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WHAT SCENARIO STUDIES TELL ABOUT SECURITY OF ENERGY SUPPLY IN EUROPE

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Preface

This report provides selected background information to the draft Green Paper on European energy supply security issued by the European Commission and focuses on a comparison of the supporting scenario study with some other scenario studies and on the current situation with respect to energy resources. This brief background study was commissioned by the General Energy Council of the Netherlands. With the usual disclaimer on remaining errors, the authors acknowledge the stimulating exchange of ideas with Messrs B.J.M. Hanssen and P.W. Broekharst.

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Abstract

On behalf of the Dutch General Energy Council (AER) ECN Policy studies performed a brief technical fact-finding study on security of energy supply from the European point of view and from the point of view of the Netherlands, as a background to the draft Green Paper on European energy supply security by the European Commission.

In this study a brief assessment is presented of fossil fuel resources. Based on data from the United States Geological Survey (USGS) and other literature, the reserves/production ratio of conventional and unconventional oil is estimated at approximately 200 years. Based on the same USGS data, the reserves/production ratio of conventional natural gas is estimated at 190 years. The unconventional gas resources are extremely large. However, environmental damage has to be prevented. The amount of recoverable resources will remain a question mark for the time being. The world's proved recoverable coal reserves amount to a reserves/production ratio of 230 years. All in all, oil remains a strategic fossil fuel, whereas the supply of natural gas seems to be more well-balanced and the supply of coal is more secure than both of oil and gas.

The so-called 'Shared analysis project', performed by a number of research institutes in the EU, gives useful points of departure for energy policy formulation. However, the results of notably the reference scenario and to a lesser extent its variants in terms of primary energy use, CO_2 emissions, and the EU's import dependence for fossil fuels have to be regarded carefully.

A similar picture arises from IEA's World Energy Outlook 2000. The 'Outlook' gives due attention to OECD Europe's dependence on imported oil and gas. The share of oil imports is due to rise from 32% in 1990 to 80% in 2020. Due to a projected steady growth of gas consumption, import dependence with respect to natural gas is due to rise from 34% in 1997 to about 65% in 2020.

In the scenarios developed by CPB, in collaboration with AVV, ECN, and RIVM, in 1997, the share of natural gas in total primary energy demand is projected to increase to 50-55% in all of the scenarios. In the most energy intensive scenarios, natural gas is very dominant, both in PJ and in relative terms. In the related ECN study it is argued that a too strong focus on gas-fired power incurs risks of security of supply, due to ongoing depletion of indigenous gas resources.

Finally, a few main themes from the Green Paper are highlighted, viz.:

- Controlling the growth of demand. Fiscal interventions in energy prices should remove distortions between alternative energy carriers and between Member States and make that energy prices will reflect real costs including environmental damage costs.
- Managing supply dependence. New renewables should be vigorously stimulated. In particular for natural gas geographical diversification of supply would appear desirable, especially as far as LNG is concerned. Funding research on civil nuclear technology should be continued. A minimum coal production platform should be maintained.

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SUMMARY

Recently - on November 29th, 2000 - the (draft) Green Paper on European energy supply security was issued. The Dutch General Energy Council (AER) wishes to dispose of adequate background information on the results of relevant energy scenario analyses of some selected reputed institutes and the implications thereof for energy supply security at the European level with special attention to the Netherlands. This brief technical fact-finding study sets out to provide a broad overview of the issues at stake.

The Green Paper identifies two main priorities:
- Controlling the growth of demand. Fiscal interventions in energy prices should remove distortions between alternative energy carriers and between Member States and make that energy prices will reflect real costs including environmental damage costs.
- Managing supply dependence. New renewables should be vigorously stimulated. In particular for natural gas geographical diversification of supply would appear desirable, especially as far as LNG is concerned. Funding research on civil nuclear technology should be continued. A minimum coal production platform should be maintained.

In this study a brief assessment is presented of fossil fuel resources. The recoverable conventional and unconventional oil resources of the earth are estimated at 5,250 billion barrels (an R/P ratio of 200 years). Yet, oil remains a strategic fossil fuel. It is the most important fossil fuel today. Moreover, the oil resources are not evenly distributed around the globe. A main producing area is the Middle East. Canada and Venezuela could become main producers of unconventional oil. However, Canada's unconventional oil production will not exceed 1.65 million b/d in 2015, which is 7.5% of the current Middle East oil production.

The world's conventional gas resources are estimated at 444 trillion m^3, equal to 190 years at the current production level. Regions with large resources are the Former Soviet Union and the Middle East. Compared to oil, the supply of gas appears to be more well-balanced. The unconventional gas resources are extremely large. However, environmental damage has to be prevented. The amount of recoverable resources will remain a question mark for the time being.

WEC's 1996 analysis presents an estimate of the world's proved recoverable coal reserves of nearly 500 billion tons of oil-equivalent. This represents an R/P ratio of 230 years. Because of the shear magnitude of the proved reserves, consideration of the total coal resources is less relevant than in case of conventional oil and gas.

The so-called 'Shared analysis project', performed by a number of research institutes in the EU, gives useful points of departure for energy policy formulation. However, the results of notably the reference scenario and to a lesser extent its variants in terms of primary energy use, CO_2 emissions, and the EU's import dependence for fossil fuels have to be regarded carefully:
- The reference scenario shows rising CO_2 emissions on the EU level and strongly rising CO_2 emissions on the global level in the timeframe 1990-2020. Depletion of fossil fuel resources - sometimes a neglected issue - is not irrelevant as regards conventional oil. This aspect makes the forecasted EU's import dependence for fossil fuels (roughly 65% in 2020) all the more worrying. The 'shared analysis project' scenario study stresses that the Kyoto Protocol is a crucial guideline for Annex I countries, that could at the same time curb Europe's GHG emissions, lessen the depletion of fossil fuels and enhance security of supply.
- The scenario variant with higher oil and gas prices indicates that the possibility of a less steeply increasing dependence on oil and gas cannot be excluded, albeit in this variant at the expense of rising CO_2 emissions due to a shift to coal-fired power.

- A scenario variant with higher efficiency targets for vehicles in terms of g of CO_2/km has beneficial effects in terms of mitigation of the increase in CO_2 emissions; in case of a CO_2 reduction target of -13% in 2020, the additional costs are much lower than in the reference scenario. A revival of nuclear energy would also alleviate the mitigation costs.

IEA's World Energy Outlook 2000 ('the Outlook') gives due attention to OECD Europe's dependence on imported oil and gas. Oil remains the most important energy source with a share of 38% in primary energy demand in 2020. The rising share of oil imports (from 32% in 1990 to 80% in 2020) will also mean a higher dependence on OPEC countries, which currently account for 61% of Europe's oil imports. The Outlook projects that gas demand will increase faster than any other energy source. Gas will rapidly become the second fuel after oil, with 31% of total primary energy demand in 2020. Given steady growth in gas consumption, increasing imports will be needed. Russia and Algeria are expected to remain the primary sources, but new ones will supplement. Import dependence will increase from 34% in 1997 to about 65% in 2020.

In 1997, CPB in collaboration with AVV, ECN, and RIVM published scenarios with divergent developments of the society and the economy for the period 1995-2020. The CPB scenarios are analysed from the point of national security of supply. In all of the scenarios natural gas remains the main energy source, with a share in primary energy demand varying from 50% to 55%. Coal-fired power is assumed to be less competitive. In two of the three scenarios, gas-fired (industrial) co-generation would become even more dominant than today. In the most energy intensive scenarios, natural gas is very dominant, both in PJ and in relative terms.

In the related ECN study it is argued that a too strong focus on gas-fired power incurs risks of security of supply, due to ongoing depletion of indigenous gas resources. Only in case of the 'low-growth' scenario security of supply is more or less warranted. At current levels of fossil fuel prices, coal-fired power is able to compete, also in the liberalised market. Coal-fired power provides security of supply, as the international coal market is very competitive and not ruled by OPEC. Therefore, climate policies should take into account this point of view.

This study regards the Netherlands with regard to (industrial) co-generation as an example for other countries. However, irrespective of the potential of cogeneration, it is very important not to overly rely on the 'going gas' option and to give due attention to other power generation options that are environmentally benign or could become acceptable:
- Wind energy, especially but not exclusively promising because of its offshore potential.
- Biomass (preferably co-combustion or co-gasification).
- Photovoltaic energy, which may have a very large potential in the long run (nowadays expensive).
- Fossil-fired power plants with CO_2 sequestration, particularly if coal could be used as fuel and if it could be combined with CO_2 enhanced coal-bed methane recovery (currently in the RD&D stage).
- Nuclear energy, notably if a new type of High Temperature Reactor (HTR) could be used.

Europe's gas supply security will be served by more interregional trunk gas pipeline routes from Russia, North Africa (Libya) as well as Central Asia and even the Middle East via Turkey. In addition, further development of LNG infrastructure on the exporters' side (Nigeria, Angola, Egypt, Middle East) and on the receiving side in Europe will further improve Europe's negotiation position as far as interregional imports are concerned.

The National Transmission System Operator (TSO) Tennet is planning to enlarge the high voltage transformer at Meeden in Groningen in order to increase the net transfer capacity with Germany by 1000 MW. All things being equal, the net import from Germany and Belgium could be raised to some 30 TWh per year in the near future, which is equal to roughly 30% of the total consumption in the Netherlands.

1. INTRODUCTION

1.1 Background

Recently - on November 29th, 2000 - the (draft) Green Paper on European energy supply security was issued (European Commission, 2000). Currently discussions within the Member States, among which the Netherlands, are taking place within the governments, usually with consultation of main stakeholder groups, to define the stand of the respective Member States regarding the Green Paper. The Dutch General Energy Council (AER) intends to submit an Advisory Paper on the issue to the Ministry of Economic Affairs, responsible for energy policy in the Netherlands. In preparation of the upcoming Advisory Paper, the AER wishes to dispose of adequate background information on the results of relevant energy scenario analyses of some selected reputed institutes and the implications thereof for energy supply security at the European level with special attention to the Netherlands. To that effect, the AER has commissioned the unit Policy Studies of the Energy research Centre of the Netherlands (ECN) to conduct a brief technical fact-finding study.

1.2 Objective of the study

This report sets out to provide broad insight into the main assumptions of some selected international scenario studies and the consequences of the possible realisation of the energy scenarios concerned for the European supply security in the medium and long run. The emphasis is put on the presentation of factual information that may serve as a basis for policy advice on this issue by the AER.

1.3 Report outline

This report is organised as follows. A brief introduction to the recent EU Green Paper on energy supply security is given in Chapter 2. Chapter 3 provides an overview of the latest information on the size and regional distribution of the world's fossil fuel resources. An analysis of some recent energy scenario studies and implications for energy supply security are presented in Chapter 4. Chapter 5 recapitulates the main findings of this report.

2. THE GREEN PAPER ON ENERGY SUPPLY SECURITY

2.1 Introduction

In order to set the stage for the scenario analysis and other background information, this Chapter presents a brief overview of the highlights of the recent Green Paper of the EU on energy supply security. No comments are made on the views and policy recommendations, as expounded in the Green Paper. Reference is made to the upcoming Advisory Paper of the AER on this issue.

2.2 The Green Paper: main conclusions

The main points emerging from the Green Paper are:

- The European Union will become increasingly dependent on external energy sources. Enlargement will not change the situation.
- The European Union has very limited scope to influence energy supply conditions but the EU can intervene on the demand side: mainly by promoting energy saving in buildings and the transport sector.
- At present, the European Union is not in a position to respond to the challenge of climate change and to meet its Kyoto Protocol commitments.

2.3 The Green Paper: introduction to the supporting projection exercise

A projection exercise covering the period 1995-2020 was made in European Energy Outlook 2020, Energy in Europe Special Issue, November 1999. In preparation of the present Green Paper, this exercise has been expanded by way of updating the baseline scenario and by extending the analysis to 2030. Furthermore, the analysis for the Green Paper covers 30 countries; the EU countries, the candidate countries as well as Norway and Switzerland. Some results of this analysis are presented hereunder.

The EU is poorly endowed with conventional oil and gas resources, while these are mostly expensive to harness. Accession of gas-rich Norway to the EU would only slightly improve this situation. The endowment situation with respect to solid fuels is much better, yet extraction of these resources is not cost-competitive compared to coal from major external producers.

Primary energy demand in the EU is poised to grow from year 1998 to 2030 by 11%, while the baseline growth projection of CO_2 emissions by the EU from 1990 to 2030 is 22%. The main cause for the growing CO_2 emission is the change in fossil fuels used for power generation. Natural gas is the favoured power generation fuel for the next ten to twenty years. However, the trend to shift from coal to gas will reverse towards 2030, as gas is assumed to become too costly compared to coal. Also, coal-fired power is assumed to substitute some of the nuclear power plant capacity at the end of its economic lifetime. Corresponding projected growth rates for Europe-30 are even higher, i.e. a 25% increase in energy demand and a 31% increase of CO_2 emission respectively. The EU has succeeded in reducing energy dependence from 60% in 1973 (the year of the first world oil crisis) to 50% in 1999. Yet, according to the projected baseline, Europe's energy dependence will reach increasingly worrying levels (Table 2.1).

Table 2.1 *Projected energy import dependency, baseline scenario 1998-2030 [%]*

	1998	2010	2020	2030
EU	49	54	62	71
Europe-30	36	42	51	60

EU's GDP is projected to grow by 90% between 1998 and 2030. While energy imports are projected to increase by 81%, net energy import intensity (energy content of net energy imports per unit of GDP) is projected to decrease by 11% between 1995 and 2030. Given assumed increases in import prices for oil, gas, and coal of 86%, 81% and 5% respectively between 1995 and 2030, the ratio of energy imports to GDP is projected to rise from 1.2% in 1995 to 1.7% in 2030.

2.4 The Green Paper: policy analysis and recommendations

Adopting a policy of geopolitical diversification has not been able to free the Union from effective dependence on the Middle East (for oil), Russia and Algeria (for natural gas). Unless specific measures are taken to diminish the dominance of the oil sector, especially in the transport sector, oil import dependence could reach 90% by 2020, making Europe prone to serious consequences of any prolonged oil crisis. In the long run, the supply of gas in Europe risks creating a new situation of dependence. Geographic gas import diversification is presently quite poor with Russia and Algeria accounting for 41% and almost 30% of the EU's natural gas imports. A number of Member States, and in particular most applicant countries, are entirely dependent on a single gas pipeline that links them to a single supplier country.

Apart from the powers established by the ECSR and EURATOM treaties, there is no explicit mandate for a European energy policy, like the OPEC countries have today and other producer groups may have in the future. The lack of real energy policy reduces the bargaining power of the EU.

