# Towards a fossil free future: The technical and economic feasibility of phasing out global fossil fuel use

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## 1. SYNOPSIS

This paper assesses a range of global energy futures over the next century. The climatic technological and economic implications of a Fossil Free Energy Scenario are assessed using three computer models.

## 2. ABSTRACT

The environmental impacts of utilising fossil fuels are severe. The paper assesses the likely carbon dioxide (CO2) and climatic impacts of the global energy system in the absence of new policies. It then assesses the technical, economic and policy feasibility of phasing out fossil fuels over the next century, and the likely climatic benefits that would follow. It draws out the crucial role of energy efficiency.

## 3. THE ENVIRONMENTAL IMPACTS OF FOSSIL FUELS

Fossil fuel combustion is the major source of greenhouse gas (GHG) emissions, largely in the form of carbon dioxide (CO2), accounting for 85 percent of current net anthropogenic CO2 emissions (Subak et al., 1991). Over the past 50 years, fossil fuel consumption has increased fivefold, from approximately 57 exajoules in 1937 to around 282 exajoules in 1988 (Fulkerson et al., 1990). Predominant among these fuels is the use of coal and oil, though natural gas use is projected to increase rapidly over the next few decades (IEA, 1991, Stern, 1990). If fossil fuel consumption continues to grow, a doubling of pre-industrial CO2 concentrations could occur as early as 2030, leading to a projected increase in global average equilibrium temperature of 1.5 to 4.5°C (IPCC, 1990a & 1992). Increasing concentrations of the other greenhouse gases would add to this increase.

In the past three years, a major international study under the auspices of the Inter-governmental Panel on Climate Change (IPCC, 1990 & 1992) has largely confirmed the previous findings of a range of scientific assessments that a continuation of current fossil fuel and deforestation trends will likely increase global temperatures to unprecedented levels. The reduction in greenhouse gas (GHG) emissions, and particularly gases such as carbon dioxide which are linked to fossil fuel combustion, provided the basis for a study commissioned by Greenpeace International (Greenpeace, 1993).

## 4. THE FOSSIL FREE ENERGY STUDY

The Stockholm Environmental Institute - Boston and other independent consultants (See Acknowledgements Section 12) carried out the bulk of the analysis for the Greenpeace study. The main objective of the study was to assess the technical, economic and policy implications of moving towards a fossil free energy system. The study considered the world in terms of ten separate regions, reflecting, to the extent possible, varying patterns of economic activity, personal consumption, energy use, and energy resources. These regions are listed in Table 1.

The time frame for this study extends to the year 2100. This is an end year common to a number of global studies. The long time frame is necessary, as the climate effects of GHG emissions are expected to lag substantially behind the emissions themselves. Given the speculative nature of such long-range scenarios, greater emphasis should be placed on the time period between now and 2030. In fact, the next 40 years present the most challenging period if we are to reverse the trend of rising emissions of carbon dioxide, and develop policies that enable humankind to meet climate stabilization targets.

### 4.1. Computer modelling approach

The overall Greenpeace study utilised three computer models to assess the climate, technical, economic and policy implications of moving towards a 'fossil free' energy system over the next century. A main fossil free energy scenario (FFES), with variations, was developed. The computer models were used to (a) to develop climate targets which the energy modellers used as limits in order to bring climate impacts down to manageable levels; (b) to assess the climate impact of the fossil free energy scenarios developed; (c) to develop a disaggregated, sectoral global energy scenario which was based on high levels of energy efficiency and an increasing quantity of renewable energy sources; (d) to assess the pricing and overall cost implications of the scenario; and (e) to inform the evolution of policies which would be needed to achieve the scenario. The three models were as follows:

Table 1. *Regional disaggregation for this study (based on the Edmonds-Reilly model)*

| *Abbreviation* | *Region* |
|---|---|
| AFR | Africa |
| CPA | Centrally planned Asia (China, Laos, Cambodia, Vietnam, N. Korea) |
| EE | Central and Eastern Europe |
| JANZ | JANZ/OECD Pacific (Japan, Australia, New Zealand, Fiji) |
| LA | Latin America |
| ME | Middle East (Asia East to Afghanistan) |
| SEA | South and East Asia (All other Asian countries) |
| US | United States |
| USSR* | Former USSR, now CIS and adjoining states |
| WE** | Western Europe and Canada |

* In contrast to the Edmonds-Reilly model, we consider separately the former USSR and Eastern Europe

** This region was only chosen to be compatible with the Edmonds-Reilly model of regional breakdown.

(1) The end-use global energy model called LEAP - Long Range Energy Alternative Planning system. LEAP is linked to Environmental Data Bases (EDB) compiled from international data sources, that was used here to estimate future greenhouse gas emissions. The model allows assessment of regional and energy sector end-uses, energy resources and technologies applied to a world which for the purpose of the study, was divided into ten regions.

(2) A model called Atmospheric Stabilisation Framework (ASF), developed for the US Environmental Protection Agency. The energy component is based on the widely used Edmonds-Reilly (ER) model. This takes account of price and income factors to a greater extent than LEAP. Linked to the results from LEAP, it was used to give additional cost information to the project.

