10. Five letters to the President

A LETTER TO PRESIDENT GEORGE W. BUSH BY LENNART HJALMARSSEN*

Global Climate-change Policy: A European Perspective

Mr President, from a European Union (EU) perspective, Kyoto is not dead. Many Americans would have been startled to see the newspaper headlines and the rage and alarm in Europe caused by the recent statements from your administration. Even if – as David Victor has shown here – there are good reasons to reject the Kyoto accord as it stands, because the targets are almost literally unachievable, and the instruments suggested not cost-effective, a withdrawal from the issue of global warming altogether would be inexcusable. I want to use my time with you to discuss the issue of global warming from an EU perspective. Since I know that you have a positive attitude towards nuclear power and because of my extensive experience from work in Eastern Europe and my experience from European panels of experts on nuclear power issues, I shall also address the development in Eastern Europe and the future role of nuclear power in climate policy.

Present trends

The EU accounts for about 15 percent of global energy consumption. According to the commitments undertaken at the Kyoto conference in 1997, the EU should reduce its greenhouse gas (GHG) emissions in the 2008–12 period to a level that is 8 percent below their level in 1990. This commitment has then been allocated into national targets ranging from +27 percent for Portugal to –28 percent for Luxembourg. These huge divergences among EU countries reflect a large number of factors including economic growth and changing market structures. They also highlight the difficulties involved in devising an equitable scheme for allocation of reductions in GHG emissions.

So far, between 1990 and 1998, the EU has reduced its GHG emissions by 2 percent, to some extent due to methane reductions caused by new regulations for waste disposal, but especially due to CO_2 reductions in the UK and Germany, where natural gas has been replacing coal in electricity generation, outweighing the increase in all other countries' CO_2 emissions. Thus, there

has been an increase compared to the 2008–12 commitments even in 'high-profile' countries[1] such as:

- Austria: +6% achieved vs –13% commitment;
- Belgium: +6.5% achieved vs –7.5% commitment;
- Denmark: +9% achieved vs –21% commitment;
- Sweden: +6% achieved vs +4% commitment.

Because the energy and transport sector is responsible for 80 percent of all emissions in the EU, I shall focus on this. The EU energy system is – and will over the next 25 years remain – dominated by fossil fuels. Renewables, including hydropower, biomass and waste, wind and geothermal power, cover less than 5 percent of energy supply. Again, the variation among countries is large:

- For electricity generation, carbon-free nuclear and/or hydro power dominate in France, Sweden and (non-EU) Norway, while the UK has rapidly expanded natural gas – combined cycle and, to some extent, nuclear power generation.
- For heating, Germany, Finland, Denmark and Sweden have developed extensive cogeneration-district heating systems in urban areas with large shares of biomass and waste as fuels.

In general, electricity has gained market shares during the 1990s. The change between 1994–1999 for the whole of Western Europe was (see Enerdata 2000):

- total energy: +7%
- electricity: +12%
- nuclear: +9%
- hydro: +6%
- thermal: +15%
  - natural gas: +74%
  - coal: –9%.

According to the most recent comprehensive EU-wide study, *The Shared Analysis Project*,[2] the share of fossil fuels is projected to increase marginally over the projection period, 1995–2020, from its present 80 percent share, despite significant expected increase in renewables, energy conservation, and the rate of technical progress. If extensive decommissioning of nuclear power takes place, even coal consumption for power generation is projected to increase. Moreover under the baseline assumptions, EU CO_2 emissions by 2010 will exceed those of 1990 by more than 7 percent.

My conclusion is that the EU is not going to meet the Kyoto targets without extensive use of flexible mechanisms. Extensive use of such mechanisms, Mr President, seems also to be consistent with your own view. This is not, however, the EU view. According to this, flexible mechanisms should not account for more than 50 percent of emission reductions. Let me then briefly review the current policy issues related to the EU climate-change policy.

Deregulation of energy markets

The deregulation of the electricity and gas markets will enhance competition and lower prices, especially for electricity, in which case there is a large capacity locked in due to regulation, the release of which will depress electricity prices for an extended period of time. Low electricity prices will slow down investments in new capacity and make life extensions of existing capacity (coal and nuclear in particular) relatively more profitable. This will slow down the rate of fuel switching from coal to natural gas, but it will also extend the life of nuclear power.

Waste-disposal regulations

New waste-disposal regulations in several countries will enhance fuel switching in co-generation from coal to waste, but also investments in new capacity. This will further reduce emissions of non-CO_2 GHG emissions.

Subsidized renewables

All EU countries promote renewables and cogeneration by different kinds of subsidies, involving subsidization of capital costs, preferential electricity selling prices and electricity tax exemptions. This is most evident in the case of wind power, the expansion of which is solely driven by large subsidies. Still, except for Denmark, the share of renewables in total energy use is small and, according to *The Shared Analysis Project*, it will grow slowly as a share of final energy use in the EU.

Green taxation

There is no common EU tax policy to implement any EU-wide CO_2 taxation. For other reasons, Sweden and the UK vehemently oppose such a common tax policy. Therefore, there are large differences in tax structures and tax levels across the EU. While taxation of household energy consumption is extensive, industrial energy use is usually not taxed outside Scandinavia. Several countries outside Scandinavia, however, plan to implement taxation of energy or CO_2 emissions in industry. Thus, switching taxes on industry from labor to energy is high on the political agenda, although more in the debate than in actual policy.

A lot of research has been devoted to the double dividend hypothesis in order to find out whether green taxation may both improve environment and enhance employment. The results are ambiguous and rather model dependent. Since taxation of labor is high in the EU, even if there is a double dividend the impact would be small. Take Sweden, for example: a 100 percent increase in CO_2 taxation would reduce the labor tax distortion by 1 to 2 percentage points. Only in Eastern Europe, where energy prices are extremely high relative to labor, will tax switching have a substantial impact.

While proponents of green taxation refer to the double dividend, opponents refer to the erosion of competitiveness of energy-intensive industries in our small open economies. In order not to force these industries to close down or relocate to low-tax countries, tax exemptions are frequent in countries with CO_2 taxation. The problem with this is that, in principle, tax exemptions are regarded as subsidies according to both the World Trade Organization rules and the EU rules. The most prominent high-tax country, Sweden, has a pending case in the EU, concerning its tax exemptions for energy-intensive industries.

Thus, for several reasons one should not expect CO_2 taxation to play a major role in climate policy of the EU in the near future, although a few countries may develop their own policies. This means that the most efficient instrument to achieve lower emissions will not be utilized to anywhere near its full potential. A caveat holds for gasoline and diesel taxation.

Transport policy

The transportation sector is of serious concern from the point of view of GHG emissions. In the EU it accounts for about 30 percent of final energy demand. It has been consistently the fastest growing final energy demand sector, exceeding 3 percent per year since 1985, compared to 1 percent per annum growth in total energy use. It has proved to be quite insensitive to a number of measures to reduce consumption, including, huge investments in rail systems and mass transit and, compared to the US, very high fuel taxation.

The last EU-driven fuel-tax increases in France in 2000, caused violent protests, spreading to several other countries. As an effect of those, France, Spain, Belgium and the UK decreased their fuel taxes.

Thus, it is hard to imagine much higher fuel taxation as an important policy instrument in the EU in the short term. Fuel taxes may increase further, especially during periods of falling world market prices – at a pace accepted by public opinion – and mainly for fiscal reasons and not primarily as an instrument to reduce fuel consumption. Instead, the main policy option seems to be wishful thinking, involving hope for more energy-efficient vehicles and hope that, despite ever-rising incomes, individuals will start approaching saturation levels for their personal travel.

On the other hand, Mr President, Europeans would like to see much higher fuel taxes in the US. European governments discovered long ago that gasoline taxes are optimal from a fiscal point of view, causing very small economic distortions. Therefore, not only to finance your large tax cuts but also to finance investments in public transport, I strongly recommend that you introduce a low CO_2 tax on gasoline as a first step towards a more energy-efficient transportation system.

