/a	per annum, per year
bcm	Billion cubic metres (10^9 cubic metres)
boe	Barrel of oil equivalent
C	Carbon
CEEC	Central and Eastern European Countries
CH_4	Methane
CHP	Combined heat and power generation
CO_2	Carbon dioxide
COP	Conference of the Parties to the UNFCCC
EC	European Commission
EU	European Union (EU-15 : EU with current 15 Member States)
FSU	Former Soviet Union
GDP	Gross Domestic Product
GW	GigaWatt, or 10^9 Watt
HFCs	Hydro-fluorocarbons
IEA	International Energy Agency
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
LNG	Liquid Natural Gas
M€	Million Euro
kWh	Kilowatt-hour
Mt	Million metric tonnes
Mtoe	Million toe
N_2O	Nitrous oxide
NO_x	Sum of NO (nitric oxide) and NO_2 (nitrogen oxide)
OECD	Organisation for Economic Co-operation and Development (excluding Hungary, Czech Republic and Poland)
OPEC	Organisation of Oil producing and Exporting Countries
PFCs	Per-fluorocarbons
ppp	Purchasing power parities
SF6	Sulphur hexa-fluoride
SO_2	Sulphur dioxide
t	Metric tonne, or 1000 kilograms
toe	Tonne of oil equivalent (41.86 GJ)
TWh	Terawatt-hours (10^{12} Watt-hours)
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change

DIRECTORATE - GENERAL FOR ENERGY

200 RUE DE LA LOI • B-1049 BRUSSELS

- EUROPEAN COMMISSION -

OFFICE FOR OFFICIAL PUBLICATIONS
OF THE EUROPEAN COMMUNITIES

L-2985 Luxembourg

ISBN 92-828-7529-6

CS-24-99-114-EN-C

ECONOMIC FOUNDATIONS FOR ENERGY POLICY IN EUROPE TO 2020

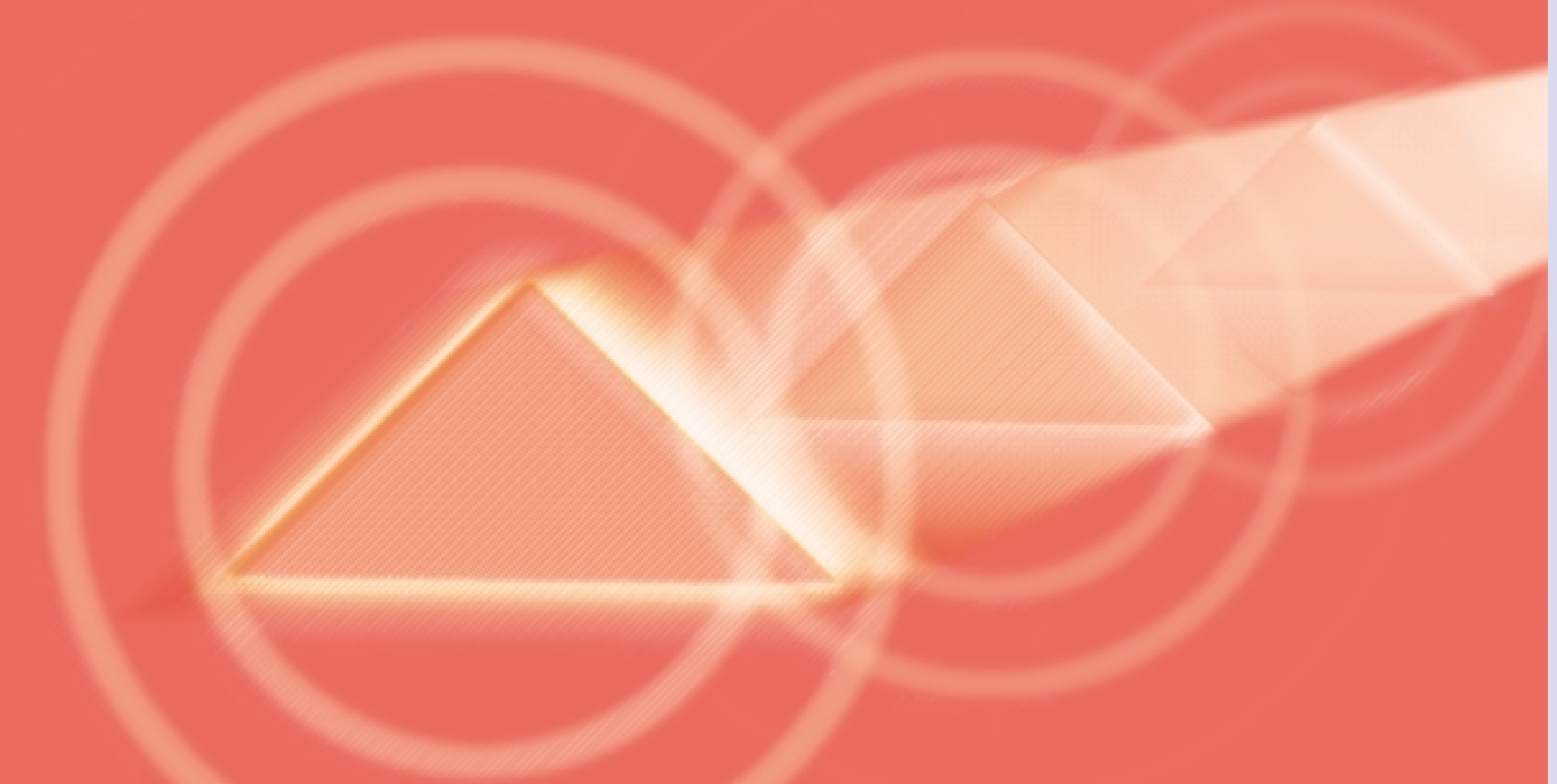
SPECIAL ISSUE - DECEMBER 1999

DIRECTORATE - GENERAL FOR ENERGY

ENERGY IN EUROPE

ECONOMIC FOUNDATIONS FOR ENERGY POLICY

SPECIAL ISSUE - DECEMBER 1999



The Shared Analysis Project

EUROPEAN COMMISSION

Prepared by:
The Shared Analysis Project team

FhG-ISI, Karlsruhe (Co-ordinator)
NTUA, Athens
SPRU, Brighton

ADEME, Paris
ECN, Petten
IEPE, Grenoble
IEFE, Milano
IER, Stuttgart
RISØ, Roskilde

For further information concerning articles or items in this issue please contact:

The project co-ordinator:
Fraunhofer Institute for Systems and Innovation Research
FhG-ISI
c/o Wolfgang Eichhammer
Breslauer Str. 48
D-76139 Karlsruhe • Germany
Fax 0049/721/6809-272 • e-mail: ei@isi.fhg.de

Information on the project as well as on the other Volumes of the Shared Analysis project is available on the project Internet site
http://www.shared-analysis.fhg.de

The editor: Energy in Europe
Directorate General for Energy - Information Group
European Commission
Rue de la Loi 200
B-1049 Bruxelles

Manuscript completed on 30 September 1999.

Additional information on the European Union is available on the internet. It can be accessed through the Europa server (http://europa.eu.int).

