Climate Change Policy And Economic Growth: A Way Forward to Ensure Both

International Council for Capital Formation

Institute of Economic Analysis

Istituto Bruno Leoni

CLIMATE CHANGE POLICY AND ECONOMIC GROWTH:

A Way Forward to Ensure Both

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Executive Summary

This book should be both timely and useful. It provides insights into why many internationally renowned climate policy modelers conclude that the Kyoto Protocol – with its "targets and timetables" approach to climate change policy – is not an effective tool for addressing the potential threat of climate change. The ideas offered here provide a path forward for engaging the developing world with industrialized economies in a process that can result in decreases in the growth of greenhouse gas emissions. If combined with new energy technologies, they could also lead eventually to stabilization of man-made GHG emissions and significant economic development in poor nations.

Measures of the economic impact of curbing energy use

As a new report by Andrei Illarionov of the Institute for Economic Analysis observes, the total volume of world carbon emissions is a function of four variables: population, GDP per capita, energy intensity of GDP and carbon intensity of energy. All these variables except GDP per capita are more or less given and change only slowly over time. Accordingly, the only effective tool that policymakers can use to effect near term emission reductions is the rate of change in GDP per capita. Using conservative assumptions about world economic growth, Illarionov calculates that the world CO_2 emissions will increase by 3.3 times from 2001 to 2050, from 23.7 to 78.4 trillion tons. Thus holding CO_2 emissions at the Kyoto Protocol goal of 19 trillion tons annually (by industrialized nations) is clearly not a realistic target, as it would require severely depressing economic growth. Further, the adoption and enforcement of current EU and British proposals to reduce emissions by 60 to 80 percent by 2050 would bring the world into a deep and prolonged recession. (**Chapter 1**)

Given the potentially significant economic cost of the Kyoto Protocol and the additional tighter targets being discussed for the post 2010 period, policymakers need to understand the strengths and weaknesses of the three types of economic models used to measure the cost of curbing energy use to meet emission reduction targets. Michael E. Canes of the Logistics Management Institute explains that different types of economic models capture different effects. Partial equilibrium models such as PRIMES (used by DG Environment in Brussels) capture effects in energy markets and the direct costs of energy use, but do not measure the indirect costs or those associated with market adjustment. General equilibrium models, such as the GTAP-ECAT model, capture both direct and indirect costs but assume long-run full adjustment of resources; they thus fail to capture the near term economic impacts. Macroeconomic models, such as those used by Oxford or DRI-WEFA (now Global Insight) not only identify long-run costs but can also provide the most complete assessment of the near and intermediate economic costs of reducing energy services. These models provide widely varying measures of what complying with Kyoto in the EU would cost. The general equilibrium models show costs that are 50 to100 percent higher than the partial equilibrium models. Macroeconomic models, in turn, produce economic costs for the EU that exceed the sectoral models by a factor of 15 to 20. (**Chapter 2**)

A macroeconomic analysis of five major EU countries (Spain, Germany, the Netherlands, the United Kingdom and Italy) shows that, if these countries were to achieve their Kyoto Protocol emission reduction targets, both GDP and employment levels would be negatively affected. Italy, for example, could see GDP levels fall by as much as 0.52 percent below the baseline forecast by 2010 and over 50,000 fewer jobs. By 2025, assuming Italy were on a trajectory to reduce emissions by 70 percent below 1990 levels by 2050, GDP could be 2.9 percent lower and there could be 277,000 fewer jobs. Margo Thorning of the International Council for Capital Formation concludes that the economic burden of reducing energy use to comply with Kyoto targets is likely to result in a shift in emphasis away from “targets and timetables” toward reducing emission intensity per Euro of output. (**Chapter 3**)

The urgent needs of developing countries like China, India, Indonesia and other members of the Asia-Pacific Economic Cooperation (APEC) group for increased access to energy are not being addressed by the Global Environment Facility (GEF) or the Clean Development Mechanism, according to a new report by Alan Oxley and Steve McMillan of the Australian APEC Study Center. The Kyoto approach to reducing human greenhouse emissions mandates the reduction of emissions. In the absence of alternative fuels, stabilizing emissions this way imposes vast costs on the global economy, as shown in previous sections. The Kyoto approach, if carried forward with bigger targets beyond 2012, threatens great expense to global GDP. However, these problems do not mean that APEC developing economies are unable to address the consequences of human-induced climate change. Practicable approaches to tackling the risk of climate change must permit non-industrialized and fast-growing economies access to affordable energy. Growth, not stagnation, is likely to produce technological outcomes that improve standards of living and our capacity to deal with risk. (**Chapter 4**)

Some policymakers view international trading in GHG emissions as a useful tool for reducing the cost of complying with reduction targets. However, a recent study by David Montgomery of Charles River Associates, and an earlier analysis by Denny Ellerman of the Massachusetts Institute of Technology, concludes that policies that impose carbon caps – even with full use of domestic and international permit trading to achieve short-term cost minimization – are particularly vulnerable to uncertainty about their future direction and viability. The authors also view the Kyoto Protocol as fundamentally unenforceable. This lack of enforceability stems not from poor drafting of the treaty, but from the fact that an agreement on targets and timetables among sovereign countries is in principle unenforceable and therefore unstable. The instability of the agreement creates in the minds of private investors a built-in bias that leads private sector actors to put a high probability on carbon limits being less than those explicitly agreed upon. (**Chapters 5 and 6**)

Policymakers need to take care that they are not mislead by engineering analyses that report on technical solutions that improve energy efficiency, without taking account of the real cost of these approaches. Henry Jacoby of the Massachusetts Institute of Technology notes that economists favor the market based approach, because it focuses on market price as the essential mechanism through which policy affects economic activity. In contrast, the technology-costing or “bottom-up approach” tries to estimate the cost of particular technologies totals the energy savings and then compares such costs to reduced energy expenditures. The U.S. Department of Energy’s “Five Lab Study” is a prime example of faulty reliance on the bottom-up approach. With its focus on short-term technology fixes, it could serve to divert resources from an effective long-term technology response to reduce GHG emissions. (**Chapter 7**)

Low income families would be disproportionately affected by polices that curb energy use, according to a report by Roger H. Bezdek of Management Information Services, Inc. on the impact of higher energy prices on Hispanic and Black families in the United States. For example, between 1973 and 1975, when energy prices increased sharply, the Black unemployment rate increased by 50 percent (from ten percent to 15 percent) and the Hispanic unemployment rate increased by two thirds (from 7.5 percent to 12.5 percent). Sharply higher transportation costs forced many minority employees to shift to public transportation, which in many cases (especially in heavily Black and Hispanic areas like Los Angeles) caused their commuting times to increase by several hours a day. (**Chapter 8**)

Sustaining Economic Development and Achieving Environmental Goals

According to new research by Jae Edmonds and John Clarke of the Pacific Northwest National Laboratory, in conjunction with Chris Green of McGill University, a major increase in public and private R&D funding is required to make real progress toward emission stabilization. Currently projected improvements in energy efficiencies – plus plausible levels of nuclear, wind, solar, biomass and other renewables – are not likely to achieve stabilization of atmospheric carbon dioxide concentrations in the ranges being discussed (350 to 750 ppm). Given the fact that a larger share of the world's population will reside in developing countries where per capita energy use tends to grow, the development of new ways of providing energy services is the only way to slow emission growth. Even if global population growth slows in the latter half of the 21st century, there may well be continued increases in energy use per capita. Edmonds stresses that there are a variety of very powerful economic forces that make a portfolio of technologies more attractive than any single technology. Furthermore, additional R&D efforts to develop promising technologies – such as carbon capture and storage, hydrogen and advanced transportation systems and biotechnology – have the potential to replace gigatons of carbon per year. (**Chapter 9**)

Reducing GHG emissions through faster turnover of a country's capital stock can lead to significant reductions in emission growth and emission intensity per unit of output, according to Margo Thorning. Efficient economic activity already carefully matches desired energy services with the minimum of energy needed to run equipment. Near-term policies that seek to rapidly reduce fossil fuels use clash with long-lived nature of costly energy services capital equipment. Climate policies that take a longer-term view can avoid the premature scrapping of capital equipment, and the high costs that this would impose on society. (**Chapter 10**)

Whether the Kyoto Protocol ever goes into effect is quickly becoming irrelevant, according to a report by W. David Montgomery (Charles River Associates) and Roger Bate (American Enterprise Institute), because few European countries are reaching their targets. Because developing countries are likely to emit well over half of future GHG emissions, limiting emission growth, while also fostering economic development, may be a more promising strategy. New investment currently taking place in developing countries like China and India embodies far lower energy efficiency and pollution control than do recent technology investments in developed countries. If developing countries could simply put in place the most efficient technologies, the emission reductions would be comparable to the emission reductions that would be achieved over the same period if all the Annex B parties met their original commitments. (**Chapter 11**)

Accelerating the spread of economic freedom is another useful tool in reducing the growth of greenhouse gas emissions, Montgomery and Bate argue. Economic freedom is highly correlated with per-capita income, economic growth and life expectancy, according to the Economic Freedom of the World Index developed by the Fraser Institute. Economic freedom is likewise highly correlated with increased energy efficiency. Removing barriers to trade and foreign investment, protecting property rights and removing subsidies to state-run enterprises are examples of policies that could make a significant difference in the growth of global GHG emissions. (**Chapter 12**)

A new framework for climate change policy to replace the flawed Kyoto Protocol is advocated by Brian Fisher of the Australian Bureau of Agricultural and Resource Economics. Policies to address human induced climate change, without compromising countries' capacity for development, must adhere to three principals: environmental effectiveness, economic efficiency and equity. Achieving environmental effectiveness requires that all large emitters, including those from the developing world, must be included within any climate change regime, if GHG concentrations are to be stabilized. Economic efficiency means embracing all opportunities for mitigation, facilitating market based solutions, recognizing the vital role of technology, and allowing enough time for a country's capital stock to turn over in the normal replacement cycle, so as to avoid the costs of premature obsolescence. Meeting the goal of equity requires that: (1) climate change policy allows countries to use the resources required to achieve social and economic development, (2) there is no coercion, and (3) barriers to transferring existing clean energy technology to developing countries are removed. (**Chapter 13**)

In the final chapter, Julian Morris of the International Policy Network outlines a new approach to the concept of sustainable development. The current concept focuses on specific outcomes, like controlling the climate or saving the periwinkle; trying to achieve these outcomes usually requires stronger global governance, and less flexibility in achieving agreed goals. Morris's alternative approach to sustainable development places the emphasis on trying to increase the chance of a superior outcome in terms of poverty alleviation, disease control or climate change. Pointing out that direct aid to poor countries often reinforces brutal, corrupt political regimes, Morris suggests promoting individual and intellectual property rights and the rule of law to enforce contracts, removing tariffs and trade barriers, and limiting the size of government. These policies would increase global welfare and promote both economic progress and environmental quality. (**Chapter 14**)

Margo Thorning
Managing Director
International Council for Capital Formation
February 2005

Chapter 1

REASONABILITY OF KYOTO PROTOCOL AND KYOTO-TYPE TARGETS

Andrei Illarionov

Overview

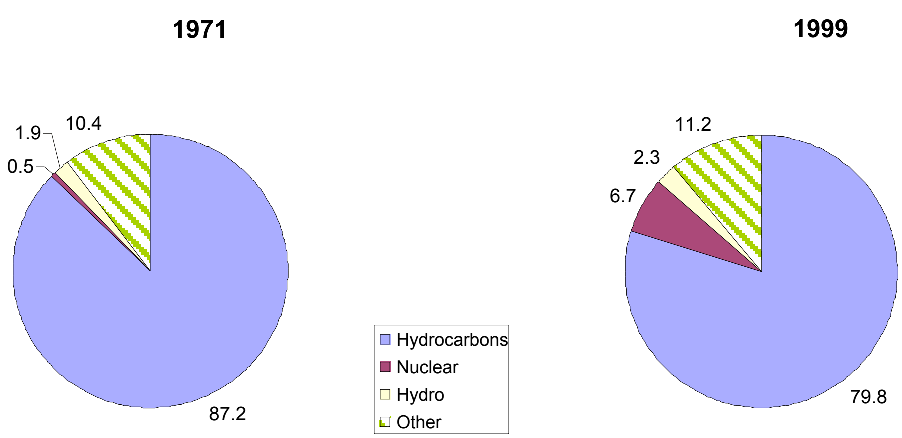
In order to assess the reasonability of the Kyoto Protocol's requirements and their impact on the world economy, one needs to understand long-term patterns in human-induced emissions of CO_2 (carbon dioxide). What are the main sources of CO_2 emissions? What factors can influence the change in those patterns? Which marginal rate of change can be achieved without unnecessary costs of adjustment? If adjustment is unavoidable, how great will be the price of adjustment to rigid requirements of the Kyoto Protocol in terms of economic growth and, therefore, of people's health and well-being?

An estimate of the potential decline in economic growth rates can be based on the declining rate of hydrocarbon use in line with the Kyoto Protocol requirements.

Patterns in human-induced carbon dioxide emissions

A major source of human-induced emissions of carbon dioxide is human energy consumption for economic activity. Hydrocarbons remain the principal source of energy used by modern humankind and currently provide about four-fifths of all energy consumed (**Figure 2-1**).

Figure 2-1. World consumption of energy – by source of energy



Source: World Resources Institute, http://earthtrends.wri.org

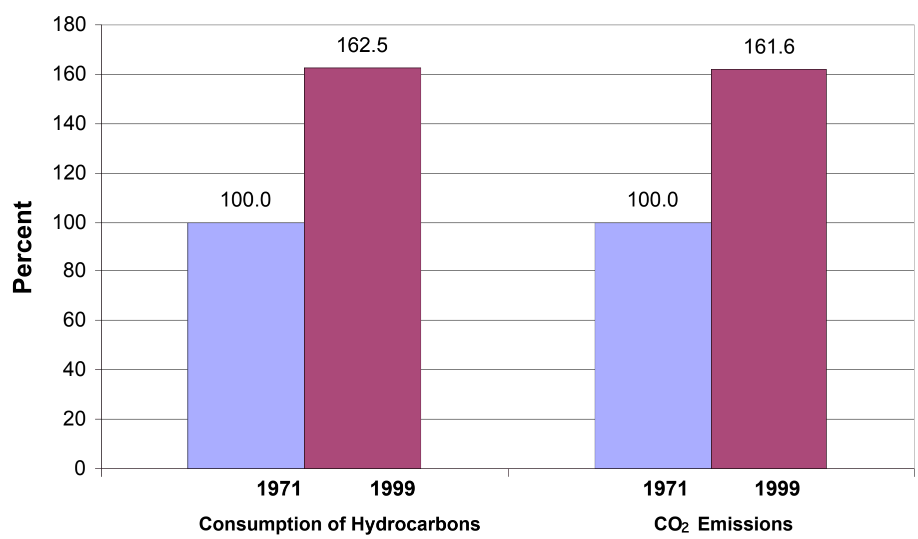
The last three decades have seen a trend toward the gradual reduction of the share of hydrocarbons in the total volume of energy consumed by humans. Between 1971 and 1999, the share of hydrocarbons fell by 7.4 percent, while the share of nuclear power increased by 6.2 percent, the share of hydroelectric power grew by 0.4 percent, and the share of other sources of power rose by 0.8 percent.

Given the technological nature of modern economies, nuclear power is the only commercially viable source of energy that may in the medium term partially offset the relative decline in the use of hydrocarbons. At higher levels of economic development, the share of nuclear power in total energy consumption generally tends to grow. However, to avoid declines in economic growth rates, it would require decades and large-scale investments for even the most developed nations to substitute the existing hydrocarbon-based energy sector infrastructure with a nuclear power-based system. The other sources of energy cannot provide any serious alternative to hydrocarbons.

Between 1971 and 1999, the share of hydrocarbons in total world energy consumption has been declining at an average rate of approximately 2.6 percentage points per decade. In view of this, one should hardly expect that hydrocarbons will at any time in the foreseeable future (in the next few decades and, possibly, not even before the end of the 21st century) lose their significance as the most important source of energy for the world economy.

It should be kept in mind, however, that recent reductions in the relative share of hydrocarbons in energy consumption do not imply a reduction in their use in absolute terms. Between 1971 and 1999, worldwide consumption of hydrocarbons grew by 62.5 percent. Over the same period of time, worldwide emissions of human-induced carbon dioxide gases increased in almost direct proportion by 61.6 percent (**Figure 2-2**).

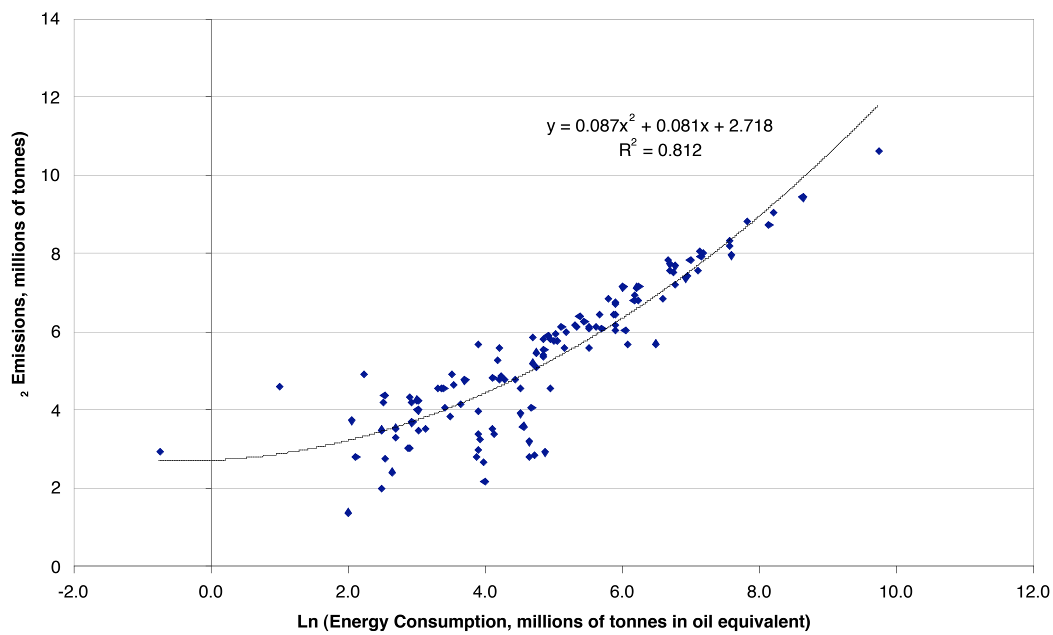
Figure 2-2. Consumption of hydrocarbons and CO_2 emissions in 1971-1999 (1971 = 100 percent)



Sources: World Resources Institute, International Energy Agency.

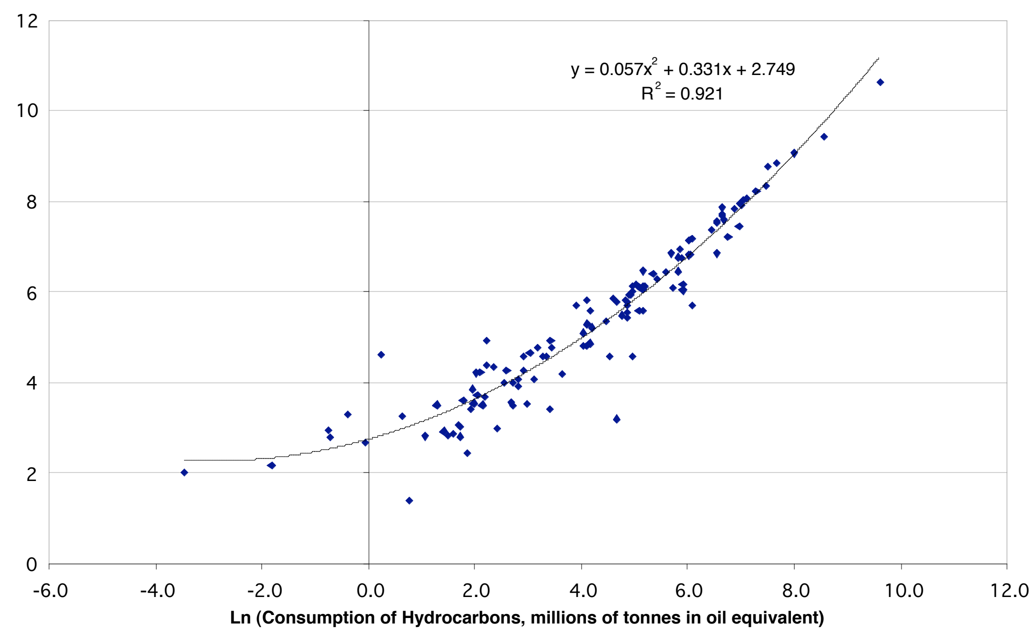
There exists an unmistakable link between energy consumption and the emission of carbon dioxide (**Figure 2-3**). Naturally, the connection is even stronger between the consumption of hydrocarbon fuel and the emission of carbon dioxide (**Figure 2-4**).

Figure 2-3. World consumption of energy and CO_2 emissions in 1992-1999 (124 countries)



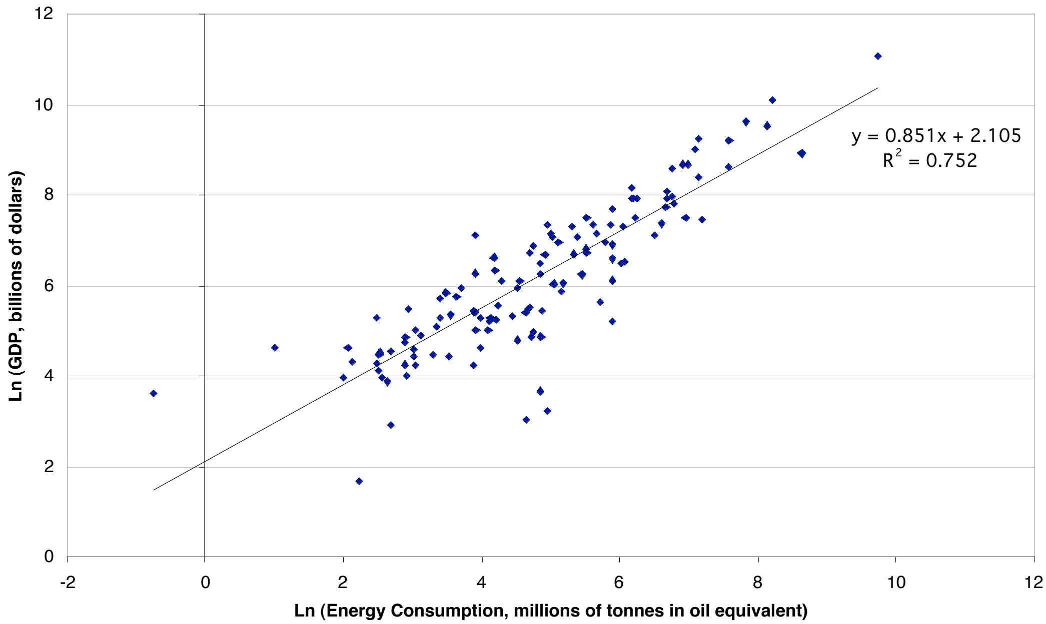
Sources: World Resources Institute, International Energy Agency.

Figure 2-4. World consumption of hydrocarbons and CO_2 emissions in 1992-1999 (124 countries)



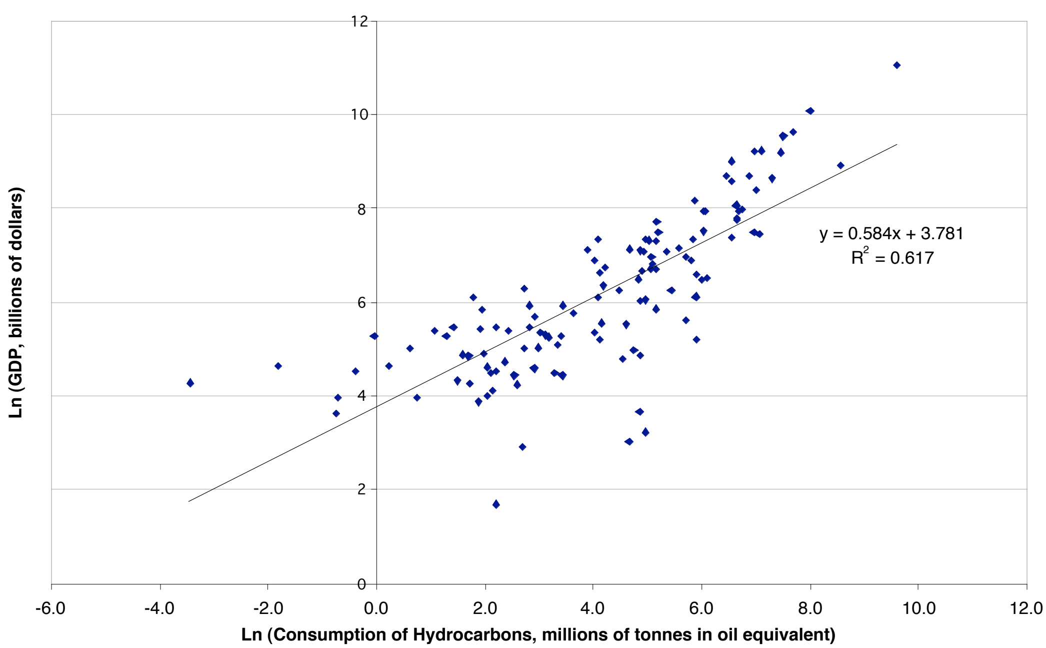
Sources: World Resources Institute, International Energy Agency.

Figure 2-5. World energy consumption and GDP production in 1992-1999 (124 countries)



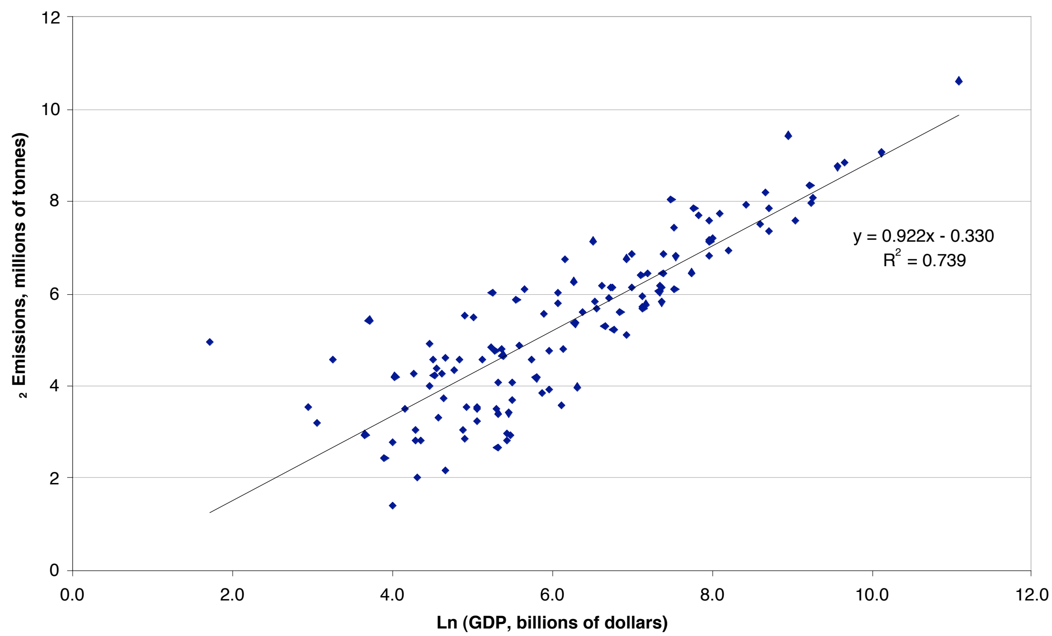
Sources: World Resources Institute, IMF.

Figure 2-6. World consumption of hydrocarbons and GDP production in 1992-1999 (124 countries)



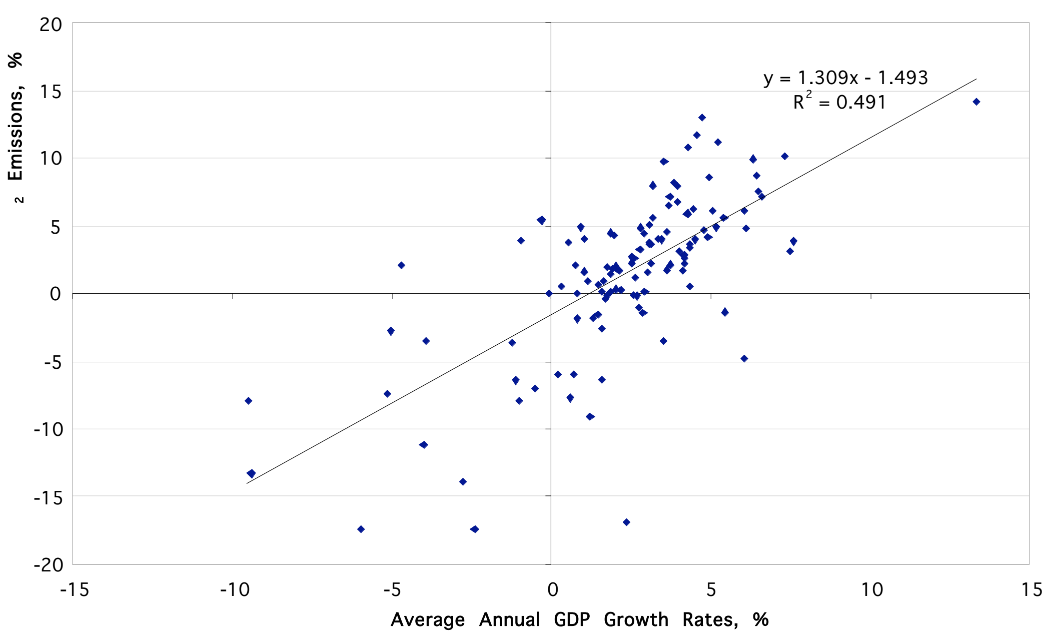
Sources: World Resources Institute, IMF.

Figure 2-7. World GDP production and CO_2 emissions in 1992-1999 (124 countries)



Sources: International Energy Agency, IMF.

Figure 2-8. World GDP production and CO_2 emissions in 1992-1999 (124 countries)



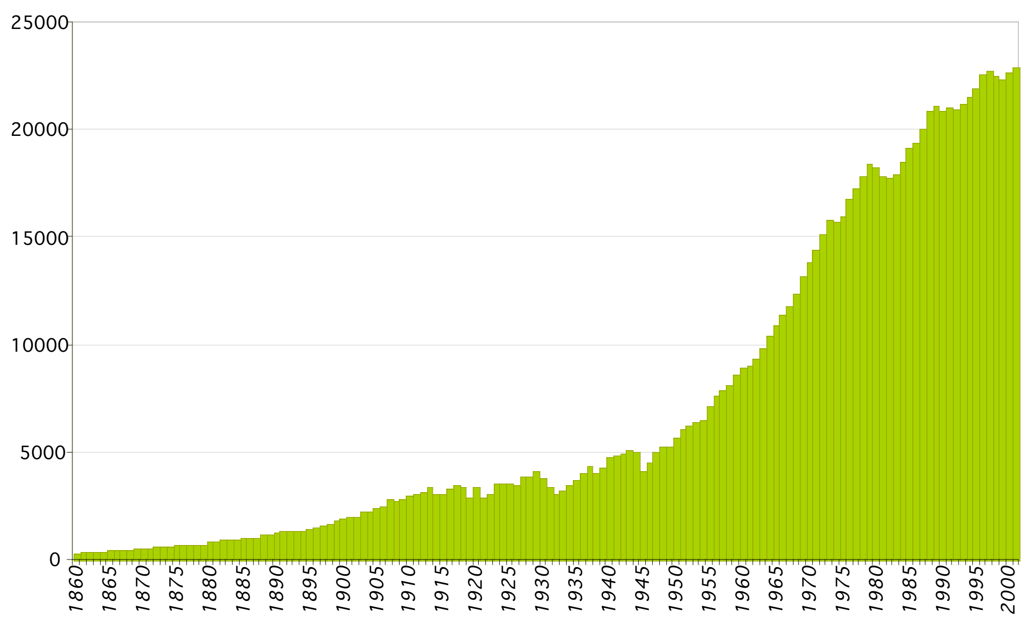
Sources: International Energy Agency, IMF.

Energy is consumed in the course of human economic activity, which has the ultimate objective of generating improved productivity and economic value at a micro-level and GDP at a macro-level (**Figure 2-5**). The link between hydrocarbon consumption and GDP generation is somewhat weaker, since different sources of energy, other than hydrocarbons, are used in the course of economic activity (**Figure 2-6**).

The link between GDP and carbon dioxide emissions illustrates the fact that hydrocarbon fuels serve as the most important source of energy used by humans for commercial purposes (**Figure 2-7**). A similar link is also observed for their growth rate indicators (**Figure 2-8**).

The increase in absolute terms of emissions of human-induced carbon dioxide is a distinctive feature of modern civilization (**Figure 2-9**). Decreases in the absolute volume of CO_2 emissions have been observed only at times of military and political and economic upheavals of cataclysmic proportions that caused reductions in production of material wealth and human energy consumption. Such decreases can be seen clearly during World War I and World War II, global economic crises of 1921-1922, 1929-1933, 1937-1938, 1974-1975, 1981-1982, 1990-1991, and during the crisis in transition economies in the 1990s. The reduction in world carbon dioxide emissions in the early 1980s was caused also by reduction in oil consumption as a result of world oil price shocks.

Figure 2-9. Human-induced carbon dioxide emissions in 1860-2001



Sources: Carbon Dioxide Information Analysis Center, International Energy Agency.

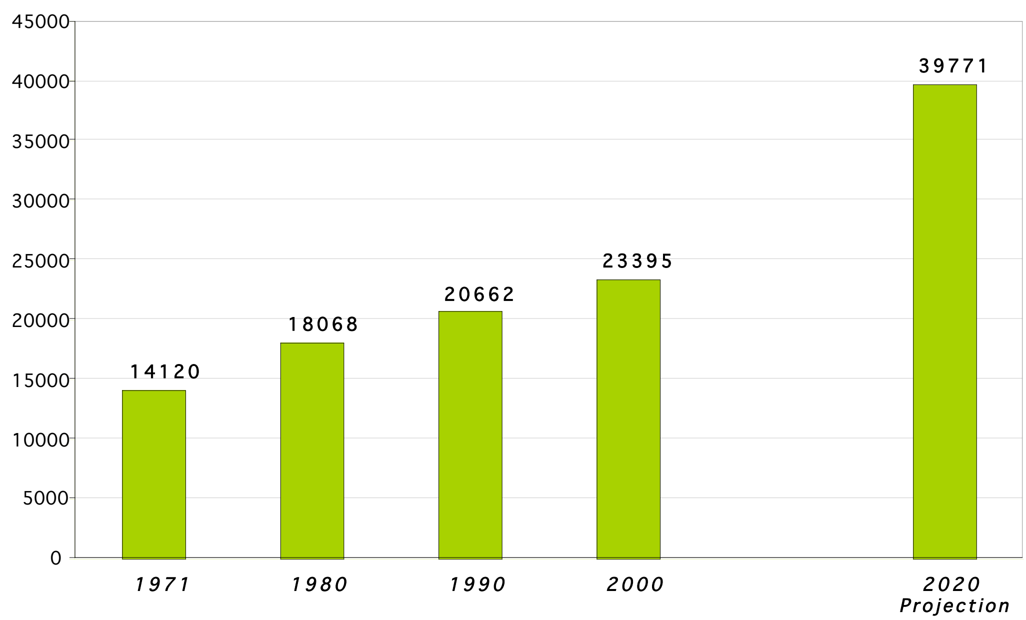
Continued growth in human-induced carbon dioxide emissions is also projected for the next several years by many leading analysts and international organizations, including the International Energy Agency or IEA (**Figure 2-10**).

In the 1990s, the trend towards higher nominal carbon dioxide emissions continued for most countries of the world (151 out of 198) (**Figure 2-11**).

At the same time, human-induced CO_2 emissions decreased in absolute terms in 47 countries. In 31 of them, lower emissions were accompanied by declining GDP per capita (**Figure 2-12**). This contraction of per capita GDP in those countries during the 1990s was caused mainly by crises of different kinds, leading to lower economic activity and lower carbon dioxide emissions in the following groups of countries:

1. Transition economies – 13 of the former USSR countries (with the exception of Uzbekistan and Turkmenistan), the Czech Republic, Slovakia, Bulgaria, Romania, Croatia, Serbia and Montenegro, Macedonia, Albania, and Mongolia;
2. Still existing centrally planned economies – North Korea and Cuba;
3. Low-income countries affected by external and internal conflicts (Afghanistan, Congo, Liberia, Zaire, Zambia, Zimbabwe);
4. The Bermudas.

Figure 2-10. Human-induced carbon dioxide emissions in 1971-2020



Source: International Energy Agency

In 16 countries in the 1990s, reductions in CO_2 emissions were accompanied by growth in per capita GDP (**Figure 2-13**). This case should be discussed appropriately. These 16 countries can be put into three groups:

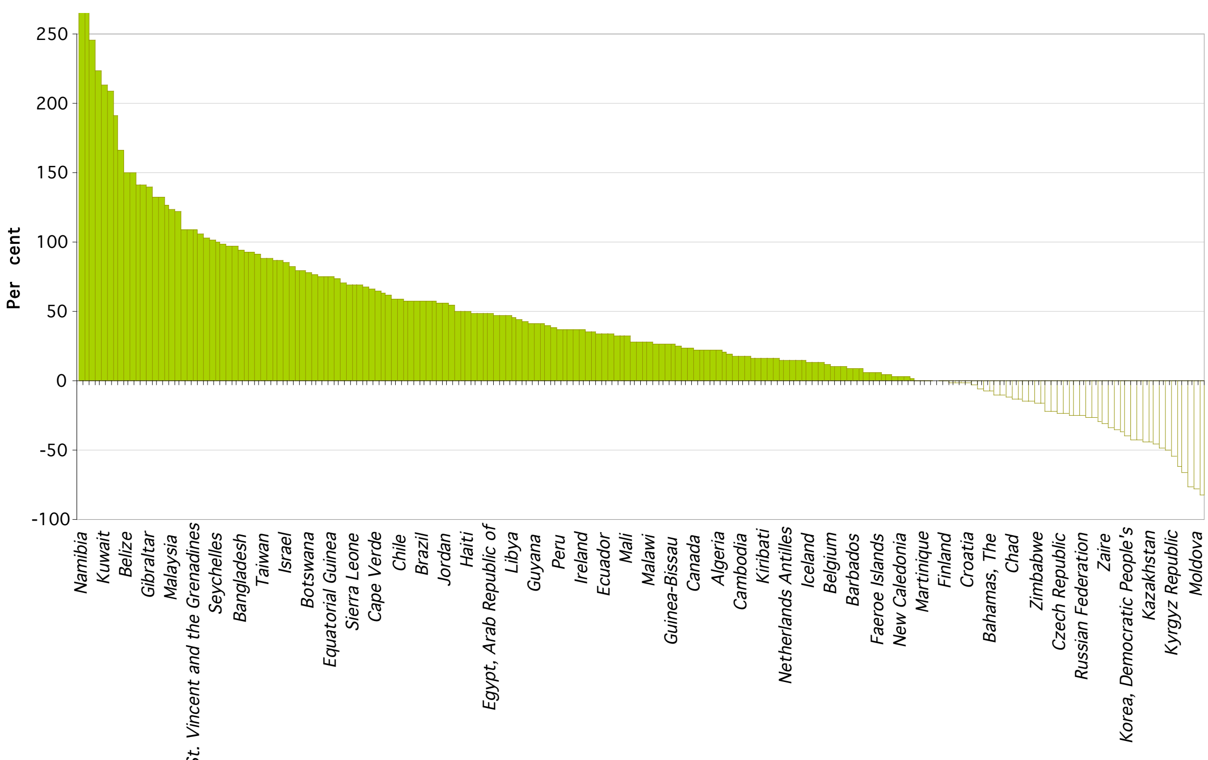
1. Eight high-income economies that are on the right (descending) part of the Kuznets curve (GDP per capita more than US$15,000 by purchasing power parity (PPP) in 1999 prices) – Luxemburg, Denmark, Finland, Great Britain, Germany,[1] the Bahamas, Puerto Rico, Malta. Having already been structurally rather advanced, and having limited access to cheap hydrocarbons, they had utilized serious structural adjustment of their economies to secure relatively moderate real growth rates with lower carbon dioxide emissions. [2]
2. Two countries in transition that previously had had excessively high levels of carbon intensity, relative to GDP for countries at their levels of economic development. They were able to quickly adapt their economies to new and higher prices of imported hydrocarbons (Poland and Hungary).

3. Six relatively small low-income economies that had in recent years quickly geared their economies toward exports of natural resources without substantial domestic processing and, therefore, without CO_2 emissions (Sudan, Chad, Swaziland, Fiji, French Polynesia, Papua-New Guinea).

In the first two groups of countries, the difference in the directions of the trends for economic growth and CO_2 emissions are pretty well explained by objective characteristics of their level of economic development and stage of economic transformation. At the same time, annual GDP growth rates in the 1990s for the eight countries of the first group (2.3 percent) happened to be lower than averages either for the world (3.0 percent), or for high income countries (2.7 percent). Therefore, a reduction in absolute volume of CO_2 emissions for the advanced economies does not look impossible. Nevertheless, the price of adjustment paid for such a reduction could be a significant decline in real GDP growth rates.

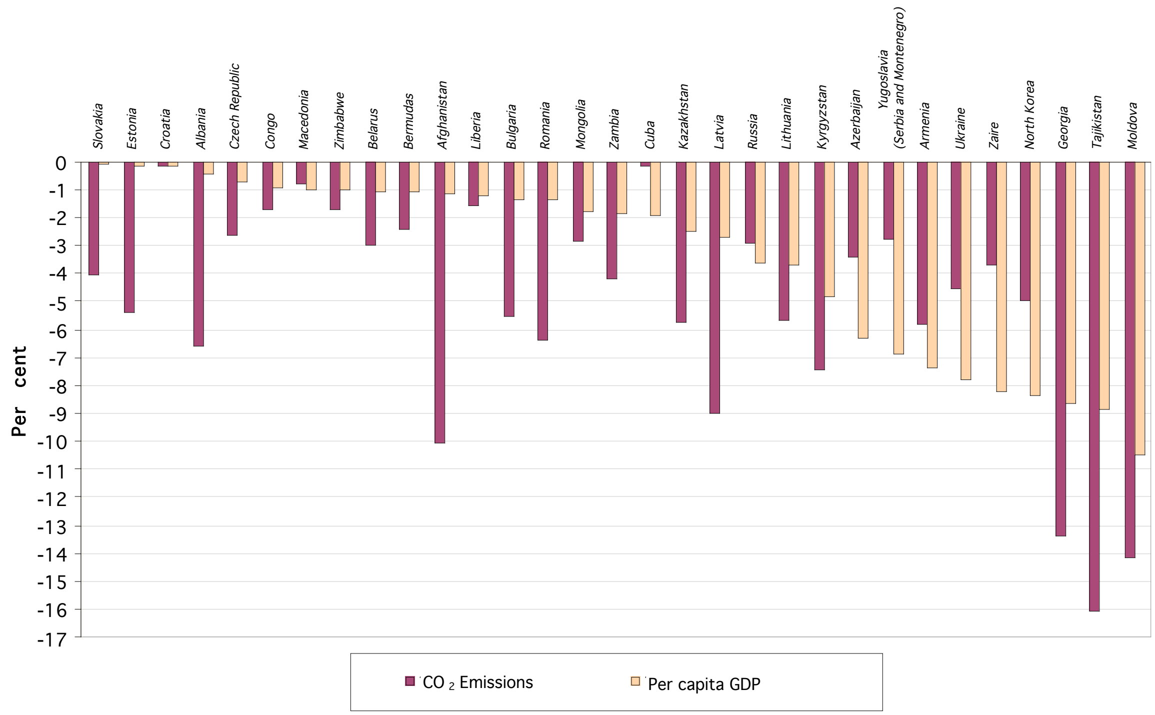
In a striking contrast to them, in six low-income countries (the third group), the combination of conflicting trends (real GDP growth along with CO_2 emissions decline) is observed. It is these six countries that truly are exceptions to the world-wide rule, and it is they that can genuinely be called “Green Trend” countries. In 2000, their share was 0.04 percent of the world’s total CO_2 emissions, and 0.23 percent of the world’s total GDP. Therefore, 99.96 percent of the world’s CO_2 emissions and 99.77 percent of the world’s GDP are produced in the countries that are bound by the world-wide pattern of an inalienable link between economic activity and CO_2 emissions.

Figure 2-11. Changes in CO_2 Emissions for 198 countries in 1991-2000



Sources: Carbon Dioxide Information Analysis Center, International Energy Agency.

Figure 2-12. Average annual rates of decline in CO_2 emissions and per capita GDP in 31 countries in 1991-2000



Sources: Carbon Dioxide Information Analysis Center, International Energy Agency, IMF.

Figure 2-13. Average annual rates of decline in CO_2 emissions and per capita GDP growth rates in 16 countries in 1991-2000

Sources: Carbon Dioxide Information Analysis Center, International Energy Agency, IMF.

GDP carbon intensity factors

Countries do have different rates in the intensity of carbon dioxide emissions per unit of GDP, or *carbon intensity of GDP*.[3] International as well historical comparisons show that this indicator is somewhat inert, and this implies that the quantitative value of carbon intensity of GDP for a given country remains roughly consistent over certain periods in its development.

The most important factors that predetermine the quantitative value of carbon intensity of GDP for one or another country, as well as the curve and rate of its change, involve the level of economic development (GDP per capita) and access by economic agents to hydrocarbons (coal, oil, and gas) that are relatively cheap compared to prices for other energy resources. The economic agents' access to relatively cheap energy resources to a large degree determines the energy consumption pattern (share of hydrocarbons in total energy consumed) and, respectively, the structure of the economy (the share of energy-intensive sectors in GDP). Furthermore, the carbon intensity of GDP is further substantially influenced by the climate of a particular country (its average annual temperature).

Based on the former two criteria,[4] the 124 countries for which information on carbon dioxide emissions in the years 1971-2001 is available from the IEA database were sorted into more uniform groups that demonstrate distinct patterns for carbon intensity of GDP and its change over time:

- carbon non-intensive market economies (73 countries);
- carbon intensive market economies (18 countries);
- highly carbon intensive 'factory countries' (6 countries);
- carbon non-intensive transitional economies (22 countries);
- carbon intensive transitional economies (5 countries).[5]

See **Table 2-1** for listing of countries by group. Some indicators for levels of economic and energy sector development for these groups of countries are shown in **Table 2-2**.

Table 2-1. Country listings by groups

1. Carbon non-intensive market economies

with per capita GDP below US$16,000 at PPP in 1999 prices

1. Angola
2. Argentina
3. Bangladesh
4. Bolivia
5. Brazil
6. Gabon
7. Haiti
8. Ghana
9. Guatemala
10. Honduras
11. Greece
12. Dominican Republic
13. Egypt
14. Zaire
15. Zambia
16. India
17. Indonesia
18. Yemen
19. Cameroon
20. Kenya
21. Columbia
22. Congo
23. Costa Rica
24. Cote d'Ivoire
25. Malaysia
26. Malta
27. Morocco
28. Mexico
29. Mozambique
30. Myanmar
31. Nepal
32. Nigeria
33. Nicaragua
34. Pakistan
35. Panama
36. Paraguay
37. Peru
38. Portugal
39. Salvador
40. Senegal
41. Sudan
42. Thailand
43. Tanzania
44. Tunisia
45. Turkey
46. Uruguay
47. Philippines
48. Chile
49. Sri Lanka
50. Ecuador
51. Ethiopia

with per capita GDP above US$16,000 at PPP in 1999 prices

1. Austria
2. Belgium
3. Great Britain
4. Germany
5. Hong Kong
6. Denmark
7. Israel
8. Ireland
9. Iceland
10. Spain
11. Italy
12. Cyprus
13. Netherlands
14. New Zealand
15. Norway
16. Singapore
17. Taiwan
18. Finland
19. France
20. Switzerland
21. Sweden
22. Japan

2. Carbon intensive market economies

with per capita GDP below US$16,000 at PPP in 1999 prices

1. Algeria
2. Venezuela
3. Zimbabwe
4. Jordan
5. Iran
6. South Korea
7. Lebanon
8. Libya
9. Oman
10. Saudi Arabia
11. Syria
12. Trinidad and Tobago
13. South Africa
14. Jamaica

with per capita GDP above US$16,000 at PPP in 1999 prices

1. Australia
2. Canada
3. Luxemburg
4. USA

3. Highly carbon intensive 'factory countries'

1. Antilles Islands (the Netherlands)
2. Bahrain
3. Brunei
4. Qatar
5. Kuwait
6. UAE

4. Carbon non-intensive transition economies

1. Albania
2. Armenia
3. Belarus
4. Bulgaria
5. Bosnia and Herzegovina
6. Hungary
7. Georgia
8. Kyrgyzstan
9. Latvia
10. Lithuania
11. Macedonia
12. Moldova
13. Poland
14. Romania
15. Slovakia
16. Slovenia
17. Tajikistan
18. Ukraine
19. Croatia
20. Czech Republic
21. Estonia
22. Yugoslavia (Serbia and Montenegro)

5. Carbon intensive transition economies

1. Azerbaijan
2. Kazakhstan
3. Russia
4. Turkmenistan
5. Uzbekistan

Sources: International Energy Agency, World Resources Institute, IMF.

Table 2-2. Selected energy and economic indicators in 1992-2001, by country groups

Country Groups	Number of countries	Carbon intensity of GDP		GDP per capita, US$ by PPP in 1999 prices	Hydrocarbons as % of total energy consumption in 1991-1999	CO_2 emissions per capita, kg	Average annual growth rates, %		
		kg of CO_2 per dollar of GDP	as % of average				CO_2 intensity of GDP	CO_2 emissions	GDP
1. All countries	**124**	**0.474**	**100.0**	**8456**	**68.1**	**4.0**	**-0.6**	**2.3**	**3.0**
2. Market economies	**97**	**0.467**	**98.4**	**9523**	**64.3**	**4.0**	**-0.8**	**2.2**	**2.9**
Carbon non-intensive	**73**	**0.366**	**75.0**	**6452**	**55.9**	**2.3**	**-0.8**	**2.0**	**2.8**
less than US$ 16,000 per capita	51	0.334	70.4	3207	46.9	1.1	0.4	4.3	3.9
above US$ 16,000 per capita	22	0.371	78.2	22898	76.9	8.5	-1.4	0.6	2.0
Carbon intensive	**18**	**0.654**	**138.0**	**19925**	**86.7**	**13.0**	**-1.0**	**2.2**	**3.3**
less than US$ 16,000 per capita	14	0.726	153.2	7597	86.2	5.5	0.8	4.0	3.2
above US$ 16,000 per capita	4	0.639	134.8	30403	88.3	19.4	-1.4	1.8	3.3
High carbon intensive 'factory countries'	**6**	**2.226**	**469.5**	**12766**	**99.8**	**28.4**	**2.0**	**6.7**	**4.6**
3. All transition economies	**27**	**1.322**	**278.8**	**5908**	**81.7**	**7.8**	**-2.8**	**-3.1**	**-0.3**
Carbon non-intensive	22	1.016	214.3	6056	78.0	6.1	-4.5	-3.8	0.8
Carbon intensive	5	1.667	353.7	5728	93.8	9.6	-1.2	-2.4	-1.2

Sources: International Energy Agency, World Resources Institute, IMF.

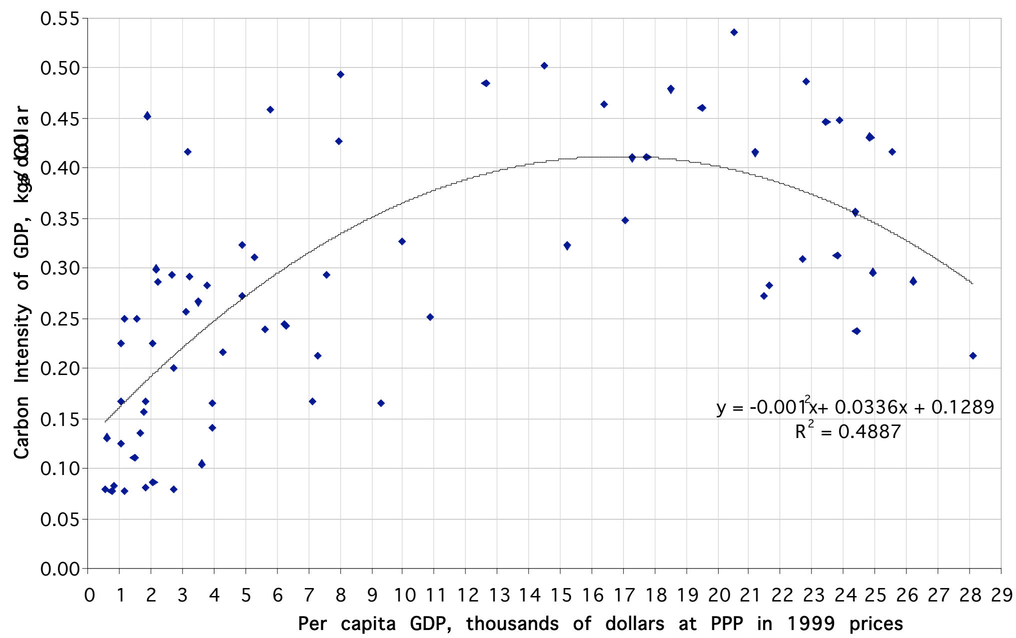
The impact of various factors on the carbon intensity of GDP can be seen clearly in the case of carbon non-intensive market economies (**Figure 2-14 through Figure 2-18**).

Countries with low per capita GDP usually have relatively low carbon intensity of GDP (**Figure 2-14**). A substantial part of the energy used in these countries involves human and animal muscle power.

With growing industrialization and a higher level of economic development, muscle energy is replaced by various sorts of industrial energy. Use of this energy grows very rapidly at rates exceeding the rates of GDP growth. Since hydrocarbons are one of the most easily available and transportable sources of this energy, they are widely used. The share of hydrocarbons in energy consumption thus tends to increase as per capita GDP grows (**Figure 2-15**). With growth of the share of hydrocarbons in energy consumption, the carbon intensity of GDP rises as well (**Figure 2-16**).

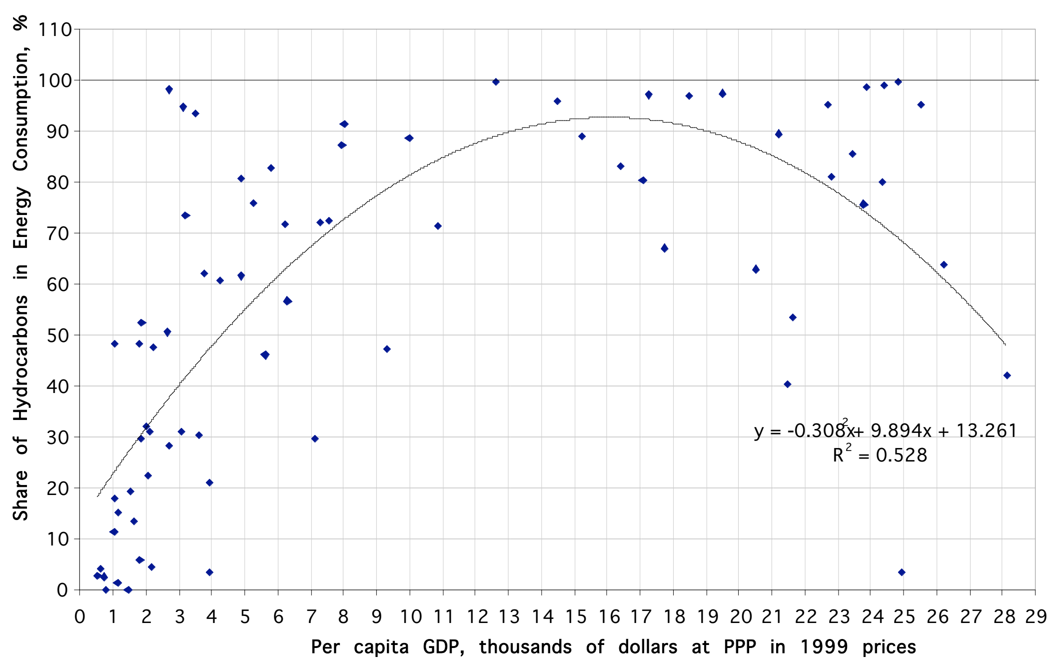
The correlation between levels of economic development and the carbon intensity of GDP is non-linear. It is best described by the Kuznets curve – an upside-down Latin U-shaped correlation. As the share of hydrocarbons in total energy consumption approaches 100 percent (**Figure 2-15**) and the country attains a level of economic development typical in advanced economies (now approximately US$15,000-20,000 at purchasing power parity in 1999 prices) (**Figure 2-14**), the pace of increase in the carbon intensity of GDP begins to slow down. The carbon intensity of GDP then continues to remain stable for some period of time.

Figure 2-14. Economic development and carbon intensity of GDP levels in carbon non-intensive market economies (73 countries) in 1992-2001



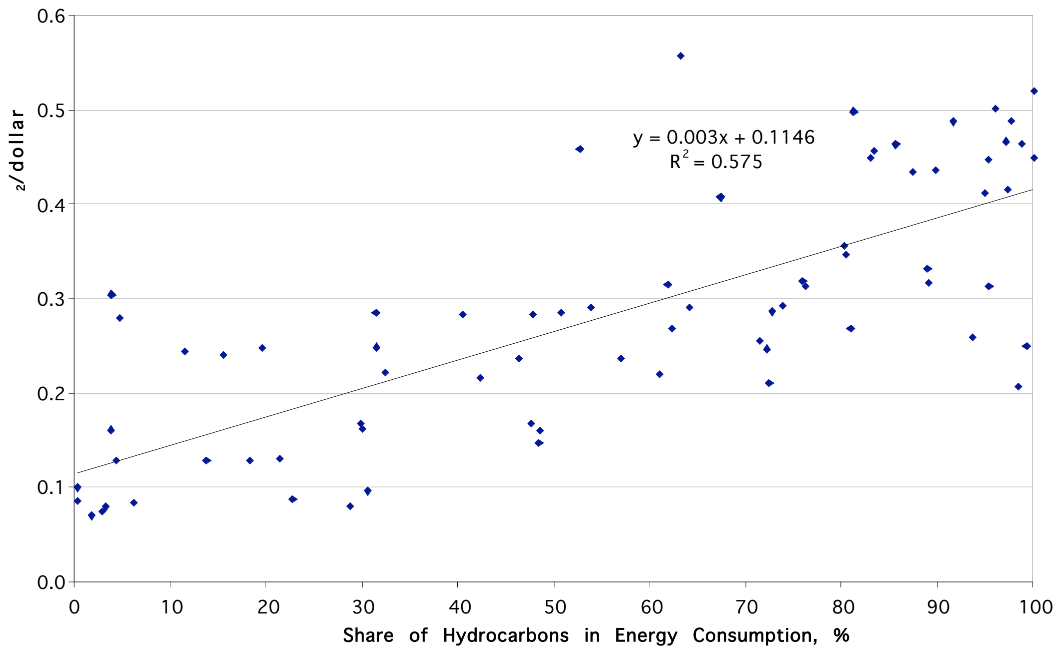
Sources: International Energy Agency, IMF.