(3) The Sea-level and Temperature change Under the Greenhouse Effect climate model (STUGE), developed by the Climatic Research Unit at the University of East Anglia in the UK. This wa employed to develop climate targets and assess the climate impacts of the FFES and its variants. In addition, a range of projections for carbon emissions from biogenic sources was developed.

### 4.2. Assumptions for the study

A number of assumptions were made to guide the modelling exercise by SEI - Boston and other analysts. It should be noted that these are not necessarily Greenpeace policy, but were used in order to make the study comparable with other studies:

(1) Fossil fuel combustion was to be eliminated by the year 2100. This outcome was a scenario 'constraint', and did not result from an economic cost-benefit or modelling analysis of the value of substituting for every energy use of fossil fuels.

(2) Carbon removal technologies were not considered.

(3) Nuclear power was eliminated by 2010. Nuclear power is not regarded by Greenpeace as an attractive substitute for fossil fuels, because of the significant risk factors from catastrophic accidents and proliferation, the high costs of generating nuclear electricity in many countries, plus the environmental concerns of solid and liquid radioactive wastes.

(4) New renewable and other resources were subject to environmental restrictions. Concerns about the construction of new, large hydro facilities were reflected in a downgrading of the global technical/economic potential of hydropower by 35 percent. No municipal waste incineration was considered.

(5) Conventional assumptions for GDP and Population were made, with one exception, that relating to equity. This does not signify acceptance by Greenpeace of such assumptions, but to allow cross-comparison of the FFES with other policy scenarios. World population grows to over 11 billion by the year 2100, with over five-fold growth in Africa from 560 million to almost 3 billion (Bulatao, 1989). Total global GDP grows more than 14 times. In the FFES analysis an approach to regional income equity was proposed wherein the ratio of highest to lowest average regional income drops to 2:1 by 2100, compared with the projected ratio of over 14:1. This is not true equity, of which GDP is only a very crude and inadequate measure anyway, but the gap continues to narrow after the year 2100. GDP is redistributed among regions to achieve the same total world GDP as the IPCC forecast does in 2100: 258 trillion ECUs or 23,028 ECUs per capita ( $213 trillion or $19.000 per capita 1985 US $).

(6) Structural Change. The concept of structural change in economies is fundamental to the FFES. With the rapid GDP growth rates for the South embodied in our scenarios, SEI -Boston anticipated the general transition among sectors that has accompanied the industrialization process in the North: from agricultural and other primary production to a period of greater industrial activity, and finally to the ascendancy of the service sector. The specific path for future economic development in the industrializing countries of the South is impossible to predict; the model of the currently industrialized countries is used as one possible option. Once again this is not Greenpeace policy.

(7) Economic Criteria. It was sought where possible, to ensure that measures undertaken over the near and medium term (to 2030) yielded net economic benefits or were unlikely to incur significant costs. The emphasis here is on proven or near-market technologies that have been shown to be either cost-effective or cost-competitive with other options. The economic analysis utilising the ASF model addresses this issue in greater detail (Waide, 1992a). Any cost estimates for the period beyond 2030 are inherently speculative; for this period, the scenarios reflect what currently appears credible and achievable.

## 5. BUSINESS AS USUAL SCENARIOS

Many researchers have constructed forecasts into the early or mid 21st century. The far smaller number that have attempted to forecast to the year 2100, have done so primarily for the purpose of CO2 projections and climate studies. Two reference case projections were selected for comparison with the results of the FFES, an IPCC projection and an average of the EPA's Rapidly and Slowly Changing World cases. This range of reference cases is shown in Figure 3 for CO2.

### 5.1. The climate implications of a Business-as-usual Scenario

The climatic consequences of these scenarios were assessed using STUGE. By 2100 the global-mean induced radiative forcing exceeds 10 W/m2, while under a 2.5°C climate sensitivity, global-mean temperature is forecast to exceed 4°C above pre-industrial times. Even if emissions were held static or cut, the long atmospheric residency time of GHGs would ensure that global-mean temperatures continue to rise beyond 2100. Sea level is projected to increase from 35 to 115 cms. (depending on climate sensitivity), while rates of temperature increase are between 0.2 and 0.6°C per decade.

## 6. RESULTS OF THE FOSSIL FREE ENERGY SCENARIO (FFES)

The findings of the Fossil Free Energy Scenario (FFES) indicate that a combination of efficiency improvements, renewable energy technologies and fuel switching, could achieve significant long-term reductions in CO2 emissions. As shown in Figure 2, annual CO2 emissions peak around the year 2000, and decline to 48 percent and 29 percent of current global levels by 2030 and 2075, respectively, before reaching the fossil-fuel target of zero net CO2 emissions by 2100. (Figure 1)