Cataloguing data can be found at the end of this publication

Luxembourg : Office for Official Publications of The European Communities, 1999

ISBN 92-828-7529-6

Printed in Belgium
Design AVVISI, Belgium

Venta • Salg • Verkauf • Πωλήσεις • Sales • Vente • Vendita • Verkoop • Venda • Myynti • Försäljning

BELGIQUE/BELGIË

Moniteur belge/Belgisch Staatsblad
Rue de Louvain 40-42/Leuvenseweg 40-42
B-1000 Bruxelles/Brussel
Tél. (32-2) 552 22 11
Fax (32-2) 511 01 84

Jean De Lannoy
Avenue du Roi 202/Koningslaan 202
B-1060 Bruxelles/Brussel
Tél. (32-2) 538 51 69
Fax (32-2) 538 08 41
E-mail: jean.de.lannoy@infoboard.be
URL: http://www.jean-de-lannoy.be

Librairie européenne/Europese Boekhandel
Rue de la Loi 244/Wetstraat 244
B-1040 Bruxelles/Brussel
Tél. (32-2) 295 26 39
Fax (32-2) 735 08 60

DANMARK

J. H. Schultz Information A/S
Herstedvang 10-12
DK-2620 Albertslund
Tlf. (45) 43 63 23 00
Fax (45) 43 63 19 69
E-mail: schultz@schultz.dk
URL: http://www.schultz.dk

DEUTSCHLAND

Bundesanzeiger Verlag
Breite Straße 78-80
Postfach 10 05 34
D-50667 Köln
Tel. (49-221) 20 29-0
Fax (49-221) 202 92 78
E-mail: vertrieb@bundesanzeiger.de
URL: http://www.bundesanzeiger.de

ΕΛΛΑΔΑ/GREECE

G. C. Eleftheroudakis SA
International Bookstore
Panepistimiou 17
GR-10564 Athina
Tel. (30-1) 331 41 80/1/2/3
Fax (30-1) 323 98 21
E-mail: elebooks@netor.gr

ESPAÑA

Mundi Prensa Libros, SA
Castelló, 37
E-28001 Madrid
Tel. (34-1) 431 33 99
Fax (34-1) 575 39 98
E-mail: libreria@mundiprensa.es
URL: http://www.mundiprensa.es

Boletín Oficial del Estado
Trafalgar, 27
E-28010 Madrid
Tel. (34-1) 538 21 11 (Libros)/
384 17 15 (Suscripciones)
Fax (34-1) 538 21 21 (Libros)/
384 17 14 (Suscripciones)
E-mail: webmaster@boe.es
URL: http://www.boe.es

FRANCE

Journal officiel
Service des publications des CE
26, rue Desaix
F-75727 Paris Cedex 15
Tél. (33) 140 58 77 01/31
Fax (33) 140 58 77 00

IRELAND

Government Supplies Agency
Publications Section
4-5 Harcourt Road
Dublin 2
Tel. (353-1) 661 31 11
Fax (353-1) 475 27 60

ITALIA

Licosa SpA
Via Duca di Calabria, 1/1
Casella postale 552
I-50125 Firenze
Tel. (39-55) 64 54 15
Fax (39-55) 64 12 57
E-mail: licosa@ftbcc.it
URL: http://www.ftbcc.it/licosa

LUXEMBOURG

Messageries du livre SARL
5, rue Raiffeisen
L-2411 Luxembourg
Tél. (352) 40 10 20
Fax (352) 49 06 61
E-mail: mdl@pt.lu

Abonnements:

Messageries Paul Kraus
11, rue Christophe Plantin
L-2339 Luxembourg
Tél. (352) 49 98 88-8
Fax (352) 49 98 88-444
E-mail: mpk@pt.lu
URL: http://www.mpk.lu

NEDERLAND

SDU Servicecentrum Uitgevers
Externe Fondsen
Postbus 20014
2500 EA Den Haag
Tel. (31-70) 378 98 80
Fax (31-70) 378 97 83
E-mail: sdu@sdu.nl
URL: http://www.sdu.nl.

ÖSTERREICH

Manz'sche Verlags- und Universitätsbuchhandlung GmbH
Siebenbrunnengasse 21
Postfach 1
A-1050 Wien
Tel. (43-1) 53 16 13 34/40
Fax (43-1) 53 16 13 39
E-mail: auslieferung@manz.co.at
URL: http://www.austria.EU.net:81/manz

PORTUGAL

Imprensa Nacional-Casa da Moeda, EP
Rua Marquês de Sá da Bandeira, 16 A
P-1050 Lisboa Codex
Tel. (351-1) 353 03 99
Fax (351-1) 353 02 94, 384 01 32

Distribuidora de Livros Bertrand Ld.ª
Rua das Terras dos Vales, 4/A
Apartado 60037
P-2701 Amadora Codex
Tel. (351-1) 495 90 50, 495 87 87
Fax (351-1) 496 02 55

SUOMI/FINLAND

Akateeminen Kirjakauppa/Akademiska Bokhandeln
Pohjoisesplanadi 39/
Norra esplanaden 39
PL/PB 128
FIN-00101 Helsinki/Helsingfors
P./tfn (358-9) 121 41
F./fax (358-9) 121 44 35
E-mail: akatilaus@stockmann.mailnet.fi
URL: http://booknet.cultnet.fi/aka/index.htm

SVERIGE

BTJ AB
Traktorvägen 11
S-221 82 Lund
Tfn (46-46) 18 00 00
Fax (46-46) 30 79 47
E-post: btjeu-pub@btj.se
URL: http://www.btj.se/media/eu

UNITED KINGDOM

The Stationery Office Ltd International Sales Agency
51 Nine Elms Lane
London SW8 5DR
Tel. (44-171) 873 90 90
Fax (44-171) 873 84 63
E-mail: jill.speed@theso.co.uk
URL: http://www.the-stationery-office.co.uk

ÍSLAND

Bokabud Larusar Blöndal
Skólavördustig, 2
IS-101 Reykjavik
Tel. (354) 551 56 50
Fax (354) 552 55 60

NORGE

NIC Info A/S
Ostenjoveien 18
Boks 6512 Etterstad
N-0606 Oslo
Tel. (47-22) 97 45 00
Fax (47-22) 97 45 45

SCHWEIZ/SUISSE/SVIZZERA

OSEC
Stampfenbachstraße 85
CH-8035 Zürich
Tel. (41-1) 365 53 15
Fax (41-1) 365 54 11
E-mail: uleimbacher@osec.ch
URL: http://www.osec.ch

BĂLGARIJA

Europress-Euromedia Ltd
59, Bld Vitosha
BG-1000 Sofia
Tel. (359-2) 980 37 66
Fax (359-2) 980 42 30

ČESKÁ REPUBLIKA

NIS CR — prodejna
Konviktská 5
CZ-113 57 Praha 1
Tel. (420-2) 24 22 94 33, 24 23 09 07
Fax (420-2) 24 22 94 33
E-mail: nkposp@dec.nis.cz
URL: http://www.nis.cz

CYPRUS

Cyprus Chamber of Commerce & Industry
Griva-Digeni 38 & Deligiorgi 3
Mail orders:
PO Box 1455
CY-1509 Nicosia
Tel. (357-2) 44 95 00, 46 23 12
Fax (357-2) 36 10 44
E-mail: cy1691_eic_cyprus@vans.infonet.com

MAGYARORSZÁG

Euro Info Service
Európa Ház
Margitsziget
PO Box 475
H-1396 Budapest 62
Tel. (36-1) 111 60 61, 111 62 16
Fax (36-1) 302 50 35
E-mail: euroinfo@mail.matav.hu
URL: http://www.euroinfo.hu/index.htm

MALTA

Miller Distributors Ltd
Malta International Airport
PO Box 25
LQA 05 Malta
Tel. (356) 66 44 88
Fax (356) 67 67 99

POLSKA

Ars Polona
Krakowskie Przedmiescie 7
Skr. pocztowa 1001
PL-00-950 Warszawa
Tel. (48-22) 826 12 01
Fax (48-22) 826 62 40, 826 53 34, 826 86 73
E-mail: ars_pol@bevy.hsn.com.pl

