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Energy and Industry

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The following chapter is the Executive Summary, not the full report, of the Energy & Industry Subgroup.

ENERGY AND INDUSTRY

3.1 INTRODUCTION

3.1.1 THE ESTABLISHMENT OF THE ENERGY AND INDUSTRY SUBGROUP

The Energy and Industry Subgroup (EIS) was established at the first session of the Response Strategies Working Group (RSWG) and held its own first session on that occasion. Membership is open to all countries participating in the IPCC. As of March 1990, 26 countries have participated in the work of EIS together with eight international organizations and 29 non-governmental organizations (as observers). Representatives of Japan and the People's Republic of China were appointed as Co-Chairmen, and a representative of Canada as rapporteur. Membership grew in pace with the growing awareness of the significance of the issues involved.

3.1.2 TERMS OF REFERENCE

The EIS was charged with defining "policy options for national, regional and international responses to the possibility of climate change from greenhouse gas emissions produced by energy production, conversion and use." In doing so, the EIS was to consider greenhouse gases (GHGs), primarily carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) and "define technology and policy options to attempt to reduce emissions of these gases to a level consistent with, or below, emission scenarios defined by the Steering Group (of RSWG)." It was to concentrate on options which could be adequately assessed within eighteen months and also consider those that may require a longer time frame. The mandate also emphasized the necessity of considering the social, economic and environmental implications of technology and policy options on national, regional and international levels.

The EIS was originally given the following five tasks:

- Task 1 Review past and current work on technology and policies related to GHGs.
- Task 2 Select appropriate analytical tools for assessing social, economic, and emission level implications of policy options.
- Task 3 Categorize options by the timing of their potential application.
- Task 4 Analyze nearer-term options for their economic, social, and emission reduction implications and prepare a report for the RSWG.
- Task 5 Prepare a plan to define and further develop and analyze longer-term options based on the information derived from Task 1.

Subsequently, the IPCC at its Third Plenary asked the EIS to conduct analyses related to the remits from the Ministerial Conference in Noordwijk, Netherlands in November 1989, particularly with regard to the feasibility of alternative emission targets.

Although the issues fell within its original mandate, it was agreed that these new, specific tasks would require more time, data, and analysis in order to be dealt with properly. It was decided, therefore, that the results of the deliberations of the EIS on these remits could not be fully included in this report but only treated in an incomplete and preliminary way. A progress report would be presented to the fourth IPCC Plenary following an international workshop to be hosted by the United Kingdom in June 1990.

3.1.3 THE ACTIVITIES UNDERTAKEN

Since the first meeting, the EIS has met on four occasions to discuss the tasks stated above. A series

TABLE 3.1: Primary Energy Consumption and CO_2 Emissions (Exajoules and Billion Tonnes Carbon)

	PRIMARY ENERGY						
					Average Annual Growth Rate		
	1985	2000	2010	2025	1985–2000	1985–2010	1985–2025
Global Totals	**328.2**	**462.1**	**572.1**	**776.9**	**2.3%**	**2.2%**	**2.2%**
Developed	234.7	308.1	357.2	434.6	1.8%	1.7%	1.6%
North America	85.4	108.2	120.7	142.1	1.6%	1.4%	1.3%
Western Europe	54.7	64.8	71.2	81.3	1.1%	1.1%	1.0%
OECD Pacific	19.2	29.6	34.6	42.2	2.9%	2.4%	2.0%
Centrally Planned Europe	75.5	105.4	130.7	169.0	2.2%	2.2%	2.0%
Developing	93.4	154.0	215.0	342.3	3.4%	3.4%	3.3%
Africa	13.5	21.0	31.3	52.9	3.0%	3.4%	3.5%
Centrally Planned Asia	31.2	47.0	61.6	91.9	2.8%	2.8%	2.7%
Latin America	19.1	27.5	35.8	55.0	2.5%	2.5%	2.7%
Middle East	8.0	19.2	27.7	43.2	6.1%	5.1%	4.3%
South and East Asia	21.6	39.3	58.6	99.2	4.1%	4.1%	3.9%
	CARBON DIOXIDE						
					Average Annual Growth Rate		
	1985	2000	2010	2025	1985–2000	1985–2010	1985–2025
Global	**5.15**	**7.30**	**9.08**	**12.42**	**2.3%**	**2.3%**	**2.2%**
Developed	3.83	4.95	5.70	6.94	1.7%	1.6%	1.5%
North America	1.34	1.71	1.92	2.37	1.6%	1.4%	1.4%
Western Europe	0.85	0.98	1.06	1.19	0.9%	0.9%	0.8%
OECD Pacific	0.31	0.48	0.55	0.62	3.0%	2.3%	1.8%
Centrally Planned Europe	1.33	1.78	2.17	2.77	2.0%	2.0%	1.9%
Developing	1.33	2.35	3.38	5.48	3.9%	3.8%	3.6%
Africa	0.17	0.28	0.45	0.80	3.5%	4.1%	4.0%
Centrally Planned Asia	0.54	0.88	1.19	1.80	3.3%	3.2%	3.1%
Latin America	0.22	0.31	0.42	0.65	2.4%	2.6%	2.7%
Middle East	0.13	0.31	0.44	0.67	5.8%	4.9%	4.1%
South and East Asia	0.27	0.56	0.89	1.55	5.1%	4.9%	4.5%

Note: Totals reflect rounding

of expert group meetings was held to discuss various issues concerning methodological tools and analytical approaches. There was a general consensus that no single approach would be adequate. A combination of modeling and non-modeling approaches was suggested. A hybrid approach was taken by which "bottom-up" national approaches would be combined with "top-down" global approaches to produce integrated assessments in order to exploit the advantages of both approaches. The issue of cost-effectiveness analysis was identified as one of the areas of future work.

It was decided to limit the scope of the EIS analysis to carbon dioxide, nitrous oxide, and methane emissions from the energy and industry sectors (including transportation and waste management). Emissions estimates for these GHGs were made, but additional future analysis of emission scenarios would be useful for evaluating response strategies in the energy and industrial sectors.

3.1.4 THE MATERIAL USED IN PRODUCING THE REPORT

This report is based on the country case studies presented to the IPCC by experts. These studies are preliminary and not necessarily official government positions.

Individual national case studies, to be based in part on IEA oil price scenarios, were solicited. These studies, often drawn from work conducted for domestic policy purposes, were submitted by national delegations. All but one were for industrialized market economies. Only Canada, the Federal Republic of Germany, the Netherlands, France, Japan, the United Kingdom and Switzerland examined response options. Only the Netherlands, Switzerland, and the United Kingdom included some assessment of costs. Furthermore, the national case studies often differed with respect to time frame, assumptions, and other factors.

The national case studies were supported by additional materials submitted to EIS. These included: a regional study by the Commission of the European Communities; a global/regional study from the IEA; a joint comparative study of their members from the IEA and OECD and a technical analysis of the potential of nuclear power by the International Atomic Energy Agency and ten independent studies of developing and Eastern European countries commissioned by the U.S. EPA. Response Options studies were included for China, Brazil, India, Indonesia, the Republic of Korea, Mexico, Venezuela, the USSR and Poland. Other valuable contributions were received from all EIS participants—for example, the RSWG Task A emission scenarios.

In total, the countries for which studies were received by EIS accounted for around 80 percent of global CO_2 emissions.

3.1.5 The Nature of the Report

This report represents only a first tentative step toward the goal of identifying the paths and strategies needed to ensure that energy and industry related greenhouse gas emissions are compatible with the concept of sustainable development. Such strategies should be economically efficient and compatible with other policy goals.

As discussed above, the report relies on various materials submitted to the EIS. However, their coverage in terms of all greenhouse gases and regions remains short of producing consistent global analysis. Adequate data were not available on the emissions of greenhouse gases at all stages of the fuel cycle and no methodology was available to compare the effects of various gases on a standard basis, (e.g., CO_2 equivalence). The report therefore puts a heavy emphasis on CO_2, for which there were the most definitive data. Further, most of the country case studies submitted pertain to reference cases, rather than policy options, and thus little material was available on the socio-economic consequences of emission controls.