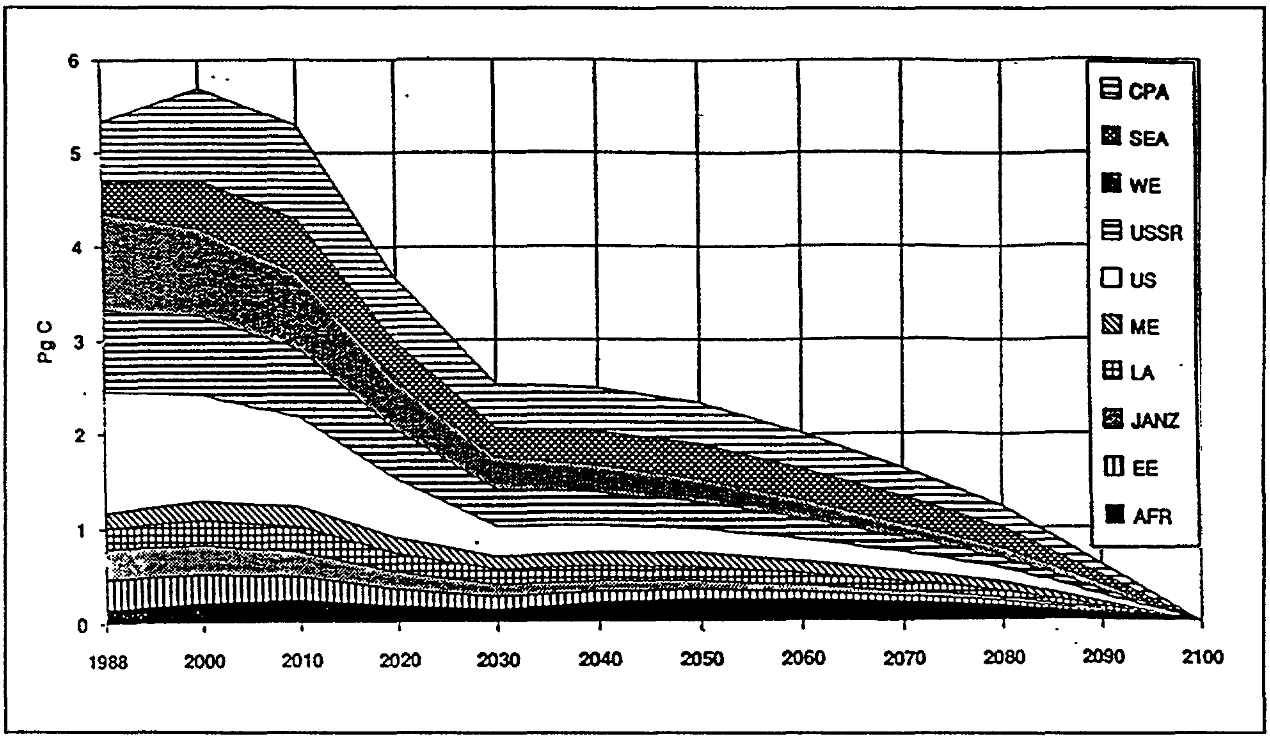


Figure 1. *Carbon dioxide emissions by region (Pg C)*

The initial rise in CO2 emissions reflects the momentum of current energy use patterns, the embedded stock of energy-inefficient equipment, and the time required to effect of large shifts in fuel and technology choices throughout the world.

The scenario roughly achieves a 20 percent reductions by 2005 among industrial countries. These reductions

**Table 2.** ***Carbon dioxide emissions by region: 1988-2100 (Pg Carbon)***

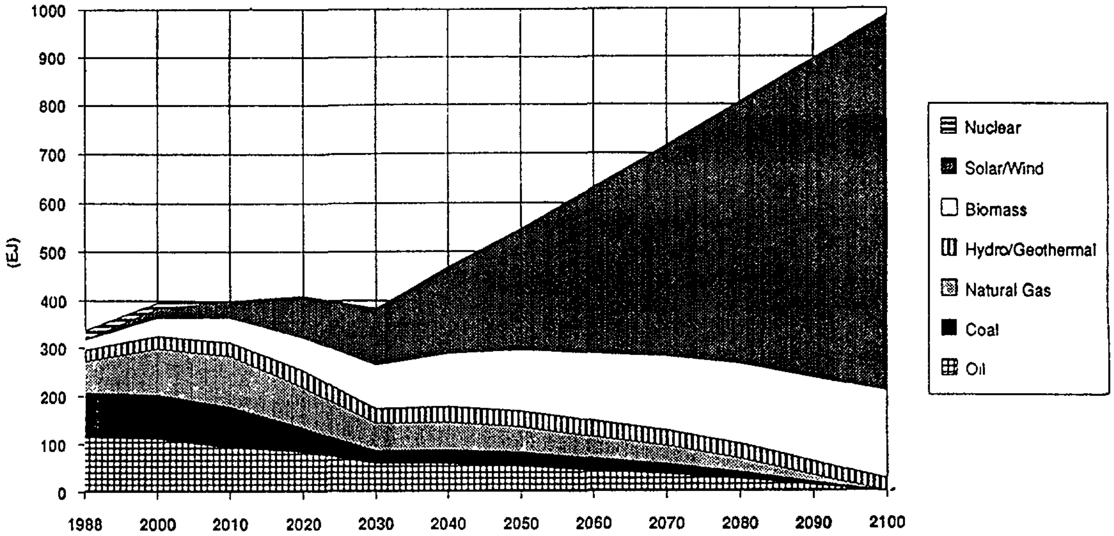
| | 1988 | 2000 | 2010 | 2020 | 2030 | 2040 | 2050 | 2075 | 2100 | Est-Cum 1988 to 2100 |
|---|---|---|---|---|---|---|---|---|---|---|
| AFR | 0,16 | 0,23 | 0,26 | 0.19 | 0,16 | 0,22 | 0,26 | 0,22 | 0,00 | 22 |
| CPA | 0,65 | 0,98 | 1,00 | 0,69 | 0,46 | 0,46 | 0,43 | 0,28 | 0,00 | 55 |
| EE | 0,31 | 0,29 | 0,24 | 0,16 | 0,12 | 0,10 | 0,09 | 0,04 | 0,00 | 14 |
| JANZ | 0,32 | 0,30 | 0,25 | 0,18 | 0,13 | 0,11 | 0,09 | 0,04 | 0,00 | 14 |
| LA | 0,22 | 0,27 | 0,28 | 0,20 | 0,17 | 0,17 | 0,15 | 0,10 | 0,00 | 18 |
| ME | 0,16 | 0,20 | 0,21 | 0,17 | 0,14 | 0,15 | 0,15 | 0,11 | 0,00 | 15 |
| SEA | 0,34 | 0,53 | 0,59 | 0,44 | 0,32 | 0,37 | 0,38 | 0,29 | 0,00 | 39 |
| US | 1,28 | 1,13 | 0,97 | 0,65 | 0,33 | 0,30 | 0,28 | 0,21 | 0,00 | 53 |
| USSR | 0,88 | 0,85 | 0,73 | 0,52 | 0,40 | 0,34 | 0,28 | 0,14 | 0,00 | 43 |
| WE | 1,01 | 0,90 | 0,74 | 0,50 | 0,33 | 0,28 | 0,24 | 0,12 | 0,00 | 42 |
| TOTAL | 5,34 | 5,68 | 5,26 | 3,69 | 2,55 | 2,50 | 2,35 | 1,56 | 0,00 | 314 |
| North | 3,81 | 3,47 | 2.92 | 2,01 | 1,31 | 1,14 | 0,97 | 0,55 | 0,00 | 165 |
| South | 1,53 | 2,21 | 2,33 | 1,69 | 1,24 | 1,36 | 1,38 | 1,01 | 0,00 | 148 |