Energy conservation

Among all the instruments available, energy conservation measures would seem to be one of the most important and most promising. The *potential* for energy conservation appears very large in almost all energy conservation studies for different countries. Because of the often large gap between best-practice and average-practice technology, the impression from such studies is that at least 50 percent of energy use could be *avoided* in most countries, by closing this gap. But there is very little empirical evidence of significant *realized* energy savings even in modern market economies with well-informed agents and efficient bureaucracies, in spite of the enormous amount of money spent on energy conservation and demand-side management programs. Why is this so?

In my view there are two main reasons for the disappointing results of energy conservation programs:

- Since most programs are optional, there is an important *selection effect*. Many or most participants participate just because they were anyway, in the near future, going to implement the measures for which they now get paid or subsidized.
- Because technical progress does not come to a halt just because we have installed best-practice equipment, there is also an important *dynamic vintage effect*. The gap between our now modern equipment will again widen every year until we invest next time. If we do not renew all equipment every year, there will always be a gap between best-practice and average-practice technology. Energy conservation programs will therefore to a very large extent only have a temporary effect on reducing the gap between average-practice and best-practice technology.

Thus, energy conservation efforts are based on the illusion that it is possible to reduce long-term energy consumption by permanently closing the gap between best-practice and average-practice technology. My view is that higher energy efficiency will mainly be achieved through the gradual improvement of capital stocks in industry and households and not through large government-directed energy conservation programs. Thus, the uncertainty about the

efficiency of energy conservation programs is huge, making such programs high-risk projects.

An exception is Central and Eastern Europe, where there is a large gap between its existing best-practice and worldwide best-practice technology. Although efficient implementation of energy conservation programs in this part of the world is difficult to achieve, the potential for Joint Implementation and Clean Development Mechanisms to decrease the 'gap' could be substantial, depending on the design of these mechanisms.

Central and Eastern Europe

The development of energy consumption in the Central and Eastern European (CEE) countries reflects the general economic development in these regions. The economic transition has made a large share of the existing capital stock obsolete. In all countries concerned, the energy sectors are undergoing structural reforms. Market liberalization and regulatory reforms are in different stages in different countries, but in general the process is slow. Because of lack of maintenance and investments, a large share of the conventional thermal electricity-generating capacity is obsolete from an economic point of view and even more so from an environmental one. Many plants are old and in different stages of decay. It is difficult to know exactly how much of the old thermal capacity should be regarded as economically and environmentally obsolete, but it may be a substantial share.

In general, the nuclear part of the electricity sector is in much better physical and economic condition than the conventional thermal part. Thus, nuclear power (and hydro power) has gained market shares in all countries which have nuclear power. Today nuclear power has an electricity production share close to 50 percent in the Slovak Republic and close to 40 percent in Bulgaria and Hungary. The development of the energy sector during 1994–99 may be summarized as follows:

- total energy: –9%
- electricity: –3%
  - nuclear: +14%
  - hydro: –5%
  - thermal: –6%
    - natural gas: –15%
    - coal: –1%.

In most countries final energy demand has declined since its peak during the late 1980s. The drop in demand has mainly been at the expense of solid fuels, gas and distributed heat, while oil (transport) and electricity have increased their market shares.

In general, energy intensity has decreased in most countries during the 1990s in terms of energy/GDP and energy/capita. To a large extent this is caused by the relative decline in heavy industry output and a worsening standard of living in the household sector. Industry modernization, reduction of heat losses, and other energy conservation measures have also contributed to lower energy intensity, measured in terms of total energy input per dollar of GDP; the energy intensity is very high in most of these countries. Yet, in terms of per capita energy consumption in the household sector the pattern is quite different.

Even if the energy prices are still below world market prices in some countries, the energy prices are actually *extremely high*, that is, from the point of view of purchasing power and relative price. In Ukraine, for example, about one-third of monthly earnings goes to household energy bills compared to about 3 percent in Sweden and even less in many EU countries. Thus, the relative cost of energy within households is at least 10 times higher than in the West. Correspondingly, the relative price of industrial electricity relative to labor or capital is even more extreme. The price of one GWh of electricity relative to the monthly wage rate is about 400 in Ukraine and Romania. In Sweden it is about one and in the EU the average is somewhat higher than one. This means that, in the future, we should expect the price of energy to *decrease* substantially relative to labor and capital in industry and relative to other goods and services in households. Thus, there will be a demand-enhancing effect from these relative price changes when the economy starts to grow.

However, the argument for energy prices at world market levels is still valid. From an overall nationwide point of view, world prices converted at the equilibrium exchange rate represent the social opportunity costs to the economy of utilizing tradeable goods. If the signals provided by such prices are distorted, the economy will not use its comparative advantage in its most efficient way, that is, we get a less efficient pattern of production and consumption. This is the economic argument for world market prices on energy.

Industry restructuring, from heavy industry to light manufacturing and services, might cause a decline in future energy demand. However, there is a lot of uncertainty about this component for at least two reasons. First, energy demand in general and electricity demand in particular is strongly correlated with changes in plant utilization. In many countries the capacity utilization in heavy industry is very low today even if the plants have not yet been closed. Thus, most of the impact on energy demand of industry restructuring may already be realized. Second, even if the prospects for heavy industry in Central and Eastern Europe seem gloomy today with a lot of uncertainty surrounding the future comparative advantages of those countries, nevertheless, some countries must have comparative advantages in heavy industry. Some CEE countries are indeed going to produce all the steel and cement

required for the reconstruction and future growth of Central and Eastern Europe even if we today do not know exactly which ones.

According to the Kyoto Convention, the CEE countries agreed to reduce emissions of six greenhouse gases by 8 percent by 2008–12 using 1990 as the base year.[3] Between 1990 and 1999, CO_2 emissions in the CEE countries decreased by 40 percent. With slow economic growth most CEE countries are likely to meet their targets by a significant margin. But if economic growth takes off at 2–3 percent per year, most of them would probably have to undertake actions to avoid exceeding their emissions target. Thus, even if Eastern Europe, and especially Russia and Ukraine, may positively contribute to the achievement of the Kyoto target in the short run, the stock of unused emissions will gradually disappear in the long run.

Is there a future for nuclear power?

Imposing limitations on greenhouse gas emissions will have a fundamental impact on the comparative advantages of different energy production technologies and their relative costs, because the energy sector in most countries is responsible for a large share of GHG emissions. Considering the politically feasible potential for emissions reductions in the transport sector, a heavy burden will rest on the electricity, hot water and steam-generating sectors. This would require an extensive increase in the production of electricity from renewables – hydro-, wind, biofuels and geothermal energy – and nuclear power. Because of a rather limited potential supply of renewables at an economically viable level in most countries, extending the life of existing plants and even investments in new nuclear power provides an economically attractive activity.

In comparison with many other countries, and with the United States in particular, the cost of nuclear power is very low all over Western Europe. The most important reasons seem to be:

- a successful choice of reactor technology;
- efficient management during construction and operation and short (about 5 years for the most recent and largest units) construction periods;
- an efficient nuclear safety regulation and an efficient licensing process; and
- low estimated costs of decommissioning and spent fuel treatment in an international comparison and much lower than US estimates. Moreover, the costs of already built deposits for medium-radioactive waste, confirm those estimates.

In spite of all the cost advantages, nuclear power is very controversial in several European countries, mainly now with regard to the unsettled issue of reprocessing or long-term storage of spent fuel. Thus, Sweden and Germany have decided to phase out nuclear power. When this will occur – or whether it actually will take place – is very uncertain. To illustrate the uncertainty, Sweden (where nuclear power has a market share above 50 percent) provides an excellent example.

After the Three Mile Island accident, the Swedish parliament (the Riksdag) in 1980 decided to hold a non-binding national referendum on the future of nuclear power in Sweden. As a result of the referendum, the Riksdag took two steps. First, it was decided that no more nuclear power reactors would be licensed, but the ones under construction (a capacity increase of about 50 percent) would be finished. Second, it was decided that the existing nuclear reactors should not be allowed to operate beyond the expected lifetime of the youngest reactor, often taken to be the year 2010.