Figure 2-15. Levels of economic development and share of hydrocarbons in energy consumption in carbon non-intensive market economies (73 countries) in 1991-1999



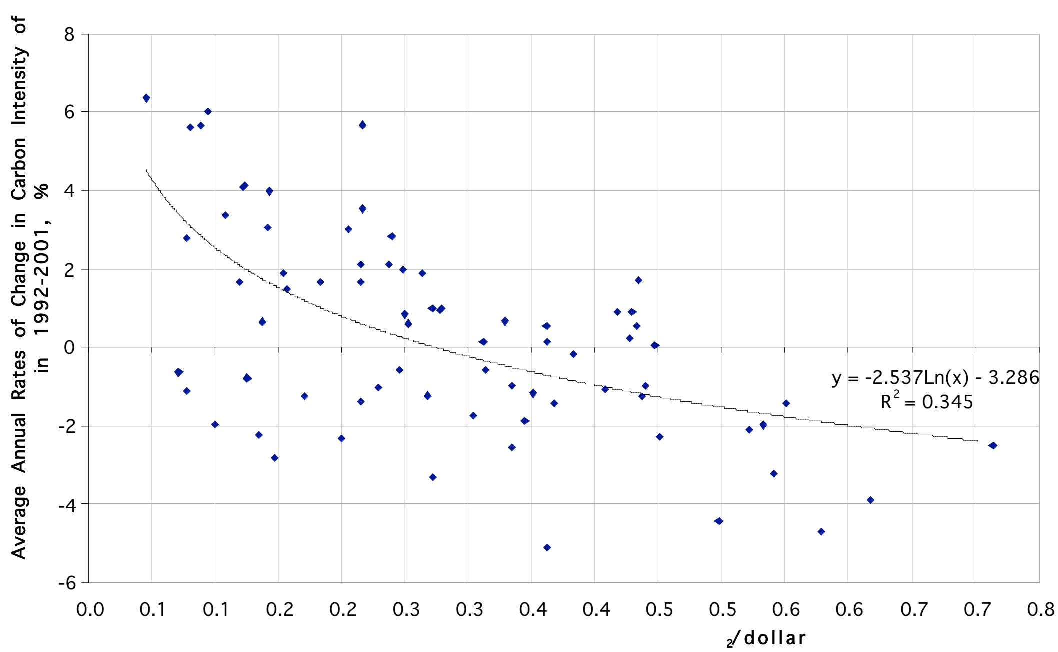
Sources: IMF, World Resources Institute.

Figure 2-16. Share of hydrocarbons in energy consumption and carbon intensity of GDP in carbon non-intensive market economies (73 countries) in 1991-1999



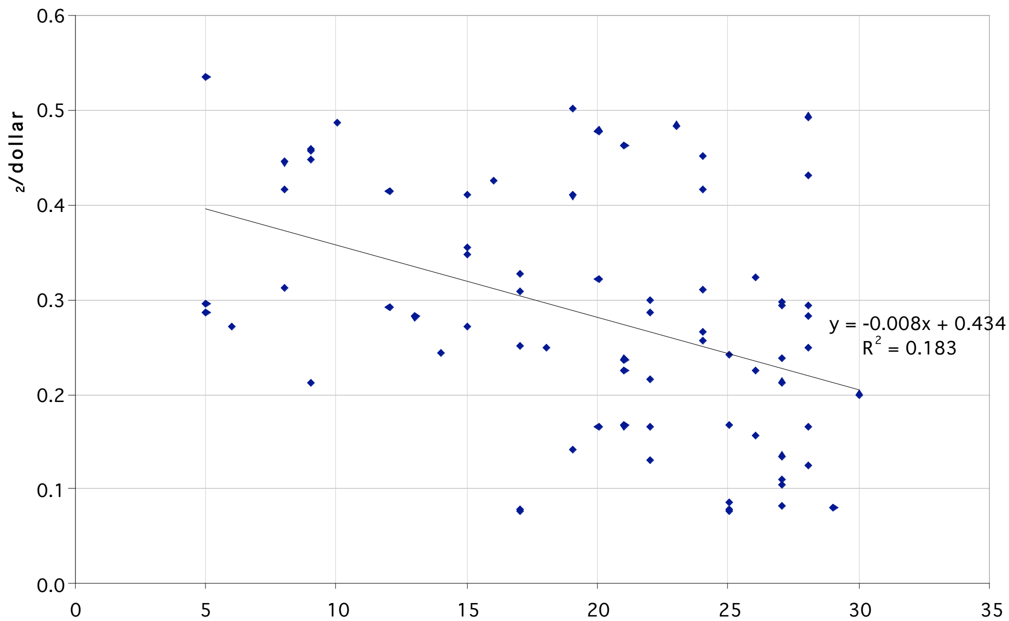
Sources: International Energy Agency, IMF, World Resources Institute.

Figure 2-17. Carbon intensity of GDP in 1982-1991 and rates of change in 1992-2001 in carbon non-intensive market economies (73 countries)



Sources: International Energy Agency, IMF.

Figure 2-18. Average annual temperatures and carbon intensity of GDP in 1991-2000 in carbon non-intensive market economies (73 countries)



Sources: Parker Philip M., National Cultures of the World, Statistical Reference. Cross-Cultural Statistical Encyclopedia of the World. Vol. 4. Greenwood Press. London, 1997, International Energy Agency, IMF.

As economic development reaches higher levels, we see a gradual substitution of less efficient and more carbon intensive hydrocarbon-based fuels by more efficient and less carbon intensive fuels: firewood, peat and oil shale are gradually replaced with coal; coal is replaced with oil and petroleum products; and oil and petroleum products are replaced with natural gas. Hydrocarbons themselves (where the climate, science and technology development levels, and the legal, social and political attitudes permit) are gradually replaced by hydroelectric power and nuclear power. These developments bring about a contraction in both the share of hydrocarbons in energy consumption (**Figure 2-15**) and the carbon intensity of GDP (**Figure 2-14**).

Once a country reaches per capita GDP of US$15,000-20,000 at PPP in 1999 prices, the carbon intensity of GDP, as a rule, tends to contract. However, in no countries with higher per capita GDP does the carbon intensity of GDP fall to levels typical of countries with low levels of economic development.[6]

In those countries where the carbon intensity of GDP is declining, the rates of decline in the carbon intensity of GDP are often stronger in countries that have significant initial values of carbon intensity of GDP (**Figure 2-17**).

Nevertheless, in some carbon non-intensive high-income countries (including Spain, Portugal, New Zealand, Taiwan, Israel and Cyprus), the carbon intensity of GDP continued to grow in the 1990s.

Countries with lower average annual air temperatures, as a rule, show typically higher carbon intensity of GDP values (**Figure 2-18**).

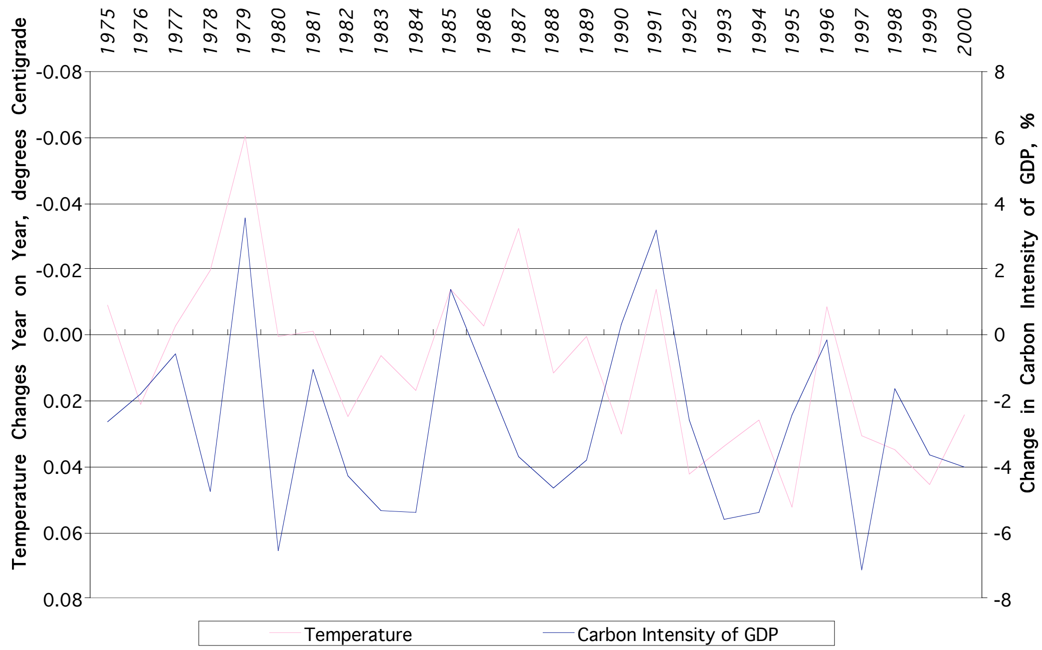
Even a high level of economic development does not prevent the carbon intensity of GDP from being very sensitive to changes in average annual air temperatures. The cold winter of 2003 in Finland spurred a 10 percent increase in the carbon intensity of GDP, almost offsetting its decline over the preceding five years. Against the background of a steady trend toward the reduction in the carbon intensity of GDP in previous years, a cold wave in Northern and Central Europe in 1996 brought about an immediate spike in CO_2 emissions per unit of GDP: in France by 2.7 percent, in Germany by 3.6 percent, in Austria by 5.0 percent, in Belgium by 5.3 percent, in Finland by 8.4 percent, in Sweden by 8.7 percent, and in Denmark by 19.1 percent.

Even in a very advanced economy like United Kingdom, which finds itself in rather favorable weather conditions (with average annual air temperatures in central England of 9.5 degrees Celsius above the freezing point), and whose authorities are keen on reducing the country's carbon intensity of GDP, the changes in this indicator remain highly dependent on changes in air temperatures (**Figure 2-19**). According to data for the years 1975-2000, a decrease in the temperature of air of 0.1 degrees Celsius results in an increase of carbon intensity of British GDP on average by 9 percent.

In other groups of countries, the patterns discussed above are observed as well, but are less conspicuous. For example, within the group of carbon intensive market economies, the carbon intensity of GDP declines slightly with higher levels of economic development (**Figure 2-20**). However, it remains at a relatively high level (above 0.5 Kg of carbon dioxide per dollar of GDP), even when per capita GDP reaches US$15,000-20,000.

For both groups of market economies (carbon intensive as well as carbon non-intensive), there is evidence of a steady link between the level of economic development and per capita carbon dioxide emissions (**Figure 2-21**). High levels of economic development and high standards of living in developed nations are, as a rule, dependent on high per capita energy consumption, including energy from the combustion of hydrocarbon fuels, which result in carbon dioxide emissions. For developed nations these indicators prove to be much stronger than for countries that have lower per capita GDP. Any substantial and prolonged decline in the growth of per capita carbon dioxide emissions in market economies is observed only once they reach per capita GDP levels of approximately US$15,000-20,000 at PPP in 1999 prices (**Figure 2-22**).

Figure 2-19. Air temperatures and carbon intensity of GDP in Great Britain in 1975-2000



Sources: International Energy Agency, Hadley Center for Climate Prediction and Research.

Figure 2-20. Levels of economic development and carbon intensity of GDP in market economies in 1992-2001 (91 countries)

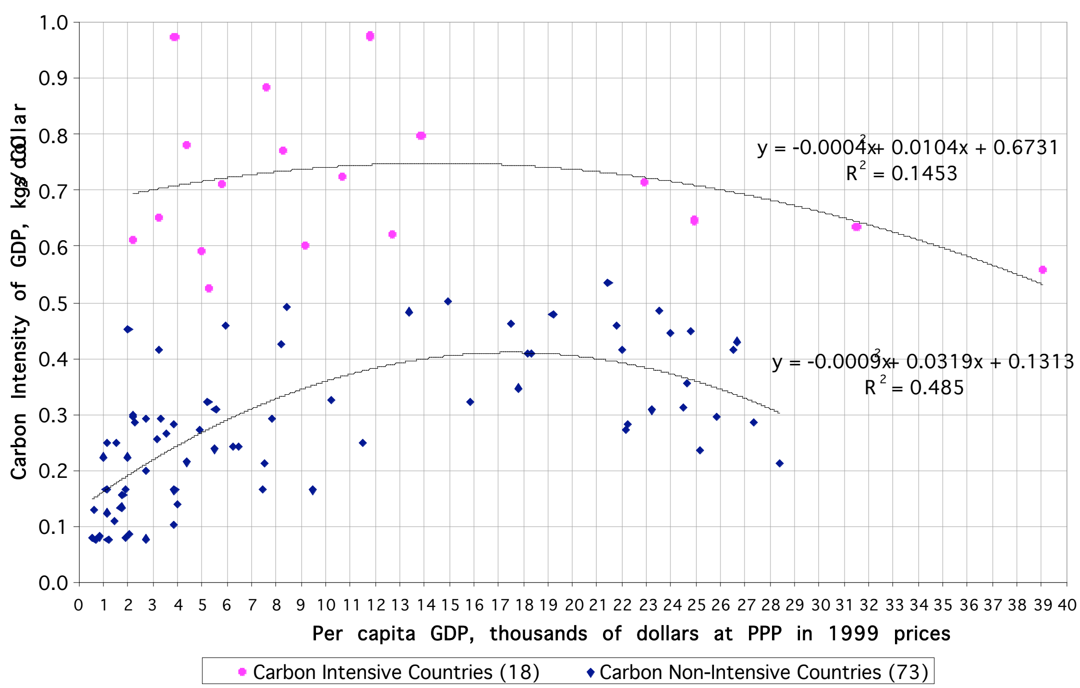
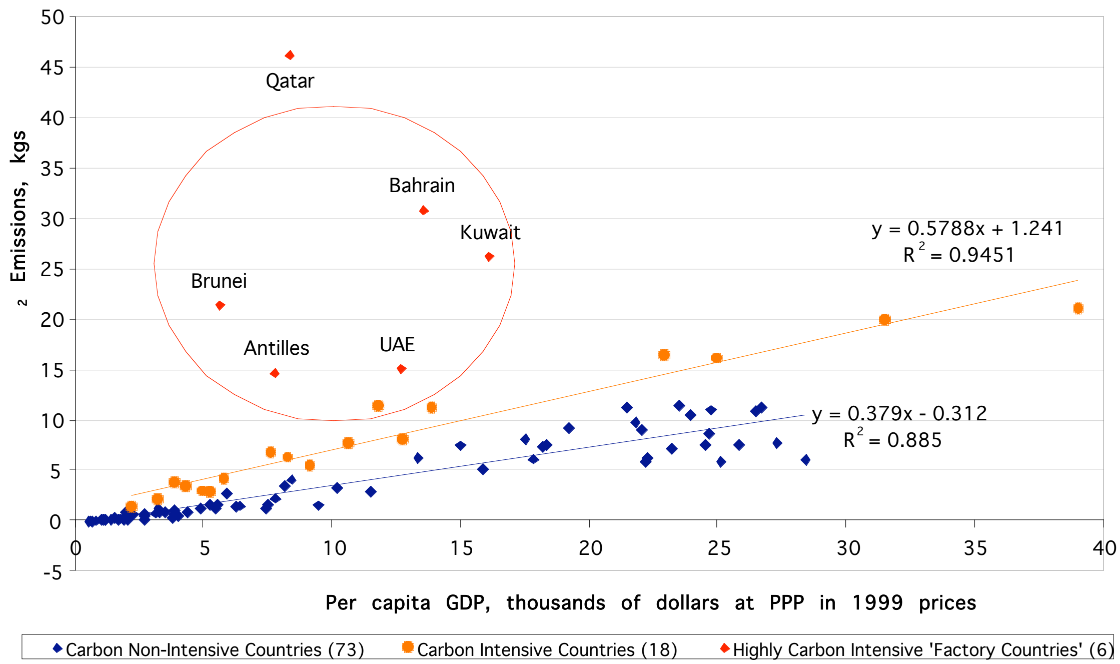
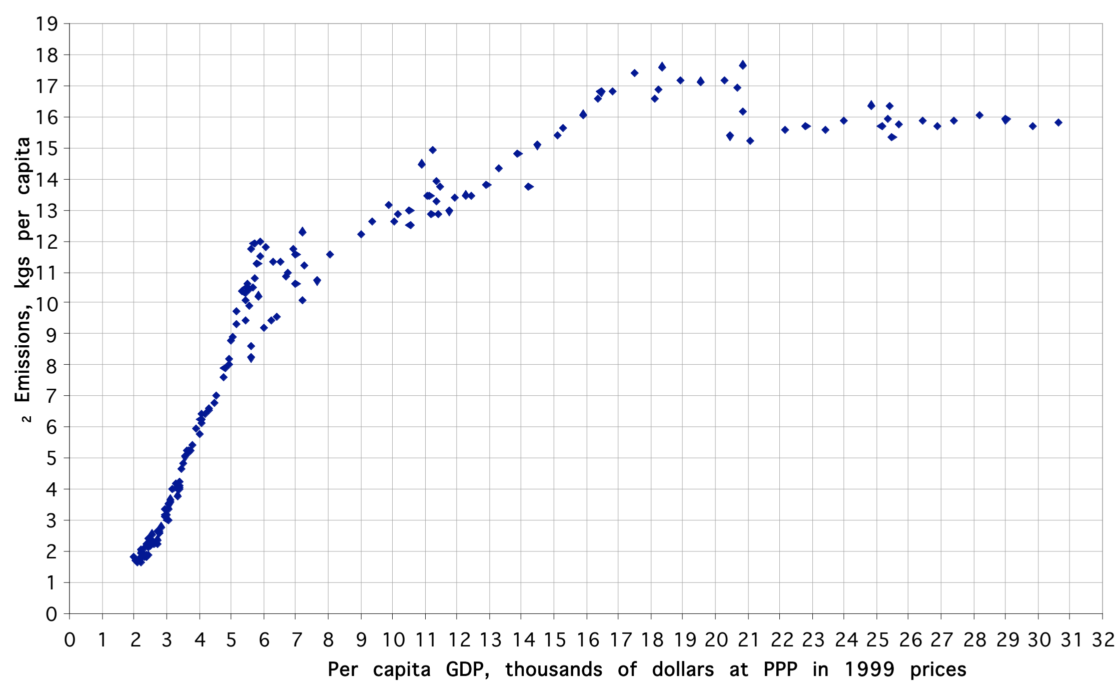


Figure 2-21. Levels of economic development and per capita CO_2 emissions by groups of market economies in 1992-2001 (97 countries)



Sources: International Energy Agency, IMF.

Figure 2-22. Levels of economic development and per capita $\_\__2$ emissions on average for 5 developed nations (USA, Great Britain, Canada, Germany, Belgium) in 1830-2000



Sources: Carbon Dioxide Information Analysis Center, A. Maddison.

Forecasting world carbon dioxide emissions not bound by Kyoto Protocol restrictions

Since CO_2 emissions can be presented either as a product of CO_2 emissions per capita and population or as a product of GDP and CO_2 emissions per unit of GDP, forecasting world carbon dioxide emissions can be done in two ways:

- either forecasting world average CO_2 emissions per capita with world population growth;
- or forecasting carbon intensity of world GDP with world GDP growth.

CO_2 emissions can be presented as a product of total energy consumed times CO_2 emissions per unit of energy consumed, and carbon intensity of GDP can be presented as a product of CO_2 emissions per unit of energy consumed times the amount of energy consumed per unit of GDP. In turn, total energy consumed can be presented as a product of energy consumed per capita times the population, while GDP growth can be presented as a product of GDP per capita growth times the population. Energy consumed per capita can be presented as a product of energy consumed per unit of GDP and GDP per capita.

Therefore, all forecasting scenarios can be presented as different combinations of the following exogenous factors:

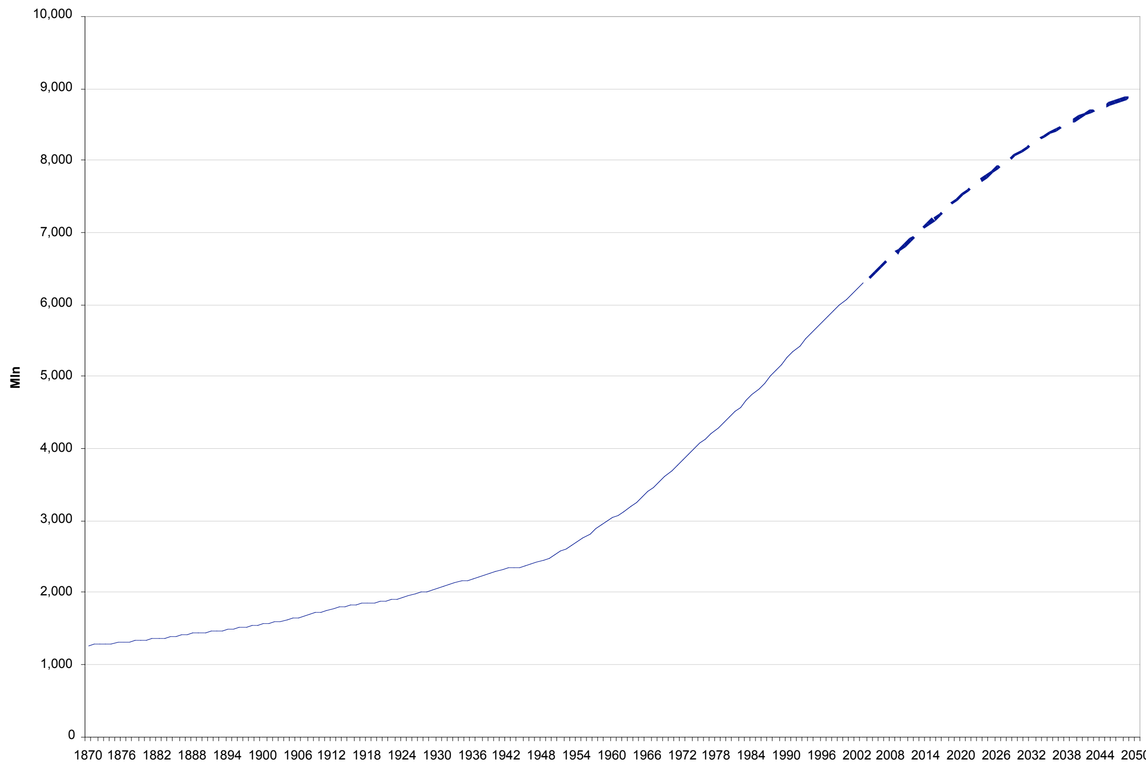
- population growth;
- GDP per capita growth;
- energy intensity of GDP (energy consumed per unit of GDP);
- carbon intensity of energy (CO_2 emissions per unit of energy consumed).

There could be some endogenous links between GDP per capita growth rate, on one hand, and energy consumed per unit of GDP, as well as CO_2 emissions per unit of energy consumed, on the other. The expected sign of these links is negative – meaning that, given normal conditions, the higher the GDP per capita growth rate, the faster the decline in energy consumed per unit of GDP – and the faster the decline in CO_2 emissions per unit of energy consumed. Nevertheless, in this chapter we assumed that the relationship between those indicators remained steady.

Forecasting growth rates of population

The forecasts of population growth are regularly produced by the UN Demographic Division. We have borrowed the latest one, according to which the world population will reach 8.9 billion by 2050[7] (see **Figure 2-23**).

Figure 2-23. World Population (millions of people)



Forecasting growth rates of GDP per capita

Over the last 180 years of modern economic growth, the world real GDP per capita growth rate had increased by roughly 53 percent every 50 years.[8] Since GDP per capita grew on average 2.12 percent a year between 1950 and 2000, and assuming that steady increase in GDP per capita growth rate observed in the past two centuries could be sustained in the coming 50 years, we arrive at 3.23 percent a year for world GDP per capita growth rate as a plausible scenario for 2001-2050. World GDP per capita would rise from US$7,500 by PPP in 1999 prices in 2001 to US$35,500 in 2050 (**Figure 2-24**).

In this case, the world GDP growth rate in 2001-2050 will be 4.02 percent a year on average, which is consistent with the overwhelming majority of the existing long-term forecasts for the world economy. To see that this forecasted growth rate is reasonable and not too ambitious, it is worth mentioning that this rate is very similar to the actual world GDP growth rate in 1950-2000 (3.93 percent a year) and approximately 20 percent *lower* than the actual world GDP growth in 1950-1973 (4.90 percent a year).

According to this forecast, the world GDP will reach US$316 trillion by PPP in 1999 prices, compared to US$50 trillion in 2004 (**Figure 2-25**). Its forecasted growth of 7.0 times over the 2001-2050 period is consistent with actual historical growth of 6.8 times for this indicator over 1950-2000.

Figure 2-24. World GDP per capita in 1999 US$ by purchasing power parity (PPP)

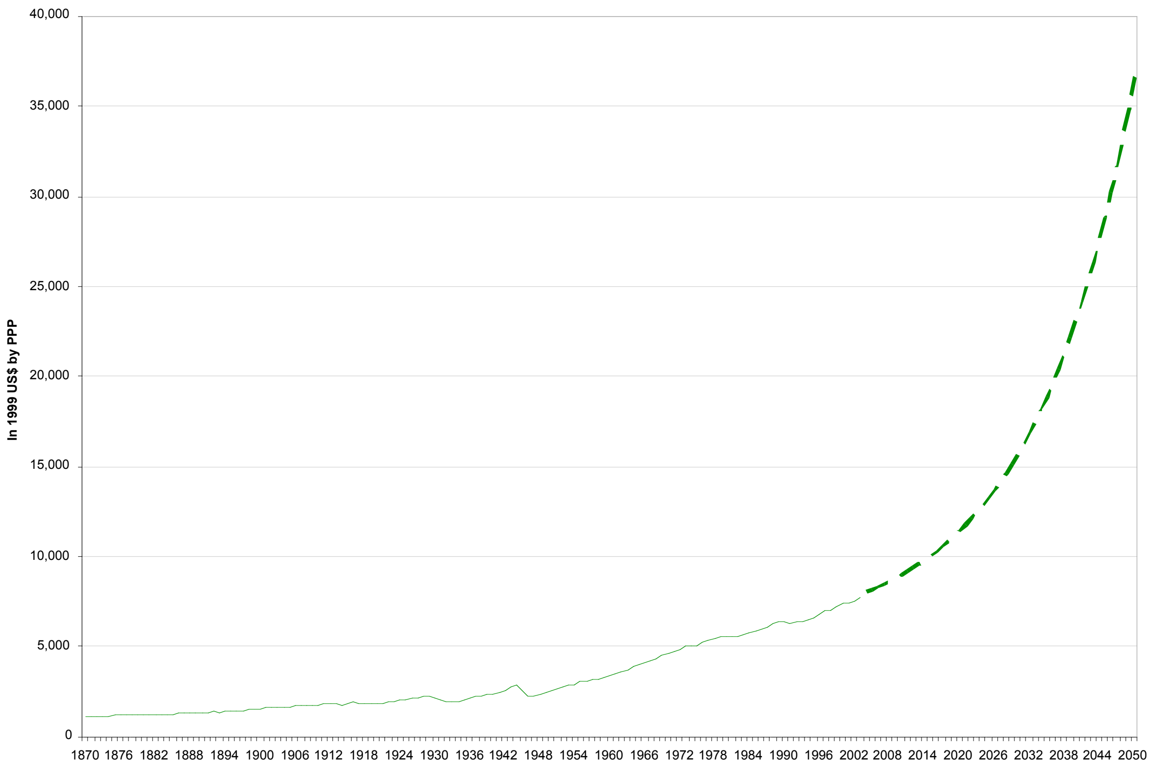
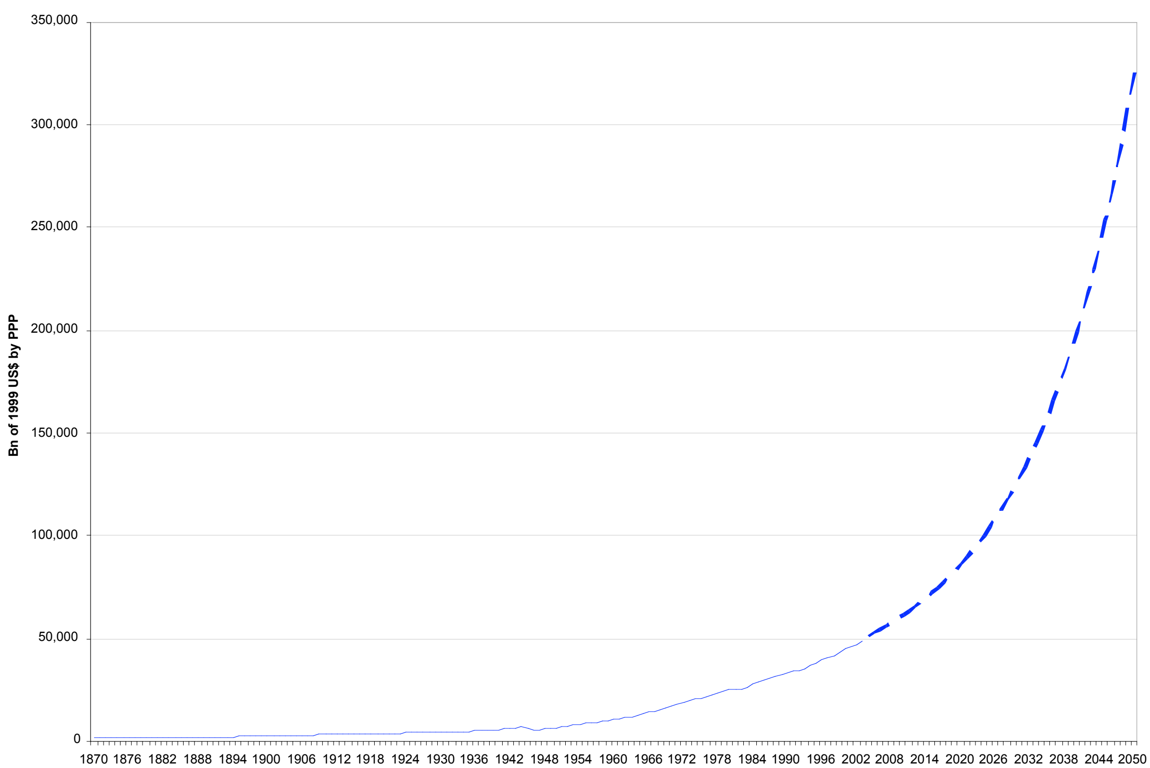


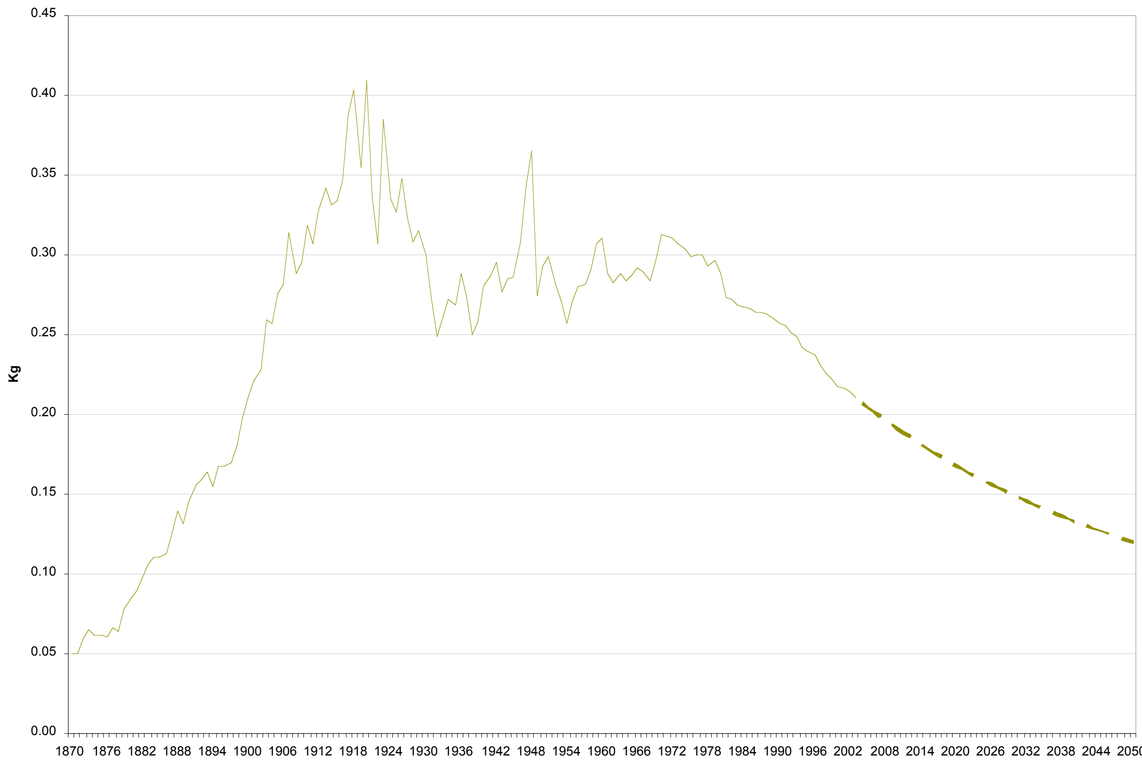
Figure 2-25. World GDP, billions of 1999 US$ by PPP



Forecasting growth rates of energy intensity of GDP

Energy intensity of GDP grew sharply from 0.049 kilograms (Kg) of oil equivalent per one 1999 U.S. dollar by PPP in 1870 to 0.409 Kg in 1920 (**Figure 2-26**). It declined somewhat during the 1920s and demonstrated no clear trend in 1930-1980, when it fluctuated around level of 0.300 Kg. The energy consumption per unit of GDP started to decelerate sharply in the last 30 years and fell from 0.312 Kg in 1970 to 0.216 Kg oil equivalent per dollar in 2001. Its average rate of decline in 1971-2001 was –1.20 percent per year.

Figure 2-26. Commercial energy consumption per dollar of GDP, Kg of oil equivalent



We have made an assumption that this rate of decline might be sustained over the coming 50-year period. In this case it will fall by 45 percent from 0.216 Kg of oil equivalent per one 1999 U.S. dollar by PPP in 2001 to 0.120 Kg in 2050. This forecast should be considered with caution, as it seems rather ambitious, since such a rate of reduction in energy intensity of GDP has had no historical precedent over such a prolonged period of time. Nevertheless, over the last 30 years, it has been observed and therefore should be treated as a realistic scenario that is close to the marginal rate of reduction.

Understanding the trends of world GDP and energy consumption per unit GDP allows us to make predictions on the path that world energy consumption could take in 2001-2050 (**Figure 2-27**) and of world energy consumption per capita (**Figure 2-28**).

Figure 2-27. World commercial energy consumption, millions toe

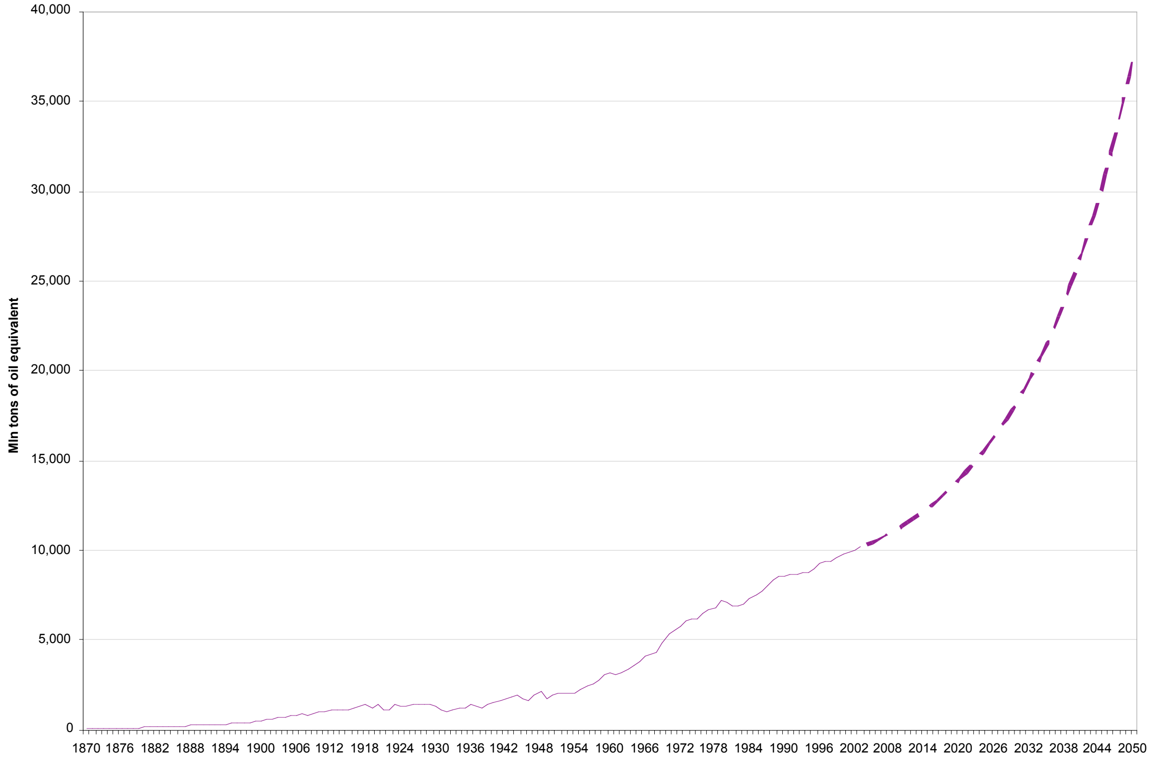
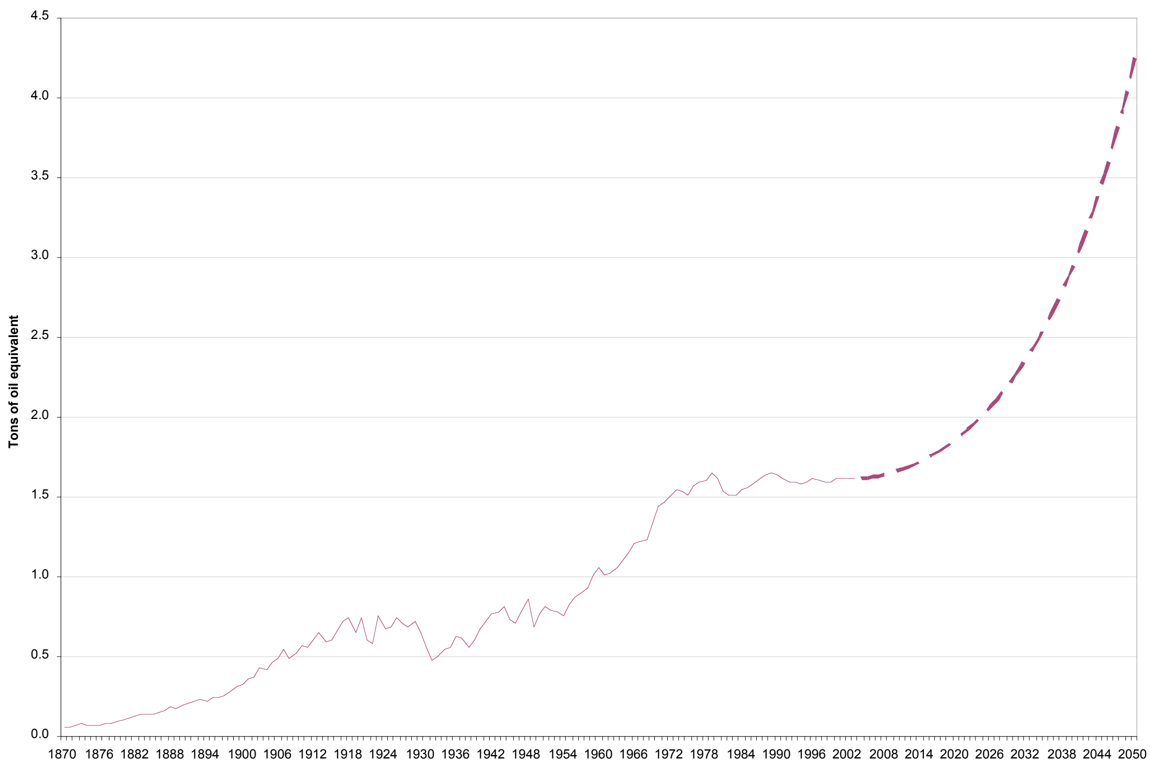


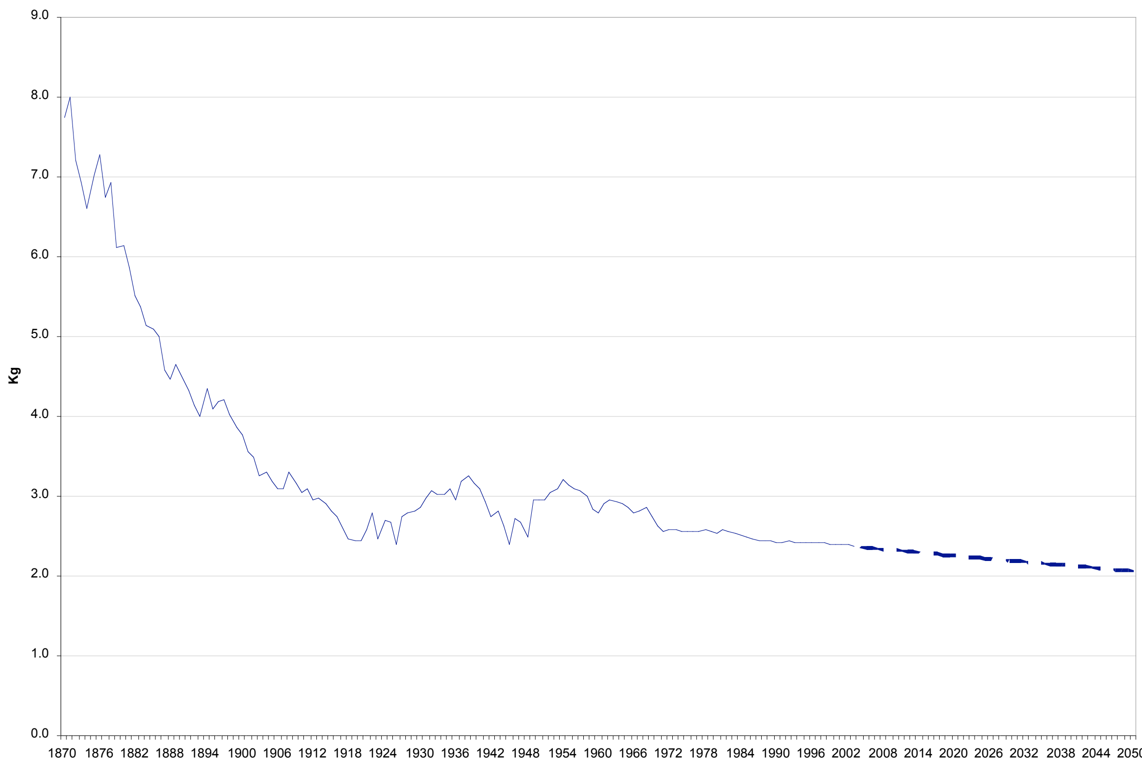
Figure 2-28. Commercial energy consumption per capita, toe



Forecasting growth rates of carbon intensity of energy

The actual path of the world's carbon intensity of energy over the last 130 years can be divided into two distinct periods (**Figure 2-29**). In 1870-1920, it fell sharply from 8.0 Kg of CO_2 per metric ton of oil equivalent to 2.4 Kg/toe. Over the following 30 years, it fluctuated considerably, rising up to 3.0-3.3 Kg/toe in the 1930s and 1950s, but since then it has embarked on a steady gradual downward path, reaching by 2001 virtually the same level at which it was in 1920 – 2.4 Kg/toe. The rate at which CO_2 emissions per unit of energy consumption declined over the last 30 years was -0.3 percent a year on average.

Figure 2-29. Carbon intensity of energy (CO_2 emissions per toe), Kg



We have made an assumption that this rate of decline might be sustained over the coming 50-year period. According to this forecast, carbon intensity of energy would fall from 2.4 Kg/toe in 2001 to 2.1 Kg/toe in 2050, or by 13.5 percent. For historical comparison, in 80 preceding years, 1920-1980, it fell by only 1.9 percent.

Calculations of the carbon intensity of GDP, carbon dioxide emissions per capita, and total carbon dioxide emissions

The changes in the carbon intensity of energy, as well as in the energy intensity of GDP, predetermine the changes in the carbon intensity of GDP (**Figure 2-30**). The changes in the carbon intensity of GDP, along with changes in GDP per capita, provide an opportunity to present the actual and forecasted level of CO_2 emissions per capita (**Figure 2-31**).

Figure 2-30. CO_2 emissions per dollar of GDP, Kg

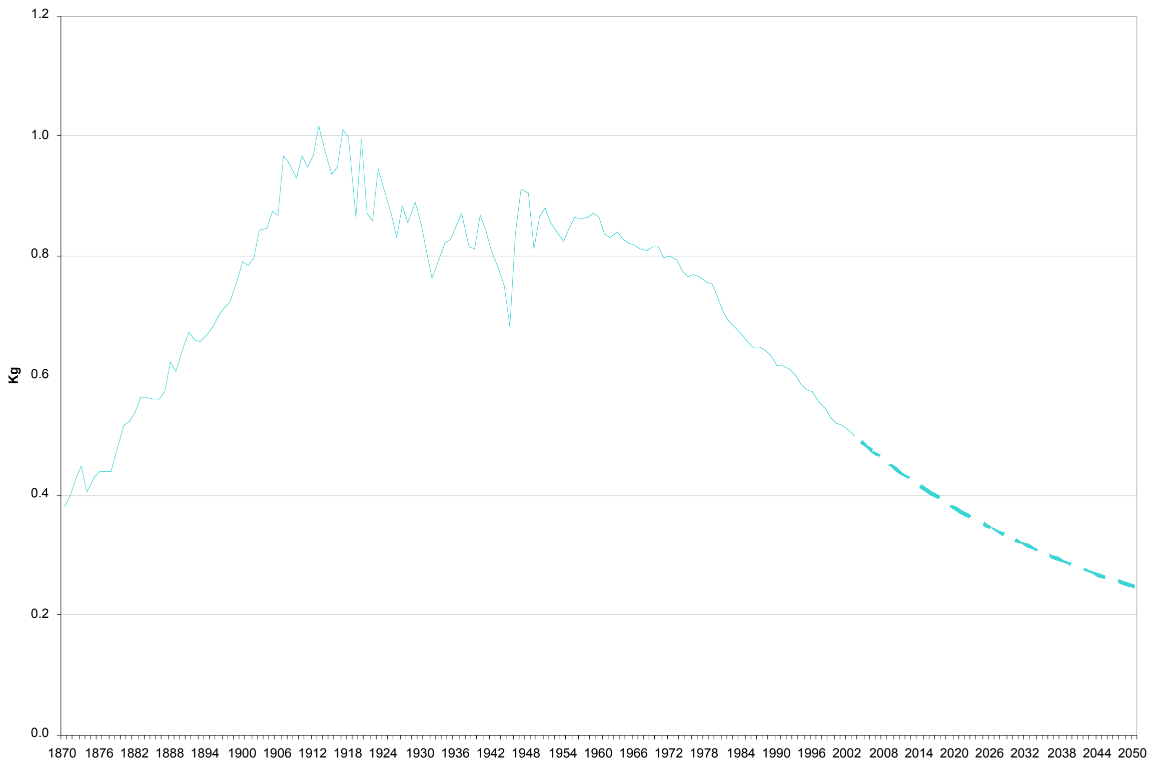
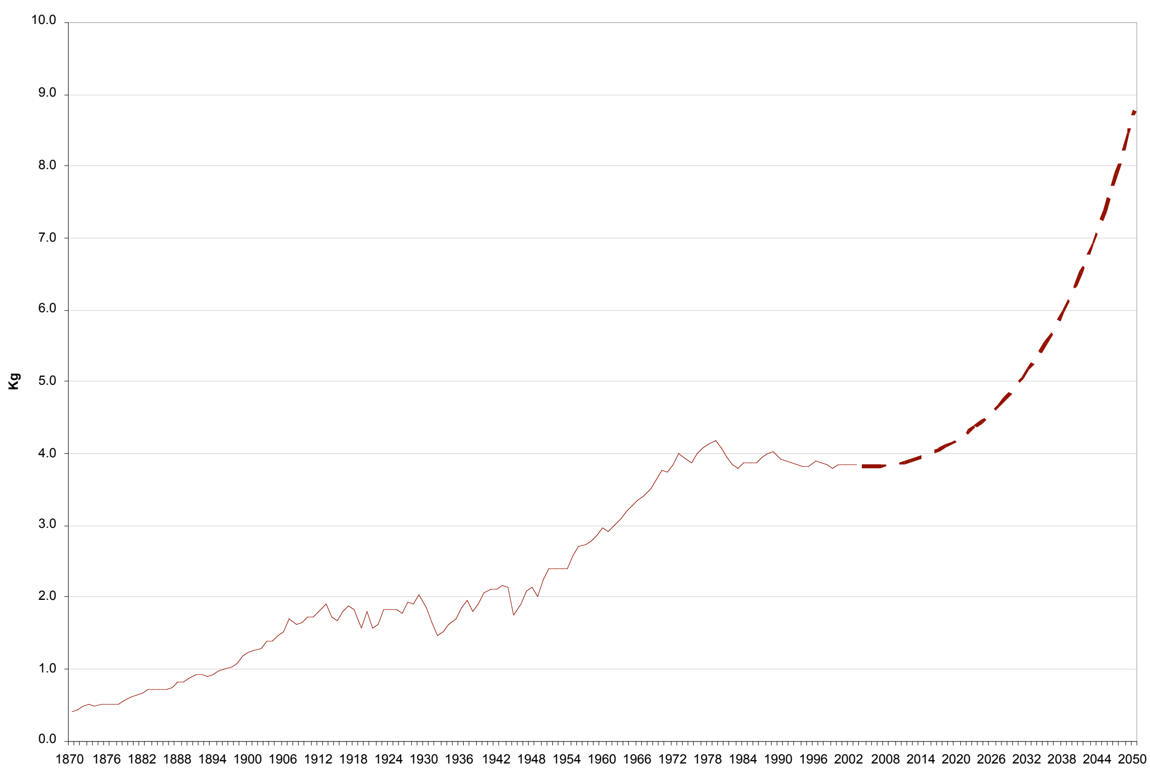
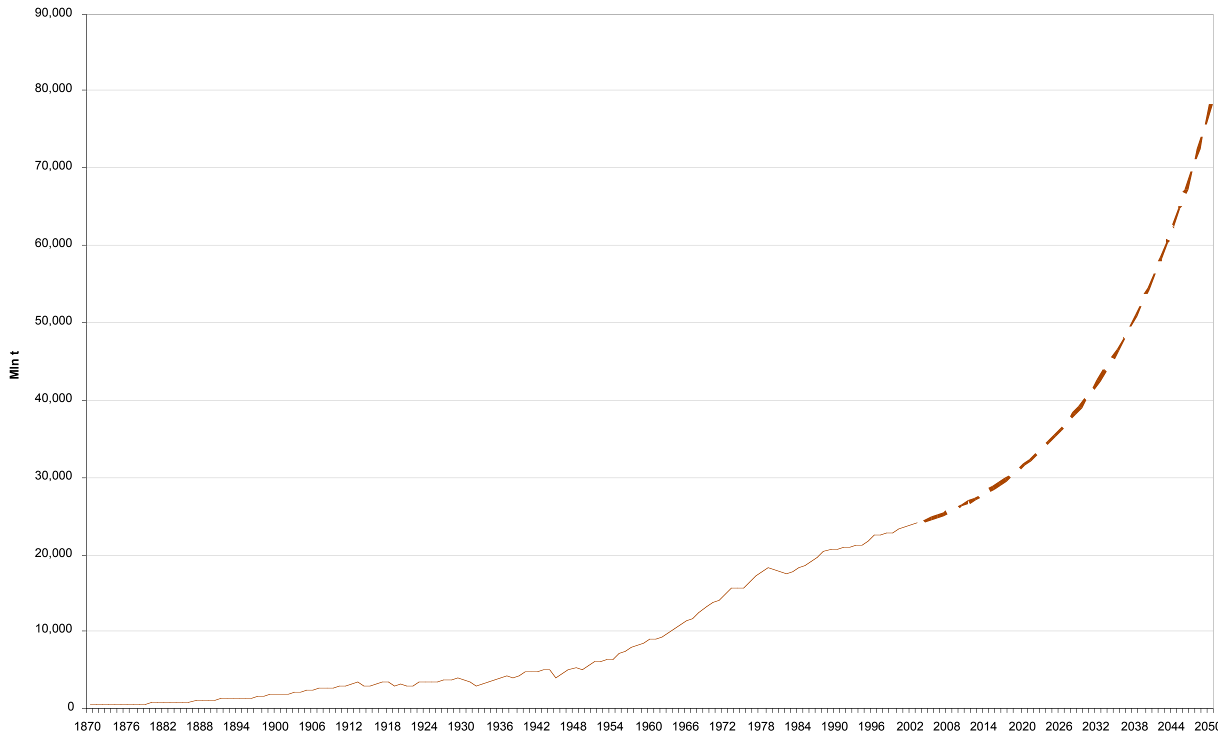


Figure 2-31. CO_2 emissions per capita, Kg



The availability of all necessary components allows us to calculate the forecasted volume of total carbon dioxide emissions, using all possible combinations of exogenous indicators (**Figure 2-32**). Under the above assumptions, world CO_2 emissions will increase 3.3 times by 2050 (in 1950-2000 it grew 4.1 times). In the first half of the 21st century, the average CO_2 emissions growth rates will be 2.5 percent a year, compared to 2.9 percent a year in 1950-2000.

Figure 2-32. CO_2 emissions, millions of tons



As one can see, the results of these calculations happen to be much more modest than the results produced by the IEA (see **Figure 2-10**). Unlike the IEA numbers, which show a possible rise in world total CO_2 emissions up to 39.8 trillion tons by 2020, this forecast envisions an increase to only 31.7 trillion tons. In terms of absolute increases of the emissions, this difference is even starker. According to the IEA, in 2001-2020, world CO_2 emissions could increase by 16.4 trillion tons of CO_2, while according to the forecast presented above the increase will be to only 8 trillion tons.

This conclusion implies that assumptions used in this forecast are much stricter than those used by IEA. Therefore, it will be rather hard to make them even stricter, while at the same time trying to remain within the framework of realistic forecasting.

The growth of the world economy under realistic though rather tough assumptions – which are nevertheless unrestricted by Kyoto Protocol limits – would in 2001-2050 lead to a 3.3-fold increase in annual world CO_2 emissions, from 23.7 trillion tons to 78.4 trillion tons of CO_2. **Therefore, the announced goal of the Kyoto Protocol – namely, to bring world CO_2 emissions to a level that is somewhat lower than it was in 1990, or approximately 19 trillion tons of CO_2 – is clearly beyond the limits of reality.**

If the goal of the Kyoto Protocol remains to control emissions only by the industrial nations – even in the face of an expected increase in world emissions by 54.7 trillion tons in 2011-2050 – **then the Kyoto requirements to reduce industrial nation emissions in 1990-2010 by approximately 0.4 trillion tons looks negligible and unnecessary.**

Forecasting world carbon dioxide emissions bound by Kyoto Protocol restrictions

The total volume of world carbon dioxide emissions is a function of four relatively independent variables – population, GDP per capita, energy intensity of GDP and carbon intensity of energy. The rates of increase in population, energy intensity of GDP and carbon intensity of energy can be considered to a high extent as a given at particular levels of technological, economic and social development. The changes in their patterns are usually relatively smooth and slow and subject to the complex interaction of many factors, most of which lie far beyond the reach of policy makers in a short-term perspective. Therefore, the only effective instrument for managing worldwide emissions of CO_2 left in the hands of policy makers is rates of change in GDP per capita.

However, any actual attempts to achieve the 1990 level of world CO_2 emissions set up in the first phase of the Kyoto Protocol for countries of the world not included in Annex B would bring the world economy into a deep recession.

Another possible goal of Kyoto-type restrictions that can be discussed in this regard is to keep world emissions of carbon dioxide at a level close to the volume of world CO_2 emissions that is expected within the first phase of the Kyoto protocol in 2008-2012 until, let's say, 2050. This would require that the real world GDP per capita rate be kept not higher than 0.98 percent a year on average for the half century. The world GDP per capita in this case would grow by 62 percent to approximately US$12,000 by PPP in 1999 prices. The possible rise of this indicator is 4.8-fold, to slightly more than US$34,000 if the world is not bound by the Kyoto-type restrictions (see **Figure 2-33**).

The total volume of world GDP will rise 2.4-fold, in comparison to a 7-fold increase if the world is not bound by Kyoto-type restrictions. In this case, over a 50-year period, the world will not be able to produce cumulative GDP worth of approximately US$210 trillion by PPP in 1999 prices, or about US$27,000 in per capita terms for the whole world population. Well-being, living standards and financing for programs in health, education, environment and science will be affected accordingly (see **Figure 2-34**).