Two broad conclusions are supported by the national case studies from which the EIS reference scenario is drawn:

- First, the nature of the problem varies significantly depending on each country's economic structure, the situation of its energy sector, and its stage of development. The national case studies showed that economic growth and reductions from the reference case in the growth of greenhouse gases can co-exist and that policies and technologies can make a substantial contribution to limiting GHGs.
- Second, there is no single quick-fix technological option; improving efficiency on both the demand and supply side should be a priority; technological solutions must be cost effective; non-economic barriers to diffusion of attractive technologies were a fruitful area for further analysis; and technological research and development was a prime area for international cooperation. Overall, there was a consistent emphasis on energy efficiency and conservation.

3.2 ROLE OF THE ENERGY SECTOR

The energy sector plays a vitally important role in economic development for all nations. Energy policies need to ensure that sustained economic growth occurs in a manner that also preserves the global environment for future generations.

3.2.1 Current Contribution to Greenhouse Gas Emissions

The energy sector is the most important single source of greenhouse gases, accounting for approximately 57 percent of radiative forcing from anthro-

TABLE 3.2: Examples of Short-Term Options

I. Improve Efficiency in the Production, Conversion, and Use of Energy			
Electricity Generation	**Industry Sector**	**Transport Sector**	**Building Sector**
· Improved efficiency in electricity generation: –repowering of existing facilities with high efficiency systems; –introduction of integrated gassification combined cycle systems; –introduction of atmospheric fluidized bed combustion; –introduction of pressurized fluidized bed combustion with combined cycle power systems; –improvement of boiler efficiency. · Improved system for cogeneration of electricity and steam. · Improved operation and maintenance. · Introduction of photovoltaics, especially for local electricity generation. · Introduction of fuel cells.	· Promotion of further efficiency improvements in production process. · Materials recycling (particularly energy-intensive materials). · Substitution with lower energy-intensive materials. · Improved electro-mechanical drives and motors. · Thermal process optimization, including energy cascading and cogeneration. · Improved operation and maintenance.	· Improved fuel efficiency of road vehicles: –electronic engine management and transmission control systems; –advanced vehicle design: reduced size and weight, with use of lightweight composite materials and structural ceramics; improved aerodynamics, combustion chamber components, better lubricants and tire design, etc.; –regular vehicle maintenance; –higher capacity trucks; –improved efficiency in transport facilities; –regenerating units. · Technology development in public transportation: –intra-city modal shift (e.g., car to bus or subway); –advanced train control system to increase traffic density on urban rail lines; –high-speed inter-city trains; –better intermodal integration. · Improved driver behavior, traffic management, and vehicle maintenance.	· Improved heating and cooling equipment and systems: –improvement of energy efficiency of air conditioning; –promotion of introduction of area heating and cooling, including use of heat pumps; –improved burner efficiency; –use of heat pumps in buildings; –use of advanced electronic energy; management control systems. · Improved space conditioning efficiency in house building: –improved heat efficiency through highly efficient insulating materials; –better building design (orientation, window, building, envelope, etc.); –improved air-to-air heat exchangers. · Improved lighting efficiency. · Improved appliance efficiency. · Improved operation and maintenance. · Improved efficiency of cook stoves (in developing countries).

TABLE 3.2 (*continued*): **Examples of Short-Term Options**

II. Non-Fossil and Low Emission Energy Sources

Electricity Generation	Other Sectors
· Construction of small-scale and large-scale hydro projects. · Expansion of conventional nuclear power plants. · Construction of gas-fired power plants. · Standardized design of nuclear power plants to improve economics and safety. · Development of geothermal energy projects. · Introduction of wind turbines. · Expansion of sustainable biomass combustion. · Replacement of scrubbers and other energy-consuming control technology with more energy efficient emission control.	· Substitution of natural gas and biomass for heating oil and coal. · Solar heating. · Technologies for producing and utilizing alternative fuels: –improved storage and combustion systems for natural gas; –introduction of flexible-fuel and alcohol-fuel vehicles.

III. Removal, Recirculation, or Fixation

Energy/Industry	Landfills
· Recovery and use of leaked or released CH_4 from fossil fuel storage, coal mining. · Improved maintenance of oil and natural gas and oil production and distribution systems to reduce CH_4 leakage. · Improved emission control of CO, SO_X, NO_X, and VOCs to protect sinks of greenhouse gases.	· Recycle and incineration of waste materials to reduce CH_4 emissions. · Use or flaring of CH_4 emissions. · Improved maintenance of landfill to decrease CH_4 emissions.

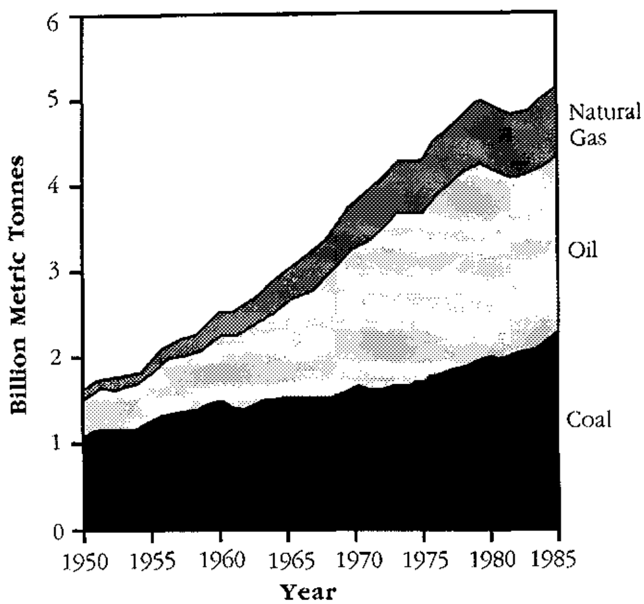
pogenic sources in the 1980s. The major greenhouse gases produced by the energy sector include CO_2 and CH_4 from combustion of fossil fuels and CH_4 from coal mines and oil and gas facilities. In 1985, approximately 5.3 billion tonnes of CO_2 as carbon (BTC) were released from fossil fuel combustion, and 50–95 million tonnes (MT) of CH_4 were released due to fossil fuel production and consumption. Another source of greenhouse gas emissions is solid waste landfill, which produces CH_4. Additionally, biomass burning for heating and cooking produces CH_4 and when not based on sustainable resources will produce net CO_2 emissions. Nitrous oxide, another important greenhouse gas, is also released from the energy sector, but the exact contribution is uncertain.

Other gases that contribute indirectly to greenhouse gas concentrations include CO, NO_x, and NMHC (non-methane hydrocarbons). Comparing relative contributions to radiative forcing across the various gases is complicated and dependent on a number of key assumptions, particularly time horizon. The relative importance of current emissions of different gases varies considerably depending on the time horizon over which the contribution to radiative forcing is considered. These differences are due to the significant differences in the average atmospheric lifetimes of the radiatively important gases. However, integration over longer time horizons tends to increase the importance of energy as a source category.

Table 3.7 on page 68 shows the current contribution to radiative forcing from all sources and from the energy sector.

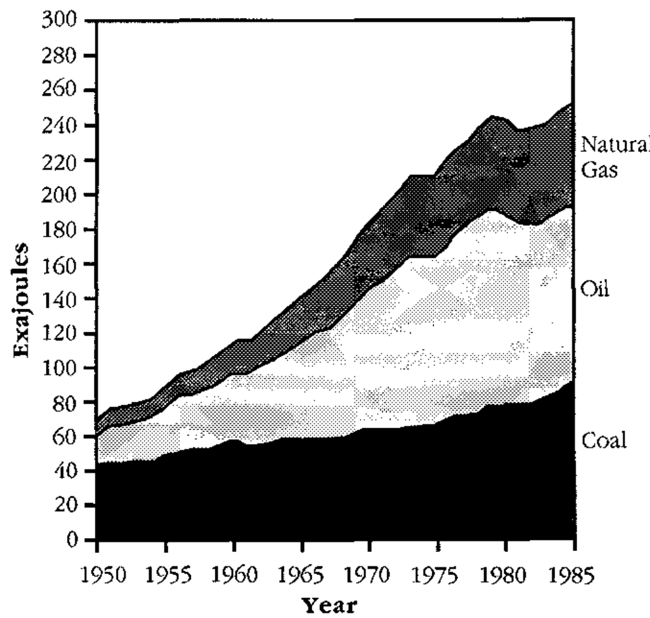
During the period 1950–1985, global energy consumption in total and per capita from fossil fuel increased by nearly a factor of four, while CO_2 emissions increased from 1.5 to 5.3 BTC, or nearly 3.5 times. During this time the liquid fuel share increased from 31 to 45 percent, the coal share declined from 60 to 33 percent, and natural gas increased from 9 to 22 percent. See Figures 3.1 and 3.2.