Much has happened in the 21 years since the nuclear referendum. The debate faded, was revived by the Chernobyl accident, and was once again swept under the political carpet. In 1997, however, the government decided to close down the two reactors at Barsebäck, located opposite Copenhagen, the first one before July 1, 1998, and the second one before July 1, 2001. One reactor at Barsebäck was in fact closed down in 1999, while the other one is still operating in the summer of 2002, and it is highly uncertain when or if it will be closed down in the foreseeable future.

For the moment, nuclear power has strong support from the Swedish public. Moreover, analyses indicate that it would be extremely costly for Sweden to simultaneously phase out nuclear power and stabilize CO_2 emissions; see Andersson (1997)[4] and Nordhaus (1995).[5] According to Andersson (1997), the present value cost of a *combined* nuclear power phase-out and fulfillment of the CO_2 commitment is about $7000 per capita, while an isolated nuclear power phase-out or fulfillment of the CO_2 commitment would cost 'only' about $2000 per capita. Therefore in my view, it is highly unlikely that Sweden (or any EU country) will phase out nuclear power before the reactors are obsolete.

The same conclusion holds for Central and Eastern Europe. Here, nuclear power is clearly cheaper than any foreseeable alternative. The operating costs, including an allowance for decommissioning, are low – at about the same level as in Scandinavia. Even the figures available for investment costs indicate that new nuclear power is also cheaper than any alternative, including natural gas. Hydropower may be an alternative, but in most cases only as a load-topping capacity since non-exploited hydro resources are limited and in any case are generally of small unit size and hence relatively high cost.

The large comparative advantages of nuclear power in the CEE countries raises a concern for the safety of nuclear power in this region. Nuclear safety is of primary importance when considered within the context of European

Union enlargement: the Agenda 2000 agreement emphasizes that nuclear safety is a priority. In the Report to the European Commission from a Panel (of which I was a member) of High Level Advisors on Nuclear Safety in Central and Eastern Europe and in the New Independent States (1998), the following conclusions emerged:

- After the revolutions in 1989, extensive reactor safety improvement programs had been realized in all countries. At least in those CEE countries that had nuclear power, the utilities had been able to finance their own investments (even in Bulgaria) for safety and performance improvements. Thus, the need for direct financial support from the EU for reactor improvement projects was regarded as rather limited.
- Regarding the oldest reactors of conventional (VVER 440 and 230) and Chernobyl (RBMK) designs, these have safety deficiencies primarily concerning their ability to cope with accidents, which are normally safeguarded against in Western designs. They can be operated for a short time without excessive risk, but life extension is highly undesirable.
- Regarding the later (VVER type reactors 213 and 1000 and later RBMK) designs, these can be upgraded by means of improved instrumentation and control, maintenance, testing, operational safety improvements and the inclusion of mitigative features, enough to justify their continued operation.
- The most important area for future EU support lies in those parts of the infrastructure that are publicly funded and play an important role in guaranteeing all aspects of nuclear safety. The most obviously important aspect of publicly funded activities is that of the nuclear regulatory bodies themselves. But it also concerns the clean-up of uranium mining activities, radioactive waste and spent fuel management, the improvement of safeguard capabilities, the care of research reactors and a general need to support nuclear safety research activities.

Meeting limitations on GHG emissions according to the Kyoto accord and its future extensions may have a major impact on the cost of a closure, since alternative options may be much more costly. This may be less relevant for Russia and Ukraine, where emissions are far below 1990 levels and economic growth is slow. But it is very relevant for the CEE countries. In 1995, Slovenia had already exceeded the 1990 CO_2 emission level by 8 percent, while Poland was close to the 1990 level. Without the nuclear power option or with reductions in nuclear power generation, meeting the Kyoto agreement could be very costly for most CEE countries.

Concluding remarks

While change of fuel mix in electricity and steam generation may be the cheapest solution in most European countries for the period to 2010, the importance of this effect will probably decline in the longer term. One set of policy analyses in *The Shared Analysis Project* calculated the necessary levels of general EU-wide CO_2 taxation to achieve different emission targets in the most cost-effective way. The results suggest a tax level of about $50 per ton of carbon just to stabilize the emissions at the 1990 level and a tax level about $100 per ton of carbon to achieve a reduction of 6 percent. Carbon tax levels in the range of $50 to $100 per ton of carbon would make nuclear power least costly in most European countries. Substituting nuclear power for conventional thermal electricity generation is one of the few economically attractive options to GHG reductions, and indispensable in the long term. Therefore Mr President I strongly support your efforts to revitalize the nuclear power sector in your own country.

So far the progress to meet the Kyoto targets has also been slow in Europe. To meet these, the EU needs less rhetoric and more policy implementation based on cost-effective measures. A new architecture for the Kyoto framework is needed. Without the support of the country with the biggest emissions, a global GHG policy is doomed to fail. With American support, it would become not only forceful but also much more cost-effective than the present one, which does not ensure that the economic burden is supportable. Therefore, Mr President your leadership on this issue is vital.

A LETTER TO PRESIDENT GEORGE W. BUSH BY PAUL PORTNEY

Mr President, you were absolutely right to reject the targets and timetables in the Kyoto Protocol. Everyone around the world knew that the United States, and probably some countries in Europe, were not going to meet their targets in the given time frame. Getting this protocol out of the way clears the deck for something meaningful on climate change. But having indicated what you are *not* going to do, you now have a responsibility to indicate what you *will* do.

I do not have to tell you that this problem is extraordinarily complicated on a number of dimensions – scientifically, economically, politically, diplomatically and philosophically. Such noted scientists as Bill Schlesinger and Gerald North have indicated the dimensions of scientific uncertainty. Distinguished economists such as Larry Goulder, Robert Mendelsohn, Jae Edmonds and Ron Sands, Alan Manne and Joel Smith have suggested how complicated and uncertain this issue is economically. People like David Victor have indicated how complicated it is diplomatically and politically, both domestically and internationally.

In the international arena, a number of the countries with whom we negotiate on climate issues have been occasionally duplicitous in expressing their concern for the environment. In fact, they have been at least partially motivated by an interest in leveling the playing field economically with the United States, which has reigned supreme at least over the last decade. This issue is also quite complicated philosophically. It affects the way we are viewed by other countries in the world – which may affect your ability, Mr President, to negotiate treaties on things that you really do seem to care about, such as free trade, intellectual property, the expansion of NATO and other matters. So for these reasons this is an issue that is worth thinking about.

Finally, by way of introduction we need to realize that some warming appears to be inevitable, whether or not we choose to take mitigation measures. We should help prepare for the warming that will occur both in the United States and in other countries.

What could you do then? There many possible policy responses, ranging from doing nothing to undertaking things like the Kyoto Protocol. I have suggested that the latter would be too much and much too soon for the United States to undertake. Let me raise for your consideration one particularly interesting proposal put forward by four of my colleagues at Resources for the Future. It would establish a mandatory domestic cap-and-trade program for CO_2 emissions, in which one would choose both the cap at which CO_2 emissions would be limited in the United States, as well as one other parameter I will talk about subsequently. Most or all of the permits would be auctioned off by the federal government. Some of these permits could be distributed on the basis of historical emissions – and there are reasons why 'grand fathering' at least some permits would make this program more politically palatable. It is important for other reasons that most of the permits be auctioned off. However, neither you nor I believe that Washington should have still more revenues to hold. Therefore, the revenues from the CO_2 permit auction should be returned to the public on a dollar-for-dollar basis. Furthermore, over time and provided we are able to do this, we would negotiate ways to both trade out of carbon reduction obligations or to allow carbon sinks to take the place of the carbon reduction obligations that we have.