ROMÂNIA

Euromedia
Str. G-ral Berthelot Nr 41
RO-70749 Bucuresti
Tél. (40-1) 210 44 01, 614 06 64
Fax (40-1) 210 44 01, 312 96 46

SLOVAKIA

Slovak Centre of Scientific and Technical Information
Nàmestie slobody 19
SK-81223 Bratislava 1
Tel. (421-7) 531 83 64
Fax (421-7) 531 83 64
E-mail: europ@tbb1.sltk.stuba.sk

SLOVENIA

Gospodarski Vestnik
Zalozniska skupina d.d.
Dunajska cesta 5
SLO-1000 Ljubljana
Tel. (386) 611 33 03 54
Fax (386) 611 33 91 28
E-mail: belicd@gvestnik.si
URL: http://www.gvestnik.si

TÜRKIYE

Dünya Infotel AS
Istiklâl Cad. No: 469
TR-80050 Tünel-Istanbul
Tel. (90-212) 251 91 96
Fax (90-212) 251 91 97

AUSTRALIA

Hunter Publications
PO Box 404
3167 Abbotsford, Victoria
Tel. (61-3) 94 17 53 61
Fax (61-3) 94 19 71 54

CANADA

Subscriptions only/Uniquement abonnements:

Renouf Publishing Co. Ltd
5369 Chemin Canotek Road Unit 1
K1J 9J3 Ottawa, Ontario
Tel. (1-613) 745 26 65
Fax (1-613) 745 76 60
E-mail: renouf@fox.nstn.ca
URL: http://www.renoufbooks.com

EGYPT

The Middle East Observer
41, Sherif Street
Cairo
Tel. (20-2) 393 97 32
Fax (20-2) 393 97 32

HRVATSKA

Mediatrade Ltd
Pavla Hatza 1
HR-10000 Zagreb
Tel. (385-1) 43 03 92
Fax (385-1) 43 03 92

INDIA

EBIC India
3rd Floor, Y. B. Chavan Centre
Gen. J. Bhosale Marg.
400 021 Mumbai
Tel. (91-22) 282 60 64
Fax (91-22) 285 45 64
E-mail: ebic@giasbm01.vsnl.net.in

ISRAËL

ROY International
17, Shimon Hatarssi Street
PO Box 13056
61130 Tel Aviv
Tel. (972-3) 546 14 23
Fax (972-3) 546 14 42
E-mail: royil@netvision.net.il

Sub-agent for the Palestinian Authority:

Index Information Services
PO Box 19502
Jerusalem
Tel. (972-2) 627 16 34
Fax (972-2) 627 12 19

JAPAN

PSI-Japan
Asahi Sanbancho Plaza #206
7-1 Sanbancho, Chiyoda-ku
Tokyo 102
Tel. (81-3) 32 34 69 21
Fax (81-3) 32 34 69 15
E-mail: psijapan@gol.com
URL: http://www.psi-japan.com

MALAYSIA

EBIC Malaysia
Level 7, Wisma Hong Leong
18 Jalan Perak
50450 Kuala Lumpur
Tel. (60-3) 262 62 98
Fax (60-3) 262 61 98
E-mail: ebic-kl@mol.net.my

PHILIPPINES

EBIC Philippines
19th Floor, PS Bank Tower Sen.
Gil J. Puyat Ave. cor.Tindalo St.
Makati City
Metro Manilla
Tel. (63-2) 759 66 80
Fax (63-2) 759 66 90
E-mail: eccpcom@globe.com.ph

RUSSIA

CCEC
60-letiya Oktyabrya Av. 9
117312 Moscow
Tel. (70-95) 135 52 27
Fax (70-95) 135 52 27

SOUTH AFRICA

Safto
5th Floor Export House,
CNR Maude & West Streets
PO Box 782 706
2146 Sandton
Tel. (27-11) 883 37 37
Fax (27-11) 883 65 69

SOUTH KOREA

Kyowa Book Company
1 F1. Phyung Hwa Bldg
411-2 Hap Jeong Dong, Mapo Ku
121-220 Seoul
Tel. (82-2) 322 67 80/1
Fax (82-2) 322 67 82
E-mail: kyowa2@ktnet.co.kr.

THAÏLANDE

EBIC Thailand
Vanissa Building 8th Floor
29 Soi Chidlom
Ploenchit
10330 Bangkok
Tel. (66-2) 655 06 27
Fax (66-2) 655 06 28
E-mail: ebicbkk@ksc15.th.com

UNITED STATES OF AMERICA

Bernan Associates
4611-F Assembly Drive
MD20706 Lanham
Tel. (800) 274 44 47 (toll free telephone)
Fax (800) 865 34 50 (toll free fax)
E-mail: query@bernan.com
URL: http://www.bernan.com

ANDERE LÄNDER/OTHER COUNTRIES/ AUTRES PAYS

Bitte wenden Sie sich an ein Büro Ihrer Wahl / Please contact the sales office of your choice / Veuillez vous adresser au bureau de vente de votre choix

DIRECTORATE - GENERAL FOR ENERGY

ENERGY IN EUROPE

ECONOMIC FOUNDATIONS FOR ENERGY POLICY

SPECIAL ISSUE - DECEMBER 1999

The Shared Analysis Project

EUROPEAN COMMISSION

CONTENTS

/a	per annum, per year
bcm	Billion cubic metres (10^9 cubic metres)
boe	Barrel of oil equivalent
C	Carbon
CEEC	Central and Eastern European Countries
CH_4	Methane
CHP	Combined heat and power generation
CO_2	Carbon dioxide
COP	Conference of the Parties to the UNFCCC
EC	European Commission
EU	European Union (EU-15 : EU with current 15 Member States)
FSU	Former Soviet Union
GDP	Gross Domestic Product
GW	GigaWatt, or 10^9 Watt
HFCs	Hydro-fluorocarbons
IEA	International Energy Agency
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
LNG	Liquid Natural Gas
M€	Million Euro
kWh	Kilowatt-hour
Mt	Million metric tonnes
Mtoe	Million toe
N_2O	Nitrous oxide
NO_x	Sum of NO (nitric oxide) and NO_2 (nitrogen oxide)
OECD	Organisation for Economic Co-operation and Development (excluding Hungary, Czech Republic and Poland)
OPEC	Organisation of Oil producing and Exporting Countries
PFCs	Per-fluorocarbons
ppp	Purchasing Power Parities
SF_6	sulphur hexa-fluoride
SO_2	Sulphur dioxide
t	Metric tonne, or 1000 kilograms
toe	Tonne of oil equivalent (41.86 GJ)
TWh	Terawatt-hours (10^{12} Watt-hours)
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change

EXECUTIVE SUMMARY

ENERGY POLICY OBJECTIVES

(1) The Amsterdam Treaty of 1997 established the requirement for Community policy to *contribute to sustainable development*. Achieving sustainable development in its different dimensions – economic, environmental, social and geopolitical – is a complex and long-term process. Energy policy contributes to it by adapting its three core objectives to reflect the requirements of sustainable development:

- *security of supply* - which aims to minimise risks and impacts of possible supply disruption on the EU economy and society;
- *competitive energy systems* - to ensure low cost energy for producers and consumers to contribute to industrial competitiveness and wider social policy objectives;
- *environmental protection* - which is integrated in both energy production and energy use to maintain ecological and geophysical balances in nature.

(2) To assist in designing a policy which is supportive of sustainable development in the Community and also meets the challenges of the future, the European Commission is utilising its own and other *analytical and modelling capabilities* to provide rigorous evaluation of major EU and global trends and their policy implications. With this objective in mind, the European Commission funded the Shared Analysis Project. This commenced in January 1998 and was intended to provide a common framework of energy analysis involving experts from all Member States, as well as from academic institutes, industry and Non Governmental Organisations (NGOs). The Shared Analysis Project analysed *generic EU-wide issues* at the heart of energy policy for the Community and its Member States with the aim of assisting both Commission services and various other stakeholders.