Figure 2-33. Forecasts of world GDP per capita
(with and without Kyoto-type restrictions in 2004-2050, in US$ by PPP in 1999 prices)

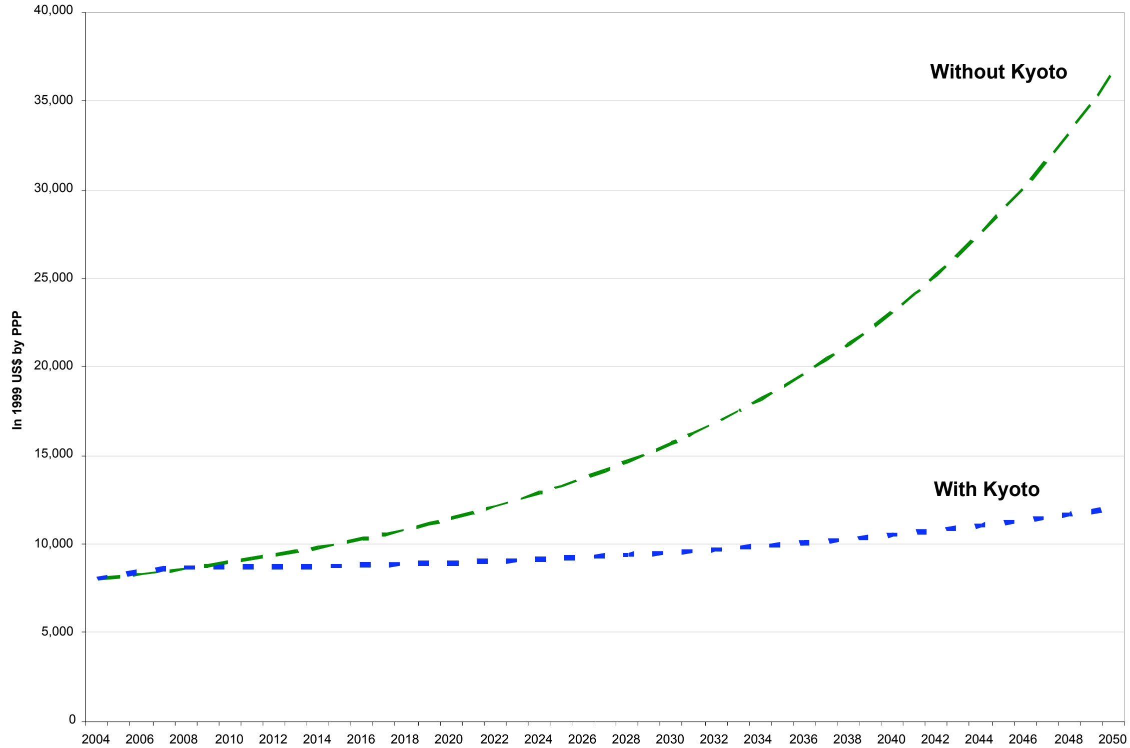
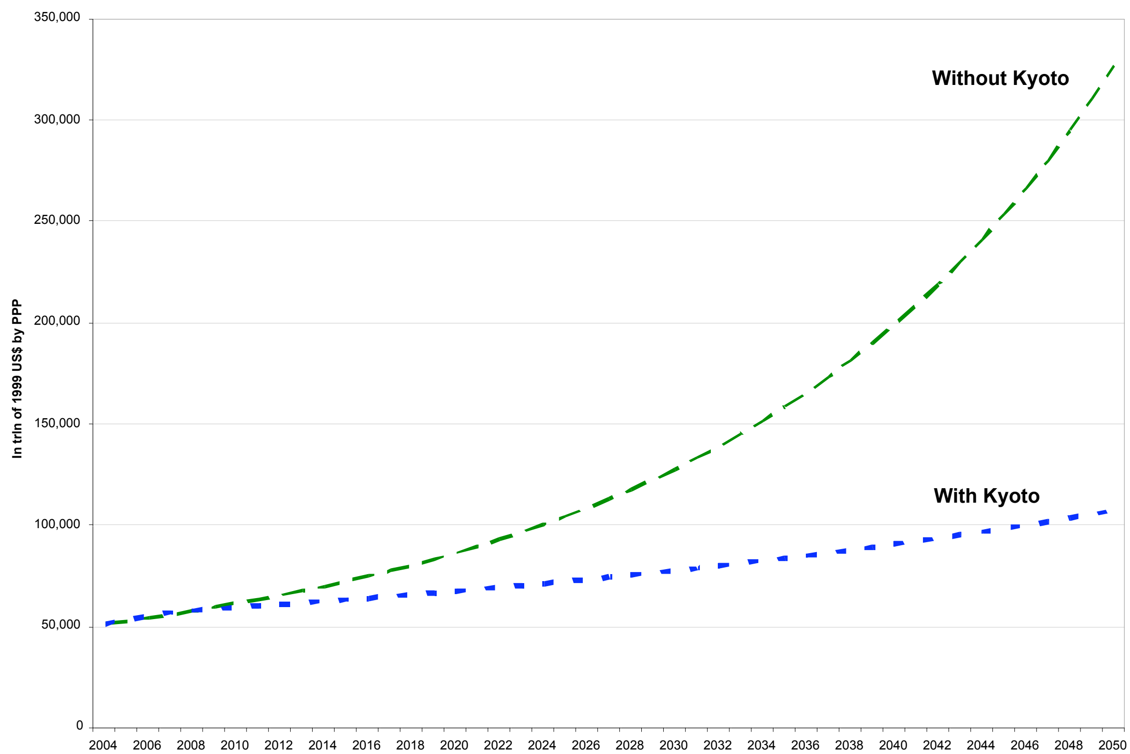


Figure 2-34. Forecasts of World GDP
(with and without Kyoto-type restrictions in 2004-2050, in trillions of 1999 US$ by PPP)



Main findings

Carbon dioxide emissions are an inevitable by-product of human economic activity at the current stage of its economic and technological development.

The volume of carbon dioxide emissions is a function of four relatively independent variables – population, GDP per capita, energy intensity of GDP and carbon intensity of energy.

Rapid declines in the carbon intensity of GDP are often accompanied by deceleration of economic growth.

Assuming a stable and rather rigid link between rates of economic growth and rates of carbon dioxide emissions, the limitations imposed by the Kyoto Protocol vis-à-vis volumes of carbon dioxide emissions, would unavoidably constrain the scale of economic activity and, therefore, negatively affect growth rates of the world economy.

Imposition of the Kyoto-type restrictions on the countries of the world would imply a substantial deceleration of their growth rates. The adoption and enforcement of the current EU and British proposals to restrict carbon dioxide emissions in commitment periods under the Kyoto Protocol beyond 2012 (according to which emissions by 2050 are to be reduced by 50-80 percent, compared to 1990) would bring the world economy into a deep and prolonged recession.

About the author

Andrei Illarionov is with the Institute for Economic Analysis in Moscow. He is also a Presidential Aide and Chief Economic Adviser to Russian President Vladimir Putin. Dr. Illarionov came to Moscow in the early 1990s as Boris N. Yeltsin launched Russia's first market reforms by freeing prices. An adviser to President Yeltsin's early architect of reform, Yegor T. Gaidar, Dr. Illarionov forged a reputation as an independent thinker.

Notes

1 Germany was able to achieve this to a large extent due to significant reductions of industrial output and energy consumption in the former East Germany part of the country.

2 "Purchasing power parity" is a method used to equalize the exchange rate between the currencies of different countries, by examining and equalizing the costs of selected goods and services, standards of living and other factors in each country.

3 Carbon intensity of GDP needs to be distinguished from the carbon intensity of fuel, which is defined as the weight of carbon dioxide emitted during the combustion of one unit of organic fuel.

4 The classification uses data for 124 countries that in 2000 produced 86 per cent of world GDP and generated 83 per cent of world emissions of carbon dioxide. Carbon dioxide emissions data are available from the International Energy Agency (1971–2001).

5 See Table 2-1 for listing of countries by group.

6 Perhaps, the only exception is Iceland, which possesses nearly free thermo power resources that are abnormal in terms of per capita population.

7 UN Demographic Division, *World Population Forecast by 2050*.

8 Angus Maddison, *The World Economy: Historical Statistics*, Paris, OECD, 2003.

Chapter 2

ECONOMIC MODELING OF CLIMATE CHANGE POLICY

Michael E. Canes

Overview

This paper focuses on the economic modeling of European policies to achieve the goals of the Kyoto treaty. The central question addressed is what sorts of models are best suited to analyze the costs of such policies when what is desired is to analyze effects on GDP, employment, labor productivity, savings and investment over a period of several years. I also examine the relative merits of bottom-up and top-down approaches to energy market modeling. The following conclusions are reached:

- CO_2 emissions in most European countries in 2010 will be well above levels needed to meet their commitments. For that reason, a substantial carbon tax or tradable permit price will be needed for them to meet the goals of the Kyoto treaty. Estimates in the literature vary depending on assumptions, but given that action to curb emissions is slow to develop and trading probably will not be worldwide, the cost of tradable permits is likely to be substantial.
- A Kyoto-implementing carbon tax or tradable permit price will have a number of implications for European economies. These range from reduced energy use and substitution of non-fossil for fossil fuels to indirect effects in non-energy markets and changed trade relationships. Because shocks to an economy require realignment of resources among markets, a Kyoto-implementing policy will temporarily result in involuntarily unemployed resources. It also will result in longer run costs from decreased use of energy and a reduction in economically useful capital stock.
- Different types of economic models capture different impacts. Partial equilibrium models such as PRIMES or MARKAL capture effects in energy markets and the direct costs of reducing energy use, but do not capture indirect costs or those associated with market adjustment. As shown in **Table 3-3** herein, such models capture only a fraction of the full macroeconomic costs of adjusting to policies to reach climate change goals.
- General equilibrium models capture both direct and indirect costs, but assume long run full adjustment of resources and hence fail to capture the costs of those adjustments. Nevertheless, they are useful for analyzing many longer-term issues and provide estimates of longer-term costs. Estimated European climate policy GDP impacts from several such models also are shown in **Table 3-3**.
- Macroeconomic models such as Oxford or DRI-WEFA are general equilibrium models that explicitly account for market disequilibria caused by economic shocks. In addition to identifying long term costs, these models provide the most complete near and intermediate-term analysis of the costs of Kyoto-implementing policy. Results in **Table 3-3** indicate such models provide cost estimates for European compliance with Kyoto that are 50-100 percent higher than those from pure general equilibrium models.

- Bottom-up energy models are constructed from engineering data applied to specific technologies whereas top-down energy models are based on statistical analysis of past data. Both can be useful in understanding the effects of policy on energy markets, but bottom-up models often neglect certain costs that reduce returns on investment below what is predicted, resulting in unrealistic estimates of what will occur if energy markets are shocked. Top-down models are based on technology and institutions existing at the time their data applies to and hence may underestimate the ability of markets to adapt. However, such models often incorporate technology parameters, induced technological change, or explicit changes in technology in order to avoid such bias, thus incorporating bottom-up features within a top-down approach. Because these models are based on actual behavioral responses rather than simulation under somewhat idealized conditions, they appear to be the most realistic way to accurately estimate the consequences of climate change policy.

Introduction

It is widely recognized that country commitments made under the Kyoto climate change treaty and prospectively under follow-on agreements may have important implications for national economies. To analyze these implications, a variety of economic models have been constructed and utilized. Though there is agreement that such modeling can help to understand the economic consequences of implementing the Kyoto treaty, there is less agreement as to exactly which model provides the most accurate and reliable numbers. Indeed, there even is disagreement over what kind of model is needed for the task.

This paper investigates these issues. To do so, I review what policies are required to meet the goals of Kyoto and possible follow-on commitments, what sorts of impacts these are likely to have on an economy, and what sorts of models are needed to analyze such impacts. I argue that models of the energy market alone, while useful for understanding some of the effects of climate change policies, cannot reveal their full impacts. I argue further that economy-wide models can reveal such effects, but these should be capable of analyzing short and intermediate-term market adjustments necessitated by shocks and that not all economy-wide models are constructed for such purposes. Finally, I look more closely at energy market modeling, specifically at “bottom-up” and “top-down” approaches. While bottom-up information can aid the predictions of a top down model by identifying new cost-reducing technologies or barriers to the use of energy saving techniques, it also can mislead by suggesting lower costs than actually occur in energy supply or conservation activity. This is especially problematic if bottom-up information is used to establish normative standards to which energy markets are compelled to adhere. I conclude by summarizing my views on the best way to analyze the macroeconomic effects of climate policy.

Policies to implement the Kyoto Climate Change Treaty

Country commitments to reduce greenhouse gases (GHGs) under the Kyoto treaty generally call for reductions by 2008-2012 relative to 1990 levels.[1] The European Union (EU) , for example, has collectively agreed to an 8 percent reduction.[2] With some exceptions, country emissions have grown since 1990 and without policy intervention are likely to grow further between now and the 2008-2012 period.[3] To simplify, the year 2010 often is taken as the endpoint for analysis of policies to constrain GHGs.

Since carbon dioxide (CO_2) accounts for 80 percent or more of most countries’ GHGs, analytic efforts have focused on means to reduce this gas. These efforts reveal that the cheapest method is a carbon tax or its economic equivalent, tradable permits, to emit carbon in a given year. The trading of permits is efficient because it enables lower cost sources of GHG reductions to sell some of their emission rights to higher cost sources, reducing costs overall. Capros and Mantzos estimate, for example, that a CO_2 tradable permit scheme within each EU country would reduce compliance costs by over 50 percent relative to a scheme in which countries assign to individual industry sectors their proportionate share of national reductions.[4]

How much would the cost of carbon have to rise to bring countries into compliance with their Kyoto commitments? That depends on a number of factors, such as:

- what would have happened in the base case (usually called Business As Usual or BAU),
- whether other GHGs (methane, nitrous oxide, HFCs, PFCs and SF_6) are constrained along with carbon dioxide,
- the extent to which trading of carbon permits is allowed,
- when action to constrain GHGs is begun,
- the malleability of capital,
- the extent to which sinks are counted, and
- the assumed rate of technological change.

If base case assumptions indicate a substantial rise in carbon emissions, perhaps because of rapid economic growth, then a large rise in the cost of carbon is needed to constrain emissions to their required level. Country situations differ, so that greater efforts will be required in some than in others to achieve Kyoto targets. Taking all EU countries together, however, considerable effort appears necessary. An analysis by the International Energy Agency in 2001 estimated that EU carbon dioxide emissions will be 16 percent above target in 2010 in a BAU case, while a U.S. Department of Energy analysis done in 2002 projected that Western Europe taken as a whole will be 18 percent above. [5] More recently, a Danish study projected that the 15 older EU countries (EU15) would experience a 21 percent gap between actual and target emissions in 2010.[6]

Inclusion of the five non-CO_2 GHGs could result in greater or lesser need to constrain carbon. The result in any given country depends on what growth is expected for these other gases and how expensive it is to reduce them. If for example they are expected to grow rapidly and to be expensive to reduce, then a higher increase in the cost of carbon than otherwise would be necessary to compensate.

The extent to which emission permits are traded has important implications for the cost of carbon among countries. Some have argued for limitations on countries' ability to purchase tradable permits, and on the extent to which permits should be granted to countries whose economies have declined sharply since 1990. However, many objections to trading were dropped in the Marrakech COP-7 agreements on Kyoto implementation;[7] and in July 2003 the EU agreed to a phased GHG emission trading scheme to begin in 2005.[8] Generally speaking, the greater the extent of trading the lower the price of permits.

Earlier action provides more time for reducing a country's use of carbon, and hence the earlier a country acts to achieve its Kyoto goals the less it needs to raise the cost of carbon. To date, few countries have begun serious programs to achieve their targets, implying that substantial increases in the cost of carbon eventually may be necessary for them to do so.

The ease with which capital can move from one to another use within an economy affects the extent to which the price of carbon must rise. Researchers have shown via simulation that highly malleable capital can reduce the cost of complying with Kyoto by over 50 percent relative to a substantially fixed capital stock.[9]

The COP-7 agreement suggests that sinks from forest management, agricultural activities and the Clean Development Mechanism may be counted to some extent in calculating country commitments under Kyoto. The counting of sinks reduces needed reductions in carbon, and hence decreases the amount by which the cost of carbon must rise.[10]

Technological change can reduce the cost of complying with the Kyoto agreements. What is assumed about the rate of change of energy technology thus affects the extent to which the carbon price must rise.[11]

The above considerations suggest there is a good deal of uncertainty concerning what the price of tradable carbon permits might be. Nevertheless, for purposes of policy analyses, relevant scenarios have been constructed.

For example, a recent analysis of the macroeconomic impact of Kyoto commitments and beyond on four individual European countries based on work by the consulting firm DRI-WEFA shows a permit price range between 85 and 180 Euros per metric ton of carbon.[12] In this case, countries trade internally but not with other countries. EU-wide trading likely will reduce the cost of permits somewhat, but the UK and Germany, two countries expected to be net sellers of permits within the EU, already are included in the analysis.

For present purposes it is not necessary to precisely specify the value of tradable permits or the equivalent carbon taxes for countries to achieve their Kyoto targets. What is necessary to understand is that projections of GHG emissions through 2010 relative to target levels suggest it will be necessary to substantially raise the cost of carbon within Europe and elsewhere to achieve the Kyoto targets.

Modeling the economic effects of Kyoto

What happens to an economy when it is subject to a carbon tax or its equivalent, the use of tradable permits, to achieve the Kyoto goals? There are a number of effects, and it is necessary to look at these individually to grasp what sort of model is most useful to estimate them.

Suppose that an economy is in equilibrium before such a tax is imposed. This means that capital, labor and energy resources are fully employed to produce goods and services, and that the economy grows as more of these inputs are added. The economy is open to trade with other countries, and so has export and import sectors.

Now the tax is imposed, in one form or another. The price of energy rises, and people economize on its use. Energy intensive industries contract, and energy using activities are curtailed. Some of the capital stock is rendered obsolete because it is no longer economic to employ it with the higher energy price. Since both energy and capital are inputs into the production of the economy's output, the reduction in energy use and the obsolescence of capital stock reduce GDP.[13]

Contractions by energy suppliers and by energy intensive industries have further effects. Such industries purchase goods and services from other industries, things like raw materials, transport and retailing services. These industries in turn purchase from others. Thus, the effects on the economy stretch well beyond energy use. A large number of industries are affected indirectly by the changed pattern of spending in the economy.

The trade sector imposes further effects. Exports of goods that are energy intensive to produce are less competitive. Over time, markets for such goods are largely or wholly lost to countries that are not party to the Kyoto protocol. Energy intensive-to-produce goods also flow in from such countries.

The government receives new revenues, either from a carbon tax or by the auctioning of tradable permits. These revenues reenter the economy via some form of government action. They could be used to reduce deficits, to cut other taxes, to develop new energy-saving technologies, or they are simply redistributed to consumers. However the government uses the revenues, the real incomes of consumers of energy are reduced while those receiving the revenues are enhanced. This redistribution has economic effects of its own. Reduced spending by energy users is contractionary while increased spending by those receiving the revenues is expansionary.

The economy cannot adjust instantaneously. Resource owners must spend time and effort to find where they are best employed under the new circumstances. There is friction in the labor market as people laid off in some industries seek employment in others. Capital also must investigate where the best returns may be earned. Some capital may depart for abroad, to countries that are not participating in the Kyoto protocol. The process takes time, months and even years to complete, and if the institutions of the country impede the economic adjustment process (e.g., stringent restraints on worker layoffs), its duration is lengthened.

Finally, there is interaction between the real and financial sectors. These include effects of possible bankruptcies of companies unable to compete under the new price structure, which would adversely affect the lending sector. They also include the reaction of the monetary authorities, and possible fiscal policy initiatives. These could exacerbate or reduce the macroeconomic impacts of the Kyoto-based energy sector policies. Even if they are neutral, it is necessary to assess the effects of the energy policy on interest rates, investment and savings to fully understand the near and intermediate-term macro impacts.

Applying economic models to greenhouse gas reduction policies

For convenience, I divide the many economic models described in the literature into three classes: partial equilibrium models of energy markets, instantaneous adjustment general equilibrium models, and macroeconomic general equilibrium models, which do not assume instantaneous adjustment of resources. It is especially important to distinguish these last two classes of models, as many models that are described as macroeconomic models assume instantaneous adjustment of resources and therefore do not capture some of the costs of economic shocks over the near and intermediate term.

Table 3-1 shows the three types of models and some important attributes. These include key assumptions, what the models capture, and what they are best at doing. For example, partial equilibrium models of the energy market generally assume instantaneous adjustment and calculate the cost of a carbon tax to energy users and suppliers. Depending on the amount of detail, energy market models can provide estimates of such things as inter-fuel substitution, what happens in the separate energy markets, impacts on the power sector, and by how much energy prices will rise.

Table 3-1. Analytic tools to examine GHG policy measures

Type of Economic Model:	Partial Equilibrium (energy market only)	General Equilibrium	Macroeconomic
Key assumptions:	Instantaneous full adjustment in energy market	Instantaneous full adjustment in all market sectors	Market adjust over time
What it captures:	Cost of carbon permits to energy users	Long run cost to the economy	Short and intermediate term adjustment cost to the economy
Bottom line:	Best for analyzing energy market responses	Relatively uncomplicated especially useful if market shocks are small or gradual	More complex. Most accurate if economic shock requires substantial market adjustment

As shown in **Table 3-2**, the PRIMES model is an example of a partial equilibrium model that can be used to understand the impact of Kyoto policies in EU energy markets.[14] It develops costs of adjusting to higher energy prices for each sector in every EU country, and combines them into country-wide supply curves of CO_2 reduction. The country supply curves then can be combined into an EU-wide supply curve of such reduction, and estimates made of the total cost of CO_2 reduction under alternative assumptions. These assumptions can range from requiring each industrial sector to reduce CO_2 on its own to assuming EU-wide permit trading, in which case CO_2 reduction costs are minimized for that group of countries.

Table 3-2. Classification of economic models analyzing climate policy

Partial Equilibrium (energy market only)	General Equilibrium	Macroeconomic
PRIMES MARKAL	MIT-EPPA WORLDSCAN MS-MART ABARE-GTEM MERGE3 CETA FUND	OXFORD G-CUBED DRI-WEFA

PRIMES - (National Technical University of Athens - Greece)
MARKAL (Brookhaven National Laboratory - USA)
MIT-EPPA - Emissions Projection and Policy Analysis Model (Massachusetts Institute of Technology - USA)
WorldScan (Central Planning Bureau - Netherlands)
MS-MRT - Multi-Sector - Multi-Regional Trade Model (Charles River Associates and University of Colorado - USA)
ABARE - GTEM - Global Trade and Environment Model (Australian Bureau of Agriculture and Resource Economics (ABARE) - Australia)
MERGE3 - Model for Evaluating Regional and Global Effects of GHG Reductions Policies (Stanford University and Electric Power Research Institute - USA)
CETA - Carbon Emissions Trajectory Assessment (Electric Power Research Institute and Teisberg Associates - USA)
FUND- Climate Framework for Uncertainty, Negotiation, and Distribution (Vrije Universiteit Amersterdam - Netherlands)
MARKAL-MACRO (Brookhaven National Laboratory and Stanford University - USA)
SGM - Second Generation Model (Battelle Pacific Northwest Laboratory - USA)
GTAP-ECAT - Global Trade Analysis Project - European Carbon Allowance Trading (COWI A/S - Denmark)
OXFORD - Oxford Model (Oxford Economic Forecasting - Great Britain)
G-Cubed - Global General Equilibrium Growth Model (Australian National University, University of Texas and U.S. EPA - Australia - USA)
DRI-WEFA - (DRI-WEFA Forecasting - USA)

PRIMES provides a useful tool for understanding the effects of policy initiatives on energy users and producers. The costs it calculates are the direct costs of reduced CO_2 use. But it is not a macroeconomic model and cannot be used to assess overall country costs from a Kyoto-implementing policy that shocks the economy.

General equilibrium models assume long run adjustment to a Kyoto-implementing policy in all market sectors. The assumption is key because in the long run all resources are assumed to find their highest valued use, and therefore there is no resource unemployment. General equilibrium models examine economic impacts in energy markets and other markets that are indirectly affected by the policy change. They reveal the long run cost to the economy of substituting away from carbon-intensive energy and of reducing the stock of economically useful capital.[15]

MARKAL-MACRO is one of many general equilibrium models built to examine Kyoto-implementing policies (see **Table 3-2**). The MARKAL portion of MARKAL-MACRO originally was developed by the Brookhaven National Laboratory in the United States and is similar to the PRIMES model in that it models responses in the energy sector to changes in policy such as a carbon tax or tradable carbon permits.

MARKAL-MACRO represents the combination of MARKAL with MACRO, a general equilibrium model developed at Stanford University by Professor Alan Manne. With this combination, changes in the energy sector are communicated to the rest of the economy and resource movements among other markets are captured. The effects of capital obsolescence and of increased energy scarcity are captured. This then accounts for a larger set of costs than those experienced in energy markets alone, and hence provides a more complete picture of the consequences of shocking the economy through a change in energy prices. However, the model is a long run model which effectively assumes full resource adjustment. Thus, while it calculates economy-wide effects from changes in energy production and use, it does not model the adjustment process itself and therefore underestimates the full macroeconomic costs.

MARKAL-MACRO and other models of this type are useful for a variety of analyses that are less concerned with costs of adjustment. Very gradual changes in policy, for example, would lend themselves to analysis by this sort of model because actors in the economy would have long periods to anticipate and react to the policy changes, and adjustment costs could be small. Alternatively, such models can be used to analyze long run consequences of climate policy, after resources have had time to fully adjust.[16]

The chief question for most policy makers, however, is what are the impacts of climate change policy on national economies, particularly over the near and intermediate term, meaning the next several years. The impacts of most interest are on GDP, employment, labor productivity, investment and savings. Policy makers also are interested in what leverage they may have on these impacts, for example how to implement climate policy in ways that minimize economic costs.

For these purposes, a third class of models, macroeconomic models, is more appropriate. Such models capture interactive effects between the energy and other sectors of the economy and in that sense are general equilibrium models. They also capture trade effects by accounting for an economy's relationship with other economies. However, unlike other general equilibrium models, macro models do not assume instantaneous full market adjustment but rather allow an economy to suffer involuntarily unemployed resources for a period as market participants adjust to a policy shock. In this way they capture near- and intermediate-term as well as longer-term costs.

The DRI-WEFA and Oxford models are examples of macro models. They start by assuming an economy on a long run growth path, but then allow policy initiatives to shock it in such a way that it deviates from the path while adjustment takes place. In other words, resources become involuntarily unemployed while they seek their new most valuable uses, and the economy produces below its potential. As noted above, the length of adjustment depends on the magnitude of the shock and the flexibility of a country's internal markets, and can take several years to fully work itself out. DRI-WEFA and the Oxford model contain a financial sector as well a real sector and therefore allow for changes in monetary or fiscal policy, which can mitigate or exacerbate energy policy initiatives through changes in interest rates and their economy-wide effects on savings and investment.

For purposes of modeling economic shocks of the magnitude implied by Kyoto policies, macro models such as DRI-WEFA or Oxford provide the most complete analysis. Like pure general equilibrium models, they capture costs borne in energy markets and other markets, and international trade effects. But unlike these models, they also capture the costs associated with an economy having to adjust to policy over a period of time. Since economic shocks create adjustment costs, the ability of macro models to estimate near and intermediate-term resource unemployment and its consequences for GDP, investment, savings and productivity is an important contribution to understanding the full economic consequences of climate change policy initiatives. For policy makers interested in near- and intermediate-term costs of policy-related shocks to an economy, such models provide the most complete analysis.

Table 3-3 illustrates the differences in estimated impacts of climate policy on European GDP. In **Table 3-3**, estimates of the macroeconomic costs to Europe of implementing the Kyoto agreement are shown for the year 2010. Each estimate is associated with a different model, and the models are classified into the three categories I have described. Partial equilibrium models such as PRIMES and MARKAL project quite small numbers, slightly over 0.1 percent of EU GDP for that year. General equilibrium models such as ABARE-GTEM and MERGE3 show numbers that are nearly an order of magnitude higher, around 1 percent of GDP. Macroeconomic models such as G-Cubed and Oxford show still higher numbers for the European economy, around 1.5-2.0 percent of GDP. And DRI-WEFA, with results only for selected individual European countries, shows higher numbers still.[17]

Table 3-3. Estimates of European macroeconomic costs in 2010 from policies to implement Kyoto*

MODEL TYPE		percent of GDP in 2010
Macroeconomic	G-Cubed	1.50
	Oxford	2.00
	DRI-WEFA: Germany	2.90
	DRI-WEFA: Netherlands	1.90
	DRI-WEFA: UK	1.80
	DRI-WEFA: Spain	4.80
General Equilibrium	ABARE-GTEM	0.94
	MERGE3	0.99
	MS-MRT	0.63
	GTAP-ECAT	0.48
Partial Equilibrium	PRIMES	0.12
	MARKAL	0.12

Sources: Macroeconomic and General Equilibrium estimates for OECD-Europe are from Energy Modelling Forum results shown in "Climate Change 2001: Mitigation," Chapter 8 of Global, Regional and National Costs and Ancillary Benefits of Mitigation, IPCC, Third Assessment Report, Working Group III. GTAP-ECAT results are from "Competitiveness and EU Climate Change Policy," Interim Report produced by COWI for UNICE, October 2004. The number is for the short term adaptation case. Individual European country macroeconomic results are from M. Thorning, "Kyoto Protocol and Beyond: Economic Impacts on EU Countries," International Council for Capital Formation, October 2002. Partial equilibrium estimates are derived for PRIMES from E3M Lab, P. Capros & L. Mantzos, "The Economic Effects of EU-Wide Industry-Level Emission Trading to Reduce Greenhouse Gases: Results from the PRIMES Model," May 2000, and for MARKAL from J.P.M. Sijm, K.E.L. Smekens, T. Kram and M.G. Boots, "Economic Effects of Grandfathering CO_2 Emission Allowances," Energy Research Center of the Netherlands, April 2002.

The partial equilibrium estimates capture costs in energy markets, the general equilibrium models costs over the entire economy, and the macroeconomic models those plus the adjustment costs associated with policy implementation. If the purpose is to understand the full macroeconomic costs associated with implementing GHG policies, this last category of model provides the most comprehensive approach.[18]

Bottom-up and top-down approaches to energy modeling

I turn now to a second issue associated with analysis of Kyoto policies, namely the use of bottom-up and top-down approaches to energy modeling. The issue has been discussed by others,[19] but bears continuing attention because there has been evolution in modeling technique and because it remains important to understand how these approaches can best support climate change policy analysis.

Bottom-up and top-down models aim at the same objective, namely identifying demand and supply side reactions to changes in energy market conditions. Bottom-up models do so by conducting engineering analyses of the lifetime costs of various energy-producing or energy-using technologies and comparing these to what can be realized in revenues or savings. Top-down models, in contrast, analyze past behavior in energy markets using statistical techniques to estimate what supply or demand response might be expected with a change in price or some other variable.

Conceptually, the two approaches are complementary. Bottom-up analysis can be helpful in identifying prospects for new energy technologies as well as possible barriers to market acceptance of otherwise attractive options. It also may be useful in demonstrating to entrepreneurs or other market participants the relative attractiveness of technologies that otherwise might have escaped notice. This identification of new technologies and revelation of the attractiveness of options may reduce the costs of complying with a Kyoto carbon constraint below what a top-down model might predict. Also, by identifying possible barriers to the use of energy-saving or energy-producing technologies, policies might be changed to facilitate such compliance.[20]

On the other hand, bottom-up models by their nature are not based on actual behavior. Their reliance on engineering data can lead to omitting vital information that renders real-world behavior different from what the models predict. For example, such models often fail to recognize transactional costs associated with using new energy technologies (e.g., costs associated with learning about the technologies, trying them out, training people to use them, financing them, and measuring the results). For that reason, bottom-up models can over-project the extent to which new energy technologies will be adopted within an economy where an increased carbon constraint is imposed.[21]

Another problem sometimes associated with bottom-up models is their use as normative instruments, i.e., to identify technologies that then are mandated via policy. For example, the U.S. Department of Energy has used engineering estimates of the lifetime costs of alternative versions of capital equipment such as washing machines and refrigerators to establish mandatory efficiency standards for them. Also, state public utility commissions have used engineering estimates of the returns to energy conservation investment to fund such investment using ratepayer monies. Reviews of these programs have revealed that their returns often are much less than calculated, however.[22] By implication, many of the resources diverted into the programs have been wasted. Thus, while resource allocation can be improved by using engineering analyses to inform market participants of opportunities or to seek removal of regulatory barriers, it likely is harmed if these analyses are used to compel resource expenditures that otherwise would not be made.

Top-down models avoid many of the problems associated with bottom-up, because the behavior they reflect incorporates all of the costs of employing energy producing or conserving technologies. They can anticipate introduction of new technologies by including a parameter which allows the costs of energy conservation and supply to decrease with time. In addition, they can allow technology to advance more rapidly with extra inducement to do so. In effect, this allows them to incorporate much of the information that a bottom-up model provides. They are, however, based on technology and institutions existing at the time their underlying data were gathered. Use of more recent data could change the market responses estimated by such models. Also, the underlying data generally covers only a limited range of experience, so that market shocks beyond such experience may yield inappropriate model estimates. Still, the advantage of incorporating behavioral responses to changed market conditions provides such models a means to validate their structure that bottom-up models cannot readily duplicate.

The partial equilibrium energy market models mentioned in this paper (PRIMES, MARKAL) are largely based on bottom-up appraisals. As such, they likely understate the costs of complying with a carbon tax or CO_2 tradable permit scheme, even in energy markets alone. Thus, they should be viewed as useful tools to assess potential responses in such markets, not as predictors of aggregate costs.

The general equilibrium and macroeconomic models reviewed here, by contrast, take a top-down approach. Past data has been used to estimate the relationships embodied within them, and to validate their predictions. Most also incorporate technology improvement parameters, induced technological change, or a backstop energy technology whose cost falls with time. Some also incorporate sectoral changes in technology, e.g., in the average fuel economy of automobiles. By so doing, they incorporate elements of a bottom-up approach within their top-down structure. Overall, this appears to be the most realistic approach to accurate estimation of climate change policy impacts.

Conclusions

A great deal of scientific effort and international communication has gone into furthering understanding of climate change and developing means to deal with it. Economic modeling can contribute by analyzing the macroeconomic impacts of alternative policies such as the Kyoto agreement and possible follow-on commitments. The macroeconomic models reviewed in this paper suggest that attempts to constrain European GHG emissions at the rate required by Kyoto may have large economic costs. The strength of such models is their ability to capture near and intermediate-term adjustment costs as well as longer term costs associated with Kyoto-implementing policy shocks. For decision makers concerned with European GDP, employment and other economic indices over the next several years, these models offer the most complete understanding of what to expect.

About the author

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Notes

1 Annex B of the Kyoto agreement identifies the 38 countries who have collectively agreed to reduce their GHG emissions by 5.2 percent below 1990 levels. For convenience of discussion, countries participating in Kyoto are termed Annex B countries.

2 Some members already are proposing further future reductions. The German government, for example, has proposed that the EU cut its emissions by 30 percent relative to 1990 by 2020 (See BNA Environment Reporter, 33(2), October 25, 2002).

3 The latest EU data is for 2001 and shows that 10 of the EU15 are above their 1990 levels. In the aggregate, the EU15 were 2.3 percent below their base year emissions but 6.2 percent above the 2010 target. Further, emissions increased by 1 percent in 2001 and are projected to continue increasing without policy intervention. See "Analysis of greenhouse gas emission trends and projections in Europe 2003," European Environment Agency, EEA Technical Report, 2004.

4 E3M Lab, P. Capros and L. Mantzos, "The Economic Effects of EU-Wide Industry-Level Emission Trading to Reduce Greenhouse Gases," unpublished manuscript, May 2000.

5 International Energy Agency, *Energy Policies of IEA Countries*, Paris, OECD/IEA, 2001.and U.S. Department of Energy, Energy Information Administration, Office of Integrated Analysis and Forecasting, *International Energy Outlook 2002*, Washington, DC, March 2002.

6 COWI A/S, "Competitiveness and EU Climate Change Policy," Interim Report produced by COWI for the Union of Industrial and Employer's Confederations of Europe (UNICE), October 2004.

7 COP-7 refers to the 7th Conference of the Parties to the original Rio De Janeiro agreements.

8 The agreement is limited to CO_2 in its first phase (2005-2007) and only covers certain sectors of the economy. Also, the participant countries are still harmonizing their individual trading programs. Thus, while the EU GHG permit trading program has the potential to reduce the cost of emission reductions, it is premature to judge how efficient this mechanism will be.

9 See Henry D. Jacoby and Ian Sue Wing, "Adjustment Time, Capital Malleability and Policy Cost," *The Energy Journal*, Special Issue, 1999.

10 The effects of counting sinks are analyzed in Christoph Boehringer, "Climate Policies from Kyoto to Bonn: From Little to Nothing?" *The Energy Journal*, 23(2), 2002. A broader analysis of the effects of COP-7 is contained in Jean-Charles Hourcade and Frederic Ghersi, "The Economics of a Lost Deal: Kyoto -The Hague - Marrakesh," *The Energy Journal*, 23(3), 2002.

11 Edmonds et al provide a useful discussion of how assumptions about technological change directly affect the results from climate change modeling. See Jae Edmonds, Joseph M. Roop and Michael J. Scott, "Technology and the Economics of Climate Change Policy," Report Prepared for the Pew Center on Global Climate Change, September 2000.

12 See Margo Thorning, "Kyoto Protocol and Beyond: Economic Impacts on EU Countries," International Council for Capital Formation, October 2002. The DRI-WEFA analysis examines macroeconomic impacts from policy affecting all six GHG gases, not just carbon dioxide.

13 The impact on productivity and GDP of reducing energy available to workers is analyzed in W.W. Hogan and D.W. Jorgenson, "Productivity Trends and the Cost of Reducing CO_2 Emissions," *The Energy Journal* 12(1), 1991.

[14] A description of the PRIMES model can be found in "The PRIMES Energy System Model: Summary Description," National Technical University of Athens, European Commission Joule-III Program.

[15] Such models are useful for a variety of purposes, including analyses of alternative policies to achieve long-run stabilization of greenhouse gases in the atmosphere. For example, the Second Generation Model (SGM) of Battelle Pacific Northwest Laboratory and the MERGE3 model (Model for Evaluating Regional and Global Effects, version 3.0) of Stanford University and the Electric Power Research Institute have been used to address effects on stabilization costs of R&D policies, the timing of GHG constraints, learning behavior and numerous other variables.

[16] Yet another interesting application of such models is analysis of the effects of climate change policies in Annex B countries on other countries. Early versions of the Multi-Sector Multi-Regional Trade model (MS-MRT) were built for this purpose, linking economic effects among countries through trade and investment.

[17] The macroeconomic and general equilibrium models show somewhat different prices for tradable permits among themselves, but all are well over 100 Euros per ton of carbon. The partial equilibrium models provide marginal costs of carbon *dioxide* abatement, which when translated into Euros per metric ton of carbon are very similar to those of the other models.

[18] ACROPOLIS ("Assessing Climate Response Options: Policy Simulations," DG Research (ENERGIE), European Commission) compares results among economic models from applying several policy options to reduce EU GHGs. The models include some of those shown in **Figure 2-2** and **Figure 2-3** and provide partial equilibrium, general equilibrium and macroeconomic approaches. Unfortunately, published results to date do not show GDP effects by model.

[19] See for example Jonathan Fisher and Michael Grubb, "The Use of Economic Models in Climate Change Policy Analysis," Royal Institute of International Affairs, EEP Climate Change Briefing No. 5, October 1997.

[20] For example, removal of protective quotas or subsidies for fossil fuel production could facilitate the substitution of less carbon intensive technologies with overall economic gain.

[21] An important example is the so-called "Five-Labs Study" done by the U.S. Department of Energy in 1997, which assumed widespread adoption of a number of energy saving technologies. ("Scenarios of U.S. Carbon Reductions," Interlaboratory Working Group on Energy-Efficient and Low-Carbon Technologies, Office of Efficiency and Renewable Energy). A number of parties including the U.S. General Accounting Office and various private scholars leveled criticisms that this study seriously overstated prospects for adoption of energy saving technologies (see for example Henry D. Jacoby, referenced in footnote 11, and Ronald J. Sutherland, "Commentary: Technology Policy to Reduce Carbon Emissions," which comments and elaborates upon the Jacoby criticisms.

[22] See for example Gilbert E. Metcalf and Kevin A. Hassett, "Measuring the Returns to Energy Conservation Investment: Evidence from Monthly Billing Data," *Review of Economics and Statistics*, August 1999. Also, see Paul L. Joskow and Donald B. Marron, "What Does a Megawatt Really Cost? Evidence from Utility Conservation Programs," *The Energy Journal* 14(4), 1992.

Chapter 3

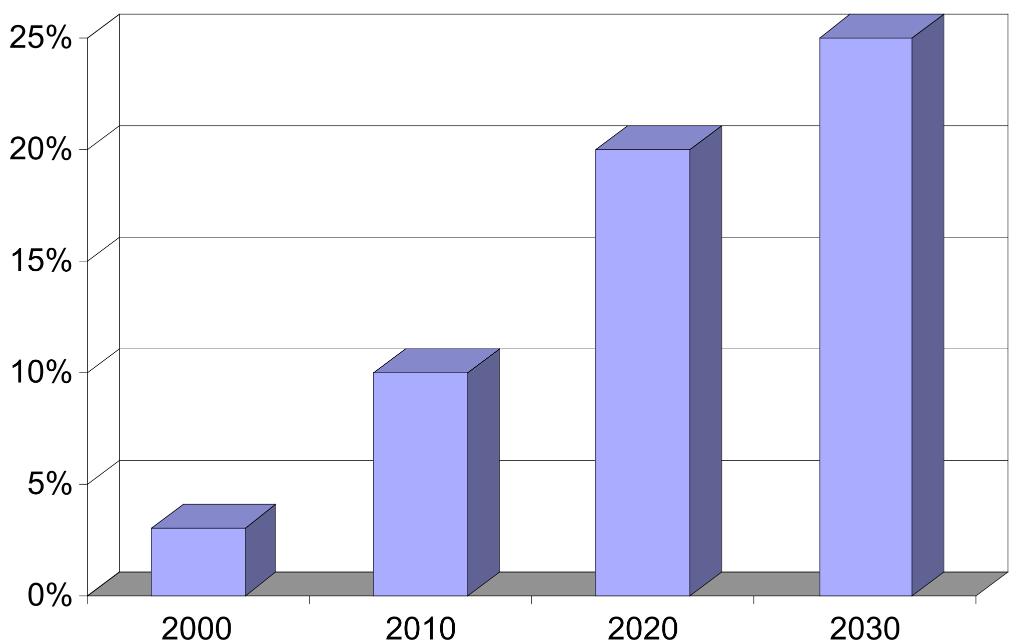
THE IMPACT OF EU CLIMATE CHANGE POLICY ON ECONOMIC COMPETITIVENESS

Margo Thorning

Overview

Notwithstanding the European Union's ratification of the Kyoto Protocol on climate change, the world's second largest economy faces major challenges in meeting not only the Kyoto greenhouse gas (GHG) targets but also the more stringent emission reductions being debated for the post Kyoto commitment period (after 2012). Data from the International Energy Agency (IEA) suggest that EU carbon emissions will continue to rise over the 2000-2030 period (see **Figure 4-1**). Even with strong new policies to reduce emissions, there are almost no changes from 1999 emissions levels, according to the IEA report. The cost for developed countries to meet the emission reduction goals of the Kyoto Protocol and the tighter targets that may be proposed for the second and subsequent commitment periods will be much higher than is generally understood. Policymakers need to have access to cost estimates based on appropriate climate policy models.

Figure 4-1. Growth in carbon emissions in the European Union: 2000-2030 under the baseline forecast (percent change from 1999)



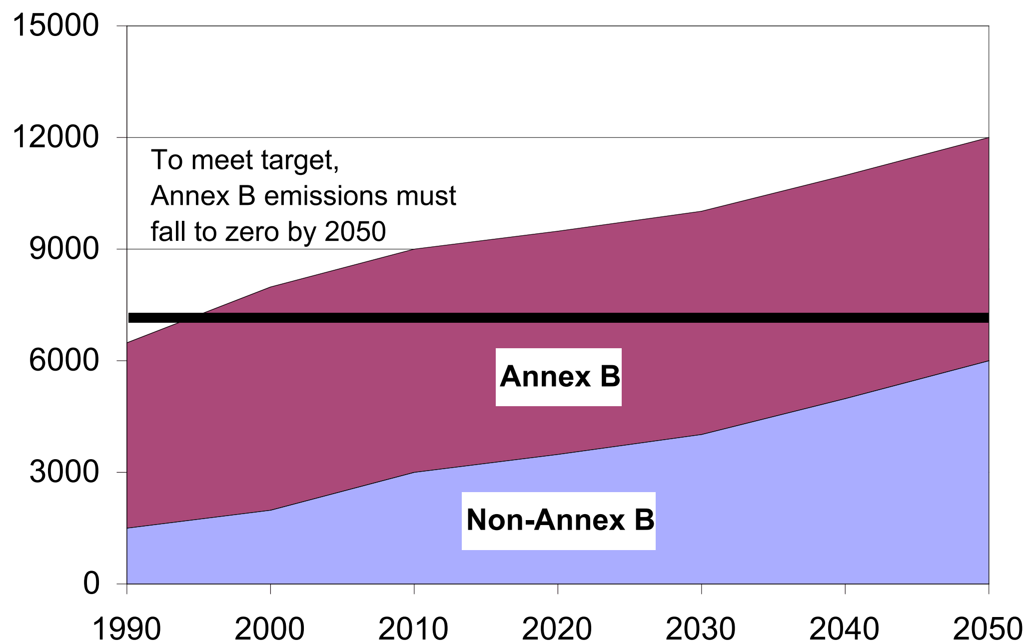
Source: International Energy Agency, World Energy Outlook 2002, p. 37

Post-2012 carbon emission targets

Despite the current lack of specificity regarding policies to prevent the projected growth in emissions between now and 2010, more stringent greenhouse gas emissions targets are being opposed for the years after the Kyoto Protocol's first compliance period (2008-2012).

For example, some EU officials are calling for a 60 percent reduction in carbon dioxide (CO_2) emissions by 2050. Others have suggested that we must stabilize CO_2 concentrations in the atmosphere at 550 ppm by 2100. Based on Climate Change, in order to put the world on that trajectory developed country emissions must fall to zero by 2050 in order to allow developing countries to continue to grow (see **Figure 4-2**). (The Kyoto Protocol does not require developing countries to reduce their emissions.)

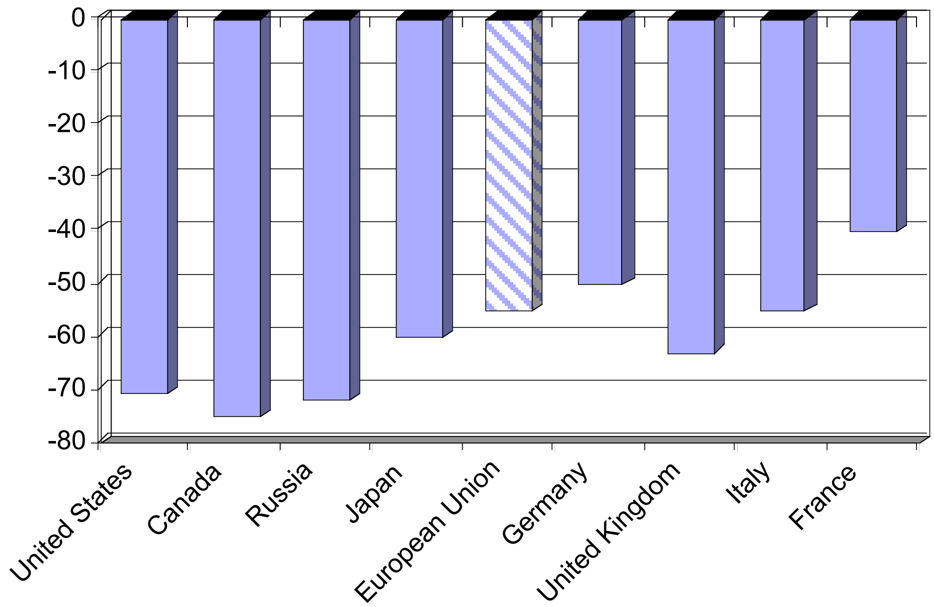
Figure 4-2. Carbon emissions for developed (Annex B) and developing countries: business-as-usual case and emissions cuts required to meet target of 550 PPM using IPCC data



Source: DRI-WEFA, 2002

In another example, the February 2002 report by the Interdepartmental Analysts Group (IAG) for the UK government considers the implications of a 60 percent reduction in CO_2 emissions from 1998 levels by 2050 in the UK. The report notes that aiming for stabilization at 550 ppm could imply even larger cuts against a 1998 base by Russia, Germany, Canada, and the USA (See **Figure 4-3**).

Figure 4-3. CO_2 Reductions required by 2050 under 550 ppm scenario (1998 base year)



Source: Interdepartmental Analyst Group, February, 2002

Does choice of economic models matter?

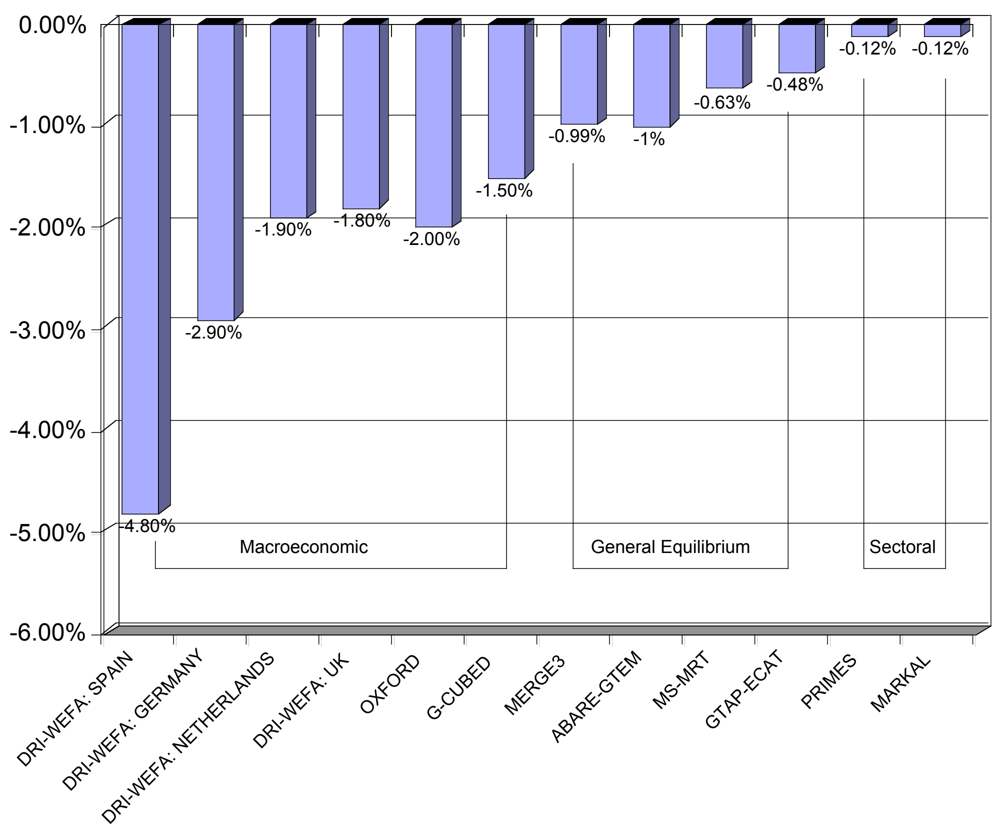
Many experts believe the economic models currently employed by environmental policymakers throughout Europe provide an incomplete picture of the full economic costs and competitiveness impacts of compliance with the Kyoto Protocol and the tighter targets in the post-2012 period.

Measuring the economic impact of Kyoto

As a recent study by the International Council for Capital Formation (ICCF) illustrates, an accurate portrayal of the costs of complying with GHG emissions reduction targets depends largely on choosing an economic model that captures all the short- and medium-term costs of adjusting to higher energy prices or regulatory mandates on the economy as a whole. (See "Economic Modeling of Climate Change Policy" at www.iccfglobal.org.)

For example, some economic models such as the PRIMES model used by EU environmental agencies are designed only for measuring sectoral effects, not economy-wide effects. PRIMES is primarily designed to show the effect of policy changes on energy markets. It can calculate the direct cost implications of reduced energy use but not the economy-wide impact on gross domestic product (GDP) , employment, investment, etc. Thus, the results of this model, which show a reduction of only 0.12 percent in GDP to the EU in 2010 from complying with the Kyoto Protocol, are not an accurate measure of the total costs to EU households, businesses, the economy, and government. (See **Figure 4-4**). These sectoral models underestimate the negative economic effects by a factor of 10 to 15 times (0.12 vs. 1.5 to 2.0). Such reliance on results from PRIMES has led EU officials, industry, and households to believe that the costs of achieving the Kyoto Protocol's targets and the further cuts planned for the second and subsequent commitment periods will be relatively small. However, the new study "ACROPOLIS," released by DG Research of the European Commission in September 2003, noted that the tighter targets required under the second commitment period could reduce GDP by 1.3 percent annually by 2030.

Figure 4-4. Impact of Kyoto Protocol on GDP levels in the EU in 2010 (alternative model forecasts)

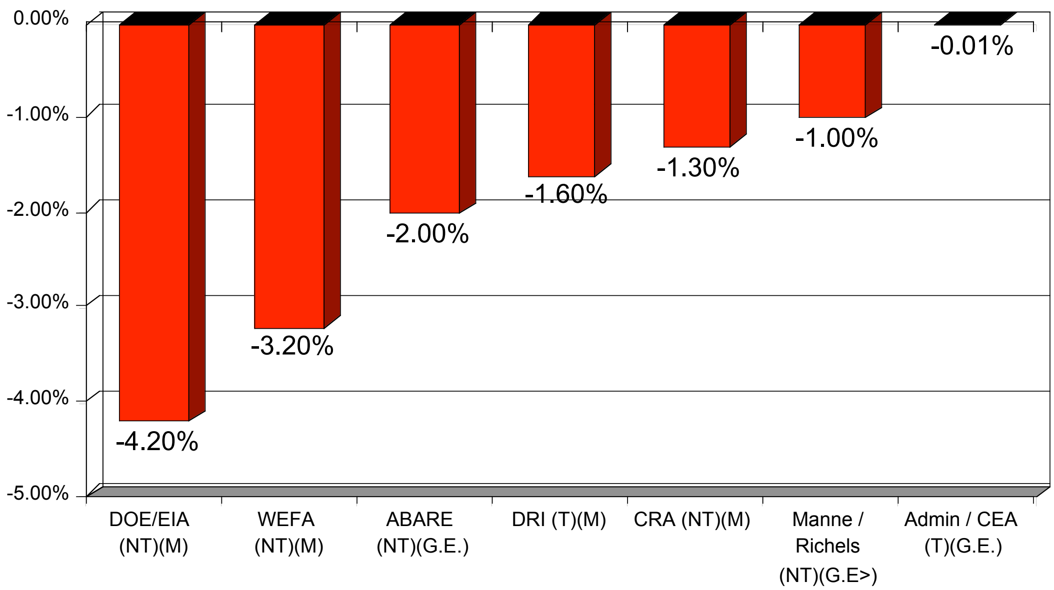


Source: Michael E. Canes "Economic Modeling of Climate Change Policy", 2002

Even general equilibrium models, which measure "big picture" impacts on an economy after it has had time to adjust (over 30 to 40 years) to higher energy prices, show GDP losses of about 1 percent per year under Kyoto, which are an order of magnitude greater than PRIMES. (See **Figure 4-4.)** Even though general equilibrium models look at a period of time much longer than the Kyoto timetable, their results more accurately reflect the consequences of curbing emissions than does a sectoral model like PRIMES. General equilibrium models reflect the full economic impact of reducing emissions, not just the impact on the energy sector. Given their long time frame, general equilibrium models are unable to capture short-term adjustment costs and therefore probably underestimate near-term impacts. Despite that fact, they still indicate that the economic impact of meeting Kyoto and post-Kyoto emissions targets will have an economic impact far greater than PRIMES.

Macroeconomic models provide an assessment of the overall economic costs of meeting emission targets where the short-term, frictional costs of adjustment are included. These models, which U.S. scholars and climate policy modelers began using in the early 1990s to measure the impact of Kyoto on the U.S. economy, quantify the impact on employment, investment, budget receipts, and GDP growth when an economy is "shocked" by having to make quick changes in its capital stock, production processes, lifestyles, etc. Results of macroeconomic models show that Kyoto would have negative effects on the U.S. economy in the range of 1.5 percent to about 4 percent of GDP in 2010. (See **Figure 4-5**).

Figure 4-5. Annual impact of reducing carbon emissions to the Kyoto Target on U.S. GDP, 2008-2012 (percent of GDP)



Source: Testimony by Margo Thorning before the Senate Governmental Affairs Committee, July 18, 2001.

Macroeconomic model estimates for the UK, Germany, the Netherlands and Spain

When macroeconomic models are used to measure Kyoto's effects on the EU, the impacts are greater – 1.8 to 5 percent less GDP in 2010 – than those derived from sectoral models like PRIMES. For some countries like Spain, the GDP loss due to reduced energy use will be severe – Spanish GDP in 2010 is estimated to be about 4.8 percent smaller.

Studies by the ICCF on the impact of reducing all six Kyoto gases on four major EU economies, UK, Germany, the Netherlands, and Spain, demonstrated the impact on GDP of carbon taxes (or tradable permits) large enough to actually force greenhouse gas emissions down to the Kyoto target. (See **Figure 4-6**). The ICCF also measured the economic impact of two alternative emission targets being discussed by EU policy-makers: (1) 60 percent below 2000 levels by 2050 and (2) zero emissions by 2050.