The other wrinkle in my colleagues' proposal is that the price of the permits would be capped at some so-called 'safety-valve' level. In other words, it would be a permit trading system but there would be a guarantee that the price of the permits would go no higher than some level that would be set legislatively. There is reasonably broad interest in a program like this, attracting the support of some environmental groups who have never before been willing to support an incentive-based approach to environmental policy. There is also support from many in the business community who fear a world in which there is no certainty whatsoever on what they might have to pay for carbon emission reductions in the future.

How much would such a program cost? Clearly, that depends on the quantitative cap that you put on emissions, and also on the safety-valve price. For purposes of discussion, suppose we decided to cap US CO_2 emissions at 1990 levels and establish a safety-valve price (or a maximum permit price) of $50 per ton of carbon. According to my calculations, I believe that this would increase the price of gasoline by ten to fifteen cents a gallon and increase the price of electricity by perhaps one cent a kilowatt-hour in those parts of the country where average prices are on the order of six cents a kilowatt-hour. But I need to point out to you that we have been wrong estimating the cost of various environment regulatory programs in the past – most notably the expected cost of controlling sulfur dioxide emissions from coal-fired power plants – so we could be wrong here.

Who is going to be hit hard by this? The coal industry would take a big hit, and that has serious implications in turn for the railroad industry. Rural areas will be harder hit because they depend more on gasoline than urban areas do. Large parts of the Midwest will feel a pinch because much of their electricity comes from coal. And western parts of the United States, where the distances that people drive are greater, will be much harder hit than the East.

If you paid careful attention to the television on election night, as I know you did, this prediction has a special implication for you. It suggests that it is those 'red' parts of the country where you did very well that will be hit the

hardest from this climate-change proposal. It will have the least impact on those areas from Seattle to San Diego and Maine to Maryland where the Democrats tended to do very well, clustered along the coast as they are. Needless to say, you would have to pay careful political attention to a proposal that would have such political ramifications. Even small changes in electricity or other energy prices can have significant electoral impacts.

What would such a proposal like this get you? What would its benefits be? First of all, in addition to slowing the accumulation in the atmosphere of CO_2, my colleagues' proposal would also result in reduced emissions of volatile organic compounds, nitrogen oxides, and particulate matter. This in turn would translate into improved air quality – and, therefore, less acute chronic and acute morbidity, less premature mortality, improvements in visibility, reductions in materials damage, and possibly reduced acidification in aquatic ecosystems that we care about. We would also reduce our oil imports, which would have favorable consequences for trade and possibly even macroeconomic and military well-being.

Truth be told, the reduction in carbon dioxide emissions in the United States alone would have an absolutely meaningless impact on atmospheric concentrations of CO_2 from this program. However, if you choose to undertake such a program it would demonstrate to the other countries of the world that this is a problem that we take seriously, and might induce them to take action whereas otherwise they would be disinclined to do so.

What should you do? You were elected President of the 280 million people in the United States to work with Congress in making such choices. As you think about what to do, keep in mind that it would be best to take what is sometimes called an 'options' approach. In the same way that you would never commit yourself to a ten-year tax cut when assumptions about future revenues are highly speculative, you need to think about a carbon policy in which any commitments you make now would be reviewed on a fairly short periodic basis. The policy should be reviewed in the light of both the economic impacts that climate mitigation measures are having, as well as the accretion of future scientific evidence. Anything other than an options approach, which you continually revisit, would be sure folly, because of the tremendous scientific, economic and other types of uncertainties that we have talked about. There is absolutely no way the US should commit itself to any kind of inflexible long-term climate policy that cannot be revisited.

Thank you for the opportunity to speak with you, Mr President.

A LETTER TO PRESIDENT GEORGE W. BUSH BY JOHN P. WEYANT

Mr President, I would like to give you my suggestions regarding climate-change policy. The bottom line on my advice is to not forgo the good and useful alternatives in hopes of finding pure and perfect solutions that are unattainable. I shall start by giving you an overview of what the climate problem seems to be, then discuss some desirable characteristics for a climate-change policy, and end with a discussion of how to get started with or without the Kyoto Protocol structure.

Human-induced climate change will most likely become a big problem and could become a very big problem during this century. Human influences on the climate system have already been detected and the problem will probably worsen gradually, but steadily over time. There is, however, some possibility of abrupt climate change or abrupt climate-change impacts at some point along the way and that possibility will probably increase over time as well.

At present it is impossible to predict exactly when and how bad the climate-change problem will become because of significant and pervasive uncertainties concerning at least the following factors: (i) the science of climate change, (ii) the science of climate-change impacts, including the evaluation of market and non-market impacts, (iii) the policies other countries might implement, (iv) the policies we in the US will want to and be able to implement, and (v) how undeveloped countries will participate in climate-change policies in the future.

Despite these uncertainties, however, there is now enough evidence to justify preparing to avoid some of the worst possible outcomes we can envisage. Some of these measures could be designed to reduce greenhouse gas emissions, while others might simply prepare us to do so, or prepare us to adapt to or compensate others who are adversely impacted by any climate changes that might occur.

Given the long-term nature of the climate-change problem and in light of these uncertainties, a prudent course of action might include the adoption of a tentative long-term limit on the concentration of greenhouse gases in the atmosphere. Whatever shape an international agreement on limiting greenhouse gas emissions might take, we know that there are several ways (often referred to as flexibilities) by which the total cost of achieving our objectives can be reduced. Fully exploiting each of these flexibilities has the potential to reduce the cost of achieving any emission limitations by a factor of two or more relative to not exploiting them at all, and combined they could reduce costs by more than an order of magnitude.

Since greenhouse gas emissions everywhere cause climate changes everywhere we should try to make greenhouse gas emission reductions wherever it

is cheapest to do so regardless of who pays for them. Since climate change is related to the stock of greenhouse gases in the atmosphere rather than the much smaller annual flow into it, we should reduce greenhouse gases at a rate that is gradual enough to allow the existing stock of energy-producing and -using equipment to reach the end of its useful economic life, focusing the substitution of less carbon-emitting equipment on new installations to satisfy new or replacement demands. We should reduce emissions of all greenhouse gases in a way that minimizes the cost of slowing climate change, that is, so that the marginal cost of reducing climate change by one unit via reductions of one greenhouse gas is the same as for any other greenhouse gas. Finally, we should use a portfolio of policies covering emission reductions (taxes, cap and trade, subsidies), research on the nature of the problem to refine our understanding of its likely timing and magnitude, and implement measures designed to stimulate technology research and development, etc.

One key issue to be addressed in the international negotiations on climate change is the extent to which developed countries like the United States ought to contribute to the solution of the climate change problem above and beyond what would be in our own direct (short run) interest. Developing countries observe that most of the greenhouse gases in the atmosphere above the natural background level was put there by developed countries. Moreover, research on the likely impacts of climate change suggest that developing countries are much more vulnerable to climate change because their economies are much more dependent on weather dependent activities like farming than those of developed economies, because they are generally located in lower latitudes where plants and animals are closer to their thermal limits, and because they have less resources and cruder institutions for adapting to any climate changes that may occur. You do not have to resolve the question of responsibility for all time with climate policy now, but you must address it in some way in formulating climate policy as it is a key issue for developing countries (witness the explicit or implicit attention paid to this issue in the UN Framework Convention on Climate Change (UNFCC) and all seven Conferences of the Parties initiated by the UNFCC). Moreover, the countries currently classified as developing will be emitting more (and probably a lot more) greenhouse gases than the currently developed countries by the end of the century, so we will definitely need their cooperation at some point to address the problem effectively.

Given these general desiderata for effective climate policy, I think it is useful to consider two paths forward – one with the US participating in a Kyoto type system and the other without the US participating in the system proposed in the Kyoto Protocol. I was not a proponent of the specific type of agreement that was reached in Kyoto as evidenced by the following quotation from a *Wall Street Journal* editorial piece entitled the 'Greenhouse Follies' that Harry Rowen and I wrote in the middle of the Kyoto negotiation process:

The delegates to Kyoto will declare victory, but their claim will be hollow. But perhaps this meeting will be the last run of the Greenhouse Follies, followed by a process that accomplishes something useful.