FIGURE 3.1: **Global Fossil Fuel Carbon Emissions, 1950–1985**



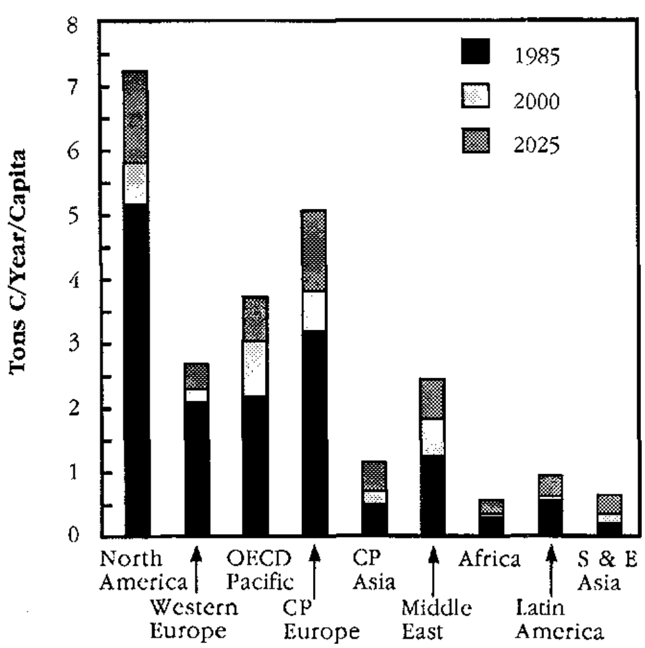
Source: Marland, 1988

FIGURE 3.2: **Global Fossil Energy Consumption, 1950–1985**



Source: Marland, 1988

FIGURE 3.3: **CO_2 Emissions per Capita**



The historical growth in energy consumption and CO_2 emissions differs by region of the world (for per capita carbon emission, see Figure 3.3). For example:

- Fossil fuel energy use in developed market economies grew by 4 percent per year for the period 1950–1970. From 1970 to 1985 fossil energy consumption increased by an amount equal to only a 0.4 percent per year average growth rate. This was due to slow economic growth and energy price increases that accelerated structural changes and other shifts in energy use and production. Over the entire period 1950–1985, the average annual rate of growth in fossil energy use was 2.6 percent. Annual CO_2 emissions from these countries accounted for approximately 2.5 BTC in 1985 and on a per capita basis was 2.95 TC per person (down slightly from 3.1 TC per person in 1970).
- Fossil fuel energy use in centrally planned Eastern Europe and the USSR increased steadily

TABLE 3.3: Examples of Medium-/Long-Term Options

I. IMPROVE EFFICIENCY IN THE PRODUCTION, CONVERSION, AND THE USE OF ENERGY

ELECTRICITY GENERATION	INDUSTRY SECTOR	TRANSPORT SECTOR	BUILDING SECTOR
· Advanced technologies for storage of intermittent energy. · Advanced batteries. · Compressed air energy storage. · Superconducting energy storage.	· Increased use of less energy-intensive materials. · Advanced process technologies. · Use of biological phenomena in processes. · Localized process energy conversion. · Use of fuel cells for cogeneration.	· Improved fuel efficiency of road vehicles. · Improvements in aircraft and ship design. –advanced propulsion concepts; –ultra-high-bypass aircraft engines; –contra-rotating ship propulsion.	· Improved energy storage systems: –use of information technology to anticipate and satisfy energy needs; –use of hydrogen to store energy for use in buildings. · Improved building systems: –new building materials for better insulation at reduced cost; –windows that adjust opacity to maximize solar gain. · New food storage systems that eliminate refrigeration requirements.

II. NON-FOSSIL AND LOW EMISSION ENERGY SOURCES

ELECTRICITY GENERATION	OTHER SECTORS
· Nuclear power plants: –passive safety features to improve reliability and acceptability. · Solar power technologies: –solar thermal; –solar photovoltaic (especially for local electricity generation). · Advanced fuel cell technologies.	· Other technologies for producing and utilizing alternative fuels: –improved storage and combustion systems for hydrogen; –control of gases boiled off from cryogenic fuels; –improvements in performance of metal hydrides; –high-yield processes to convert ligno-cellulosic biomass into alcohol fuels; –introduction of electric and hybrid vehicles; –reduced re-charging time for advanced batteries.

III. REMOVAL, RECIRCULATION, OR FIXATION

- Improved combustion conditions to reduce N_2O emissions.
- Treatment of exhaust gas to reduce N_2O emissions.
- CO_2 separation and geological and marine disposal.

TABLE 3.4*: CO_2 Emissions from the Energy Sector and Comparison of Emissions Reductions (from the Reference Scenario)

	CO_2 Emissions in Billion Tonnes Carbon			
	1985	2000	2010	2025
Global Totals	**5.15**	**7.30**	**9.08**	**12.43**
Developed	3.83	4.95	5.70	6.95
North America	1.34	1.71	1.92	2.37
Western Europe	0.83	0.98	1.06	1.19
OECD Pacific	0.31	0.48	0.55	0.62
Centrally Planned Europe	1.33	1.78	2.17	2.77
Developing	1.33	2.35	3.38	5.48
Africa	0.17	0.28	0.45	0.80
Centrally Planned Asia	0.54	0.88	1.19	1.80
Latin America	0.22	0.31	0.42	0.65
Middle East	0.13	0.31	0.44	0.67
South and East Asia	0.27	0.56	0.89	1.55
Stabilize		−2.14 (29%)	−3.92 (43%)	−7.26 (59%)
20% Reduction		−3.17 (44%)	−4.95 (55%)	−8.29 (67%)

	CO_2 Emissions in Tonnes Carbon per Capita			
	1985	2000	2010	2025
Global	**1.06**	**1.22**	**1.36**	**1.56**
Developed	3.12	3.65	4.02	4.65
North America	5.08	5.73	6.11	7.12
Western Europe	2.11	2.29	2.44	2.69
OECD Pacific	2.14	3.01	3.29	3.68
Centrally Planned Europe	3.19	3.78	4.32	5.02
Developing	0.36	0.51	0.64	0.84
Africa	0.29	0.32	0.41	0.54
Centrally Planned Asia	0.47	0.68	0.85	1.15
Latin America	0.55	0.61	0.71	0.91
Middle East	1.20	1.79	2.11	2.41
South and East Asia	0.19	0.32	0.44	0.64
Stabilize		−0.16 (13%)	−0.30 (22%)	−0.50 (32%)
20% Reduction		−0.38 (31%)	−0.51 (38%)	−0.71 (46%)

* This table should be read in conjunction with Table 2 of the Policymakers Summary, which also provides data on carbon intensity by region, another important index of CO_2 emissions. Table totals reflect rounding.

between 1950 and 1985 at an average growth rate of 5.2 percent per year, from approximately 12 exajoules to approximately 70 exajoules. Annual CO_2 emissions increased from about 300 to 1400 MTC, while on a per capita basis emissions were nearly 3.3 TC per person.

- Fossil fuel energy growth in the centrally planned economies of Asia was not steady during the period 1950–1985, but it did increase dramatically from about 1 exajoule to over 23 exajoules, a growth rate of 9.8 percent per year. CO_2 emissions increased from around 20 MTC to over 500 MTC during this period, but on a per capita basis emissions were only 0.5 TC per person or roughly one sixth of developed country levels.

- Energy consumption in the developing market economies grew at an average rate of 5.7 percent per year, or by sevenfold, during the period 1950–1985 (from about 5 to 35 exajoules) even during the period of rapidly increasing oil prices. Total CO_2 emissions reached about 700 MT in 1985 but on a per capita basis were only 0.3 TC per person.