do not reflect Greenpeace policy as higher individual national targets would be expected. In the scenario reported here, CO2 emissions from 1988 to 2000 decline by 3-12 percent in industrialized regions, while increases in developing regions which range from 21 percent in Latin America to 55 percent in South and East Asia, lead to a 6 percent overall increase in global CO2 emissions.

Between 2000 and 2010, the effects of technology improvements begin to outweigh the underlying forces of economic and population growth, and global CO2 levels begin to decline. Reductions in the industrialized regions offset continued increases in the South. Beyond 2010, emission levels decline in all regions, as the current stock of energy consumption and production equipment turns over, and high efficiency end-use and electricity generation technologies are widely implemented. Reduced dependence on coal and modest levels of renewable fuels and electricity further contribute to CO2 savings. The contribution of fuels to primary energy is shown in Figure 2.

By 2030, a new generation of lower-cost renewable supply technologies provide a cleaner, low-CO2 mix of fuels and electricity. Over the longer-term, the transition to a solar and biomass-based energy system, leads to the complete reduction of fossil fuel carbon dioxide emissions by 2100.Though the FFES is a global study, different penetration levels for the various types of renewable technologies were assumed, taking account of resources (ie great wind potential in Europe, then Africa, and vice-versa for solar-electric).

Estimated cumulative global CO2 emissions from 1988 to 2100 amount to 314 (Pg C), as shown in Table 2. Emissions from the 5 industrialized regions account for 53 percent (165 Pg C) of these cumulative emissions.



* Solar, wind, hydro, geothermal and nuclear energy converted from electricity to primary energy using then-current average fossil/biomass plant efficiencies (see explanatory notes)

**Figure 2.** ***Primary energy supply mix: 1988-2100***

Improved end-use energy efficiency in residential, industrial, transport and service sectors, accounts for the major source of emission reductions between now and 2030. On average, the rate of improvement in energy intensities (through energy efficiency and structural change) is 2.5 per cent per year. For the period beyond 2030, smaller improvements are assumed. The dip in energy use from 2010 to 2030, followed by a subsequent rise for the remainder of the scenario, largely results from strong efficiency improvements prior to 2030 that outweigh the dual forces of growing economies and population for a brief period of time. Beyond 2030, much slower rates of efficiency improvement and structural change of 0.5 per cent per year were assumed.

The levels of end-use efficiency improvements included in this scenario are based upon current assessments of economic and technical potential: levels based on market or near-market technologies that can be implemented within 40 years.

Improved efficiency on the supply side, including the more efficient use of fossil fuels for electricity production (e.g., combined cycle and fuel cell systems) provide important contributions to reducing emissions over the next 40 years. This also includes the overall efficiency gains offered by on-site and centralized combined heat and power generation (cogeneration). After 2030, approximately 20 percent of global electricity demand is supplied from centralized and on-site cogeneration.