Nonetheless, despite its flaws, most of the nations of the world have invested four and a half years in negotiating the details of this type of agreement so it should not be discarded without thinking through the likely reactions to that course of action. I liken this exercise to the analysis done by then President Kennedy's team during the Cuban missile crisis where do nothing, quarantine, and all-out attack options were fully developed to help guide the thinking of the President and his national security team in developing an appropriate course of action.

What might staying with the Kyoto Protocol negotiations bring? First, based on your public statements on the efficacy of this agreement, your negotiators would be in a strong position to win longstanding debates with the EU over 'open' versus 'severely restricted' use of the flexibility agreements dealing with emissions trading, trading of emission obligations over time and the use of multiple gases and sinks. They would also be in a strong position in negotiations with the developing countries to require that they be obligated to take future actions contingent on their income per capita reaching some threshold. At the same time you could pursue complementary activities on problem detection and monitoring, on supporting technology research and development (R&D) (for example, pre-competitive conservation, renewables, nuclear, and carbon sequestration R&D), technology transfer, on removing barriers to improvements in energy efficiency, the introduction of non-carbon fuels, and on institution building here and abroad.

What implications would walking away from the Kyoto Protocol have and what options might that open up? First, given the history of the negotiations, this would lead to some loss of face for the US in subsequent negotiations which could make the international cooperation that all nations desire more difficult to achieve. There might also be some retaliation in the form of less cooperation on other contemporary international policy issues or attempts at retribution by those most seriously affected by climate change such as low-lying island nations that become submerged. The other activities mentioned as possible complementary actions to a Kyoto-style agreement would also be even more crucial in this situation. In addition, it might prove useful to pursue bilateral and smaller multilateral international agreements than that being pursued in the United Nations Convention on Climate Change.

In sum, I would recommend three actions that would ease the negative reaction to the US pulling out of the Kyoto negotiations. First, I would explain why you are doing it. One explanation might be your belief that we (the international community) can achieve our objectives at much lower cost via another style of agreement. Second, I would put forward a proposal for another style of agreement, perhaps one that would initially put more weight on coordinating R&D and institution building than in focusing directly on short-term emission reductions. Finally, I would put forward a specific proposal for starting the post-Kyoto negotiations. This would seem most credible if accompanied by a tangible pledge of resources from the US, for example, in the form of $1 to 5 billion pledge to support targeted R&D and technology transfer. That might be matched by other developed countries according to some formula. There seem to be three road blocks to an international agreement on climate-change policy at present: (i) the cost to US industry and consumers might be too high, (ii) if a tax is used to ensure efficient emission reductions the tax revenues would, given political realities, be too high to recycle efficiently, and (iii) if an extensive international emissions rights trading program is used, the wealth transfers between nations would be politically unacceptable.

The main reason I favor a technology-driven approach to the climate problem is that lower-cost technology solutions can be developed that would reduce the stakes involved in the negotiations over targets and timetables along all three of the above dimensions.

A LETTER TO PRESIDENT GEORGE W. BUSH BY ROBERT L. BRADLEY, JR

Background

You President George W. Bush, inherited the Kyoto Protocol (Kyoto), an agreement signed by the Clinton administration but not submitted for ratification to the US Senate for fear of rejection. Kyoto would obligate the United States to reduce greenhouse gas (GHG) emissions 7 percent below 1990 levels between 2008 and 2012 as part of a 5.2 percent cutback among 38 developed countries. (The developing world, representing over one-third of global emissions, was not included in the agreement.) The US cutback was a tall task given a Department of Energy projection that GHG emissions would be 34 percent above 1990 levels by 2010 and 50 percent higher by 2020. The 2020 forecast represented a 1.4 percent annual increase, slightly above the 1990–2000 actual.[1]

In the face of such projections, you wisely withdrew the US from the Kyoto Protocol negotiations in March 2001. Unlike the Clinton/Gore administration (1993–2000), both Bush administrations have been careful to label CO_2 an *emission* and not a *pollutant*. CO_2 is a natural atmospheric component as well as a byproduct of the modern energy economy and an input to the Earth's biosphere. This is why in chemical and legal terms CO_2 is not classified as a criteria pollutant or toxic.

Is Climate Science Sounding an Alarm?

The third scientific assessment of the Intergovernmental Panel on Climate Change (IPCC), published in 2001, has been presented as narrowing the uncertainties and ratcheting up the climate alarm. Yet the main body of the scientific study is less alarmist than the Summary for Policymakers (SP) section, and many key issues for policy making remain unanswered. An evaluation of the IPCC report by the National Academy of Sciences (NAS), requested by the Bush administration, concluded that the SP 'could give the impression that the science of global warming is "settled," even though many uncertainties still remain'.[2] The NAS report also concluded:

- Model-estimated warming is 'tentative' due to uncertainties with the net effect of aerosols and black carbon forcing as well as future emission scenarios;
- Most of the predicted warming generated by climate models (60 percent) is due to feedback effects whose physical properties are in dispute;

- Carbon sequestration by oceans and terrestrial sinks that may offset incremental carbon emissions is not sufficiently understood;
- Regional climate change from the human influence on climate is even more uncertain than global climate change; and
- Much more research and time will be necessary to understand the past and future of natural and anthropogenic climate change.

The study also flagged the most fundamental unknown of all – 'A causal linkage between the buildup of greenhouse gases in the atmosphere and the observed climate changes during the 20th century cannot be unequivocally established.'[3]

Richard Kerr of *Science*, a journal published by the American Association for the Advancement of Science, also questioned the simplistic and consensus-driven SP. His survey of leading climate scientists found 'a growing appreciation of climate prediction's large and perhaps unresolvable uncertainties'.[4] Indeed, the error bars surrounding the predictions of climate models in the IPCC report were increased, not decreased from the prior 1995 report, and a clear link between observed warming and GHG concentrations in the atmosphere remained in doubt.[5]

The uncertain link between industrial emissions and global warming after a century of GHG buildup and decades of study points toward *lower-range, benign warming scenarios*. The 'empiricist school' of climate science weighs several key facts in place of relying on problematic model-generated long-range warming projections. The atmospheric concentration of anthropogenic GHCs has reached 65 percent of the global warming potential of a doubling of CO_2 compared to pre-industrial (1750) levels.[6] Thus we are over half way to the doubling of atmospheric GHG concentrations that the (feedback-driven) climate models estimate will eventually increase global surface temperatures between 1.4°C (3°F) and 5.8°C (10°F). *Yet how much anthropogenic warming exists given today's increase in GHG concentration?* The most recent IPCC report states, 'most of the observed warming over the last 50 years is likely to have been due to the increase in greenhouse gas concentrations'.[7] That increase would be around 0.4°C (0.7°F) of a total surface increase estimated to be 0.6°C (1.1°F). Extrapolating to a 100 percent increase – a doubling – would give an *anthropogenic* increase in surface temperature of around 0.6°C (1.1°F).[8] By point of comparison, a person cannot notice such a temperature change – one that in terms of global climate change will have taken two centuries (1850–2050) to create.

Ocean delay associated with anthropogenic warming could portend a more rapid warming over the second half of the doubling period. Equilibrium settling will also increase temperature even after the GHG forcing is stabilized. Yet a substantial 'underwarming' still remains compared to model estimates since the alleged offset cooling effect of sulfate aerosols is now recognized to have significant warming properties as well.[9] The enhanced greenhouse effect, moreover, predominantly affects minimum temperatures, which increase at twice the rate of maximum temperatures.[10] Anthropogenic warming is also disproportionately distributed toward below-freezing temperatures in the coldest air masses at the coldest times of the year.[11]

Lower-range warming suggested by the balance of evidence – a 1–1.5°C (1.8–2.7°F) increase from a doubling of GHG concentrations – is far from cataclysmic and for the US may be on balance beneficial. Robert Mendelsohn in this volume calculates *net economic benefits* for the United States and much of the world in the next half-century assuming climate sensitivity for a doubling of GHGs of up to 2.5°C (4.5°F) from pre-industrial levels. Such an extended time frame makes short-term policy activism inappropriate beyond free market no-regrets, price-neutral policies. Technological response addressing what turn out to be real problems will be profoundly different in future decades and centuries from what it is today.