The historical growth in methane emissions also differs by region of the world, but is much more difficult to evaluate because of the lack of historical data.

3.3 SCENARIOS FOR FUTURE GREENHOUSE GAS EMISSIONS

The broad determinants of energy use that will affect greenhouse gas emissions:

- The population level of the country is an important determinant of overall energy requirements. Generally, countries with rapid population growth rates are likely to experience high growth rates in energy use.
- The level and structure of economic activity, often measured by annual income or product flows as gross domestic product (GDP). The energy intensity of the economy is measured by the amount of energy used per unit of aggregate income or product. The amount of energy used to create GDP depends on a number of factors, including the composition of economic activity between more or less energy intensive industries or sectors, climate, transportation distances, energy efficiency, etc. The energy efficiency of the economy is affected by the technologies used to produce goods and services. Management practices, behavioral attitudes and infrastructure also affect energy efficiency.
- The carbon intensity of energy facilities influences GHG emissions. Carbon intensity reflects the mix of fossil fuels used in the economy, the proportion of total energy requirements met through non-fossil energy such as nuclear and hydroelectric power, and the methods of resource production, distribution, transmission, and conversion.

Future levels of emissions are difficult to predict because of the inherent uncertainties in these and other factors, such as the introduction of new technologies. Therefore, scenarios of future emissions are necessary for assessing climate trends. The uncertainty surrounding such scenarios increases rapidly (and their usefulness decreases) as they are projected further into the future. Policy options need to be tested and costs assessed, therefore, against a range of possible future scenarios. This did not prove possible in the time available for production of this interim report.

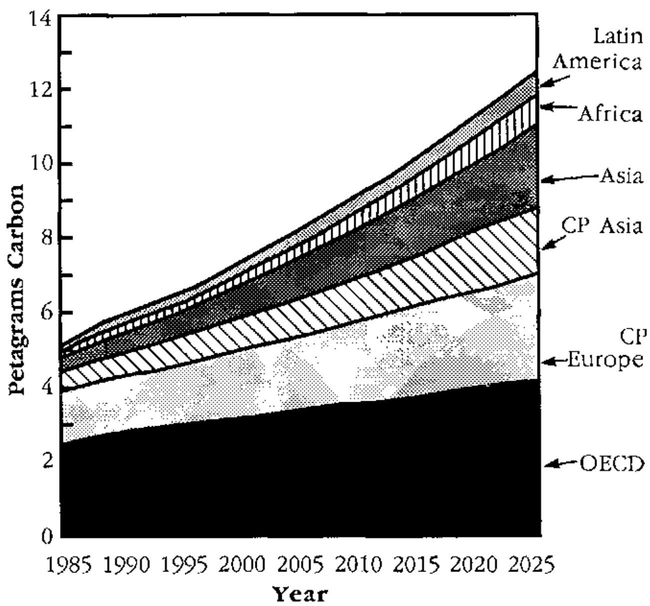
3.3.1 The EIS Reference Scenario

The EIS Reference Scenario deals only with CO_2 and is presented in Table 3.1 on page 50. This was developed from the national case studies and other data submitted to EIS. It broadly reflects current trends but includes some limited measure of response to the climate change issue. Figure 3.5a on page 60 shows this scenario along with others produced by the IEA, EC, and WEC.

3.3.2 Future CO_2 Emissions in the EIS Reference Scenario

The EIS Reference Scenario portrays a future where, in the absence of further policy measures, energy use and CO_2 emissions grow rapidly to over 9 BTC by 2010 and over 12 BTC by 2025. Global emissions rise faster than those in the high emission scenario provided by the RSWG Task A Group (see Figure 3.5a). Table 3.5 on page 59 shows that economic growth and the rate of improvement in energy intensity are modest at 3.0 percent and 0.8 percent a year respectively. Table 3.1 reveals that primary energy demand more than doubles be-

FIGURE 3.4: CO_2 Emissions by Region (Petagrams carbon/year)



tween 1985 and 2025, reaching 777 EJ at the end of the period, an average annual growth rate of 2.2 percent.

The average annual rate of growth in CO_2 emissions over the period 1985–2025 varies from 0.8 percent in Western Europe to 3.6 percent in developing countries with 1.4 percent in North America and Pacific OECD countries. Overall the share of emissions from OECD countries declines from 48 percent in 1985 to 43 percent in 2000 and to 33 percent in 2025, and the share attributable to Eastern Europe declines from 26 percent to 24 percent in 2000 and to 22 percent in 2025. Meanwhile, emissions from developing countries rise from 26 percent in 1985 to 32 percent in 2000 and to 44 percent in 2025. Under this scenario, the per capita emissions in the developed countries increase from 3.2 TC per capita to 4.5 TC per capita in 2025. For the developing countries the per capita emissions rise from 0.4 TC per capita in 1985 to 0.8 TC per capita in 2025.

The estimated global growth in CO_2 emissions is higher than the high emission scenario provided by RSWG to WG1. Figure 3.5b on page 61 shows the 1990–2025 emissions from the OECD countries and global totals, in the EIS Reference scenarios and in selected RSWG Task A scenarios. The High Emissions Scenario envisages that equivalent CO_2 concentrations reach a value double that of pre-industrial atmospheric concentrations of CO_2 by 2030. The Accelerated Policies Scenario represents the largest emissions reduction projected by RSWG. Equivalent CO_2 concentrations in this scenario stabilize at a level less than double the pre-industrial atmospheric concentrations of CO_2. A line which represents a reduction to a level 20 percent below 1988 emission levels is also shown.

3.3.3 FUTURE METHANE EMISSIONS

Methane is emitted from coal mining, oil and natural gas systems, and waste management systems (i.e., landfills, wastewater treatment facilities). Growth in these emissions is highly dependent upon population and economic growth. Using the same assumptions as described above, methane emissions from these sources may increase by 85 percent by 2010 and 163 percent by 2025. Individually, emissions from coal mining may increase by 93 percent by 2010 and 186 percent by 2025; methane emissions from oil and natural gas systems by similar percent changes; and methane emissions from landfills by 50 percent by 2010 and 100 percent by 2025.

It should be noted that the future estimates of methane emissions from coal mining may be understated. It is likely that as developing countries intensify their coal mining activities to meet rapidly increasing demand for energy, they will mine more coal and coal that is deeper and more gaseous.

3.4 THE SCALE OF THE EMISSION GAP

Table 3.4 summarizes the emission levels in the EIS Reference Scenario and illustrates possible alternative emission levels. It shows that stabilizing emissions at current levels poses a global policy challenge and that the capacity of regions to reduce emission levels varies greatly. Stabilizing emissions globally at 1985 levels would require reductions below the levels estimated in the Reference Scenario of 29 percent by 2000 and 43 percent by 2010. Table 3.5 summarizes trends in economic growth, energy intensity, and carbon intensity for the period 1985–2025.

A 20 percent reduction of emissions below estimated 1990 levels by 2025 is a much more significant policy challenge. Table 3.4 shows that, if implemented globally, it would require a 67 percent reduction (reduce 8.29 BTC from 12.4 BTC) from the reference emission levels in 2025.

TABLE 3.5: Trends in Economic Growth, Energy Intensity, and Carbon Intensity, 1985–2025 (Average Annual Rate of Change, %)

	GDP	Energy Intensity	Carbon Intensity
Global Average	3.0	−0.8	0.0
Developed	2.6	−1.0	−0.1
North America	2.2	−0.9	0.1
Western Europe	2.3	−1.3	−0.2
OECD Pacific	3.1	−1.1	−0.2
Centrally Planned Europe	3.2	−1.1	−0.2
Developing	4.4	−1.1	0.3
Africa	4.0	−0.5	0.5
Centrally Planned Asia	5.3	−2.5	0.3
Latin America	3.3	−0.6	0.1
Middle East	4.9	−0.5	−0.2
South and East Asia	4.6	−0.7	0.6

3.5 RESPONSE OPTIONS AND MEASURES

There are a number of technical options available to reduce greenhouse gas emissions and policy measures to implement them. We define technical options to include not only the installation of new capital stock with lower emission characteristics (or the modification of existing stock) but also the managerial and behavioral changes which can reduce future emissions. Policy measures are the actions, procedures, and instruments that governments adopt to bring about additional or accelerated uptake of the technical measures beyond that in a reference scenario.