Figure 4-6. Impact of purchasing carbon emissions permits on GDS levels under the Kyoto Protocol and under more stringent targets

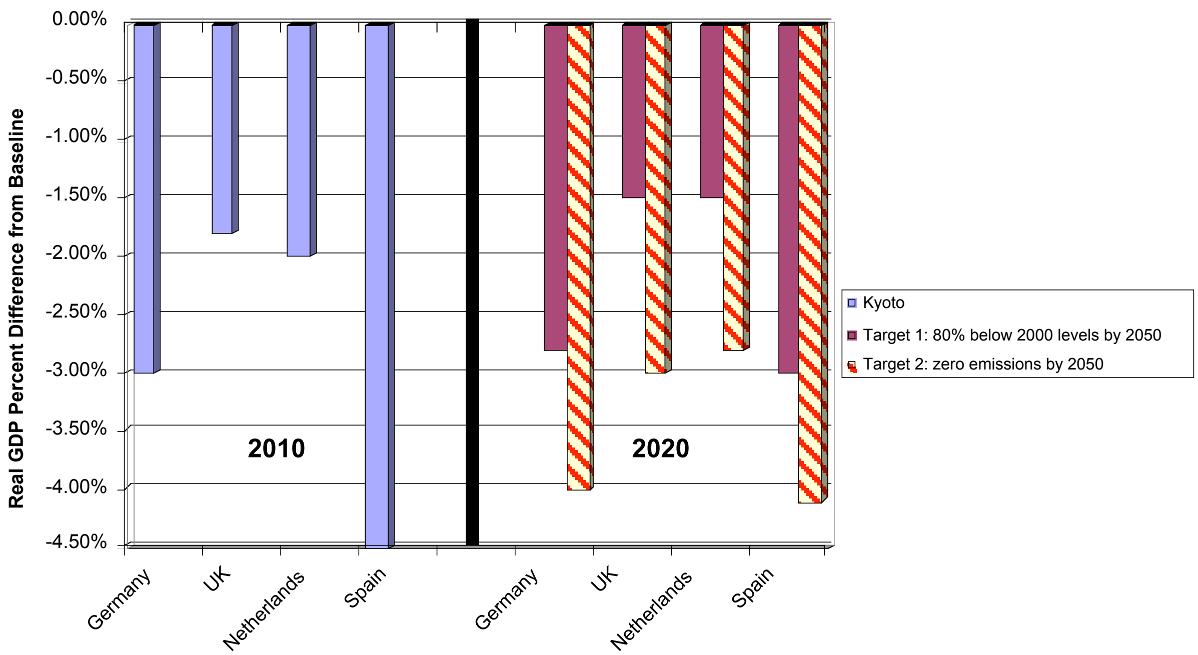
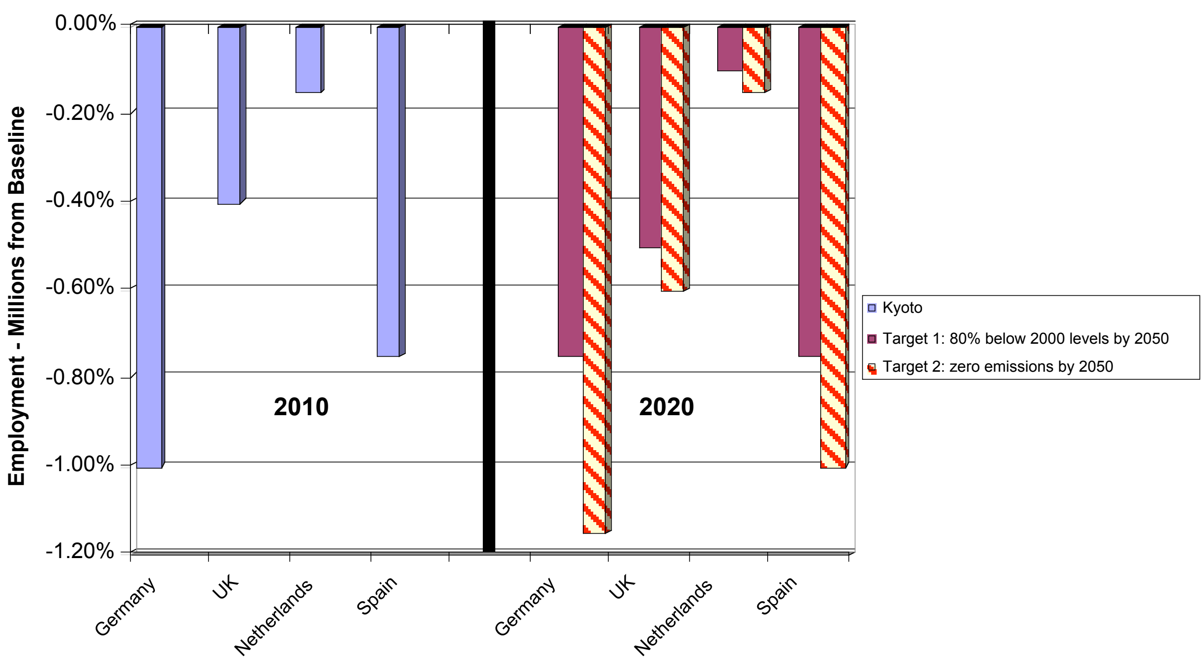


Figure 4-7. Impact of purchasing carbon emissions permits on jobs under the Kyoto Protocol and under more stringent targets



Getting on the path for these targets has significant impacts on GDP and employment because of the cost of the carbon permits by 2020. (See **Figure 4-6** and **Figure 4-7**).

The simulations for Germany, the Netherlands, the UK, and Spain assume that the United States does not participate in the Kyoto Protocol. The simulations do assume intracountry trading. The analysis assumes that emission permits would be auctioned to energy producers at the point of first sale.

This study assesses the marginal cost of CO_2 abatement accounting for projected changes in other GHGs, and the resulting economic cost. While the Kyoto Protocol established limits for participating countries' emissions from six GHGs, this analysis analyzes the cost of reducing CO_2 from energy use after taking into account reductions in the other GHGs that were projected by reliable sources. There was no attempt to quantify the cost of these reductions in the analysis.

Further, the so-called Kyoto mechanisms such as Joint Implementation (JI) (within Annex B) or the Clean Development Mechanism (CDM) (outside of Annex B) were not included in the analysis. These measures would allow countries to reduce carbon emissions in other countries through investments in capital or technology. However, as these analyses for the UK, Germany, Spain and the Netherlands were completed in 2002, the proposals under consideration by the EU government did not spell out how these credits would be implemented

Macroeconomic model estimates for Italy

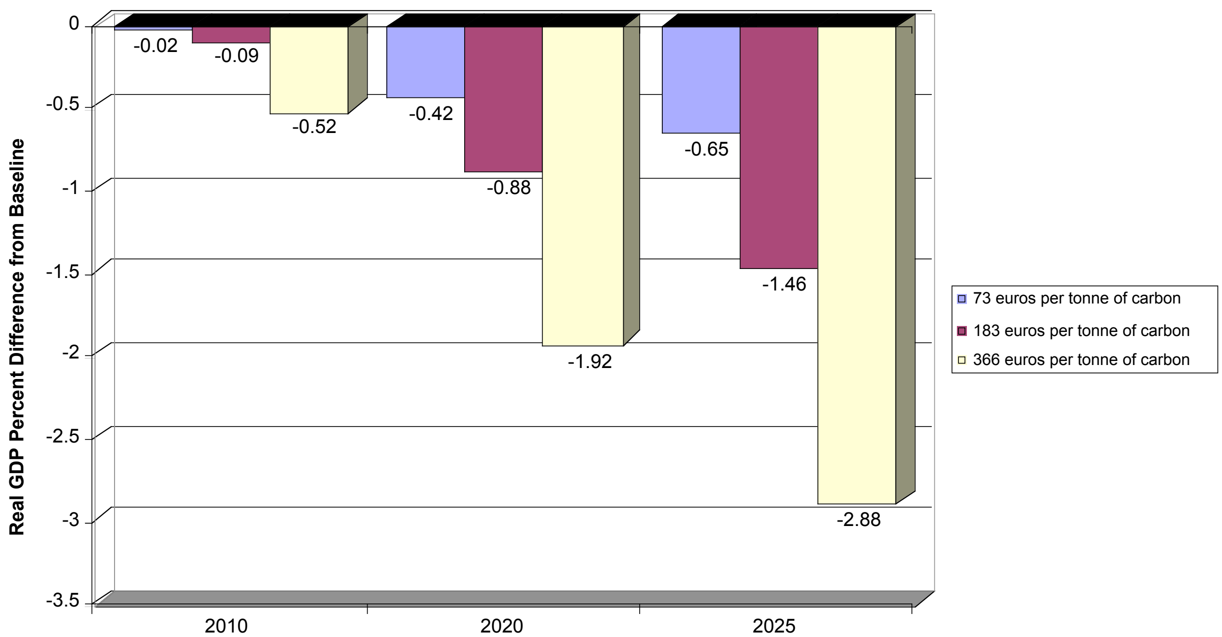
A 2003 ICCF analysis of the impact of Kyoto and additional emission targets on Italy includes the purchase of emission credits from abroad and other features described in the December 2002 climate action plan released by the Italian government (see www.iccfglobal.org). The ICCF analyzed the impact on Italy's economic performance in meeting its Kyoto Protocol target during the first budget period (2008-2012) and further reductions over the post-2012 period through the purchase of approved credits. It was assumed that the target is the Kyoto-defined reduction for Italy for 2008-2012 followed by continuous reductions in the target to 70 percent below 1990 levels by 2050.

Further, it was assumed that current actions can meet 43 percent of the Kyoto target reductions by 2010, but all further reductions are met through the purchase of credits from either other countries or JI/CDM participants under three credit price assumptions (see **Figure 4-8**).

- €20 per ton of CO_2 (equivalent to €73 per ton of carbon)
- €50 per ton of CO_2 (equivalent to €183 per ton of carbon)
- €100 per ton of CO_2 (equivalent to €366 per ton of carbon).

The range of price assumptions reflects the EU's expectation of a low price (€20) up to the maximum compliance penalty (€100) for countries that do not meet the specified target reduction.

Figure 4-8. Impact of the Kyoto Protocol and additional GHG reductions on Italian GDP, 2010-2025



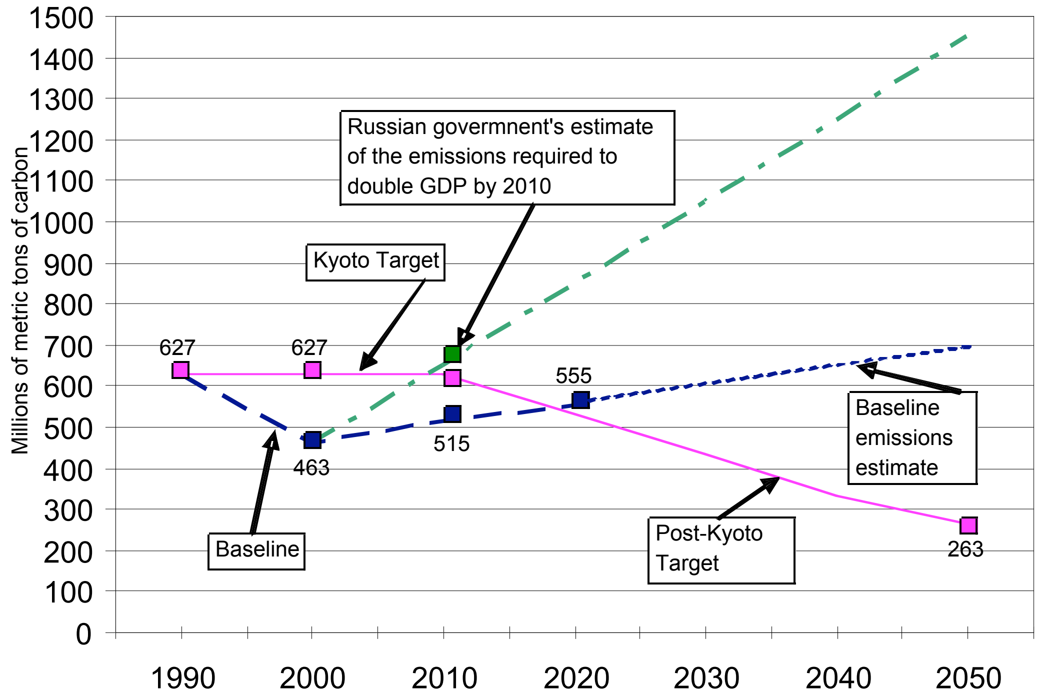
For the three credit price scenarios, analysis by the macroeconomic forecasting firm, Global Insight, assessed the impact on Italy's economic performance and employment. The results of the analysis show that real GDP would fall 0.5 percent below Reference Case levels during the 2008-12 budget period and would be 1.9 percent and 2.9 percent lower in 2020 and 2025 (see **Figure 4-8**) respectively under the assumption that emission credits would cost 100 euros per ton. The annual employment reductions from the Reference Case in Italy would be as high as 51,000 jobs in 2010, rising to 277,000 by 2025.

Russian ratification of the Protocol: what does it mean?

The apparent decision of Russian policymakers to ratify the Kyoto Protocol is described as a political, rather than one based on the economics or the science of climate change policy. Many pundits conclude that the decision to ratify is linked to Russia's gaining membership in the World Trade Organization. Other Russian reasons for ratification are reputedly said to be strengthening its ties with the EU and with UK Prime Minister Tony Blair (the EU's leading proponent of the Kyoto Protocol).

Besides allowing the protocol to come into being, what does Russian ratification mean for the EU? Other than possibly transferring wealth from the EU to Russia for two or three years for the purchase of CO_2 emission credits, not much according to knowledgeable observers. Russia's CO_2 emissions will exceed its Kyoto target by 2009 according to a presentation by Dr. Andrei Illarionov, Adviser to the President of Russia. In an October 1, 2004 presentation (see www.iccfglobal.org), Dr. Illarionov predicts that Russia's strong economic growth will cause it to become a net buyer of emission credits in the 2009-2010 period, rather than a seller(see **Figure 4-9**). At that point Russia would be faced with a difficult choice: either suppress its economic growth by curbing emissions or pay large fines to the European Commission in Brussels(the fine for excess emissions is 100 euros per ton of CO_2 or 366 euros per ton of carbon). It seems very unlikely that Russia would agree to go down either growth-suppressing path, but would instead continue to focus on increasing the size of its economy. In the post 2012 period, if CO_2 emission target are tightened, the economic pain for the Russian economy would become even more severe.

Figure 4-9. Russian emissions: what does the future hold?



Impact of the EU Emission Trading Program on competitiveness

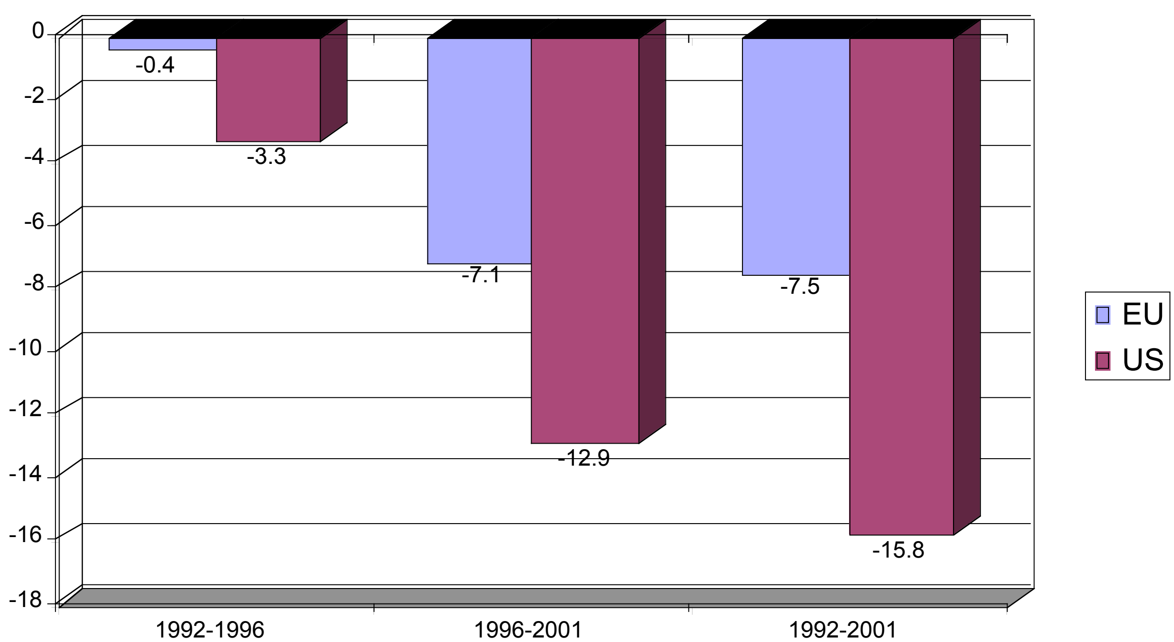
The contrast between the EU and the U.S. approach to addressing the potential threat of climate change is highlighted by the release of the UK's draft emission allocation scheme. Allocating emissions means rationing energy use, much like food, petrol and other essentials were rationed in the UK during World War II. This time however, the sacrifice will be in vain, because the "enemy" (global warming) will not be defeated by UK industry consuming less energy. Only a truly global approach to climate change, which helps countries like India, China and Brazil reduce their rapid emission growth can gradually reduce the growth in global CO_2 concentrations.

In fact, as industries bid for permits to emit CO_2, energy prices will rise; the UK energy minister says by 6 percent, other experts say by 10 percent. As documented by ICCF analyses for the UK and other major EU countries, (see www.iccfglobal.org), higher energy prices mean less investment, job loss, slower growth in GDP and migration of UK industry elsewhere. As GDP growth slows, industry will have less of the wherewithal to invest in new equipment which emits less CO_2.

In contrast to the EU "target and timetables" approach to climate change, the U.S. has chosen a different path, one based on gradually reducing energy intensity. The reason that the Bush Administration rejected the Kyoto Protocol approach was that they had analyzed the costs of sharp, near-term emission reductions and found that the economic costs were significant and the benefits (in terms of reduced global concentrations of CO_2) were negligible.

In fact, the U.S. government's voluntary approach to emission reduction shows more promise than the targets and timetable approach in the 1997 Kyoto Protocol supported by the Clinton Administration and now by the EU. It should be noted that the Clinton Administration never submitted the Kyoto Protocol to the U.S. Senate for ratification because they knew it would be overwhelmingly rejected. According to data the U.S. Department of Energy's Energy Information Administration, the U.S., using a voluntary approach, has cut its energy intensity (or the amount of energy required to produce a dollar of GDP) by a significantly larger percentage than has the European Union. *The EU, which ratified the Kyoto Protocol and thus faces mandatory emission reductions, has reduced energy intensity by only 7.5 percent compared to the 15.8 percent reduction achieved by the U.S over the 1992-2001 period. Similarly, the ratio of* CO_2 *emissions per dollar of output has decreased faster in the U.S. than in the EU over the past decade, 15.3 percent for the U.S. compared to 13.8 percent in Europe. By adopting a voluntary approach to emission reductions, the Bush Administration balances multiple policy objectives, including maintaining strong economic growth and enhanced environmental quality. In contrast EU economic growth is weak and unemployment high (about 10 percent in recent years). (See* ***Figure 4-10****).*

Figure 4-10. EU and U.S. Energy Intensity Reductions 1992-2001



Judging by the experience of Europe thus far, it seems highly unlikely that mandatory targets and timetables for GHG emission reductions for developed countries are achievable: 13 of the 15 EU member states are not on target to achieve their Kyoto Protocol targets. Further, they have little hope of achieving the additional cuts (50 to 70 percent below 1990 levels by 2050) being proposed for the post-2012 period.

The U.S. government's approach will, however, require a major commitment to incentives for deploying new technology, a long-term research and development program for carbon sequestration, alternative energy sources for electricity generation, transportation and energy conservation.

A better path forward

Renewables have a role to play in the goal of reducing GHGs. However, as a November 2002 article in Science Magazine points out, developing renewables requires a major commitment to a long-term R&D program for alternative energy sources for electricity and transportation. Candidates include solar, wind, biomass, nuclear fission, fusion, and fossil fuels from which carbon has been sequestered. Efficiency improvements, hydrogen production, super-conducting global electric grids and geo-engineering also hold great promise for reducing the growth of CO_2 during the 21st century. Commercially viable technologies capable of weaning the world from fossil fuels are still a long way off. Achieving major advances in energy technology will require both serious government and private sector investment in R&D.

Transferring technology to the developing world, where most of the growth in emissions will occur over this century, can play a major role in emission reductions. It is essential to continue transferring existing technologies, such as clean coal, combined heat and power, and others, that will enable those countries to “grow” their economies without similarly growing their emissions. It would be a positive step if developed countries could accelerate efforts to alleviate global poverty and increase the developing world’s access to cleaner energy sources. In addition, barriers to the adoption of new energy technologies in the developing world (where the most emission growth is occurring) must be removed so that these countries can enjoy higher living standards while helping to reduce global emission growth.

Adopting a thoughtfully timed climate change policy – one that is based on accurate science, improved climate models, and global participation – is essential to global economic growth and to the eventual stabilization of the carbon concentration in the atmosphere, if growing scientific understanding indicates such a policy is needed.

About the author

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Chapter 4

THE KYOTO PROTOCOL AND THE APEC ECONOMIES

Alan Oxley and Steven Macmillan

With the Kyoto Protocol about to come into effect,[1] attention among policy makers is focusing on what do after 2012, when the program of commitments to reduce emissions of greenhouse gases finishes. The APEC region includes the fastest growing developing economies (including China, Korea, and Thailand) which have had the greatest success in reducing poverty. They also have the largest demand for power. What climate change strategies are appropriate for these economies?

The impact of the strategy implicit in the mechanisms of the Kyoto Protocol is to reduce emissions of greenhouse gases by reducing consumption of energy from fossil fuels. With no comparably priced mainstream sources of alternative power (other than nuclear) available, the broad, long-term impact of the strategy will be to slow global economic growth. This will constrain efforts of governments in the developing world to raise living standards.

The direct economic impact on developing economy members of APEC is mixed. For some countries the effect will be negative on GDP growth and terms of trade but for several countries it will be positive on investment. The expectation is that some investment will be diverted to the East Asian economies. The impacts are likely to be small either way because of uncertainty about what action will be taken after 2012.

The Kyoto Protocol does not oblige developing countries to reduce emissions of greenhouse gases. The Protocol instead established mechanisms to provide technical assistance to assist with strategies to reduce production of greenhouse gases. The most tangible activity has been activities coordinated by the Global Environment Facility (GEF) to fund energy programs. The focus of these programs has been on delivery of forms of power in poor economies where energy systems are not well developed. The effectiveness of these programs cannot yet be assessed. GEF has also supported the introduction of new forms of renewable energy rather than encouraging greater efficiency in combustion and energy use.

Since economies in East Asia are major consumers of power, projects to promote efficiency in generation of power would have produced greater reductions in emissions of CO_2. (Modest programs have been undertaken in China to reduce emissions from combustion of coal and in Thailand to manage demand for power). This has not been a focus of GEF programs and East Asian economies thereby have not been major recipients of GEF funding.

The impact of technology transfer and technical assistance on developing economies

The most tangible activity under the current international regime on climate change has been the programs of the Global Environment Facility (GEF) to assist developing countries to reduce emissions of greenhouse gases (GHG). GEF climate change projects to facilitate technology transfer and provide technical assistance target a number of countries in the APEC region. But do the projects provide real benefits for APEC economies and reduce reliance on fossil fuels?

Provisions in the UNFCCC and the Kyoto Protocol for technology transfer and assistance

The United Nations Framework Convention on Climate Change (FCCC) commits developed country parties to provide financial assistance, including the transfer of environmentally sound technologies to enable developing countries to reduce greenhouse gas emissions.[2] These commitments are reiterated in the Kyoto Protocol.[3]

Article 11 of the Convention creates a financial mechanism to enable financial assistance and technology transfer.[4] The Kyoto Protocol affirmed that the financial mechanism would provide financial resources to meet the agreed, full costs for developing countries to meet their commitments under the FCCC.[5]

The financial mechanism is operated by the World Bank, through its Global Environment Facility.[6] Developed countries are also invited under the terms of the Convention to provide financial resources through bilateral, regional or multilateral channels.[7]

Assistance provided to developing countries

The GEF provides grants to developing countries for climate change projects. The GEF receives guidance from the Kyoto Protocol Conference of the Parties (COP) on policy, program priorities and eligibility criteria. The GEF has been facilitating projects to meet climate change objectives since 1991. Between 1991 and April 2004, $1.63 billion has been allocated to climate change programs.[8] Of the 207 projects undertaken on climate change, only 43 have been completed to date.[9]

In 2002, in its role as the financial arm of the FCCC, the GEF allocated $127.07 million to climate change projects. With additional funding provided from other sources, the total value of projects was $951.34 million. This is a small amount compared to state aid from developed economies. Official development finance from OECD member economies in 2002 was $62.7 billion.[10]

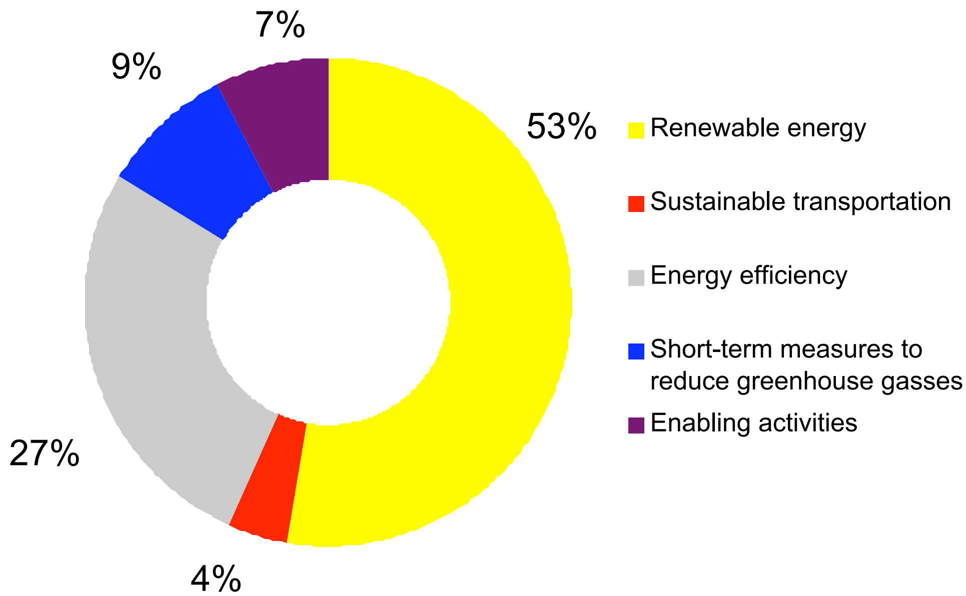
In 2003 (after attracting other funding) the GEF allocated $171.66 million to climate change projects. The total value of the projects was $1.08 billion. The largest projects allocated from GEF fund were a regional project developing geothermal resources in Europe and Central Asia ($25.7 million) and a large-scale renewable energy development project in Mexico ($25.35 million). Nineteen of the 23 projects had funding allocations under $10 million.[11]

GEF climate change programs are organized into four operational areas:

- Removing barriers to energy efficiency and energy conservation;
- Promoting the adoption of renewable energy by removing barriers and reducing implementation costs;
- Reducing the long-term costs of low greenhouse gas emitting technologies; and
- Supporting the development of sustainable transport.

As shown in **Figure 5-1**, between 1991 and 2003, 53 per cent of GEF's total investment was for renewable energy projects and 27 percent was for energy efficiency projects.[12] The operational area for sustainable transport was only established in 2001 and the operational area for reducing greenhouse gases does not yet have sizable long-term programs.

Figure 5-1. GEF climate change investments, 1991-2003 ($ millions)



Source: GEF (2003)

The majority of projects aim for electrification through renewable energy or promote energy efficient products or markets. There has been relatively little focus on achieving efficiency in current use of fossil fuels and future development of, and reliance on coal, oil and gas.

Outcomes

The value of GEF funding on climate change projects is relatively insignificant. Despite being structured in such a way as to combine GEF allocations with investments by other organizations, the size and scope of projects are not adequate to meet the aims of the financial mechanism. Evaluating the impact of GEF projects is similarly problematic.

A review of the GEF climate change program in November 2004 found that for the 27 closed projects in the 13 years since 1991, the estimated avoided direct and indirect emissions amount to 224 million metric tons carbon dioxide at an incremental cost of US$194 million.[13] This is a modest result given that annual global emissions of energy-related carbon dioxide are predicted to reach 38 billion tons by 2030, with China accounting for 6.7 billion tons per year.[14]

According to the 2004 review, "individual projects may be responsible for high achievements in GHG avoidance, but have little potential for replication or sustained barrier removal."[15] The review found that the GEF had been satisfactory in fulfilling its role but that program focus and allocations have not been maximized and have not fully addressed "the *major* climate change needs, even in countries with considerable potential for benefits."[16]

The greatest progress in terms of outcomes to date has been made in the energy efficiency portfolio. The GEF aims for strategies to remove barriers to replication of energy efficiency measures across sectors. Achievements are promotion of energy-efficient appliances and products in Mexico and Poland and industrial boiler conversion in China. Renewable sources of energy remain more expensive and less accessible than traditional energy sources. The GEF has concentrated on promoting the increased use of photovoltaic (PV) technology with some small successes in clinics and schools. However, PV technology remains an unaffordable and inefficient option for the market at large in developing countries.

The clean development mechanics and developing economics

The Clean Development Mechanism (CDM) is one of the “flexibility mechanisms” of the Kyoto Protocol. The mechanisms comprise provisions placed in the Protocol to reduce the cost of meeting emission targets. The CDM is designed to enable investors (governments, companies, funds) in countries with emission targets to invest in projects to reduce emissions in developing country members of Kyoto (who do not have emission targets). Each CDM project must reduce emissions beyond what would have been the case in the absence of the project. By carrying out projects that are approved through a process outlined in the Protocol, investors can generate “credits” under the Protocol which can be used to meet reduction commitments in their own country, or sold to another party to use.

The idea was that the “credits” generated by the project could be sold to others. CDM projects were intended to promote commercially sound measures enabling developing countries to participate in global efforts to abate human greenhouse gas emissions and to acquire benefits.

An alternative to foreign investment in the CDM is for entities in developing countries to engage in a CDM unilaterally (i.e. without investors from other countries). This is called “unilateral CDM.” The entities carry out the project and receive the credits which they would then sell to other parties to help the other parties meet their commitments.

The CDM is designed to achieve a range of goals, not only the reduction of emissions but also social and economic development. It is intended that the permits created by a successful CDM will carry market value as permits to emit “greenhouse gases.” This would depend on the existence of a single price for CDM units created in all countries and for these units to be fully fungible.

Conditions were to apply to CDM projects

Under Kyoto, a central “CDM Executive”[17] is to be created to ensure that the CDM performs as intended. Equally, host governments must be satisfied that the project meets development goals as well as goals to reduce greenhouse gases. Understandably, for a mechanism designed to do many things in many different environments, the functioning of the CDM is fraught with complexity. While the mechanism intends to harness market power, its structure is more akin to government development assistance.

As a result of this complexity, the impacts of the CDM are uncertain. Important doubts were raised in the literature about whether the CDM could deliver anything more than a limited number of development assistance projects. These doubts were raised at the time the CDM was negotiated in 2001[18] – when the rules for the mechanism were laid down – and have been raised since.[19]

The Environment Directorate at the Organization for Economic Co-operation and Development (OECD) and the International Energy Agency (IEA) produced a joint paper in June 2004 entitled *Taking stock of progress under the Clean Development Mechanism* (OECD/IEA, 2004). The OECD report finds a reasonable estimate of the value of funds likely to be directed to CDM annually at around US$1 billion, two thirds of what has been spent on climate change investments in the World Bank’s Global Environment Fund since inception. This represents around 0.15 percent of the required investment in energy infrastructure in developing countries in the 2001-2030 timeframe.[20] The paper reports that as of June 2004 no CDM projects had been registered. Further, the report found in July 2004 that "the contribution that the CDM is expected to make to emission reductions in the first Kyoto commitment period is likely to be small."

What stands in the way of large volumes of foreign investment flowing to developing countries on the back of the CDM? The problems with the CDM from an investor's point of view, either public or private, all fall broadly under the heading of risk. Some of these risks may decrease as time passes, but some of them are inherent in the structure of the CDM and the Kyoto Protocol.

Whatever the benefits of the CDM, its benefits for developing countries in Kyoto's first commitment period look likely to be small. The operation of the CDM provides significant risks and uncertainties. It looks unlikely that projects can achieve all their goals: reducing emissions, providing enough return to perpetuate investment and serving social and economic development goals. Either the CDM will have to change in form, or developing country hosts will have to compromise on the structure they negotiated. Long term uncertainty about the suitable role of developing countries in the Kyoto Protocol after the first commitment period continues to hinder involvement of developing country parties.

Energy Demand in Developing Countries

According to the 2004 IEA *World Energy Outlook* (IEA, 2004) developing countries in Asia will contribute up to 80 per cent of world incremental coal demand and 21 per cent for gas between now and 2030.[21] Energy demand growth is predicted to outpace development of domestic energy supply.

Table 5-1. Primary energy demand in China (Mtoe)

	1971	2002	2010	2030	2002-2030*
Coal	192	713	904	1,354	2.3%
Oil	43	247	375	636	3.4%
Gas	3	36	59	158	5.4%
Nuclear	0	7	21	73	9.0%
Hydro	3	25	33	63	3.4%
Biomass and waste	164	216	227	236	0.3%
Other renewables	0	0	5	20	0.0%
Total	405	1,242	1,622	2,539	2.6%

**Average Annual Growth Rate*
Source: IEA, 2004, p. 264

Table 5-1 shows that China's total primary energy demand is predicted to expand by 2.6 per cent annually between 2002 and 2030. The IEA suggests that coal will remain the dominant source of primary energy, accounting for 53 percent of energy needs being met through imports, primarily oil. Indeed, 92 percent of Thailand's oil requirements were not met through imports in 2001.

The Philippines' energy consumption per capita is 0.2 toe, one of the lowest in the region, but it is a growing consumer. It is primarily reliant on oil and geothermal resources.

Vietnam has low levels of energy consumption. It exports energy at present. However, per capita GDP was only US$1,965 in 2001 and energy requirements can be expected to increase as the economy grows. Oil provided 56.8 percent of primary energy supply in Vietnam in 2001. Vietnam is a net energy exporter and is developing further capacity for gas and coal.

The Kyoto approach to reducing human greenhouse emissions mandates the reduction of emissions. In the absence of alternative fuels, stabilizing emissions this way imposes vast costs on the global economy, as shown in previous sections. The Kyoto approach, if carried forward with bigger targets beyond 2012, threatens great expense to global GDP, as outlined in Section 3. Section 8 shows that renewable fuels appear unlikely to provide fast-growing, transitional APEC economies opportunities to reduce emissions of greenhouse gases in the medium term without seriously sacrificing growth.

Practicable approaches to tackling the risk of climate change must permit non-industrialized and fast-growing economies access to affordable energy. Growth, not stagnation, is likely to produce technological outcomes that improve standards of living and our capacity to deal with risk.

Investment from high technology energy producers is a primary vehicle for technology transfer to developing markets and the most effective means for APEC developing economies to reduce emissions of CO_2 in the short to medium term.

The paucity in genuine, large-scale alternatives to fossil fuels, nuclear power excepted, suggests that other options must be considered for dealing with the risk of increased concentrations on CO_2. Research on new technologies for sequestration of CO_2 and combustion is a practical long term alternative.

About the authors

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Notes

1 While the Russian Government has decided to ratify the Protocol, analysis by Russian experts also summarizes important questions about the science upon which the IPCC report and the Kyoto Protocol are based (Illarionov, 2004).

2 United Nations Framework Convention on Climate Change (UNFCCC) 1992, Article 4 (3), (5).

3 Kyoto Protocol to the UNFCCC, Article 10(c) – FCCC/CP/1997/7/Add.1

4 UNFCCC 1992, Article 11 (3).

5 Kyoto Protocol to the UNFCCC, Article 11 – FCCC/CP/1997/7/Add.1.

6 Kyoto Protocol, Decision 3/CP.4.

7 UNFCCC 1992 Article 11 (5).

8 The total value of individual projects is higher than the GEF investment which forms only part of the project funding.

9 GEF, *Program study on climate change*, 4 November 2004.

10 OECD, Statistical annex of the 2003 Development co-operation report.

11 GEF *Annual report 2003*, pp. 13, 17-18.

12 GEF *Annual report 2002*, p. 13.

13 GEF, *Program study on climate change*, 4 November 2004, p. iii.

14 International Energy Agency (IEA), In 2030, *Global CO_2 Emissions will be 70 percent more than today*, www.iea.org/dbtw-wpd/textbase/weo/papers/Weoc02.pdf, accessed 17 November 2004.

15 GEF, *Program study on climate change*, 4 November 2004, p. iii.

16 GEF, *Program study on climate change*, 4 November 2004, p. iv.

17 Under the Kyoto Protocol's Article 12.

18 The negotiations were at the 7th meeting of the Conference of the Parties and were held in Marrakesh. The resulted in documents called the "Marrakesh Accords".

19 See for example Michaelowa and Jotzo (2002): "*The prospect for large scale emission reductions in developing countries through CDM projects appear slim in the medium term*." See also Varilek & Cohen (2002); Blanchard *et al.* (2002); and Schneider and Wagner (2002).

20 OECD, 2004: 18.

21 IEA, 2004, p. 262.

Chapter 5

DOOMED TO FAILURE: WHY EMISSIONS TRADING WILL DO LITTLE TO STABILIZE GREENHOUSE GASES

W. David Montgomery

Introduction

For decades, economists have recommended emission trading as a method of controlling pollution at minimal cost to society. As proof that such a system will work, they cite the United States' experience with trading permits for sulfur emissions from electric power plants, under a very successful program that reduced costs inherent in an earlier, badly designed regulatory system.

This experience and their general preference for market-based instruments made economists hopeful that international emissions trading under the Kyoto Protocol could successfully create greenhouse gas emission caps at minimum cost to the global economy. Unfortunately, this is not proving to be the case. The design of emission trading under the Kyoto Protocol falls short of the theoretical ideal in key respects, leading to competitive distortions, excessive costs, and wealth transfers that are likely to undercut popular support for the entire program.

Even more unfortunately, when one examines the conditions that must be met for emission trading to meet targets and minimize costs, it becomes apparent that these goals cannot be satisfied by any international trading regime that might be possible under the Kyoto Protocol. For markets to achieve these goals, companies and countries must be able to trade today for all the future periods in which prices are relevant to current decisions. The mismatch of time scales built into the Kyoto Protocol forces them to lurch from one five-year commitment period to the next, with no ability to define long-term targets, calculate future prices or enforce achievement of emission targets.

The result is illusory "property rights" in future emission reductions – made all the more untenable by a general assumption that explicit targets will be weakened, rather than strengthened, as Parties realize that achieving those targets will be more difficult and expensive than they initially assumed. This undercuts the entire emission trading system, and moots the expectation that emission trading will produce desirable outcomes.

Moreover, the unenforceability of the Kyoto Protocol makes the entire agreement unstable. All Parties to the Protocol have a reasonable expectation that at some point in the future another Party will find that its costs of meeting near term targets will be too large to bear, for all sorts of reasons beyond any Party's control. The Party that finds costs too hard to bear cannot be forced to meet its targets, since even the "penalty" provisions in the Protocol are meaningless. This expectation of future defections diminishes the incentive of any Party, or legal entity that might participate in emission trading, to undertake costly current actions on the basis of expectations that future targets will be met and future emission permit prices will rise.

This is exactly what has happened under Kyoto. No major Party has taken costly measures to achieve compliance. The only two large countries that are likely to be in compliance – Germany and the United Kingdom – have attained that position solely because of events in the 1990s that had nothing to do with climate change. No party and few private businesses show any belief that the price of emission permits will reach levels sufficient to justify changes in long-term investment behavior at this point. The international emissions trading system thus shows no signs of being successful in motivating cost-effective long-term efforts to reduce carbon dioxide emissions.

Emission trading under ideal conditions

Enthusiasm about emission trading is based on a true perception that allowing the free play of competitive market forces leads to the most efficient use of society's resources. These market forces do not now lead to control of greenhouse gas emissions, because those emissions cannot be bought and sold in competitive markets. This market failure is due to the fact that one person's greenhouse gas emissions (when I drive my automobile, for example) affect concentrations of greenhouse gases all over the globe. There is no effective way for all the billions of people potentially affected by those greenhouse gases now and in the future to offer me a deal to reduce my emissions.

The idea of emissions trading is to circumvent this "public goods" problem by setting up a system of emission rights that can be traded, by first placing a cap on total emissions, and then dividing that total allowable amount (emission cap) up and enforcing limits on greenhouse gases from every individual source. Once these limits and the required monitoring and enforcement are set up, allowing those well-defined emission rights to be traded makes it possible for market forces to determine where emissions should be reduced, so that the aggregate limit is achieved at the lowest possible cost.[1] **Emission trading will achieve this result, but only if all the relevant markets exist and operate reasonably effectively.**

Economists have spent centuries pondering the questions of how and why competitive markets achieve the efficient use of resources.[2] The answers that emerged in the middle of the twentieth century were that:

- competitive markets lead to efficient resource use only if there are "complete" markets for everything that matters, and
- these markets must extend over space and time and allow for trades that are conditional on how uncertain events turn out.[3]

These conditions also extend to the creation of new markets through emission trading: those markets can be expected to lead to efficient use of resources only if they are also complete, cover all the relevant sources and time periods, and allow participants to lay off risks through use of appropriate securities or other instruments.[4]

In practice, none of these conditions is being met. More disturbingly, there is a fundamental inconsistency between the time scales for action to reduce greenhouse gas emissions, and the time frames over which policies can be put in place. This makes it impossible in principal for international emission trading to lead to efficient use of global resources in addressing climate change. The practical problem is that emission trading systems now being designed layer on so many restrictions, distortions and limitations that they differ greatly from the theoretical idea.

But even if all these unwise design features now being put in place were eliminated, there is a more fundamental impossibility: essential property rights cannot be created, when their foundation is an agreement among sovereign nations that is based on unenforceable promises to take action in the future.

Practical problems with Kyoto approach

Current systems being developed for national and international emission trading depart significantly from the theoretical ideal in a number of ways.

Partial coverage. First, trading systems currently under development fail to cover all emission sources, even within the jurisdictions where they are being put into effect. These mixed and partial approaches lead to highly inefficient use of resources in controlling emissions, because they cause great disparities in marginal cost between covered and non-covered sectors, and they default to inefficient regulatory policies in the non-covered sectors.

In the trading system being developed by the European Union, only large industrial sources and power generators are covered by the emission trading system. Most observers have suggested that the aggregate cap for the covered sectors in most EU countries seems to have been set at a level that will require little or no effort to reduce emissions below levels they would reach on their own. Residential, commercial, small industrial and transportation sectors will be responsible for achieving the remaining reductions through other voluntary or regulatory measures.

Canada is developing an odd system in which there is technically more or less universal emission trading, but the *price* of permits issued to certain energy producers is capped. Once the price cap is hit, emissions from energy producers are likely to exceed their assigned emission levels, requiring either reductions in emission limits for the rest of the economy or purchase of permits on international markets by the Canadian government.

In the United States, proposals for national and state-level emission trading systems include only power generation – or power generation, large industrial facilities and transportation fuels.

The use of a combination of (a) command and control regulations that impose far higher compliance costs and (b) voluntary measures that may fall short of meeting emission targets in sectors not covered by emissions trading raises the costs of achieving emission reductions in those sectors, compared to the minimum costs that could be achieved by use of true market-based instruments. It also creates a risk that the overall cap will not be achieved at all. Moreover, there are likely to be substantial opportunities to reduce costs by adjusting caps between sectors that are included in emission trading and those that are not.

Universal emission trading would equate the cost of reducing emissions by one more unit across all sectors. These gains from trade are sacrificed by partial systems because, in systems that regulate only selected sectors, mismatches in cost can be achieved only by starting over again in deciding what cap should be placed on sectors that are included in emission trading.

Competitive distortions. The almost universal practice of grandfathering some or all of the permits being allocated to businesses included in the trading system creates competitive distortions and increases costs, sometimes substantially. The competitive distortions arise from the inevitable differences in the partial (fractional) allocation of baseline emissions that will be grandfathered in different jurisdictions.

Consider for example a multinational company that may be thinking about building a new petrochemical complex. The company could choose to locate the plant in an EU country, where it will be required to make large reductions from its business as usual emissions to meet a Kyoto target; in a different EU country where much smaller reductions will be needed to meet emission targets; or in a non-Annex B country that requires no emission reductions at all. The comparison between the two EU countries and the non-Annex B country clearly favors locating in the non-Annex B country, because the cost of meeting emission limits in the EU countries is high, whereas the non-Annex B country will impose no such costs. This is the well-known phenomenon of “leakage.”

However, even between the two EU countries there will be a competitive distortion, unless each gives the petrochemical company exactly the same fraction of its future emissions as a free allocation. But it will be virtually impossible for the two countries to do that, unless they decide to auction all permits and grandfather none.

The reason is that, due to their different emissions caps under the EU burden-sharing scheme and their different baseline emission forecasts, any two EU countries are likely to have very different emission reduction requirements. This implies that the country with the larger required reductions will not have enough emission permits available to match the free allocation offered by the other. The country that needs to do little will be able to offer a new facility almost 100 percent of the permits required to cover its projected emissions. By contrast, the country with a long way to go in reducing emissions will generally not have enough permits to make such an offer, unless (like Canada) it is willing to purchase permits from international markets, and give them to new facilities.

This granting of free emission allocations for new or future facilities (a new twist variation on common grandfather clauses) potentially results in a significant difference in the expected cash flow for the favored facility, depending on which country is chosen for investment. Thus, other things being equal, the decision on where to locate will be distorted for no good economic reason.

One of the preconditions of the underlying theory of how emission trading can lead to the most efficient use of resources is violated by this kind of free permit allocations. In theory, all emission permits must be allocated according to rules that make it impossible for any party to obtain more permits by changing its future behavior. Offering a share of permits to new facilities, contingent on their locating in a particular country, violates this condition. Only by requiring that all new facilities purchase all their required permits on the open market can a Party achieve the desired emission outcome. However, that rule does not appear to be contemplated in any actual system.

The free allocation of permits that seems to be favored for political reasons in most actual systems also sacrifices any possible double dividends that might accrue from using revenues from selling emission permits to reduce other distorting taxes. This then leads to disproportionate increases in the net burden of the existing tax system, and further increases overall negative economic impacts of emission limits.

Wealth transfers. Finally, the entire system of international emission trading relies at this point on massive international wealth transfers for doing nothing. As **Figure 6-1** makes plain, the European Union, Canada, and Japan clearly cannot meet their emission targets by measures to reduce emissions within their own borders.

Greenhouse gas emissions by most of these nations in 2002 were well above the levels they would be permitted by 2010 under the Kyoto Protocol. They would thus have an extremely difficult time meeting emission targets. The social, economic, employment and, above all, political ramifications of actions that would be necessary to meet those targets are only now being recognized by corporations, consumers and politicians in those countries.

It is interesting to note that two nations that have refused to ratify the climate change treaty – Australia and the United States – exceed these targets by a smaller percentage than do a number of signatory nations. Three signatories (Denmark, Austria and Canada) are further away from meeting their treaty obligations than the USA would be if it were to ratify the treaty. Those three and five others (Japan, Ireland, Italy, Luxembourg and Spain) are all further above their emission reduction targets than Australia would be, were it to sign the Protocol.

These facts make it obvious that it will be necessary for all these countries to look to Russia to buy permits. In terms of economic efficiency, this is no real problem. But what Russia will be selling, at least in the first commitment period, are permits allocated to it in excess of its expected actual emissions. Russia will be generating these permits not by undertaking costly measures to reduce emissions, but simply because of its intelligent and successful negotiation strategy when the Kyoto Protocol was created. Russia obtained an allocation of permits far larger than any expectation of what its emission levels could reach in the first commitment period, assuming it would take no action to reduce emissions in the interim.

An example of potential wealth transfer is seen in U.S. Energy Information Administration CO_2 emission projections for 2010, as summarized in **Figure 6-2.** The combined carbon dioxide (CO_2) emissions from Western Europe, Japan and Canada – without additional policies and measures – are projected to *exceed* their combined Kyoto Protocol targets by roughly 1 billion metric tons of CO_2, while Russian CO_2 emissions (excluding other former Soviet Bloc countries) are projected to be roughly 600 million metric tons *below* that country's Kyoto target in 2010. Based on this simple CO_2-only comparison, Russia could well receive a wealth transfer from Western Europe, Japan and Canada in exchange for unneeded Russian allowances during the first Kyoto compliance period.

Inclusion of developing countries in the international emission trading system of the Kyoto Protocol would likewise lead to large international wealth transfers. Developing countries have rightly pointed out that their poverty and needs for growth make commitments to incur net costs to reduce emissions untenable. Thus, to induce them to join a trading system, their initial allocation of permits would have to be high enough that their revenues from selling permits would cover any costs they incurred in reducing emissions.

The purchase of emission permits that leads to these international wealth transfers is necessary to avoid the much higher costs of domestic measures to achieve limits that the Kyoto Protocol imposes on the EU, Canada and Japan. But at the same time, the magnitude of the transfers, and the transparent fact that they are not compensating for efforts undertaken by the recipient countries, jeopardize the political sustainability of the system.

Figure 6-1. Exceeding greenhouse gas emissions gaps: actual 2002 emissions versus Kyoto Protocol or EU burden sharing targets[5]

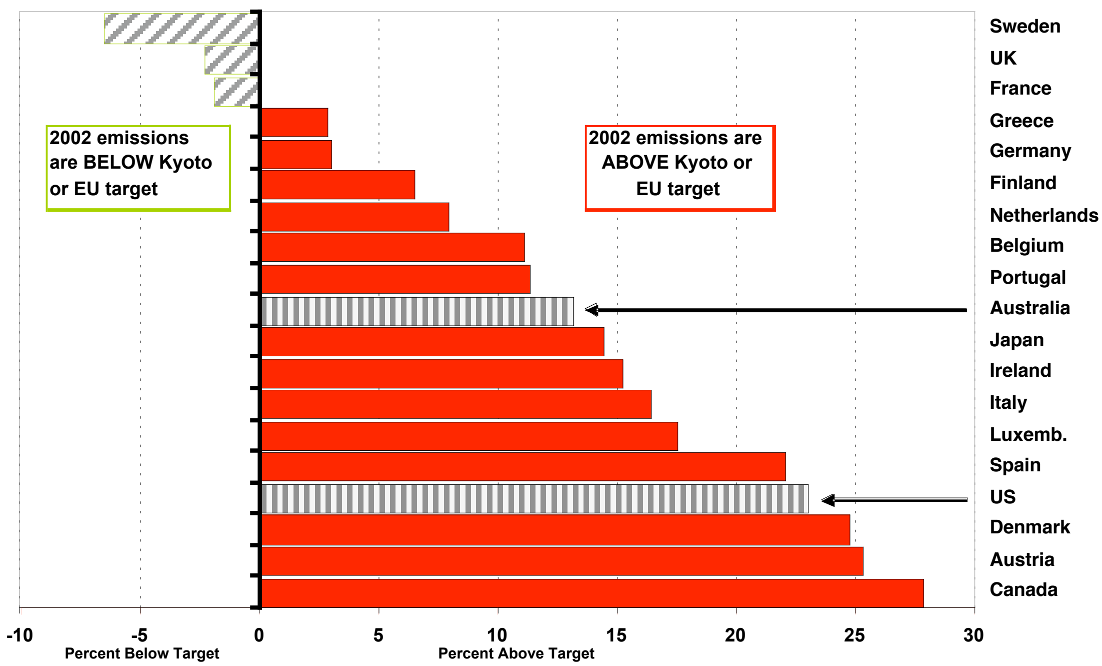
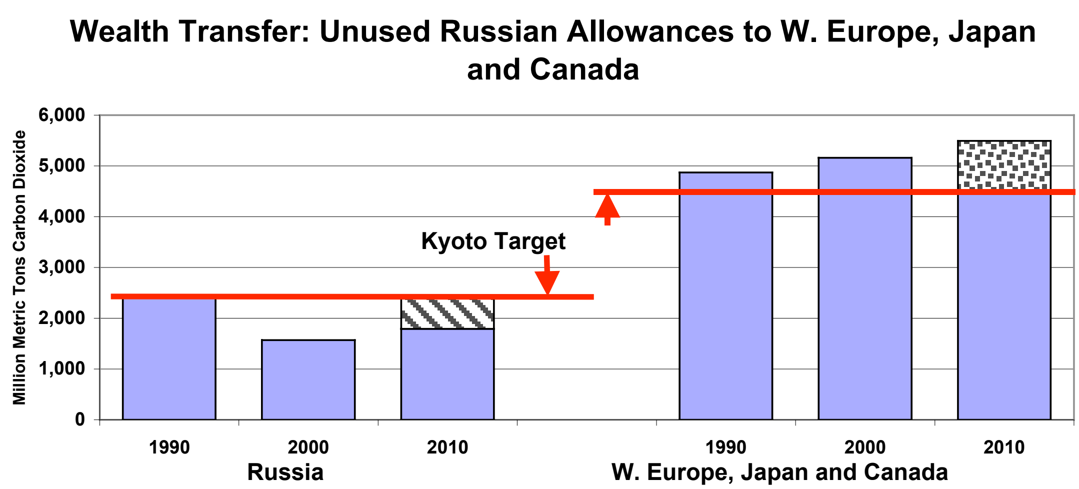


Figure 6-2. The transfer of Russian CO_2 allowances[6]



Bars represent CO_2 emission projections from the U.S. Energy Information Administration's International Energy Outlook 2004.

The fundamental impossibility

These practical deficiencies in the design of current emission trading systems imply that what is being created thus far falls far short of the theoretical ideal, and is therefore not likely to achieve the most efficient use of resources in reducing emissions. But there is a deeper problem.

The time period over which emission rights are defined is the most critical question in evaluating whether emission trading can be a viable approach to climate change.[7] Emissions trading motivates actions, by creating current and expected future price incentives. It is clear from virtually every study that stabilizing global average temperatures at any level will require large-scale research and development to create new technologies, as well as massive changes in the physical stock of capital equipment on a global scale. (This, of course, assumes that human influences on the climate are much greater than natural forces, and that controlling those human influences will thus make it possible to stabilize the Earth's climate at some chosen temperature.) Bringing about these investments in R&D and fixed capital is thus something that any approach to climate policy must be able to achieve.

The naïve hope has been that, by setting up a system of international emission trading, the climate treaty will create incentives to spur these investments. In theory, the system of international emission trading would put a price on carbon emissions, thereby creating value for investments and technologies that can bring about reductions in carbon emissions at unit costs less than the price of permits. Thus expectations about the future price of carbon permits would be the motivating force to change long-term investment behavior, and stimulate R&D.

This is a very attractive picture. Not only does it promise a route to solving the climate policy problem. It also allows decisions to be made by the scientists, inventors and investors in the private sector who, one surmises, know what they are doing. And it keeps government agencies, who have demonstrably failed to conduct successful energy R&D programs, out of the picture.

The problem is, it won't work. All the really important actions by the private sector have to be motivated by price expectations far in the future. Creating that motivation requires that emission trading establish not only current but future prices, and create a confident expectation that those prices will be high enough to justify the current R&D and investment expenditures required to make a difference. This requires that clear, enforceable property rights in emissions be defined far into the future – so that emission rates for 2030, for example, can be traded today in confidence that they will be valid and enforceable on that future date.

The international framework for climate policy that has been created under the UNFCCC and the Kyoto Protocol cannot create that confidence. Indeed, there may be no international agreement to which sovereign nations could agree that would do so.[8]

Unzipping of international agreements

The Kyoto Protocol approach is based on future targets and timetables, which will supposedly motivate private sector action through emission trading. However, it is fundamentally incapable of sending adequate signals to current investment. At this point, the complete lack of definition for future timetables undermines any reasonable expectation that investments today would generate any actual value in future emission reductions created by those investments.

Moreover, this problem cannot be fixed by getting started on negotiations for the Second Commitment Period, because the Protocol provides no enforcement mechanisms or other incentives to induce reluctant parties to sign the treaty and continue their participation in emission targets and timetables. This lack of enforceability stems not from poor drafting of the treaty, but from the fundamental fact that an agreement on future targets and timetables among sovereign countries is in principle unenforceable and therefore unstable. They cannot be compelled to commit to a future course of action.

The instability of the agreement, in turn, creates in the minds of private investors a built-in bias that leads them to assume there is a high probability that carbon limits will ultimately be less than those explicitly agreed upon.

The impossibility of sustaining an agreement based on targets and timetables removes the underlying foundation for emission trading. Emission trading must motivate long-term commitments in R&D and investment to lead to cost-effective mitigation. The impossibility of enforcing compliance leads to a self-fulfilling expectation that the agreement will unravel and carbon prices will fall in the future.

Even if the Kyoto Protocol is not declared officially dead, as now appears likely, these problems ensure that no party has an incentive to incur material costs to achieve compliance in current time periods. If current period commitments are met, it will be with short-term measures that bring some emission reductions, but are not cost-effective in addressing long-term risks.

Sovereignty and enforceability

Sovereign countries are unable to make binding, unilateral commitments, because the Protocol deals with targets, not observed actions. Moreover, there are no consequences under the Kyoto Protocol for failure to participate or to comply with an agreed target. Any country can avoid its commitments *de jure* by withdrawing with two years notice, or *de facto* by rolling any violation of a target into future periods. The Kyoto Protocol fails to define emission targets beyond 2012, and negotiations on the Second Commitment Period (2013 – 2017) had not begun in 2004.

The only enforcement provisions in the Protocol provide that any failure to meet a target in a given period must be made up with a penalty in a future period. However, the lack of definition of targets beyond the first commitment period makes these penalties meaningless. No country that is likely to be in violation of its first commitment period target needs to agree to a second commitment period target, until that second target is increased sufficiently to avoid the penalty.

Since no commitments are defined for any future period, any country that expects to exceed its target can negotiate a sufficiently high future commitment to cover the excess, without requiring any real action to make it up. A country that wishes to do so is in a good bargaining position, because its fallback is to withdraw completely. In short, the hard caps of the Protocol become soft when violations can be rolled into yet to be negotiated future target.

This ability to withdraw, *de facto* or *de jure*, has profound implications for expectations of future carbon prices under the Kyoto Protocol. Explicit noncompliance may be concealed or withdrawal avoided by negotiation of weaker future targets, or forgiveness of current excess. In any case, Parties will be able to exceed their targets if they wish to do so, because the targets are unenforceable.

Even if commitments for future periods were negotiated, the agreement would remain myopic because noncompliance cannot be punished as long as participation is voluntary. Indeed, credible commitments are impossible as long as negotiations deal with future targets, not observed actions.

Since future mitigation costs and the ability of Parties to meet their targets are uncertain, it is highly likely that some Parties will find themselves in a position where noncompliance or withdrawal is preferable to maintaining the agreement.

Sovereignty implies that no country can be compelled to join or remain a party to the protocol. The entire negotiating process exists to deal with that fact, and the related fact that each country has a strong incentive to free ride on the efforts of others. For an agreement to have any chance of being accepted and remaining in force, it must satisfy a criterion of individual rationality. A country must be able to see that it is better off by remaining in the agreement that it is in pulling out. That is, the difference between climate damages avoided and mitigation costs that a country expects to incur by *adhering* to the agreement must be perceived to be greater than the difference between avoided climate damages and mitigation cost should the country *pull out*.

Climate damages theoretically avoided depend on how many countries participate in the agreement – and on how much each does to limit emissions. On the other hand, mitigation cost depends entirely on each country's own target and efforts to meet that target. Only when a country perceives that benefits going forward will be in excess of its costs of compliance will there be any chance that it will adhere to the agreement.

The likelihood of future defections unzips the agreement and assures inaction

The difficulty is that all Parties can anticipate from the start that eventually some Parties will find their commitments too onerous, and thus will either renegotiate or withdraw. There is a level of cost at which a country will prefer effective withdrawal to continued adherence, even if all others adhere to the agreement. That is, since costs and ability to comply with the targets are uncertain, it is almost certain that some Parties will find themselves in a position where noncompliance or withdrawal is preferable to maintaining the agreement.

This will be the case if a party discovers that costs of meeting its target are much higher than it had anticipated, and now exceed the avoided damages that the agreement provides. This country will then want to reduce its commitment until its costs fall below the benefits it receives.

The statistical phenomenon known as the "Gambler's Ruin" is relevant here. It is a mathematical proof that in the long term every gambler, even one playing with fair odds, will go bankrupt. The reason is that, over a long enough time period, there will be some run of bad luck long enough to use up the gambler's entire stake, and from that point there is no recovery. Over a long enough time, since costs of mitigation are uncertain but real, some country is virtually certain to discover that its costs will exceed its expected benefits of avoided climate damages.

As soon as this happens to one country, that country is motivated to use one of the routes available to withdraw *de facto* or *de jure* from its commitments. As a result of this withdrawal, expected future emissions will increase, the treaty will accomplish less toward stabilizing global temperatures, and its benefits for all countries will fall. This will put more countries in the position of having their mitigation costs exceed their avoided damages under the treaty, and they too will pull out. This then "unzips" the agreement.