The best guarantee of security of energy supply is to maintain a diversity of energy sources and suppliers. Yet the future of the nuclear option is unclear. Five out of eight Member States with nuclear power have now adopted or announced a moratorium on nuclear energy (Sweden, Spain, Netherlands, Germany, Belgium). Yet the EU must retain its leading position in the field of civil nuclear technology.

A more harmonised Community framework on taxation on energy products is needed. Lack of harmonisation in energy taxation can lead to distortion of competition between Member States and affects the unity of the internal market. The liberalisation of the gas and electricity markets could even come under threat. Yet the unanimity rule stands in the way of any real harmonisation of tax levels. The draft directive, COM(97)30 final, OJ C 139, 6.5.1997, on the taxation of energy products aims to make it possible to restructure national taxation systems and achieve objectives in environment, transport and energy while complying with the single market. Adoption is being blocked in the Council of Ministers, in particular by Spain.

To date, the milestones on the way to opening up the electricity and natural gas markets to competition have been five Directives covering price transparency (1990), the transit of electricity and gas through grids (1990 and 1991), the internal electricity market (1996) and the internal natural gas market (1998). Meanwhile, two-thirds of the electricity and 80% of the gas market has been opened up. Yet, intra-Community trade in electricity is still a low 8% of total electricity production.

A European mechanism for collaboration between interested parties with a view to defining a European plan for the major missing (power) interconnection infrastructure is recommended. Furthermore, there is a need for greater separation between electricity generators and transport network managers, non-discriminatory network access by new generators and distributors, minimal charges for cross-border trade, clearer public service obligations and widespread establishment of an independent national regulator.

2.5 The Green Paper: policy priorities

The Green Paper identifies two main priorities:

- *Controlling the growth of demand.* Fiscal interventions in energy prices should remove distortions between alternative energy carriers and between Member States and make that energy prices will reflect real costs including environmental damage costs. Completion of the internal market will stimulate a.o. gas-to-gas competition which, in turn, may lead to an uncoupling of the price of gas from the price of oil. Priority demand sectors for which the growth of energy use should be diminished are transportation (especially road transportation) and buildings. This can be done through stimulation of energy-efficient technology (regulation, certification, fiscal measures, and funding of R&D).
- *Managing supply dependence.* New renewables should be vigorously stimulated. This can be achieved by several ways. One is internalisation in the energy prices of the social costs of damage of energy production and use to the local and global environment. Another is relatively long-term financial aid to be funded through temporary levies on profits of operators in the oil, gas and nuclear subsectors. The strategic stocking mechanism should be extended to natural gas. In particular for natural gas geographical diversification of supply would appear desirable, especially as far as LNG is concerned. Funding research on civil nuclear technology should be continued. A minimum coal production platform should be maintained. Establish an ongoing dialogue with producer countries and an energy partnership with Russia. Monitor opportunities related to the development of oil and gas resources in the Caspian Sea basin. Strengthen supply infrastructure networks with due regard for environmental impacts, with for oil shifting the emphasis towards oil pipelines. Improve the interconnections between the electricity transmission networks between the Member States.

3. FOSSIL FUEL RESOURCES

3.1 Introduction

Fossil fuels are hydrocarbons based on fuel sources such as crude oil, natural gas, natural gas liquids and coal. Fossil fuel resources are not only determined by geological occurrence, but also by technological development. The percentage of oil that can be recovered from an oil reservoir has increased steadily since the last few decades. Also exploration technologies have been improved dramatically. Therefore, resource estimates of fossil fuels are a function of time.

Section 3.1 addresses conventional and unconventional oil resources, Section 3.2 covers conventional and unconventional gas resources, including methane hydrates in subpolar regions and at the ocean floor, and Section 3.3 summarises the world's reserves of hard coal and lignite.

3.2 Oil resources

3.2.1 Introduction

Oil is used for transport (road and air transport, bunkers), as a feedstock in the chemical industry, for heating in the residential and commercial sector and for steam generation in industry. Conventional oil resources are the main source of oil today (Paragraph 3.2.2). However, unconventional oil - heavy and extra heavy oil, tar sands, oil shale - also needs attention (Paragraph 3.2.3).

3.2.2 Conventional oil

The US Geological Survey (USGS), a science agency of the U.S. Department of the Interior[1], publishes detailed assessments of the world's conventional oil and gas resources (USGS, 2000). Table 3.1 provides USGS data, based on Annex A. These data refer to three categories of resources, viz.

- Identified reserves
- Mean undiscovered reserves
- Futures.

Annex A provides the definitions of these reserve categories. In short, identified reserves are the proved and probable reserves; the next category (mean undiscovered reserves) are less certain, but still have some probability, whereas the 'futures' refer to relatively speculative resources[2].

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[1] The USGS serves as an independent fact-finding agency, with 10,000 scientists, technicians and support staff.

[2] Oil resources are reported in billions of barrels, gas resources in billions of m^3 and coal reserves in million tons of oil-equivalent (Mtoe). For reasons of comparison, the data are summarised in Annex C in the unit of energy EJ.

Table 3.1 *Conventional oil resources according to the USGS [billion barrels]*

Region	Annual production (1999)	Cumulative production	Identified reserves	Mean undiscov. Reserves	Futures	Identif.+ Mean undiscov. +futures
Africa	2.72	21	31	22	136	261
Asia&Oceania	2.79	41	61	74	129	264
Europe	2.54	25	40	23	60	124
FSU	2.76	109	129	151	297	577
Middle East	7.99	167	545	135	652	1,333
North America	5.05	198	104	111	300	514
South America	2.39	61	75	56	154	284
Total	26.24	622	986	571	1,729	3,360

The USGS data make plausible that the resources of conventional oil amount to 3,360 billion barrels. This is equivalent to a resources/production (R/P) ratio of 128 years.

Some organisations publish proved conventional oil reserves. The proved oil reserve is the amount of oil to be recovered from known natural reserves, which has been both carefully measured and assessed as exploitable under present and expected local economic conditions with existing available technology. In its ‘Statistical review of world energy’ (BP, 2000) BP presents proved reserves of 1034 billion barrels (R/P ratio 41 years). The WEC (World Energy Conference) (WEC, 1996) figure is 1080 billion barrels (R/P ratio 42 years).

For scenarios covering the period until 2010 or 2020, data of proved oil reserves might be useful. However, for energy studies or scenarios with a more distant time horizon (2050 and beyond) resource data like those of the USGS should be used.

If we focus on proved conventional oil reserves, the countries holding the largest reserves are the Middle East countries Saudi Arabia, Iraq, the United Arab Emirates, Kuwait, and Iran. Their reserves amount to 660 billion barrels, which is approximately 64% of the world’s proved reserves. Currently, the Middle East produces 30% of the world’s oil. Therefore, it seems inevitable that the world will become more dependent on Middle East oil in the long term.

The USGS data (Table 3.1) show that the Middle East comprises 40% of the total conventional oil resources. Therefore, the Middle East will be able to increase its share of the world’s conventional oil production from 30% today to some 40% in the long run.

3.2.3 Unconventional oil

Tar sands

One of the countries with large unconventional oil resources is Canada. Canada’s resources of tar sands occur entirely within the province of Alberta and are found in the oil sands regions Athabasca, Cold Lake en Peace River (Canada’s Oil Sands, 2000). The total area of the three regions is comparable in size to Scotland or Belgium. These areas contain an ultimate volume of some 400 billion m^3 of crude bitumen, 12% of which is estimated to be ultimately recoverable. The amount of recoverable oil is 49 billion m^3 (309 billion barrels), which is equal to 70% of the world’s recoverable tar sands.

Oil sands deposits deeper than about 75 meters are considered too deep to be surface mined economically. About 20% of the aforementioned recoverable oil in Alberta are considered amenable to surface mining. The remaining 80% will require some form of in situ recovery, for instance by Cyclic Steam Stimulation (CSS) or Steam-Assisted Gravity Drainage (SAGD).

A lot of technical improvement has taken place since the start of commercial tar sands production in 1967, e.g. mining trucks and power shovels in the mining operations and hydrotransport of the slurried bitumen. The same holds for extraction and upgrading processes. Today's extraction processes are able to extract about 91% of the bitumen contained in the oil sands, compared to about 84% in 1975.

The operating costs of mining of oil sands are currently \$11-\$14 per barrel, with a target of \$10 or less before 2005. The supply costs of bitumen produced by primary or 'cold production' in the Cold Lake area are \$10-\$13 per barrel, while the Wabasca area has slightly lower costs of \$7-\$10 per barrel. The supply costs of in situ production are \$10-\$16 per barrel for Cyclic Steam Stimulation (CSS) and \$8-\$14 per barrel for Steam Assisted Gravity Drainage (SAGD).

A price of \$18 per barrel for the marker crude Western Texas Intermediate (WTI), after considering transportation charges, exchange rates, blending costs and a \$5 light/heavy differential, translates to a realisation of about \$11 per barrel in the field for in situ or mining operations. This is a reasonable price level, based on the current technological state-of-the-art.

In 1999, oil production from oil sands mining was 325,000 b/d (barrels/day), equivalent to 15% of the total Canadian oil production. Based on an oil price of \$18 per barrel (WTI), the production of synthetic crude oil from oil sands mining is expected to increase nearly three-fold, reaching 1 million b/d by 2015. The production of bitumen from in situ production is projected to increase from 165,000 b/d in 1999 to 650,000 b/d in 2015. So, the total unconventional oil production of Canada could increase from 0.5 million b/d in 1999 to 1.65 million b/d in 2015. Notably, this is approximately 7.5% of the current level of oil production of the Middle East.

Heavy and extra heavy oil

Venezuela has vast resources of heavy and extra heavy oil. They try to push the technology for production and extraction of (extra) heavy oil to its practical limits. The Eastern and Maracaibo basins rank prominently among the 10 largest oil basins of the world. The state oil company Petroleos de Venezuela S.A. (PdV) has identified 1,800 billion barrels of heavy and extra heavy oil in place. Other sources say that the amount of oil in place is 1,300 billion barrels. According to PdV, 270 billion barrels may be classified as recoverable as a result of current projects and technology (Inciarte, 1997). Venezuela could hold 47% of the global resource base (572 billion barrels).

Oil shale

There are major deposits of oil shales in Australia, Brazil, Estonia, Israel, Jordan, Morocco, Thailand and the USA. The recovery of oil from oil shale is in an early stage of development. Production costs may be higher for oil shale than for tar sands and (extra) heavy oil. The environmental consequences could be larger too. Based on current technological experience, 880 billion barrels of oil may be recoverable from an amount in place of 13,900 billion barrels (Bundesanstalt, 1989; Warfield, 1995).

Total unconventionals

From the literature the following unconventional resource base has been compiled (Table 3.2).

Table 3.2 *Recoverable unconventional oil resources [billion barrels]*

	Heavy oil	Tar sands	Oil shale	Total
Africa	6		6	12
Asia&Oceania	13		241	254
Europe	8		9	17
FSU	130	117	16	263
Middle East	61	5		66
North America	44	309	355	708
South America	310	6	253	569
Total	572	437	880	1,890

With a wide uncertainty margin, the world's recoverable unconventional oil resources are estimated at 1,890 billion barrels. This is equivalent to 72 years of current oil production (1999).

3.2.4 Summary

The recoverable conventional and unconventional oil resources of the earth are estimated at 5,250 billion barrels (an R/P ratio of 200 years). Yet, oil remains a strategic fossil fuel. It is the most important fossil fuel today. Moreover, the oil resources are not evenly distributed around the globe. A main producing area is the Middle East. Canada and Venezuela could become main producers of unconventional oil. However, Canada's unconventional oil production will not exceed 1.65 million b/d in 2015, which is 7.5% of the current Middle East oil production.

Every now and then, the OPEC shows its ability to determine the world oil price. This is also a matter of concern for countries and regions (the EU) that import most of their oil. Therefore, from the point of view of security of supply, particular attention should be paid to oil.

3.3 Gas resources

3.3.1 Introduction

Natural gas is used in the residential and commercial sector, for combined heat and power in industry, as a feedstock in the chemical industry, and for sole power generation. Commonly, the focus is on conventional natural gas, the main source of gas today (Paragraph 3.3.2). Unconventional gas comprises methane hydrates in permafrost regions and at the ocean floor (Paragraph 3.3.3).

3.3.2 Conventional gas resources

The United States Geological Survey (USGS) publishes detailed assessments of the world's conventional gas resources. Annex B contains USGS data on the conventional gas resources of world regions. Two classes of resources from the USGS data are considered in Annex B:

- Remaining reserves
- Mean undiscovered reserves

'Futures' are included in the total resource base of the USGS. However, in order to end up with the total gas resources for the world regions, another resource estimate of Enron has been used (Carson, 1997).

Table 3.3 summarises the total conventional gas resources according to the USGS and Enron.

Table 3.3 *Conventional gas resources according to the USGS and Enron [billion m^3]*

	Annual production (1999)	Remaining reserve	Mean undiscovered	Additional (Enron)	Total
Africa	114	9,60(	10,200		19,80
Asia&Oceania	255	10,70(	15,300	4,80	30,80
Europe	282	7,80(	8,700		16,50
FSU	656	47,30(	44,100	55,30	146,70
Middle East	187	46,00(	36,400	53,70	136,10
North America	740	7,30(	19,300	46,90	73,50
South America	95	6,90(	13,800		20,70
Total	2,330	135,60(	147,800	160,70	444,10

The total conventional gas resources (Table 3.3) are 444 trillion m^3. The potential gas resources according to Enron are 437 trillion m^3, whereas the USGS figure is 436 trillion m^3. The conventional gas resources (444 trillion m^3) are equivalent to an R/P ratio of about 190 years.

BP and the WEC make reference of proved reserves of 146 trillion m^3 and 147 trillion m^3 respectively. The proved reserves represent an R/P ratio of some 63 years.

With respect to the global distribution of the gas resources two regions stand out, viz. the Former Soviet Union and the Middle East, with 33% and 31% respectively of the conventional gas resources (Table 3.3). Note that the Middle East is a main although not dominant gas region.

3.3.3 Unconventional gas resources

Coal-bed methane, tight formation gas, and clathrates - methane hydrates found in Arctic areas and at specific depths of the ocean floor - are denoted as unconventional gas. One estimate is that 98% of the clathrates are offshore. The remaining 2% in permafrost zones on land could contain more than 300 trillion m^3 of methane, twice the proved conventional gas reserves (Collet, 1998; Henriet, 1998). The amount of gas in place at the ocean floor could be 3,100 to 7,600,000 trillion m^3.

Gas hydrates have been known to form and exist in nature since 1966. They occur mainly in the subpolar regions of continents and in deepwater regions (at the ocean floor). The first naturally occurring gas hydrate field was discovered in 1967.