When analyzing the costs and benefits of alternative response strategies, a systematic approach is needed that identifies the overall effect not only of the technical options but also of the policy measures needed to bring them about. This task must take into account the international nature of energy markets as well as the individual characteristics of national economies. EIS has not, therefore, been able to complete such an analysis but some example resource costing was included in some of the national case studies submitted to EIS.

3.5.1 Criteria for Response Strategy Evaluation

In deciding whether, how, and how much to accelerate the implementation of technologies, adoption of management techniques, and structural or behavioral change that could limit CO_2 emissions, a wide range of factors must be considered. These include:

- technical, economic and market potential of technologies;
- development status and time scale for implementation of technologies;
- implications for other GHGs;
- interaction between measures;
- resource costs and private costs;
- macroeconomic and microeconomic effects;
- implications for other policy goals, and social consequences;
- policy robustness;
- political and public acceptability, effectiveness, limitations, and effect of policy instruments.

Understanding the distinction between technical, economic, and market potential is important for developing realistic response strategies. The technical potential of an energy technology is its capacity to reduce potential greenhouse gas emissions, irrespective of the costs involved. This capacity is largely a function of technical feasibility and resource availability.

However, the economic potential may be significantly less. This occurs where there are positive resource costs when evaluated at social discount rates—allowing for second round effects. The inclusion, where possible, of the economic benefits of emission reduction might also influence the economic potential of measures. Finally, the market potential might be even less, due to market imperfections and the use of higher discount rates by private sector decision makers. Attitudes to risk and the presence of non-monetary costs will also be major influences.

The challenge for policymakers is to enhance the market uptake of appropriate options taking full account of all the interactions, second round effects, costs, and benefits.

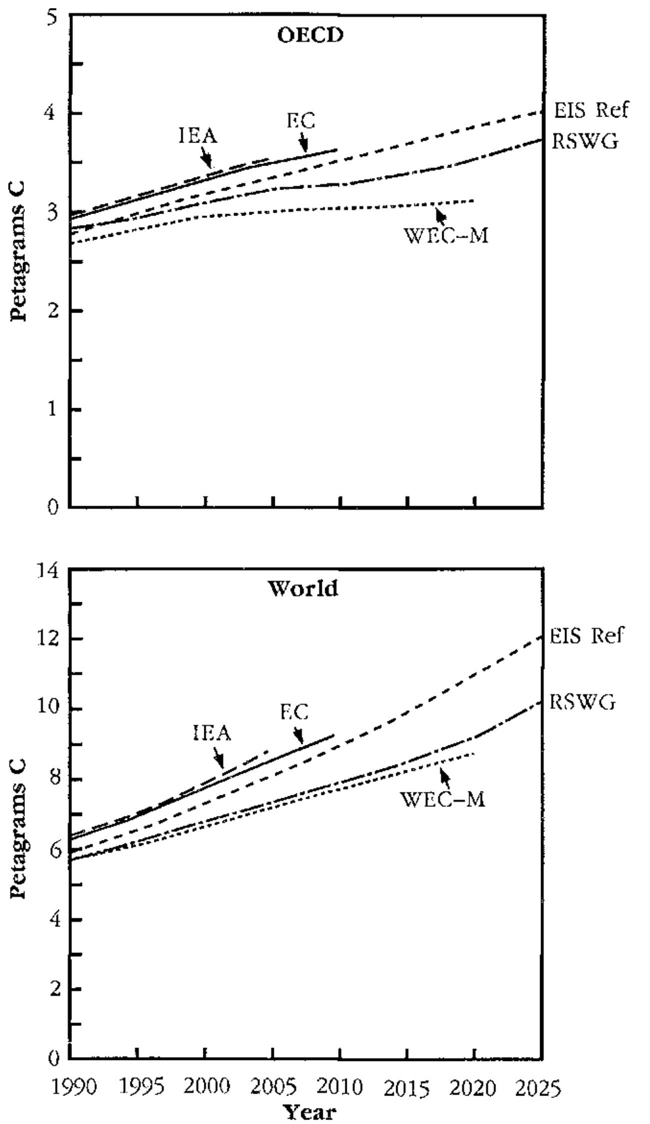
3.5.2 TECHNICAL OPTIONS

The most relevant categories of technologies to reduce greenhouse gas emissions from energy systems are:

- efficiency improvements and conservation in energy supply, conversion, and end-use;
- fuel substitution by energy sources that have lower or no greenhouse gas emissions;
- reduction of greenhouse gas emissions by removal, recirculation, or fixation; and
- management and behavioral changes (e.g., increased work in homes through information technology) and structural changes (e.g., modal shift in transport).

To fully understand their present and future potential and the types of actions that might be taken to enhance their potential, technologies and consumer or producer actions must be viewed in terms of the time frame in which they can be effective. Changes in management and behavior that lead to energy conservation and emissions reduction can begin now. Many technologies are available now, whereas others need further development to lower costs or to improve their environmental characteris-

FIGURE 3.5a: CO_2 Emission Comparison EIS Reference Scenario vs. Other Emissions Scenarios



*Emissions Scenarios:**

EIS Ref=EIS Reference Scenario

RSWG=RSWG Task A Scenario

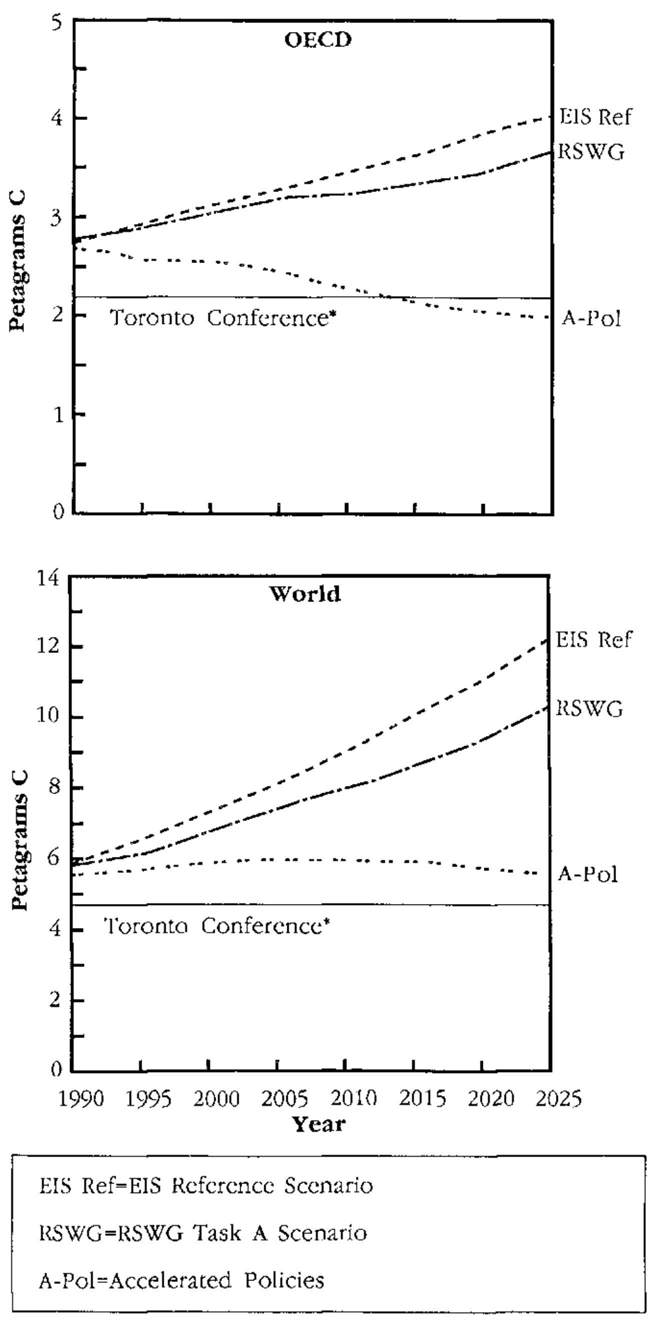
WEC-M=World Energy Conference (Moderate Scenario)

IEA=International Energy Agency

EC=Commission of the European Communities

* CO_2 emission coefficients calculated from those found in Marland and Rotty, 1984

FIGURE 3.5b: CO_2 Emission Comparison EIS Reference Scenario vs. RSWG Task A Scenario



* Recommended 20% reduction from 1988 levels by 2005

tics. Tables 3.2 and 3.3 provide examples of technologies within each of the broad categories defined above, and their possible application in the short- and medium- or long-term time frame.