(3) The Shared Analysis Project concentrated on several specific core issues:

- future world energy demand - focusing particularly on the emerging countries in Asia and Latin America; and energy supply, especially as regards longer-term oil and natural gas availabilities and prices;
- the progress and implications of liberalisation of electricity and gas supply on the EU energy system and the wider economy;
- strategic policy responses to the Kyoto Protocol, taking into consideration energy- and non-energy-related greenhouse gas emissions and the possibility of trade in emission certificates among industrialised countries (Annex B countries);
- the opportunities for technological innovation in the energy conversion and end-use sectors which is likely to occur; or which might be accelerated by policy initiatives over the next two decades; and
- the specific and value added role of the Community's energy policy in supporting Member States' own policies.

(4) The underpinning analysis in this project has based its conclusions on quantitative energy demand and supply projections at the global and EU level and on extensive policy analyses conducted by the member institutes of the research consortium. The analysis was enriched by two symposia which drew upon the analytical results provided by experts drawn from leading energy suppliers, technology producers and NGOs.

ENERGY MARKET TRENDS

(5) *The analysis of the 1990s* concludes that the energy system of the Community has developed positively as regards both the objectives of energy policy and the goal of more sustainable development. In particular:

- The EU's energy import dependence has remained slightly below 50 %, due to technological progress in oil and gas production; supply diversity has increased due to larger oil and gas imports from CIS countries and Norway, growing coal imports from other countries, and to increased use of nuclear and renewable energies in the Community over the past decade.
- Energy use per capita has stagnated at 3.8 toe/cap, despite declining real energy prices since the mid-1980s and economic growth of 25 % during this period. This 'decoupling' of energy use and economic development was primarily due to improved energy efficiency in all sectors and to structural changes towards services and less energy-intensive production in manufacturing.
- Finally, energy-related emissions of sulphur dioxide, hydro-carbons and nitrogen oxides have been substantially reduced; while energy-related CO_2 emissions have been kept almost constant at their 1990 level.

Thus, history may consider the past decade as the *"Golden 1990s" of the EU energy system* for two reasons: a successful outcome of energy policy, in particular with regard to the internal market and the liberalisation of electricity and gas supply; and the coincidence of other factors such as the closer co-operation with the countries in economic transition, and major technological advances in energy production, energy conversion and end-use efficiency.

CHALLENGES

However, the results of this Shared Analysis Project suggest a possible turnaround in many of these favourable trends leading to a new set of significant challenges:

ENERGY DEPENDENCE AND DIVERSITY OF SUPPLY

(6) World total primary energy consumption is likely to increase by around 2 % per year in the period of 2000-2010 and by slightly more thereafter (see Chapter 4.1). World *dependence on fossil fuels is expected to remain at high levels* - close to 90 % by 2020 with the following major trends foreseen for resource use and availability:

- Global crude oil production is likely to be re-concentrated upon the Middle East, rising from 32 % at present to over 42 % by 2010 and thereafter.
- In the North Sea, crude oil production is likely to decline progressively, leading to a higher dependence of around 85 % on oil imports in 2020.
- The rapid projected growth of natural gas demand in the EU (+ 28 % between 2000 and 2020) also increases import dependence, from some 40 % at present to more than two thirds by 2020.
- Although solid fuel use may fluctuate at around present levels over the next two decades, coal imports could well increase by some 50 Mtoe due to declining domestic hard coal production in a few Member States.
- The additional contribution of renewables to overall EU primary energy supply is likely to be small (around +30 Mtoe in 2020 compared to 1995).
- The nuclear contribution in 2020 is expected to be somewhat lower than today as result of progressive decommissioning of the older power plants.

COMPETITIVE ENERGY PRICES

(7) Global energy markets are likely to remain well supplied at relatively modest costs throughout the projection period and thus to convey the impression of a world of low energy prices. Crude oil prices (at the EU border) by 2020 are projected to be around 20 to 25 $\$_{90}$/barrel. Natural gas prices in Europe are estimated to rise somewhat faster. The price of hard coal imported into the EU is projected to remain relatively stable at around 45 $\$_{90}$/tonne. These projected, relatively low, prices of fossil fuels will strengthen their competitive position in global energy markets over the next 10-20 years and also that of the related fossil fuel conversion technologies.

Box 1: European Energy Outlook to 2020 – the Baseline Scenario

Key assumptions: EU population of the present 15 Member States increases by 12 million people until 2010 and stabilises thereafter. The world economy is expected to grow slightly above 3 % annually throughout the projection period to 2020, whereas EU economic growth is assumed to develop linearly over time by around 430 EURO per capita per year, i.e. 2.4 %/a until 2010 and 1.8 %/a thereafter.

The main *policy assumptions* of the Baseline Scenario are: for further integration and liberalisation of electricity and gas supply in the EU; further efficiency improvement in the end-use and conversion sectors; the continuation of support for renewables, co-generation, and natural gas supply infrastructure; the extension of the life time of nuclear power plants to 40 years; and stringent regulation of acid rain emissions. However, the Baseline Scenario does not include any new policies which specifically address the climate change issue.

EU primary energy demand is expected to continue to grow throughout the outlook period: close to 1 % per year over the period to 2010 and 0.4 % per year thereafter. The EU energy system remains dominated by fossil fuels over the next 20 years; their share rises marginally from their level of just under 80 % in 1995. The use of solid fuels is expected to continue falling to 2010. Natural gas is by far the fastest growing primary fuel. Its share in primary energy consumption increases to 26 % by 2010, but stabilises thereafter. The share of oil in primary consumption remains relatively stable at 41 %.

Economic implications: Due to efficiency and productivity gains throughout the energy system, the cost of energy to the consumer stabilises or even decreases. Facilitated by liberalisation, the average electricity price is projected to decrease in 2010-2020 by 15 % below the current level. The share of energy costs in total production costs (for companies) or in total income (for private and public households) continuously decreases.

Environmental trends: The rising share of fossil fuels is likely to increase CO_2 emissions by an average of 0.6 %/a in the period 1995-2020. The transport sector contributes nearly two thirds to the total increase until 2010 (+220 million t CO_2). Beyond 2010, electricity and steam generation are projected to contribute most to the increase in CO_2 emissions. The Baseline Scenario suggests that, in 2010, CO_2 emissions are expected to exceed the 1990 level by 7 %. But conventional emissions of sulphur dioxide, nitrogen oxides and hydrocarbons of the energy system, from power generation in particular, are expected to decline rapidly over the whole period.