Much more work needs to be done on understanding the potential of this resource and the morphology of hydrate crystals that form in porous media. Better estimates have to be made of the gas-in-place in various basins around the world. Also, techniques have to be developed for producing gas from the hydrate-containing formations. Hydrates may have an effect on the earth's thermal regime and the generation of greenhouse gases, and they may also hold clues about the formation and dynamics of cosmic bodies (Oil & gas, 2001).

For these various reasons gas hydrate research got more interest lately in countries like the USA, Japan and India.

3.3.4 Summary

The world's conventional gas resources are estimated at 444 trillion m^3, equal to 190 years at the current production level. One of the main suppliers is the Former Soviet Union. Another region with large potential is the Middle East. Compared to oil, the supply of gas appears to be more well-balanced. There is no equivalent of OPEC in the world of gas production today.

The global unconventional gas resources are extremely large. However, it is unknown which part of these resources could be recovered. Also, environmental damage has to be prevented. The amount of recoverable unconventional gas will remain a question mark for quite some time.

3.4 Coal reserves

The WEC (World Energy Conference) provides data of the world's proved coal reserves, which are used by BP in its 'Statistical review of world energy' (BP, 2000) (Table 3.4).

Table 3.4 *World coal reserves according to WEC and BP [Mtoe]*

	Annual production (1999)	Hard coal	Lignite	Total
Africa	122	40,80	100	40,900
Asia&Oceania	884	123,00	36,000	159,000
Europe	254	27,80	26,800	54,600
FSU	186	65,00	44,200	109,200
Middle East	1	100		100
North America	624	77,80	46,600	124,400
South America	31	5,20	4,600	9,800
World	2,103	339,70	158,300	498,000

WEC's 1996 analysis presents an estimate of the world's proved recoverable coal reserves of nearly 500 billion tons of oil-equivalent. This represents an R/P ratio of 230 years. Because of the shear magnitude of the proved reserves, consideration of the total coal resources is less relevant than in case of conventional oil and gas. Thus, only the reserves of coal are shown here.

Coal reserves are rather evenly distributed around the globe. Production and consumption are much more regionally balanced than in case of oil. Compared to the world oil market, countries like Australia, South Africa and the United States export relatively small amounts of coal. The international coal market is very competitive. Sudden price escalations are really exceptional.

4. ENERGY SCENARIOS AND SECURITY OF SUPPLY

4.1 Introduction

There are many recent studies on the long-term development of economy, energy and environment. These cover a.o. the global, EU level, and/or the Netherlands. In the framework of the present limited study it is impossible to regard all the recent studies of interest. Therefore, a few studies have been selected. In case of Europe (Section 4.2) two studies have been selected, the so-called 'shared analysis project' (European Commission, 1999a) which forms a point of embarcation for the recent EU Green Paper on energy supply security, as well as IEA's World Energy Outlook 2000 (IEA, 2000). In case of the Netherlands (Section 4.3) the 1997 study (CPB, 1997) of CPB[3] has been selected as the reference study. As far as global CO_2 emissions are concerned, the projections of the 'shared analysis project' and IEA's World Energy Outlook 2000 are compared with recent IPCC scenarios.

4.2 The European level: 'Shared analysis project'

4.2.1 Introduction

The 'shared analysis project' gives a broad overview of the main challenges of energy policy, which will be briefly summarised hereafter. The EU has made commitments following the Kyoto Protocol of December 1997 to curb emissions of a basket of six greenhouse gases (GHG) - particularly carbon dioxide (CO_2). Given liberalisation and privatisation of the energy markets, the shared analysis project concludes that energy policy has to give due attention to:

- the demand side, and, consequently,
- the wider energy 'system'.

It is stated that reduction of GHG emissions deserves a systemic policy response, based upon dialogue with stakeholders, e.g. with the road and rail transport sector. Another related issue that is indicated to need due attention, is harmonisation of energy efficiency regulation on the European level.

4.2.2 General description

Besides GHG reduction, import dependence and supply security are qualified as being important issues for the EU. This is done so because of the projected steady decline of the EU's high-cost indigenous coal production, the decommissioning of (ageing) nuclear power plants, and the increasing maturity of major oil and gas fields in Western Europe such that output will peak sooner rather than later and subsequently decline.

The assumed GDP growth in the timeframe 1990-2020 is briefly mentioned here. For Western Europe, GDP growth is assumed to be: 1.8%/a from 1990 to 2000, 2.4%/a from 2000 to 2010 and 2%/a from 2010 to 2020.

Under the so-called POLES reference scenario, the world's conventional oil resources are estimated at 2,900 billion barrels, 500 billion barrels more than a 1996 estimate of the US Geological Survey (USGS). In Chapter 3 an even higher estimate of the world's conventional oil resources based on recent USGS data has been presented (3,360 billion barrels).

[3] The study of CPB (Central Planning Bureau, affiliated to the Ministry of Economic Affairs) contains contributions from AVV (Adviesdienst Verkeer en Vervoer), ECN (Energy research Centre of the Netherlands), and RIVM.

The relation between oil resources and the oil price is not straightforward. The scenario study of the shared analysis project assumes an oil price of 23.8 $/barrel in 1990, 16.9 $/barrel in 2010, and 20.1 $/barrel in 2020 (1990 $). These assumptions may be compared to a higher oil price projection in IEA's World Energy Outlook 1998: $25/barrel in 2020. This may be an equally probable level of the oil price in 2020, presuming a 'business-as-usual' scenario.

The aforementioned 'shared analysis project' study notes that the prices of natural gas have declined in Western Europe during the 1990's due to overcapacity, partial market liberalisation and low oil prices. In the longer run, the pressure of increasing demand, especially for power generation, will make the import of gas from a number of distant fields from Russia, North Africa and Middle East a necessity. The study assumes a modest increase in gas prices, although doubling of the consumption of natural gas requires increasing imports from 'less politically stable countries'.

4.2.3 Primary energy demand and CO_2 emissions

The 'shared analysis project' study presents results of the POLES model for four world regions, viz. OECD, CEEC&FSU (Central and Eastern Europe & Former Soviet Union), China&South Asia, and Other developing countries. The assumed GDP growth of the FSU is 5.8%/a for 2000-2020. Comparable growth rates are assumed for developing nations. Table 4.1 shows the projected global CO_2 emissions.

Table 4.1 *Projected global CO_2 emissions ('Shared analysis project')*

	Emissions [Mton of CO_2]			Shares [%]		
	1990	2010	2020	1990	2010	2020
OECD	2,730	3,370	3,690	47.1	41.0	34.2
CEEC&FSU	1,290	960	1,330	22.3	11.6	12.4
China&South Asia	850	2,070	2,990	14.6	25.2	27.8
Other developing countries	990	1,830	2,760	16.1	22.2	25.6
World	5,860	8,230	10,770	100	100	100

By 2010 global CO_2 emissions could exceed the 1990 level by 42%, and by 2020 by 86%.

The results for the European Union in terms of primary energy demand by fuel and CO_2 emissions are shown in the Tables 4.2 and 4.3 respectively.

Table 4.2 *Primary energy demand by fuel, EU-15 ('Shared analysis project')*

	[Mtoe]					Shares [%]		
	1990	1995	2000	2010	2020	1995	2010	2020
Solid fuels	302	238	207	182	218	17.4	11.7	13.5
Liquid fuels	545	578	606	655	663	42.2	42.1	41.1
Gas	222	274	338	401	431	20.0	25.8	26.7
Nuclear	181	205	223	227	199	15.0	14.6	12.3
Electricity	2	1	1	2	3	0.1	0.1	0.2
Renewable energy	64	72	79	88	100	5.3	5.7	6.2
Total	1,31	1,36	1,45	1,55	1,61	100	100	100

Table 4.3 *CO_2 emissions by fuel, EU-15 ('Shared analysis project')*

	[Mt CO_2]				Shares [%]		
	1990	1995	2010	2020	1995	2010	2020
Solid fuels	1,090	870	660	820	35.5	20.1	23.3
Hard coal	620	550	400	570			
Coke	120	90	60	50			
Lignite	280	210	200	200			
Liquid fuels	1,420	1,510	1,710	1,710	46.1	51.8	48.9
Gasoline	350	350	420	420			
Kerosene	90	110	170	200			
Diesel oil	580	640	730	730			
Fuel oil	270	260	230	190			
Gas	560	660	920	970	18.4	28.0	27.8
Natural gas	480	590	870	930			
Other gas	80	70	50	40			
Total	3,080	3,040	3,300	3,510	100	100	100

The projected use of coal shows a pattern of decline and revival. Coal-fired power plants are assumed to substitute decommissioned nuclear power plants. Transportation is the main cause of increasing demand for oil. Demand for natural gas is bound to almost double between 1990 and 2020, mainly because gas will be increasingly used in power generation. Output from nuclear power plants is projected to remain flat until 2010, and to decrease significantly towards 2020 due to decommissioning of ageing nuclear reactors. The output from renewable energy sources would increase by 56% between 1990 and 2020.

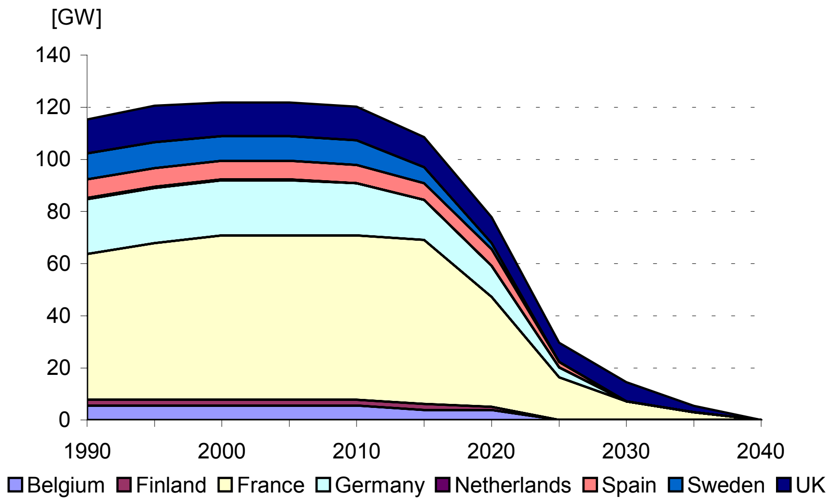

Figure 4.1 *Existing nuclear capacity (EU-15), assuming a generic lifetime of 40 years*

The reference scenario presumes that the capacity of nuclear power plants is 135 GW in 2010 and 117 GW in 2020. This can only be realised by a combination of life extension and construction of new nuclear power plants. In case of a generic lifetime of Light Water Reactors (LWRs) of 40 years, the EU's installed nuclear capacity would decline slightly to 120 GW in 2010 and at an accelerated speed to 78 GW in 2020 (Figure 4.1).

In a similar way the development of coal-fired capacity in the EU can be shown, based on the decommissioning assumed in the 'Shared analysis project' study (Figure 4.2).

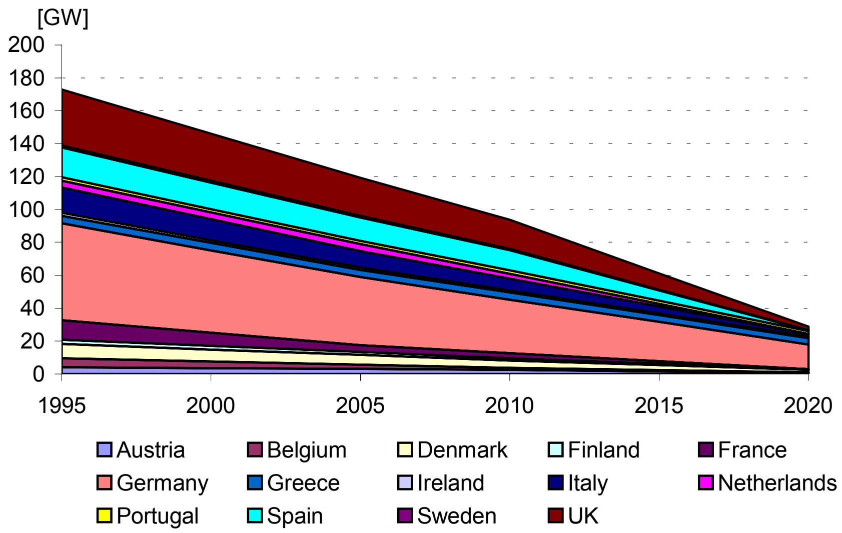

Figure 4.2 *Installed coal-fired capacity (EU-15), decommissioning according to the 'Shared analysis project'*

The reference scenario assumes that 3.4 GW of new coal-fired capacity is installed until 2010 and a total of 26.6 GW until 2020. Therefore, the total coal-fired capacity declines to 104.5 GW in 2010 and 63.5 GW in 2020.

In the reference case, CO_2 emissions are projected to have increased by 7% in 2010, compared to those in 1990. The corresponding figure for 2020 is 14%. Stabilisation of CO_2 emissions would cost 25 billion € in 2010 (1990 €). In a scenario of 6% CO_2 reduction in 2010 and 13% reduction in 2020, mitigation costs are put at 55 billion € in 2010. The CO_2 reduction cost in the latter scenario is € 102/ton C in 2010 and € 115/ton C in 2020.

4.2.4 Scenario variants

In the aforementioned 'shared analysis project' study three scenario variants are addressed, which could alleviate the problems of climate change:

- Nuclear renaissance
- Higher prices for oil and gas
- A more efficient transport system.

Nuclear renaissance

In this variant nuclear capacity is projected to increase from 132 GW in 1995 to 181 GW in 2020. Obstacles as regards fuel transport, nuclear waste reprocessing and disposal, etc. are assumed to be overcome by technical progress. The nuclear capacity expansion would resemble that of the 'nuclear era' 1960-1990. In 2020 the EU's CO_2 emissions could be reduced by about 13% compared to 1990 at a cost of € 75/ton C. This is appreciably lower than the aforementioned level of € 115/ton C.

Higher prices for oil and gas

In the high prices variant, in 2010 the oil price is assumed to be nearly 30% higher than in the reference case, and the gas price is 25% higher. In 2020 these figures are 40% and 50% respectively. Higher prices for oil and gas cause a reduction of primary energy consumption. However, rising CO_2 emissions from fuel switching in power generation - from gas to coal - would outweigh the effects on energy demand.

A more efficient transport system

The voluntary agreement between the European Commission and the European automobile industry, requiring an average CO_2 emission for new cars of 140 g/km in 2008, is supposedly extended to 2020 stipulating a more stringent target of 100 g/km by 2020. Due to a lower oil demand (4% reduction), the increase of CO_2 emission would be 4.5% in 2010 and 9% in 2020. The cost of 13% CO_2 reduction in 2020 is put at € 67/ton C.