This distinction on time frame is suggested in order to comprehend the remaining technological needs of each category and to formulate a technological strategy. First-wave or near-term technologies are those that are or will be ready for introduction and/or demonstration by 2005. Second-wave technologies are available, but not yet clearly economic and thus would mainly be implemented in the medium-term time frame of 2005 to 2030. They could be introduced sooner if they were close to economic or particularly beneficial to the environment. Third-wave technologies are not yet available but may emerge in the long term or post 2030 as a result of research and development.

The technical, economic, and market potential of cross-cutting technological options will vary, depending upon the sector in which they are to be applied. Cross-cutting technologies include those for energy efficiency and conservation, natural gas fuel use, renewable energy, other non-fossil fuels, and energy storage. For this reason, the specific technological options within the three broad categories listed above are analyzed by sector. There is in general extensive information and data available on the technical potential of the many technological options. However, the economic and market potential of the options depends on specific circumstances (national, local, and even sectoral) in which the option is to be applied. Therefore, no figures for these potentials are provided. Rather, it is left to the country case studies to analyze economic and market potential of options in the context of national circumstances.

For management and behavioral changes regarding technologies in the first-wave stage as described above, the advisability of applying policy measures to accelerate their implementation should be determined. A phased approach to technology development and introduction into the market is offered as an important strategy to be considered for concerted national and international collaborative action. Near-term technological potential of particular relevance to the developed world is discussed by sector below. Technological potential for developing countries has not been developed in the same detail due to a lack of information.

TABLE 3.6a: **Applicability, Effectiveness, Limitations, and Economic Effects of Information**

MEASURE APPLICABILITY	EFFECTIVENESS	RELATIVE IMPACTS		LIMITATIONS
		DURATION	SIZE	I/P/C[1]
Exhortation	all responses, especially those making economic sense	short	small	I/P/C
Negotiation	development of charges, regulations or policies for all responses	long	large	p
Training	services/operations	long	small	P/C
Testing	industrial equipment, vehicles and other consumer products	medium	small	P/C

[1] I/P/C: Effectiveness to Influence Investment, Producer, or Consumer
[2] na: not assessed
Source: IEA Secretariat.

3.5.3 TRANSPORTATION SECTOR

Substantial technical potential exists for fuel substitution through the use of fuels derived from natural gas and of ethanol or other fuels derived from biomass. Substantial technical potential also exists for electric or hydrogen-fueled vehicles, which could also reduce emissions with appropriate primary energy sources. Presently, the economic and market potentials of most of these options are very low because petroleum fuels are relatively cheap, alternative non-CO_2-producing fuels are relatively costly, and some alternative vehicular technologies have performance drawbacks. The technical potential for vehicle efficiency improvements is very high despite the substantial improvements already made. Economic and market potentials are constrained by replacement rates of vehicles, consumer demand and preference for larger, more powerful and better-equipped cars, and higher incremental costs. Improved driver behavior, vehicle maintenance, traffic management, and promotion of public transportation could also reduce CO_2 emissions.

3.5.4 BUILDINGS SECTOR

The technical potential for energy efficiency gains in the residential and commercial sectors is also substantial. Space conditioning energy requirements in new homes could be roughly half of the current average for new homes. The technical potential for retrofits could average 25 percent. Reductions of energy use in existing commercial buildings by at least 50 percent may be technically feasible, and new commercial buildings could be up to 75 percent more efficient than existing commercial buildings. However, market potential is lower and depends on the replacement rate. The realization of significant gains in this sector requires the involvement of government, the many concerned institutions, and ultimately the individual residential or commercial consumers. This sector therefore requires special efforts in order to achieve desired levels of market penetration of energy efficient technologies. For these technologies to achieve their market potential, institutional barriers must be removed and careful attention given to the design of R&D programmes

Implementation		Micro-Economic Effects	Macro-Economic Effects	Economic Effects
Cost to Govt.	Duration			
low	quick	–easily erodes –usually not enough to achieve substantial effects	may alter consumption	n.a.[2]
low	quick	depends on willingness of industries to be regulated	may alter consumption	n.a.
low	quick	getting participation of "needless" groups	may alter consumption	n.a.
moderate	medium	requires facilities, constant update	may alter consumption	n.a.

for this sector. Improved operation and maintenance of buildings could also help. Fuel substitution usually occurs in this sector only when there are equipment replacements and a source exists for the alternative, more competitive fuel. Therefore, the possibilities in the sector include decreasing coal and oil use for heating and substituting natural gas use or district heating applications. However, consumers and firms in existing structures may find the infrastructure unavailable or highly expensive even if the fuel itself is cost-competitive.

3.5.5 Industry Sector

The technical potential for efficiency improvements in the industry sector ranges from 13 percent in some sub-sectors to over 40 percent in others. The most dramatic efficiency improvements over the last 15 years have been in the energy-intensive industries. Technical options exist for accelerating this trend and for achieving similar savings in other industries. Such options stem mainly from recent improvements in process technologies, as well as better design and materials. Considerable opportunities for energy savings also exist in the industrial sector by the recycling of energy-intensive waste. There may also be significant potential for reducing greenhouse emissions through industrial fuel switching, especially as many industrial boilers are already dual-fuel capable, with natural gas being the fuel typically substituted for fuel oil under present circumstances. Combined heat and power, cogeneration, combustion of biomass wastes, methane from landfill, and other renewable energy sources also have potential.

The technical potential for methane recovery and reduction exists in solid waste landfills (through gas recovery, flaring, and incineration), oil and natural gas production, gas transmission and distribution systems, and underground coal mines.

3.5.6 Electricity Sector

Under current price conditions, both efficiency and fuel substitution are largely dependent on the rate of

TABLE 3.6b: **Applicability, Effectiveness, Limitations, and Economic Effects of Regulatory Measures**

MEASURE APPLICABILITY	EFFECTIVENESS	RELATIVE IMPACTS		LIMITATIONS
		DURATION	SIZE	I/P/C[1]
Mandatory Standards	equipment and appliances, buildings, "add-on" technologies	medium to long	varies with stringency	I/P/C
Voluntary Standards	equipment and appliances, buildings, "add-on" technologies	medium to long	varies	I/P/C
License/Permit	–siting new facilities –tradeable permits	medium to long	varies	I/P/C

[1] I/P/C: Effectiveness to influence Investment, Producer, or Consumer
[2] Self: Can be made self-funding

retirement of existing units, the growth in demand for electricity, and the cost of the replacement units. The technical potential for greater efficiency in generation is in the range of 15 to 20 percent. Fuel substitution could achieve CO_2 reduction in CO_2 emissions from electrical generation in the range of 30 percent (from oil to natural gas) to 100 percent (from fossil fuel to non-fossil fuel). The electricity sector has a potential to substantially increase its efficiency where cogeneration of electricity and heat or combined cycle power generation can be applied. The economic potential for greater fuel efficiency is considerably lower and for substitution from coal or oil to natural gas or non-fossil fuel is critically dependent on the relative prices and availability of the fuels in question. In evaluating switching between fossil fuels it is necessary to account for any potential increases in methane emissions from production and transmission of the fuels in calculating the net benefit of such strategies. Overall, efficiency of the electricity system can be improved through the use of least cost utility planning. The goal of least cost utility planning is to meet energy-service requirements through the least cost combination of supply additions and demand management.