Fuel switching from coal and oil to natural gas, also plays an important role in reducing emissions in the near and medium term (to 2030). Estimates were made for each region regarding the ability to switch to lower carbon fuels, based on the availability of fossil fuel supplies, particularly natural gas, and end-use considerations. The resulting primary energy shares are shown in Table 3. The cumulative global consumption of natural gas and oil in the FFES is 6200 EJ and 6600 EJ, respectively. For regions heavily dependent on coal, with limited supplies of natural gas and other fuels, coal continues to account for an

Table 3. *Primary Energy Supply, 1988-2100*

| **Source** | **1988** | | **2000** | | **2010** | | **2030** | | **2100** | |
|---|---|---|---|---|---|---|---|---|---|---|
| Oil | 116 | 34% | 112 | 28% | 93 | 23% | 59 | 15% | 0 | - |
| Coal | 93 | 27% | 93 | 23% | 85 | 21% | 28 | 7% | 0 | - |
| Natural Gas | 65 | 19% | 96 | 24% | 105 | 26% | 57 | 15% | 0 | - |
| Hydro/ Geothermal* | 23 | 7% | 26 | 7% | 28 | 7% | 3 | 8% | 28 | 3% |
| Biomass** | 22 | 7% | 38 | 10% | 52 | 13% | 91 | 24% | 181 | 18% |
| Solar/ Wind* | 0 | - | 20 | 5% | 36 | 9% | 118 | 31% | 778 | 79% |
| Nuclear* | 19 | 6% | 12 | 3% | 0 | - | 0 | - | 0 | - |
| **Total** | **338** | | **396** | | **400** | | **384** | | **987** | |

* Solar, wind, hydro, geothermal and nuclear energy converted from electricity to primary energy using then-current average fossile/biomass plant efficiencies (see explanitory notes following section 10).

** Note that 1988 biomass figures reflect UN estimates (UN 1990) and may be low by a factor of 2 (see Hall 1991).

important but declining share of primary supply. For example, in Centrally Planned Asia, coal use drops from 72 percent of primary energy in 1988, to 51 percent in 2010, and to 22 percent in 2030.

A major transition to solar and biomass sources of energy accounts for most emission reductions after 2030. Over the next 40 years, several renewable sources play an important role, including biofuels for transport, wind energy for electricity, and various cost-effective applications of solar technologies,(including solar space and water heating, solar thermal electricity and solar photovoltaic cells). These projections are based upon technical potentials, assessed in a range of countries and taking account of electricity storage and load management issues. They are also based on the growing experience of some significant renewable technologies in a few countries.

## 7. COMPARISON OF FFES RESULTS WITH OTHER SCENARIOS

Figure 3 compares the results of the Fossil Free Energy Scenario (FFES) with one of the US EPA reference case scenarios, and the EPAs lowest policy CO2 emission scenario, Rapidly Changing World with Rapid Reductions' (RCWR) (US EPA, 1990). The contrast in fossil fuel usage between the FFES, the "business-as-usual" scenarios and other policy scenarios is stark. Even in one of the more radical policy scenarios produced by the US EPA (RCWR), though oil use falls rapidly to a similar level as the FFES in 2030, oil from polluting synthetic fuels increases rapidly. Overall oil usage increases over the period. This is double the level of the FFES in 2030, and increases throughout the remainder of the century.

## 8. THE CLIMATE BENEFITS OF THE FFES

### 8.1. Other greenhouse gases

The dominant GHG is CO2 , accounting for 61 percent of the global warming impact of all GHG emissions in 1990, followed by methane (CH4) at 15 percent, halocarbons (CFC's and HCFC's) with 11 percent, and nitrous oxide (N2O) at 4 percent (Shine et al, 1990).The 1992 IPCC scientific assessment of climate change indicated that CFCs may not provide a net radiative forcing effect. Given the attendant uncertainties, this was not incorporated in the climate modelling analysis. If it had been, the role of CO2 would have increased in relative terms. Given the rapid phase-out of CFCs and other halocarbons, the net effect on the climate results would have been small. To complete the climate analysis, assumptions were made for the other GHGs, which effectively stabilised emissions at current levels.

## 8.2. Climate modelling results

Modelling the results of FFES using STUGE demonstrates that it significantly reduces the risks of climate change (Waide, 1992). Based on the FFES total emission of 314 Gt carbon, carbon dioxide concentrations in the atmosphere are kept to below 400 ppm., in contrast to well over 750 ppm. in the Business-As-Usual (BAU) scenario. Under a climate sensitivity of 2.5°C for a doubling of pre-industrial carbon concentrations, global average temperature increases are kept from increasing above 1.5°C within the time period, in contrast to more than 4°C under BAU. Temperatures are actually falling from the year 2050 onwards in the scenario. Rates of temperature increase are brought to below 0.1°C per decade around the year 2020. Sea level increases are kept between 10 and 35 cms, in contrast to 35 to 115 cms. in the BAU.