4.2.5 Outlook for security of supply

The 'Shared analysis project' indicates in its reference scenario an increasing dependence on imported oil, gas and coal. Figure 4.3 shows the percentage import dependence for fossil fuels.

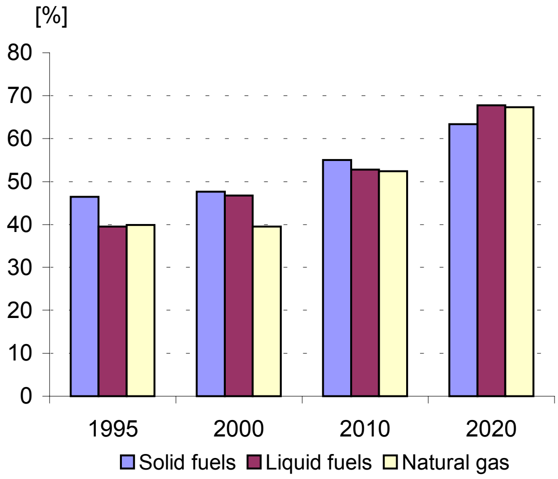

Figure 4.3 *Percentage import dependence: reference scenario 'shared analysis project'*

The relatively favourable reserve situation of natural gas does not prevent a sharp increase in gas import dependence, from less than 40% in 2000 to more than 52% by 2010 and more than two thirds by 2020, due to the relatively rapid increase in gas consumption.

4.2.6 Reflection

The 'shared analysis project' postulates a reference scenario with rising CO_2 emissions (increase of 7% in 2010 and 14% in 2020). On a global scale CO_2 emissions would rise by 42% in 2010 and 86% in 2020 (both compared to 1990). Such CO_2 emission levels are considered not sustainable.

In the reference scenario, oil consumption in the EU-15 is assumed to increase by 20% in 2020 compared to 1990. On the global level the corresponding figure is 67%. Chapter 3 of the present report provides some key information on unconventional oil resources. This data can be interpreted as follows:

- Canada's unconventional oil production could amount to 1.65 million b/d in 2015.
- Extrapolation to 2020 suggests a level of 4.5 million b/d for the world's unconventional oil production, if we presume that Canada and Venezuela would take the lion's share.

It follows, that a global oil demand of 106.5 million b/d in 2020, as projected by the reference scenario, would require a staggering level of conventional oil production, viz. 102 million b/d, i.e. 45% more than in 1999.

The 'shared analysis project' gives useful points of departure for energy policy formulation. However, the results of notably the reference scenario and to a lesser extent its variants in terms of primary energy use, CO_2 emissions, and the EU's import dependence for fossil fuels have to be regarded carefully:

- The reference scenario shows rising CO_2 emissions in the EU level and strongly rising CO_2 emissions on the global level in the timeframe 1990-2020. Depletion of fossil fuel resources - sometimes a neglected issue - is not irrelevant as regards conventional oil. This aspect makes the forecasted EU's import dependence for fossil fuels (roughly 65% in 2020) all the more worrying. The 'shared analysis project' scenario study stresses that the Kyoto Protocol is a crucial guideline for Annex I countries, that could at the same time curb Europe's GHG emissions, lessen the depletion of fossil fuels and enhance security of supply.
- The scenario variant with higher oil and gas prices indicates that the possibility of a less steeply increasing dependence on oil and gas cannot be excluded, albeit in this variant at the expense of rising CO_2 emissions due to a shift to coal-fired power.
- A scenario variant with higher efficiency targets for vehicles in terms of g of CO_2/km has beneficial effects in terms of mitigation of the increase in CO_2 emissions; in case of a CO_2 reduction target of -13% in 2020, the additional costs are much lower than in the reference scenario. A revival of nuclear energy would also alleviate the mitigation costs.

The assumptions underlying the scenario analysis are crucial. To some extent, the dramatic results of the aforementioned reference scenario with regard to CO_2 emissions and security of supply could be related to the type of model used. In this respect, it is remarked that dynamic optimisation models seem to be more suitable for analysis of inter-generational issues like CO_2 emissions and fossil fuel depletion. A study for Western Europe (Lako, 1998a; Lako, 1998b) shows that stabilisation of CO_2 emissions instead of a 14% increase in 2020 could be feasible in case of a low discount rate of 5%. In technology-driven models the depletion of fossil fuels can be imposed as cumulative constraint, just like CO_2 emission. In most dynamic optimisation models used today energy demand and the economy are, if weakly, interrelated. The suitability of dynamic optimisation models is confirmed by the Energy Information Administration (EIA) of the US Department of Energy. Recently the EIA decided to turn to dynamic optimisation for policy analysis.

All in all, the 'shared analysis project' has clearly shown that GHG emissions and security of supply - decline of indigenous coal production, decommissioning of nuclear power plants, increasing maturity of major oil and gas fields - are interrelated issues, that call for a comprehensive policy.

4.3 IEA's World Energy Outlook 2000: the picture for Europe

4.3.1 Introduction

IEA's World Energy Outlook (to be denoted as 'the Outlook') is one of the authoritative sources for energy projections of the world's energy future. Therefore, it was deemed useful to take this source duly in consideration. Moreover, the time horizon of reference scenario of the IEA's study, viz. 2020, corresponds with the ones of the 'Shared analysis project' and CPB's 1997 study.

4.3.2 General description

The Outlook expects the world economy to grow by 3.1%/a on average to 2020, which is equivalent to a more than doubling compared to 1997. The GDP growth of the OECD is 2%/a, lower than the annual average of close to 3%/a in the last three decades. The GDP growth in

OECD Europe[4] is 2.1%/a from 1997 to 2020. Assumed GDP growth rates for Europe in the Outlook and the EU according to the 'shared analysis project' are comparable. Russia's GDP growth is put at 3%/a through 2020 in the Outlook on the assumption that the pace of reform accelerates. Developing economies have significantly better growth prospects: their share of world GDP would rise from 46% in 1997 to 58% in 2020.

The OECD's population is assumed to grow by 0.3%/a. The population in the transition economies remains broadly constant. The population of the developing countries increases by 1.3%/a through 2020, significantly less than its growth rate of 2% in the last three decades. It follows that the world's population will rise from six billion in 2000 to 7.4 billion in 2020. The share of the population of developing countries is forecasted to increase from 77% today to 81% in 2020.

Table 4.4 shows the Outlook's assumptions with respect to prices of imported fossil fuels.

Table 4.4 *Assumptions for fossil fuel prices (World Energy Outlook 2000)*

	Unit	1997	1998	1999	2010	2020
Import prices Europe	As reported					
Crude oil	[$ 1990/barrel]	16.0	10.5	13.9	16.5	22.5
Steam coal	[$ 1990/tonne]	36.8	32.8	29.3	37.4	37.4
Natural gas	[$ 1990/toe]	90.5	79.2	67.3	80.9	132.8
Import prices Europe	In GJ					
Crude oil	[$ 1990/GJ]	2.80	1.84	2.43	2.89	3.94
Steam coal	[$ 1990/GJ]	1.32	1.18	1.05	1.34	1.34
Natural gas	[$ 1990/GJ]	2.16	1.89	1.61	1.93	3.17

The Outlook's forecasted fossil fuel prices compare to those of the 'shared analysis project' as follows:

- The crude oil price is put at $22.5/barrel in 2020 ($20.1/barrel in the 'shared analysis project').
- The price of imported natural gas would rise to $3,17/GJ ($3.47/GJ for 'shared analysis project').
- The price of imported steam coal is set at $1.34/GJ ($ 1990) in 2020, compared to $1.80/GJ for 'hard coal' (an average of indigenous and imported coal) in the 'shared analysis project'.

4.3.3 Primary energy demand and CO_2 emissions

Table 4.5 shows the global CO_2 emissions according to the Outlook's reference scenario. By 2010 global CO_2 emissions could exceed the 1990 level by 42%, and by 2020 by 73%. These percentages are roughly comparable to those of the 'shared analysis project'. How the global CO_2 emissions trends until 2020 of the Reference scenarios of the Outlook and the 'shared analysis project' compare with other world scenarios is shortly addressed in Paragraph 4.3.6 (notably Figure 4.4).

[4] OECD Europe includes the EU-15, Czech republic, Hungary, Iceland, Norway, Poland, Switzerland and Turkey.

Table 4.5 *Projected global CO_2 emissions (World Energy Outlook 2000)*

	Emissions [Mton of C]				Share			
	1990	1997	2010	2020	1990	1997	2010	2020
OECD	2,900	3,130	3,620	3,900	51.0	50.8	44.9	39.6
Transition economies	1,110	700	840	1,040	19.5	11.4	10.5	10.6
Developing countries	1,680	2,330	3,600	4,910	29.6	37.8	44.6	49.8
World	5,690	6,150	8,070	9,850	100	100	100	100

The trends in primary energy supply in OECD Europe are presented in Table 4.6.

Table 4.6 *Primary energy demand by fuel, OECD Europe (World Energy Outlook 2000)*

	[Mtoe]				Shares [%]			
	1971	1997	2010	2020	1971	1997	2010	2020
Coal	428	342	327	301	34.4	19.9	16.2	14.0
Oil	661	686	776	815	53.1	40.0	38.4	38.0
Gas	91	344	522	650	7.4	20.0	25.9	30.3
Nuclear	13	238	239	188	1.0	13.9	11.8	8.8
Hydro	28	42	50	52	2.2	2.5	2.5	2.4
Other renewables	24	64	104	137	1.9	3.7	5.2	6.4
Total	1,246	1,716	2,019	2,144	100	100	100	100

The use of coal decreases slowly from 1990 to 2020. The use of oil increases due to rising transportation demands. The demand for natural gas increases by 175% through 2020 (95% for the ‘shared analysis project’). The output from nuclear power declines substantially towards 2020 (partial phase-out). The output from renewables increases by 75% in 2020. Despite quite similar GDP growth rates in both studies, the Outlook’s projections for primary energy demand (+36%) and gas demand (+175%) are substantially higher than in the ‘shared analysis project’.

CO_2 emissions in Europe (Table 4.7) are assumed to rise by 16% in 2010 and by 23% in 2020. These figures are even higher than the corresponding ones of the ‘Shared analysis project’.

Table 4.7 *CO_2 emissions by fuel, OECD Europe (World Energy Outlook 2000)*

	[Mt CO_2]				Shares [%]			
	1971	1997	2010	2020	1971	1997	2010	2020
Coal	1,680	1,340	1,270	1,170	44.7	33.4	27.6	23.8
Oil	1,860	1,870	2,130	2,240	49.6	46.8	46.2	45.6
Gas	210	790	1,200	1,500	5.7	19.8	26.1	30.6
Total	3,750	4,010	4,610	4,910	100	100	100	100

4.3.4 Scenario variants

Four scenario variants are considered, which could alleviate the problems of climate change:

- alternative transportation case,
- alternative power generation case 1: shift from coal-fired power to gas-fired power,
- alternative power generation case 2: stabilisation instead of reduction of nuclear capacity,
- alternative power generation case 3: increased share of renewable energy sources.

Alternative transportation case

For all the regions it is assumed that the fuel tax on transportation fuels increases by $95 per tonne of C. For Western Europe in particular the following additional policies are assumed:

- Further increased commitment until 2020 under the Voluntary Agreement of the European Association of Automobile Manufacturers.

- Demand- restraint and demand-shift policies: urban car restraint; expansion of urban public transport; high-speed rail expansion; and electronic charging of trucks per tonne-km.

In 2020, primary energy demand would be reduced by 39 Mtoe, and CO_2 emissions by 117 Mt from the Reference Scenario. Nevertheless, CO_2 emissions would be 20% higher than in 1990.

Improved efficiency and higher share of gas-fired power
In this case the generating efficiency of gas-fired combined cycle power plants goes up to 62% in 2020 (60% in the Outlook's reference scenario). Also, a shift from coal-fired to gas-fired power is assumed. The share of gas-fired power in the total power generation increases to 48% (instead of 38%), whereas the share of coal-fired power is 15% (instead of 25%). CO_2 emissions of power generation in 2020 would be 12% less than in the reference scenario. The CO_2 emissions reduction is 200 Mt CO_2, equivalent to a reduction by 4.0% of the total CO_2 emissions in 2020.

Stabilisation of nuclear power instead of substantial decline towards 2020
The Outlook's reference scenario assumes a substantial decline of nuclear power. The alternative case presumes a load factor of nuclear power plants of 87% instead of 85%, and a stable capacity of around 133 GW instead of a decline to 97 GW. The share of nuclear energy in the generation mix could be 22% instead of 16% in the reference case, at the expense of coal-fired power (from 25 to 22%) and gas-fired power (from 38 to 35%). Stabilisation of the nuclear capacity - mainly by life extension instead of a partial phase-out of nuclear power plants - would CO_2 emissions of power generation in 2020 9% less than in the reference scenario. The CO_2 emissions reduction is 160 Mt CO_2, equivalent to a reduction by 3.2% of the total CO_2 emissions in 2020.

Increased share of other renewables in the power generation mix
In this alternative case it is assumed that the deployment of renewable energy will evolve along the lines of the European Union's White Paper on Renewable Energy Sources (European Commission, 1997) (Table 4.8).

Table 4.8 *Capacity of other renewables in alternative case, OECD Europe [GW]*

	1997	2010		2020	
		Reference	Alternative	Reference	Alternative
Geothermal	0.6	1	2	1	3
Wind	4.5	21	32	38	57
Biomass and waste	6	12	26	17	40
Solar/tidal/other	0.5	1.6	2	4	5
Total	12	36	62	60	105

The Outlook estimates that the output from renewable sources other than hydro could increase by more than 20 TWh every year until 2020. Consequently, the shares of coal-fired and gas-fired power could be reduced 2 and 3% percentage points respectively. This case would entail a CO_2 reduction of 113 Mt of CO_2, equivalent to a reduction by 2.3% of the total CO_2 emissions.

4.3.5 Outlook for security of supply

The Outlook gives due attention to OECD Europe's dependence on imported oil and gas. The impacts of the reference scenario for both oil and gas import dependence are shortly addressed.

Oil
Oil remains the most important energy source with a share of 38% in primary energy demand in 2020. More than 90% of the incremental demand comes from the transportation sector.

Europe's oil import is bound to increase substantially due to rising demand and declining production. The rising share of oil imports (from 32% in 1990 to 80% in 2020) will also mean a higher dependence on OPEC countries, which currently account for 61% of Europe's oil imports (Figure 4.4).