The amount of collectively rational mitigation declines when there are defections from the initial agreement. Therefore, defection by one country lowers the cost threshold at which others decide against joining or adhering to the agreement. This defection can be overt or through reduced future commitments. Moreover, the lack of commitments for future periods makes it easier to conceal noncompliance and avoid withdrawal by negotiation of weaker future targets. In other words, the negotiation of a weaker future target disappoints the expectations of other parties, in the same way as would overt withdrawal from an agreement to explicit targets.

All parties can expect that this will happen at some point in the future. As a result the expectation of future defections unzips the agreement long before any country finds that its costs have in fact increased to an intolerable level. The consequent expectation that whatever has been agreed to will not hold up to future cost shocks leads to several consequences for behavior:

- No party will be willing to undertake costly policy measures domestically.
- Parties without emissions obligations will remain outside the agreement.
- New Parties will have diminished incentives to join the agreement.
- Every party ending up withdrawing from the agreement on targets and timetables – either de facto (by formally bowing out) or de jure (by missing its current target and negotiating a non-binding future agreement).

It is also important to recognize that Parties to the protocol are actually made up of entities that will actually have to bear the costs of compliance: companies, shareholders, retirees, consumers, travelers and local communities. As their costs rise, they perceive few climate benefits and additional, more costly agreements are proposed, the pressure to withdraw will increase steadily.

Incentives for long term action disappear

An unenforceable future agreement cannot motivate costly action or support cost-effective use of emission markets. Incentives for private parties to participate in emission trading will also be nullified. No legal entity will anticipate or be willing to pay a high enough carbon price to motivate long term investment. Even if the agreement specified targets and timetables for future periods, it could not motivate R&D and investment in solutions, because the potential unzipping of the agreement creates a bias against expectations of high future carbon prices. Private investors will substantially discount forecasts of future permit prices.

As a result, in every commitment period, it is rational for legal entities to distrust continuation of international trading in the next period, and to expect lower prices than literal interpretation of the agreement would predict, whether or not future commitments are negotiated in advance. The impossibility of binding future commitments thereby reduces the incentive for cost-effective private sector investments, even with long term targets.

This undercuts the entire expected range of policy benefits from emission trading, because cost-effective responses require investments with long payouts, including R&D, energy and transport infrastructure, and power generating equipment. Sequential targets (the only possible outcome with sovereign governments) and impossibility of credible commitments combine to promote short-term efficiency, conservation and fuel-switching measures – but not long term solutions such as R&D.

Uncertainty about the future of the agreement also influences current behavior. When future permit prices are uncertain, decisions are biased toward options that have low capital commitment and higher expected cost. The scope of international trading is restricted compared to the ideal, so that savings from international trading are unlikely.

Another way of putting this is that the property rights in future emission credits are so vague that they create seriously incomplete markets. Therefore, emission trading is not necessarily a first best policy: it cannot stimulate sufficient R&D or other long-term investment. It is not just uncertainty, but a clear bias in favor of expecting lower future carbon prices than would be observed with complete markets.

For a private investor attempting to factor the market implications into long term decisions, the best possible scenario for carbon prices is one in which Parties are assumed to adhere to the agreement as written, and new parties accept and act on their obligations. This is the upper bound. However, the risk is extremely high that carbon prices will be much lower or even hovering near zero, as a result of future defections and Parties staying outside the agreement. The all but unavoidable result is the unzipping of the climate agreement.

Self-fulfilling expectations

Understanding the dynamics of unzipping should lead both governments and businesses contemplating investments to the conclusion that there is a very high probability of defections (approaching certainty for some country at some point in time). Thus, there is no good reason to expect permit prices at levels required to achieve the Kyoto Protocol caps. That means there will not be a sufficient incentive to take the actions that would achieve the caps.

This effect on decisions of private parties then leads to a failure of the emission trading system to produce compliance with targets. That will become increasingly apparent as the commitment periods near. This then leads governments to realize that a crash program to meet their target would be very costly, and therefore to *de facto* or *de jure* withdrawal. Thus the expectation created for the business sector – that there will be defections by national governments – turns into a self-fulfilling prophecy.

In summary, if there is some probability that that some party will reach a cost level leading it to withdraw, and this probability increases over time, then this reduces the benefits of the treaty to all remaining parties. It likewise increases the likelihood that other parties will find that the treaty no longer has benefits great enough to justify the costs of compliance with targets.[9] Thus the nearly certain expectation that some party will eventually default unzips the agreement, since all Parties can anticipate from the start that this will happen. Expecting this, no party will undertake costly policy measures domestically. Private sector parties will have expectations biased toward the weakening or dissolution of the agreement, implying that carbon prices will fall over time. The inadequate mitigation that takes place due to these expectations then leads to the equilibrium result – namely that remaining Parties ignore the limits set forth in the agreement.

Empirical test – is the impossibility revealed?

This is exactly what has happened. If we look at compliance with the Kyoto Protocol, we find that only two major countries likely to meet their targets. Moreover, those two nations – the United Kingdom and Germany – do so because of historical accidents that brought their emissions below their assigned Kyoto targets, without their having to take any specific action to limit emissions or incur costs.

The reduction in German emissions compared to 1990 is generally attributed to the reunification of Germany that same year, leading to the almost immediate shutdown of a large share of the inefficient energy infrastructure in the former DDR. The unified Germany gets credit for this "emission reduction." The reduction in emissions by the UK is generally attributed to a political decision by the Thatcher government to eliminate support for the coal industry, accompanied by a one-time reduction in methane emissions from coal mining.

Two parties – the United States and Australia – dropped out early. They have taken the honest approach that could be summarized as, "It's not going to work out in our best interest, so let's tell the truth and withdraw."

Two other parties, Canada and Japan, are at this point highly unlikely to meet their commitments except through massive purchases of permits from other countries, and have hedged. Their governments and industries have avoided making sufficient capital commitments to reduce emissions and, now that Russia has ratified the treaty, Canada and Japan may be able to delay any other decisions through government permit purchases – *if* Russia does not set too high a price.

Then there is the European Union, which appears to be taking the "don't worry" approach. Based on current evidence about how likely the EU is to reach its target. (See Figure 6-1 and the accompanying discussion above, and the analysis surrounding Figure 11-2 in Chapter 10) and the status of policies to close the gap, the EU appears to expect that it can always wriggle out from under the cap in one way or another.

France and Germany set a precedent for violating the timetable of actions required by international agreements unilaterally and with impunity. They announced in 2003 that they would not meet the fiscal policy requirements of the Maastricht Agreement (which created the European common currency), because they had concluded that reaching those targets would harm their economies. The EU took no action against either country, reinforcing the perception (or expectation) that such treaties are ultimately toothless and unenforceable.

Why wasn't this a problem before?

As noted earlier, emission trading has worked extremely well in the United States for sulfur pollution from electric power plants. However, there are a number of critical differences between this program and international emission trading in greenhouse gases. First, the regulatory and enforcement system was already in place when the U.S. moved from a system of command and control regulations on generators to emission trading. No questions arose about enforcement or caps or the validity of permits, such as now plague international permit trading.

Nevertheless, there were problems in sulfur trading. Permit prices have been very volatile, plunging to unexpectedly low levels and rising to surprising heights. This price volatility and uncertainty was driven in many cases by government and regulatory policy. Remaining new source performance standards and individual state policies probably forced controls onto units that were not the most cost-effective choices, and thereby flooded the market with permits that drove the permit price below the marginal cost of adding additional controls. At the same time, the market for permit sales was further chilled by concerns that the government might tax revenues generated when a company sold permits that it could have used to comply with emission requirements on its own units.

On the other hand, the time scales for decisions that mattered for sulfur emissions were sufficiently short that this uncertainty was not a critical factor. The major issue in achieving cost-effective reductions in sulfur emissions was how to allocate retrofits most economically over existing pollution control equipment. It did not involve what type of new equipment a company should install, or when. Most of the new scrubbing equipment had to be installed in any event. By contrast, the issue for climate change prevention is what *new* technologies should be developed and installed over many decades to control entirely new classes of pollutants (GHGs).

There is a fundamental economic principle at work here: when costs are very uncertain, it is better to use price signals, rather than binding caps, to determine the quantity of new emissions.[10] Since there is a fundamental cost uncertainty in new technology for reducing greenhouse gas emissions, this principle indicates that caps are not the way to go.

When the important decisions were about retrofit controls, the issue of what the cap would be in future, and what path prices would likely take, did not matter greatly. If future Congresses ratcheted the cap down, the appropriate response would be to add more retrofits that were not economic under the higher cap. Decisions made prior to the change in the cap would still be valid.

However, when new capacity and technology are the issue, the future course of the cap and its implications for permit prices are all that matters. But, as already noted, *incentives for new technology will be inadequate when they are provided only by unenforceable expressions of an* ***intention*** *to cause permit prices to rise over time*. Moreover, a carbon cap will place an unnecessary tax on existing technology (which cannot and need not respond to the price signal), while attempting to move new technology to a different plane.

Using the announcement of a future set of emission caps – or a rising "safety valve" price or carbon tax – to create an incentive for private sector R&D is fatally flawed, because it is impossible to commit a government to a future course of action. To stimulate investment in R&D, the price must reach a level that is adequate to provide a sufficient return on capital invested in R&D. This price must exceed the price required to induce adoption of the technology once it is developed.

To persuade a company to adopt a particular technology, the carbon price need only exceed the amount by which the average variable cost of the new technology exceeds the average variable cost of the next best alternative. But to motivate R&D, the carbon price must exceed the difference in variable cost by enough to provide adequate return on investment in research, development *and* adoption.

Even if the government announces a policy that creates such an incentive, the government will prefer to renege once the technology is developed.[11] As in the case of patents, there is a tradeoff between efficiency in resource allocation and providing an incentive for R&D. A carbon price above the level necessary to induce adoption of the new technology will cause avoidable deadweight losses, as all energy supply and use decisions are distorted.

The government can avoid these deadweight losses by limiting the carbon price to the level just necessary to get the technology adopted, and not high enough to provide a return on R&D. Since private investors can understand that this is the optimal strategy for government – and indeed would likely be skeptical of the political ability of any government to proceed with what will look like "corporate welfare" – they will not be motivated to invest in R&D by any announcement of future climate policy.

Therefore, both history and economic theory suggest that a technology strategy has a much greater chance of success than do near term targets and timetables designed to support emission trading and create incentives through changes in expected future prices.

Irreversible policies and policies that produce irreversible actions

All these issues about expectations and their implications for lessened incentives and more costly compliance arise from policies that provide incentives for current investments by changing expected prices and costs over the life of the investments. Such policies are by their nature reversible, though some may be viewed as less likely to be reversed than others.

Policies with low and slowly rising prices are least likely to be reversed. The most likely to be reversed are policies that have high prices or are dependent on the actions of sovereign countries under an international agreement that has no penalties for nonparticipation or noncompliance. Unfortunately, policies that are most likely to remain in place do little to bring about needed investments, whereas those that would likely spur investment are also prone to reversal.

There are alternatives, since policies and measures differ in their degrees of reversibility. A different class of policies, involving current actions by government to bring about irreversible changes in the economy, would avoid the problem. Because fiscal and regulatory measures are reversible by sovereign governments, they dilute incentives based on expectations of future carbon prices supported by such measures – especially ones tied to international agreements like the Kyoto Protocol.

But once an investment is made in R&D or physical capital, it will not be reversible. Thus policies that stimulate such investments through up-front incentives can indeed have long lasting effects, even if there is uncertainty about whether they will continue. Likewise, technology transfer that makes it possible for developing countries to improve both energy intensity and their standard of living will be both irreversible and incentive-compatible.

About the author

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Notes

[1] This leaves out the question of how the limit is chosen. The operation of competitive markets can achieve the limit efficiently under the conditions stated, but the only way to tell if a limit is justified is to compare its overall costs and benefits. No one has ever devised a form of emission trading that could use market forces to reveal where the overall limit should be set and, indeed, the limits defined by the Kyoto Protocol and similar agreements have been primarily political in nature.

[2] Adam Smith, *The Wealth of Nations*, 1776, Leon Walras, *Elements of Pure Economics,* 1874, Alfred Marshall, *Principles of Economics*, 1890.

[3] K.J. Arrow. "The role of securities in the optimal allocation of risk-bearing." *Review of Economic Studies*, pages 91-96, 1964. Arrow and F. Hahn, *General Competitive Analysis*, Holden-Day, 1971. Gerard Debreu, *The Theory of Value*, Yale, 1959.

[4] W. D. Montgomery, "Markets in Licenses and Efficient Pollution Control Programs." *Journal of Economic Theory* Vol. 5, No. 6, December 1972. ; K-G Maler, *Environmental Economics: A Theoretical Inquiry*, Resources for the Future, 1974.

[5] EU-15 data are taken from *EEA – Annual European Community greenhouse gas inventory 1990-2002 and inventory report 2004 – Submission to the UNFCCC Secretariat.* Other countries' data are from inventory reports on UN-FCCC Secretariat Internet site. Excluding LUCF.

[6] Bars represent CO_2 emission projections from the U.S. Energy Information Administration's *International Energy Outlook 2004.*

[7] Uncertainty is not the issue, as long as contingent claims and futures markets exist – and if the property rights were well defined for all time periods, there is no reason to believe those markets would not exist. See Arrow, "The Role of Securities Markets in the Optimal Allocation of Riskbearing," in *Essays in Riskbearing*. However, the nature of international emission trading leads to a systematic bias against the expectation that there will be a market in the future.

[8] Scott Barrett, *Environment and Statecraft: The Strategy of Environmental Treaty-Making*, Oxford University Press, 2003 provides a clear and complete exposition of how the lack of enforcement and participation incentives leads to the ultimate breakdown of the Kyoto Protocol and failure to motivate effective action. He also proposes an alternative approach, which involves negotiations on setting binding international policy standards, and avoids the problem of relying on unenforceable promises to take action in the future. However, this proposed solution is not one that would lead to efficient use of resources in reducing emissions.

[9] One theorem on such international agreement is that the amount that it is collectively rational to do falls as defections increase (Barrett, *op. cit.*).

[10] Weitzman Martin L. (1974) Prices vs. Quantities, Review of Economic Studies; 41, pp. 477-491

[11] This is known as a lack of sub-game perfect equilibrium (or dynamic inconsistency).

Chapter 6

OBSTACLES TO GLOBAL CO_2 TRADING: A FAMILIAR PROBLEM

A. Denny Ellerman

Overview

The creation of an international emissions trading system starts at home. Once a functioning national system of emissions trading is in place, there is every reason to believe that it would extend first to Annex I parties and, eventually, to non-Annex I parties who see the value of participating more fully in the benefits of emissions trading. The real problem – even in a domestic trading system – is not monitoring and enforcement, which would exist in any case, but in the allocation of permits, which is fundamentally a political issue. Current concerns about such issues as equity and distributions of wealth reveal a basic lack of consensus on the nature of the climate change problem and suggest that action is not imminent.

Introduction

Global trading in CO_2 emissions appeals to policymakers for two reasons. First, U.S. experience with the acid rain program demonstrates that tradable permits are an efficient means of meeting both environmental and economic goals[1]. Second, the cost of meeting any domestic target can be lowered by purchasing less expensive emissions reductions abroad.[2]

This study examines issues that must be resolved in order to develop a global CO_2 emissions trading program. We start by examining how emission permits might be allocated and how best to handle the rents associated with this newly created scarcity. Second, we analyze how a national tradable permit system might evolve into global emissions trading.

The problem of allocating CO_2 emissions rights

The Kyoto Protocol, if implemented, would impose a national cap for greenhouse gas emissions on each Annex I party to the Framework Convention on Climate Change. In the aggregate, this limit purports to recognize an emerging scarcity of the capacity of the Earth's atmosphere to act as a repository for greenhouse gas emissions. We may debate whether the atmospheric sink is limited, and, if so, what the limit is from a physical sciences perspective, but as far as climate negotiators are concerned, an interim cap is now in place, subject only to ratification by the requisite number of parties.

In anticipating the cost of keeping within the proposed emissions limit, policymakers have begun examining the merits of a global emissions trading system. However, a global system will not exist until at least one national system proves functional. In short, the greatest challenge lies at home, and the biggest obstacle to implementing such a system – should we decide to – is a crassly familiar one: who gets the rent generated by limiting the right to emit CO_2 (i.e., making this commodity a scarcity)? What previously was free would now become scarce, and scarcity presents any society with the decision of who has the right to use what has become scarce and who is to receive the rent associated with that use. Indeed, creating a national system may be even more daunting than assembling an international trading system.

The use of a resource and the receipt of rents attached to that use are often viewed as a single phenomenon. However, these two facets can be separated practically and analytically in a permit trading system. For example, most people would agree, at least in principle, that the atmospheric "sink" should be reserved for the most highly valued uses.

Distributing revenue from carbon ceilings

Today, many people – and certainly economists – would trust markets, more than government, to allocate use to the highest value. Accordingly, auctioning off permits granting access to the sink is frequently proposed; however, auctioning creates a new problem: what to do with the revenue. There is a rich literature on this subject, and some very appealing arguments on how the revenue might be recycled optimally. But there are two problems with any auction that involves large amounts of revenue. First, most people do not have any more faith in a government's ability to distribute rents optimally than they have in a government's ability to allocate use – a suspicion that gave rise to the auction in the first place. As such, the auctioning of permits takes on the appearance of a disguised tax.

The second and more fundamental problem is the assumption that a government owns the rights that are to be auctioned. The inconvenient fact is that these incipient rights are possessed de facto by existing emitters and actively exercised by them. From their point of view, the auction is not just a tax in disguise, it is confiscation of property rights established by time-hallowed use. In a society that seeks to be just and equitable in dealing with its citizens, CO_2 emitters have a legitimate claim to compensation.

There are other ways to allocate use and rents, but as a matter of political economy, taxes and auctioned permits lose out unless there is overwhelming consensus to take action and existing users are poorly organized. When existing users are organized, which is usually the case, and there is sufficient consensus to take action, a deal can be and will be struck. The deal that can be struck is one in which the rights are limited, but given to the existing users, either through conventional command-and-control regulation or through grandfathered permits. If emissions rights are allocated through a grandfathering process, many find the explicit grant of the rent to be objectionable. They may prefer command-and-control regulation, for it does not appear to grant rents, but this is not quite the case. True, the allocated right is not as explicit as with grandfathered permits – and it may not be as secure – but it is still there, just well-hidden. It shows up in the value of the underlying physical asset, the power plant or factory, that is permitted by regulation to emit some amount.

In short, grandfathered permits alone seem to combine efficient allocation of use to the highest value with the politically expedient granting of the rents to existing sources. Of course the rent will remain obvious and will be charged to consumers. What is not clear is whether consumers would be more willing to pay fees to local utilities or energy companies that, under different circumstances, would be collected as taxes by Uncle Sam.

Grandfathered permits: what are the issues?

Rents and recycling. Allocation to private corporations lends itself easily to the demagoguery that already-rich corporations will be further enriched. However, it is not at all clear that corporate profits would be higher since charging for the use of the emissions' permit will reduce demand for that company's products or services. From this perspective, rents can be seen as compensation. From a societal standpoint, however, the discussion does not end here. Since the corporation is a shell, any revenue will be recycled through a combination of taxes, investment, and dividends. Approximately one-third would go to the government, hopefully to be optimally recycled. Moreover, the new set of prices would create an incentive to retool or replace existing capital stock with less carbon-intensive stock. In the best of all worlds, the increment of revenue here would make the financing of such investment easier, and might even reduce demands for tax credits. Finally, appreciated stock values would benefit stockholders, who are, because of the role of mutual funds, individual retirement accounts, and pension funds in modern industrial societies, a broadly distributed group. In fact, an interesting test is suggested: Would the government recycle its one-third as efficiently and equitably as the two-thirds that would remain with corporations?

New entrants. Another concern is often voiced by potential new entrants, who say that grandfathered permits favor existing parties with whom they must compete. However, the real issue is whether the grandfathering process affects decisions at the margin. Typically it does not; it is a lump-sum transfer that benefits the recipient but does not change decisions about entry, retirement, or whether to produce more or less.[3] Nevertheless, potential new entrants would complicate the development of a domestic emissions trading system, even if their claims are nothing more than disguised entreaties for their share. Behind their complaint is an even more serious concern: Who along the vertical chain of existing users has the superior claim to the right? In the case of the automobile, do the rights to the use of carbon reside in the fuel, or in the car? Or for that matter, with the driver? The same could be said of power plants. Do coal producers have the right to produce carbon, or do electric utilities have the right to emit CO_2?

Monitoring. There is no necessary connection between monitoring emissions and permit ownership, but history suggests that monitoring will have a strong influence on who gets the permits. For example, in the U.S. acid rain program, monitoring and the distribution of permits occur at the same point, the power plant. So long as transaction costs are negligible, permits could be distributed to any party along the vertical chain. Thus, to take electricity as an example, carbon permits could be distributed to coal producers or even consumers as well as to power plant operators. All would have assets that would be adversely affected by the new set of prices.

Utility deregulation. The allocation of rents associated with the SO_2 permits in the acid rain program was relatively easy because the recipients (electric utilities) were presumed to be subject to cost-based regulation. Thus, the rent associated with the grandfathered permits was to be passed on to rate-payers. Still, there was plenty of jockeying for permits.[4] Utility deregulation will make the allocation of carbon permits harder since it can no longer be argued that utilities act as agents for rate-payers. Furthermore, the other prospective recipients – oil companies, natural gas pipelines, and large industrial users – are not now regulated. Consequently, carbon rents will be as transparent as taxes, but not necessarily more politically acceptable.

Land as an example. Land is a God-given resource made more scarce by increasing human and economic activity, not unlike the Earth's atmosphere. It just became scarce a lot sooner. The history of establishing and perfecting the title to land is long, convoluted, and instructive. Today, in most industrialized societies, no one questions private ownership of this limited resource; and any entitlement we may receive comes through private inheritance, not from the state. Although there surely was an original recipient of the right to this land, now lost in the shrouds of history, no one seems to care. For example, it would be nearly impossible today to settle competing claims to all of mid-town Manhattan, but in the seventeenth century the value was low and there would have been little controversy over the rents, and probably active encouragement to settlers to take title to the land.

This would not be the case with the Kyoto Protocol. Emissions targets are so stiff – about 30 percent of 2010 emissions – that the value of the right is high and many parties would want ownership of the rents. This fact argues for gradually creating scarcity, so that discounting of future costs would dampen their present value.

Summary. My point in making these distinctions is not to argue for any particular rent allocation, but rather to emphasize the range and complexity of problems any government will face if it decides to set up a national emissions trading system. Creating a scarcity of the magnitude envisioned in the Kyoto Protocol raises fundamental issues of equity and of the definition of rights that are preeminently political questions. Analytically, the scarcity and the allocation of carbon emitting rights and rents can be separated, but in practice the two are fused and there will likely be agreement on the creation of the scarcity only as there is agreement on the allocation of the rents thereby created.

Evolving into an international system

The evolution of a national system into a global system is most easily described as a matter of trade. When the thing being traded can be produced abroad as cheaply as at home, we can anticipate that trade will develop across national boundaries. Parties at home will seek cheaper supplies abroad, and parties abroad will seek to tap into this new market opportunity. Here, we will discuss two types of international emissions trading: with other Annex I countries, and with non-Annex I countries who reduce carbon emissions and wish to sell this the right to emit thereby created.

Impacts of Annex I trading

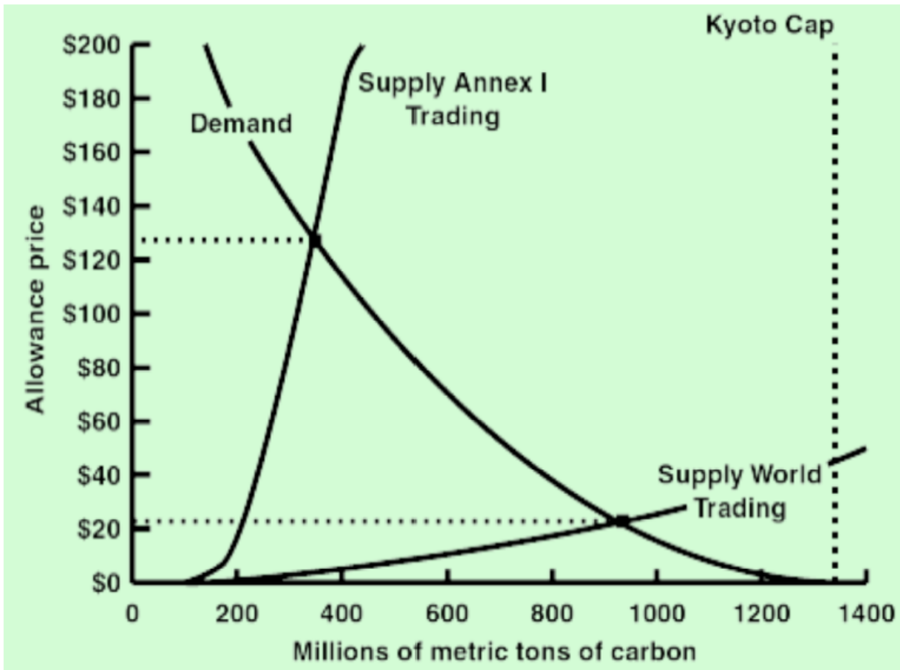
Trade among Annex I parties is not expected to bring the large benefits associated with global trading, but it is a useful point of departure. Suppose the United States and Norway, two Annex I countries, have solved their domestic allocation problems and adopted domestic emissions trading systems.[5] Each would have its own autarkic market price for the right to emit CO_2, and Norway's price likely would be higher than the U.S. carbon emitting price. This difference in price would signal an opportunity for U.S. firms to abate more in order to free up permits for sale to Norway at a higher price. Full trading between these two parties would lead to an equilibrium price that would be higher than otherwise in the United States and lower than otherwise in Norway, but of mutual gain to both.

Such trading could be easily extended to other Annex I countries; all that would be required is faith in the validity of the permit, which would be provided by accurate monitoring of emissions and effective enforcement of each domestic permit system. This faith in the value of the permit is identical to what applies for any good or service in international trade. Moreover, the monitoring of emissions that ensures the value of the permits would be the same as would be needed to determine compliance with the Kyoto targets, even if there were no trading.

Trade with developing countries

While Annex I trading would be desirable, it would not lead to really large reductions in the cost of meeting the Kyoto targets. Less expensive abatement opportunities will be found in Eastern Europe and the former Soviet Union, both Annex I parties, but even these sources of emission credits will not be sufficient to bring about the really low price that models predict for full global trading.[6] **Figure 7-1** illustrates the demand and supply for emission permits, and indicates just how much difference participation by non-Annex I countries makes in these models. Note that the demand curve is the same for both Annex I and global markets, but the supply curves are very different. In the Annex I market, about 350 million tons (or 25 percent of the total reduction needed) would be supplied by the former Soviet Union. However, in a truly global trading system, predicted supplies are so ample that prices fall by two-thirds (or more) and Annex I countries import about 70 percent of the total reduction requirement.

Figure 7-1. Aggregated supply and demand curves in 2010 under the Kyoto Protocol: Annex I trading/world trading



Estimates vs. measurements. The logic of non-Annex I participation in emissions trading is fundamentally no different than that for Annex I trading. Trade is a response to opportunity, and emissions trading is the mechanism by which emissions reductions would be made available outside Annex I parties. However, the emissions permits must not be counterfeit, and this requirement introduces a critical difference when non-Annex I emissions reductions are involved. When there is no cap, it is much harder to establish that the permit represents a real or "additional" reduction of emissions. Establishing that fact requires measuring a difference, and what would have been (but now is not) can be estimated but never truly measured. Consequently, the non-Annex I permit is only as good as the estimate – and even then the estimate will be costly and subject to challenges by anyone opposed to the proposed trade.

Transaction costs – and how to avoid them. Policymakers can hope for the best in this process, but making these baseline estimates (and even more getting them approved) will limit this form of trading, as they have all forms of credit-based emissions trading. These transaction costs will limit Annex I access to low-cost reductions, and this will frustrate would-be non-Annex I exporters, but the underlying requirement cannot be avoided. No Annex I party operating under a tight cap-and-trade system can tolerate ersatz goods. What is needed are institutions to help reduce transaction costs, but project costs in the Activities Jointly Implemented program have not been particularly encouraging.[7]

It will not take non-Annex I exporters long to realize that these costs can be avoided – and are in trading among Annex I countries. If non-Annex I countries were to accept a limit and implement the monitoring and enforcement mechanisms necessary to ensure the integrity of their permits, transaction costs would be avoided and export quantities and earnings increased. The necessary monitoring and enforcement would already be in place, and there would be a certain economy of scope in negotiating the baseline all at once.

However, can an acceptable cap be negotiated for non-Annex I countries? Within the framework of the Kyoto Protocol it is possible to discern a principle concerning a non-Annex I country cap during the first commitment period: whatever emissions would have been, absent any trading-related emissions reduction activity. Put differently, no constraint would be imposed on a non-Annex I party's economic growth and there would be no "hot air." All exported permits would reflect real emission reductions.

"Headroom." The reality is not so neat. No one will know what emissions would have been without emissions trading, and given the possibility that economic growth, and therefore counterfactual emissions, might be greater than expected, prospective Annex I countries are likely to want to protect themselves by claiming the need for some "headroom."[8] Unfortunately, granting "headroom" increases the probability of "hot air." On a practical level, both sides will have to compromise and some element of an enabling myth will be required. However, raising the negotiation from the project to the national level involves more than establishing a multi-project baseline for the first commitment period. Other considerations, discussed below, provide flexibility, but they also raise issues of allocation on the international scale.

Making global allocation work

To stabilize atmospheric concentrations, limits on developing country emissions will be needed eventually. This means extending limitations on the use of the atmospheric sink to all countries, or at least all major emitters. Accordingly, there is some advantage in having non-Annex I countries accept limits earlier, even if some headroom were involved.

For instance, if the ultimate allocative principle for global access to the atmospheric sink had been agreed to and were enforceable, and that principle allowed headroom now for some countries, then there should be no objection. The country would be free to bank or to sell currently according to its judgment of its interests, and cumulative emissions would be no greater. Even without such an ultimate principle, there is a strategic interest in establishing the precedent and the procedures of monitoring and enforcement, as would be required if Russia and the Ukraine are to export emissions reductions including their hot air. Moreover, if concern about hot air is sufficiently strong, nothing prevents any or several of the Annex I countries from transferring some of their limit to the non-Annex I applicant. For example, a very small part of the U.S. limit of 1.27 billion metric tons would provide comfortable headroom for Mexico. Indeed, if the reduction of transaction costs associated with accepting an Annex I limit were to increase supply sufficiently, the United States might lower costs by opening up these new supplies.

In fact, the ability of Annex I parties to use Article 4 of the Kyoto Protocol to transfer a portion of their limit to others raises new possibilities of bringing non-Annex I countries to accept limits. But this opportunity also returns us to the very issue that will have to be solved at the national level: how would the new scarcity be allocated? Theoretically, a global tradable permits system would allow separation of the assignment and actual use of emission rights. However, there is no more agreement on the global allocation of rights than at the national level, and perhaps less. The discussion will not even become serious among non-Annex I parties until there is some advantage in accepting an Annex I limit.

Flexible mechanisms

So far, little has been said about how the Clean Development Mechanism (CDM) and Joint Implementation may assist the development of a global trading system. And for good reason; both are essentially transitional institutions. There would be no place for either in a truly global emissions trading market. However, their current role is very important. These institutions could keep project transaction costs as low as possible by locating cheap abatement possibilities and demonstrating the advantages of trade to both exporter and importer. In addition, such activities could provide measurement and enforcement experience and help host countries feel more comfortable in making the transition to a cap.

However, the creation of the CDM as the sole intermediary between Annex I buyers and non-Annex I sellers does raise important questions. At times, the Clean Development Fund appears to be a vehicle for North-South resource transfer. At other times, parties express concern about avoiding price-reducing competition among host countries for projects. Finally, the CDM sometimes is presented as a mechanism to facilitate trade by providing valuable recording, certification, and verification services. The CDM could become very bureaucratic and costly; if so, it will increase the incentive for those interested in emissions trading to bypass it by becoming Annex I signatories.

Conclusion

The creation of an international system of global trading starts at home. While very large reserves of cheap carbon abatement may lie abroad, these reserves will remain untapped until demand is created and value is imparted to them. Once a functioning national system of emissions trading is in place, there is every reason to believe that emissions trading would extend beyond national borders, particularly to other Annex I parties. Trade with non-Annex I parties faces difficult problems regarding transaction costs that diminish the prospects of abundant supply, but these same problems create an incentive for non-Annex I parties to accept Annex I limits and enjoy the full benefits of emissions trading. The evolution from a national to an international trading system will not come quickly, or easily, but it is the most likely path of development because it is based on self-interest.

The main obstacle to global emissions trading lies at home. It is not monitoring and enforcement, which would exist in any case, but rather the distribution of the rents, which is fundamentally a political and even philosophical concern. Moreover, the issue is not simply public vs. private good, but also one of deciding which private claimants among many are most suitable. Unfortunately, making rents transparent also makes reaching agreement more difficult, yet a transparent domestic system lends itself most easily to expansion abroad.

Perhaps more than anything, expressions of concern about the fundamental issues of equity raised by the allocation of the proposed scarcity in rents reveal a basic lack of consensus on the nature of climate change and the need for action. Those who view the problem as one of allocating a scarce resource are typically not much concerned about the allocation of rents. These individuals focus mostly on adapting to new circumstances and consider assigning rents to existing users a convenient way to provide compensation. The opposing view is that interested parties are not so much allocating a scarcity as they are limiting socially undesirable activity. To these individuals, there is no issue of preexisting rights or of compensation, and no other place for the revenue generated than the government.

Currently, no one view prevails, and there is little willingness to accommodate differing points of view. Indeed, the political solutions required to put a domestic emissions trading system in place – including passage of permit legislation and allocation of rents – are not readily apparent. In the meantime, it is worth working on the many details of an international system, because those details will facilitate the development of a market once national action has been taken.

About the author

A. Denny Ellerman is the director of the MIT Center for Energy & Environmental Policy Institute, Massachusetts Institute of Technology. This paper was prepared for the September 23, 1998 policy conference sponsored by the ACCF Center for Policy Research and was published in the Center's forthcoming book, Climate Change Policy: Practical Strategies to Promote Economic Growth and Environmental Quality.

Notes

[1] Richard Schmalensee, Paul L. Joskow, A. Denny Ellerman, Juan Pablo Montero, and Elizabeth M. Bailey, "An Interim Evaluation of Sulfur Dioxide Emissions Trading," *Journal of Economic Perspectives* 12(3)(Summer 1998): 53-68, provides a quick summary of the essential features of the initial experience with emissions trading under the U.S. acid rain program.

[2] This point was emphasized in the testimony of the chairman of the Council of Economic Advisers, Janet Yellen, and illustrated in the recently released supporting analysis (Council of Economic Advisers, *The Kyoto Protocol and the President's Policies to Address Climate Change: Administration Economic Analysis,* July 1998). Other models of global emissions and economic cost arrive at similar conclusions, when comparable assumptions are made.

[3] A fine distinction must be made here between the initial allocation, which determines receipt of the rent, and the use of the permits. In a functioning market for the permits, any party willing to pay the price has access to the permits, and every party using a grandfathered permit to cover emissions forgoes the opportunity cost of selling the permit.

[4] Paul L. Joskow and Richard Schmalensee, "The Political Economy of Market-based Environmental Policy: The U.S. Acid Rain Program," Journal *of Law and Economics,* forthcoming, provides a good discussion of the allocation of SO2 permits.

[5] Norway has in fact decided to implement a system using grand-fathered permits to meet its Kyoto commitment; see "Norway Opts for Emissions Trading over CO_2 Tax Expansion," *Global Environmental Change Report,* 10 July 1998, p. 5.

[6] At Massachusetts Institute of Technology, we estimate a market price of about $120 for Annex I trading but only $25 with full global trading. See A. Denny Ellerman and Annelene Decaux, "Analysis of Post-Kyoto Emissions Trading Using Marginal Abatement Curves," Report No. 40, MIT Joint Program on the Science and Policy of Global Change, 1998.

[7] The United Nations Conference on Trade and Development, "Greenhouse Gas Emissions Trading: Defining the Principles, Modalities, Rules, and Guidelines for Verification, Reporting, and Accountability," Geneva, Switzerland, Draft of July 1998, is unequivocal on this point. For instance, "Under the pilot program for AIJ, [the] verification process has led to the rejection of many proposed trades, and can take one to two years, creating high transaction costs and uncertainty" (p. 6). Or, "In general, past programs that impose emission caps coupled with allowance trading have performed well, whereas credit trading systems have generally not performed to expectations" (p. 1).

[8] Jonathan Baert Weiner, "Designing Markets for International Greenhouse Gas Control," Climate Issues Brief No. 6, Washington, D.C.: Resources for the Future, October 1997.

Chapter 7

THE USES AND MISUSES OF TECHNOLOGY DEVELOPMENT AS A COMPONENT OF CLIMATE POLICY

Henry D. Jacoby

Overview

The current misplaced focus on short-term climate policies is a product both of domestic political exigencies and badly flawed technical analyses. A prime example of the latter is a U.S. Department of Energy study, prepared by five national laboratories in late 1997. The Department's "Five-Labs" study assumes – incorrectly – that technical solutions are readily at hand. Also, it wrongly suggests that a short-term technology fix is easily available at little or no cost. Worse, advocates of short-term emissions targets under the Framework Convention on Climate Change are using this study to justify the subsidy of existing energy technologies – diverting resources from the effective long-term technology response that will be needed if the climate picture darkens.

Introduction

The search for cleaner energy technologies is central to any long-term response to the threat of global climate change. Unfortunately, most climate debates focus on short-term Kyoto Protocol-type emissions targets and Congressional reaction to that approach. This is a tragic mistake. Valuable time is being lost that could better be spent searching for cost-competitive, low-carbon energy sources that may be needed in the future.

The misplaced focus on short-term policies is a product both of domestic political exigencies and badly flawed technical analyses. For example, a 1997 "Five-Labs" study of technology options prepared for the Administration by five U.S. Department of Energynational laboratories incorrectly argues that technical solutions are readily at hand and can, at no cost, yield major reductions in U.S. greenhouse gas emissions.

Taken seriously, as it has been, this study contributes to a misdirection of the technology component of climate policy. The consequences for the future could be serious. At present, many argue the risk of human influence on climate appears substantial. No doubt there is great uncertainty about the possible magnitude of potential change. Our own Massachusetts Institute of Technology analysis shows that the range of possible outcomes over the next century is very wide.[1] We have only a partial understanding of the behavior of the climate system, and our ability to forecast the future path of economic growth and technical change, and the resulting greenhouse emissions, is naturally limited. Our understanding of the ecosystem effects of rapid climate change is even weaker. But this type of uncertainty means that the problem may turn out to be either not so important, or worse than we imagine. Thus, whatever one's position regarding the current conflict over near-term emissions controls, we should be able to agree that we are taking considerable risks with global climate in the long term. Further, we should anticipate that increased knowledge could well lead to general international agreement that stringent measures are needed.

Unfortunately, even universal consensus would not necessarily lead to meaningful action. Parties to any treaty will have very different national priorities and interests, and it is difficult to imagine an agreement that could suppress the incentive to be a free rider on the efforts of others. Also, while rich countries could (in principle) use various forms of foreign aid, emissions permit trading, or other side payments to encourage other countries to participate, the amount of money involved would be very large, both by historical standards and in the eyes of most politicians and taxpayers.

Thus it may be that the key to future response capability is the development of low-carbon technologies capable of competing head-to-head with conventional fossil-fuel burning, or technologies that require only small cost penalties. These technologies are not now available, and we cannot expect resource depletion to give them a cost advantage over conventional fossil fuels. With limited R&D resources, and with political attention focused on short-term policy targets, the United States runs the very real risk of forfeiting promising long-term technology development – perhaps to our considerable regret later. Understanding the flaws in Five-Labs-type studies is a key to getting the climate debate back on track.

Two approaches to analyzing emissions control policies

Two approaches commonly are used to analyze emissions control policies: market-based analysis and technology-costing. The market-based approach is favored by economists because it focuses on market price as the essential mechanism through which policy affects economic activity. This "top-down" analysis examines the entire economy (or a number of interacting sectors) and the interplay of specific policies within the larger economic system. By contrast, the technology-costing or "bottom-up" approach tries to estimate the cost of particular technologies and/or devices, totals the energy savings (or emissions reductions) from these technologies, and compares such costs to reduced energy expenditures and/or other environmental benefits.

Both analytic approaches have strengths and weaknesses. Market-based methods capture input costs (such as capital, labor, and natural resources) and reflect, at least to some degree, consumer preferences and how such preferences change as wealth increases. There is a trade-off, of course. By relying on simplified representations of production processes and aggregation of industrial sectors, market-based analyses sacrifice some technical detail. On the other hand, market interactions are crucial to capturing the size of economic change that would result from climate policies now being considered. Thus, so long as its unavoidable uncertainty is appropriately expressed, a market-based approach is superior to a technology-costing analysis of the Kyoto Protocol.

Pitfalls of technology-costing

Technology-costing studies often suffer from one or more of the following shortcomings:

Confusing market failures with market barriers

Technology-costing studies often begin by listing individual technologies or devices that save energy or otherwise look attractive but are "under-used," either because of "market failure" or "market barriers."[2] A market failure occurs when some flaw in the way markets are organized causes consumers and/or producers to respond to the wrong price signals. Such failures include situations where decision makers have insufficient or incorrect information (consumers do not perceive how costly it is to own a power-guzzling air conditioner), where there is an asymmetry between the person making the energy-use decision and the one paying the bills (the landlord-tenant problem), or where there is some form of non-priced externality (such as urban air pollution).

Market barriers, often resulting from buyer preferences, also may retard the spread of a technology that has positive net present value (NPV) on an engineering cost basis. Several reasons may lie behind this behavior. Potential buyers simply may not like the technology. Or there may be transaction costs or other expenses of adoption that are hard to include in the calculations. Uncertainty about performance, or about energy prices, may also lead users (quite rationally) to exercise their option to wait and reconsider the technology next year. And, importantly, in their day-to-day decisions buyers may use discount rates higher than those assumed by the cost analysts. The key difference between market barriers and market failures is that correcting failures may sometimes produce a net benefit, whereas overcoming barriers always involves cost.

Lack of attention to market structure

Incomplete analysis – not consumer behavior – is another reason why analysts' expectations so often exceed actual market penetration of a technology. After all, it is not easy to assess factors other than engineering NPV that determine whether – and how fast – a new technology is adopted by consumers and businesses. These factors include the structure of distribution channels, other industries that supply key (and perhaps new) inputs, regulatory and legal-liability issues (such as health, safety and environmental quality) and, most important, the internal organization of the industry at which the new technology is aimed.

Failure to account for inter-market adjustments

Finally, analyses that look at individual technologies and the policies that might aid their entry into the marketplace often overlook the many complex interactions across markets. If these changes are small, market interaction can be ignored. But if changes are large in relation to the markets at issue, then the analysis can be deeply flawed. Proposed climate policies, such as the Kyoto Protocol, clearly involve major shifts in the structure of energy supply and use. An obvious source of concern, therefore, is how analysts evaluate large-scale policy-induced changes in the use of a particular fuel or other input, especially when a study assigns an exogenous (and constant) estimate to domestic energy prices.

The Department of Energy Five-Labs study

A late-1997 analysis of U.S. carbon reductions prepared by a consortium of five national government laboratories[3] begins with an observation that many energy-efficient technologies remain "underutilized," then sets out to "quantify the reductions in carbon emissions that can be attained through the improved performance and increased penetration of efficient and low-carbon technologies by the year 2010." As stated in the report, if the policy measures discussed are taken, "the cases analyzed in the study are judged to yield energy savings that are roughly equal to or greater than the costs." How the authors arrived at this conclusion is worth examining since the faulty assumptions and logic behind their work threaten to undermine the very foundations of energy R&D efforts needed to foster effective long-term climate technology development.

The study's structure

The Five-Labs study divides the U.S. energy economy into four sectors (buildings, industry, transportation, and electric utilities), and estimates how much a technology push might reduce carbon emissions in 2010. Reductions in energy and carbon emissions are calculated from a baseline or "business as usual" case drawn from forecasts in the Energy Information Administration's 1997 Annual Energy Outlook. Possible carbon reductions are compiled for three policy cases:

- **Efficiency Case.** This case presumes "an invigorated public- and private-sector effort to promote energy efficiency through enhanced R&D and market transformation activities."
- **High-Efficiency/Low-Carbon (HE/LC) Case with a $25 price per ton of carbon ($/tC).** This case presumes that the carbon premium is attained through a cap-and-trade system. This policy is accompanied by a "greater commitment" through federal programs, strengthened state programs, and "very active" private sector involvement.
- **High-Efficiency/Low-Carbon (HE/LC) Case with a $50/tC price.** This case doubles the carbon price but is otherwise the same.

Under the Department of Energy's pre-Kyoto "business as usual" forecast, returning to 1990 emissions levels would require a decline of about 390 million tons of carbon (MtC) annually.[4]

The study's shortcomings

Two general points should be made about the analytic method used in the Five-Labs study. First, only in the electric utility sector is the potential impact of carbon prices actually quantified. For all other sectors, the net decreases claimed are the result of judgments about the effects of carbon price, supposedly augmented by a "greater commitment" by government and a "very active" private sector. Second, the Five-Labs study does not describe the policies that might be used to increase market penetration of energy-efficient or low-carbon technologies.

Then there are the details of the calculations for individual sectors. A closer look at just three of the many components of this study – automobile fuel efficiency, building efficiency, and the reduced use of coal for electric power generation – indicates why the analysis cannot support its main conclusion, that a return U.S. carbon emissions in 2010 to 1990 levels could be costless.

Automobile fuel efficiency

The Five-Labs study asserts that stiffer fuel efficiency standards will result in substantial reductions in carbon emissions by 2010. Of the 73 MtC reduction in its efficiency case, 61 MtC supposedly results from increased vehicle efficiency and most of the remainder from the introduction of ethanol from biomass (see **Table 8-1**). Note that the efficiency increase is the result of the assumed introduction of new technologies, including direct-injection stratified charge engines, direct injection diesels and gasoline- and/or diesel-electric hybrids, as well as changes in vehicle design and materials.

This raises an important question: Why do these technical improvements appear in the Efficiency Case but not in the baseline when no price incentives, such as higher gasoline prices, exist to spur their introduction? The answer comes in two parts. First, vastly increased R&D activity is assumed to reduce by 25 percent the time required for market introduction of new technologies (the mechanism is not explained). And, most important:

[The study] assumes that policies necessary to draw energy-efficiency technology into the market are implemented as needed... [including] fuel economy standards, revenue-neutral feebates, fuel taxes, public information, or some other initiative...".

That is, underlying the analysis which is supposedly about technology is a regulatory and tax program. In effect, regulation and tax programs are treated as freely available political options – and free of economic costs as well.

Building efficiency: arbitrary assumptions about markets

The Five-Labs study's handling of the building sector provides an equally disturbing example of how a failure to examine the structure of markets can also lead to false conclusions. The authors first constructed an estimate of how much energy and carbon would be saved if maximum cost-effective energy improvements were installed in 100 percent of U.S. homes and commercial and public buildings. Improvements assumed include consumer appliances, heating and air conditioning equipment, and building design.

For the Efficiency Case, the Five-Labs study assumes that 35 percent of this maximum reduction is achieved (see **Table 8-1**). Why the efficiency case should differ from the baseline in this way (with no price incentives) is not discussed, except to say that the expected savings result from a "moderately vigorous effort" to reduce energy use by a "...combination of mechanisms that may include higher prices...energy-efficiency standards and information programs." The HE/LC cases assume that 65 percent of the maximum is achieved. Again, no discussion is offered about how energy prices might respond to a carbon permit system. Rather, the 65 percent result flows from a judgment as to the effect of a "vigorous effort" to reduce energy use (in contrast to a "moderately vigorous" effort in the Efficiency Case). That is the extent of Five-Labs analysis.

Table 8-1. Forecast for carbon reduction below the 2010 baseline

	Efficiency	High Efficiency / Low Carbon $25/tC	$50
Buildings	**25**	**44**	**62**
Industry	**28**	**54**	**93**
Transportation	**73**	**88**	**103**
Electricity	**0**	**48**	**136**
Total (rounded)	**120**	**230**	**390**

(Millions of metric tons of carbon)

Electricity: ignore inter-market adjustments

The electric sector is the one area in which the study authors do examine the potential impact of a cap-and-trade program. This sector accounts for one-third of the total reduction needed to achieve the 390 MtC emissions reduction in 2010 (see **Table 8-1**). In turn, roughly 70 percent of the 136 MtC electric sector emissions decline results from shifts away from coal generators.

Keeping our eyes on coal switching for a moment, it is worth noting that **Table 8-1** reports calculations from only one emissions permit system, i.e., the one yielding a carbon price of $50/tC. (The $25/tC case was constructed using analysts' judgment). To arrive at this number, a base case was constructed that approximated the results of the Energy Information

Administration's *1997 Annual Energy Outlook* and an attempt was made to adjust the model for market changes that might accompany electricity deregulation. In short, the $50/tC carbon case considers two adjustments that influence coal burning. First, the demand for electric generation is reduced because lower end-use is projected in the building and industry sectors. The lower demand allows reallocation of generation among existing units, away from coal to less carbon-emitting natural gas. Second, whatever the demand level there is assumed to be a re-powering of coal-fired units with natural gas.

At this point, the study's authors fall prey to the third pitfall described above, namely, they assume that the prices of oil, natural gas, and coal remain constant across all cases. This means that the coal-gas price ratio, which is a crucial input to the calculation of coal-to-gas conversion, also is constant. However, in the real marketplace, if climate policy forces coal demand to fall domestically (electricity generation accounts for about 80 percent of U.S. coal use), coal prices also will fall. Moreover, the conversion of coal plants to natural gas will cause a substantial increase in gas demand, driving up its price. In the Five-Labs analysis, omitting these inter-market effects results in an overestimate of the amount of carbon that would be removed through re-dispatching and re-powering electric power plants. In short, technology-costing analysis is ill suited, as an analytic methodology, to capture important aspects of the policy question it attempts to address.

Conclusion

In its 1999 budget request, submitted in February, 1998, the Administration included a $6.3 billion Climate Change Technology Initiative (CCTI). In keeping with the short-term focus of policy discussions, and Five-Labs-type technological optimism, the CCTI consists principally of tax cuts and other measures aimed at spurring market adoption of existing technologies, not true long-term R&D. Worse, this focus on short-term emissions goals could result in a shrinking of the CCTI itself, including that portion that does contribute to long-term energy R&D. This is a very real risk. Members of the U.S. Congress fear "backdoor implementation" of the Kyoto Protocol, circumventing a Senate resolution that sets forth ground rules for ratification, and R&D is caught up in the conflict.

Given these political realities, a truly long-term energy technology initiative is all the more necessary. Technology-costing studies, such as the Five-Labs study, can provide useful guidance to the process. They can help sort out the most important targets for R&D, identify policies that would advance a technology, and provide some justification for advancing technologies that are almost ready to compete in the marketplace. However, these studies can be misused by analysts and policymakers. For example, the Five-Labs study wrongly suggests that a short-term technology fix is readily available at little or no cost. Science does not run on the policymakers' clock. Technology takes time to develop and markets require time to respond to new consumer devices. Time also is needed to refine industrial processes and to develop new distribution and materials supply systems. Furthermore, capital turnover varies by sector, particularly in capital-intensive energy supply sectors.

In short, the Five-Labs study misguides the policymaking process by applying a long-range policy tool to short-term emissions goals. Our long-term outlook can be hopeful, provided a well-designed effort is launched and sustained, making adjustments as new knowledge is acquired. However, the Five-Labs study's vision of the role of technology development will not serve us well if the climate picture darkens, and it turns out we do need an effective long-term response to climate change.

About the author

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Notes

[1] The estimated range of impacts varies widely. See R. Prinn, H. Jacoby, A. Sokolov, C. Wang, X. Xiao, Z. Yang, R. Eckaus, P. Stone, D. Ellerman, J. Melillo, J. Fitzmaurice, D. Kicklighter, G. Holian, and Y. Liu, "Integrated Global System Model for Climate Policy Assessment: Feedbacks and Sensitivity Studies," *Climatic Change,* forthcoming 1998.

[2] For a lucid analysis of this distinction, using somewhat different terminology, see A.B. Jaffe and R.N. Stavins, "The Energy Efficiency Gap: What Does It Mean?" *Energy Policy* 22(10) (1994): 804-810.

[3] Frequently referred to as the Five-Labs study, see Interlaboratory Working Group, "Scenarios of U.S. Carbon Reductions," Interlaboratory Working Group on Energy-Efficient and Low-Carbon Technologies, Office of Efficiency and Renewable Energy, U.S. Department of Energy, 1997.

[4] It is worth pointing out that the size of the needed reduction is subject to considerable uncertainty; see M.D. Webster, "Uncertainty in Future Carbon Emissions: A Preliminary Exploration," Report No. 30, MIT Joint Program on the Science and Policy of Global Change, Cambridge, Mass., 1997. Our own MIT base implies a 470 MMtC reduction to achieve 1990 levels, and the latest Administration analysis uses a 2010 baseline which would yield a number in the same range; see U.S. Administration, *The Kyoto Protocol and the President's Policies to Address Climate Change: Administration Economic Analysis,* July 1998. The larger the number, the higher the cost.

Chapter 8

REFUSING TO REPEAT PAST MISTAKES

Roger H. Bezdek

Introduction

Several studies have examined the regressive nature of effects that climate change policies are likely to have on minorities, the elderly, and others in low and fixed income groups. This analysis summarizes the results of an extensive study that presents an overview of impacts that the Kyoto Protocol is projected to have on Hispanic and Black families and minority-owned businesses in selected U.S. states where the bulk of those minority populations reside, and in the nation as a whole.

The Management Information Services, Inc. (MISI) report's findings should remind policy makers in all countries that people in low and fixed income categories will be impacted disproportionately and to a much greater extent than those in moderate to high income sectors. Unless those effects are recognized and addressed, as a component of every proposal to control greenhouse gas emissions, those actions will have a significant negative impact on poor people's ability to afford food, housing, heating, clothing, air conditioning, health insurance, college and other basics, as well as their ability to save, invest or open a new business. Many small minority-owned businesses could be forced to close their doors, and many low salary jobs could be lost, according to MISI.

The MISI conclusions are based on studies by the U.S. Energy Information Administration and a number of other government and private analysts.[1] They are also supported by assessments conducted by the Center for Energy and Economic Development (CEED), American Council for Capital Formation and other organizations that have reached similar conclusions regarding the Kyoto Protocol, McCain-Lieberman climate legislation and other federal and state proposals to reduce GHG emissions.

Lower income groups would be disproportionately harmed

The long-term implications for Blacks and Hispanics of major energy and environmental programs have rarely been ascertained prior to their enactment, and these groups are rarely consulted to obtain their input or comments on such programs. This is unfortunate, because the programs may significantly affect minorities. This study, conducted in consultation with major Black and Hispanic organizations, examined the impacts that the Kyoto Climate Change Protocol would likely have had on Black and Hispanic income, employment and economic opportunities between 2000 and 2012, if the Protocol had been ratified and its energy reduction requirements had gone into effect.

The MISI analysis reviewed the major studies of the economic and employment impacts of the Kyoto Protocol. It found that the consensus of these studies – including those conducted by the Federal government – is that *implementing the Protocol would result in severe negative economic consequences: losses in U.S. gross domestic product (GDP) in the range of $250 billion to well over $300 billion (1998 dollars), and employment losses as high as 3.2 million jobs.*

Most of the job losses would be concentrated in the services, trade and construction sectors, which contain disproportionately large numbers of Black and Hispanic workers. Utilizing these macroeconomic results, MISI estimated the economic impacts of the Kyoto Protocol on Blacks and Hispanics. Those impacts are summarized below.

U.S. population and demographic trends for the next 50 years indicate that, while Blacks will continue to account for a gradually increasing portion of the population, the projected growth in the Hispanic population is the salient demographic feature of the next half-century. The portion of the population comprised of Hispanics will increase from 11 percent in 2000, to 16 percent in 2020, and 25 percent in 2050. By 2005, Hispanics will outnumber Blacks as the largest U.S. minority group, and their numerical dominance will increase throughout the forecast period. Further, Hispanics are disproportionately located in certain states, such as California, Florida, Illinois, New York, and Texas, and this concentration will expand over time.

Some 86 percent of the Hispanic population resides in ten states, and over 90 percent of the Hispanic population and 65 percent of the Black population reside in 15 states. By virtually every measure of economic well-being and security, Blacks and Hispanics on average are worse off than Whites, and tend to be especially vulnerable to the economic downturn and job losses likely to result from implementation of the Kyoto Protocol.

- Black per capita income of $18,400 is 70 percent of the overall U.S. average of $26,400, and Hispanic per capita income of $16,000 is only 61 percent of the national average.
- Poverty rates for Blacks and Hispanics have consistently been much higher than those for Whites, and are currently more than three times as high. The poverty rate for Blacks and Hispanics is 26 percent, whereas for Whites it is eight percent.
- Minority families have assets that are, on average, only about 20 percent of those of White families. Minorities thus have little to cushion themselves from the economic downturn and job losses that will likely result from implementing the Kyoto Protocol.
- The unemployment rates for Blacks (nine percent) and Hispanics (seven percent) during the study period were nearly twice the overall U.S. average of four percent, and those who are employed generally have less job security than their White counterparts. Both Blacks and Hispanics still suffer from the “last hired, first fired” syndrome.
- Blacks and Hispanics are disproportionately concentrated in jobs that pay the minimum wage or less.
- Both groups have relatively little discretionary income, compared to other socio-economic strata.
- Blacks and Hispanics spend a large share of their incomes on basic necessities, such as food, housing, utilities and energy.
- By increasing the costs of energy and energy-intensive building materials, the Kyoto Protocol will increase the costs of housing, including construction and rental. This will seriously affect Blacks and Hispanics, because they already spend a greater portion of their incomes on housing, and have lower rates of home ownership than Whites.
- Blacks and Hispanics are also more economically vulnerable to the negative economic effects of the Kyoto Protocol than Whites with respect to a variety of other measures. For example, they are less likely to have health care coverage, less likely to have private pensions, and more likely to be classified as work-disabled.

- Because Black- and Hispanic-owned businesses represent a disproportionately small share of total businesses, and tend to be smaller and less well capitalized than White-owned businesses, they are more vulnerable to the economic dislocations likely to result from implementing the Protocol.