TABLE 1: PRIMARY ENERGY DEMAND, ENERGY DEPENDENCE AND CO_2 EMISSIONS OF EU-15, BASELINE SCENARIO 1995 TO 2020

	Mtoe				Annual growth rates (%)			Shares (%)		
	1990	1995	2010	2020	1995/ 2010	2010/ 2020	1995/ 2020	1995	2010	2020
Total	**1,318**	**1,368**	**1,556**	**1,612**	**0.9**	**0.4**	**0.7**	**100.0**	**100.0**	**100.0**
Solid fuels	302	238	182	218	-1.8	1.8	-0.3	17.4	11.7	13.5
Liquid fuels	545	578	655	663	0.8	0.1	0.5	42.2	42.1	41.1
Natural gas	222	274	401	431	2.6	0.7	1.8	20.0	25.8	26.7
Nuclear	181	205	227	199	0.7	-1.3	-0.1	15.0	14.6	12.3
Electricity	2	1	2	3	2.7	1.2	2.1	0.1	0.1	0.2
Renewable energy sources	64	72	88	100	1.4	1.2	1.3	5.3	5.7	6.2
Energy import dependence (%)	47.7	46.5	55.0	63.4						
CO_2 emissions (Mt)	3,079	3,037	3,298	3,508	0.6	0.6	0.6			

(8) The *impacts of liberalisation* of electricity supply are now becoming clearer and some issues may need further attention:

- Increasing productivity of the electricity generation and distribution system has been observed, in particular in all early or fast liberalising Member Countries.
- As a consequence of initial liberalisation, electricity prices have been declining, increasing the competitiveness of the energy-intensive firms and reducing energy bills of households. Observed price reductions indicate, however, that (large) industry and companies in the tertiary sector are more likely to be able to reap the advantages of liberalisation.
- Reduced electricity price differentials among Member Countries can be observed.
- Specific environmental emissions from electricity generation are likely to decrease faster due to improved fuel conversion efficiencies in new and refurbished power stations; this is particularly supported by the huge observed, and expected, investments in combined cycle gas turbines (CCGT).
- Lower electricity prices may, however, reduce the economic incentives for greater end-use electricity efficiency, particularly by large users. But efficiency increases at the plant level through energy service contracting by utilities (as part of their efforts to hold on to important customers) or by other players may offset some of the efficiency losses caused by lower electricity prices in industry.
- The larger use of gas in power generation, whether within combined cycle systems or not, substituting for coal, has a positive effect for climate change policy.

(9) Similar impacts can be expected from the *liberalisation of the gas market* in the Community, although these will differ between Member Countries. This is because the extent of the natural gas provision varies across the EU-15 (accounting 49 % of primary energy use in the Netherlands, but still close to zero in Portugal; with an EU average of 22 %). During the implementation period of the EU Gas Directive over the next few years, it is very likely that most large gas consumers will benefit from the liberalised EU gas markets and the fierce upstream competition between large gas producers/suppliers.

(10) *Traditional trade of gas* via the transmission pipeline networks may decline and be substituted by swap deals and other "paper trade", thereby reducing the transmission costs for consumers, as these and other auxiliary costs (storage, quality) become relatively more important in a fully competitive market.

(11) For consumer services in electricity and gas market, facing more competition at the distribution level, one can expect increasing 'product differentiation'. Recent mergers of utilities indicate a trend towards multi-utilities and *energy service companies* offering service packages consisting of heating, cooling, compressed air, steam heat, water and cable services to consumers. Different electricity and gas tariffs, (or even district heat tariffs) will be offered, depending on energy inputs for electricity or heat generation (e.g. 'green tariffs'), the quality of electricity or gas delivered (e.g. contract provisions for supply interruption), the time of use and other aspects.

ENVIRONMENTAL TRENDS

(12) Conventional emissions of sulphur dioxide (SO_2), nitrogen oxides and hydro-carbons from EU energy use (and from power generation in particular) are expected to decline quite rapidly until 2020, due to the continuing impacts of environmental legislation in road transport, power generation and other stationary sources; but also due to improved energy efficiency in all end-use and conversion sectors.

(13) *Global emissions of CO_2*, however, are projected to grow quite rapidly (on average by 2.1 %/a). For the period 1995 to 2020, China and India - with high economic growth and populations over 1 billion - each account for almost 40 % of the increase in CO_2 emissions. The commitments made by the EU and its Member Countries in the Kyoto Protocol, to reduce total greenhouse gas emissions by 8 % in 2008 to 2012 relative to the year 1990, is a specific challenge for energy policy as some 80 % of the EU's total greenhouse gas emissions originate from energy use.

(14) Much of the increase in the Community's energy-related greenhouse gas emissions is expected to arise from *road and air transportation*. Thus improving the efficiency of the European transport system is a major challenge given the growing demand for mobility, decreasing car occupancy levels and consumer preferences for more powerful cars. To avoid increasing CO_2 emissions from power generation, *more efficient production and use of electricity* will also be a major challenge, given decreasing electricity prices due to the liberalisation of electricity supply. The imposition of carbon constraints could lead to further penetration of most of the renewables, but at a rather slow rate.

(15) As regards the commitments of the *Kyoto Protocol*, the analysis of the current initiatives and policy actions of Member States concludes that the emissions of the two major non-energy related greenhouse gases, methane and N_2O, could be reduced by about 18 % by 2010. This expected decline would decrease the necessary reduction target for *energy-related CO_2 emissions* from the –8 % of the greenhouse gas basket to *approximately* –5 % (i. e. 180 Mio t) relative to their 1990 level. As energy-related CO_2 emissions almost stagnated during the 1990s, the Community may have a good chance to meet the present Kyoto targets by realising the potentials for methane and N_2O reductions, and by intensified energy policies at the EU and national level. Purchases of emission permits would have a supplementary role.

Box 2: Projected emission reduction variants of the Baseline Scenario

The Baseline Scenario highlights that, without specific climate change policies, it would be unlikely that the EU will meet its Kyoto commitments. Under the assumptions made, the analysis expects a 7 % increase of energy-related CO_2 emissions for 2010 relative to their 1990 level. Given the greenhouse gas reduction potentials outside the energy sector a scenario was calculated representing a CO_2 emission reduction of 6 % of the 1990 level or around 400 million tonnes compared to the unrestricted Baseline emissions in 2010.

Nearly half of the 6 % reduction is achieved through improved efficiency; the other half is due to the intensified use of less carbon-intensive fuels and renewables. The power and steam generation system appears to be the sector that can adjust in the most cost-effective way to the required CO_2 emission reductions, as it contributes almost 60 % of the required decline in 2010.

The direct total costs of achieving the 6 % CO_2 reduction from the energy system depend on many factors and their dynamics in the next decade. The direct total costs have been investigated in the Report and are discussed extensively in Chapter 5. Additional indirect costs have not been analysed, neither have the ancillary benefits from avoided environmental and social costs, or from reduced energy dependence and employment effects.

(16) These challenges of the next 10 years are also very likely to prevail over the period between 2010 and 2020, when major strategic decisions have to be made particularly *in power generation and transportation* to support further sustainable development in the Community. A high degree of flexibility of the EU energy system and the Community's energy policy may be essential to meet these identified and future challenges.

THE ENERGY POLICY AGENDA

(17) Due to the expected substantial changes in both world energy markets and within the Community, and the related challenges within the next decade (see also Figure 1), energy policy in the EU and its Member States is likely to have to undergo a further period of learning and searching to be able to react adequately to the possible new challenges. The uncertainties remain great; and thus maintaining flexibility to respond to them is judged essential.

- As regards *short term measures*, within the next 2-3 years, energy policy has to bear in mind the long-term re-investment cycles, slowly changing consumer behaviour and the time necessary for policy debate and decisions which inevitably limit the speed of change of the EU energy system.
- As regards *medium- and long-term measures* for the next decade and beyond, the next few years are needed for further research, discussions with stakeholders and preparation of any further policy changes judged necessary.