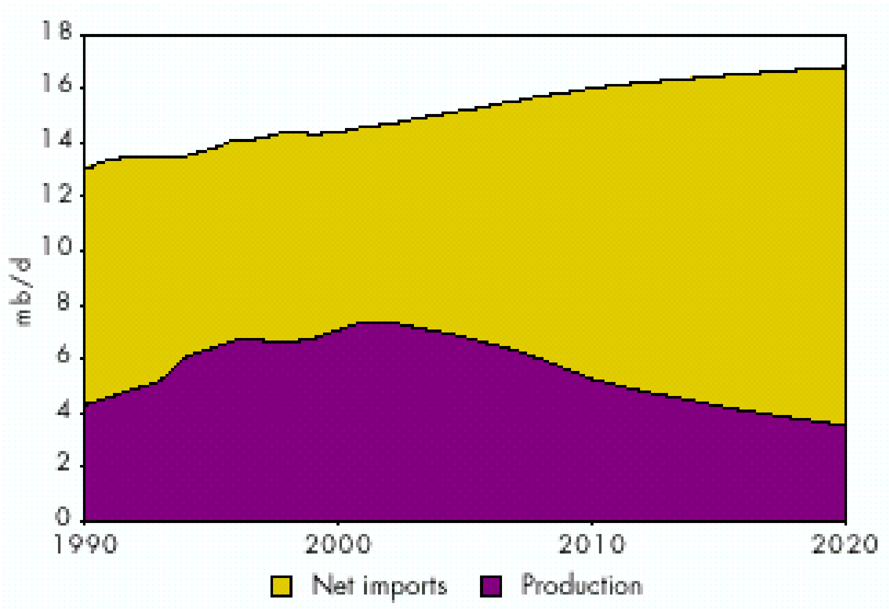

Figure 4.4 *OECD Europe oil balance, Reference Scenario 'World Energy Outlook 2000'*

Almost 95% of European oil production comes from the North Sea. Despite further technological developments, production will decline, most steeply in the relatively mature UK sector. Production in the UK sector is expected to peak in 2001 at around 3.1 million b/d with the commissioning of three new large fields. While new fields will still be found, they will most often be relatively small and probably economic only where they can take advantage of existing infrastructure. In the Norwegian sector production is expected to peak in 2002 at 3.6 million b/d and decline gradually thereafter. However, considerable uncertainty clouds prospects for new discoveries, which could allow Norwegian output to remain steady through the projection period (until 2020). The Outlook's reference scenario projects a fall in OECD Europe oil production from 6.7 million b/d in 1997 to 5.2 million b/d in 2010 and 3.5 million b/d in 2020.

Gas

Total primary gas supply is projected to increase faster than any other energy source. The average growth of gas demand is 3%/a. Gas will rapidly become the second fuel after oil, with 31% of total primary energy demand in 2020. Gas penetration increases in power generation and all end-use sectors. Figure 4.5 shows OECD Europe's gas balance according to the Outlook.

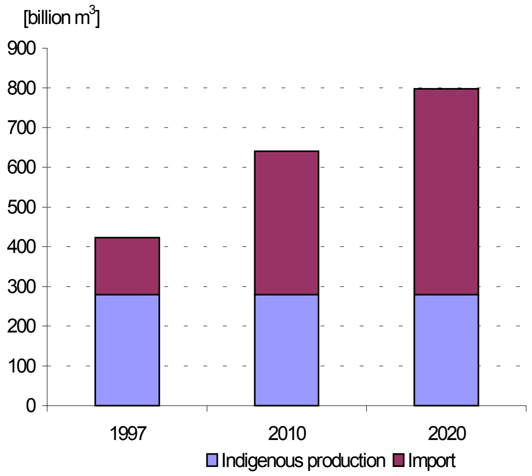

Figure 4.5 *OECD Europe gas balance, Reference Scenario 'World Energy Outlook 2000'*

Projected total production in OECD Europe will remain broadly unchanged to 2020, with Norway accounting for a growing share. Given steady growth in gas consumption, increasing imports will be needed. Russia and Algeria are expected to remain the primary sources, but new ones will supplement, such as LNG from Nigeria, Trinidad and Tobago and Quatar[5]. Import dependence will increase from 34% in 1997 to about 65% in 2020.

Major challenges for the European gas industry in meeting the need to secure gas supply are:
- Europe does not have a privileged entry to the giant Russian gas resources. It will need to offer competitive price terms to producers.
- The development of additional reserves and transportation capacity will need huge investments. This in turn will probably require strong alliances and increased vertical as well as horizontal integration.

4.3.6 Reflection

The Reference Scenario of the World Energy Outlook 2000 shows CO_2 emissions on a global scale (increase of 42% in 2010 and 73% in 2020) and in OECD Europe (+16% in 2010 and +23% in 2020). Such CO_2 emission levels are not sustainable.

The consequences of both the 'Shared analysis project' and the Outlook, in terms of global CO_2 emissions, are compared with the range of 'non-intervention scenarios' as well as the mean value of the 'intervention scenarios' contained in the recent 'Emissions scenarios' study (SRES) of IPCC (IPCC, 2000) (Figure 4.6).

[5] Other potential supply sources include Turkmenistan, Iran, Yemen, Venezuela, Egypt, and Angola.

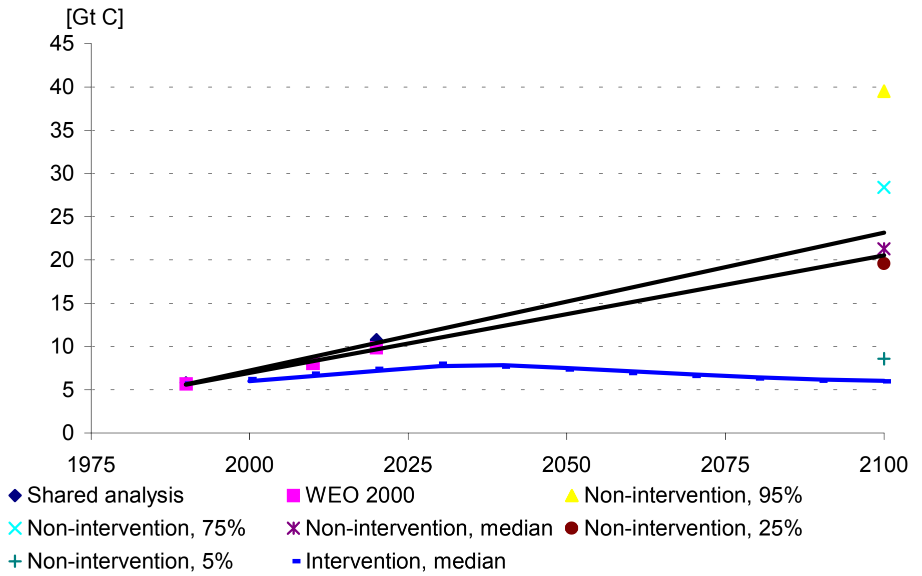

Figure 4.6 *Global carbon emissions, 'Shared analysis project', 'Outlook' (WEO 2000) and 'non-intervention' as well as 'intervention' scenarios of IPCC's 'Emissions scenarios'*

Figure 4.6 shows where the world would end up in terms of CO_2 emissions, if the emissions figures of both studies for 2010 and 2020 were extrapolated to 2100. It turns out that, in those two cases, the global carbon emissions would end up around the median value of the 138 non-intervention scenarios analysed by the IPCC in the so-called 'SRES' report. Note that the extremes of the range of the non-intervention scenarios are roughly stabilisation (5% percentile) and an emissions level seven times the world's current emission of nearly 6 Gt C per year. The mean CO_2 emission value of the 75 'intervention scenarios' is 6 GtC in 2100 (roughly the same as the current global CO_2 emission). Thus, the reference scenarios of both studies are typical 'business-as-usual' scenarios (non-intervention scenarios).

The World Energy Outlook 2000 gives a useful overview of the consequences of current trends with regard to (global) primary energy demand and CO_2 emissions. However, the results of the Outlook's reference scenario - and to a lesser extent its variants - for OECD Europe in terms of primary energy demand and CO_2 emissions are far from reassuring. Also the depletion of fossil fuels, particularly conventional oil, is worrying, although the Outlook states that one needs not expect a global 'supply crunch'. It has been contended, however, that a 50% rise of conventional oil production between 1999 and 2020 is a daunting perspective. So is the perspective of OECD Europe's rising import dependence for fossil fuels, viz. 80% for oil and 65% for gas in 2020.

4.4 The Netherlands: CPB study

4.4.1 Introduction

In 1997, CPB in collaboration with AVV, ECN, and RIVM published scenarios with divergent developments of the society and the economy for the period 1995-2020. The development of energy use (ECN, 1997) and spatial planning consequences of the scenarios are shown in much detail. The scenarios are 'Divided Europe', 'European Coordination' and 'Global Competition':

- 'Divided Europe' (DE) assumes a lack of co-ordination within the EU, a slow growth of GDP (1.5%/a), a sluggish speed of technological development, and lasting unemployment.

- 'European Renaissance' (ER) stresses the co-ordination on the EU level. The economic growth is high (2.75%/a), and technological development and employment are satisfactory.
- In 'Global Coordination' (GC) the focus is on global competition. This scenario has high GDP growth (3.25%/a), fast technological development, and a low level of unemployment.

The study gives much background information on societal preferences, migration issues, and regional economic development. However, none of the scenarios has mitigation of GHG emissions as its central objective. The low level of energy demand in 'Divided Europe' (compared to ER and GC) is due to slow economic growth, lack of EU co-ordination, and sluggish technological development.

4.4.2 CO_2 emission outlook

The results of the three scenarios are presented in a comprehensive way. Table 4.9 contains a few characteristics of the scenarios like GDP growth rate and oil price level. It also presents data on primary energy use by energy carrier and overall CO_2 emission.

Table 4.9 *Summary of basic assumptions and results of CPB scenarios of 1997*

		1990	1995	2010			2020		
				DE	EC	GC	DE	EC	GC
GDP growth	[%/a]			1.5	2.75	3.25	1.5	2.75	3.25
Oil price	[$/barrel]		17	20.0	17.0	28.0	20.0	15.1	26.0
Primary energy use									
Coal	[PJ]	374	378	314	257	302	294	191	206
Oil	[PJ]	975	1011	1155	1199	1301	1170	1358	1496
Natural gas	[PJ]	1290	1451	1624	1948	1981	1623	2087	2370
Electricity	[PJ]	34	43	10	1	24	12	3	30
Renewable energy	[PJ]	19	24	68	60	68	85	81	122
Rest category	[PJ]	43	58	58	51	62	65	66	71
Total	[PJ]	2735	2965	3229	3516	3739	3249	3786	4295
CO_2 emission	[Mton]	168	180	187	202	210	183	217	233

The results of the CPB study of 1997 should be interpreted carefully. First of all, CPB and the other institutes developed the scenarios a few years ago. Since 1997, energy and environmental policy has changed profoundly; currently, the Dutch government facilitates CO_2 reduction on a much larger scale than anticipated. Secondly, the current capability of the institutes to analyse CO_2 reduction policies - amount of CO_2 reduction realised and CO_2 reduction potentials available - is appreciable. Therefore, an update of the CPB study could entail more sophisticated estimates for different sectors like energy use by energy carrier, CO_2 emission etc.

Total primary energy demand in 2020 is projected to increase by 19% (Divided Europe) to 57% (Global Competition) compared to 1990 (See Table 4.9). CO_2 emissions in 2020 would increase by 9% (Divided Europe), 29% (European Coordination) or 39% (Global Competition).

4.4.3 Security of supply from the national perspective

In this sub-section, the CPB scenarios are analysed from the point of national security of supply. In Paragraph 4.4.5 the perspective is widened to the European security of supply.

In all of the scenarios natural gas remains the main energy source, with a share in primary energy demand varying from 50% in DE to 55% in EC and GC. Coal-fired power is assumed to be less competitive. It is regulated in scenario DE. In the other scenarios, gas-fired (industrial) co-generation would become even more dominant than today. In the most energy intensive scenarios, natural gas is very dominant, both in PJ and in relative terms. So, the CO_2 emissions are even somewhat flattered.

In the related ECN study it is argued that a too strong focus on gas-fired power incurs risks of security of supply, due to ongoing depletion of indigenous gas resources. Scenario DE, which is not attractive from a socio-economic perspective, is the only scenario in which security of supply is more or less warranted. At current levels of fossil fuel prices, coal-fired power is able to compete, also in the liberalised market. Coal-fired power provides security of supply, as the international coal market is very competitive and not ruled by OPEC. Therefore, climate policies - be it in the Netherlands or elsewhere - should take into account this point of view.

The energy-intensive scenarios EC and GC may well be qualified as 'unsustainable' for a number of reasons:

- Projected CO_2 emissions in EC and GC overshoot the 'Kyoto' target (-6% GHG in 2010) by far.
- Oil demand increases by 39% (EC) to 53% (GC) in 2020 compared to 1990. The corresponding figure for DE is 20%. In Section 4.2 (Paragraph 4.2.5) it has been argued that a 20% increase of oil consumption in the western world and a much higher increase in developing nations would incur a staggering level of conventional oil production in 2020.
- The dependence on natural gas in the energy economy in general, and more specifically in power generation, becomes dangerously high from the point of view of security of supply.

4.4.4 Reflection

The CPB study is useful, as it shows the range of economic and energy developments under the policy conditions of 1997. The outcomes of the scenarios in terms of CO_2/GHG emissions might be less frightening in practice:

- Government policies and the commitment of the government and the EU to technological development could be effective in curbing the trend of rising CO_2/GHG emissions.
- The assumed relation between GDP growth and energy use is too strong. The residential and commercial sectors offer perspectives for decoupling by reduced heating requirements, even taking into account population growth and rising numbers of houses and buildings.
- Also transport and industry offer energy conservation potentials with ongoing technological development, the conditions for which seem to be good in the Netherlands and the EU.

With regard to (industrial) cogeneration, the Netherlands is an example for other countries. However, irrespective of the potential of cogeneration, it is very important not to overly rely on the 'going gas' option and to give due attention to other power generation options that are environmentally benign or could become acceptable:

- Wind energy, especially but not exclusively promising because of its offshore potential.
- Biomass (preferably co-combustion or co-gasification).
- Photovoltaic energy, which may have a very large potential in the long run (nowadays expensive).
- Fossil-fired power plants with CO_2 sequestration, particularly if coal could be used as fuel and if it could be combined with CO_2 enhanced coal-bed methane recovery (currently in the RD&D stage).
- Nuclear energy, notably if a new type of High Temperature Reactor (HTR) could be used.

4.4.5 Security of supply from the international perspective

Security of supply deserves a more European perspective with regard to natural gas and electricity.

Natural gas
It has been noted that the Netherlands is an example for other countries with regard to cogeneration, although Scandinavian countries also rank very high in this respect. The Netherlands is also an example of a country with a highly developed gas infrastructure. However, both are strongly connected with the indigenous gas resources available in Groningen and elsewhere. The dependence on gas has not been a problem until now, but that could change.

