trillion, which is expected to grow to over $9.4 trillion (1992 dollars) in 2010, the percentage loss in output ranges from 0.1 percent to 0.8 percent. In this context, the economy continues to grow, but at a slower rate.

Because it takes time to adjust to a new set of factor-costs, however, there are, in addition to losses in potential GDP, transitional costs--which probably cannot be avoided entirely. Such short-run costs arise whenever price increases disrupt capital or employment markets. The transitional costs are very uncertain, but possibly very significant. They impact the "actual" GDP. Hence, the actual GDP losses are greater than the "potential" losses. The transitional costs can be softened to the extent that price changes are anticipated and appropriate compensatory adjustments can be made to Federal monetary and fiscal policies.

This analysis assumes a carbon-permit trading system is introduced in the form of an auction run by the Federal Government (to focus on the most economically efficient means of reducing carbon emissions). The domestic auction would produce substantial revenue. This study assumes that the revenues would be recycled back into the economy to bolster disposable income and encourage both consumption and investment, counteracting the adverse short-term effects on the economy associated with higher energy prices and speeding the transition to equilibrium. Taking money out of the economy through a carbon price and then returning it encourages a shift in priorities that accomplishes the goal of achieving a carbon emissions reduction while moderating the impacts on the economy. It modifies the national energy mix and makes the overall economy less energy-intensive, while partly compensating consumers and business for the loss in income resulting from higher energy prices. EIA evaluates two illustrative recycling cases: one providing rebates via reductions in the personal income tax, and the other through the social security tax.

EIA projects the loss in actual GDP in 2010 to range between $61 billion and $183 billion if revenues are recycled via a reduction in social security taxes, and between $96 billion and $397 billion if they are recycled via a reduction in personal income taxes (1992 dollars). Again, the economy grows even during the period of adjustment but does not reach the levels of growth in potential GDP. Although there is a definite slowing of economic growth during the transition period, actual GDP returns to its potential path, so the effects on the economy are almost totally muted over the longer term.

The total cost to the economy can be estimated as the loss in actual GDP (the loss in potential GDP plus the macroeconomic adjustment cost) plus the purchase of international permits. It is assumed that the U.S. will purchase international permits at the marginal abatement cost in the U.S., i.e., the domestic carbon price. Total costs range from an average annual level for the period 2008 to 2012 of $77 billion to $338 billion 1992 dollars depending on the carbon reduction case and how funds are recycled back to the economy.

As energy prices rise in the United States, downstream prices for all goods and services are affected. A rule of thumb for the year 2010 is that each 10-percent increase in the level of aggregate energy prices may lead to a 1.5- percent increase in producer prices and a 0.7- percent increase in consumer prices. Final prices for goods and services in the 1990+9% case, as shown by the CPI, are approximately 3.5 percent higher than the Reference Case by 2010 if carbon permit revenues are recycled through a personal income tax rebate, and 2.0 percent higher if revenues are recycled through a social security tax rebate.

Throughout these cases, the role of monetary policy is critical. Higher energy prices place upward pressure on interest rates. Based on past behavior of the Federal

Reserve Board, it is assumed that they will adjust interest rates to moderate the impact on the economy and return it to its long-run path.

For Reference: A Matrix of Variables for Cases Analyzed by EIA

Would Some Changes In Assumptions Revise These Projections? How? How Much?

The House Science Committee asked EIA to determine how sensitive the results of its analysis might be to changes in three basic assumptions made for the Reference Case. These were analyzed against the 1990+9% Case, except for the changes in nuclear power assumptions. The changes can be framed as three questions.

Suppose . . . underlying economic growth of the nation were higher (or lower)?

If higher or lower growth is assumed in such factors as population, the labor force, and productivity, there would be differences in industrial output, inflation rates and interest- rate levels. Assuming a range of annual GDP growth between 1996 and 2020 from 1.3 to 2.4 percent, compared to 1.9 percent in the Reference Case, total U.S. energy consumption would be lower/higher in 2010 by about 2.2 quadrillion Btu. (A quadrillion Btu is equivalent to consuming about 500,000 barrels of oil per day for one year). To meet the same level of carbon reductions with higher (or lower) energy consumption, the "carbon price" would also be higher (or lower)--as shown on the adjoining graph. With a higher carbon price, less coal and more natural gas, renewables, and nuclear power are used.

Suppose . . . technology advanced more rapidly as a result of increased national emphasis on research and development (or suppose--technology choices stayed as they were in 1998)?

The technology assumptions in the main cases in the EIA report reflect expert engineering opinion of likely technological advances--i.e., they are not technologically pessimistic. Nevertheless, to analyze the effects of even more advanced technology, assumptions were developed by energy technology experts for the end-use and generation sectors, considering possibilities based on increased Research and Development. This could mean earlier introduction of products and processes, lower costs, and higher efficiencies than assumed in the Reference Case. It was also assumed that technology for extracting and storing carbon emissions from coal and natural gas-fired electric generators might become available. A "low tech" sensitivity assumes all future choices are made from today's technology.