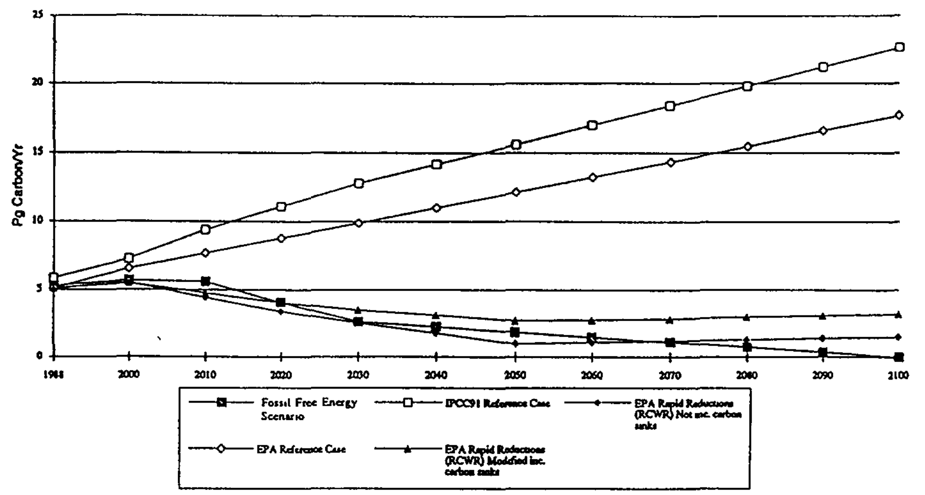
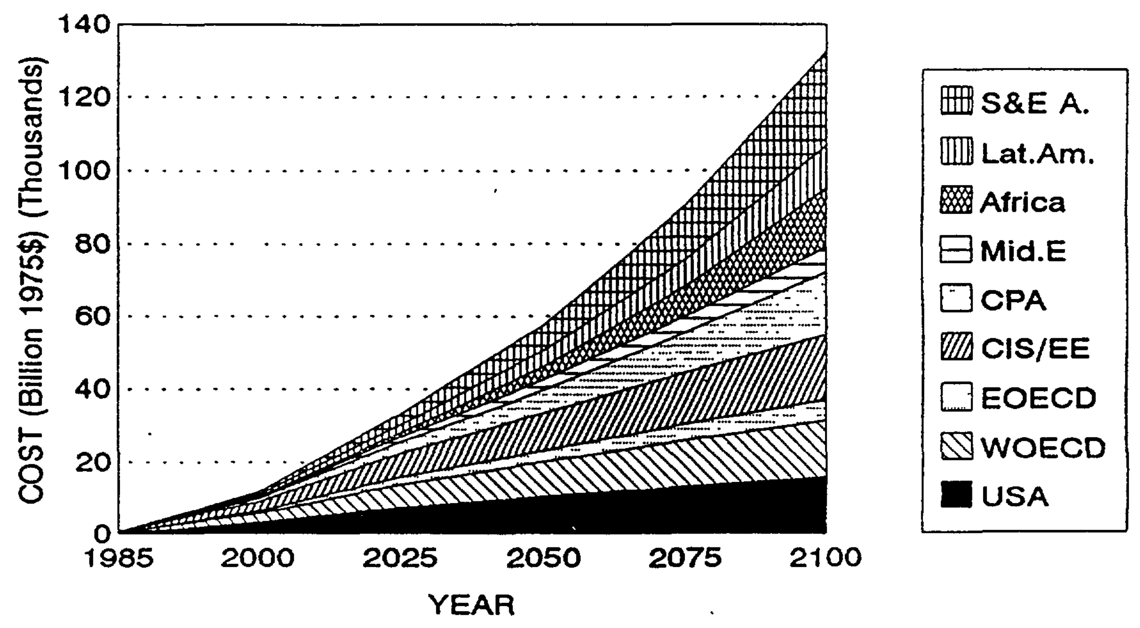


Figure 3. *Summary comparison results*

## 9. THE ECONOMIC IMPLICATIONS OF THE FFES

The costs of a scenario developed over a time period of more than century are necessarily speculative. The projected costs of future energy systems crucially depends on assumed costs for the various fuels, the costs of implementing policies for energy efficiency and renewable energy, the type of computer model used, and assumptions about the current energy market. A number of authors have commented on the wide range of cost estimates for carbon dioxide abatement (Grubb, 1991, Boyle, 1992). A major difference in cost estimates emerges between those developed using 'top down' macro-economic models, and those using 'bottom-up' end-use models.The latter are less reliant on price alone as a policy lever, hence costs tend to be lower. A common criticism of this type of end-use' study is that the penetration rates for more efficient technology are optimistic (Manne and Richels, 1992). In part this reflects current market failures such as the very high discount rates applied by private consumers in contrast to large utilities (30 to 50 per cent is common, as against 5 to 12 per cent respectively). The FFES has responded to such criticism in two ways, by scaling back some of the technical potential for energy efficiency, and implicitly assuming that such barriers will be tackled by policy changes. The FFES utilised both types of model to give some indication of the costs.

Considerable evidence suggests that implementation of the measures in this scenario could be achieved at modest cost, or even at net economic benefit relative to a business-as-usual world'. Projections of renewable energy supply costs indicate that solar, wind, and biomass technologies could be close enough to those of fossil fuels to enable a transition to occur without major economic penalties, Williams and Ogden (1989), Johannson et al (1992) and Nitsch et al (1990). Major economic benefits in avoided electric capacity requirements could result from investments in efficient end-use technologies.



1. Very low carbon tax of $17.20/tonne carbon introduced over a 65 year period.

Figure 4. *Cumulative costs of secondary energy consumption for scenario 1*[1]

A full benefit analysis would include the avoided costs and capital requirements (e.g., dikes to stem coastal flooding) that would otherwise be needed to mitigate the impacts of global warming, if the world were to continue its current dependence on fossil fuels.

## 9.1. Other cost studies

The FFES was based on data supplied from a wide range of sources. It also utilised more than 100 national, regional and global reports on carbon dioxide reductions which have been produced in the past two years. Several provided significant input to the development of the scenario. These include studies by Levine et al., 1991, UCS et al., 1991, Johannson et al, 1992.