The current government policy that offers incentives for development of relative small gas reservoirs is sensible, and will postpone the depletion of our gas resources. Export of gas will necessarily decline in the next decades. Although neighbouring countries (Germany, Belgium, etc.) will have to switch to other gas exporting nations, this is more or less inevitable in order to prolong the lifetime of the large Groningen field, which has an excellent swing capacity.

The policy of Gasunie to gradually increase gas import volumes is also sensible. The supply of gas becomes more diversified (Norway, the UK, Russia), and Gasunie is able to offer the swing capacity of the Dutch gas infrastructure, just like it does in case of Dutch gas exports. As far as the liberalisation of the gas market offers opportunities for additional import contracts, as has been the case lately (from the UK), the security of supply becomes even better than it already was in the pre-liberalisation era.

In the next decades, exploration on the Continental Shelf will remain important from the point of view of security of supply, especially for the UK but also for the rest of the EU. If sufficient gas would be available, imports from exporting regions like Russia, Africa, and the Middle East could be stepped up steadily in order to maintain the balance between supply and demand.

During the last decade the UK witnessed a ‘dash for gas’. The shift from coal-fired to gas-fired power caused a large CO_2 reduction. Switching from coal to gas could also occur in other EU countries, dependent on the economics and the remaining lifetime of coal power plants. Some EU countries aim to reduce their dependence on nuclear energy. Such a transition should be carefully planned in order to prevent rising CO_2 emissions and risks of security of supply.

Electricity
In 1986 the terrible Chernobyl accident triggered a moratorium on nuclear power plants in a number of countries in Western Europe, among which the Netherlands. Import of electricity has been one of the measures to maintain competitive electricity prices. Contracts between the former Sep and foreign power producers are still in place. Liberalisation of electricity markets showed the attractiveness of additional import contracts. Therefore, the import capacity will be increased on short notice.

The already high security of supply in the electricity market could be maintained and further strengthened:
- The current structure of power generation in the Netherlands is efficient and competitive, with a large number of highly efficient power plants with a considerable remaining lifetime.
- The current agreement between the Ministry of VROM and the operators of coal-fired power plants enables a substantial CO_2 emissions reduction by increasing the percentage of co-combustion (-gasification) of biomass, whereas the security of supply is strengthened.
- A subsea cable with Norway (hydro power) was anticipated in the CPB study. Such a cable and large-scale offshore wind energy, possibly combined with a high voltage DC cable to the UK to link the wind farms, could reduce CO_2 emissions and enhance security of supply.

5. COMPETITION AND INFRASTRUCTURE DEVELOPMENT

5.1 Introduction

In this chapter some special attention will be given to recent and expected developments with respect to international competition on energy markets and transmission infrastructure development, a key factor in the integration of national and regional energy markets. As the present study has rather stringent resource limitations, only some key aspects of the complex issues of this chapter will be addressed.

5.2 Competition for gas and oil resources

Hitherto, no strong interregional competition for gas resources did occur that are situated favourably to serve European markets. The reason is that intercontinental gas transmission infrastructure still is in a fledgling stage of development. Reasons are that only recently gas has penetrated in major EU markets as a fuel of choice for certain applications, especially for CCGT (combined cycle gas turbine) power plants and for heating and cooking in the residential and commercial sectors.

The relatively long market development process in many gas markets relates to the very high upfront gas field development and transmission costs for remote gas resource locations relative to the EU gas demand centres, while low-cost gas resources near major potential EU markets have reached (Netherlands) or are near their peak output (UK, southern Norway). At present, the cross-border European gas market is developing from one dominated by pay-or-take long-term contracts between producers and the often parastatal gas companies of importing countries into one dominated by spot prices and privatised gas importing distribution companies. As gas from new extra-EU producers such as Norway, Russia, and Algeria had to find adequate markets to use the gas production and transmission infrastructure at a viable capacity utilisation levels, gas-to-gas competition in EU markets has tended towards a downward pressure on the gas price as such and also in relation to oil. Now that the appetite of major EU energy markets for gas has been created, gas prices tend to firm. This creates further incentives to bear risks by the private sector in further mega gas development and transmission projects.

Several factors point to the direction of fast production expansion of more remote gas sources that can cater for the European market. These factors are:

- New technological development with a downward trend in unit cost of gas resource development and pipeline transportation.
- Even stronger recent cost-saving technological development in LNG transportation.
- Promising new technology in the medium term future, such as *solid gas* technology turning natural gas into a slurry that can be stored on floating platforms and transported on less sophisticated tankers than LNG and *Shell Middle Distillate Synthesis* that can transform gas to a sort of clean diesel liquid thereby expanding the potential market for gas.
- The environmental externalities relative to coal and oil (especially air quality problems with coal and gas combustion, as well as the climate change issue associated with GHG emissions) tend to be gradually more internalised in the fuel pricing system, partly depending on the progress on international climate change negotiations.
- Technological developments on the user end (such as CCGT - Combined Cycle Gas Turbine - technology) increase the relative attractiveness of natural gas with respect to competing fuels.

- Ongoing liberalisation in the power sector boosts deployment of the financially most attractive technologies with relatively short lead times in view of future risks, such as especially CCGT.

As a result, natural gas is expected to gain market share in the global energy markets, especially in the largest and most dynamic energy demand regions. By 1999, according to information provided by DOE/EIA[6], demand for natural gas in Europe excluding the Former Soviet Union has reached a level of 476 billion cubic meters and gas with a share of gas in total energy demand of nearly 22% (See Table 5.1). The DOE/EIA forecasts a surge in European gas demand, reaching by 2020 a level of 1000 billion m^3 and a market share of 35.5%. This gas demand will importantly increase the import dependency of Europe (excluding FSU). Imported gas will have to come from Russia and Algeria by pipelines, while in the medium term piped gas may come from Libya and Central Asia (mainly Turkmenistan, Kazakhstan). Gas imports will be increasingly supplemented by ship (LNG) from sources such as the Middle East, Nigeria, Egypt and Angola.

A major issue is to what extent potential European demand for extra-regional gas will meet competition from other world regions. The projected gas demand from North America (US, Mexico, Canada) - presently the world's largest regional gas market - is projected to continue outstripping European gas demand. However, the North American region is forecasted to remain by and large self-sufficient, perhaps in the second decade of this century supplemented by either piped or shipped imports from Venezuela. Yet, a major contender for extra-European gas imports is likely to become East Asia. By now, only Japan and recently also (South) Korea is a major importer of LNG gas, mainly from Indonesia, Malaysia, Australia and the Middle East. Huge projects are being planned by Japan to import gas from eastern Siberia (Sakhalin) and southern Siberia (Irkutsk-Kovytka). A development which most analysts presently discount as a long-term possibility is that these huge project proposals will be accelerated by gas demand from China. Presently, the penetration of gas on China's very dynamic energy market is still quite modest with a market share of 2%. Analysts of IEA and DOE/EIA forecast a penetration of some 5-6% by 2010 and some 8% by 2020 and expect that China will be mainly self-sufficient in gas throughout the 2000-2020 period, apart from LNG import in Guangdong, Shanghai, and possibly also Tianjin and Dalian. Imports of piped gas from Russia and Central Asia is considered as a remote possibility by those analysts stating current red tape preventing financial viable international pipeline projects with destination China. The present authors feel that the penetration of gas in China could well go much faster than generally expected, given the ongoing economic liberalisation process in China gradually removing existing subsidies on domestic coal and the fast increasing awareness of local environmental problems, especially in the big cities of China.

At present, a tender is being organised for a 14 billion $ pipeline and gas development project (the Kela-2 field, the largest onshore gas field in China with a proven reserve of 250 billion m^3), that should result in the transmission of gas from northwestern Xinjiang as far as 4,200 km to Shanghai. In March 2001, PetroChina and Shell have signed a Letter of Intent on a joint study on gas transmission and market development for the Changbei gas field in the northern Shaanxi and Inner Mongolia provinces, including gas production, gas transmission and the development of markets in Beijing, Tianjin, Hebei, and Shandong and other east China provinces. Full realisation of the project for delivery of up to 3 billion m^3 of natural gas per year over a 20 year period would require some 3 billion $. Once big reticulation network projects of gas in mega cities such as Beijing, Shanghai and many others have been completed, national gas resources can be expected to be insufficient in meeting the gas demand in eastern China. Hence, the possibility of big quantities of imported piped gas by China in addition to LNG imports as from 2010 on-

[6] While the figures of EIA/DOE are in line with those of the IEA, we have taken the EIA/DOE figures as these give some more country details.

wards should not be totally discounted. This will greatly impact on world gas markets, turning the European gas market from a buyers' into a sellers' market.

Certain possible political events may well speed up the go ahead for mega gas pipeline projects from Russia to East Asia, such as:

- *Returning the jurisdiction over the Kurilles Islands to Japan by Russia*. This would tremendously boost confidence of Japanese investors to invest in Russia, from which Russia stands to gain big economic benefits.
- *Reunification of (south and North) Korea*. This would pave the way for a pipeline project through North Korea to demand centres in Japan and South Korea.
- *Beijing winning the contest to organise the 2008 Olympic Summer Games*. This would give a strong political backing for fast gas reticulation infrastructure projects in Beijing and other Chinese mega cities.

Table 5.1 *World natural gas consumption by region, reference case of DOE/EIA International Energy Outlook 2001, 1990-2020 [billion m^3]*

	History		Projections				Average annual percent change
Region/Country	1990	1999	2005	2010	2015	2020	1999-2000
Western Europe	286	396	504	566	634	739	3.0
Turkey	3	11	14	20	25	34	4.7
Eastern Europe ex FSU	88	68	93	139	190	227	5.9
Europe ex FSU	377	476	612	725	850	1000	3.6
Former Soviet Union	708	569	609	663	759	835	1.8
China	14	25	54	83	130	181	10.1
Japan	54	74	82	85	93	102	1.9
South Korea	3	17	25	34	48	62	6.5
Selected East Asia	71	116	161	201	272	354	5.5
North America	623	739	861	951	1062	1161	2.2
Rest of world	285	484	671	850	1038	1232	4.6
Total world	2064	2384	2914	3390	3981	4582	3.2

Table 5.2 *Penetration of natural gas by region, reference case of DOE/EIA International Energy Outlook 2001, 1990-2020 [Percent share of natural gas in total energy consumption]*

		History			Projections	
Region/Country	1990	1999	2005	2010	2015	2020
Western Europe	16.2	21.7	25.6	27.5	29.8	33.3
Turkey	5.2	13.9	14.8	17.7	19.6	22.6
Eastern Europe ex FSU	20.7	21.8	26.5	36.2	44.7	49.5
Europe ex FSU	17.6	21.4	25.2	28.3	31.5	35.1
Former Soviet Union	41.9	52.2	50.8	51.5	52.8	54.0
China	1.9	2.9	4.5	5.4	6.8	7.8
Japan	10.8	12.4	13.1	13.2	13.6	15.5
South Korea	2.8	8.4	10.0	11.9	14.7	15.4
Selected East Asia	5.3	6.9	7.7	8.1	9.3	10.4
North America	22.7	23.2	24.2	24.9	26.2	27.0
Rest of world	17.4	20.4	23.2	24.8	25.8	26.2
Total world	21.5	22.8	24.2	25.4	26.7	27.8

5.3 Gas transmission infrastructure development

An overview of the situation with respect to EU crossborder gas pipelines and LNG receiving terminals in the EU is presented in Tables 5.3 and 5.4 respectively. Major interregional gas trunk lines are:

- from Russia: one trunk route through Belarus (3 × 40 inch) a second (20+40+40+56+56 inch) through Ukraine from northwestern Siberia (Yamal peninsula). A trunk route from Central Asia to Russia feeds notably into the second trunk pipeline to Central Europe (through Ukraine: 20+40+40 inch). A tributary trunk route goes though Ukraine to south-eastern Europe (48+40+28 inch).
- from Algeria: one to Spain (Maghreb Europe 48 inch) and one to Italy through Tunesia (Transmediteranean: 48 (?) inch).

A planned gas pipeline route would connect Libya with Italy in the short run. A plan for the more distanced future is a trunk route from Central Asia through Turkey to southern Europe.
Existing European LNG import terminals are located in Belgium (1), France (2), Italy (1), Spain (3), UK (1), and Turkey (1).

Europe's gas supply security will be served by more interregional trunk gas pipeline routes from Russia, North Africa (Libya) as well as Central Asia and even the Middle East via Turkey. In addition, further development of LNG infrastructure on the exporters' side (Nigeria, Angola, Egypt, Middle East) and on the receiving side in Europe will further improve Europe's negotiation position as far as interregional imports are concerned.