Principal findings

The major finding of this study is that there are strong indications that **implementation of the Kyoto Climate Change Protocol would have severe negative economic consequences for Blacks and Hispanics.** As illustrated by charts that accompany the original executive summary and the full report, if the Protocol is implemented, the following could result:

- Twenty-five million Black and Hispanic workers would be earning ten percent less than they did in 2000.
- Fifteen million Black and Hispanic families would see their incomes decrease in both relative and absolute terms (**Figure 9-1**).
- Future growth in Black and Hispanic incomes would be retarded and much of the growth in the incomes made by both groups over the past decade would be negated (**Figure 9-1**).
- Nearly 1.4 million additional Blacks and Hispanics would become unemployed (864,000 Blacks and 511,000 Hispanics), and the length of their unemployment would increase.
- Four million additional Blacks and Hispanics would be forced into poverty.
- Most Blacks and Hispanics would be forced to pay proportionately more for basic necessities like energy.
- Six million Blacks and Hispanics would have their discretionary incomes reduced, and millions more would be deprived of any discretionary income.
- Most Blacks and Hispanics would have to pay 10 to 20 percent more for housing, and many would be precluded from buying their own homes.
- The job losses and reductions in incomes would increase the numbers of Blacks and Hispanics who lack health insurance.
- Blacks and Hispanics would suffer special hardship, since they have relatively poor private pension coverage.
- Black and Hispanic jobs and incomes would be significantly reduced in every state (**Figure 9-2**).
- States' revenues would be reduced by two or three percent, and many states would be forced to reduce expenditures on health, employment and social service "safety net" programs during a time when it would be likely that Blacks and Hispanics will become more dependent upon such programs.
- The United States' major cities and inner city areas would suffer, as hundreds of thousands of Black and Hispanic residents lose their jobs, and millions of Blacks and Hispanics experience reduced incomes (**Figure 9-3**).
- Black and Hispanic businesses would decline by 100,000 firms – these businesses also suffer from the "last hired, first fired" syndrome (**Figure 9-4**).

Figure 9-1. Black and Hispanic earning as a percent of White earnings, 1979 and 1997

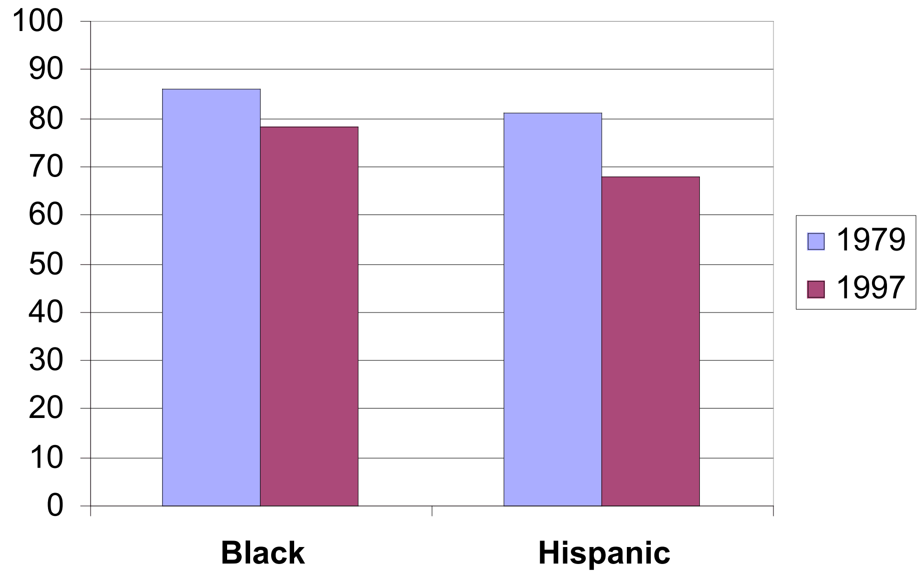

Figure 9-2. Black and Hispanic state job losses due to the Kyoto Protocol, 2010

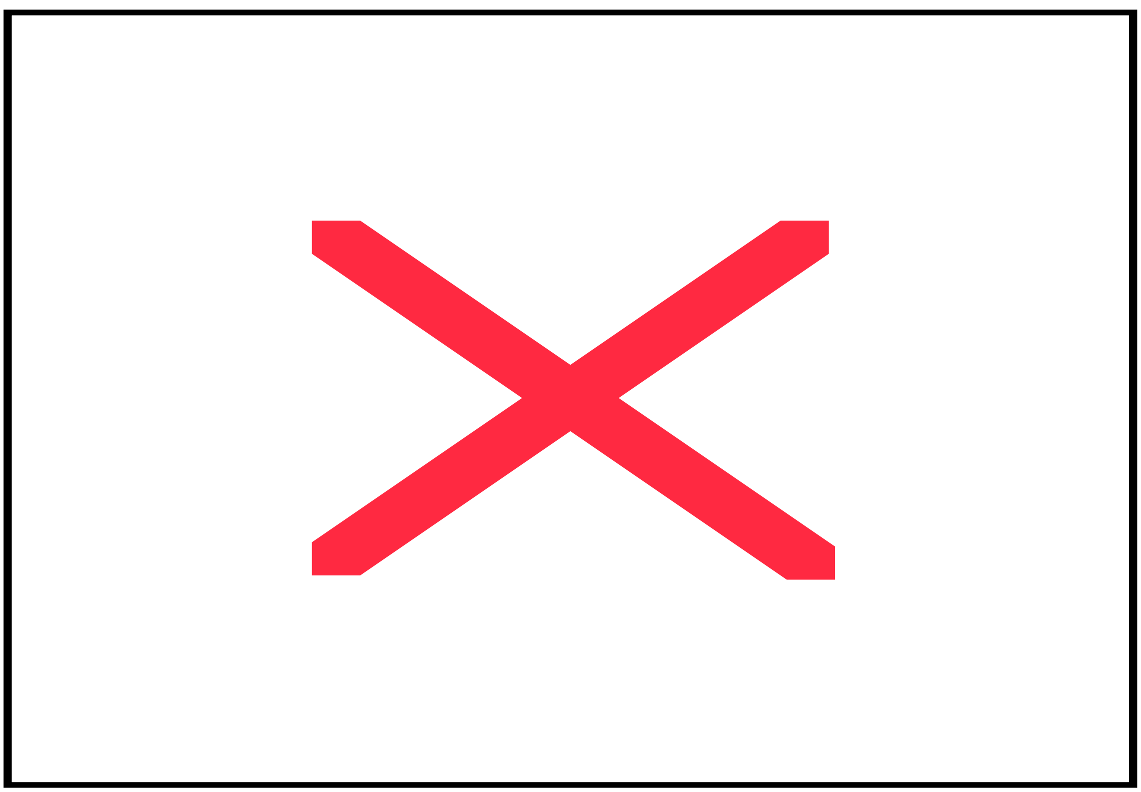

Figure 9-3. Job losses in cities caused by the Kyoto Protocol, 2010

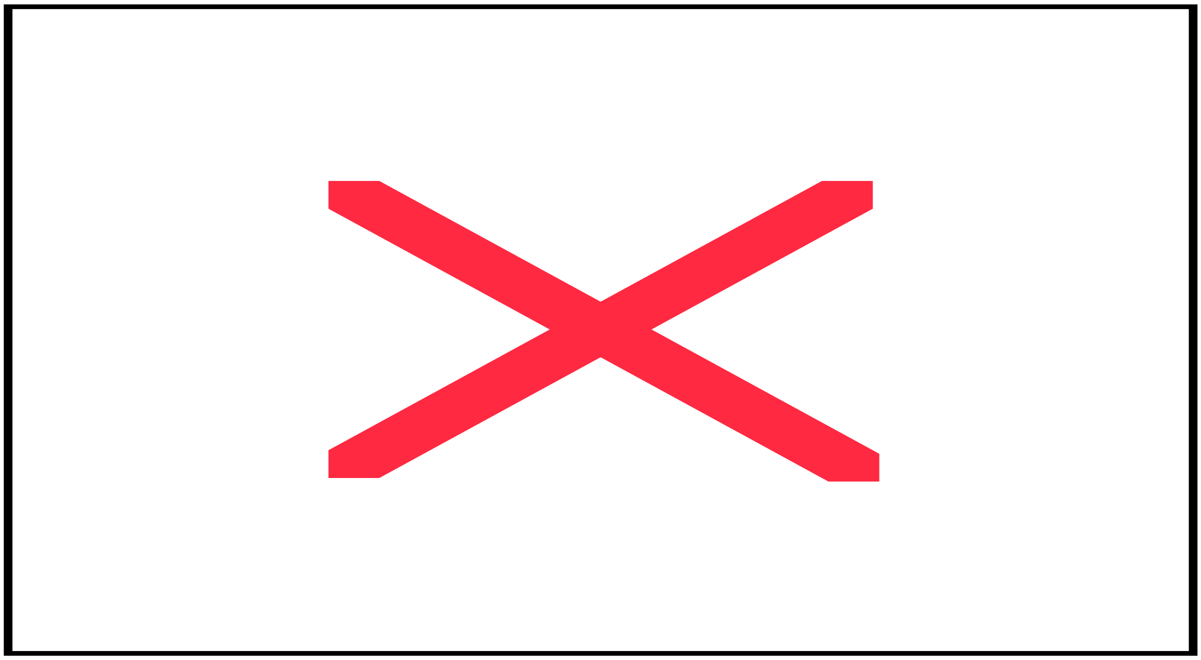

Figure 9-4. Black and Hispanic businesses lost due to the Kyoto Protocol, 2010

Implementing the Kyoto Protocol would likely impact the living standards of Blacks and Hispanics in two ways. It would decrease Black and Hispanic incomes below where they would be in the absence of the Protocol, and it would increase the costs of the basic goods upon which Blacks and Hispanics would have to spend their reduced incomes. One of the more significant impacts of implementing the Kyoto Protocol could be to force millions of Blacks and Hispanics below the poverty line – only a short time after many of those families had managed to work their way out of poverty. The welfare reforms of the 1990s made the social safety net at both the Federal and state levels less comprehensive, and this would have unfortunate implications for those Blacks and Hispanics whose incomes are reduced below the poverty level because of the Protocol.

The reductions in Black and Hispanic earnings, incomes and jobs, and the increases in Black and Hispanic unemployment and poverty, would negatively impact Black and Hispanic-owned businesses that serve those communities. Those businesses would already be suffering disproportionately from the general economic downturn resulting from implementation of the Protocol. Small business has traditionally represented a path to the American middle class for minority entrepreneurs, their employees, and their suppliers and contractors. Thus, an indirect effect of implementing the Protocol would be to close this path for hundreds of thousands of Blacks and Hispanics.

Standards of living and quality of life would be substantially affected, as relative income growth decreases and unemployment increases for Blacks and Hispanics. Implementation of the Kyoto Protocol would likely result in substantial economic and job losses for Blacks and Hispanics throughout the United States, and these adverse effects would be widespread throughout the states and urban areas.

Finally, and perhaps most seriously, implementing the Kyoto Protocol could halt and in many cases reverse the gradual, substantial economic progress that Blacks and Hispanics have achieved in recent years. In effect, a major impact of the Protocol could be to largely eliminate a decade or more of Black and Hispanic economic progress, and to reduce the gains made in incomes, employment, housing and finances. The Black and Hispanic middle classes are especially vulnerable because, more so than non-Hispanic Whites, Black and Hispanic middle class households depend on the wage and salary incomes of both spouses.

During the recession that followed the OPEC Oil Embargo of the 1970s, the United States economy was disrupted by skyrocketing energy costs and the widespread unemployment, record-high interest rates and rapid inflation that resulted. In 1973 alone, consumer prices rose 10 percent. While all Americans were affected, it was especially hard for minority working families to make ends meet. In fact, the situation deteriorated so much that *Ebony* published an article titled “Inflation in the Ghetto: A Poor Man’s Survival Kit,” and *U.S. News and World Report* featured a story on how non-Whites were among those most likely to be unemployed because of the downturn in the economy.

That experience underscores the regressive effect that energy taxes and other methods for raising energy costs have on society: they impose a disproportionately negative impact on those who are least able to afford higher costs. As energy prices increase, the price of housing, food, clothing and other basic necessities also increases.

It took more than 20 years to overcome the economic harm done to minority communities by the energy crisis of the 1970s. Indeed, it was not until the economic boom of the late 1990s that many African- and Hispanic-Americans were again able to make sufficient economic strides to have the full employment, home and business ownership, college education and other benefits that many middle and higher income families have long enjoyed. Many people remain concerned that state and national policy makers might make serious mistakes in the name of preventing climate change or other environmental problems, without first understanding the potential adverse effects that those decisions could have on the 65 million

Americans who are either Black or Hispanic – and on tens of millions of others who are on low or fixed incomes.

Achieving the greenhouse gas emission reductions contemplated by the current Kyoto Protocol alone would require a roughly 30 percent reduction in anticipated energy usage in America. Such a radical shift in energy policy will seriously damage the U.S. economy. According to the nation's leading economic forecasting firms, as the well as the independent federal Energy Information Administration (EIA), American consumers would be forced to pay higher energy and consumer costs, and millions of American jobs would be lost.

For example, in 1998, the EIA released its *Impacts of the Kyoto Protocol on U.S. Energy Markets and Economic Activity*. The EIA study confirmed that this climate treaty would impose a high price on the American people, and projected that the total cost to the U.S. economy could be as high as $348 billion in 2012 alone. Additional climate treaties – which many say would be needed if greenhouse gas emissions are to be actually stabilized worldwide – would likely increase these costs many times over.

At the same time, while more and more families are forced to turn to government assistance for food, shelter, transportation and medical assistance, the economic disruptions brought about by the Kyoto Protocol would also significantly reduce federal, state and local tax revenues. As in the 1970s, this squeeze on government budgets would greatly reduce the likelihood that programs could be expanded to meet the increased need.

Based on the studies it analyzed, MISI concluded that the Kyoto climate treaty could also cost more than 3 million U.S. jobs, including 800,000 in black and 500,000 in Hispanic communities. Minority family incomes would likely plummet by $2,000 and nearly 100,000 minority businesses could be forced to close.

- In Florida alone, where more than 2 million people are below the poverty line, food and medical costs could rise by 9 percent or more – while the state's real economic output could plunge by $11 billion a year. Just in the Miami area, 10,000 minority businesses could be lost.
- In Michigan, MISI calculated, food and medical costs could rise by 10 percent or more – while economic output could plunge by $8 billion a year.
- In Pennsylvania, those costs could rise by 11 percent, economic output could plunge by $10 billion, and tax revenues could fall by nearly $4 billion a year.

Moreover, the adverse impacts from the Kyoto Protocol would be felt far beyond U.S. shores. Poor countries around the world would also be hard hit. Many of them depend on the United States (and other wealthy countries) for the exports that generate half (or more) of their annual revenues. Any economic and employment downturn in these developed nations – among poor, middle and wealthy classes alike – would thus ripple far and wide, causing severe economic dislocations in Africa, Asia and Latin America, which in turn could lead to racial and international tensions within and among different countries.

Conclusions

In sum, several independent studies have forecast seriously negative economic and employment consequences for the U.S. if the Kyoto Protocol is implemented. The key premise of this study – that the Protocol will negatively affect Blacks and Hispanics – is thus strongly supported by the findings of these independent studies, as well as by analyses prepared by the U.S. Energy Information Administration.

Further, the impact on Blacks and Hispanics of the energy-induced recessions of the 1970s presents a relevant example of the vulnerability of both groups to these types of economic downturns. For example, between 1973 and 1975 the Black unemployment rate increased by 50 percent (from ten percent to 15 percent) and the Hispanic unemployment rate increased by two thirds (from 7.5 percent to 12.5 percent). Sharply higher transportation costs forced many minority employees to shift to public transportation, which in many cases (especially in heavily Black and Hispanic areas like Los Angeles) caused their commuting times to increase by several hours a day.

This, too, was a time of rapidly increasing energy prices, caused by the OPEC oil embargo.

These findings should serve as a warning to those who advocate radical shifts in U.S. energy policy based on initiatives intended to counteract suspected global climate change, without fully understanding the potential economic consequences of their proposed policies.

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Notes

[1] Among the studies utilized by MISI in reaching its conclusions are those conducted by the U.S. Department of Energy's Argonne National Laboratory (1997), White House Interagency Analytical Team (1997), U.S. Energy Information Administration (1998), WEFA, Inc. (1997 – Wharton Econometric Forecasting Associates, now Global Insight), Resources Data International), and Charles River Associates (1997).

Chapter 9

THE VALUE OF ENERGY TECHNOLOGY IN ADDRESSING CLIMATE CHANGE

Jae Edmonds, Chris Green and John Clarke

Overview

Currently projected improvement in energy efficiencies, plus plausible levels of nuclear, wind, solar, biomass and other renewable energy sources, by themselves, are not generally believed to be adequate to stabilize atmospheric carbon dioxide concentrations at levels frequently discussed. Limiting cumulative emissions of carbon over the course of the 21st century, at minimum economic cost, means not only establishing economic institutions conducive to efficient resource allocation, but also:

- substantially improving existing technologies;
- expanding the portfolio of energy and energy transformation technologies to include promising options such as carbon capture and storage, biotechnology, and hydrogen and advanced transportation systems; as well as
- developing the scientific foundations for yet another generation of technologies, such as advanced fission, fusion and perhaps even space-based solar power.

Making real progress toward this goal implies a substantial and near-term global commitment to both public and private energy R&D investment.

Energy as a source of greenhouse gases

Greenhouse gases are those gases that are believed to affect the Earth's energy balance and through that mechanism impact the Earth's climate. Naturally occurring greenhouse gases such as water vapor (H_2O), ozone (O_3), carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) play a critical role in making the world habitable to life as we know it. Among the potential human impacts on climate are actions that increase the concentration of these gases in the atmosphere beyond certain limits.

Manufactured substances such as chlorofluorocarbons (CFCs), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6) also are direct greenhouse gases. Other gases like carbon monoxide (CO) and nitrogen oxides (NO_x) can likewise affect the chemistry of the atmosphere and indirectly affect greenhouse gas concentrations. Additionally, particles such as aerosols and dark particles resulting from human activity can have potentially strong local, regional and even global effects on the Earth's energy balance.

Two major pathways account for a large share of human emissions of greenhouse related gases:

- the production and use of energy, and
- agricultural and other land-use activities.

Wuebbles and Edmonds (1991) estimated that the combined contribution of these two sectors account for more than 85 percent of global warming potential (GWP) weighted emissions. While the relative contribution of energy versus agriculture-land-use emission sources varied depending on the time horizon considered, these two sources of greenhouse gas emissions – when combined – consistently were the most important sources of human greenhouse gas emissions.

GHG emissions and the Framework Convention

Energy-related activities consistently contributed more than half of the total GWP weighted emissions. The importance of energy can be traced primarily to the use of fossil fuels. According to recent studies, energy use is the largest category of emission of CO_2 to the atmosphere (6.6 PgC/y in 2000, Marland et al., 2003), with land-use change emissions a distant second (0.6-2.5 PgC/y, IPCC, 2001). Additionally, energy use also contributes to methane emissions such as fugitive emissions from natural gas production, transmission and distribution, incomplete combustion, coal mining, and landfills. Further, its emissions are directly associated with the production of dark particles (such as "black carbon"), and aerosols in fossil fuel and biomass combustion.

The United States and more than 160 other nations are party to the 1992 United Nations *Framework Convention on Climate Change* (UNFCCC; United Nations, 1992). Its objective is clear enough:

"… stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner." (Article 2)

But the practical implications for public policy are still being worked out. While anthropogenic interference in the climate system may take many forms, such as land-use change possibly impacting the earth's albedo or a wide range of emissions, the international community has focused on emissions of the so-called six Kyoto gases, of which carbon dioxide from fossil fuel energy is the most visible. *However, there is no consensus, either scientific or political, as to the concentrations of greenhouse gases at which stabilization should occur.*

Technology development as an option

Conceptually, the nature of actions by individual nations of the world in pursuit of the common objective can include elements of several different classes of actions:

- Improving scientific understanding, to better target society's scarce resources devoted to the climate issue;
- Emissions mitigation, including actions to reduce near-term fossil energy and land-use emissions;
- Actions to promote technology development and lower the cost of future efforts to reduce emissions; and
- Adapting to climate change, to lessen damage and avoid costs associated with mitigation.

Policies addressing century-scale problems will inevitably evolve with time, so the relative emphasis on each of these courses of action can also change with time. While this paper looks at the role that technology can play in addressing the problem of climate change, it must be borne in mind that technology is only one component of the larger portfolio of actions to address the issue of climate change.

Elements of change in the global energy system

Although the global energy system has grown steadily over time, it is important to note, first, that the relative contribution of different energy sources has changed dramatically. Renewable resources like wood, as well as animal and human power, originally dominated the system. Wood's share in global energy consumption has declined steadily since 1850, displaced initially by coal. Coal's share of the global energy system grew steadily until 1913, when it peaked, and in turn began to be displaced by oil, whose share grew continuously until 1973, when it peaked and began to decline, displaced in turn by an ascendant share for nuclear power and natural gas.

Second, although the ascent of each energy mode is followed by a period of decline, each successive mode of energy supply has peaked at a lower percent of overall energy use. For example, in 1850 wood accounted for more than 80 percent of total energy use. Coal production reached a maximum of 70 percent, and oil production reached a maximum of 40 percent. The successively lower peaks on maximum energy shares reflect a pattern of increasing diversification in the global energy portfolio.

Third, it should be noted that despite the waxing and waning of market shares, no component of the global energy system has declined in absolute terms for more than a short period of time. For example, largely because of increasing human populations and economic activities, more than twice as much wood was used in 1995 as was the case in 1850, when wood's share was 80 percent of total energy. There was almost three times as much coal used in 1995 (99 EJ) as in 1913 (36 EJ), when it accounted for 70 percent of global energy.

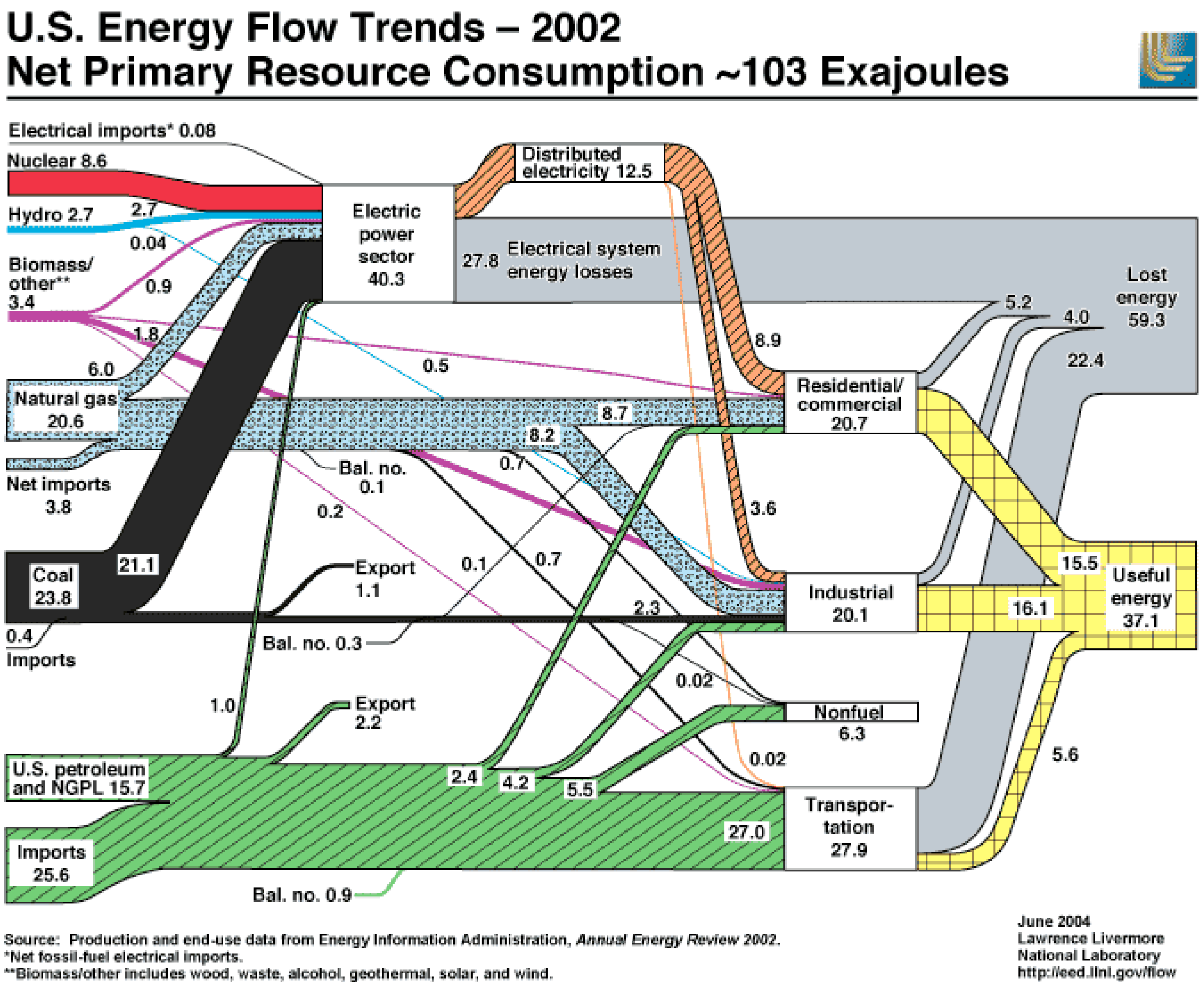
The technology of energy transformation

Much of the primary energy that is produced from wood, coal, oil and natural gas is lost in transformation to a form that provides a useful service. Still more is lost in providing the service itself. The energy flow diagram for the United States shown in **Figure 10-1** illustrates that, on average, waste heat accounts for about two-thirds of all the fossil fuel energy that is transformed and then used as electricity.

While transformation is a dominant theme of the present global energy system, future systems may evolve toward a still greater role for energy transformation. For example, most natural gas traditionally has been combusted as a gas, and most coal combusted as a solid. However, technology can now transform natural gas into liquid fuels – and coal to liquids and gases. Such transformations could become more common, depending on developments in technology and resource availability. The advent of a hydrogen economy would imply yet another layer of energy transformation – either hydrocarbons to hydrogen, or electricity (and water) to hydrogen.

Thus, in addition to reducing the direct emission of greenhouse-related gases, improving the efficiency of transformation from primary energy sources to end-use energy services is a critical area for technology development efforts. However, to compete in the market, new and improved transformation technologies must be capable of providing comparable energy services, while also satisfying environmental, health and safety performance requirements, all at a cost that is competitive with that of fossil fuels that currently provide the same services.

Figure 10-1. Energy flow diagram for the United States: 2002



Population growth and economic expansion pressures to improve technology

Although the global demand for energy has grown continuously over the past 150 years, the long-term growth in the demand for energy services is impossible to predict. The process of economic expansion has clearly fueled this expanded demand, but the economic expansion occurred both because the number of participants in the economy increased and because the amount of economic activity per person increased. Other things being constant, though, the scale of economic activity should be roughly proportional to the size of the population. Thus, the first factor to consider in contemplating the scale of future economic activity is the size of the human population.

Reasonably good projections of future population can be made for decades into the future. That is due to the relative stability of fertility and survival rates and to the long potential lifetimes of human beings. Of course, such projections assume that events such as a massive fatal epidemic or other global scale catastrophe do not occur, though projections do consider the consequences of such diseases as AIDS.

Even without massive epidemics or global scale catastrophes, however, it becomes more difficult to estimate future populations as the time scale lengthens. Dramatically different but plausible hypotheses can yield very different population estimates. Populations for the set of scenarios developed by Nakicenovic *et al*. (2000) ranged between 7.2 and 8.2 billion people for the year 2020, compared to a 1990 population of about 5.3 billion. Thirty years further into the future, however, the same methodology yields a 2050 population range that expands to 8.3 to 11.3 billion people. By the end of the century the range has expanded to encompass 6.9 to 15.1 billion people. That is, the population could be as much as three times 1990 levels or it could be a billion and a half people lower than low-end projections for 2050. More recent work at IIASA, Lutz *et al*. (2001, 2004), indicates that the range could be lower than previously estimated – 5.5 to 12.1 billion people in the year 2100.

Thus, while present day concerns focus on the accommodation of increasing populations, the second half of the century may face very different concerns – aging and declining populations.

The uncertainty surrounding future population is compounded by the uncertainty regarding per capita energy demand. Per capita energy demand has shown a long-term tendency to increase, but this tendency has not been monotonic. Periods of peaks and declines have punctuated the record from 1850 to the present. Since 1973, global per capita energy consumption has been relatively stable, as has United States per capita energy consumption. A similar stable period occurred during the first half of the 20th century, but was followed by a period of rapid expansion.

On the other hand, the last 150 years have demonstrated no long periods (multiple decades) of declining energy per capita, in either the United States or the world. Given the long history of energy use per capita in the currently developed world, as good a case for further growth in the 21st century could be made as for the cessation of growth per capita.

Of course, the fraction of the world's population in developing nations is anticipated to rise, though the pattern of economic development is impossible to predict. While it is highly unlikely that all developing countries will experience substantial economic development, it is equally unlikely that none will. *Despite these somewhat confounding trends, the magnitude of the energy production needed to satisfy this expected growing demand will depend heavily on the efficiency of energy transformation.*

The need for improved transformation technologies

Edmonds (1999) argued that stabilization of greenhouse gas concentrations would likely require a credible commitment to limits on cumulative carbon emissions into the atmosphere. A number of researchers, such as Lightfoot and Green (2002), using IPCC Working Group III estimates, have raised serious questions as to whether renewable energy sources can plausibly fulfill potential future energy service demands, due to constraints like land availability. Similarly, Hoffert *et al*. (2002: 981) observe that all non-carbon emitting sources "currently have severe deficiencies that limit their ability to stabilize global climate."

Simply put, in their current state of development, these alternative sources cannot be scaled up to provide the energy services that society wants, while simultaneously stabilizing the concentration of CO_2 at an arbitrary level.

More recently Pacala and Socolow (2004) have argued that energy technologies have been identified that could form the basis for future energy technology deployments consistent with the stabilization of emissions over the next 50 years. This is not to say that large-scale global deployment of such technologies as carbon dioxide capture and storage (CCS) is assured. Cost, performance, institutions, and non-climate environment, safety and health issues all matter. Moreover, large-scale deployment, beyond that which could be expected to emerge in the absence of a concern for climate change, requires positive developments in all those areas.

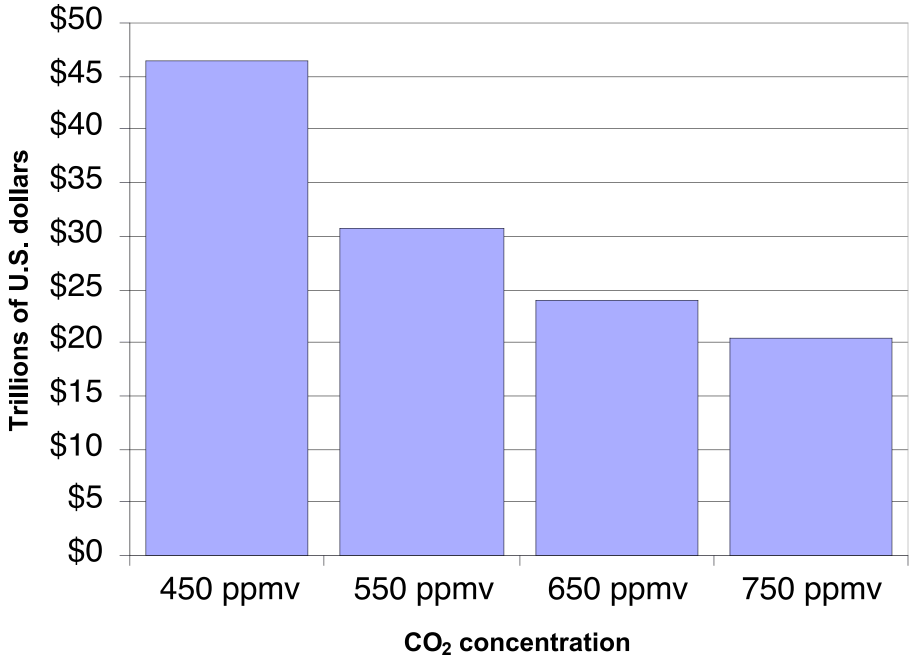
In contrast, research and development, both public and private and ranging from basic to applied, holds special promise: it has the capacity to "produce technological options that can allow both climate stabilization and economic development." Compared to a future without limits on cumulative emissions, such limits imply the diversion of resources from normal uses, to ensure that energy services are provided without carbon emissions to the atmosphere. The degree to which resources must be diverted depends in turn on the technology portfolio available – and the options in that portfolio can be improved with research and development efforts by both the public and private sectors, in areas ranging from basic scientific exploration to applied research and development. *Thus, research and development holds the promise of reducing the cost of meeting any greenhouse gas concentration limit.*

The value of improving energy technologies

What resources would have to be diverted from other competing ends to achieve that goal with the present suite of technologies, or with those that might be anticipated to become available under reference scenario conditions? This question has begun to be addressed.

The value of improving energy technologies has been estimated using a variety of different approaches. For example, Edmonds *et al*. (1997) developed estimates for the value of improving technology, compared to its average 1990 performance, while meeting different CO_2 concentration targets. As illustrated in **Figure 10-3,** the value of improved technology ranges from about $20 trillion to $45 trillion dollars (2003 present value U.S. dollars discounted from 2095 back to the present at five percent per year).

Figure 10-3. Value of reference case energy technology Discounted 2095 to 2005 at 5 percent



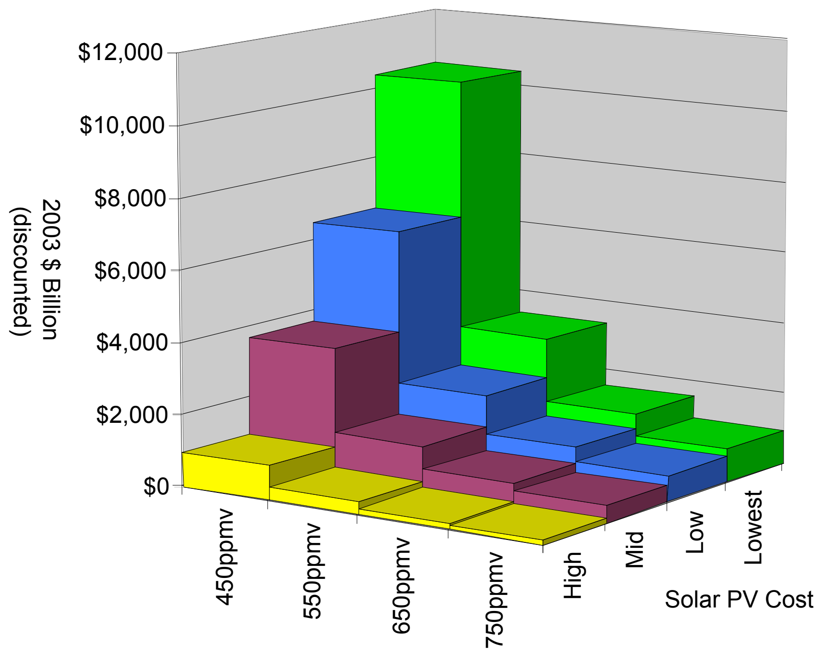
Source: Edmonds, Dooley and Wise (1997). Values recalculated to conform to the discounting period 2005 to 2095 and converted to 2003 US dollars.

These estimates are based on the change in the minimum present discounted cost of various CO_2 limits with 1990 and reference case technologies, for a reference scenario similar to the IPCC IS92a. Of course, no one believes that the world could evolve as in the reference scenario without improvements in energy technology relative to 1990. The point is not to create a plausible scenario, but rather to create a clear counterfactual basis for illuminating the value that energy technology improvements would contribute in the reference case.

This calculation, like virtually all stabilization cost calculations, makes numerous simplifying assumptions, including that *all* nations participate in programs to control CO_2 concentrations in an economically efficient manner throughout the 21st century. While heavily dependent on specific assumptions, these calculations have the virtue that they are uniquely defined, comparable to other calculations employing this standard, and yield a unique lower boundary on costs that might be encountered.

Another indication of the value of adding or improving technologies, beyond those found in the reference case, has also been examined in Kim, Smith, and Edmonds (2000), which considered the case of solar energy. They found that the global minimum value of reducing the cost of producing solar power – including the costs of dealing with intermittency – can range from tens of billions of 2003 U.S. dollars to multiple-trillions of dollars, depending on assumptions regarding the CO_2 concentration targets and degree of improvement (see **Figure 10-5**).

Figure 10-5. The value of improving solar power generation technology for four cost cases compared to a reference solar power technology producing electricity at 7.2 cents per KWh in 2100.

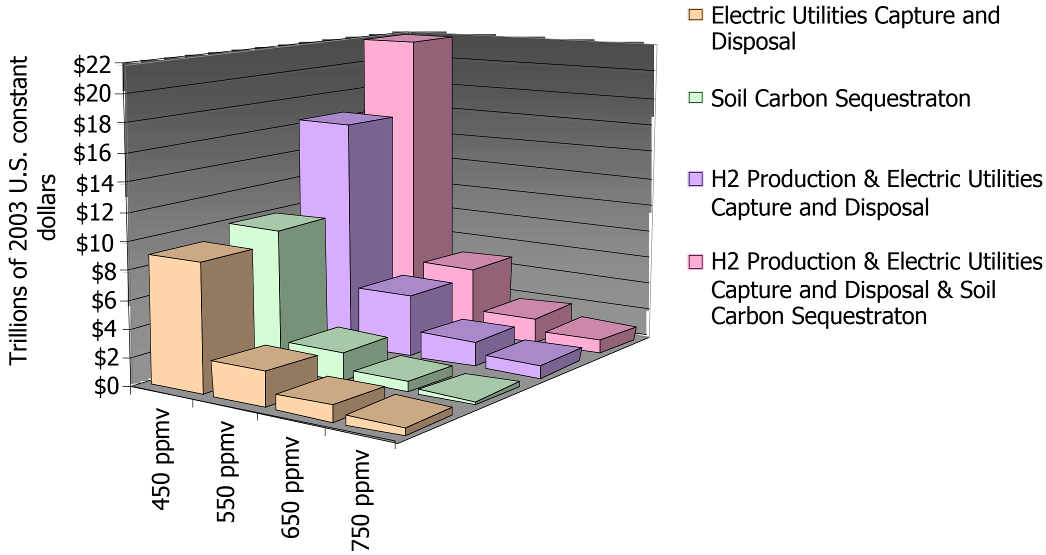


Case name	High	Mid	Low	Lowest
Cost of power generation (cents per KWh) in 2100	6.7	4.7	3.5	2.1

Source: Kim, MacCracken, and Edmonds (2000). Computations updated to 2003 US dollars and period of discounting revise to 2095 to 2005.

Adding carbon capture and storage technology to the suite of reference case technologies also appears to offer significant value. For example, Edmonds, Dooley and Kim (1999) estimated that the value of adding carbon capture and storage technology for a reference case similar to the IPCC IS92a case also is large, as illustrated in Figure 10-7**.** More recent work by Dooley, et al. (2004) confirms the magnitude of these values in a more sophisticated model with finite regionally specific geologic carbon dioxide storage.

Figure 10-7. Estimated reductions in the minimum global present discounted cost of stabilizing the concentration of CO_2 in the atmosphere at alternative levels when various technologies and technology combinations are available



Source: Edmonds, Dooley and Kim (1999).

Of special note is the value of developing technologies that can be deployed quickly – for example, advanced agricultural practices (such as low- and no-till farming via biotechnology) that keep carbon in the soil or put it back in, thus keeping it out of the atmosphere. Additionally, carbon capture and storage technologies interact strongly with many other technologies. Carbon capture and storage can be used not only in combination with central power generation, but also with other technologies, such as hydrogen production and fuel transformations. By enabling the capture of carbon during the process of producing hydrogen from fossil hydrocarbons, the cost of deploying hydrogen in a carbon-constrained world is reduced.

Furthermore, in combination with commercial biomass, carbon capture and storage technology can enable energy production with negative carbon emissions. That is, hydrogen production from biological hydrocarbon feedstocks would effectively remove carbon from the atmosphere during the growth of the plant and, when the carbon was removed and stored, this would constitute a net removal of carbon from the atmosphere, while delivering a fuel like hydrogen to the market.

A portfolio of technology improvement options

A variety of papers – including Battelle (2001), Edmonds and Stokes (2004), and Hoffert *et al.* (2002) – have argued that there is a variety of very powerful economic forces that make a portfolio of technologies more attractive than any single technology. First, the availability of renewable and fossil resources varies from place to place across the globe, as do the physical and human capital and institutional infrastructure to support their deployment.

Second, the mix of energy service demands also changes from region to region. Attempting to deploy one energy service supply strategy across all circumstances and cultures pushes the technology into circumstances where its costs begin to rise and alternative strategies would operate more successfully.

Third, technologies change, and with them the mix of technologies that are most attractive to deploy in any place or time. Fourth, improving and developing new technologies must match the time-scale of the climate issue, which is a century-plus issue, and this is the time-scale over which technology revolutions occur.

Finally, it is impossible to predict energy technology developments and the fruits of public and private sector investments in R&D, both directly in energy technologies and in other technologies, as well. The economics of competing technologies is constantly changing and evolving. As scientific knowledge progresses and complimentary techniques evolve, the economics of alternative technologies change.

For example, carbon capture and storage was considered too expensive to be taken seriously in the 1980s, but it is a technology that is taken very seriously today. Both the technology and the potential for being able to capture and store carbon from fossil fuel use have changed in the interim, even since the 1999 Edmonds, Dooley and Kim study cited above.

Furthermore, as English historian and documentary producer James Burke observed in his book and PBS television series, *Connections*, the knowledge gained from R&D investments can have surprising consequences – and investments in one sector can have unexpected benefits in another, seemingly unrelated sector. For example, 3-D seismic imagery of geologic formations enabled industry to expand economically recoverable fossil fuel reserves. That technology benefited directly from advances in computational sciences, and medical technology breakthroughs like the CAT scan. Similarly, investments to improve military jet aircraft engines lead directly to improvements in power turbine technology.

The R&D contribution

Research and development serves many functions. Basic scientific research lays down the foundations upon which new technology draws. It provides increased knowledge in particular specialized areas that are necessary for the development of new approaches to the provision of energy services. Moreover, it develops new ways to perform existing functions. It is supported by both the public and private sectors and undertaken in laboratories in the public, private and academic sectors. In some cases, it will be undertaken by international consortia, and will often be a major component of healthy competition.

Improvements in technology options, assumed and modeled in reference cases of the future, presume that energy and non-energy R&D will continue as they have historically. These scenarios typically assume existing programs will be successful in developing improvements in energy intensity, wind, solar, biomass, nuclear, and other renewable energy forms. While accelerating the rate at which energy technologies develop implies greater emphasis on their development, in no individual case is success assured. Overall, however, there are good reasons to believe that there is significant value in accelerating their development and enhancing their performance.

Adding technologies to the mix

In addition to pushing forward to further develop technologies that one can assume will achieve successful deployment in the reference case (such as energy intensity, wind, solar, biomass, nuclear, and other renewable energy), there is promise of reducing the costs of addressing climate change still further by expanding the portfolio. Three technology areas show particular promise and could be substantial components of the global energy system by the middle of the century:

- carbon capture and storage,
- hydrogen and advanced transportation systems, and
- biotechnology.

None of these has been deployed at any significant scale, but each has the potential to displace petagrams (gigatons) of carbon per year. As noted earlier, **carbon capture and storage** has the potential to allow the continued use of abundant fossil fuel resources, without releasing carbon to the atmosphere. Even though many questions remain – including the cost of capture, technology of transport, amount and security of storage, measurement, monitoring and verification – these questions are being actively addressed.

Additionally, the scale of deployment could be extremely large in scenarios where CO_2 concentrations are limited. For 550 ppm, Edmonds *et al.* (2003) show that cumulative capture could amount to hundreds of billions of tons of carbon by the end of the century.

Hydrogen systems create a new pathway by which energy services can be provided without carbon emission. However, while hydrogen is already used commercially, the quantities are small relative to the global energy system. The key question is whether or not hydrogen systems can be deployed at scale in buildings, industries and vehicles, along with their supporting infrastructure for production, transport and storage – and if so, whether deployment can be cost-competitive with other technology options. Furthermore, since hydrogen is an energy carrier, rather than a primary energy form, the question arises as to the method by which hydrogen was produced. If it is produced using fossil fuel hydrocarbons, no reduction in emissions occurs unless some method for capturing the carbon is available. If the hydrogen is made using electrolysis, then the source of the electricity becomes an issue.

Biotechnology refers to the application of findings from the rapidly developing field of biology to address energy and greenhouse issues. Advances in understanding the foundations of life could lead to any number of potential breakthroughs – ranging from the development of higher productivity commercial biomass energy crops, and traditional non-energy crops, to the use of a wide range of energy sources to biologically produce fuels such as hydrogen.

While a substantial body of literature has developed examining the potential role of commercial biomass, the interface between the biological sciences revolution and greenhouse gas emissions mitigation has only begun to be explored. See, for example, Rosenberg, Metting and Izaurralde (2004).

Over the longer-term, other technologies could potentially play a substantial role, including **advanced fission** (Clarke, Edmonds and Geffen, 2003) and **nuclear fusion** (Lako et al., 1999; Kim et al., 1996) or even **space-based solar power** (Clarke, et al. 2003; Hoffert et al. 2002; Lewis 1991). However, very substantial investments in technology development will be necessary for these technologies to be deployed at a scale sufficient to eventually stabilize greenhouse gas concentrations.

Closing thoughts

Various studies indicate that stabilizing the concentration of CO_2 at any level from 350 ppm to 750 ppm implies that, at some point between now and roughly 2060, the world would have to embark on a major energy system transition – with non-carbon emitting technologies dominating new energy system investments thereafter. This is because reaching such targets implies that between 2005 and 2060 global carbon emissions must peak and begin a long-term decline.

Evidence indicates that improvements in technology efficiencies – plus plausible levels of nuclear, wind, solar, biomass and other renewables – by themselves are not adequate to limit atmospheric carbon dioxide concentrations to levels frequently discussed. Managing the transition at minimum economic cost means substantially improving technologies and expanding the portfolio of energy and energy-transformation technologies, to include promising options like carbon capture and storage, hydrogen and advanced transportation systems, and biotechnology. It also means developing the scientific foundations for yet another generation of technologies, such as advanced fission, fusion and space-based solar power.

Achieving this goal implies a substantial and near-term global commitment to both public and private energy R&D investment.

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Chapter 10

REDUCING GREENHOUSE GAS EMISSIONS THROUGH CAPITAL STOCK TURNOVER

Margo Thorning

Overview

Our quality of life is sustained in large part not merely because we use fossil fuel energy, but because we utilize equipment that is specially designed to convert that energy into valuable services. Cars, stoves, computers and factories are but a few common examples of technology that improves our lives, efficiency, productivity and safety. Much of that equipment is expensive, but fortunately it generally has a long, useful lifespan.

Government policies that seek rapid reductions in greenhouse gas emissions clash with the potentially long lives of our energy services capital equipment. These policies require that we either stop using existing equipment – and thus forego its benefits – or scrap that equipment long before its useful life has ended, and install expensive new equipment.

It is true that the newest technology is generally more energy efficient – and therefore less GHG Intensive (emits less carbon dioxide and other greenhouse gases per constant dollar of economic output) – than equipment that has been in use for a decade or more. However, the existing rate of capital stock turnover already reflects decisions by businesses and individuals regarding the most efficient rate of investment, to meet often-competing priorities within budgetary constraints. Policies that force rapid investment in today's technology lock companies into using that technology, and thus may delay or preclude options to invest in even better technologies that may be available in just a few more years.

Governments seeking to increase current rates of reduction in GHG Intensity can consider tax policies like depreciation schedules to improve the benefit/cost characteristics of new equipment investments, and thereby encourage faster private sector action. They can also consider tax and other options to increase incentives for research and development – so that tomorrow's capital equipment will be even more technologically improved.

However, all these government and corporate options have costs that should not be ignored. These costs may be born by taxpayers (to make up for revenues lost due to R&D or depreciation incentives); by those who depend on government services that may have to be reduced (because revenues have been redirected); by corporate shareholders and employees (because there is less money available for dividends and wages); and/or by pensioners who depend on continued revenue flow and economic growth (which may be adversely affected by these policies), to name just a few of the affected parties.

Any decisions should be made only after careful consideration of all the likely consequences.

The "energy services" that fulfill basic needs are created only when energy is combined with capital equipment.

People don't use energy just to be using energy. They use energy because it provides valuable services. As highlighted in the International Energy Agency report *Toward a Sustainable Energy Future*, "Energy services help to fulfill basic needs such as food and shelter. They contribute to social development by improving education and public health and, overall, help alleviate poverty." [1]

But energy rarely provides these services by itself. The services come from using energy in a car – to get to work … in a stove – to cook food … in a furnace – to heat homes … in a lamp – to light homes and offices … and in factories – to make things while also providing people with jobs and income to pay for their food, homes, clothing and healthcare.

Much of the energy services capital equipment that will be used in 2012 already exists today – because most of the equipment has long, useful lives.

The vehicles, stoves, furnaces, electric power plants, hospitals and factories that play critical roles in delivering energy services frequently are expensive – which means we don't buy them or replace them on a whim. But because this equipment last many years, we don't have to replace it. Those two characteristics – high cost and long life – have significant implications for policies that seek to address concerns about climate change.

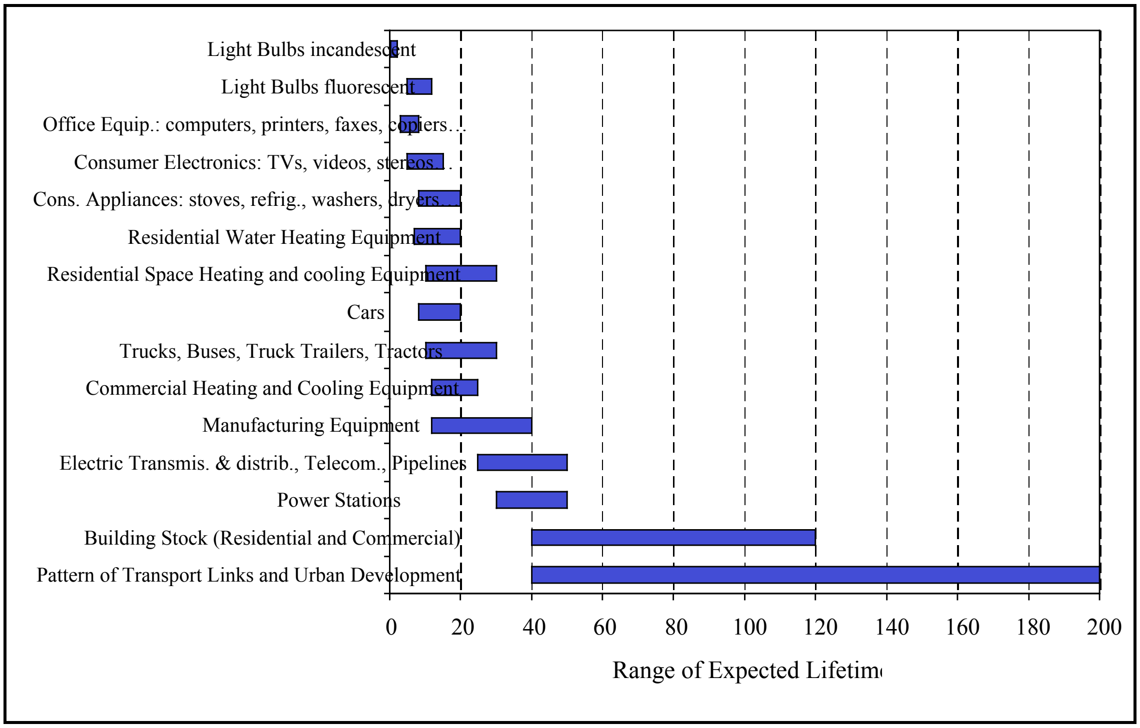
The normal life spans of selected capital equipment used to deliver energy services are illustrated in **Figure 11-1**. Many appliances (like stoves, refrigerators, washers and dryers) can last up to twenty years. Equipment for heating and cooling homes has a lifespan of up to thirty years. Cars can last as long as ten or twenty years, while heavy-duty vehicles like tractors can continue to function for up to thirty years. Power stations that generate the electricity for homes and offices can have useful lives in excess of forty years. Homes and office buildings can last even longer – frequently reaching forty years and in some cases in excess of 100 years.

The long lives of energy services capital stock means we can expect that much of the capital equipment in use today will still be functioning in the period 2010 to 2012, and in may cases well into the next decade. WEFA's (Wharton Econometric Forecasting Associates – now Global Insight) in-depth analysis of U.S. capital equipment suggests that this expectation applies to –

- roughly 70 to 80 percent of existing electricity generating capacity;
- industrial sector capital equipment like boilers, which have 20 to 40 year useful lives; and
- commercial sector energy heating, cooling and lighting equipment, which has useful lives of 10 to 20 years and accounts for roughly two-thirds of that sector's energy use.

Even for relatively short-lived equipment like automobiles, WEFA estimated that roughly 80 percent of the cars and trucks purchased this year are likely to be on the road in 2012. [2]

Figure 11-1. Average life spans for selected energy-related capital stock[3]



Forcing premature retirement or reduction in use has significant costs to society

Policies that seek to reduce greenhouse gas emissions by rapidly reducing fossil fuel energy consumption (and/or emissions) inevitably collide with the long-lived nature of the energy services capital stock that provides basic needs. As the International Energy Agency concluded in *Toward a Sustainable Energy Future*:

"The slow turnover of energy-specific capital stock creates large irreversibilities once a decision has been made: changing the way of doing things before existing structures are fully amortized involves huge costs." (Page 50.)

For most energy services equipment, energy efficiency (and emission levels) is "locked-in" when the equipment is designed, constructed and installed. As a result, a nation has two basic options when it tries to improve energy efficiency as a way to reduce greenhouse gas emissions. Each approach can have significant costs for society.

A country can attempt to reduce energy use and emissions simply by using existing capital equipment less – turning it off or persuading people to use it much less. It may, for example, use taxes to increase energy costs. Cars could be driven less, homes could be heated less, lights could be turned off, and factories could produce less – and hire fewer workers. Costs here include the loss of energy services – colder homes, darker homes – as well as lost jobs, decreased wages, increased transportation time (as people are forced to turn to mass transit), reduced productivity and gross domestic product, and impaired competitiveness in a global marketplace where other countries and companies are not required to operate under the same restrictions.

A second way to reduce near-term energy use would be to prematurely scrap energy services capital equipment currently in use – cars, home heating systems, factories or power plants – and replace them with new, more efficient equipment, even though the existing equipment still works perfectly well. The scrapping decision is one that consumers and businesses actually face every day. Sometimes equipment must be replaced because it begins to operate poorly – or not at all – and high repair costs make it cost-effective to totally replace the failing equipment with new technology. Other times, energy savings from more efficient new equipment – plus possible improved energy services – make it cost-effective to scrap existing capital equipment and pay for new equipment.

However, replacing fully functional energy services equipment can be expensive. For the individual, replacing a home heating furnace every ten years, when the furnace could last twenty or more years, means doubling household expenditures on the capital equipment that keeps the house warm. Doubling the money spent on home heating equipment means this money is not available to meet other needs like food, clothing, children's education, healthcare, retirement savings, vacations or a new roof.

Yes, some money might be saved because new equipment is more efficient than the prematurely scrapped equipment. But that choice is already being faced on a daily basis: homeowners can buy new furnaces any time they want. The fact that many tend to use them for their full expected lifespan, and forego possible energy savings during the last half of a twenty-year equipment lifespan, reflects a consumer's decision that the certain costs of early replacement are greater than the hoped-for – but somewhat speculative – benefits of energy savings from theoretically more efficient equipment. It may take 10 to 20 years for a homeowner to recoup his investment in a new car or furnace, via savings on fuel bills – and before that time is up, she may have to replace the equipment again, because it is malfunctioning or government has imposed still more energy and emission reduction mandates.

There is also the so-called "leapfrog" factor. If your furnace is ten years old and you expect it to last another ten years, you could still buy a new furnace today. But that means you are locking yourself into today's technology. If you continue to use your existing furnace for awhile longer, expected improvements in technology mean that the furnace you buy ten years from now will be more efficient than a furnace you can buy today. By not buying today, you can "leapfrog" current technology and get better technology in the future, thereby saving yourself more out-of-pocket expenditures today.

Businesses face similar problems. Companies invest in capital equipment to make products (aluminum, electricity, food, lamps, cars or furnaces), because the sales of those products can more than pay for the capital equipment over its expected life. Like homeowners, businesses continually balance the cost of buying new equipment against the gains of having more efficient equipment. But whenever existing capital equipment is prematurely scrapped before it pays for itself, the business loses money – something businesses cannot sustain and keep paying employees and shareholders or investing in other, equally important technologies.

When evaluating whether to switch from fossil fuels to wind or solar power, for example, companies, families and nations must also consider reliability, environmental and other economic costs. While switching to wind power would certainly reduce fossil fuel use and GHG emissions, for example, it could also increase risks of power failures at critical times and would also bring new environmental impacts. A single modern 555-megaWatt gas-fired power plant in California, for instance, generates more electricity each year than do all 13,000 of that state's wind turbines. The gas-fired plant requires 15 acres of land. The wind turbines impact over 105,000 acres, affect scenic vistas, and kill over 10,000 raptors and other birds annually.[4]

Yet another cost involves what many would call the wasteful premature destruction of valuable machinery that required enormous expenditures of expertise, manpower, energy and raw materials (metals, plastics, glass) to produce in the first place. Doing this on a broad, national scale – to address concerns about theoretical climate change – would mean sacrificing enormous quantities of valuable natural resources.

If indeed it would take "40 successful Kyoto climate treaties" to control the rise in global temperatures, as scientist Jerry Mahlman of the National Center for Atmospheric Research claims, the societal, economic and natural resource impacts would be incalculable.[5] Each successive treaty would impose additional constraints on energy use, electricity generation, jobs and economic development – and each would likely face increasing resistance.

In short, individuals and businesses alike face many of the same fundamental choices:

- Maintaining basic energy services;
- Balancing continued use of existing equipment against the combination of expenditures on new equipment and potential energy savings from that new equipment;
- Delaying investments in new capital equipment in order to purchase even more efficient equipment that will be available in the future;
- Living within a budget;
- Investing in other emerging or better technologies that will address other needs; and
- In the corporate arena, remaining competitive in a tough global economy; and meeting obligations to family members, employees, customers, shareholders and retirees.