## 9.2. ASF economic modelling

The ASF model was used to gain additional information on the pricing implications of the FFES (Waide, 1992a). This is a partial equilibrium model commonly used throughout the world. By feeding in a range of fuel costs for renewable and fossil fuels, using US EPA figures in the main, the relative costs of the 'business-as-usual' scenario and the FFES could be compared.

### *9.2.1. Preliminary economic conclusions for FFES*

The results are shown in Figures 4 and 5. They indicate that, accepting the assumed costs for fossil fuels and renewable energy, the costs of secondary energy consumption as paid by the consumer for the FFES are considerably lower than the BAU. In a world where there is a significant shift away from fossil fuels, fossil fuel companies may offer such fuel at very low prices - the price equilibrium effect. To deal with this potential problem, the fuel share weightings were controlled in the model. This was intended to simulate policies such as CO2 emission controls and strict international compliance of CO2 reduction Protocols.

What the results do not show are the additional costs of the end-use efficiency equipment needed to achieve the FFES demand profile. This is the subject of current analysis by Greenpeace International. Based on a preliminary analysis of the costs of efficient and solar-hydrogen vehicles, super-insulated buildings, highly efficient industrial processes, lighting, appliances and boilers, it was concluded that the costs of the FFES are likely to be equal to or less than a 'business-as-usual' scenario.

## 10. SENSITIVITY TESTING

A wide range of sensitivity tests were carried out on the FFES. These included the following, relative to the central assumptions of the FFES:

(a) Lower levels of economic growth (measured by GDP), to assess the impact of 'lifestyle' changes and alternative development models;

(b) Lower levels of population;

(c) Less intensive use of materials and resources;

(d) The impact of higher and lower efficiencies of solar and biomass technologies;

(e) The impact of lower rates of improvement in energy efficiency;

(f) Variations in the absolute and relative costs assumed for fossil fuels and solar technology. Though higher levels of population are conceivable, this was not tested in the sensitivities.

### 10.1. Slower penetration of improved energy efficiency.

This sensitivity underscores the importance of achieving the technical and economic potential for improved efficiency. In this scenario, energy efficiency improvements are scaled back by one-third through 2030. From 2030 to 2100, a 0.5 percent per year efficiency improvement rate was assumed, as in the FFES. The result of this sensitivity is a substantial increase in CO2 emissions over the next 40 years relative to the FFES scenario. Projected annual emissions increase from 5.3 to 6.1 Pg C in 2010 and from 2.6 to 3.8 Pg C by 2030. Cumulative emissions rise to nearly 400 Pg C, a 27 percent increase.

### 10.2. Other sensitivity test results

A somewhat surprising result of the sensitivity testing is that annual carbon dioxide emissions are little altered from the main FFES, with the exception of slower energy efficiency improvement rates. This does not lead to a conclusion that population and GDP levels have no impact on the results, they significantly reduce global fuel needs; it mainly reflects the already low levels of carbon emissions achieved in the main scenario. What the sensitivity tests show aboveall is the need to make an early start on measures to improve energy efficiency throughout society.

## 11. POLICY IMPLICATIONS OF THE FFES

Historically, it has taken new fuels some 50 years to capture 10 per cent of the global energy market (Marchetti, 1989). In the period 1973-86 a number of OECD countries reduced energy intensities 2-3 per cent per annum. The FFES assumes an average level of reduction of 2.5 per cent per annum. In the FFES, renewable energy sources increase from their current 14 per cent of total energy supplies, some of which is based on inefficient traditional biofuels, to 60 per cent within the next 40 years. Strong policies will clearly be needed to reach those targets.