3.5.7 POLICY MEASURES

The pool of policy measures is broadly similar for all nations. The measures fall generally into three groups:

- *Information measures* include all efforts to better inform the public on greenhouse gas emissions and the means available to the public for their reduction. This includes research, development, and demonstration programs for emerging technologies and education and training of professional experts in all sectors. These programs should be targeted at particular sections of the populace and should emphasize the present and potential future costs and benefits of such actions. The transfer of information and expertise between countries requires particular attention in order to ensure the relevance and the applicability of the information to local conditions. This is especially true in the case of technology transfer to developing countries.
- *Economic measures* include the broad areas of taxes, charges, subsidies, and pricing policies that include incorporating environmental costs into energy prices (both imposition and re-

Implementation		Micro-Economic Effects	Macro-Economic Effects	Economic Effects
Cost to Govt.	Duration			
moderate	medium to long	implementation and enforcement require technical expertise, authority	–internalizes externalities, –raises producer costs and prices	can affect trade patterns
none	medium	not enforceable by government	–internalizes externalities, –raises producer costs and prices	can affect trade patterns
moderate (self)[2]	medium	implementation and enforcement require technical expertise, authority	can create new markets and establish prices for environmental goods	

moval). Such measures may also be used to complement regulations, making them more effective in meeting environmental goals. Economic measures may also be used to support the research, development, demonstration, or application of technologies for enhanced energy efficiency, fuel substitution, or pollution control. The use of tradeable emission permits or emission compensation on a global scale for greenhouse gas abatement might take advantage of the ability of certain regions to control emissions more cheaply than others.

- *Regulatory measures* include a broad array of control mechanisms, and standards regulations used for environmental protection have ranged from emission standards to requirements for environmental impact assessments. Regulations used to enhance energy security have ranged from end-use efficiency standards to requirements for the use of certain fuels in certain sectors. Such regulations may of course help to protect the environment as well.

Tables 3.6a–c illustrate policy measures in these three groups with some of the criteria listed in Section 3.5.1. More careful exploration and examination will be required in the future.

3.6 COSTS

It is essential that the costs of emission abatement strategies are fully assessed. Anecdotal evidence suggests that the cost of some strategies could be high and that, from a given starting point, the more ambitious the strategy the higher the associated costs. The EIS is not yet able, however, to provide informed advice on the costs associated with the measures and response strategies discussed in this report. Further work in this area is essential.

Some preliminary indications are available from the individual Country Studies submitted to EIS, which suggest:

a) Significant emission abatement potential is available at low or negative resource cost when tested at social discount rates. By 2020 this might amount to around 20 percent of global

TABLE 3.6c: **Applicability, Effectiveness, Limitations, and Economic Effects of Economic Measures**

Measure Applicability	Effectiveness	Relative Impacts: Duration	Relative Impacts: Size	Limitations I/P/C[1]
Taxes	–fuel quality –fuel choice –technology development	as long as in effect and some lags thereafter	depends on magnitude and elasticities	I/P/C
Charges (Sub-set of Taxes)	–reimburse common services (solid waste water treatment) –emissions reduction	—	depends on magnitude and elasticities	I/P/C
Subsidies	–technology development or introduction –infrastructure investments	—	depends on magnitude and elasticities	I/P/C
Market Prices	–commodities, quality or type of technology choice	n.a.[3]	n.a.	I/P/C

[1] I/P/C: Effectiveness to Influence Investment, Producer, or Consumer
[2] Self: Can be made self-funding
—: same as above
[3] n.a.: not assessed

emissions in the EIS Reference Scenario for that year and is primarily attributable to the accelerated implementation of energy efficiency and conservation measures. Intervention by governments would, however, be required to realize this potential.

b) A significant further tranche of emission abatement is potentially available at relatively moderate resource costs. This is attributable primarily to additional fuel substitution and energy conservation measures.

c) As the scale of abatement rises, marginal abatement costs will escalate. Marginal resource costs would be high if emissions were to be stabilized at levels significantly below current values by 2020.

d) The costs of achieving any particular level of abatement will vary among nations, as will the preferred options for achieving such a goal.

Implementation		Micro-Economic Effects	Macro-Economic Effects	Economic Effects
Cost to Govt.	**Duration**			
low to moderate	medium	political unacceptability of taxes high enough to be effective	–raises consumer prices so lowers consumption of taxed goods –raises producer costs and so internalizes externalities -tax forgiveness does converse	–diversions of investment and consumption and output –redistribution of tax burden creates cross-subsidies
low to moderate (self)[2]	—	—	raises producer costs and so internalizes externalities	may improve efficiency of investment, consumption, and output
high	—	–difficult to eliminate once relied upon –unanticipated spin-off	–inappropriate signal to polluter/users –excess output and demand –inefficient output	–diversions of investment and consumption and output –redistribution of tax burden creates cross-subsidies
n.a.	n.a.	externalities may not be captured initially	efficient pricing tends to result in efficient allocation of resources, i.e., efficient use and production	efficient investment, consumption and output

global energy markets, plans, and infrastructure, and intervention by governments. Maintaining this emission reduction goal would require continued technological improvements, structural changes in the global economy, and changes in the proportion of carbon-intensive fuels utilized over the remainder of the next century.

The full evaluation of costs and benefits is vital to the proper development of policy. Such estimates must include not only the resource costs of technical options but also the cost of government policy implementation, macroeconomic and second round effects, social and environmental costs and benefits, and private and non-monetary costs.

The EIS is aware of the existence of a number of reports and assessments undertaken. These have not been presented to the subgroup or examined by it. It may be appropriate for the group to review these reports in the next phase of its work.

TABLE 3.7: Contribution by Greenhouse Gas to Radiative Forcing During the 1980s

	TOTAL %	ENERGY ACTIVITIES %
CO_2	49	76
CFCs	17	0
CH_4	19	7
N_2O	5	3
Other[1]	10	14
Total	100	100

[1] Primarily Tropospheric Ozone due to CO, NO_X and VOCs.

3.7 THE GLOBAL POLICY CHALLENGE

3.7.1 RESPONSE CASE STUDIES

The EIS received preliminary policy studies from a number of countries. The European Commission submitted a response scenario for the European Community. The IEA secretariat submitted a preliminary study. The IAEA presented a paper on nuclear power.

The criteria for the examination of options selected differ among studies, so that the results in terms of emissions reductions achieved are not comparable and cannot be fully integrated. Therefore, only preliminary analysis is possible. Further work needs to be done. More studies from additional countries are needed to cover a larger fraction of current CO_2 emissions. Moreover, the comparability of the results should be enhanced.

According to the material and scenarios submitted to EIS it appears that the capacity of regions and countries to limit emissions varies greatly. However, some broad generalizations are possible.

- Some developing countries may be able to reduce the annual growth in CO_2 emissions from over 3 percent to around 2 percent while maintaining economic growth. The largest opportunities in developing countries appear to be increased efficiency in both energy supply and demand.
- East European countries and the USSR may be able to slow the growth or to stabilize CO_2 emissions over the next two decades, if policies to restructure their economies, increase efficiency, and promote economic development and substitution are implemented.
- West European countries including the EC may be able to stabilize or reduce CO_2 emissions by early in the next decade through a variety of measures including taxes, energy efficiency programs, nuclear power, natural gas, and renewables, without macroeconomic drawbacks. A few of these countries (Norway, the Netherlands, and Sweden) have formally adopted policies to limit emissions.
- North American and Pacific OECD countries may be able to slow the growth in CO_2 emissions by increased efficiency in energy supply and demand, fuel switching to nuclear, natural gas, and renewables, and other measures. Further policy actions on the part of countries in this group are undergoing further analysis.

The material available to the EIS demonstrates the important role industrialized countries' emissions play in total global emissions in the near term. The material also indicates that the technical potential for reductions is large. Therefore, in the near term, without actions in the industrialized countries, no significant progress in limiting global emissions will occur. However, the costs, and the extent to which this potential can be achieved, are uncertain.

3.8 RESPONSE STRATEGIES

Climate change offers an unprecedented challenge to energy policy development. Many uncertainties remain about both the impacts of climate change itself and our response to it.

It is very important that countries begin the task of developing flexible and phased response strategies. The underlying theme of any strategy must be economic efficiency—achieving the maximum benefit at minimum cost. Strategies that focus only on one group of emission sources, one type of abatement option, or one particular greenhouse gas will not achieve this. Energy policy responses should therefore be balanced against alternative abatement options in the forestry and agricultural sectors, and adaptation options and other policy goals where applicable at both national and international levels. Ways must be sought to account for consequences for other countries, and intergenerational issues, when making policy decisions.