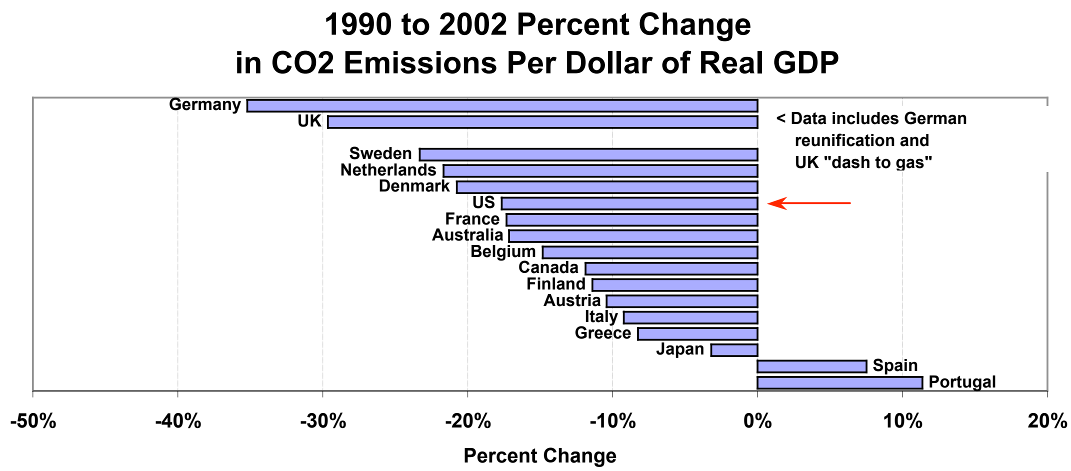
Encouraging investment and R&D to increase energy efficiency

An underlying motive for improved energy efficiency is cost savings, but improved efficiency also results in reduced greenhouse gas emissions. As **Figure 11-2** shows, most major Western countries demonstrate reductions in their CO_2 Intensity (carbon dioxide emissions divided by constant dollar economic output) and improvements in efficiency, despite widely different national circumstances and approaches to climate issues. Basically, competitive economic pressure for continuing improvements in efficiency also generates continuous incremental reductions in CO_2 Intensity (although not necessarily an overall reduction in CO_2 emissions).

Figure 11-2 illustrates the significant, rapid reductions in CO_2 Intensity by many nations. However, for at least two countries those achievements reflect very unique national circumstances. Germany's reunification allowed it to claim credit for closing down hundreds of antiquated high-polluting factories in the former East Germany; and the United Kingdom's extensive switch from older coal-fired power plants to new natural gas units in the early 1990s resulted in significant reductions in CO_2 emissions.

It is also interesting that the reductions in the United States' CO_2 Intensity between 1990 and 2002 – with the U.S. emphasis on *voluntary* and *efficiency* approaches to reducing greenhouse gas emissions growth – has exceeded that of Japan and many EU countries. In this regard, it is important to remember that an underlying factor determining the rate of reduction in a nation's CO_2 Intensity is the rate of investment in new energy services capital equipment, and the increasing efficiency of that equipment. U.S. companies continue to make such investments as a normal part of doing business and keeping their competitive edge.

Figure 11-2. Significant, Rapid Reductions in GHG Intensity by Selected Countries



Source: EU CO_2 emissions data from EEA – Annual European Community greenhouse gas inventory 1990-2001 and inventory report 2004 – Submission to the UNFCCC Secretariat. Other countries from inventory report on UN-FCCC Secretariat Internet site. Excluding LUCF. Real GDP from Energy Information Administration, International Energy Annual 2002.

The WEFA study and many other studies make it clear that the long life of energy services capital stock and the large cost of that equipment are major factors in the high costs of rapid reductions in energy use.

To encourage companies to make such expenditures without incurring the high costs associated with rapid near-term mandatory reductions in emissions and CO_2 Intensity, nations can consider two basic policy options that have important longer-term implications:

- Improving incentives for individuals and companies to invest in new, more efficient capital equipment – relying on the marketplace to determine which circumstances and which investments make the most sense; and
- Investing in research and development themselves, or providing incentives for companies to do so, to fundamentally improve equipment investment options in the future.

For example, every nation has tax policies concerning depreciation that directly affect investment decision-making by businesses and even individuals. Improving depreciation schedules allows companies to write off energy services capital equipment more rapidly and improves the cost-effectiveness of investments in newer equipment.

Of course, short-term investments in capital equipment must be made from among technologies that exist today. But there are ways to improve choices available in the future. For example, tax policies that reduce the net cost of research and development to companies will tend to increase R&D and speed technology improvement.

However, research in fundamentally new technologies raises unique risk/reward problems for many companies. Research into new technologies that generate electricity by gasifying coal – while also capturing and sequestering carbon emissions – for example, may be too risky for individual electric generating companies. In cases like these, government/private sector partnerships may bridge the gap between the socially desirable levels of R&D and what is achievable by the private sector alone.

Both cases naturally have implications for a nation's budget and tax revenues – and thus for programs that depend on such revenues. Any policy that encourages private sector investment in research and development, uses depreciation schedules to spur corporate conversion to new equipment, or fosters the creation of public-private partnerships, does so only by reducing tax revenues and/or by spending tax revenues on new government programs. The full range of costs and benefits, and the impact on the public interest as a whole, must therefore be carefully and thoroughly addressed before such decisions are made.

Conclusion

We must consider both the costs and benefits of policies that promote reduced use or rapid turnover of capital equipment.

Many scientists and politicians believe rapid, catastrophic global climate change is a very real possibility that must be addressed by quickly reducing greenhouse gas emissions. Others point out that major shifts in the world's climate have occurred throughout the Earth's history, say the verdict is still out on the nature and extent of human-induced climate change, and argue that there is little evidence to support theories of imminent disastrous change.

Still others note that even full compliance with the Kyoto Protocol would neither stabilize GHG emissions, nor delay or reverse potential climate change. It would, however, dramatically alter the amount of energy we use, the ways we generate that energy, and the jobs and lifestyles supported by that energy. Enacting a series of climate treaties, each one more stringent than its predecessors, in an effort to reduce GHG Intensity by developed and developing countries, would have significant and far-reaching implications for society, and especially for poor people and those on fixed incomes.

Among the approaches that have been proffered to reduce greenhouse gas emissions are policies that require or encourage major reductions in the use of existing equipment – or the replacement of expensive equipment long before its useful life has ended. Either approach will help reduce emissions. However, both will affect quality of life, heating and air conditioning options, tax revenues, gross domestic product, corporate profits and competitiveness, employment levels, research and investment in other technologies, and financial resources available for shareholders, retirees and those dependent on government programs.

Efficient economic activity already carefully matches desired energy services with the minimum amount of energy needed to run equipment designed to meet corporate, government and societal needs. Near-term policies that seek to rapidly reduce fossil fuel use clash with the long-lived nature of costly energy services capital equipment. These costs may or may not be offset by energy savings, emission reductions or a stabilized climate.

Climate policies that take a longer-term view can avoid the premature scrapping of equipment and related costs to society. Policies that promote research and development to improve the efficiency of future energy services equipment – albeit at some direct or indirect use of society's tax dollars – also have the potential to ensure improved living standards for growing populations with even lower emissions than would have occurred without well designed R&D.

About the author

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Notes

1 International Energy Agency report *Toward a Sustainable Energy Future*, 2001, page 233.

2 See WEFA, Inc., *Global Warming: Capital Stock Constraints on Meeting Near Term Targets*, December 2000.

3 WEFA, *Global Warming: Capital Stock Constraints on Meeting Near Term Targets*, 2000, page 5. Figures are intended to illustrate typical lifespans, for which there will always be exceptions. For example, some hydroelectric power plants are over 90 years old.

4 Joel Darmstadter, *The Role of Renewable Resources in U.S. Electricity Generation – Experience and Prospects*, Resources for the Future, Climate Change Issues Brief, No. 24 (September 2000).

5 Tim Appenzeller and Dennis Dimick, "The Heat Is On," *National Geographic*, 2004, page 11, quoting Mahlman.

Chapter 11

CUTTING GLOBAL GREENHOUSE GAS EMISSIONS BY EXPORTING TECHNOLOGICAL SOLUTIONS TO DEVELOPING COUNTRIES

W. David Montgomery and Roger Bate

Introduction and overview

Whether the world ever ratifies the Kyoto Protocol is quickly becoming irrelevant. Few European nations that ratified the convention are reaching their targets. Meanwhile, developing countries are not required to comply with Kyoto – and say they will never participate in targets and timetables, since such restrictions would retard their economic growth. Because developing countries are likely to emit well over half of future greenhouse gases (GHGs), limiting emissions while fostering economic development would appear to be a more promising strategy.

Stabilizing or even reducing global concentrations of GHGs will require two closely related actions: research and development to create new technologies that are more energy-efficient than those now used in developed countries; and effective action to spread these technologies to developing nations. Until these new technologies are available, significant savings in energy use and carbon emissions could be achieved by transferring current Western technology to developing countries. These actions will not merely reduce global emissions, but will also improve living standards and hope for the future in developing countries.

However, significant barriers impede the transfer of existing and future technologies, and thus the improvement of overall economic conditions. One of the most important is lack of economic freedom – marked by restrictions on personal choice, voluntary exchange and open markets The prospect of simultaneously reducing poverty, increasing energy efficiency and cutting pollution makes a compelling argument for developed countries to take a new approach to forging partnerships with developing countries: one centered on improving economic freedom in a way that encourages smoother technology transfers and faster economic growth.

Developing countries know increased energy use is a prerequisite for the economic development needed to combat the major problems they face today, including poverty, disease, famine, unemployment and violent conflict.[1] Can improved technologies help them reduce energy use per unit of economic output, and thus lower greenhouse gas (GHG) emissions – to produce greater wealth, health and environmental quality? If so, what policy changes are necessary to encourage technology transfers and increasing partnerships with developed countries?

Economics, energy and emissions

Growth requires energy, and countries with low income per capita use little energy per capita. As **Table 11-1** shows, all developed countries together produce about 15 billion metric tons of carbon dioxide per year, or 10.8 metric tons per capita. By comparison, developing country emissions total about 9 billion metric tons of carbon dioxide, with per-capita emissions of about 1.9 metric tons. The disparity in per-capita emissions, based in large part on widespread poverty, is a primary reason that developing countries resist suggestions that they should in any way limit their economic growth to reduce their greenhouse gas emissions.

Table 12-1. Carbon dioxide emissions: per-capita measures and shares

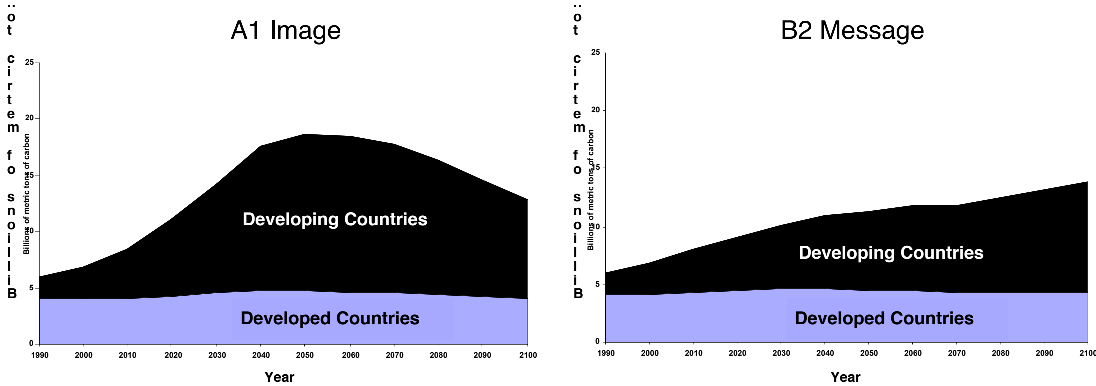
	Carbon dioxide emissions		
	Per capita (metric tons)		*Share of world total (%)*
	1980	*1999*	*1999*
Developing countries	*1.3*	*1.9*	*36.6*
Least developed countries	*0.1*	*0.2*	*0.5*
Arab States	*3.0*	*3.7*	*4.0*
East Asia and the Pacific	*1.4*	*2.3*	*17.9*
Latin American and the Caribbean	*2.4*	*2.5*	*5.4*
South Asia	*0.5*	*1.1*	*6.4*
Sub-Saharan Africa	*1.0*	*0.8*	*2.0*
Central and Eastern Europe and the CIS		*7.2*	*12.5*
OECD	*11.0*	*10.8*	*51.0*
High-income OECD	*12.2*	*12.3*	*46.4*
High human development	*10.9*	*10.8*	*53.5*
Medium human development	*1.3*	*2.3*	*38.3*
Low human development	*0.4*	*0.4*	*1.0*
High Income	*12.2*	*12.4*	*48.2*
Middle Income	*2.3*	*3.2*	*35.9*
Low income	*0.5*	*1.0*	*10.3*
World	*3.4*	*3.8*	*100.0*

Source: UN Development Program, Human Development Reports 2003

It is critical that realistic engagement with the needs of developing countries take place, because it is impossible to address perceived risks of climate change without making substantial changes in how developing countries use energy. Although developing countries have low per-capita emissions, they have huge populations. The rapid growth of this already large population leads to the paradox that developing countries will contribute the bulk of greenhouse gas emissions over the next century.

Figure 12-1 depicts GHG emissions over the next decade, in tons of carbon equivalent. It shows that, under a wide range of scenarios developed by the UN scientific advisory group, the Intergovernmental Panel on Climate Change (IPCC), GHG emissions by developing countries will exceed those from developed countries by a factor of two or three over the next century. The A1 image and B2 message scenarios illustrate the high and low ends of the range of forecasts for cumulative GHG emissions and the share due to developing countries (IPCC *Special Report on Emissions Scenarios*).[2]

Figure 12-1. Emission scenarios show developing countries will have the largest share of future emissions



Source: IPCC SRES Image A1 and Message B2 Scenarios

The question is how this engagement can be accomplished. Developing countries clearly and rightly place the highest priority on dealing with current problems that pose real risks to life and health – disease, poor nutrition, inadequate sanitation and poverty itself. These problems can be alleviated only by rapid economic growth and the infusion of modern technology. Thus, engagement on climate will be possible only if the route to bringing down projected GHG emissions simultaneously contributes to economic growth.

To begin to develop answers, one must first understand how developing countries use energy in comparison to developed countries, and how changing energy usage is connected to economic growth. A second component is a grasp of our current knowledge of key requirements for economic growth, and of policies that can simultaneously advance economic growth and begin to effect large-scale changes in how energy is used.

Energy use and economic growth in developing countries

A key fact about energy use and carbon emissions in developing countries emerges clearly from historical statistics:

Energy use per dollar of output (energy intensity) and greenhouse gas emissions per dollar of output (emissions intensity) are far higher in developing countries than in developed countries.

Both energy intensity and emissions intensity are improving in developing countries. However, even the modernizing sectors of developing countries have energy and emission intensities that are much higher than is typically seen in developed countries.[3]

The theory of economic growth based on technological progress originated with studies by Solow (1956 and 1957) and Swan (1956). It helps determine the extent to which key developing countries continue to lag behind industrial countries in their energy and emissions intensity. Solow and Swan introduced the key notion of "embodied technical change" –

- The level of productivity is built into capital equipment, as is their level of energy use and emissions output, and
- New technologies can be brought into play only through new investment.

The subsequent growth literature suggests that technical change is a key component of growth. The theory reinforces the empirically demonstrable idea that new technologies, embedded (or embodied) in new equipment, increase labor productivity, improve energy efficiency, and reduce carbon emissions. To achieve these improvements, nations must retire old and install new equipment embodied with better technology.

Bernstein *et al.* (2004) used this approach to examine the historical record for economic growth and emissions reduction. They found a clear lag in technology advancement and emission reduction in many developing countries, even in the midst of new investment. For example, China grew at 7.6 percent annually between 1995 and 2000, and its emissions grew at an annual rate of 4.5 percent. This clearly suggests that China's new investment incorporates technology that is more energy-efficient and produces fewer carbon emissions than does its installed base.

However, when Bernstein *et al.* combined these growth rates with information on the level of investment, estimated life spans of capital equipment and other macroeconomic indicators, they found an energy/GDP ratio associated with new investment that thus far is not encouraging. The results for China, and similar calculations for India, the United States and Japan, are summarized in **Figure 12-2.** China is rapidly improving its energy/GDP ratio, but its new investment is still characterized by much higher energy use per dollar of output supported by that investment, than is the case for the United States or other OECD countries.

Figure 12-2. Greenhouse gas emissions per dollar of output

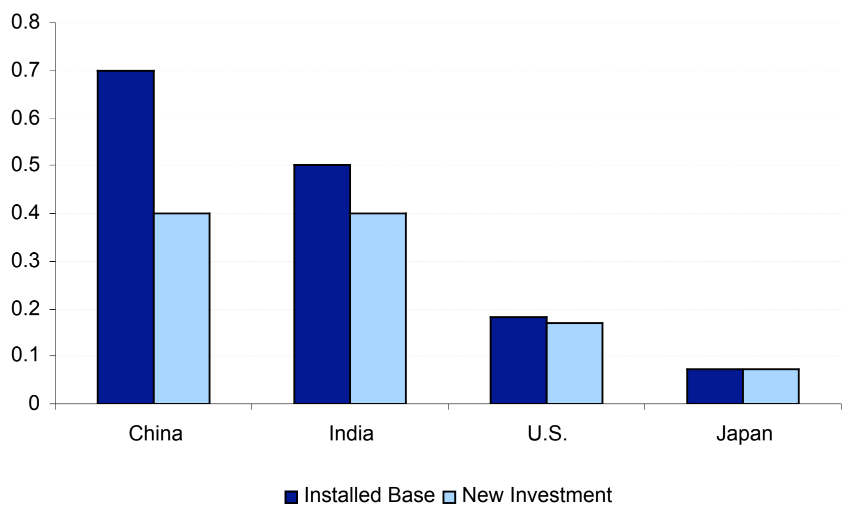


Figure 12-2 shows that in 2001 emissions intensity associated with the installed base (old equipment) substantially exceeded emissions intensity associated with new investments in China and India. China produced on average about 0.7 million tons of carbon emissions for every billion dollars of GDP produced from old equipment (measured in constant U.S. dollars at market exchange rates), and about 0.4 million tons of carbon emissions for every billion dollars of GDP from new capital equipment.

India produced about 0.5 million tons on average from old capital, and 0.4 million tons per billion dollars of GDP from new capital.

In contrast, the United States produced less than 0.2 million tons per billion dollars of output and Japan under 0.1 million tons, from old and new equipment alike. Indeed, even new equipment in China and India had emissions intensities more than twice that of old and new equipment in the United States.

These findings suggest that there is significant potential for reducing emissions from developing countries, by increasing the rate of investment in modernization and capital turnover. Even now, this is reducing emissions intensity and improving the technology embodied in new investment to levels comparable to those in developed countries. Although China has continuously improved its energy efficiency, historical evidence shows that the embodied technology in new investment in China and India has not yet caught up to the West. It is here that the greatest potential for marked environmental improvements exists.

Our finding – that even new investment in developing countries embodies far lower energy efficiency and pollution control than new investment in developed countries – suggests that global emissions can be efficiently reduced by stimulating additional investment in developing countries, to replace their existing energy-inefficient technologies with more energy-efficient ones. These countries could achieve higher energy efficiency on par with developed countries, if modern technology were transferred more rapidly.[4]

There are immediate benefits from making this transition.

If just China and India were able to utilize new investments to adopt the technology now used in the United States in their new investments, and were to accelerate the replacement of their existing capital stock with its high built-in emissions, the resulting savings in carbon emissions by 2012 or 2017 would be significant. In fact, Bernstein *et al.* (2003) estimate the savings would be comparable to the emission reductions that could be achieved by the Kyoto Protocol over the same period *if all Annex B parties met their original commitments.*

In the real world, in which Kyoto commitments are likely to be met by relatively few countries, the emission reductions available through improving technology in developing countries dwarf those achievable in the developed countries.

The question is, can this potential actually be achieved – and in a fashion consistent with the development goals of developing countries? The key to answering this question is found in another question: Are lack of economic freedom and remediable market imperfections in developing countries responsible for the observed differences in technology?

Choice of technology in developing countries

Western countries also differ in their energy efficiency and GHG emissions per dollar of GDP. Japan's emissions per dollar are about half those of the United States – but they are influenced in part by its more limited available energy resources, higher population density, and a series of government policies that tax auto fuels and vehicles highly. Moving the United States to the Japanese level of efficiency would likely impose high costs on the United States. The United States has a free and efficient set of markets, whose operations lead to cost-effective choices about energy use – in the sense that the cost of investments to save additional energy, or use less coal and more renewable energy, would be greater than the market value of energy saved (Cameron et al. 1997 and Jacoby 1998).

Can developing countries also make cost-effective energy technology choices – or do they suffer from market imperfections that hinder such choices? If the latter is true, it should be possible to implement policy changes that benefit economic development and reduce GHG emissions.

As **Figure 12-2** shows, new investment in China and other developing countries clearly does not incorporate world-class technology. What is responsible for these differences in technology?

One theory holds that that optimal allocations (including energy technologies) will have occurred, given supplies of labor, capital, energy and other factors. Under this theory, in order to slow emissions growth in developing countries, it is necessary to undertake costly measures to restrict energy use or deploy expensive renewable energy technologies to replace fossil fuels. If these countries are already using energy optimally, given their resource endowments, then any change will entail a cost, just as it does in advanced, free market economies. These changes in patterns of energy use will occur only if forced by a policy regime that limits or penalizes GHG emissions.

This is the fundamental idea behind the notion that the best way forward under the Kyoto Protocol (and beyond) is for developing countries to agree to emission limits and participation in the international emission-trading system. This theory views participation in international emission trading as a means of providing compensation to developing countries for the additional costs they would have to incur. The inducement would be to make those emission limits sufficiently higher than projected emissions growth, that developing countries could sell their excess permits and use the proceeds to cover the cost of emission reductions.

This is the same concession that Russia negotiated for the first commitment period, with an emission cap considerably greater than its actual emissions. Russia can profit from selling the excess permits, which have come to be referred to as "hot air," to other countries – the European Union, Japan and Canada in particular – that need the permits because they cannot meet agreed emission limits on their own without great economic cost.

To some extent, this approach shifts the burden of paying for emission reductions in developing countries to the developed countries that will buy the permits. But the cost remains, and developing countries doubt that adequate compensation for restraint on growth will be provided, since the required scale far exceeds current aid budgets and the willingness of developed countries to make large-scale wealth transfers. They also rightly perceive that this system will systematically slow their industrial development and put their future well-being at the mercy of the developed countries' willingness to continue making these transfers.

Fortunately, existing market failures in developing countries strongly suggest that it is possible to involve these countries in a process of improving their well-being, while simultaneously reducing their GHG emissions. First, it is far from clear that energy is currently used optimally in developing countries.

Second, there is also strong evidence from a variety of sources that developing-country markets do not function as freely and effectively as those in the developed countries of the world, and that lack of economic freedom is a major reason why they remain poor and underdeveloped. Third, there is very strong evidence that market imperfections in developing countries explain why their energy use and carbon emissions per dollar of output are so high.

If this is the case, then cooperative efforts to remove these market imperfections and improve economic freedom can be highly effective in reducing GHG emissions, as well. The analysis presented in Chapter 11 examines some of the recent comprehensive studies of economic freedom and market institutions throughout the world – and presents evidence that underscores the extent and importance of market imperfections.

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Notes

1 The Copenhagen Consensus Project, founded by "skeptical environmentalist" Bjorn Lomborg and run by some of the world's best known economists, recently considered GHG-emission reductions a "bad" policy investment (especially as compared with combating disease, lowering trade barriers and dealing with chronic water problems). This study is available at www.copenhagenconsensus.com. The World Summit on Sustainable Development (WSSD) reaffirms the need to have balanced economic development, social development and environmental protection. It also reaffirms poverty eradication and preservation of the environment as the overarching objectives of sustainable development (United Nations 2002).

2 A1 IMAGE and B2 MESSAGE are two representative scenarios from the 40 scenarios developed by IPCC using different forecast assumptions of the state of the world. The A1 storyline is based on a rapid and successful economic development, whereas the B2 scenario takes into account increased environmental and social sustainability concerns.

3 The energy intensity differences could also result from differences between the structure of developed and developing countries' economies.

4 Z. Zhang (2003) points out that the shift in the structure of economies from energy-intensive to less-energy-intensive caused real energy intensity to decline over the past two decades. Fisher-Vandan *et al*. (2003) suggest that the main reasons for improvement in energy use in China are increasing energy prices, research and development expenditures, reform in the ownership structure of the enterprise, and structural shifts at the industrial level.

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Chapter 12

A (MOSTLY) PAINLESS PATH FORWARD: REDUCING GREENHOUSE GASES THROUGH ECONOMIC FREEDOM

W. David Montgomery and Roger Bate

Freedom brings wealth

Ever since Adam Smith asserted in 1776 that freedom from government intervention is essential for economic growth and thus the wealth of nations, economists have attempted to gauge the relative importance of various factors that generate growth. These variables include economic factors, such as private and government spending, flexibility of tax regimes, and investment in the form of domestic or foreign capital. Broader societal parameters are also essential: fundamental social, legal and political institutions, the rule of law, property rights, and enforcement of contracts.

Clearly, numerous variables and indicators can be linked to economic development. In assessing any nation's economic health and wealth-generating capacity, various research studies argue for the importance of judicial independence (Berkowitz 2000); the impartiality and integrity of court systems (Sen 2001); the level of overall governance (Kaufmann and Mastruzzi 2003, Kaufmann and Kraay 2003); the adequacy of business and economic laws and regulations (WDR 2002); the protection of investment and recognition of ownership of intellectual property rights (Maskus 2000); an increase in openness to internal markets (Antweiler et al. 2001); the development of enabling investment climates, policies and institutions (Moran 1998); and basic political freedom (Friedman 1962, North 1990). Dawson (1998) provides strong empirical evidence that confirms the relationship between institutional visibility and economic growth, as well as the causal effect of economic freedom on both political and civil liberties.

To gain a better understanding of the connection between economic freedom and economic welfare, various researchers have compiled detailed data on over 120 countries into what they call "indices of economic freedom." These indices identify not only the prime motivators of wealth creation – but also the market imperfections and distortions that prevent developing countries from accessing and adopting the technologies that produce low emissions per dollar of output in the West.

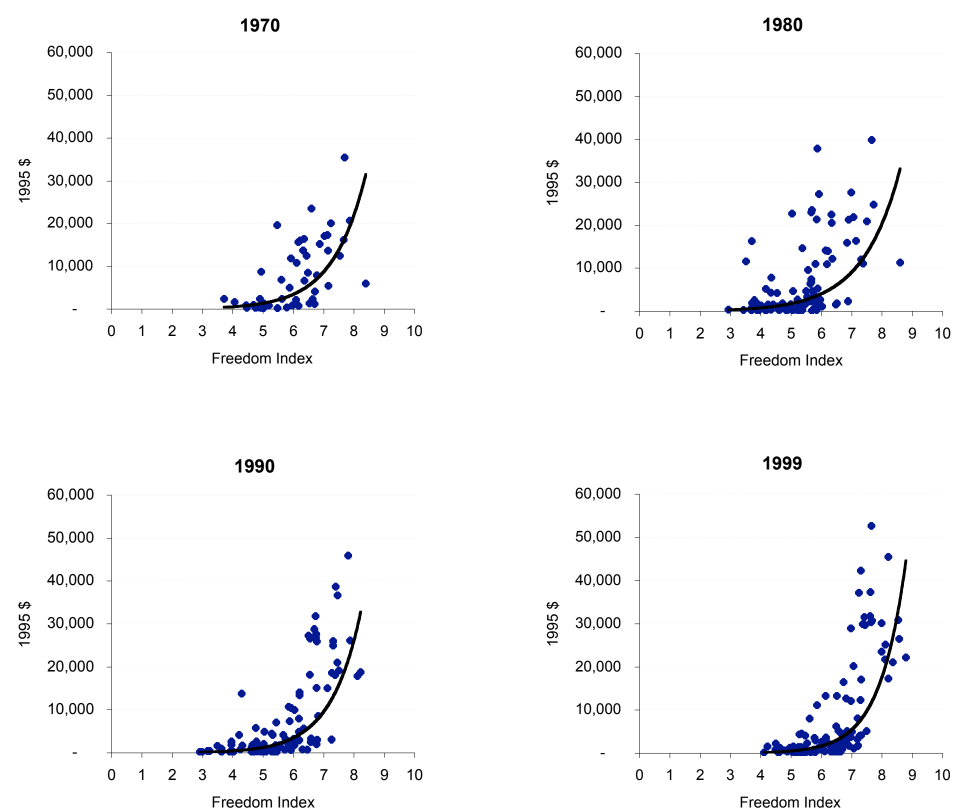
Data from the Economic Freedom of the World (EFW) index developed by the Fraser Institute make it possible to investigate whether economic freedom has a strong influence on the energy technology used in a country.[1] The index correlates positively with measures of income per capita, economic growth, the UN Human Development Index, and longevity. It correlates negatively with indexes of corruption and poverty. The Fraser report's analysis demonstrates that the correlation is most likely causal and the direction is certain – overall freedom drives development. This conclusion has also become one of the central lessons of modern development economics.

A recent *Economic Freedom of the World Annual Report* examined 128 countries in 2001, and concluded that:

- "Economic freedom is highly correlated with per-capita income, economic growth, and life expectancy."
- "Economic freedom continues to gain ground around the world. Based on the 10-point scale of this index, the average economic freedom rating was 6.35 for 2001, up slightly from 2000's average rating of 6.34. However, this compares well with the average rating of 5.96 in 1995. Economic freedom decreased through the 1970s, falling from 6.07 in 1970 to 5.36 in 1980. It has been on the rise since then."
- "Hong Kong retains the highest rating for economic freedom, 8.6 of 10, closely followed by Singapore at 8.5, the United States at 8.3 and New Zealand and the United Kingdom, both at 8.2. The rankings of other large economies out of 123 countries are: China, 100; India, 73; Brazil, 82; and Russia, 112."
- "Most of the lowest-ranking nations are African, Latin American or former Communist states." [2]

Economic freedom and per-capita income are closely related. **Figure 13-1** illustrates the close association of these variables over the past three decades and reaffirms the relationship.

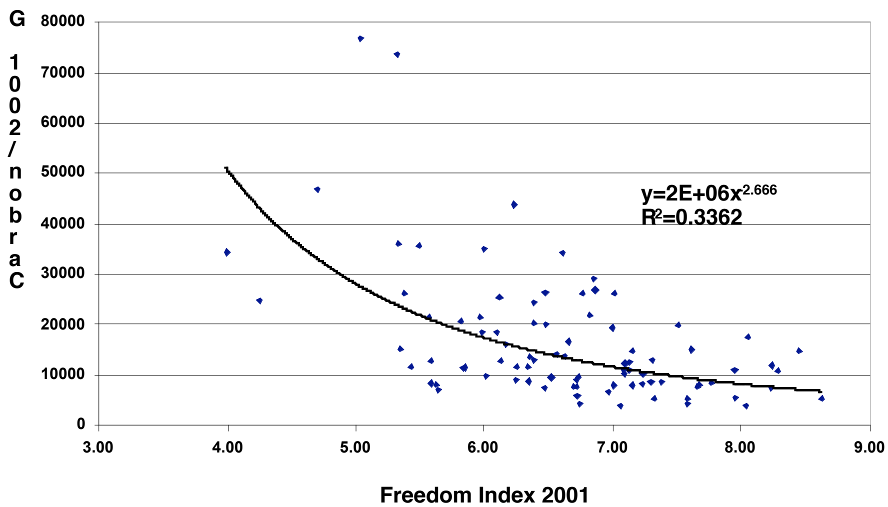
Figure 13-1. Economic freedom compared to GDP per capita



Source: Economic Freedom of the World, Annual Report 2003 and World Development Indicators, World Bank, 2000.

The connection between GDP per capita and economic freedom is striking. It suggests asking whether economic freedom is also related directly to energy efficiency and carbon emissions per dollar of GDP. And indeed there is an equally striking connection between levels of economic freedom and key indicators of how efficiently energy is used in developing countries. **Figure 13-2** illustrates the remarkably close association between the EFW index and energy use per dollar of output, using the cross-country data for 2001. Of the 128 countries in the EFW index, forty-eight provided energy use and GDP data that were available from the U.S. Energy Information Administration.

Figure 13-2. Economic freedom compared to energy per dollar (Btu per 1995 $) of GDP (2001)



Economic freedom reduces energy use and pollution

Countries with low economic freedom scores have above-average energy use, and vice versa. **Table 13-1** illustrates this relationship with data for five economies – four developing countries and one economy in a transition country (Russia) .[3]

Table 13-1. Energy and carbon per GDP for five countries

Country	Energy per GDP (Btu per 1995 $)	Carbon per GDP (MMTC per 1995 $b)	GDP per capita (Thousands of 1995 $)	Freedom Index
China	36,578	0.77	0.9	5.49
India	27,053	0.54	0.5	6.12
Indonesia	20,376	0.37	1.0	5.57
Russia	75,546	1.15	2.5	5.04
South Africa	25,568	0.58	4.0	6.77

Source: Energy Information Administration, International Energy Annual, 2002

Table 13-2. Market imperfections with the strongest influence on energy intensity

Explanatory Value	Parameter Estimate	t-Value
Constant	109541	5.6
Transfer and subsidies as a share of GDP	-3478	-2.6
Government enterprises and investment as a share of gross investment	-1425	-1.6
Hidden import barriers	-6548	-3.3
Restrictions in foreign capital market exchange	-435	-0.5
Time with government bureaucracy	-2704	-1.5
$R^2 = 0.36$		

Source: Energy Information Administration, International Energy Annual, 2002

Statistical analysis of the two data series reveals that the Economic Freedom Index explains over 36 percent of the variation in energy use per dollar of GDP across countries – a very high percentage for cross-sectional data of this type. (See **Table 13-2** for the R^2 value.) The relationship between the Freedom Index and greenhouse gas (carbon) emissions per capita likewise reflects an association that is nearly as strong.

Furthermore, when developing countries are compared, there is a strong relationship between the Freedom Index and energy and emissions intensity: the Freedom Index has similar ability to explain differences in energy and emissions intensity among developing countries. That is, the overall relationships between economic freedom and energy, or between economic freedom and emissions per dollar of GDP, are not based solely on comparing developed and developing countries. Even among developing countries, a country with a higher freedom index is likely to have significantly lower energy use and emissions per dollar of GDP.

There are several causal routes through which greater economic freedom could lead to lower energy use and emission per dollar of output. Some researchers have concluded that this is achieved by improving economic well-being *per se*. Others have addressed the question of wealth and GHG emissions by analyzing the relationship between per-capita income and GHG emissions per dollar of output. Schmalensee *et al.* (1998) find that there is a relationship, and that emissions per dollar of output increase until a middle level of per-capita income is reached, and then begin to decline. The "inverted U" pattern often referred to as the environmental Kuznets curve is based on Simon Kuznets' studies of how demand for various goods changes as income increases. Schmalensee and his colleagues find evidence for an *environmental* Kuznets curve in the existence of a within-sample peak in carbon dioxide emissions per capita as per-capita income continues to rise over time.

Developing countries with low levels of income tend to display accelerating growth of emissions, while developed countries generally have an emissions growth trend that is relatively flat or may even be decreasing. None of these studies included indicators of economic freedom as explanatory variables. The relationship identified by Schmalensee *et al*. suggests that increasing per-capita income is associated with economic changes that increase energy and emissions intensity in the short run for developing countries. Rising per-capita income thus works in the opposite direction to the relationship found between economic freedom and energy or emissions intensity.

The adoption of technology is also a specific process of supply and demand. Countries that are successful in growing rapidly also benefit from the diffusion of energy production and emission control technology throughout their economies and from the establishment of modern business and production techniques that displace traditional practices and outdated equipment. All countries start with a legacy of plant, equipment and infrastructure from pre-market, pre-industrial or centrally planned eras. More rapid investment speeds the process of replacing this legacy with more efficient capital equipment.

Economic freedom promotes and accelerates all these processes. Market imperfections that hinder investment – particularly foreign direct investment or FDI – discourage outside investors from transferring their best technologies. Imperfections that protect domestic industries from competition likewise frustrate the economic changes that lead to lower energy use and carbon emissions.

Evidence shows that modern technology used in developed countries is not being adopted in developing countries, even when they are installing new facilities and equipment. Acquiring new technology requires replacing old capital with new capital through higher rates of investment, by domestic or foreign entities. For most developing countries, foreign direct investment has been the engine for more rapid technological progress. The technology from developed countries diffuses to developing countries largely through the process of FDI or aid from individual countries and multilateral institutions (official development assistance, or ODA), though FDI dwarfs ODA in magnitude.

However, various market barriers often delay or block that investment and technology transfer. If there are obstacles to the inflow of foreign investment or disincentives to using more cost-effective technology, there will be less transfer of technology to developing countries. Similarly, if developing country policies distort factor prices, via subsidies for energy use or protection of domestic industries, for example, the adoption and diffusion of technology will be hampered. The Freedom Index also includes data on these types of obstacles to FDI and domestic market imperfections relevant to the choice of energy technology.

Since economic freedom increases per-capita income and also reduces GHG emissions per dollar of output, it is indeed difficult to disentangle the effects of greater economic freedom that work through increased income from those that work by removing market imperfections that hinder technology transfer. One simple way to assess this is to include per-capita income as an explanatory variable for emissions per dollar of GDP.[4] Although not as sophisticated as Schmalensee *et al.*, this test reveals that economic freedom, as measured by the Freedom Index, continues to have a significant effect on emissions over and above that of per-capita income.

Effects of market imperfections on energy technology

Figure 13-1 and **Figure 13-2** tell a very clear and important story. Economic growth improves income per capita and is stimulated by economic freedom. Economic freedom is also associated with much lower energy use per dollar of output, and lower energy use per dollar of output translates into lower emissions of greenhouse gases per dollar of output. The converse is also true.

Understanding this effect requires a closer look at how energy is used in developing countries and how those patterns of use are caused by lack of economic freedom. Doing this requires looking more closely at the components of economic freedom that have the most influence on energy choices.

The same set of market imperfections that slow progress of economic and overall social well-being are connected with high carbon emissions per dollar of GDP.

The following components of the Economic Freedom Index can directly influence the energy technology used in a country:

- Pricing distortions remove the incentive to adopt cost-effective technologies, by distorting internal pricing mechanisms, reducing market size and viability, and imposing subsidies administered through State-run enterprises.
- Internal policies make markets inhospitable to foreign investment that could provide world-class technology, by failing to provide adequate contract law, protection of real and intellectual property rights, infrastructure, and education and skills to handle modern technology; and by protecting inefficient industries or restricting the free flow of funds into and out of a country.

In principle, one can expect that certain of these market imperfections will slow investment, retard technology transfer in a way that impedes the development of the energy sector, and make more efficient technologies unable to compete effectively with the protected and subsidized *status quo*. These elements of economic freedom are important because the process of investment and technology transfer can be frustrated by barriers to foreign investment, pricing systems that make technologies with lower energy use less economically viable, and protection of domestic industries with their legacy capital and lack of access to world-class technology for new investment.

Barriers to foreign investment include explicit barriers, such as prohibition of foreign ownership in specific industries or regions; these are endemic in the developing world. Lack of both strong contract law and property rights protections clearly discourages foreign investment, as do excessive currency controls, since they introduce risks that expected returns will not be earned or that invested capital will be lost or not be allowed to be repatriated. Lack of protection for intellectual property discourages multinational companies from using their best technology, for fear it will be illegally copied. Protection of inefficient industries implies that even if FDI is successful in bringing in new technology, that technology will be confined to the industries in "foreign enterprise zones," where multinational companies can compete, but will not diffuse to the rest of the economy.

How market prices are formed, and whether they reflect true economic conditions and world prices or are distorted by internal regulations and subsidies, is critical to the success of the transfer and diffusion of new technologies. Most developing countries have some form of subsidized or regulated pricing of energy, with little competition. In many cases, dominant State-run enterprises administer prices far removed from economic reality through cross-subsidization of inter- and intra-industry processes, which benefit selected vested interests.

The Economic Freedom Index also includes variables that reflect infrastructure investment and access to education. Case studies of developing countries reveal that wasteful energy use is often caused by lack of gas and electricity transmission capacity, for example. This reduces the availability of the most efficient fuels and puts efficient large-scale units in competition with inefficient local power generators – driving up generation costs, increasing consumer prices, impairing electrical reliability, magnifying pollution problems, and reducing the amount of electricity that can be fed into the local or regional grid. Diffusion of technology can also be hindered by a lack of skills in the labor force, although this can often be remedied directly through FDI in which global enterprises provide training, as well as financial resources and technology.

An analysis of individual Economic Freedom Index components served as an empirical test of the theory that market imperfections are significant contributors to excessive energy use and emissions. It revealed an even more significant relationship between energy intensity and the specific market imperfections that could be expected to prevent increased investment and technology transfer through FDI. The t-statistic indicates the likelihood that the variable in fact has a significant influence. A t-statistic of approximately two implies that there is a 95 percent probability that the indicated market imperfection has an influence on energy intensity.

This combination of variables has an R-square value of 0.36, which is even larger than that for the Economic Freedom Index as a whole. In other words, this subset of variables plays an even more critical role in explaining the variance of energy intensity across countries.

A particularly useful concept for understanding the causes of economic growth is the statistical maxim that "correlation is not causation, but it's a pretty strong hint." There are strong theoretical reasons to believe that the processes that lead to lower energy use per dollar of output are frustrated by market imperfections of particular types (Bernstein et al. 2004). This theoretical connection is supported by the strong statistical association between energy use and economic freedom as a whole – and by the even stronger association between energy use and specific market imperfections that frustrate investment and technology transfer.

In fact, an examination of other explanations of energy intensity and GHG emissions per dollar of output makes it clear that none are as strong as the link to economic freedom. One possible explanation is that an increase in income (and thus standard of living) itself produces a preference for environmental benefits, and leads directly to lower emissions. This is likely true for such pressing environmental needs as clear air, clean water and efficient sanitary systems. However, a relatively weaker relationship exists between per-capita income and GHG emissions per dollar of output. Even when the analysis partially controls for the type of goods produced in different countries, there is no change in the significant relationship between GHG emissions and GDP.

Table 13-3 summarizes market imperfections that have been documented in five developing countries and one economy in transition, Russia, where emissions per dollar of GDP are similar to those of developing countries.

China's low economic freedom score indicates pervasive market distortions. The large state sector is insensitive to market pressures to improve efficiency. Subsidized energy prices remove incentives for energy efficiency and promote coal use.

China's regulation, institutional bias (Blackman and Wu 1998), and lack of protection for real and intellectual property discourage multinational companies from using their best world-scale technologies. In addition, the prevalent policy of restricting FDI only to specific enterprise zones that produce export goods means there is only limited technology diffusion through the domestic economy. The European Union's refusal to recognize China as a market economy is indicative of the extent of market imperfections in China.[5]

India's large state enterprises are likewise insulated from market forces that promote efficiency. Many domestic industries are protected and offered favored financing that allows them to continue using inefficient technology and practices without losing out to international competition. There are also restrictions on technology imports, designed to protect domestic industries, and restrictions on FDI prevent technology transfer. Energy price regulations encourage inefficient energy use, and lack of infrastructure limits the available skills for using new technology.

Indonesia combines four of the most damaging market imperfections: pervasive government enterprises indifferent to efficiency, price regulations that discourage energy efficiency, severe restrictions on FDI, and a legal and political regime that puts all investments at risk and discourages the kinds of projects that bring in new technology.

South Africa shows great promise. However, regulated prices reduce market incentives for efficient energy use, and political instability discourages foreign investment. South Africa is an interesting case, in that it also uses cheap and dirty domestic coal for power production and has an economy that is highly tilted toward energy-intensive activities such as gold and platinum mining and aluminum smelting. The modest score on economic freedom might be a reason why South Africa does not attract investment that would create greater value in mining and minerals, thereby reducing energy intensity. Its energy and carbon intensity may require both policies that address market imperfections, and research and development to find new processes and forms of energy with lower emissions.

Russia’s long list of severe market imperfections explains how such a powerful economy still lags so far in energy technology and greenhouse gas emissions.

Table 13-3. Market imperfections in key countries

Country	Market Imperfections
China	• Large state sector, party management of business, managerial tenure • Direct price controls and subsidies through state enterprises • Banks must make loans to state enterprises • FDI largely confined to Special Economic Zones and export industries, not replacing capital for domestic goods • Poor protection for property rights and contracts • Food, transport and energy prices below free market level • Investment and output figures exaggerated • FDI appears high but a large share is due to domestic savings, sent out of country and reinvested in China, but without technology transfer
India	• Large state enterprises • Restriction of some sectors to small businesses • Restrictions on FDI • Financial sector required to direct loans to specific sectors • Only partial removal of petroleum price controls • Labor regulations skew investment toward capital-intensive operations
Indonesia	• Heavy state ownership in energy and energy-intensive industries • Regulation of energy prices • Poor enforcement of property rights and contracts • Explicit barriers to FDI and intrusive regulatory regime
Russia	• Crime and corruption are pervasive • Excessive regulations discourage FDI • Restrictions on FDI in strategic sectors, including gas and power • Restrictions on repatriation of capital earnings • Energy and other prices below free market levels • Gas, electricity and telecom prices set arbitrarily • Protection of property rights and contracts is weak • Large enterprises generally limited on price increases • Inconsistent and corrupt regulation increases cost and uncertainty
South Africa	• Regulation of petroleum, coal and utility prices • Regional instability

Source: Index of Economic Freedom 2004, produced by the Heritage Foundation and the Wall Street Journal

Implications for policy makers

1. With good institutions (property rights and contracts protected, and freedom of capital flows), energy technology will become available from overseas, and it will be viable in domestic markets if subsidies are removed and protection of state-run enterprises is reduced. Inefficient technologies will be replaced faster as investment increases.

2. Traditional "sustainable development" projects sponsored by USAID and the Clean Development Mechanism (CDM) under the Kyoto Protocol will not be successful, unless these market imperfections are remedied. An approach of building one project at a time with heavy subsidies in a hostile economic environment will produce no diffusion of technology – even if the project itself succeeds.

3. One size does not fit all. Different countries have very different types of market imperfections, and in some countries emissions intensity follows logically from resource endowments. Finding the right mix of policy changes requires dialogue between individual

countries, likely starting with a diagnosis of what market imperfections exist and how they can be addressed.

4. While technological improvements improve ratios of GDP to carbon dioxide, this says nothing about overall emissions. If improvements in economic freedom are achieved, countries will grow rapidly, and their ratios will improve – but they may produce more emissions in the short run. If that occurs, more attention will need to be paid to research and development, so that emissions intensity of new investment can be brought below levels that are now cost-effective in developed countries. The good news is that by improving economic freedom, there is an excellent chance that new technologies will actually be used once they are developed.

Improving economics and emissions

The current global environmental initiative to reduce emissions is failing. It appears unlikely that policymakers will convince developing countries to do something they have no inclination to do: namely, to sign up for mandatory greenhouse gas caps that they rightly perceive will have large economic costs.

A successful policy would reconcile these nations' understandable desire for development with policies that will help reduce carbon intensity. To achieve this, policymakers could focus U.S. and international programs on measures that will encourage developing countries to change the fundamental economic conditions that simultaneously inhibit economic progress and keep greenhouse gas emissions high.

Improving economic freedom is necessary if we are to ensure the proper functioning of traditional aid programs that support investment in cleaner energy technologies. Otherwise, these projects are fighting a losing battle against an inhospitable economic and regulatory environment. As they have in the past, they will remain white elephants that exist for as long as they are paid for by donor countries.

Raising the level of economic freedom will be sufficient for most desirable outcomes, as the clear association between economic freedom and energy efficiency suggests. However, to achieve this, countries must establish the proper institutions that will promote the inflow of FDI and diffusion of new technology. Until that happens, developed countries can provide the necessary financial support on the condition of demonstrated market reform.

Improved efficiency will have beneficial affects on GDP and carbon per dollar of GDP. Whether it lowers emissions overall is not the subject of this chapter and book. However, at least helping developing countries to improve their economic growth may make them more trustful of U.S. and global policymakers when these countries are pressured to enact Kyoto-style emissions limits.

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Notes

1. The Economic Freedom Index contains thirty-eight variables, including eighteen survey-based variables obtained from survey data published in the International Country Risk Guide and the Global Competitiveness Report, which cover a variety of aspects of economic freedom and are weighted into an overall index for each country.
2. Economic Freedom of the World, Annual Report, 2001.
3. Energy per GDP, carbon per GDP, and Freedom Index for the United States are 31,695, 0.17 and 7.8 respectively (source: EIA).
4. Gross national income per capita was included as a separate explanatory variable in the regression model discussed in the next section. The explanatory power (R-square) decreased from 0.36 to 0.32.
5. The *Financial Times* (June 28, 2004) reported that the European Union will refuse "market economy" status to China. The European Commission believes that China has a long way to go, and the report identifies four major challenges: reduce government influence on the economy; implement transparent and non-discriminatory company law; implement effective and transparent property rights laws; and build an independent and market-driven financial sector.

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Chapter 13

ALTERNATIVES TO THE KYOTO PROTOCOL: A NEW CLIMATE POLICY FRAMEWORK?

Brian S. Fisher, Kate Woffenden, Anna Matysek, Melanie Ford, and Vivek Tulpulé

Overview

In the past, the earth has periodically undergone large fluctuations in surface temperatures as a result of natural phenomena, causing changes in climate and sea levels (Plimer 2001). Recently, evidence has emerged that human activity also has the potential to alter the Earth's climate (IPCC 2001a).

Since the Industrial Revolution, human activities such as burning fossil fuels and agricultural and industrial production have led to growing emissions of greenhouse gases and their increasing concentration in the atmosphere (**Table 14-1**). A problem arises because, it is argued, these higher concentrations increase the natural greenhouse effect, potentially leading to environmental and economic damage.

Table 14-1. Atmospheric concentrations of carbon dioxide, methane, and nitrous oxide

	Carbon dioxide	Methane	Nitrous Oxide
Pre-industrial concentration	**~280 ppm[a]**	**~700 ppb[b]**	**~270 ppb**
Concentration in 1998	**365 ppm**	**1,745 ppb**	**314 ppb**

[a] Parts per million by volume
[b] Parts per billion by volume

Source: IPCC 2001a, p. 38.

A number of factors make the problem a global one. First, no matter where emissions occur their effect is broadly the same, because the major greenhouse gases are well mixed in the atmosphere. Second, any resulting climate change is likely to affect all countries (although with differing specific impacts). Third, projections indicate that, while countries belonging to the Organization for Economic Co-operation and Development (OECD) will remain major emitters, the greatest growth in emissions will come from developing countries.

Responding to the climate problem poses several challenges. A key one is to design policies that balance the cost of any damage from climate change with the cost of actions to reduce that damage. The significant uncertainties surrounding the causes, nature and impacts of possible climate change magnify this challenge. A second challenge will be for countries to manage adaptation, which could involve major investments and managing economic and social change. A third challenge will be to engage all major emitters in meaningful efforts to reduce emissions. Emission abatement may involve reduced or more expensive energy use, which may hamper the development prospects of many countries. Achieving meaningful emission reductions will involve complex trade-offs between environmental and economic objectives.

The Kyoto Protocol, negotiated under the United Nations Framework Convention on Climate Change (UNFCCC), is an initial attempt to address the climate problem. The protocol is flawed, however, because it fails to meet the three principles, discussed in the next section, required for an effective response. A new path forward without the pitfalls inherent in the process that led to the Kyoto Protocol must be found.

Principles for effective policy

A policy framework to deal with the potential threats of human-induced climate change without compromising countries' capacity for development must adhere to the following three fundamental principles: it should be (1) environmentally effective, (2) economically efficient, and (3) equitable.

Environmental effectiveness

Two elements are important for environmental effectiveness.

Focus on the right environmental objective

In taking action to combat global warming it is essential to keep in mind the environmental objective. As it is the atmospheric concentrations of greenhouse gases that are understood to drive changes in global climate, the focus of the policy response must ultimately be on reducing these concentrations and not simply on the emissions of a select group of developed countries over a relatively short timeframe.

Involve all large emitters

A particularly important point in environmental effectiveness is that all major emitters need to be included in any policy response. Excluding any major emitters undermines the environmental effectiveness of abatement action in the following two ways:

1. The overall abatement effort is reduced, or the share of emission reductions to be done by others to achieve a given environmental goal is increased. Ultimately, controlling the growth in atmospheric concentrations of greenhouse gases will not be possible without the involvement of all large emitters.
2. Emitters that do not take part in abatement action may gain a competitive advantage in production, inducing movement of emission-intensive industries to these countries from countries where emission constraints do apply. This emission "leakage" partly offsets abatement undertaken elsewhere and increases the economic costs of participating in any emission reduction process.[1]

Economic efficiency

Policies that are economically efficient deliver the objective at a lower cost than those that are not. For climate change response policy, this means that the overall welfare impact can be minimized in meeting the objective of a safe level of greenhouse gases in the atmosphere. There are six important elements of an economically efficient policy framework.

Embrace all opportunities for mitigation

Opportunities to reduce emissions of greenhouse gases exist in many sectors of economies, and there is potential for sequestering carbon dioxide in soils and vegetation, as well as for geological and ocean sequestration. The greater the scope of included activities, the greater the potential for reducing the cost of abatement. The lower the marginal cost of abatement, the more can be achieved environmentally for a given total economic effort.

Facilitate market-based solutions

Although most governments will adopt a portfolio of policies and measures to reduce greenhouse gas emissions, it has been shown that market-based solutions are generally less costly than command-and-control approaches to abatement (Tietenberg 1985; Hahn and Stavins 1992; Fisher et al. 1996).

Recognize the role of technology

Globally, and for most countries, the underlying demand for energy is rising strongly over time (IEA 2002b). There are various ways to mitigate the growth in net greenhouse gas emissions under such circumstances: (1) reduce economic growth and therefore energy use, (2) discourage the use of emission-intensive technologies by increasing their cost relative to less emission-intensive technologies, and (3) encourage development of cost effective and less emission-intensive technologies. This can be done, for example, by increasing the technical efficiency of fossil fuel-based energy production through investments in new technology, by capturing and geologically sequestering carbon dioxide, or by developing new renewable sources of energy. In practice, governments might choose a combination of approaches but, given the importance of energy in driving economic growth, a technological solution is required to make a significant impact on greenhouse gas emissions without hampering development prospects. Some technology options and some issues associated with technology development and uptake are discussed later in this paper.

Take action over the appropriate timeframe

Many components of the existing stock of energy capital have long life spans.[2] Both replacing existing infrastructure and developing new technologies require time – perhaps 20 years or more for development, and longer for successful commercialization. Manne and Richels (1995) demonstrate the economic costs of premature retirement of capital equipment, compared with a more efficient policy designed to achieve the same environmental outcome.

Be flexible in light of new knowledge

Making projections about greenhouse gas emissions based on expected rates of economic growth, the cost and availability of technologies, and the pattern of consumer demands is complicated and uncertain. Current understanding of global warming and of associated climate changes and potential impacts is limited, but the scope for improved understanding over time is high. Given the long time horizon over which action will be required, it is essential to build flexibility into any response so that strategies can be modified as knowledge improves.

Include adaptation strategies

Even immediate, severe emission abatement would not avert some degree of global warming. It follows that strategies for adapting to change will be required.

A fundamental underlying aim in developing a policy response to global warming must be to achieve the maximum benefit from mitigating the adverse impacts of climate change while, at the same time, striving to minimize the total cost of the action required and the adaptation that will inevitably need to take place.

Equity

Because the problem of climate change transcends national boundaries, it requires an international response and a framework that is perceived as fair. An equitable framework would have three elements.

The strategy needs to be consistent with sustainable economic development

The UNFCCC recognizes that environmental objectives need to be met in a way that facilitates countries' expectations of future economic growth and development: "[All] countries…need access to resources required to achieve sustainable social and economic development and, in order for developing countries to progress toward that goal, their energy consumption will need to grow" (UNFCCC 1999, 4). Without this, countries will not participate in an international regime.

There should be no coercion

Forcing countries to agree to mitigation activities is unlikely to prove successful in the long run. A legally-binding framework can reduce the incentive for global participation, and the threat of punishment for failure provides an incentive to withdraw altogether if meeting some tightly defined target becomes impossible. In the long run, international agreements need a strong element of cooperation to remain successful.

Facilitate technology transfer

Technology exists today that can put developing countries on a lower emissions trajectory than their developed country counterparts were at the same stage of economic development. Despite the apparent win–win associated with technology transfer from developed to developing countries, there are a number of barriers that impede large-scale transfer. It will be essential to work toward reducing these barriers in order to enable equitable access to existing and new technologies. These issues are discussed more in-depth later in the paper.

The current policy framework scorecard

Reflecting widespread concerns about potential climate change, the great majority of national governments have chosen to become parties to the UNFCCC. The convention commits parties to taking action aimed at achieving the ultimate objective of stabilizing "greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system."

The Kyoto Protocol to the convention, adopted in 1997, is the most significant outcome of the international negotiations on climate change response policy so far. It includes legally-binding requirements for some parties in the first commitment period (2008 to 2012) to reduce their emissions relative to a 1990 base. The Kyoto Protocol has just recently entered into force as the result of ratification by the Russian Federation, which met the requirement that 55 percent of 1990 Annex I carbon dioxide emissions be covered by the ratifying countries.[3] The United States has withdrawn from the protocol but the recent decision by the Russian Federation to ratify means that the protocol entered into force in early 2005.

Some 12 years after the initial 155 countries signed the convention, we have in the protocol an agreement that would do little to curb global greenhouse gas emissions or to move toward stabilizing atmospheric concentration of these gases. Given the extent of activity that has taken place under the convention, this outcome is surely not for lack of resources or international negotiating efforts.

Why has the process failed the environment so far, and can things improve? Repudiation of the protocol by the United States in March 2001 significantly reduced the emissions reduction that the protocol could achieve. The opportunity this provided for reflection on the direction of global climate policy was unfortunately lost as a result of the prevailing attachment by many to Kyoto as “the only game in town” and a “first step.”

But does it represent a first step along a pathway toward an effective global regime, or is it a dead end? Before considering that question, it is worth reflecting on what the convention has achieved.

International awareness of the potential for global climate change has certainly been greatly heightened over the past decade. The convention has provided a forum for exchange of information and ideas. A range of non-binding actions has been promoted, and techniques for measuring and reporting emissions has been developed. Unfortunately, negotiations have often been conducted in a divisive atmosphere that has strained international relations – hardly conducive to progress when so much depends on collaboration.

Clearly, the policy framework has several significant shortcomings. Some of these are inherent in the nature of the United Nations (UN) negotiations; others have been built into the detail of the convention and the protocol. Bodansky (2001) enumerates some of the lessons to be learned from the Kyoto process.

Bodansky first points to the complexity of the protocol and its elaborate architecture. The institutional support required to maintain the many aspects of ensuring that parties meet their targets is enormous. In addition, there is a very large number of players involved in any UN negotiation, and they have a diverse range of interests and agendas. Progress is therefore cumbersome and slow as a result of the difficult logistics – and often also the politics.