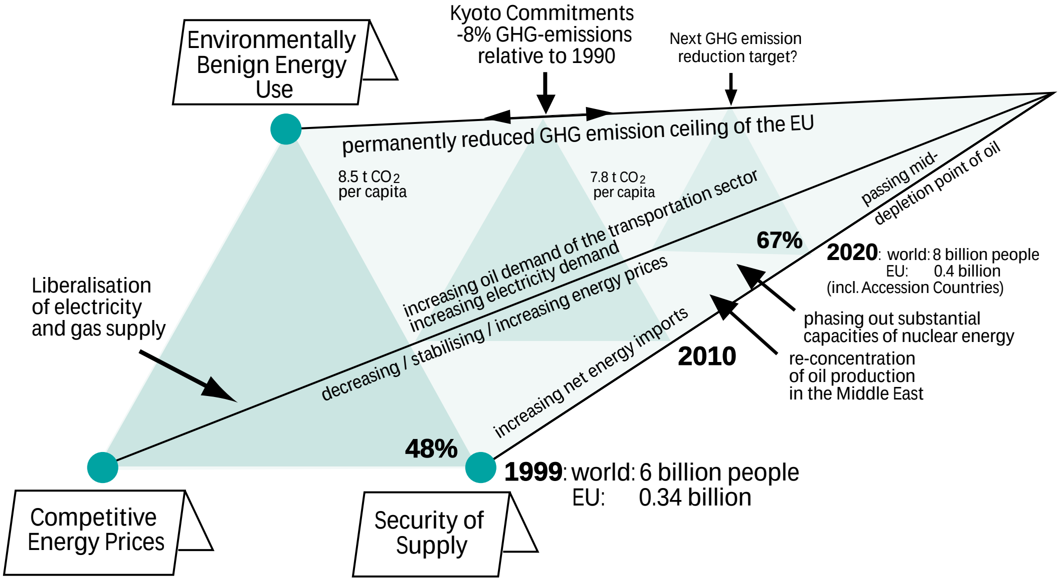


FIGURE 1: THE THREE OBJECTIVES AND NEW CHALLENGES OF ENERGY POLICY IN THE NEXT TWO DECADES

Given the challenges and related policy issues, the following key conclusions for the future policy agenda can be drawn from the results of the Shared Analysis Project:

EXTERNAL DIMENSION

(18) The analysis suggests that the EU may have to fulfil an important role in international diplomacy in the energy field with regard to:

- *energy exporters* - to secure crude oil and natural gas supplies for the EU by economic and political co-operation; reducing the potential for political instabilities; negotiations under the auspices of the Energy Charter may continue to conclude a multilateral Transit Framework to reduce the risks of physical disruptions to pipeline supplies;
- *the integration of the Accession States* - this may call for specific efforts to harmonise regulations and taxation, support for faster technological development through joint ventures, and other means of technology and know how transfer;
- *global environmental negotiations* - in particular, further negotiations will be needed to ensure that emerging Member States' experience with emission trading is compatible both with wider EU and global emissions trading regimes.

INTEGRATION

(19) The results of the analysis suggest that least-cost solutions to policy conflicts and trade-offs are unlikely to be found in the energy sector alone, but rather in the wider energy system including energy end-uses, related energy services and the underlying driving factors in final demand sectors. This means that the energy policy of the Community should perhaps pursue a *broader political approach in the next decade* than in the past by:

- ensuring that the transport sector is placed much more fully at the heart of EU energy policy, as road and air transport are likely to be the major single contributors (35 % to 55 %) to incremental growth in overall EU final energy demand (particularly dependent on oil supply) and in CO_2 emissions until 2020;
- *co-ordinating and harmonising national approaches to utility regulation* to ensure the success of liberalised energy markets by securing non-discriminatory access to the entire network and its auxiliary functions, and the protection of consumers;
- ensuring that energy policy making in future gives *due weight to energy efficiency*, by harmonising energy efficiency regulation (e. g. technical standards, labelling and voluntary agreements for mass-produced and traded appliances, such as vehicles, boilers, burners and electric motors);
- harmonising national energy taxes to ensure level playing fields; and the longer-term objectives of greater contributions to energy supply by renewables;
- broadening and *intensifying the dialogue* and co-operation among Member States, institutions, stakeholders, and the media.

CLIMATE CHANGE POLICY

(20) There are good reasons for concluding that climate change may require a *more* vigorous policy stance:

- Policy should seek to identify, and seek to implement, the *least-cost reduction potentials of other greenhouse gases*, e.g. methane in coal mining and landfills, or for N_2O from adipic acid production in the Community.

- There may also be a need for new initiatives, as the analysis suggests that the cost of CO_2 emissions reduction according to the Burden Sharing agreement differs substantially across EU Member States.
- To achieve the objectives of the Climate Convention, meaningful developing country participation will be necessary. This should start rather sooner than later, especially with high income OECD countries not yet included amongst the group of Annex B countries..

The *dynamics of climate change policy* deserve major attention. Long-term re-investment cycles of buildings, infrastructure like railways, power plants and transmission lines or district heat networks and of some basic industrial processes suggest the need for careful policy analysis and intensive dialogue with all stakeholders to avoid stranded costs, inflexibility of climate change policy or the need for purchasing emission certificates. *Power and steam generation* seem to be technological areas that can adjust in the most cost-effective way to meet initial emission constraints given their fuel switching options, increased cogeneration and further efficiency improvements. As the emission constraints are expected to tighten beyond 2010, much improved energy efficiency in all end-use sectors is also required.

CO-ORDINATION OF ENERGY POLICIES AT THE EU AND MEMBER STATE LEVEL

(21) The *principle of subsidiarity* remains of great importance in many EU Member States. However, its application to energy policy issues may now give rise to different perspectives in view of the requirements of the Single Market, liberalisation of EU electricity and gas markets, the growing cross border ownership and merging of energy companies, and the agreed EU response to global climate change.

- Much nationally-funded R&D loses its rationale in the context of the Single Market and of global players in appliance and equipment markets. Super-national R&D funding becomes increasingly important regarding energy production and conversion technologies, but also for energy efficiency of mass-produced and traded appliances, products and equipment where technical standards and labelling at EU level increasingly play a major role;
- Growing import dependence reinforces the need to re-assess the steps importing countries might consider to strengthen security of supply.

Box 3: The role of energy technologies, R&D and innovation policies

High economic potentials for improved energy efficiency are available in power generation (around 10 percentage points up to 2020) and in almost all end-use sectors (mostly 20 to 30 % in relation to today's average specific energy use). Technological analyses show that *additional efficiency potentials* can be economically realised if research and development is sufficiently directed to new promising technologies in end-use sectors (e.g. low energy buildings, more efficient cars, wide application of inexpensive sensors and control techniques including remote control, nanotechnology and biotechnology, membrane and absorption technology).

More efficient technologies in energy conversion and the end-use sectors not only strengthen the *competitiveness of energy-intensive industries*, but also represent growing world-wide markets for exports by European technology producers and, hence, contribute to additional employment in the EU.

The option of *"clean" fossil fuels* by converting them into hydrogen and CO_2 is potentially a very promising technological option in the longer term. The CO_2 produced could be sequestered in aquifers, depleted gas fields or used for tertiary recovery methods in oil production. All elements of this technological option, the gasification, hydrogen storage, its transport and use, as well as the sequestration of CO_2 in exploited gas fields are well-known elements of such a system which has huge potential for technical improvements and cost reductions.

The long-term scope for increasing conversion efficiencies of *renewables* and – more importantly – of reducing their production costs by learning effects and economies of scale is underestimated by some stakeholders at present. However, the necessary R&D and energy policy instruments need much more specific assessment of the different types of renewables, their different applications and possible niche markets.

ENERGY TECHNOLOGY

(22) Falling electricity and gas prices in the next decade due to liberalisation and technical progress and related implications may lead to a conflict of objectives, i.e. natural gas dependence may further increase and CO_2 emission reduction targets may have to be achieved with more and costly efforts. Therefore, technical progress in the energy system with regard to efficient energy use, renewables and other cleaner technical options are of major importance to minimise such conflicting objectives (see Box 3).

MONITORING AND ANALYSIS

(23) *Policy analysis and sharing of analyses* of economic, market, political, social and technological trends should be continued to develop consistent energy policies. Priorities include analysis which seeks to overcome possible inconsistencies and conflicts in different policy thrusts (e. g. liberalisation and competitive energy prices versus environmental protection and climate change policy; competitive energy prices versus diversity of supply, including nuclear energy, cogeneration and renewables). This analytical process should continue to involve, and to draw upon work undertaken by, technical specialists of the Member States and a wide range of stakeholders.