Table 5.3 *Overview of major EU crossborder pipeline routes; year 1999*

Country	Line	Onshore or Offshore	From F=field, B=border, S=sea	Via	To	Owned by	%	Length km	Diameter inches	Diameter cm	Capacity bcm/year	Transit volumes bcm	Peak volume bcm/yr	Customer	End date contract
Algeria	Maghreb (dec. 1996)	Onshore	Hassi R'mel F	Marocco	Spain and Portugal	SONATRACH	100	1255	48	122	10	can be extended to 19			
	Transmed	Onshore	Algeria	Tunesia	Italy	SONATRACH	50	550	2*48	2*122					
						SNAM	50								
Norway	Norsea Gas	Offshore													
	Zeepipe	Offshore	Sleipner F		Belgium B (Zeebrugge)				40	102	12.5				
	Zeepipe IIA	Offshore	Sleipner F		Norway B (Kollsnes)										
	Europipe I	Offshore	Sleipner F		Germany B (Dornum)										
	Europipe II	Offshore	Haltenbanken F	Norway B (Karsto)	Germany B (Dornum)				42	107					
	NorFra	Offshore	Sleipner F		France B (Dunkirk)				42	107					
	Asgard	Offshore													
	Frigg	Offshore	Frigg F		UK B (St.Fergus)	NorskHydro	32.87	50	2*32	2*91					
	Haltenpipe	Offshore	Haltenbanken F		Norway B				16	41					
	Norpipe	Offshore	Sleipner F (Ekofisk)		Germany B (Emden)			440	36	91		17.4 in 1996	20		
	Statpipe	Offshore	Troll F	Norway B (Karsto)	Norpipe			882		76					
Russia	Siyanie severa	Onshore	Russia		West-Europe B			3600	48	122					
	Urengoy	Onshore	Russia		West-Europe B			4451	56	142					
	Bratstvo	Onshore	Russia		West-Europe B			240		2*102+81+142					
	Soyuz	Onshore	Russia		West-Europe B			2750	56	142					
	Yamal	Onshore	Russia	Belarus, Poland	Germany B			4095	2*56	2*142	2*31				
Austria	TAG	Onshore	Slovakia B		Italy B	OMV		380		91+107		17	38	Snam, RDCs	2022
						SNAM	ENI (90%)								
	SOL	Onshore	Austria	Slovenia	Croatia	OMV		27		51	3		1.9	Geoplin, Ina	2017
	WAG	Onshore	Slovakia		Germany B	OMV	51	245		81	6		5.6	GdF, Ruhrgas, RDCs	2014
						Gaz de France	44								
						Ruhrgas	5								
	HAG	Onshore	Slovakia B		Hungary	OMV (Austrian part)					4.5		4.5	MOL, OMV	2016
	MAB	Onshore											0.2	GdF, OMV	2012
	Penta-West	Onshore											0.5	Wingas, Bayerngas	2016
Belgium	?	Onshore	Belgium B (Zeebrugge)		France B			142		100					
	Segeo	Onshore	Netherland B		France B			474		2*123					
Denmark															
France															
Finland															
Germany	Megal	Onshore	Chech B		France	Ruhrgas		542	28+48+42						
	Jagal	Onshore	German-Polish B		Ruckensdorf, Thuringia, Germany	Wingas	100	336			28				
	TENP	Onshore	Netherland B		Switzerland	Ruhrgas	51	490	38	96					
						SNAM	49								
	Midal	Onshore				Wingas									
	Stegal	Onshore				Wingas									
	Wedal	Onshore													

Country	Line	Onshore or Offshore	From F=field, B=border, S=sea	Via	To	Owned by	%	Length km	Diameter inches	Diameter cm	Capacity bcm/year	Transit volumes bcm	Peak volume bcm/yr	Customer	End date contract
	Netra	Onshore													
	Deudan	Onshore	Denmark B	into	Germany	Dangas	49	185		60					
						Ruhrgas									
						BEB									
	RHG	Onshore													
	?	Onshore	Netherland B	into	Germany			39		91					
Greece															
Ireland															
Italy	TAG	Onshore	Italy B	into	Italy			390		86+91+107					
	Transitgas	Onshore	Switzerland B	into	Italy	Swissgas	51	160		86					
						SNAM	46								
						Ruhrgas	3								
	Transmed	Onshore	Algeria	Tunesia	Italy			1500		2*122					
	Transmed	Offshore	Algeria	Tunesia	Italy			160		3*51					
Luxembourg															
Netherlands	?	Onshore	Netherlands		Germany B			20		107					
	Zebra	Onshore	Belgium		Netherlands						5				
Portugal															
Spain															
Sweden															
UK	Interconnector	Offshore	UK B		Belgium B	Amerada Hess	5				1				
	reverse cap 8.5 bcm/yr					BG	40				8				
						BP	10				2				
						Conoco	10				2				
						Distrigaz	5				1				
						Elf	10				2				
						Gazprom	10				2				
						National Power	5				1				
						Ruhrgas	5				1				
							100	235			20				
	CATS	Offshore	Everest and Lomond F		UK B (Teeside)	Amoco		402	36	91					

Source: Simeoni, C. Current plans and Projects … Oil&Gas 1995
Source: Jensen, J.T. Gas supplies for the World market, 1994
Source: European Gas Markets, 12 Feb. 1999 p.8

Table 5.4 *Overview of LNG Terminals catering for European gas markets; 1999*

Country	Location	Status	Type	Operator(s)	Owned by	[%]	Working capacity regasified Mcm	Peak output mcm/day
Import infrastructure								
BELGIUM	Zeebrugge		import term.				155	19
FRANCE	Montoir de Bretagne		import term.		GAZ DE FRANCE	100	210	36
	Marseilles-Fos		import term.		GAZ DE FRANCE	100	90	22
GERMANY	Willemshaven	to be build						
GREECE	Athens	to be build						
ITALY	La Spezia		import term.				59	11.5
	Montalto di Castro	to be build						
SPAIN	Huelva		import term.				39	3
	Cartagena		import term.				36	1.2
	Barcelona		import term.				140	30
UK	Canvey Island		import term.				31.2	5.1
Export infrastructure								
Algeria	Arzew		export term.		SONATRACH	100	15	62
	Bethioua		export term.					
	Skikda		export term.		SONATRACH	100	6	21
Libya	Marsa el Brega		export term.				4	10
Turkey	Marmara Ereglisi		import term.				155	16
United Arab Emirates	Das Island (Abu Dhabi)		export term.				5	18

Source: IEA, Table 18, Part I
Source: IEA, natural gas transportation 1994

5.4 Cross-border power transmission infrastructure development

Power transmission networks have a key role to play in ensuring the existence and smooth functioning of the electricity supply. Their further development and the equitable use of their presently available capacity together with cross-border trading both contribute to ensuring reliable electricity market to customers and also offer business opportunities for the Electricity Industry (www.ucte.org).

The Netherlands is part of the so-called UCTE network. UCTE is the acronym for Union for the Co-ordination of Transmission and Electricity. The 16 members of the UCTE are:
- Austria
- Belgium
- Bosnia-Herzegovina
- Croatia
- Federal Republic of Yugoslavia
- Former Yugoslav Republic of Macedonia
- France
- Germany
- Greece
- Italy
- Luxembourg
- The Netherlands
- Portugal
- Slovenia
- Spain
- Switzerland.

Within the Netherlands TenneT is the National Transmission System Operator (TSO) since the beginning of 1999. As an independent operator linking up market parties, TenneT seeks to contribute to the effective functioning of the Dutch electricity market. It does this by supplying electricity transmission products and services. TenneT also monitors the balance and quality of the electricity system, thus contributing to a reliable electricity supply throughout the Netherlands (UCTE, 1999a).

The net transfer capacities in Europe, according to ETSO, are shown in Table 5.1 (www.etso.org). The transfer capacity between the Netherlands on the one hand and Belgium and Germany is 3600 MW. The Netherlands is a heavy importer of electricity, the fourth largest of Europe (after Italy, Germany, and Switzerland). The quantity of imported power increased substantially in the wake of the start of liberalisation of the electricity market. In 2000 the net import amounted to 22.9 TWh (UCTE, 2000). Taking into account the net transfer capacity of 3600 MW, this means that the capacity utilisation was approximately 73%.

Table 5.5 *Net transfer capacities in Europe working days, winter 2000-2001 (ETSO)*

From	To	MW	Value provided by
Albania	Greece	200	Greece
Austria	Germany	1150	Germany
	Italy	200	Italy
	Centrel	2000	Austria and Centrel[7]
	Italy + Slovenia	750	Austria
	Germany + Switzerland	3000	Austria and Germany
Austria + Slovenia	Italy	500	Italy
Belgium	France	2500	Belgium
	Netherlands	1400	Belgium
Belgium + Germany	Netherlands	3600	Netherlands
Bulgaria	Greece	600	Greece
Centrel	Austria	1400	Austria and Centrel
	Germany	2250	Germany and Centrel
	Sweden	600	Sweden
Denmark	Germany	1750	Germany and Denmark
	Sweden	2310	Denmark and Sweden
	Norway	950	Denmark and Norway
Finland	Sweden	1350	Finland and Sweden
	Norway	100	Finland and Norway
France	Great Britain	2000	France and Great Britain
	Belgium	1800	Belgium
	Belgium + Germany	3750	France
	Switzerland + Italy	4950	France
	Spain	1100	France and Spain
	Germany	2850	Germany
	Italy	2000	Italy
France + Switzerland	Italy	4900	Italy
FYROM	Greece	500	Greece
Greece	Albania	200	Greece
	FYROM	600	Greece
	Bulgaria	700	Greece
Germany	Austria	1650	Germany
	Netherlands	2800	Germany and Netherlands
	Switzerland	2000	Germany and Switzerland
	France	2250	Germany
	Denmark	1350	Germany and Denmark
	Sweden	370	Germany and Sweden
	Centrel	1200	Germany and Centrel
Great Britain	France	2000	France and Great Britain
Italy	Autria + Slovenia	Pro memori	
	France + Switzerland	Pro memori	
Italy + Slovenia	Austria	1050	Austria
Morocco	Spain	300	Spain
Netherlands	Belgium	1700	Belgium
	Belgium + Germany	3600	Netherlands
	Germany	1350	Germany and Netherlands
Northern Ireland	Republic of Ireland	300	Northern Ireland
Norway	Denmark (West)	1000	Norway and Denmark
	Sweden	2450	Norway
	Finland	70	Norway and Finland
Portugal	Spain	725	Spain and Portugal

The capacity utilisation during the year 1999 (according to the UCTE) is shown in Figure 5.1.

[7] Centrel comprises the Czech Republic, Hungary, Poland, and Slovakia.

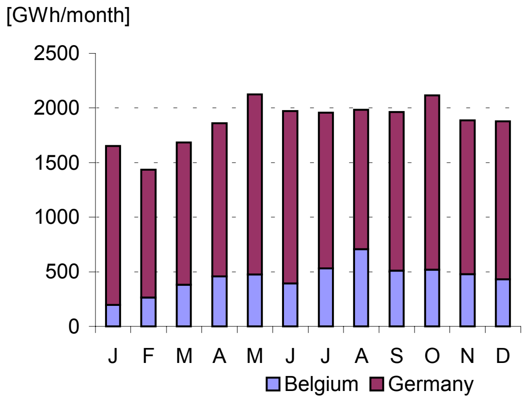

Figure 5.1 *Physical power exchanges between the Netherlands and Belgium & Germany, 1999 [GWh/month]*

In 1999 the net import from Germany and Belgium amounted to 22.4 TWh (UCTE, 1999), which is slightly less than in 2000.

Tennet is planning to enlarge the high voltage transformer at Meeden in Groningen in order to increase the net transfer capacity with Germany by 1000 MW. All else being equal, the net import from Germany and Belgium could be raised to some 30 TWh per year in the near future, which is equal to roughly 30% of the total consumption in the Netherlands.

6. MAIN FINDINGS

6.1 The EU Green Paper on energy supply security

The main points emerging from the Green Paper are:
- The European Union will become increasingly dependent on external energy sources. Enlargement will not change the situation.
- The European Union has very limited scope to influence energy supply conditions but the EU can intervene on the demand side: mainly by promoting energy saving in buildings and the transport sector.
- At present, the European Union is not in a position to respond to the challenge of climate change and to meet its Kyoto protocol commitments.

6.2 Fossil fuel resources

Oil
The recoverable conventional and unconventional oil resources of the earth are estimated at 5,250 billion barrels (an R/P ratio of 200 years). Yet, oil remains a strategic fossil fuel. It is the most important fossil fuel today. Moreover, the oil resources are not evenly distributed around the globe. A main producing area is the Middle East. Canada and Venezuela could become main producers of unconventional oil. However, Canada's unconventional oil production will not exceed 1.65 million b/d in 2015, which is 7.5% of the current Middle East oil production.

Every now and then, the OPEC shows its ability to determine the world oil price. This is also a matter of concern for countries and regions (the EU) that import most of their oil. Therefore, from the point of view of security of supply, particular attention should be paid to oil.

Gas
The world's conventional gas resources are estimated at 444 trillion m^3, equal to 190 years at the current production level. One of the main suppliers is the Former Soviet Union. Another region with large potential is the Middle East. Compared to oil, the supply of gas appears to be more well-balanced. There is no equivalent of OPEC in the world of gas production today.

The global unconventional gas resources are extremely large. However, it is unknown which part of these resources could be recovered. Also, environmental damage has to be prevented. The amount of recoverable unconventional gas will remain a question mark for quite some time.

Coal
Coal reserves are rather evenly distributed around the globe. Production and consumption are much more regionally balanced than in case of oil. Compared to the world oil market, countries like Australia, South Africa and the United States export relatively small amounts of coal. The international coal market is very competitive. Sudden price escalations are really exceptional.

6.3 Energy scenarios and security of supply

The *shared analysis project* postulates a reference scenario with rising CO_2 emissions (increase of 7% in 2010 and 14% in 2020). On a global scale CO_2 emissions would rise by 42% in 2010 and 86% in 2020 (both compared to 1990). Such CO_2 emission levels are considered not sustainable. A scenario variant with higher oil and gas prices would result in appreciable substitution of coal for oil and gas with higher CO_2 emissions as a result. Two other variants: going nuclear and setting suitable targets for energy efficiency and CO_2 emissions in road transport result each in a more favourable picture with regard to CO_2 emission mitigation.

Information on global oil resources, presented in Chapter 3 of this report indicate that a global demand for oil as high as projected in the aforementioned reference scenario would entail serious supply security risks. Use of a suitable dynamic optimisation model might have further improved the credibility of the projection results of the 'shared analysis project'. These observations do not detract from the conclusion that the 'shared analysis project' has clearly shown that GHG emissions and security of supply - decline of indigenous coal production, decommissioning of nuclear power plants, increasing maturity of major oil and gas fields - are interrelated issues, that call for a comprehensive policy.

The IEA's *World Energy Outlook 2000* gives a useful overview of the consequences of current trends with regard to (global) primary energy demand and CO_2 emissions. However, the results of the Outlook's reference scenario - and to a lesser extent its variants - for OECD Europe in terms of primary energy demand and CO_2 emissions are far from reassuring. Also the depletion of fossil fuels, particularly conventional oil, is worrying, although the Outlook states that one needs not expect a global 'supply crunch'. It has been contended, however, that a 50% rise of conventional oil production between 1999 and 2020 is a daunting perspective. So is the perspective of OECD Europe's rising import dependence for fossil fuels, viz. 80% for oil and 65% for gas in 2020.

Emission projections of the reference scenario of 'shared analysis project' and the ones of the reference scenario of World Energy Outlook 2000 are well in line with outcomes of *recent non-intervention scenarios ("SRES scenarios") of the IPCC*. The global carbon emissions as projected by both reference scenarios would end up around the median value of the 138 non-intervention scenarios analysed by the IPCC.

The *1997 CPB study* is useful, as it shows the range of economic and energy developments. The outcomes of the scenarios in terms of CO_2/GHG emissions might be less frightening in practice:
- Government policies and the commitment of the government and the EU to technological development could be effective in curbing the trend of rising CO_2/GHG emissions.
- The assumed relation between GDP growth and energy use is too strong. The residential and commercial sectors offer perspectives for decoupling by reduced heating requirements, even taking into account population growth and rising numbers of houses and buildings.
- Also transport and industry offer energy conservation potentials with ongoing technological development, the conditions for which seem to be good in the Netherlands and the EU.

With regard to (industrial) cogeneration, the Netherlands is an example for other countries. However, irrespective of the potential of cogeneration, it is very important not to overly rely on the 'going gas' option and to give due attention to other power generation options that are environmentally benign or could become acceptable:
- Wind energy, especially but not exclusively promising because of its offshore potential.
- Biomass (preferably co-combustion or co-gasification).
- Photovoltaic energy, which may have a very large potential in the long run (nowadays expensive).
- Fossil-fired power plants with CO_2 sequestration, particularly if coal could be used as fuel and if it could be combined with CO_2 enhanced coal-bed methane recovery (currently in the RD&D stage).
- Nuclear energy, notably if a new type of High Temperature Reactor (HTR) could be used.