A moderately warmer and wetter world from the human influence on climate has environmental and economic benefits unlike colder and drier scenarios. On the other hand, higher sea level from the human influence is a *per se* negative since populated coastal areas would be subject to more erosion and storm surges. Projected anthropogenic sea-level rise is trending downward, however. The IPCC's first estimate in 1990 was reduced by 25 percent in 1995, and the 2001 estimate was reduced by another 2 percent from 1995.[12] Yet as with temperature, the correspondence between *model-estimated* sea-level rise and *recorded* sea-level rise suggests model overestimation. The anthropogenic sea-level rise forecast for a year-2100 doubling of greenhouse gases in the atmosphere is 48 centimeters (18.5 inches), with a range of 9 to 88 centimeters (3.5 to 34 inches).[13] This climate-model forecast compares with an actual increase in the last century of 15 centimeters (5.9 inches).[14] Some of this rise occurred before mid-century when natural variability was controlling, continuing a trend from previous centuries and even millennia.[15] The anthropogenic portion of sea-level rise, like the temperature portion, suggests that the IPCC-estimated range is biased on the high side. In any case, sea-level rise has not accelerated in recent decades,[16] suggesting that factors other than GHG buildup are at work.

Kyoto and Economic/Energy Realism

President Bush, your decision to abandon Kyoto follows mainstream economic modeling studies that concluded that 'the emissions trajectory prescribed in the Kyoto protocol is neither optimal in balancing the costs and benefits of climate change mitigation, nor cost effective in leading to stabilization of the concentration of carbon dioxide at any level above about 500 ppmv'.[17] Few of the 38 developed countries that have signed the Kyoto agreement have a realistic chance of meeting their paper obligations. Inequities and a lack of enforcement mechanisms, as David Victor explains in Chapter 9 in this volume, doomed the agreement from the start. Even pro-treaty environmentalists have been concerned with the agreement's workability. Christopher Flavin of the Worldwatch Institute in a 'candid' assessment of the Protocol back in 1998 stated: 'The challenge now is to renovate the baroque structure that the Kyoto Protocol has become – or else scrap it and get ready to start over.'[18]

An accord reached in 2001 by 178 nations (sans the United States) on certain unresolved Kyoto issues cannot mask several realities. First, fundamental compliance and enforcement issues remain unresolved in the fifth year of the agreement. Second, anthropogenic climate change will not be measurably affected by full compliance with the treaty. Third, economies will be hurt to the extent that *real* instead of *paper* GHG reductions are made beyond no regrets.

The US rejection of both the Kyoto Protocol and lighter GHG reduction mandates will have a salutary effect on energy abundance and affordability at home and abroad. The alternative US framework all but ensures that a rigid international agreement will not emerge that could have as a compliance weapon restraints on international trade.[19]

A Kyoto-like energy mix is unrealistic for several reasons. First, consumers will question why more expensive and less reliable energy sources such as wind and solar power are adopted when cheaper grid electricity is available. Second, siting constraints will increasingly come into play with land-intensive alternative energy technologies. Third, environmentalists themselves are foes of many renewable projects and the two mass carbon-free energies. They have turned against the kingpin of renewable energy, hydropower, in favor of fish migration and returning rivers to their natural state. Environmentalists have blocked wind and geothermal projects in 'sensitive' areas – which is commonly the case. Their professed concern about the role of CO_2 emissions on global climate fails to square with the fact that carbon-free hydropower and nuclear power produced 175 times more grid connected electricity in the US in 2000 than wind and solar combined.[20] This reality is why both the US Department of Energy and the International Energy Agency forecast an *increasing* market share for hydrocarbon energy out to 2020.[21]

Starter Regulation: A Tyranny of Small Beginnings?

Climate policy activists use the uncertainty surrounding the human influence on climate to advocate 'modest' starter programs to regulate greenhouse gas emissions. They selectively apply risk and the precautionary principle to *climate change* but not to *climate change policy*. Yet regulatory programs intended to promote health must overcome a health loss that intrinsically occurs when private sector wealth is lost through taxation or regulatory burdens.[22] Part of this is the *seen–unseen* dichotomy where the well-intentioned aim of a specific regulatory is recognized but the diffuse, countervailing effects from the wealth transfer are not.

Unilateral cap and trade programs (suggested by Alan Manne and Paul Portney in this volume) have been pushed as an alternative to Kyoto. Yet as David Victor states in Chapter 9, unilateral programs increase the chances for global treaties and its corollary, global governance. Furthermore, proposals to price carbon domestically have difficulty passing a cost/benefit test since the direct economic climate benefits as measured by Mendelsohn appear negligible. If the climate effects of a massive carbon reduction program such as proposed by the Kyoto Protocol will be 'undetectable for many decades',[23] the climate impact of a *unilateral* US program as proposed by Manne and Portney will be much more so.

The rationale of putting the institutions in place in case of accelerated policy action is also problematic. Any regulatory program – and particularly one unleashed in a sea of scientific uncertainty – becomes a political football. Any CO_2 regulatory program will be ripe for politicization to disappoint even those economists who may now favor beginning a regulatory journey based on 'leadership' and 'insurance' analogies.[24] The appeal to 'market-based mechanisms' cannot undo the fact that efficiency toward an inefficient goal is still inefficient.

Conclusion

Your decision to withdraw from the Kyoto Protocol negotiations is a wise action. A voluntary, no-regrets approach toward GHG emissions is highly defensible given the current state of knowledge about the science and economics of climate change. A voluntary, flexible policy will allow more time for the scientific uncertainties to be addressed and for new technology strategies to emerge. Recent peer-reviewed work on feedback effects and surface temperature records seems to suggest that the alarm is moderating.[25] Better science – in particular next-generation climate models incorporating more realistic cloud and water vapor physics – will allow climate economists to better estimate the costs and benefits of climate change. In the meantime, a

number of free-market 'no-regrets' policies will reduce greenhouse gas emissions in an inexpensive way.

The leading threat to energy sustainability in the new century is not resource depletion, air and water pollution, or even anthropogenic-related climate change. A strong case can be made for optimism, not pessimism, on these fronts.[26] The chief threat to energy sustainability is *climate policy activism* which interferes with energy affordability and reliability for the developed world and the 1.6 billion persons still living in energy poverty.[27]

A LETTER TO PRESIDENT GEORGE W. BUSH BY JAMES A. EDMONDS

Global climate change is one of the most complex environmental, energy, economic, and political issues confronting the international community. The impacts of climate change are likely to vary considerably by geographic region and occur over a time-scale of decades to centuries. The actions needed to manage the risks ultimately require substantial long-term commitments to technological change on the part of societies worldwide.

The Challenge

Mr President, as you have been briefed, you know that the Earth's climate is governed primarily by complex interactions among the sun, oceans, and atmosphere. The increased concentration of heat-trapping 'greenhouse gases' in the atmosphere has led to concerns that human activities could warm the Earth and fundamentally change the natural processes controlling climate.

You are also aware that carbon dioxide is the greenhouse gas contributing the majority of the projected future human influence on climate. Carbon dioxide emissions can affect the atmosphere for hundreds and even thousands of years. Some of the carbon dioxide emitted in 1800 is still in the atmosphere – and today's emissions will continue to influence climate in 2100. The total concentration of carbon dioxide in the atmosphere at any given time is much more important in determining climate than are emissions in any single year. Limiting the human impact on the climate system therefore requires that atmospheric concentrations be stabilized.