CONCLUDING REMARKS

(24) Given the long-term trends of increasing energy import dependence, the dynamics of the internal market and of liberalisation of the energy markets, the enlargement of the EU, concern about climate change, and the globalisation of major industries, the analysis suggests that the responsibility *of the Community in energy policy matters will gain importance*.

PART I INTRODUCTION

BACKGROUND

The future development of energy markets and energy policy in the European Union (EU) and its Member States is facing a variety of challenges within the next decade or two:

- The growing demand for energy from the emerging Asian and Latin American economies is likely to increase the world-wide use of fossil fuels and related CO_2 emissions. This greater use of fossil fuels is likely to draw upon non-OPEC oil reserves, and – in the long-term – world production of oil may once again be concentrated in smaller regions of the planet, such as the Middle East and, hence, reduce the current more diversified structure of the energy supply markets and, possibly, the security of oil supply. It is also expected that the European energy system will in the foreseeable future increasingly rely on natural gas. Hence, the security of gas supply under competitive conditions may be one of the major concerns for the European energy policy.
- The present liberalisation of electricity and gas markets will initiate major structural changes in European energy enterprises, increase competition among energy companies and result in improved economic performance, thereby contributing to a strengthened European economy. It will also reduce electricity and gas prices in the EU and may, therefore, reduce the speed of energy efficiency improvements in end-uses of electricity and natural gas. The new market regimes will influence the nature of policy instruments that will be at the disposal of energy policy. For example, market regulation might emerge as the more suitable field for internalising long-run objectives of energy and environment policy. Also, under the liberalised market context and the ensuing restructuring of the European energy industry, energy policy is likely to be more than ever concerned with the protection of the consumer, the encouragement of small energy supply companies and the harmonisation of standards.
- Technical innovations in construction, car design and industrial processes, material science, information technology and recycling, however, will open up new fields for energy efficiency and the use of renewables. Cost reductions in these technologies are necessary and feasible by several policies to achieve the objectives of diversity of supply and of decreasing environmental burden of energy use; their trade-offs should be assessed.
- The Kyoto Protocol demands an active policy of climate change in the EU and its Member States with changes in political choices and energy market structures. The commitment of the EU to reduce six greenhouse gases by 8 % by 2008-2012 requires an analysis of the economic trade-offs between the different reduction options. In addition, the burden sharing among EU Member States may need further analysis and decisions, if economic analyses should suggest changes. The European efforts to reduce greenhouse gas emissions have, nevertheless, to be seen in the light of the rapid energy demand growth in less developed countries, and especially in the Asian economies. This will result in a continued increase of CO_2 emissions that risks off-setting any emission reduction efforts likely to be undertaken by the developed countries.

All these challenges call for an integrated analytical approach linked to the three pillars of energy policy: the competitiveness of the EU economy, the security and diversity of energy supply, and low environment stress by energy use (including climate change), all three being part of the broader sustainability issue. In order to provide consistent quantified illustrations of the complexity of the common issues and the EU-wide as well as world-wide energy prospects, the European Commission has supported the development of several quantitative models of the energy system[1]. Effective use of these models requires updated information and validation through discussion and interaction involving the modellers, energy analysts active in the Member States, industry, administration and research institutes. In a first attempt to achieve such an integrated approach, the Directorate General for Energy initiated the Shared Analysis Project. In this effort, a large group of actors in the energy field at both EU and national level was invited to participate.

OBJECTIVES OF THE SHARED ANALYSIS PROJECT

The Shared Analysis Project pursued the following three major objectives:

- The project team was to design a **common framework of energy analysis** that aimed to involve all Member States and the experts of industrial research groups (the shared approach to energy analysis). This activity was and is conceived as a dynamic process, in which the experience from current analytical work could also be used to improve the conceptualisation of the shared approach. In pursuing this objective, the project team further ensured the conceptual coherence and consistency of the proposed research and the cross-check with the analytical capability available in the Member States.

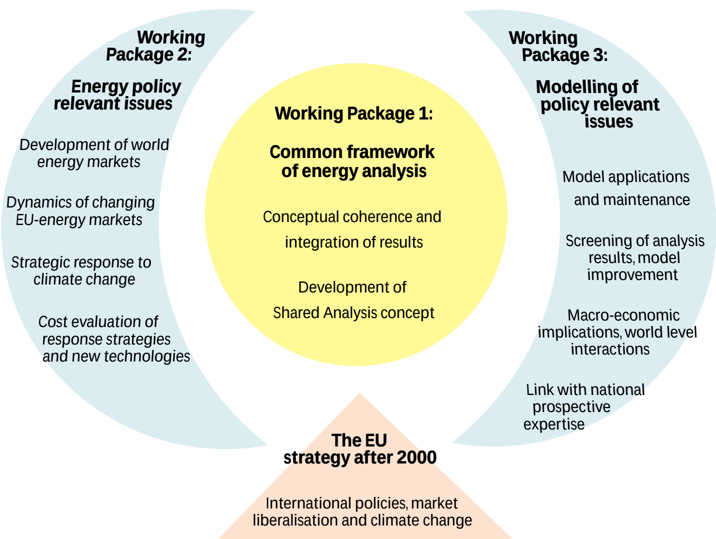
[1] The model-based part of the study relied on the energy models PRIMES and POLES, and the gas market model GASTALE. PRIMES is an energy system model for the European Union maintained at NTUA (Athens), POLES is an energy system model for the World maintained at IEPE (Grenoble). Both models have been developed under a series of research projects supported by the programme Joule of DG XII of the European Commission. The gas market model was developed for the European context by ECN (Petten) under the "Energy Analyses and Forecast Study".

- The second objective was **to analyse generic EU-wide issues important for energy policy** and for future energy demand and production, putting particular emphasis on (see Figure 1-1):
  - world energy market trends focusing on surging Asian and Latin American future energy demand and its supply, particularly with regard to oil and natural gas and their possible price trajectories;
  - the dynamics of changing European energy markets due to liberalisation, privatisation and technological innovations in both the electricity and the gas markets;
  - strategic energy policy responses to the Kyoto process, including the mitigation options of non-energy related greenhouse gas emissions and the use of emission trading among EU and other industrialised countries (Eastern European countries and Russia in particular);
  - evaluation of response strategies to increasing energy import dependence and to climate change regarding the competitiveness of European industry, the cost of energy services to the consumer, international policy, and an improved integration of policies of the EU and its Member States.

This analysis and forecasting work has relied on the collection of synthesised knowledge available across a wide range of existing relevant sources of information and includes new concepts and analytical results.

- The third objective was to carry out **quantitative analyses of energy trends and scenarios as an input for discussion**. In order to compare the results obtained in the frame of the project by the modelling analysis at the Member State level, projections that exist in all the Member States have been assessed in parallel in a comparable and uniform way. This allows more detailed and consistent policy analyses and scenario investigations at the Union level that should enlighten the debate on issues of Community energy policy. This process required further validation and harmonisation of assumptions and input data for the model-based analysis. Moreover, changing market structures and the challenge of climate change required adaptations of the existing modelling facilities, as well as the development of new features in the existing EU models (PRIMES and POLES) and of a new model for the European gas market

Figure 1-1: The structure of contents and working packages of the Shared Analysis Project



ORGANISATION

The work programme reflects these objectives in three main work packages and in a sequence of workshops, symposia and further activities which drew together the expertise in the Member States. The project started in January 1998, involving about 100 months of scientific labour.

In order to ensure efficient interaction with the Commission
- a core group from the institutes met regularly with Directorate General Energy, Policy Analyses and Forecast Unit A.2, and
- a steering group comprising all the member institutes of the consortium and several Directorates General of the Commission (energy, environment, industry, transport and research) discussed the progress of the work and considered new developments.