6.4 Gas and electricity

Penetration of gas on world energy markets is expected to continue unrelentlessly. New developments in gas transportation technology are poised to increased interregional competition for gas imports. European gas importers will face increased competition from eastern Asia, on short run foremost Japan and, to a lesser extent Korea, and with in the medium term China as a quite strong runner-up. In the medium term, eastern Asia may not only import big quantities of LNG but also piped gas from Russia's Far East and possibly also from Central Asia.

Europe's gas supply security will be served by more interregional trunk gas pipelines from Russia, North Africa (Libya) as well as Central Asia and even the Middle East via Turkey. In addition, further development of LNG infrastructure on the exporters' side (Nigeria, Angola, Egypt, Middle East) and on the receiving side in Europe will further improve Europe's negotiation position as far as interregional imports are concerned.

With regard to import of electricity, TenneT is planning to enlarge the high voltage transformer at Meeden in Groningen in order to increase the net transfer capacity with Germany by 1000 MW. All else being equal, the net import from Germany and Belgium could be raised to some 30 TWh per year in the near future, which is equal to roughly 30% of the total consumption in the Netherlands.

ANNEX A CONVENTIONAL OIL RESOURCES

The United States Geological Survey (USGS) has compiled surveys of the world's conventional oil resources by basin. These surveys contain three classes of reserves:

1. *Identified reserves*
   Identified reserves are interpreted to include not only the traditional Proved Reserves but also any additional petroleum we might conclude will be recognised by field growth attained through extension, new reservoirs, or improvements in recovery.
2. *Mean undiscovered reserves*
   Besides the identified reserves, undiscovered reserves are considered. The undiscovered reserves are not based on concrete evidence. The Mean of the undiscovered reserves is used in this survey (other classes are 95% probability, Mode, and 5% probability).
3. *Futures*
   At last another category is considered, viz. the futures. This amount of oil is not related to exploration efforts or other related indications.

Table A.1 *Conventional oil resources of Africa (USGS) [billion barrels]*

	Annual production (1999)	Cumulative production	Identified reserves	Mean undiscovered	Futures	Identif.+Mean und. +Futures
Morocco-Spanish Sahara				0.1	0.1	0.2
Mali Mauritania				0.1	0.1	0.1
Algeria	0.489	11.0	8.2	1.9	30.6	40.7
Tunisia	0.031	0.9	1.3	5.5	6.5	13.3
Libya	0.520	18.0	31.3	10.1	41.3	82.7
Egypt	0.305	6.0	6.0	2.2	7.8	16.0
NorthWest Africa					0.1	0.1
Mali-Niger					0.0	0.0
Chad			0.5	1.7	1.6	3.8
Sudan		0.6	0.3	3.1	2.7	6.1
Ethiopia				0.1	0.1	0.1
Somalia				0.9	0.6	1.5
Nigeria	0.741	15.1	20.4	6.5	28.0	55.0
Cameroon	0.035		0.4	1.2	0.5	2.1
Gabon	0.124	1.7	1.8	1.7	2.9	6.4
Congo	0.108	2.2	4.6	5.2	6.8	16.6
Angola	0.285	2.0	3.7	1.9	1.7	7.3
Namibia					0.1	0.1
South Africa			0.1	0.1	0.1	0.3
Botswana				0.1	0.1	0.2
Zaire				1.6	0.6	2.2
Other Karoo Rift Basins				0.7	0.4	1.1
East African Rift Basins				0.8	0.6	1.4
Mozambique				0.2	0.1	0.3
Tanzania					0.0	0.0
Madagascar				1.5	2.4	3.9
Seychelles					0.0	0.0
Total	2.717	21	30.9	21.6	135.6	261.4

Table A.2 *Conventional oil resources of Asia & Oceania (USGS) [billion m^3]*

	Annual production (1999)	Cumulative production	Identified reserves	Mean undiscovered	Futures	Identif.+Mean und. +Futures
China	1.164	14.1	31.4	42.7	67.1	141.2
Pakistan		0.2	0.5	0.3	0.7	1.5
India	0.271	3.5	6.5	2.1	9.5	18.1
Myanmar		0.5	0.2	1.4	1.1	2.7
Indonesia	0.471	13.8	13.0	7.7	20.2	40.9
Malaysia	0.263	2.7	3.3	6.0	9.3	18.6
Brunei	0.1	2.4	1.8	0.7	2.8	5.3
Philippines		0.1	0.3	1.8	2.0	4.1
Papua New Guinea			0.3		0.3	0.6
Pacific Islands					0.1	0.1
Thailand		0.1	0.2	1.4	1.1	2.7
Cambodia					0.0	0.0
Vietnam		0.1	0.9	6.6	6.8	14.3
Australia	0.220	3.2	2.7	3.0	7.4	13.2
New Zealand		0.1	0.3	0.1	0.4	0.8
Antarctica					0.1	0.1
Total	2.787	40.6	61.4	74.0	129.1	264.4

Table A.3 *Conventional oil resources of Europe (USGS) [billion m³]*

	Annual production (1999)	Cumulative production	Identified reserves	Mean undiscovered	Futures	Identif.+Mean und. +Futures
UK	0.956	11.2	19.5	7.9	4.2	31.6
Norway	1.146	5.8	17.1	8.5	47.5	73.1
France					0.1	0.1
Germany					0.0	0.0
Eastern Europe		7.1	2.6	2.7	3.8	9.1
Greece					0.0	0.0
Italy	0.040	0.6	1.2	1.9	2.8	5.9
Spain				2.5	1.9	4.4
Total	2.546	24.7	40.4	23.5	60.5	124.4

Table A.4 *Conventional oil resources of the Former Soviet Union (USGS) [billion m³]*

	Annual production (1999)	Cumulative production	Identified reserves	Mean undiscovered	Futures	Identif.+Mean und. +Futures
Azerbaijan	0.102	9.2				
Kazakhstan	0.230	3.7				
Russian Federation	2.256	96.4				
Turkmenistan	0.055	2.6				
Uzbekistan	0.069	0.1				
Total	2.759	112.0	129	151	297.5	577.5

Table A.5 *Conventional oil resources of the Middle East (USGS) [billion m³]*

	Annual production (1999)	Cumulative production	Identified reserves	Mean undiscov-ered	Futures	Identif.+Mean und. +Futures
Iran	1.296	33.728				
Iraq	0.942	22.414				
Kuwait	0.739	30.989				
Oman	0.332	3.552				
Qatar	0.261	5.007				
Saudi Arabia	3.137	72.776				
Syria	0.204	1.652				
United Arab Emirates	0.914	15.741				
Yemen	0.144	0.649				
Total	7.988	186.5	545.4	135.0	652.5	1332.9

Table A.6 *Conventional oil resources of North and Central America (USGS) [billion m³]*

	Annual production (1999)	Cumulative production	Identified reserves	Mean undiscov-ered	Futures	Identif.+Mean und. +Futures
USA	2.832	163.5	51.1	43.8	106.0	200.9
Canada	0.947	15.1	11.0	31.4	57.7	100.1
Greenland					0.0	0.0
Mexico	1.221	19.5	42.0	35.5	135.8	213.3
Central America					0.1	0.1
Total	5.050	198.1	104.1	110.7	299.7	514.5

Table A.7 *Conventional oil resources of South America (USGS) [billion m³]*

	Annual production (1999)	Cumulative production	Identified reserves	Mean undiscovered	Futures	Identif.+Mean und. +Futures
Venezuela&Trinidad&Tobago	1.190	44.6	49	22.4	104.4	175.8
Colombia	0.307	3.5	3.6	5.9	7.5	17.0
Equador	0.139	1.8	3.3	2.8	5.0	11.1
Peru	0.040	1.9	2.2	6.3	4.5	13.0
Guyana&Surinam&French Guiana				0.0	0.1	0.1
Brazil	0.407	3.4	12.8	12.7	25.2	50.7
Bolivia				1.0	0.4	1.4
Argentina	0.310	5.6	3.8	4.2	5.7	13.7
Chile		0.4	0.2	0.3	1.2	1.7
Total	2.393	61.2	74.9	55.6	154.0	284.5

ANNEX B CONVENTIONAL GAS RESOURCES

The United States Geological Survey (USGS) publishes data of the world's conventional gas resources. The two classes considered here are the remaining reserves (exclusive of cumulative production) and the mean undiscovered reserves.

Table B.1 *Conventional gas resources of Africa (USGS) [billion m^3]*

	Annual production (1999)	Remaining reserve	Mean undiscovered	Total
Algeria	82.2	4897	1387	6284
Egypt	14.7	150	579	729
Eritrea		0	309	309
Gabon		39	688	727
Gambia			1	1
Ghana		5	57	62
Libya	5.9	1449	598	2047
Nigeria	5.7	2365	3489	5854
Angola		177	1210	1387
Cameroon		119	158	277
Congo		64	492	556
Congo (Kinshasa)		3	28	31
Cote d'Ivoire		47	171	218
Equatorial Guinea		25	214	239
Guinea-Bissau			6	6
Mauritania			7	7
Morocco			3	3
Namibia		170	43	213
Senegal		1	8	9
South Africa		0	59	59
Sudan		24	439	463
Tunisia		87	202	289
Western Sahara			2	2
Total	113.7	9624	10151	19775

Table B.2 *Conventional gas resources of Asia & Oceania (USGS) [billion m³]*

	Annual production (1999)	Remaining reserve	Mean undiscovered	Total
Indonesia		2146	3050	5196
Australia		2435	3098	5533
Zone of Austr/Indo		170	128	298
Afghanistan		127	1210	1337
Bangladesh		260	951	1211
Brunei		414	351	765
Cambodia		5	50	55
China		963	2429	3392
India		652	857	1509
Thailand/Malaysia		147	59	206
Malaysia		2356	1421	3777
Myanmar		263	769	1032
Pakistan		604	810	1414
Thailand		119	132	251
Vietnam			22	22
Total	254.8	10662	15339	26001

Table B.3 *Conventional gas resources of Europe (USGS) [billion m³]*

	Annual production (1999)	Remaining reserve	Mean undiscovered	Total
Austria		3	2	5
Czech Republic		0	15	15
Denmark	7.8	216	22	238
France			590	590
Germany	17.8	320	368	688
Hungary	3.0	99	71	170
Italy	17.6	247	772	1019
Netherlands	60.1	1938	242	2180
Norway	51.0	2726	5183	7909
Croatia		86	49	135
Poland		93	80	173
Romania	13.8	393	153	547
Servia&Montenegro		26	8	34
Slovakia		10	7	17
Slovenia		1	0	1
Spain			504	504
United Kingdom	99.6	1670	662	2332
Malta			6	6
Bulgaria		1	1	2
Total	282.2	7832	8735	16567

Table B.4 *Conventional gas resources of the Former Soviet Union (USGS) [billion m^3]*

	Annual production (1999)	Remaining reserve	Mean undiscovered	Total
Azerbaijan	5.6	339	1910	2249
Kazakhstan	9.2	1957	2046	4003
Russia	551.0	39933	33095	73028
Turkmenistan	21.3	2470	5881	8351
Ukraine	16.8	791	780	1571
Uzbekistan	51.9	1765	426	2191
Total	656.2	47256	44138	91394

Table B.5 *Conventional gas resources of the Middle East (USGS) [billion m^3]*

	Annual production (1999)	Remaining reserve	Mean undiscovered	Total
Bahrain	8.5	220	468	688
Iran	52.5	17592	8908	26500
Iraq		1965	3398	5363
Jordan		5	69	74
Kuwait	7.0	1662	167	1829
Kuwait/Saudi Arabia Neutral		306		306
Oman	5.6	903	956	1859
Qatar	24.0	10447	1164	11611
Saudi Arabia	46.2	8152	19284	27436
Syria		61	144	205
United Arab Emirates	38.0	4182	1261	5443
Turkey		13	21	34
Yemen		485	620	1105
Total	187.2	45993	36459	82452

Table B.6 *Conventional gas resources of North and Central America (USGS) [billion m^3]*

	Annual production (1999)	Remaining reserve	Mean undiscovered	Total
Canada	162.3	1453	694	2147
Mexico	37.4	941	1395	2336
Benin		2	20	22
Greenland			2285	2285
Grenada			23	23
United States	540.5	4871	14923	19794
Total	740.2	7265	19341	26606

Table B.7 *Conventional gas resources of South America (USGS) [billion m³]*

	Annual production (1999)	Remaining reserve	Mean undiscovered	Total
Argentina	33.6	862	1039	1901
Barbados		0	254	254
Bolivia	4.1	170	708	878
Brazil	6.7	260	5505	5765
Chile		95	181	276
Colombia	5.2	519	286	805
Cuba		2	17	19
Ecuador		32	16	48
Falkland Islands			469	469
French Guiana			1	1
Guyana			170	170
Paraguay		0	128	128
Peru		30	179	209
Suriname			1019	1019
Togo			9	9
Trinidad and Tobago	10.9	535	900	1435
Uruguay			32	32
Venezuela	32.0	4373	2887	7260
Total	95.3	6879	13801	20680

ANNEX C SUMMARY OF FOSSIL FUEL RESOURCES

The resource estimates for different categories of fossil fuels - conventional and unconventional oil, conventional and unconventional gas, and coal - are based on different definitions of resources. Annex A shows the resources of conventional oil by world region, based on assessments by the United States Geological Survey (USGS). These data are summarised in Chapter 3. Besides, Chapter 3 presents a survey of the recoverable unconventional oil resources. Annex B presents the remaining identified and the mean undiscovered conventional gas reserves by world region, based on assessments by the USGS. In Chapter 3 these data are summarised and a category 'additional' is, based on a resource estimate from Enron. The resulting resource base of conventional gas can be readily compared with that of oil in Chapter 3. At last, the proved reserves of coal are presented in this Chapter.

Table C.1 compiles the various resource categories of fossil fuels from Chapter 3, making use of the same unit of energy EJ.

Table C.1 *World's fossil fuel resources [EJ]*

	Conventional oil	Unconv. Oil	Total oil	Conventional gas	Proved coal reserves
Africa	1,493	69	1,562	745	1,711
Asia&Oceania	1,510	1,451	2,961	1,161	6,654
Europe	711	97	808	624	2,285
FSU	3,299	1,502	4,801	5,528	4,573
Middle East	7,613	377	7,990	5,129	5
North America	2,939	4,044	6,983	2,771	5,208
South America	1,625	3,250	4,875	779	410
Total	19,190	10,790	29,980	16,737	20,846

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