Recognizing this fact, more than 180 countries, including the United States, with the advice and consent of the United States Senate, ratified the 1992 United Nations Framework Convention on Climate Change (FCCC), and it has entered into force under international law. The *ultimate objective* of this treaty is to achieve 'stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system' (Article 2).

The objective of the FCCC – stabilizing the concentrations of carbon dioxide and other greenhouse gases – is not the same as stabilizing emissions. Because emissions accumulate in the atmosphere, the concentration of carbon dioxide will continue to rise indefinitely even if emissions are held at current levels or slightly reduced.

The FCCC process has not yet specified a particular target concentration. But in order to stabilize concentrations at any level ranging from 450 parts per million to 750 parts per million, very large reductions of worldwide

emissions (from emissions that might be anticipated were present trends to continue) would be required during the course of the present century.

Technology is Critical

Energy is central to the climate issue. Energy use appears to be the primary contributor to the global increase in carbon dioxide concentrations. Rapidly increasing world population, together with the universal desire for economic development, will lead to growing demand for the products and services that the energy system provides. The future evolution of that system – dominated today by coal, oil, and gas – is the key determinant of the magnitude of future human influence on the climate (see Figure 7.9).

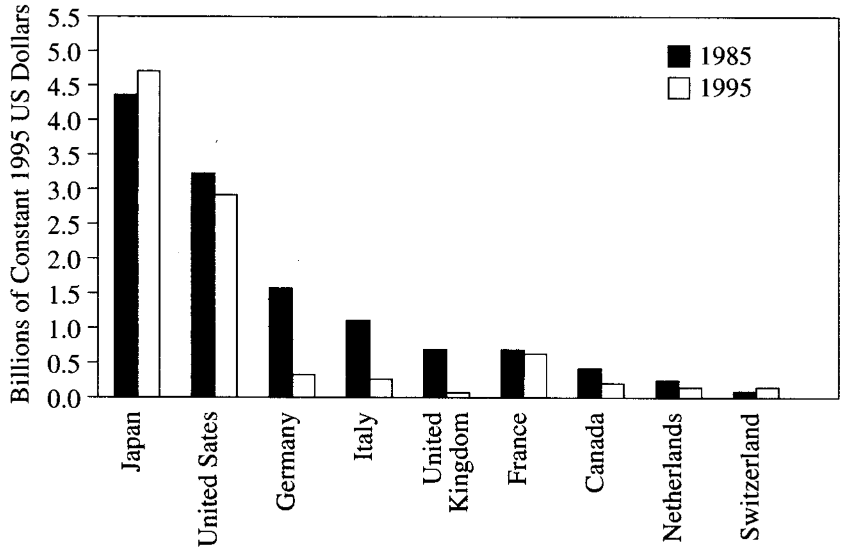
Managing the risks of climate change will require a transformation in the production and consumption of energy. Technology is critical to such a transformation. Improved technology can both reduce the amount of energy needed to produce a unit of economic output and lower the carbon emissions per unit of energy used. Successful development and deployment of new and improved technologies can significantly reduce the cost of achieving any concentration target.

Recent trends in public and private spending on energy research and development suggest that the role of technology in addressing climate change may not be fully understood Total public funding of energy research in the OECD is falling. Although public investment in energy R&D has increased slightly in Japan, it has declined somewhat in the United States and dramatically in Europe, where reductions of 70 percent or more since the 1980s are the norm. Moreover, less than 3 percent of this investment is directed at a few technologies which, although not currently available commercially at an appreciable level, have the potential to lower the costs of stabilization significantly. (See Figure 10.1.)

Energy Technology Strategy

Fundamental changes in the energy system are required to stabilize concentrations of greenhouse gases in the atmosphere. Incremental improvements in technology help, but will not by themselves lead to stabilization.

A technology strategy is an essential complement to national and international policies aimed at limiting emissions, enhancing adaptation, and improving scientific understanding. A technology strategy will provide value by reducing costs under a wide range of possible futures, which is essential given the uncertainties in the science, policies, technologies, and energy resources. The lack of a technology strategy would greatly increase the difficulties of addressing the issue of climate change successfully.



Sources: IEA (1997) and Dooley (1998).

Figure 10.1 Total public funding of energy research and development in selected nations in 1985 and 1995

In the year 2000, the Global Energy Technology Strategy Program – an international, public/private sector collaboration advised by an eminent Steering Group – delivered these results at a special session during the deliberations of the Conference of the Parties to the FCCC in The Hague. The findings and recommendations of the Global Energy Technology Strategy Program, are an initial attempt at delineating the elements that will be needed to guide the development of a technology strategy to address climate change.

These recommendations are predicated on four findings:

1. **Stabilizing concentrations of greenhouse gases in the atmosphere requires fundamental change in the energy system**

   - *Energy is central to the climate change issue* Carbon dioxide emissions from the production and consumption of fossil fuels are the largest contributor to human emissions of greenhouse gases. Fossil-fuel resources are abundant, and, if used in conjunction with present energy technology, have the potential to increase the concentrations of greenhouse gases in the atmosphere substantially.

   - *If present trends continue, carbon dioxide emissions from energy will continue to grow* The influences of future population growth and economic development on the demand for energy services are likely to exceed currently projected improvements in energy intensity and the ongoing transition to less carbon-intensive fuels. However, trends are not destiny – a global technology strategy could help change the present course.
   - *In order to stabilize concentrations of greenhouse gases in the atmosphere, global carbon emissions must peak during the twenty-first century and then decline indefinitely* This can occur only if lower carbon-emitting technologies are deployed worldwide.

2. **Technology breakthroughs are essential both to stabilize concentrations and to control costs**

   - *Although incremental technology improvements are essential, they will not lead to stabilization* Even with significant improvements in the performance of existing commercial technologies, the concentration of carbon dioxide in the atmosphere would grow to more than 2.5 times pre-industrial levels by 2100.
   - *Technology breakthroughs can reduce the cost of stabilization dramatically* Technological advances can reduce the annual cost of stabilizing atmospheric concentrations of greenhouse gases by at least 1–2 percent of global world product. The savings will depend upon the concentration target and the level of technology improvement.
   - *It is time to get started* The energy system is capital-intensive, and the development and deployment of new technologies can take decades. Given the lead-time necessary to develop and deploy new technologies with their associated systems and infrastructure, we must begin the process without delay.

3. **A portfolio of technologies is necessary to manage the risks of climate change and to respond to evolving conditions**

   - *A diversified portfolio accommodates future uncertainties* Changing scientific knowledge and economic conditions, combined with uncertainty in the resource base, requires a diversified initial portfolio of technology investments. Portfolio investment priorities will evolve over time as these uncertainties evolve or are resolved.
   - *A broad portfolio can control costs* A portfolio encompassing a broad suite of technologies can lower the costs of stabilization

significantly. However, the public and private sectors cannot fund every idea. Technology investment priorities must be established to reflect available funding.

- *A broad portfolio can meet the differing needs of key regions* Countries will need and employ different technologies based on their geography, indigenous resources, and economic, social, and political systems.
- *A flexible portfolio can accommodate alternative policy responses to the climate issue* The technology portfolio can be adapted to a diverse range of future national and international policy responses designed to address climate change.
- *A broad portfolio also can reflect the diversity of the energy system* Technologies are needed to improve the efficiency of energy use, develop non-carbon energy sources, and limit the free venting of carbon from the fossil energy that will continue to be burned.

4. **Current investments in energy research and development (R&D) are inadequate**

- *Energy R&D outlays are declining* Both public and private sector investments in energy R&D have declined significantly since the 1980s.
- *Energy R&D expenditures are unfocused and poorly coordinated* Neither public nor private sector investments are adequately focused on the technologies that could be critical for stabilizing concentrations in the long term. Among the few governments with national energy R&D programs, investments are poorly coordinated and fail to take advantage of possibilities for joint, complementary, or specialized research.
- *Terrestrial sequestration, hydrogen, and carbon capture, use, and storage technologies* potentially play an important role in stabilizing concentrations, but are currently funded at minimal levels.