Bodansky’s second point is even more important. He suggests that, contrary to typical practice in treaty making, the Kyoto Protocol does not involve a mutual exchange of promises among parties, but rather commitments made by a select number of the parties, yet done according to rules negotiated by all the parties, including those to whom they would not apply. Developing countries participated fully in the process, yet were specifically absolved from taking on emission reduction commitments. The origin of this problem is inextricably embedded in the convention itself: it contains a number of clauses that have been used by the developing country bloc to justify their unwillingness to accept mitigation commitments.

Article 3.1 of the convention contains the principle that “Parties should protect the climate system…in accordance with their common but differentiated responsibilities and respective capabilities,” and that “developed country Parties should take the lead.”

Developing countries have interpreted this to mean that developed countries must reduce their emissions before developing countries will take on any emission reduction commitments of their own, and, in fact, that developed countries must first have made demonstrable progress in reducing emissions.

Article 4.7 states that developing country commitments “will depend on the effective implementation by developed country Parties of their commitment under the convention related to financial resources and transfer of technology.”

Coupled with the reference in Article 3.1 to “respective capabilities,” this has been used to underpin the developing countries’ argument that they cannot take on mitigation unless and until developed countries provide the resources to increase their capacity to do so. Article 4.7

also contains the phrase: "[E]conomic and social development and poverty eradication are the first and over-riding priorities of the developing country Parties."

Developing countries argue that they cannot afford to divert any resources to mitigation activities – development will always be the priority. And this, of course, is a reasonable argument. However, enshrining this and related principles in the convention has inevitably led to many unproductive hours of North–South debate in the negotiations.

Thus, under the current framework not only is there no emission abatement required by developing countries, but also there is little prospect of any way forward being found for their future engagement.

A possible new framework?

The framework that resulted in the Kyoto Protocol has not led to, and is unlikely to lead to, effective policy outcomes. What, if any, economic and political framework could lead to policy outcomes that meet the principles outlined earlier? The answer depends on finding a framework that more effectively aligns the national interests of major emitters with globally optimal environmental outcomes than is the case under the Kyoto Protocol.

Existing policy drivers

There is a range of existing drivers that could move countries toward reducing greenhouse gas emissions without resorting to an over-arching multilaterally negotiated framework.

- *Economic.* There are generally a number of options within economies for energy efficiency improvements that can reduce costs over time. Energy savings often emerge as a result of broader economic reforms. An example is the economic reforms in China that have led to energy efficiency improvements in coal-fired power generation and industry, as well as a decline in direct household use of coal (and a shift to electricity).
- *International trade and investment.* Some forms of trade and investment can lead to reduced greenhouse gas emissions. For example, investment in transferring technology to developing countries offers potentially valuable long-term commercial relationships for the investor and also potentially more energy efficient production processes in the developing countries.
- *Domestic pollution*. Many developed countries have introduced regulations and mandatory standards for levels of air pollution, such as the sulfur dioxide legislation in place in many U.S. cities. A number of developing countries are also increasingly taking action to address some local pollution problems. For example, in India the judicial system is taking action to enforce previously ignored legislation dealing with air pollution. In many cases these actions have led indirectly to reduced greenhouse gas emissions.
- *Domestic desire to deal with the climate problem*. A number of developed countries already have domestic policies specifically designed to reduce greenhouse gas emissions. The United States, for example, has a target of reducing the emission intensity of its economy by 18 percent between 2002 and 2012 and is investing large amounts of money in technology development (White House 2001). A number of European countries had implemented a range of abatement actions before the European Union's ratification of the Kyoto Protocol. Some developing countries too have demonstrated a desire for domestic emission abatement. For almost all countries there are likely to be negative economic consequences of climate change in the long term.

There is, therefore, an underlying economic incentive for most countries to mitigate the impacts of climate change to the extent that it is cost-effective in conjunction with adaptation activities.

The existence of domestic drivers that work toward improved climate outcomes is critical for an effective global policy framework. These drivers can provide a basis for actions that address the climate problem and are consistent with national interests, including economic interests. Each country has different domestic drivers to different degrees, reflecting the diverse structures and circumstances of economies.

Leveraging existing abatement drivers for further action through international cooperation

It is well recognized that international trade and cooperation can deliver mutual economic benefits to the parties. It may be possible to develop an international framework under which countries cooperate to achieve more cost effectively the goals that are the basis for domestic abatement drivers, thus leveraging existing domestic drivers to achieve emission reductions.

International trade and cooperation have the potential to deliver mutual economic benefits to all involved parties. Working on this presumption, it may be possible to develop an international framework under which countries cooperate to more cost effectively achieve the goals that are the basis for domestic abatement drivers. Under such a framework, trade and cooperation would be used to leverage existing domestic drivers to achieve greater emission reductions at a reduced cost.

One way forward is through bilateral agreements that facilitate and promote cooperation between concerned countries in achieving national interest goals that are also consistent with positive climate change outcomes. These agreements could cover a number of areas, including the following examples:

- Facilitation to increase foreign direct investment in alternative or more energy efficient technology
- Facilitation of investment flows that assist in dealing with adaptation to climate change
- Facilitation of investment flows that generate capital structures more consistent with meeting domestic pollution reduction objectives
- Provision of assistance in the adoption of economic reforms that result in reduced greenhouse gas emissions
- Liberalization of trade flows to ensure that production is taking place in regions employing resources more efficiently
- Sharing of scientific and economic data and exchanges of relevant climate and technological expertise
- Some form of emissions trading that builds on countries' desire to meet emission reduction objectives, but at least cost

Technology: A key element for success

As previously discussed, the increasing global demand for energy means that technology must play a crucial role in any significant abatement in global emissions. Appendix 1 provides some examples of the possibilities afforded by new and existing technology options for achieving emission reductions. Ensuring that technology provides a useful cornerstone for a future policy framework requires incentives for technology research and development (R&D) that are appropriate to the policy environment. It is also important that appropriate mechanisms are in place to enable the transfer and adoption of technologies in developing countries.

Investing in technology

The importance of technology in any future framework that seeks to address the climate problem without hindering economic development has already been stressed. A logical progression is to examine the factors that should be taken into account when making technology choices and when attempting to make investment decisions on R&D.

There are several rationales for government involvement in, and funding of, R&D activities. Perhaps the most compelling is that, if left entirely to the private sector, the public good nature of some R&D – and the risk and uncertainty associated with R&D outcomes – would result in under-investment in innovation activities. Hence, there is often a case for government funding of R&D activities where the net present value of the investment to society is positive, but would not be undertaken by the private sector because private returns are less than the hurdle rate. Where government is involved in funding R&D activities, there are several considerations to take into account.

First, the R&D funding allocation for a given technology should be considered in light of total budget constraints. Research funding will be most effectively spent where the potential payoffs from each unit of funding are highest. Given that there are diminishing returns to investment, allocating a large share of funding to a limited range of technology options may not be optimal. In making investment decisions from one year to the next, however, consideration should be given to the fact that there may be sunk investment costs associated with a given research area and costs associated with the irreversibility of committed resources.

Second, investment in a given technology in one period will affect its cost into the future. Thus it is important to ensure, from a risk management perspective, that a range of technologies is supported; otherwise, past investment decisions could result in lock-out effects. Supporting a range of technologies is especially important given the uncertain environment that characterizes the climate debate. Over time, changing preferences regarding environmentally acceptable technologies and new information about the potential threat posed by different greenhouse gas concentrations may require a shift from existing technologies to alternatives. If technologies that are likely to play important roles in such a future scenario are left off the development list, then it may be expensive to switch to such technologies in the future.

Niche applications are another reason to ensure that a wide range of technologies is supported. For example, while options such as photovoltaics may not be currently cost-competitive with natural gas combined cycle generation in many applications on a per-unit generation cost basis, photovoltaics may be cheaper for distributed generation in remote locations than natural gas combined cycle generation, which has an associated high cost requirement to be grid-connected.

This is a key point across the breadth of the potential energy/technology portfolio. While average costs of generation may imply one technology is more cost-competitive than another, costs are highly site specific, and locational differences in fuel prices and resource availability may greatly alter the relative cost profiles of technologies.

The nature of the policy environment will also have an influence on the direction and focus of R&D finance. For example, if a government has a quantitative emissions restriction in place to achieve a given level of emissions reduction, then an incentive exists to encourage privately optimal improvements in energy efficiency. Any improvement in abatement efficiency that reduces the marginal cost of emissions reductions will also generate a net gain to society under these conditions.

More generally, the impact of investment in R&D activities may be to reduce the overall cost of each type of emission-reducing technology or to change the relative cost of technologies in relation to each other. Typically, development activities and learning effects will reduce the cost of individual technologies, while research breakthroughs that realize the full potential of fledgling technologies typically alter the cost of different technologies in relation to each other. The mix of investment in abatement activities will depend on expected success rates, adoption costs, a need to ensure that a stream of new technology options continues to become available over time, and the overall broad climate change policy setting.

Technology drivers and impediments

Technology transfer and related investments are likely to be important parts of any bilateral agreements on climate change – especially for those between developed and developing countries. In crafting such agreements, it will be important to understand the forces driving technology changes and any impediments to those changes. Some of these are discussed below.

Drivers

To understand how best to facilitate the diffusion of energy technologies between countries, it is important to recognize that drivers of technological innovation, adoption and transfer vary between developed and developing countries. In developed countries, technology may be adopted in response to regulations and energy taxation, and the level of technical innovation tends to be proportionate to the breadth of R&D portfolios where corporations and government finance research. In developing countries, technical advancement is more often the product of diffusion from more developed countries and an outcome of trade agreements. In less developed countries, there is typically less focus on environmental concerns and greater emphasis on getting technologies into place quickly so as to improve the potential for economic growth.

The timing of investment decisions also has important implications for adoption and transfer. Because there are crucial feedback mechanisms between the market and further technical developments, technological “lock-in” may occur if one form of technology gains a temporary advantage that results in market uptake. Once a technology has been integrated into a given process, investment costs have been sunk, and supporting infrastructure has been developed, then technological adoption can be difficult and expensive to reverse.

Once technology has been adopted, learning effects and associated efficiency improvements may also reduce the cost of the technology, making it attractive to additional investors and further increasing market share. The OECD provides estimates of progress ratios, whereby changes in the costs of electricity generated from different technologies are estimated under the scenario that market size doubles (OECD 2003). In this setting, the cost of photovoltaic electricity is reduced to around 65 percent of its previous value, wind power to 82 percent, biomass electricity to 85 percent, and supercritical coal and natural gas combined cycle to around 96 percent of their prior values. Thus the cost-related effects of learning by doing and market uptake are greater for newer technologies and taper off for those technologies that have been in use for some time.

Impediments

Technology adoption and transfer is not affected only by these drivers, however. There are many important barriers to the diffusion of energy sector technologies that tend to impede or slow their adoption. Any attempts to promote the diffusion of technologies will need to address such barriers using a comprehensive approach, while recognizing that impediments will manifest themselves differently in different countries, and that identification and prioritization of barriers needs to be country specific (IPCC 1999).

Concerns about intellectual property rights represent a key impediment to technology transfer. An example is the restrictions on foreign ownership of energy sector assets, which reduce firms' control over the price received for their outputs and also their ability to protect their intellectual property. The response of foreign direct investment to stronger intellectual property rights protection has been shown to increase as the level of industrialization increases (Lesser 2002). Seyoum (1996) found that in newly industrializing countries, the strength of intellectual property rights protection (as represented by patents, trademarks and copyrights) accounted for almost half of the observed variation in foreign direct investment, while in less developed countries the corresponding figure was only 13 percent.

Macroeconomic conditions greatly influence the potential for success of technology transfer. High inflation, fluctuating exchange rates, and incomplete pricing of materials, labor, energy, and other inputs – as well as trade policies that impede the free movement of capital – all act as disincentives or impediments to effective transfer by significantly increasing the risk associated with investment and reducing credit availability. Risk also increases the discount rate, thereby affecting the attractiveness of investments.

Inadequate human and institutional capacities may also hamper diffusion of new technologies. Lack of knowledge, skills and practical experience within the local labor force reduces productivity and impedes the effective implementation, operation and maintenance of technology. Since the overall level of productivity within an economy also influences the lending rate, this has important flow-on effects for credit availability. Capacity is also an issue in relation to labor having the skills required to undertake technological needs assessments, cost-benefit analyses, and environmental impact assessments, which are necessary in procuring, managing and financing technology (UNEP 2003).

Institutional capacity is important not only from the perspective of providing adequate intellectual property rights, but also in relation to providing effective linkages between technology providers, users and developers. Institutional intermediaries are essential in ensuring coordination among various information sources, partnerships and networks, to improve technical dissemination.

Inadequate infrastructure can also impede investment, as projects can be dependent on external infrastructure such as gas pipelines or electricity grids. If the infrastructure is unreliable or of poor quality, then the project will be less likely to go ahead.

Taxation regimes can deter investment if issues such as double taxation are not adequately dealt with. Market interventions, such as tax and subsidy distortions, have the potential to alter the relative prices of energy and may distort incentives for fuel-switching to low-carbon fuels.

It is essential that technology adoption and diffusion be considered in the context of complex market factors, with respect to alternatives such as the appropriateness of technologies for local environments and potential energy and cost efficiencies. In other words, a technology deemed suitable in one place and time may not be as appropriate in another place and time, as a consequence of changing preferences and perceptions about real and perceived environmental risks, for example.

Many such barriers to technology transfer could potentially be significantly reduced if governments – acknowledging the economic and environmental benefits – worked together to overcome them.

Encouraging technology adoption and transfer

It is evident that technology has the potential to deliver a major shift in the emission intensities of economies. Injecting technology into developing countries and continuing the development of the next generation of technologies, however, requires significant investment and supporting policies.

According to the Climate Technology Initiative (2001), processes that promote favorable environments for energy technology transfer include the following:[4]

- Establishing collaborative partnerships between key stakeholders for the purpose of enhancing technology transfer,
- Undertaking a needs assessment that evaluates priorities for technology transfer and available alternatives,
- Designing and implementing specific technology transfer plans and actions,
- Evaluating and refining the actions and plans as an ongoing process, and
- Disseminating technology information.

Based on the experience of practical technology transfer programs, there are also specific actions that foster technology diffusion. Institutional support and training for the assessment, development and management of new technologies is particularly useful in enhancing government efforts to stimulate the market and improve coordination. It is essential that effort is expended on building local skills and knowledge, including through the sharing of information and through strengthening the technical capacity of the labor force (IEA 2001b).

These actions may be facilitated by long-term collaborative arrangements for capacity building, foreign direct investment, and joint ventures through collaboration on research and demonstration, or through international programs for cooperation and assistance in R&D.

Often the human capital necessary to operate and maintain a technology efficiently through all stages of operation is a function of learning that is not easily or simply injected into developing countries. For this reason, it may be useful for successful technology transfer for technologies to be developed and implemented in developing countries concurrently with developed countries' implementation.

The level of maturity of a given technology, however, will play a significant role in determining the appropriate policy to pursue, since different stages of development present different problems for transfer. For example, whether the technology is commercial, near commercial, under development, or speculative will determine whether the technology should continue to be developed and commercialized in developed countries, or whether the new technology can be developed jointly in developed and developing countries.

Compulsory licensing, whereby governments grant licenses to domestic manufacturers who then pay royalties to intellectual property right holders, is one way to facilitate technology transfer that is also associated with the generation of beneficial learning effects (Ogonowski et al. 2004). Other options for improving information sharing include international collaboration for intellectual property rights, whereby both developed and developing countries pledge resources to an international institution that coordinates and develops new technologies, which are then shared with participating countries (Ogonowski et al. 2004).

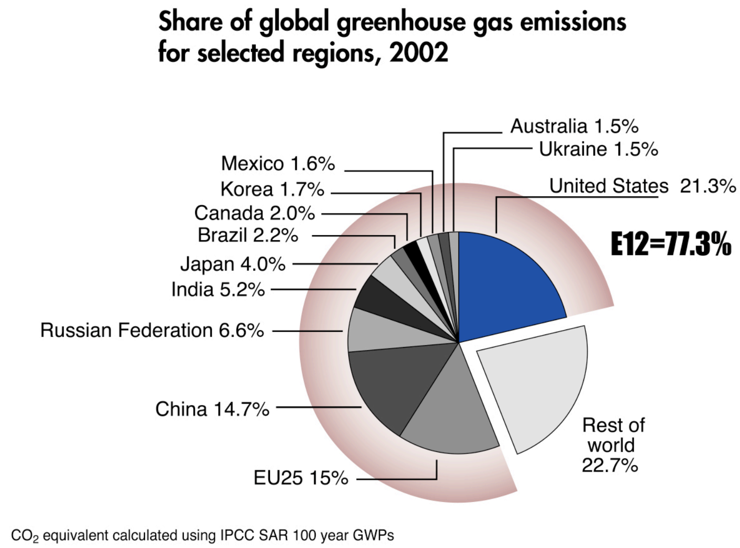
Advantages of the proposed framework

It can be seen from the discussion above that technology investment, transfer and adoption are not "one-size-fits-all" processes. Solutions must be tailored to suit individual circumstances. There is a wide range of factors that influence the rate of technological change, potentially making it less than optimal. Clearly, there is a role for governments to play in addressing many of these influences. This makes the international framework proposed here a particularly suitable one for focusing on technology while at the same time helping to address the climate change problem.

The voluntary bilateral framework outlined in this paper has a number of other advantages. Under a set of cooperative bilateral partnerships, the extent of commitment would be a question for each partner to answer, rather than being determined by a larger group. This is in contrast to the UNFCCC consensus-based approach to negotiations, which is not conducive to outcomes tailored to particular countries' circumstances.

In the case of climate change, 12 countries – if the European Union is counted as a single unit – gave rise to almost 80 percent of global greenhouse gas emissions in 2002 (**Figure 13-1**). Together, China and the United States are likely to account for 40 to 50 percent of global carbon dioxide emissions by 2050. Significant progress could be made in abatement, if agreements could be struck between these countries. This is not an argument for excluding smaller emitters – which should be free to engage in discussions at any time – but an argument for focusing on agreements between key players that meet the conditions of environmental effectiveness, economic efficiency, and equity.

Figure 14-1. Share of global greenhouse gas emissions for selected regions 2002



Such a bilateral framework avoids the demanding global negotiating and legal framework; a large international bureaucracy is not required to police actions. Negotiating efforts can be focused where they brings results, rather than being dissipated by side issues and obstructionism. The network of bilateral relationships that form could be multilateralized at some later date. This would not be essential, but it might be a natural evolution if mutual benefits were found.

Under this framework, the individual circumstances of each country can be addressed and leveraged to maximize the climate change response. Reasons for participating will differ between countries. The importance of technology in finding a solution to the climate problem cannot be over-emphasized. An approach such as the one outlined in this paper could potentially address some of the key current barriers to the transfer of technology. Importantly, because the nature of any technology transferred is the subject of bilateral arrangements only, parties are free to choose the investment that best meets their needs.

This approach relies on market forces and domestic policy drivers, rather than a multilateral regime enforced under international law. A set of bilateral partnerships to reduce greenhouse gas emissions is not inconsistent, however, with the continued existence of the UNFCCC. The convention offers a useful forum for the exchange of scientific knowledge and sharing data and technical information.

It should be noted that there are existing bilateral agreements that focus on funding and capacity building, but this is often not sufficient for technology transfer. Full technological diffusion will inevitably be integrated with trade and development. For this reason, policies that promote economic reforms that are also consistent with reduced greenhouse gas emissions are an essential component of any international arrangement focused on technology diffusion.

Conclusion

The approach to the climate problem to date – one based on mandatory targets and culminating in the Kyoto Protocol – has an enticing appearance of environmental certainty. The targets, processes and disciplinary focus create the illusion of achievement. But the reality is that such an approach is unlikely to work. The withdrawal of the single largest emitter, the United States, from the protocol is a clear signal that another approach needs to be considered, despite the fact that the protocol will now enter into force.

Although all countries have a long-term interest in finding a solution, not all have the same means at their disposal to take action, and not all can have the same effect on the outcome. An approach such as the one outlined here acknowledges that and builds on actions that relate to national interests, while at the same time recognizing that it is essential to have developing country participation if the climate problem is to be addressed. Most importantly, because the actions are the subject of bilateral arrangements without externally-imposed regulation, parties can choose the best investments for their needs.

The approach postulated moves away from the punitive approach brought by some parties to the Kyoto negotiations and seeks to rely on positive drivers for change. Everybody can be better off, which encourages participation and allows the action to develop its own momentum, without expensive negotiations that end in international stand-offs. Coercion is not required if there are demonstrable and shared benefits for developed countries, developing countries, and the environment.

Appendix 1: Some potential technology opportunities

Advances in technology present opportunities for emissions abatement throughout the economy while still allowing economic growth and development. Moomaw et al. (2001) refer to technology options for reducing emissions in the buildings, manufacturing, and energy sectors, and in the agriculture and waste industries.

Significant technological advances designed to reduce greenhouse gas emissions are occurring in the industrial sector, which currently accounts for approximately 40 percent of end-use global carbon dioxide (CO_2) emissions (IPCC 2001b). For example, technological advancements in the iron ore and steel industry that reduce carbon dioxide emissions include improvements in process energy efficiency and the recovery of CO_2 from blast furnace gas.

The aluminum industry is also experimenting with the use of inert, non-carbon anodes that potentially reduce carbon dioxide emissions by around 10 percent. Using drained/wettable cathodes is another new technology that has the potential to reduce electricity use in aluminum smelting by between 10 and 20 percent, but these technologies are unlikely to be implemented prior to 2010. It is expected that once each of these technologies has been demonstrated, then the focus will move to combining the two types of technology, not only to give greater energy savings but also to eliminate anode emissions. The combined savings would result in close to a 35 percent reduction in CO_2 emissions per ton of aluminum produced for manufacturers that rely on electricity generated using fossil fuels.

Technological improvements are also being made in the transport sector, which currently contributes approximately 22 percent of global CO_2 emissions (IPCC 2001b). These advancements that could have beneficial impacts in the transport sector include hybrid gasoline-electric cars, which can improve fuel efficiency by between 50 and 65 percent compared with conventional vehicles, and fuel cell vehicles powered by hydrogen, which could potentially reduce carbon dioxide emissions by 45 percent compared with conventional engines, depending on the source of hydrogen used (IEA 2000).

Examples of technologies that could reduce emissions in the buildings sector, which alone contributes to approximately 31 percent of end-use global carbon dioxide emissions (IPCC 2001b), include the installation of more efficient heating, cooling and lighting equipment, and advanced window and insulation retrofits, which significantly improve the energy efficiency performance of buildings.

One of the major opportunities for global emissions abatement is from technological improvements in electricity generation. Including contributions to end-use sectors, the power generation sector accounts for approximately 40 percent of global carbon dioxide emissions (IEA 2002b). There are three main technological options for reducing greenhouse gas emissions from electricity generation:

1. Efficiency in electricity generation

The average global thermal efficiency of installed coal- and gas-fired generation is approximately 33 percent (IEA 2002b). A number of emerging technologies, however, offer significant efficiency improvements compared to standard subcritical pulverized coal plants and simple cycle gas turbines.

For example, supercritical and ultra-supercritical pulverized coal plants combust coal at higher temperatures and pressures than in subcritical plants, achieving thermal efficiencies of around 45 and 55 percent, respectively.

Combined cycle turbines offer efficiency improvements over conventional coal and gas technologies by employing waste heat or gas to drive a steam cycle. This generates additional electricity, supplementary to that generated when gasified coal or natural gas is first burned in a gas turbine and used to generate electricity.

Integrated gasification combined cycle (IGCC) coal plants are a relatively new technology that are undergoing demonstration at several projects in Europe and the United States. Natural gas combined cycle (NGCC) turbines are more advanced and currently account for over 50 percent of the market for new generating capacity worldwide (IEA Clean Coal Centre 2003). The International Energy Agency (IEA) expects that the average efficiency of new IGCC plants and new NGCC plants will rise to 52 percent and 62 percent, respectively, by 2030 in OECD countries (IEA 2002b).

New NGCC plants generally have lower initial capital costs than pulverized coal and IGCC plants (IEA 2003b). By 2030 it is expected that IGCC capital costs will be lower than for pulverized coal technologies but still greater than NGCC technologies (Cottrell et al. 2003). Typically, NGCC plants have the lowest electricity cost, followed by ultra-supercritical and IGCC plants.[5] Costs will vary, however, between countries as a result of the availability, quality and price of fuels and capital.

2. Fuel-switching in electricity generation

A transition from coal to gas technologies, particularly in regions with competitive gas pricing, may reduce emissions growth, but this is unlikely to produce significant long-term reductions in global emissions, as a result of the rising demand for electricity and subsequent expected increase in emissions (Freund 2002).

A significant reduction in global greenhouse gas emissions could, however, be achieved by widespread switching from fossil fuels to low- or zero-emission technologies such as renewables, nuclear power or hydrogen (if produced from carbon-free materials).

Currently, the average costs of non-hydro renewables are not widely competitive with fossil fuel-based wholesale electricity generation. Renewables do, however, offer cost-competitive generation in some specific applications and regions (IEA 2003a). Significant declines in the cost of non-hydro renewables are expected as capacity increases and incentives are implemented to encourage low-emission electricity generation. Wind and biomass are expected to have the lowest cost and greatest installed capacity of non-hydro renewables by 2010. The projected costs of these technologies, however, are still unlikely to be competitive with coal- and gas-based technologies for some time (IEA 2003a; Cottrell et al. 2000).

Although the operating costs of nuclear power plants are similar to coal-fired plants (IEA 2001a), investment in new nuclear plants is projected to be limited because of public resistance and increasing competition from alternative technologies.

Hydrogen can be used to generate electricity by direct combustion in a gas turbine or in a fuel cell. Currently, over 90 percent of hydrogen is produced from fossil fuels. It is not expected that technologies allowing carbon-free hydrogen production and subsequent low-emission electricity generation will be practical before 2050 (IEA 2003b).

3. Carbon capture and storage

The capture and subsequent storage of carbon dioxide emissions from power plants would allow near zero emissions from electricity generation. Carbon-capture facilities can be retrofitted to existing plants or installed in new installations. The three main options are flue gas separation technologies, pre-combustion techniques, and oxygen recycling.

Once captured, carbon dioxide must be transported to a permanent storage site by land pipelines or ocean vessels. It can be stored in a variety of geologic or ocean sites, including active and uneconomical oil and gas reservoirs, saline aquifers, and deep and un-minable coal seams. It has been estimated that the capacity for geologic storage is so great that hundreds of years of global emissions at current emission rates could be sequestered (IEA 2002a).

Carbon capture and storage is typically expected to increase electricity costs by about two to three cents (US$) per kilowatt-hour, compared to conventional generation without carbon capture and storage (IEA 2003b). The higher costs are associated with additional investment and operating costs, transport and injection costs, and a decline in electricity generation efficiency. The costs of carbon capture and storage, however, are extremely site specific and will vary between regions.

Under the United Nations Framework Convention on Climate Change, the international community has sought to find a policy framework to address the threat of human-induced climate change. The most significant action to date has been the adoption of the Kyoto Protocol in December 1997. Russia's recent decision to ratify the Protocol means the treaty entered into force early in 2005, despite its repudiation by the United States. The protocol includes legally-binding emission reductions for some countries over the period 2008 to 2012.

It has not yet been possible, however, to find an approach that is truly global and that is aligned with the long-term environmental goal of reducing global greenhouse gas emissions to a "safe" level. A framework for action that addresses these shortcomings is developed in this paper. The underlying tenets are environmental effectiveness, economic efficiency, and equity. The importance of an appropriate timeframe for action is acknowledged, and involvement by all major emitting countries is facilitated. Importantly, this last point includes participation by developing countries in a way that accommodates their aspirations for economic growth. The crucial role of technology is recognized and is drawn into the solution. Together these elements allow a response that minimizes costs and maximizes the environmental outcome, while at the same time enhancing the growth prospects of developing countries.

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Notes

1 For a detailed discussion of carbon leakage, see Hourcade et al. (2001, 542–3).

2 See, for example, IEA (2002b, 82).

3 The UNFCCC divides countries into two main groups: Annex I, which is the industrialized countries, including the relatively wealthy ones that were members of the Organization for Economic Co-operation and Development (OECD) in 1992, plus countries with economies in transition (EIT), and Annex II, which is the OECD members of Annex I (EITs not included).

4 The Climate Technology Initiative (CTI) is a multilateral initiative, operating as an implementing agreement under the International Energy Agency (IEA). Its mission is to bring countries together to foster international cooperation in the accelerated development and diffusion of climate-friendly and environmentally sound technologies and practices. The CTI was established at the first Conference of Parties to the UNFCCC in 1995 by 23 IEA/OECD Member Countries and the European Commission. In 2003, the CTI gained new status as an IEA Implementing Agreement.

5 See, for example, Audus (2000) and David and Herzog (2000).

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Chapter 14

REDEFINING SUSTAINABLE DEVELOPMENT

Julian Morris

In early February 2002, two colleagues and I were driven from Delhi to Agra to see the Taj Mahal. As we crossed the border of Uttar Pradesh, we saw long lines of trucks simply waiting in line, doing nothing. Their drivers were hanging around smoking bidis. We were shocked. Then it struck me: sustainable transport. The truck drivers must have been given an edict that they should drive less, perhaps to conserve fuel or reduce nasty emissions to the environment. I asked the driver if that was the case.

"No, sir, not sustainable," he said, laughing at the ridiculous Englishman. "The truck drivers must wait to pay a toll to cross the border." "But we're still in India" I protested, "You mean they have *internal* tariffs here?" "Yes, sir," he replied.

My error had been to mistake one misguided public policy – internal tariffs that cause innumerable unintended consequences – with another equally misguided policy that likewise results in legions of harmful, unintended effects: namely, "sustainable development."

The term has been around for about 30 years but has only recently been popularized. It derives originally from the biological concept of "sustainable yield" – that is, the rate at which species such as cod and elephants may be harvested without depleting the population. Starting in the late 1980s, environmentalists and government officials began applying the terms "sustainability" and "sustainable development" when discussing environmental policy.

Thus, numerous measures aimed at conservation and pollution prevention have been justified on the ground that they are necessary to promote sustainable development. More recently, and in light of the AIDS crisis in Africa, the interpretation of sustainable development has been broadened to include issues such as healthcare and education, the lack of which are seen as constraints on economic development. It is also a linchpin for many policies affecting energy development and use, to guide or control economic decisions and (so its advocates say) prevent resource depletion, global warming and other "imminent dangers."

The most common definition of the term derives from a report prepared for the World Commission on Environment and Development, which stated in 1987:

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."[1]

So defined, sustainable development is, like motherhood and apple pie, not a concept to which many would object. It would take a perverse outlook indeed to support the idea that people's needs should *not* be met both now and in the future. But, unobjectionable as it is in principle, the concept is sufficiently broad to allow various different interpretations. Indeed, a voluminous literature has sprung up debating its interpretation in periodicals with fancy names such as the *Journal of Sustainable Development* and the *International Journal of Sustainable Development*, which is not to be confused with the *International Journal of Sustainable Development and World Ecology*, or *Sustainable Development International*.

Most of this literature has focused on identifying specific outcomes, such as controlling the climate or saving periwinkles, and then setting about developing policies intended to achieve those outcomes. Usually these policies require stronger systems of global governance (periwinkles are important).

An alternative interpretation focuses less on specific outcomes and more on increasing the chances of superior outcomes. This chapter will, first, critique the conventional outcome-oriented vision of sustainable development, and then offer an alternative vision. The key to this alternative is that it seeks to establish in poor countries the kinds of institutions that have enabled rich nations to generate and sustain research and development, health and environmental improvements, and general wealth creation for families, businesses, communities and entire countries.

Unintended consequence of outcome-oriented sustainable development policies

Some environmental groups have claimed that rich countries are burning too many hydrocarbons (coal, oil, gas) and that this harms poor countries. In order to redress the balance, these groups demand a reduction in the consumption of hydrocarbons by rich countries. (Other environmentalists say it would be harmful if developing countries were to use more fossil fuels to generate the electricity that modern economies require. They want to minimize the use of such fuels by poor countries, by persuading or compelling them to rely on wind and solar energy, instead.)

While such a policy would almost certainly reduce the differential in income and wealth between people in rich and people in poor countries, it would do so in the main by destroying wealth and reducing income of those in rich countries.

The reason for this is twofold. First, energy is an essential element of production. (Economist Robert Bradley calls it the “master resource.”) Thus, increasing the cost of energy by mandating a shift to lower-carbon forms will inevitably reduce output. Second, hydrocarbons are used by consumers in all manner of applications, both directly, for example in cars and gas stoves, and indirectly, when they turn on their lights. So reducing the availability of hydrocarbons will create energy poverty.

Although some middle-income countries might benefit from a shift in the location of industrial production, for the most part people in poor countries would suffer – those in the poorest countries especially, because they have little industrial capacity. One reason is that reducing income in rich countries will reduce demand for all products, including agriculture, minerals, textiles and apparel, which are the main products currently exported from poor to rich countries. Decreasing income in rich countries would also reduce money available for foreign aid, and increase societal pressure for curbs on trade with poor nations, in an attempt to protect industries and jobs in rich countries.

Ultimately, policies that curtail development of and access to plentiful supplies of dependable, reasonably priced energy also impair economic activity in all nations – and perpetuate the poverty, disease, malnutrition and premature death that are endemic in developing countries.

The likely adverse effect on the world’s poorest people of constraining consumption of hydrocarbons by the rich is one instance of a more general phenomenon: the unintended effects of outcome-oriented policies that are justified on the grounds that they promote “sustainable development.”

Consider the effect of the Basel Convention, an international agreement intended to prevent the illegal dumping of hazardous waste in poor countries. As Alan Oxley points out:

> "… restrictions on the export of used lead to India have undermined the formal lead recycling industry in that country, with perverse environmental consequences. The formal recycling industry, which operates under strict environmental and health and safety regulations, requires high throughput of lead. Because of the relatively low levels of lead use locally, the industry requires imported lead in order to operate at a profit. The restriction on exports of used lead to India has led to the closure of a number of formal-sector lead recycling facilities, which became unprofitable. As a result, more of the locally-produced waste lead is now being recycled in the informal sector. These are unregulated backyard operations, which typically cause contamination of water and air, with adverse health consequences."[2]

Likewise, the ban on trade in elephant ivory, enacted under the Convention on International Trade in Endangered Species, probably does more harm than good, by undermining incentives to conserve elephants locally. In Southern Africa, governments have, to a greater or lesser extent, decentralized management of wildlife. In many places in Botswana, Namibia, South Africa, Tanzania and Zimbabwe, local people receive a proportion of the income from hunting, eco-tourism and other economic activities associated with the wildlife with which they share their land.

As a result, local people have become stakeholders in the wildlife management system and, instead of seeing elephants and other wildlife as a threat, they realize that by conserving them, they are able to benefit. The ban on international trade in elephant ivory reduced the value of elephants to these people and thereby reduced their incentives to conserve them.

Delaying or restricting energy and economic development in poor countries also results in many undesirable and unintended consequences. Restrictive policies may be rationalized and implemented to preserve habitats or prevent resource depletion and global warming, for instance. In many cases, they impede certain activities directly, through laws or treaties like the Basel Convention or Kyoto Protocol. But often they are more subtle and indirect, as in the case of pressure exerted on the World Bank and private lending institutions to restrict credit for the construction of large centralized power generation facilities, and instead fund only wind or solar generation programs.

Either way, they mean that poor countries must continue to do without the abundant, reliable, affordable energy they need to become modern, thriving economies. Communities throughout the developing world thus continue to be hampered by intermittent and unreliable electricity for hospitals, schools, homes, businesses, sanitation and industrial plants.

These facilities must do without adequate electricity, function at greatly reduced capacity, and endure frequent power interruptions that disrupt assembly operations, ruin manufactured goods, and interrupt surgeries, computer operations and business enterprises. Families are forced to continue burning wood and dung for heating and cooking, causing millions of people to die every year from lung and other diseases that would largely disappear if their countries had adequate supplies of electricity, generated by large centralized nuclear, hydroelectric or fossil fuel plants.

Nevertheless, virtually everything the UN Commission on Sustainable Development does is outcome-oriented. One need only search for a few minutes on its website to find a hundred outcomes that it seems to favor – most of which seem, mysteriously, to involve global governance by the United Nations.[3] In 2000, the UN issued *The Millennium Declaration*, which included a commitment to halve by the year 2015 the proportion of the world's population whose income is less than $1 per day.[4] Now, of course, such an outcome may seem laudable; reducing poverty and its accompanying misery is certainly a good thing.

But several objections to this proposition could be raised. First, one could object that the outcome is far too modest. How can we accept that in 2015 there will still be 400 million people living on only a dollar a day? Second, one could reasonably argue that the simply reducing the number of poor people is not enough. What happens to the people who were poor is important. Merely ensuring that they have $1.10 per day for a few years, by sending them food packages or other forms of emergency aid, is hardly much use in the long-run.

Simply put, greater emphasis must be placed on creating wealth in developed and developing countries alike. Less must be placed on transferring it via aid programs from rich countries that often suffer from anemic economic growth within their own borders – frequently because of their own misguided policies – to developing nations that are themselves hamstrung by corruption and deficient internal legal, political and economic systems.

Equally essential: increases in wealth must be sustained if they are to be considered sustainable. This points to a general problem of starting with a desired outcome and then attempting to formulate an appropriate policy to achieve that outcome: all sorts of mischief become acceptable under such a system, because the ends justify the means.

Good intentions are not enough

Good intentions are laudable. However, if good intentions were enough to alleviate poverty, malnutrition and disease, these dreadful problems would no longer plague us. Indeed the fact that more than 10 million people each year die of preventable or curable diseases, and that 800 million people survive on less than $1 per day, are testament to the failure of good intentions – and the many billions of dollars spent in their pursuit.[5]

In July 1944, officials representing 44 of the world's wealthiest nation states gathered in Bretton Woods, New Hampshire, for the United Nations Monetary and Financial Conference. At this conference, under the chairmanship of John Maynard Keynes, officials agreed to use money taken from taxpayers in the wealthier countries to subsidize loans to the governments of the war-ravaged countries of Europe. To facilitate this operation, the International Bank for Reconstruction and Development (IBRD) and the International Monetary Fund (IMF) were set up with a mandate to make loans to governments. In 1949, following President Harry S. Truman's Point Four Program, the IBRD and IMF began lending to the governments of "developing" countries.

Since then, hundreds of billions of dollars have been spent on "aid." Yet, a balanced assessment indicates that, although there may have been a few benefits, on average it has caused extensive harm. Graham Hancock, former East Africa correspondent for *The Economist*, noted 15 years ago:

"Garnered and justified in the name of the destitute and the vulnerable, aid's main function in the past half century has been to create and then entrench a powerful new class of rich and privileged people. In that notorious club of parasites and hangers-on made up of the United Nations, the World Bank and the bilateral agencies, it is aid – and nothing else – that has permitted hundreds of thousands of 'jobs for the boys,' and that has permitted record-breaking standards to be set in self-serving behaviour, arrogance, paternalism, moral cowardice, and mendacity. At the same time, in the developing countries, aid has perpetuated the rule of the incompetent and venal men whose leadership would otherwise be utterly non-viable; it has allowed governments characterised by historic ignorance, avarice and irresponsibility to thrive; last but not least, it has condoned – and in some cases facilitated – the most consistent and grievous abuses of human rights that have occurred anywhere in the world since the dark ages.

"In these closing years of the twentieth century the time has come for the lords of poverty to depart."[6]

Since then, unfortunately, there have been few signs that "aid" is being put to better use, or that the "lords of poverty" will soon depart.

Institutions for sustainable development

The reason transfers of financial resources from the governments of rich countries to the governments of poor countries have been largely unsuccessful in stimulating economic development is that lack of resources is not the primary problem in poor countries. Take the case of Nigeria, which happens to contain one of the largest oil deposits on the planet. The oil wealth in Nigeria has been controlled by government officials – until recently it was in the hands of the murderous kleptocrat General Sanai Abache – who used it to line their pockets and keep the politically important elite happy, rather than to promote development.

There is little point to pouring money into a country whose government has no intention to encourage economic development. What poor countries need, says Kenyan economist James Shikwati, is trade – not aid. Foreign aid, he says, is just "life support for corrupt dictators." Indeed, as Mengistu showed in Ethopia, Mobutu in Zaire, Pol Pot in Cambodia, and Idi Amin in Uganda, dictators will happily accept "aid" if it helps to prop up their regime. In such cases, government-to-government transfers are not merely counterproductive; they are murderous.

This disastrous situation will be made even more difficult if access to abundant, affordable electricity is prevented in the name of another commonly sought outcome: the prevention of global climate change that many scientists remain convinced is being caused primarily by natural factors, rather than human activities.[7] If rich nations become poorer – as a result of agreeing to curb their energy use, greenhouse gas emissions and economic growth to comply with the Kyoto Protocol, for instance – they will not be able to sustain their current level of economic aid.

However, the more fundamental problem is that "aid" is based on a largely false premise, namely that poverty itself is a barrier to development. In general, this is simply not true. Economic development in Western Europe did not require massive redistribution from the rich to the poor. Rather, it required a change in the structure of Europe's institutions; a move away from the Feudal system of the early Middle Ages to a trading economy.[8]

While Sub-Saharan Africa now appears to be facing a genuine crisis, in the form of disease that is destroying the economically productive sector of society, it is probably unique in the world (if not world history) in requiring external assistance to escape from such a quagmire. And even then, such assistance is unlikely to lead to significant growth; rather, it might prevent total economic collapse. If countries are to develop sustainably, institutional reform, not aid, is the solution.

But what do we mean by "institutional" reform? Institutions are the framework within which people act and interact – they are the rules, customs, norms and laws that bind us to one another and act as boundaries to our behavior. Institutions reduce the number of decisions that we need to take; they remove the responsibility to calculate the effect of each of our actions on the rest of humanity and replace it with a responsibility to abide by simple rules. In a system in which rules emerge spontaneously and rules are selected by evolutionary processes, good rules will tend to crowd out bad rules. That is to say, over time, rules that result in better outcomes will be preferred to rules that result in worse outcomes.

Some rules are, of course, essentially arbitrary – which side of the road to drive on, for example. Clearly a rule is required here, or the consequences would be fatal. But whether one follows the English rule, which is based on the fact that (right-handed) jousters would pass on the left, or the French rule, which is based on the fact that it is not English, is of no great consequence.

Other rules are not so arbitrary. For example, the rule that contracts should, generally, be upheld in a court of law has a very distinct consequence. It grants people greater certainty in their transactions with one another and thereby encourages such transactions to take place. If the rule were that contracts are not legally binding, the effect on commerce would be devastating.

In *The Other Path* and *The Mystery of Capital*, Hernando de Soto documented the plight of his fellow countrymen in Peru, most of whom were and are denied the formality of such law.[9] They must, instead, rely upon informal mechanisms to enforce contracts, property rights and other relationships.

While such informal mechanisms – customs and norms, for example – work well for groups that are relatively homogeneous and where there is little trade with outsiders, they impose significant constraints on the ability of groups to improve their lot. Societies that have adopted formal institutions – such as property rights, markets, contract law, tort law, trademarks, patents, copyright, and so on – have tended to do much better economically and socially than societies that have relied primarily on informal institutions.

Property rights[10]

It is the institution of private property that, more than any other, has enabled people to escape from the mire of poverty. Property rights are capital; they give people incentives to invest in their land and they give people an asset against which to borrow, so that they might become entrepreneurs. As in Peru, and again as documented by de Soto, the 700 million rural poor in India are not oppressed by multinational companies. Most of them have never even heard of multinational companies, and those that have probably dream of working for them. No, the 700 million rural poor in India are oppressed by tenure rules that make it difficult for them to rent, buy or sell property formally. Land transactions typically involve paying large bribes to local officials, who have a vested interest in maintaining the status quo.

Property rights are created in order to resolve competing claims over resources. Thus, if 10 men all graze their cattle on the same piece of land and there are no rules governing how much each man can graze, then each one has a strong incentive to graze as much of the available land as possible. Under such a system – known as “open access” – the cattle will quickly denude the land and, in the absence of free land on which to move the cattle, will eventually die.

Historically, open access has been a rarity, occurring only when land is so plentiful that ownership is not necessary, or when people are prevented from owning property. In most cases, before the tragedy occurs, the users of the land would see the advantage of either dividing it up into individual plots or creating rules for using it that reduce the likelihood of denudation. In either case, the land has been privatized – made the exclusive property of one or more people. If the land is split into plots, it becomes "several" or "individual" property; if the owners agree to common rules, it is called "common" property.[11]

Privatization is expected to occur when the costs of exclusion (that is, the costs of limiting access to a piece of previously open land, for example by fencing and policing) are equal to or less than the external costs (which, in this case, means the costs associated with the denudation of the land).[12] But the costs of exclusion will depend upon the exclusion technologies available. Wherever there are externalities present (such as the threat of encroachment by cattle belonging to other ranchers), users would have an incentive to produce new and cheaper exclusion technologies. So, over time, we would expect more and more land to become privately owned and the sum of external costs to decline precipitously.

Land that is owned privately (whether individually or in common) will in general be better managed than land that is un-owned or owned by the state. This is because the owner(s) know that they will reap the benefits from any investments made in the land, so they have stronger incentives to make those investments. Going back to our cattle-rancher example: those who graze more cattle than their land can support will soon cease to be cattle ranchers. That creates a strong incentive to discover the "carrying capacity" of the land – and to increase it through new technologies. Entrepreneurial peasants constantly introduce new crops and production methods, creating an environment of diverse agriculture.[13]

Technological innovation not only enables peasants to improve their lot; it also benefits those with whom they trade, by lowering the cost of purchasing food and other goods and reducing the risk of famine. But agro-diversity will be stifled if those who might innovate new technologies are not allowed to benefit from the investments they make through the ownership of property. The individual's *incentive* to *invest* in his land and *innovate* new methods of production will be greater when he can *own* and *exchange property*. Thus, Michael Stahl concludes:

"At the farm level, the presence or absence of clearly defined property rights makes the difference between active interest in investing in soil conservation measures or apparent indifference to environmental degradation."[14]

Individual property rights also encourage pollution prevention. In the English common law for example, if the owner of property A emits a substance that causes damage to property B, then the owner of A must compensate the owner of B for the harm caused.[15] Thus, even at the height of the industrial revolution, a smelting works in an industrial area was enjoined for causing damage to shrubs and trees on a nearby property.[16] There remains an ancient maxim, *sic utere tuo ut in alienum non laedas*, roughly translated as "so use your own as not to harm another."

Widely applied in the courts of law, this rule would protect not only the property of the owner but also neighboring properties and even the environment – and society – as a whole. However, the maxim has not received sufficiently general application, mostly because states have stepped in and asserted that the polluting activities should continue, albeit at a regulated level, because they are in the general interests of mankind.

Property also begets wealth. Once a person owns property, he or she can use it as collateral against a loan. Because such collateral gives lenders security, they will be willing to offer loans at lower rates. So property reduces the cost of becoming an entrepreneur.

Of course, some of these entrepreneurs will fail, and they may have their property repossessed by the lender. But at least they will have had the opportunity to try to escape from poverty and, of course, most will be no worse than if they never had the property in the first place. In any case, many will succeed in their endeavors. Some may become wealthy; most will simply be less poor.

Intellectual property rights[17]

Another institution that encourages innovation is intellectual property. In 1474, the Venetian Republic enacted a law that entitled inventors to a temporary exclusive right to profit from their inventions. Later such laws were adopted widely throughout Europe and North America. In some cases the laws have been abused, but for the most part they have been very beneficial to humanity.

Strong, readily enforceable intellectual property is particularly important for those products and processes that require large investments in research, development and marketing, but for which the costs of copying are relatively low. Chemicals, pharmaceuticals and biotechnology rely heavily on patents. The music, film, book, art and software industries rely heavily on copyrights. Meanwhile, all manufacturers and sellers of brand goods (which is most manufacturers and most sellers) rely on trademarks and servicemarks to guarantee the identity (and hence brand-associated characteristics) of products.

There are of course drawbacks to IP, including temporarily higher prices of the protected goods, a reduction in the number of goods directly derived from those that are patented,[18] the legal and administrative costs involved in enforcement, and so on.[19] These drawbacks have led several commentators to conclude that patents and other forms of intellectual property are not desirable. However, the problem with focusing on these drawbacks is that, in doing so, one often forgets that the inventions and creative works might never have come about but for the existence of IP.

It is all very well to criticize the excessively broad application of patent to the internal combustion engine or airplane wing control (which was patented by Orville Wright). But if there were no patent protection, how much longer would we have had to wait for the car and the airplane? Perhaps more importantly, without the stimulus of patent protection, would we have had all the wonderful synthetic chemicals and pharmaceuticals that make our lives and the lives of our loved ones so much better? Without copyright protection, would we have enjoyed the explosion of music, art, literature and film that we have experienced over the course of the past century? Without trademarks and servicemarks, how much more complicated would our lives be, constantly battered with confusingly similar marks and products?

In sum, were we to abandon or significantly diminish our system of intellectual property rights, we might gain in the very short term through lower cost products. However, the cost in the medium to long term would be felt in terms of fewer products, as well as higher expenditures on trade secrecy and other means of protecting knowledge, which might well increase the cost of products.

Freedom of contract

Another fundamental institution for sustainable development is freedom of contract. This includes both the freedom *to* contract – the freedom to make whatever agreements one desires, subject to fair and simple procedural rules – and the freedom *from* contract – the freedom not to be bound by the decisions of others. Freedom of contract is a fundamental part of the freedom to associate with others. It includes the freedom to transact – to buy and sell property – and as such it is an essential adjunct to the right to clearly defined and readily enforceable property rights.

The freedom to contract enables people to bind themselves to agreements, and thereby creates greater legal certainty. This in turn encourages people to engage in trade and investment. Armed with enforceable property rights and contracts, the peasant becomes a merchant.

The freedom from contract prevents others from attempting to interfere with one's right to engage in exchange. Sadly, governments rarely respect the rights of parties to freedom from contract. Restrictions on trade abound in every country in the world.

As I pointed out, in India they even have tariffs on the borders, where trucks can wait for days while their drivers pay a small fee (Uttar Pradesh charges 160 rupees – about three dollars). The delay comes from the drivers having to go backwards and forwards filling out ridiculous forms. As they wait, their loads rot or are stolen.

Such interventions are truly unsustainable. They waste capital, for the trucks and goods lie idle for days on end, when they could instead be engaged in productive pursuits. They raise relatively small sums via the tariffs – but at the expense of very large amounts that would be generated through greatly increased economic activity.

They waste energy and generate pollution, as trucks inch forward, stand idle, and must be turned off and then started up again. They waste good food, which reduces the market in perishable agricultural goods, drives up food prices, and keeps both farmers and consumers poor. And they encourage a large prostitution trade, in which thousands of often HIV-positive women spread disease as they service idle drivers – forcing India to spend more scarce resources treating AIDS

The rule of law

Property rights and contracts are nothing if they are not enforceable. And enforcement is possible only if there are courts wherein disputes over the rights and duties of parties may be resolved, and a legal system exists that will enforce those judgments. There are two key issues of concern here: the first is the willingness of the state to permit competition in the provision of legal services; the second is the enforcement of whatever decision is made.

When the state exerts a monopoly on the provision of law, the costs of resolving disputes through the formal judicial system are typically large. The costs of such dispute resolution can, however, be dramatically reduced if people are able to resolve their disputes privately, for example through arbitration. However, for such arbitration to be enforceable, the courts must accept the rights of parties to settle disputes by arbitration.

This is essentially a matter of freedom of contract. If parties contract to have their dispute settled by arbitration, then the courts should get involved only if *that* contract is breached. Sadly, in most countries the courts have resisted this simple premise – presumably because they see it as a threat to their power. The United States is an exception and, as a result, the U.S. has a far more competitive legal (and economic) system.

The second issue, enforcement of decisions, requires the existence of a credible system of sanctions. One of the reasons rich countries have been able to become rich is that the police and the administrators of criminal justice are generally trusted and are trustworthy. That is not to say that they are free from corruption; rather, that the level of corruption is small in comparison to the levels of corruption in many poor countries. In Indonesia, for example, it is common for criminals to use a combination of threats and bribes to ensure that they stay out of jail. Similar problems exist in many other countries.

In Nigeria and South Africa, people have so little trust in the police that they employ private security agencies. In South Africa these seem on the whole to be rather reliable. In Nigeria they are no doubt better than the police – if you can afford them – but they also run scams, stealing from the very houses they are supposed to protect.

Decentralized decision-making and sound science

If government is to intervene in the actions of the citizens, there must be both a strong justification – the benefits must outweigh the costs – and there must be in place mechanisms to ensure that poor decisions can be changed.

Space does not permit a discussion of how in practice costs and benefits would be estimated. Needless to say, however, decisions must at the very least be informed by sound science – that is, science that has undergone a rigorous process of peer review and is not subject to overt or substantial political or economic pressure.[20]

To prevent mistakes from being perpetuated, decisions must be reviewable. Given the difficulties associated with reviewing legislation, that probably means building in redundancy: legislation should perhaps have a "sell-by" or "sunset" date of two or three years, after which it must go through the same process of assessment to determine if it is still justified.

In addition, decisions to limit human activities should be taken at the most local level possible. But they must be bound by the other principles that prevent abuses of local power. Those principles are mostly contained within the other principles already adumbrated, such as respect for property and freedom from contract.

Generally speaking, state bureaucracy should be avoided, because bureaucracies have a tendency to expand and to create justifications for expansion. One way to deal with this would be to contract out all or many government services.[21]

Developed country policies

It is not only institutions in poor nations that need to change. Rich and poor countries alike must recognize that certain policies being imposed via treaties and other means on developing countries are having serious negative consequences for African, Asian and Latin American nations that clearly want to modernize and take what Rabbi Daniel Lapin has called "their rightful places among the Earth's prosperous people."

They need to have abundant, affordable, reliable electricity – enough for a modern society, enough to power homes, schools, shops, businesses, factories, hospitals, sanitary facilities and other operations. To ensure this, rich nations must do more to transfer their most advanced energy production and pollution control technologies, as suggested in previous chapters.

Among other things, developed countries should encourage, rather than frustrate, the financing and construction of hydroelectric, nuclear and fossil fuel projects in poor developing nations, and help ensure that they are built with proper safety features and state-of-the-art efficiency and pollution control technologies.

Wealthy countries must also promote institutional and public policy reform, not just in developing countries, but also in developed nations, the United Nations, global institutions like the World Bank and major private lending organizations. These Western institutions must begin to recognize the harmful, debilitating effects that their own laws, policies and practices have on poor countries and the very outcomes that rich countries purport to want for poor nations.

A good place to start is policies that seek to preclude energy development and economic growth, in the name of preventing the future theoretical danger of global climate change. Those policies do little or nothing to achieve the goals they seek, while having many seriously negative impacts on developing nations. At the very least, policies that delay or prevent the establishment of a modern energy infrastructure prolong the burning of wood and animal dung, widespread deforestation, the absence of safe water and proper sanitation, extensive poverty, and millions of deaths from lung and intestinal diseases.

All this also means rich nations must likewise redefine sustainable development (and the so-called “precautionary principle”), to recognize and implement important social, legal, political, economic and technological systems that have worked in the developed world and would greatly assist poor countries.

Toward good governance for sustainable development

This combination of property rights, freedom of contract, the rule of law, decentralized decision-making, sound science and wise policies on transferring energy technology provides the basis upon which real sustainable development can take place. In short, they represent good governance. Sadly, up to now, few countries have come close to instituting such systems of good governance.

The challenge for those eager to see the world become a more sustainable place is clear: stop squealing about the importance of global governance, and instead promote good governance.

About the author

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Notes

1 WCED (1987), p. 43.

2 Alan Oxley, "Environmental protection and the WTO," in J. Morris (ed.), *Sustainable Development: Promoting progress or perpetuating poverty?* London: Profile Books (2002), p. 127.

3 http://www.un.org/esa/sustdev/index.html -- Accessed 12 June 2002.

4 UN General Assembly resolution 55/2, para. 19. New York: United Nations.

5 The following description is taken from Morris (1995).

6 Hancock (1989), pp.192-93.

7 In fact, some scientists have argued that planetary warming is a desirable outcome. "We may need global warming, after all," the late Sir Arthur Clarke observed, "as the current interglacial period draws to a close. As Will Durant said many years ago, 'Civilization is an interlude between ice ages.'" [Sir Arthur C. Clarke, *Science*, Vol. 280, 5 June 1998] "The renewal of ice-age conditions would render a large fraction of the world's major food-growing areas inoperable, and so would inevitably lead to the extinction of most of the present human population," Sir Fred Hoyle and Chandra Wickramasinghe, commented on CCNet in 1999. "We must look to a sustained greenhouse effect to maintain the present advantageous world climate. This implies the ability to inject effective greenhouse gases into the atmosphere, the opposite of what environmentalists are erroneously advocating…. Without some artificial means of giving positive feedback to the climate, such an eventual drift into ice-age conditions appears inevitable."

8 North and Thomas (1972)

9 De Soto (1989)

10 Portions of this section are taken from Morris (1995)

11 The meaning of "private" property should be clarified. In the sense in which it is used here, private property means property for which an identifiable person or group of people is the principal "residual claimant." See Barzel (1989). Residual claimants have a right to any good produced by that property, and are liable for any externalities generated. Many fascinating alternative mechanisms for managing property, especially where individual rights are difficult to delineate, are discussed in Elinor Ostrom (1988, 1990) and Schlager and Ostrom (1992).

12 Alchian (1965); Demsetz (1967); Anderson and Hill (1975); Ault and Rutman (1979).

13 Brookfield and Padoch (1994).

14 Stahl (1993).

15 It is necessary only for the owner of B to show that this physical harm was most likely the result of the pollution emanating from A. However, it must be shown that the damage actually exists or is imminent; otherwise there is only the potentiality of an action, not an action as such: *Pemberton v Bright* [1960] 1 WLR 436.

16 *St Helen's Smelting Co v Tipping* (1865) 11 All ER 1483.

17 The following is drawn from Morris et al. (2002).

18 "If later innovators cannot freely build on the work of others, or must pay to do so, they may be less likely to engage in inventive activity themselves" (Besen and Raskind, 2001).

19 For example, the legal fees arising out of a battle between Kodak and Polaroid cost Kodak $100 million (Cole, 2000).

20 It is important to distinguish here sound science from consensus science. Often interest groups on both sides of a particular argument will say that so many thousands of scientists have said X. While such statements probably persuade a certain section of the public, they rarely reflect the very real disputes that exist in the scientific literature. Ensuring that these disputes are taken into consideration is not an easy task – but forcing "consensus" is no solution. In addition, any cost-benefit analysis must consider the opportunity costs of diverting resources towards one action rather than another. So, for example, if one believes that the global climate will warm by two degrees Celsius by the year 2100 and that the cost of this will be 5 per cent of total world output, then before taking action to prevent this harm one should calculate what the cost of taking action will be. If it turns out that no action can be taken that reduces world output by less than 5 per cent, then it would be folly to take any action.

21 Of course, strict rules would be necessary to prevent abuse of power, such as a requirement that all tenders be clearly specified and bids be considered strictly on the basis of conformity with hurdle-type criteria and cost.

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