The range of energy consumption differences was similar to the GDP growth sensitivity. Higher technology lowers energy consumption in 2010 by 2.1 quadrillion Btu; freezing technological progress forces consumption to grow by an extra 1.5 quadrillion Btu. The related graph compares carbon price changes. In the residential and commercial sectors, lower carbon prices encourage higher consumption and balance the effect of advanced technology. Efficiency improvements and lower carbon prices allow coal use in generation to be about 40 percent higher in 2010. With low technology, converse trends prevail; more natural gas, nuclear energy, and renewables are needed to meet carbon reduction targets. The industrial and transportation sectors are more sensitive to technology changes than to price changes.

Suppose . . . building of nuclear power plants resumed in this country?

Because new nuclear plants did not compete economically with fossil and renewable plants in the 1990+9% Case, this sensitivity was analyzed against 1990-3% Case (with a carbon price of $294 in 2010). Some of the extra costs assumed for "first of a kind" advanced-design plants were also relaxed. Under these conditions, 1 to 2 new 600- megawatt nuclear plants would be added by 2010; and 2020 could see about 68 new plants. Because most would start up after the 2008-2012 period, carbon prices in 2010 would be relatively unchanged. By 2020, however, the 1990-3% Case carbon price of $240 per metric ton would be reduced to $199. Because of the lower carbon price in this sensitivity, all sectors have higher energy consumption.

How (and Why) Do These Results Differ from Other Projections?

Why haven't all projections agreed? Other analyses of the Protocol have different results because of different assumptions for--

• Economic growth in the United States and the resulting emissions--these alter the base from which reductions must be made

• The extent of international trading, joint implementation, and the clean development mechanism

• Cost and efficiency of new technologies

• How rapidly and to what extent consumers respond to energy price increases--observations of past behavior indicate that consumers may change habits rather slowly

• How rapidly capital stock turns over--much of the equipment purchased in 1999 will likely still be in use in 2010 but some analyses do not capture all the transition costs

• When actions to reduce emissions begin--EIA assumes that actions begin in 2005 but some analyses assume actions have already begun

• How much knowledge consumers have of future events and how early they begin to adjust. EIA assumes that end-use consumers begin to adjust when a price increase occurs, but some analyses assume that adjustments begin well in advance

Six **other** projections of carbon prices and their effects, from various sources, are outlined in Chapter 7 of the full report. Two cases were analyzed: the1990-7% Case in which the United States is assumed to reduce carbon emissions to 7 percent below 1990 levels for the period 2008-2020 without the benefit of sinks, offsets, international carbon permit trading, or the Clean Development Mechanism (CDM); and a best estimate of the impact on U.S. energy markets if sinks, offsets, and emissions trading among the participating developed nations (Annex I) were allowed, but not global trading or CDM.

If the United States is required to achieve stabilization at the 1990-7% levels without Annex I trading and no credit for sinks and offsets, the estimates of carbon prices required in 2010 range from a low of $221 per metric ton to $348 per metric ton, with the vast majority in the $265 to $295 per metric ton range. Actual GDP losses are projected to range from $102 to $437 billion dollars in 2010 (1996 dollars). With Annex I trading and credits for sinks and offsets from other gases, the carbon price ranges between $100 per metric ton to $175 per metric ton and the loss of actual GDP ranges between $56 and $207 billion dollars in 2010. Estimates of internationally purchased carbon credits by the U.S. range from 147 to 288 million metric tons.

Energy Information Administration Reports on Greenhouse Gas Emissions:

- *Impacts of the Kyoto Protocol on U.S. Energy Markets and Economic Activity,* published in October 1998, with analysis of the Kyoto Protocol
- *Annual Energy Outlook 1998,* published in December 1997, with projections of domestic energy carbon emissions through 2020
- *International Energy Outlook 1998,* published in April 1998, with projections of international energy carbon emissions through 2020
- *Emissions of Greenhouse Gases in the United States 1996,* published in October 1997, with an inventory of all domestic greenhouse gas emissions
- *Mitigating Greenhouse Gas Emissions: Voluntary Reporting,* published in October 1997, reporting voluntary actions in 1995 to reduce greenhouse gases in the United States
- *Greenhouse Gas, Global Climate Change, and Energy,* an information brochure on greenhouse gases

What Are Some of the Issues in Reducing Carbon Emissions in the United States?

- Availability and cost of technology
- Consumer acceptance of more advanced or efficient technologies--and of nuclear and renewable generating plants
- Identification of fiscal and monetary policies to moderate economic impacts
- Feasibility of the electricity, natural gas, and renewable industries to adjust to the new requirements
- Possible changes in industrial composition
- Timing and phase in of the necessary transitions

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