These four findings in turn support four recommendations:

1. **Emissions limitations and controlling costs complement a technology strategy**

- *Emissions limits are needed to stabilize concentrations* Without such limits, individual nations have little incentive to reduce greenhouse gas emissions. It is unlikely that the required technologies to achieve stabilization will be developed and deployed if there is not any value placed on developing such technologies.
- *Controlling the costs of stabilization is necessary* The costs of stabilizing concentrations of greenhouse gases are uncertain and are distributed unevenly across generations, nations, and sectors of the economy. Better definition and control of these costs is critical to achieving societal consensus to take action.

If the Kyoto Protocol does not represent the path forward, a suitable path is nonetheless needed. There are many options. But, without a credible commitment that cumulative emissions will be limited, important technologies will either not be developed, or be developed inappropriately.

2. **Increase global investments in energy R&D**

- *Increase investment in energy R&D* to improve the performance of existing technologies and to develop the next generation of technologies that are required to stabilize greenhouse gas concentrations.
- *Develop dedicated long-term funding sources* for energy R&D to support the necessary technology transformation.
- *Direct investments to specific technologies* that have significant potential to substantially reduce greenhouse gas emissions over the long term.
- *Build broad-based public support* by communicating the climate and ancillary benefits of energy R&D.

3. **Improve the implementation and performance of energy R&D**

- *Incorporate climate change* when revisiting current energy R&D priorities.
- *Better coordinate the roles of the public and private sectors* in the R&D process to reflect their specific strengths.
- *Fund all stages of the innovation process* from basic research to market deployment of the most promising technologies.
- *Establish long-term goals and near-term milestones* for technological performance to drive progress and to maximize returns on technology investments.
- *Design flexible R&D programs* to allow for the shifting of resources to accommodate new knowledge and conditions, particularly when sufficient technological progress is not being achieved.

4. **Reflect the international nature of the research challenge**

- *Develop and coordinate international and national energy technology R&D strategies* to take advantage of national scientific strengths and regional needs.
- *Provide assistance to key developing countries* to build their technical and institutional capacities for implementing energy R&D programs effectively and for deploying advanced technologies.

These findings and recommendations demonstrate the importance of technology in addressing climate change and provide general principles for moving forward.

NOTES

Letter by Lennart Hjalmarsson

* I am grateful to Henrik Hammar for useful suggestions.
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3. Russia and the former Soviet countries agreed to stabilize their emissions.
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5. W. Nordhaus, *The Swedish Dilemma – Nuclear Energy v. the Environment*, Stockholm SNS, 1995.

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1. US Energy Information Administration, *International Energy Outlook 2001* (Washington, DC: Government Printing Office, 2001), p. 185.
2. Committee on the Science of Climate Change, *Climate Change Science: An Analysis of Some Key Questions* (Washington, DC: National Academy Press, 2001), p. 22.
3. Ibid., p. 17.
4. Richard Kerr, 'Rising global temperature, rising uncertainty', *Science*, April 13, 2001, p. 192. Kerr made a similar revision to the Summary for Policymakers of the second (1995) IPCC assessment: 'An international panel has suggested that global warming has arrived, but many scientists say it will be a decade before computer models can confidently link the warming to human activities.' Richard Kerr, 'Greenhouse forecasts still cloudy', *Science*, May 16, 1997, p. 1040.
5. 'The uncertainties give some researchers pause when IPCC so confidently attributes past warming to the [enhanced] greenhouse [effect], but projecting warming into the future gives almost everyone the willies … . By all accounts, knowledge [about the human role in climate change] will be evolving for decades to come.' Kerr, 'Rising global temperature, rising uncertainty,' *Science*, pp. 192, 194. On the growing uncertainty of climate prediction and a behavioral bias of climate modeling toward conformity, see Gerald North, 'Book Review: L.D. Harvey, *Global Warming: The Hard Science*', in *Climate Change*, vol. 49, 2001, p. 496.
6. Intergovernmental Panel on Climate Change, *Climate Change 2001: The Scientific Basis* (Cambridge, UK: Cambridge University Press, 2001), pp. 350, 357.

7. Ibid., p. 10.
8. The extrapolation is not linear but logarithmic due to the properties of carbon dioxide absorptivity on infrared wavelength. E-mail communication from Gerald North, Department of Atmospheric Sciences, Texas A&M University, to author, July 6, 2001.
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10. IPCC, *Climate Change 2001*, pp. 2, 4, 27, 30, 101, 104, 106, 108, and 129.
11. Ibid., pp. 13, 67, and 116–17. Higher temperatures that are still below freezing can be considered *dead warming* for purposes of ecological and economic evaluation.
12. Intergovernmental Panel on Climate Change, *Climate Change 1995 – The Science* (Cambridge, UK: Cambridge University Press, 1996), p. 6; IPCC, *Climate Change 2001*, p. 16.
13. IPCC, *Climate Change 2001*, p. 642.
14. Ibid., p. 641.
15. Ibid., p. 641.
16. Ibid., p. 31.
17. John Weyant and Jennifer Hill, 'Introduction and Overview', in *The Energy Journal*, Kyoto Special Issue, 1999, p. xliv.
18. Christopher Flavin, 'Last tango in Buenos Aires', *Worldwatch*, November/December 1998, pp. 11, 18.
19. See, for example, Duncan Brack, Michael Grubb and Craig Windram, *International Trade and Climate Change Policies* (London: Royal Institute of International Affairs, 2000).
20. US Energy Information Administration, *Annual Energy Review 2000* (Washington, DC: US Department of Energy, 2001), p. 221.
21. International Energy Agency, *World Energy Outlook* (Paris: OECD/EIA, 2000), p. 21; US Energy Information Administration, *International Energy Outlook, 2001* (Washington, DC: Department of Energy, 2001), p. 176.
22. See John Graham and Jonathan Wiener (eds), *Risk versus Risk: Tradeoffs in Protecting Health and the Environment* (Cambridge, MA: Harvard University Press, 1995) and Robert Hahn (ed.), *Risk, Costs, and Lives Saved* (Washington, DC: Oxford University Press, 1996).
23. T.M.L. Wigely, 'The Kyoto Protocol: CO_2, CH_4 and climate implications', *Geophysical Research Letters*, July 1, 1998, p. 2288.
24. The insurance rationale for beginning a small GHG regulatory program assumes that the cost of the 'policy' is cost-effective and that the redemption value is reasonably known. Neither is the case. Climate science has not defined a 'dangerous' level of anthropogenic GHG concentrations in the atmosphere. Climate economics predicts substantial benefits will accrue to offset costs from the human influence on climate many decades in the future. The 'no-regrets' action advocated below is not insurance either but a strategy to incrementally reduce GHGs in a cost-effective manner, while advancing societal wealth to adapt to climate change.
25. For new evidence on a neutral-to-negative water vapor feedback, cloud cooling from sulfate aerosols, and overestimated surface warming since the 1970s, see, respectively, Richard Lindzen, Ming-Dah Chou and Arthur Y. Hou, 'Does the Earth have an adaptive infrared iris?', *Bulletin of the American Meteorological Society*, March 2001, pp. 417–32; Robert Charleston, John H. Seinfeld, Athanasios Nenes, Markku Kulmala, Ari Laaksonen and M. Cristina Facchini, 'Reshaping the theory of cloud formation', *Science*, June 15, 2001, pp. 2025–7; and John Christy, David E. Parker, Simon J. Brown, Ian Macadam, Martin Stendel and William B. Norris, 'Differential trends in tropical sea surface and atmosphere temperatures since 1979', *Geophysical Research Letters*, January 1, 2001, pp. 183–6.
26. See, generally, Robert Bradley, *Julian Simon and the Triumph of Energy Sustainability* (Washington, DC: American Legislative Exchange Council, 2000).
27. The estimate of 1.6 billion persons is from World Energy Council, *Energy for Tomorrow's World – Acting Now* (London: World Energy Council, 2000), p. 5.