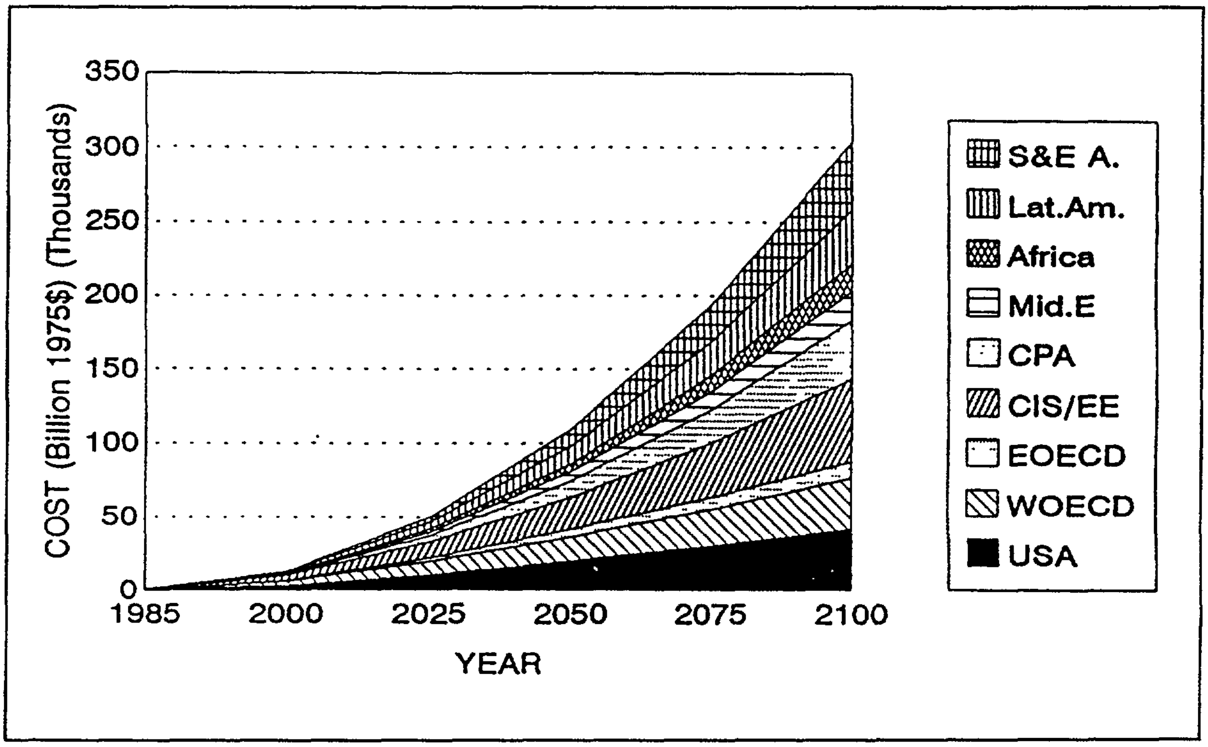


Figure 5. *Cumulative costs of secondary energy consumption for US E.P.A. slowly changing world scenario*

A detailed consideration of the policy implications of achieving a fossil free energy future is beyond the focus of this paper. However, a number of key policy points have been developed by Greenpeace.

### 11.1. Pricing policies

A perfect energy market requires full knowledge of all market elements and alternatives, equal access to capital, and free competition. The perfect energy market does not exist, as government and industry interfere with the market in numerous ways. In the last fifty years, legislation, pricing, and institutions have developed to favour fossil fuels and nuclear power. These now form market barriers, preventing producers and consumers from using new technologies to save money and utilise cleaner and sustainable energy systems.

Realistic energy pricing will not on its own solve global warming. As part of a wider strategy, however, it is important in sending the correct signals for investment choices and removing subsidies. Policies should include the introduction of energy taxes to reflect the full environmental costs of fossil fuels and nuclear power; the introduction of tax credits for renewable energy developers; and removing the financial incentives for utilities to sell increasing quantities of gas or electricity.

### 11.2. Intervening in the market.

In addition to realistic energy pricing, regulation is needed to prevent cartels forming and the market from being manipulated. Policies should include new mandatory efficiency standards for appliances, vehicles, buildings, industrial motors and other technologies; government support for public transport; planning regulations which discourage major new road-building and urban sprawl; integrated resource planning (IRP) and Demand Side Management (DSM) programmes could be encouraged. DSM spend is doubling from 3.6 billion ECUs per year ($3 billion) in the US to some 8.4billion ECUs ($7 billion) by 2000, (Krier and Goodman, 1992). 12-24 billion ECUs ($10-20) per year could be justified (Pringle, 1992).

### 11.3. Research and development

There are a number of reasons why certain technologies achieve success and capture a large portion of the energy market. Improving efficiencies and reducing costs are important objectives for accelerating the impact of renewable energy technologies, and enhanced research, development and deployment (R,D & D) can assist in this. One study has estimated that an expenditure of some 3.6 billion ECUs ($3 billion) in the USA over the next few decades could double the projected contribution of renewable energy over the period (SERI et al., 1990).

A new approach towards energy Research and Development is needed. International Energy Agency governments' energy R & D budgets are currently heavily skewed towards fossil fuels and nuclear power. Only 12.5 per cent of the total budget of 9.3 billion ECUs ($7,675 million) is allocated to renewables and energy conservation: over 70 per cent is allocated to fossil fuels and nuclear power.

### 11.4. Changing institutions

None of the current energy institutions are guided by environmental concerns. At the international level, organisations exist to promote and develop oil use (OPEC), coal (the International Energy Agency), and nuclear power (the International Atomic Energy Agency). Transnational corporations promote and lobby for oil, coal, gas, and nuclear power. No international organisations exist for energy efficiency and renewable energy.

A major reassessment of energy institutions is needed if global energy policies are to change. New lending criteria for power sector loans, which encourage energy efficiency investments, would be a start. The creation of a new international agency for the development and promotion of technologies for renewables and energy efficiency (TREEs) has been proposed by Greenpeace and others.
A TREEs agency could provide a focus for energy funding, R&D collaboration, technology transfer, education and information supply.

### 11.5. International climate protection policies

One hundred and fifty four nations signed the International Climate Convention at the Earth Summit in June, 1992. Article 2 of the Convention commits signatories to the stabilisation of concentrations of greenhouse gases at a level which will prevent dangerous anthropogenic changes. Achieving this will require a range of strong Protocols and tough international compliance, assisted with tough national and regional CO2 reduction targets. A priority follow-up Protocol to the Convention would be an Energy Efficiency Protocol committing signatory countries to achieving annual improvements in energy efficiency over the next few decades. A challenging target would be an average of 2.5 per cent per year over the next forty years.

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