Responses must also balance increasing understanding of the science and impacts of climate change with increasing efforts to avoid as much as possible its negative consequences. In parallel, we must develop a clearer understanding of the full social and economic implications of various response options available.

Encouragement for accelerated implementation of energy efficiency measures (on both the demand and supply side) should be a major common focus of initial policy responses. This will need to be supported by enhanced R&D if momentum is to be maintained. Encouragement for additional use of natural gas and low-cost renewable or less greenhouse gas producing energy technologies is also likely to be a common feature.

The appropriate mix of policy instruments will require detailed evaluation in the light of individual national circumstances. Initially, the highest priority must be to review existing policies and remove inappropriate conflicts with the goals of climate change policy. New initiatives will, however, be required. The international implications of some policy instruments (e.g., trade and competitiveness issues associated with carbon taxes, energy efficiency standards, and emission targets) will need to be resolved quickly if effective responses are not to be hampered.

The recommendations presented below suggest increasing levels of response with increasing knowledge and post-hoc evaluation of previous actions. It is predicated on a determined drive to take actions now to start with measures that make sense for other policy reasons; to promote energy efficiency and lower greenhouse gas emission technologies; and to accelerate R&D aimed at evaluating future options, developing new alternatives and reducing the cost of those options already available.

This is, of course, a simplified summary of a complex process. It does, however, contain the key points of a phased, planned response with regular review of both previous actions and outcomes and of future options. It is inevitable that some countries will progress faster than others, particularly perhaps in the early stages. But it is vital that all nations begin the journey now.

3.9 RECOMMENDATIONS

IPCC countries have made a commitment to negotiate a framework convention as soon as possible. That convention will provide the international community with a legal mechanism for considering and developing subsequent agreements and protocols. The energy sector is a major source of greenhouse gas emissions. The consideration of energy sector emissions, reduction opportunities, policies, and costs should be an important part of a convention process.

The Subgroup is of the view that because of the critical role of the energy sector in the economic development process and because of the strong linkages with other sectors, there is a need to develop both general policy recommendations and specific short- and long-term recommendations.

3.9.1 General Recommendations

Despite the fact that many uncertainties remain, we recommend that *all* individual nations should:

1) Take steps now to attempt to limit, stabilize, or reduce the emission of energy-related greenhouse gases and prevent the destruction and improve the effectiveness of sinks. One option that governments may wish to consider is the setting of targets for CO_2 and other greenhouse gases.

2) Adopt a flexible progressive approach, based on the best available scientific, economic, and technological knowledge, to action needed to respond to climate change.

3) Draw up specific policy objectives and implement wide-ranging comprehensive pro-

grammes that cover all energy-related greenhouse gases.

4) Start with implementing strategies that have multiple social, economic, and environmental benefits, are cost effective, are compatible with sustainable development, and make use of market forces in the best way possible.

5) Intensify international, multilateral, and bilateral cooperation in developing new energy strategies to cope with climate change. In this context, industrialized countries are encouraged to promote the development and the transfer of energy-efficient and clean technologies to other countries.

6) Increase public awareness of the need for external environmental costs to be reflected in energy prices, markets, and policy decisions to the extent that they can be determined.

7) Increase public awareness of energy efficiency technologies and products and alternatives, through public education and information (e.g., labeling).

8) Strengthen research and development and international collaboration in energy technologies, economic and energy policy analysis, which are relevant for climate change.

9) Encourage the participation of industry, the general public, and NGOs in the development and implementation of strategies to limit greenhouse gas emissions.

While the specific recommendations for action that follow apply in general to all countries, industrialized countries in particular should seek to implement such measures as soon as possible, given their greater economic and technological capacity to act in the shorter term.

3.9.2 SHORT-TERM STRATEGY

As short-term strategies all individual nations should:

1) Establish interim policy objectives to limit energy-related greenhouse gases, draw up programmes to meet the objectives and monitor the effectiveness and cost of the programmes against the objectives.

2) Start on measures that are technically and commercially proven, and beneficial in their own right.

3) Focus on economic instruments that could have an important role in limiting greenhouse gas emissions. We note with approval the work on these issues under way within the IPCC process and urge all countries to contribute to progress on that work.

4) Identify and take immediate steps to remove inappropriate regulatory barriers. Countries should review energy-related price and tariff systems, with the aim of removing disincentives to the efficient use of energy.

5) Promote the market penetration of:
   - improved efficiency in the production, conversion, and use of energy;
   - non-fossil and low greenhouse emission energy sources; and
   - technologies to remove, recirculate or fix methane emissions from landfills, coal mines and other sources.

   Actions should be taken on a number of the options identified in Table 3.2, e.g., in the transport sector. The choice of options should be based on cost-effectiveness analysis on a national and international level.

6) Integrate consideration of environmental costs into policy decisions at all levels of energy planning, both public and private.

7) Improve efficiency standards for mass produced goods—e.g., cars, trucks, buses, electrical appliances, buildings, air conditioners, ventilators, industrial motors, pumps for heating systems.

8) Start to develop and make widely available tools to assist in the evaluation and development of options and strategies to reduce energy-related greenhouse gas emissions (e.g., analyzing and quantifying the full fuel cycle effects, least-cost energy planning, developing a measure to facilitate comparison such as CO_2 equivalence, constructing a

framework for multisectoral policy decisions).

9) Collaborate on development, validation, and monitoring of national and global energy-related emission data.

10) Encourage the effective transfer of appropriate technology and information on the effectiveness of policies that are successful in promoting energy efficiency.

11) Contribute to an international common understanding of how to limit or reduce energy-related greenhouse gas emissions.

3.9.3 Long-Term Strategy

As our understanding of climate change develops, policies and strategies should be kept under review. It is not possible to forecast how they will develop in any detail, but it is clear that implementing the concept of sustainable development should be a central theme.

In this context all individual nations should:

1) Accelerate work on the longer-term options identified in Table 3.3 including:
   - improved efficiency in the production, conversion, and use of energy;
   - increased use of non-fossil and low greenhouse gas emission energy sources; and
   - reduction of greenhouse gas emissions by removal, recirculation, or fixation.

2) Formulate and implement strategies achieving sustainable emission levels that take account of the factors listed in Tables 3.6a–c regarding the impacts on energy prices, long-term economic growth and risk/security aspects of energy supply.

3) Evaluate the relative cost effectiveness of limitation and adaptation climate change strategies, and seek ways to account for international and intergenerational consequences.

4) Encourage the development of new technologies to limit, reduce, or fix greenhouse gas emissions associated with economic and energy activities.

5) Encourage infrastructural improvements—e.g., in transport, electrical grids, and natural gas distribution systems.

3.9.4 Further Work to Be Done

There is much work remaining to be done. A brief list of items related to the mission of the EIS is presented below.

1) An area of high priority is to assess the feasibility of different targets and strategies for limiting climate change and their costs, benefits and effectiveness. Such assessments should take a full fuel cycle approach and consider trade-offs among all greenhouse gases. Secondary effects should also be considered.

2) There is an urgent need to improve the data available from the developing and East European countries and for additional studies in the future, through the participation of a larger number of countries in the EIS.

3) No single analytical tool or model is sufficient to analyze the many issues discussed in this report. A broad set of tools ranging from macroeconomic models, technology assessment tools, and policy models of specific sectors—e.g., the transportation, utilities, and residential/commercial sectors—need to be developed in the future.

4) There is an important need to collaborate on development, monitoring, and validation of national and global energy-related emission data. Common methods of measuring, monitoring and evaluating energy-related greenhouse gases that can accommodate such issues as accounting for greenhouse gas emissions from bunkers, non-energy fuel use and energy trade, CO_2 equivalence, and CH_4 and N_2O, should be developed.

5) Further comparisons of target options and response strategies in the energy and industry sectors using "top down" and "bottom up" approaches are needed.

6) There is a need to move beyond simply assessing broad emission strategies to assessing the specific technologies and options open to individual countries. This will require the development and exchange of more detailed information both at the country and international levels than has been possible to date.

7) All nations should analyze the feasibility of arrangements in a worldwide context to discourage the movement of high emitting production facilities from countries with high environmental control standards to countries with lower standards.