The project consortium consisted of nine member institutes co-ordinated by the Fraunhofer Institute for Systems and Innovation Research, Karlsruhe (FhG-ISI):

Core group:
- FhG-ISI: Fraunhofer Institute for Systems and Innovation Research, Karlsruhe (Co-ordinator)
- NTUA: National Technical University of Athens, Athens
- SPRU: Science Policy Research Unit, Brighton

Further institutes participating in the Steering Group:
- ADEME: Agence Française de l'Environnement et de la Maîtrise de l'Energie, Paris
- ECN: Netherlands Energy Research Foundation, Petten
- IEPE: Institut d'Economie et de Politique de l'Energie, Grenoble
- IEFE: Istituto di Economia delle Fonti di Energia, Milan
- IER: Institut für Energiewirtschaft und Rationelle Energieanwendung, Stuttgart
- RISØ: RISØ National Laboratory, Systems Analysis Department, Roskilde

The consortium was supported by sub-contractors, and with the advice and expertise of the member institutes of the European Network of Energy Economics Research (ENER) serving as national focal points.

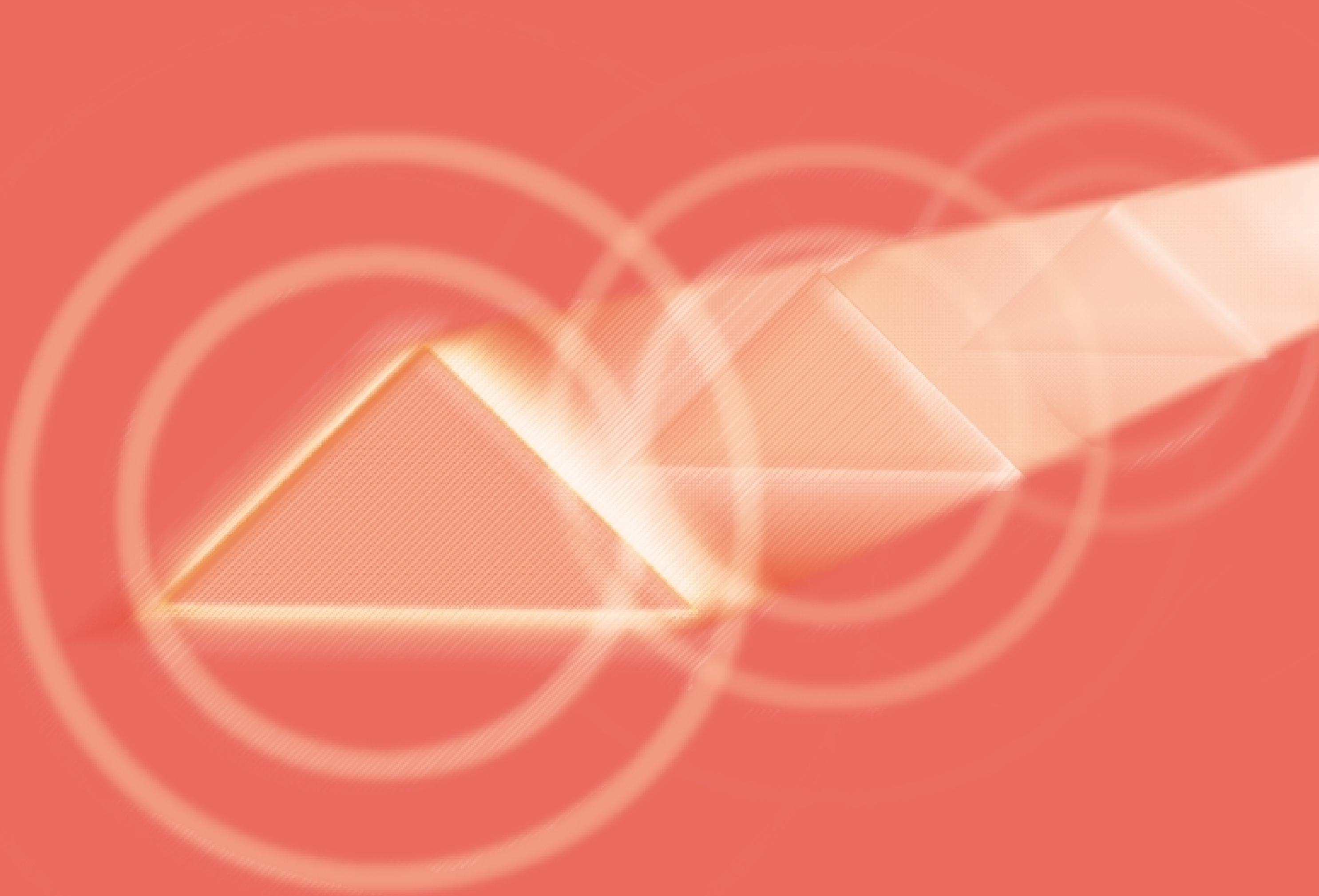
Two symposia were held in June 1998 and March 1999 in order to discuss emerging results of the energy policy analyses and to gather views on future challenges and policy issues from the communities in industry, administration, NGOs, and academia. Participants contributed most usefully to broaden the views on global issues as well as sectoral and national policy perspectives.

The Shared Analysis Project was developed in close co-operation with the staff members and the Head of the policy analysis, and forecast unit, A2 of the Directorate General Energy. They were involved from the launching of the analysis, the design of the research for identifying the major challenges that EU energy policy will have to face, the preparation and the arrangements of the two symposia, and the discussion of major results, policy issues, uncertainties and opportunities. In addition, the national experts of the governments of the Member States have been involved via special briefing meetings, comments and active participation in the symposia.

The results of the Shared Analysis project are summarised in the current report. The issues are presented in detail in 13 additional volumes to the final report[2]. The effective dissemination of the results is also ensured through an Internet site dedicated to the project (http://www.shared-analysis.fhg.de), through printed papers and Compact Discs (CDs).

[2] See the list of volumes at the end of the report

PART II ENERGY POLICY CHALLENGES



This chapter briefly describes the wide range of issues and the new challenges of energy policy at present and over the next two decades. The purpose is to identify the many complex inter-relationships within the energy sector itself, and between it and the wider energy system at the level of both the EU and the global economy. These inter-relationships reveal the need for well-considered and effectively co-ordinated policy responses involving dialogue with a wide range of actors. It is these issues which have been at the heart of the Shared Analysis Project and which are described in more detail in the following chapters of this report.

2.1 OBJECTIVES OF ENERGY POLICY

Competitive, diverse and secure energy supplies are the very life-blood of modern economies. These supplies are often taken for granted. But, as past experience has shown, even brief interruptions in supply have very serious economic and social consequences. With this central importance of energy in mind EU energy policy has, for many years, been based upon three main objectives. These have aimed to address the complex set of strategic challenges facing the energy sector and the wider energy "system", the latter comprising end-use sectors and the economy at large. They have also been intended to ensure that the energy system has contributed to sustainable development of the EU economy with regard to the economic, social and environmental dimensions of sustainability. The three objectives have served as the pillars of traditional energy policy and are likely to retain their central importance in future (see Figure 2-1):

SECURITY AND DIVERSITY OF ENERGY SUPPLIES

This dimension of policy has been most pressing at times of crisis in energy markets, as in the oil shocks of 1973/74 and 1979/80. Since the significant fall in oil and other international energy prices, which commenced in 1986, energy security has received somewhat less attention from policy makers. However, this study anticipates that import dependence and supply security issues will assume greater significance in future. This is because of the projected steady decline of the EU's high-cost indigenous coal capacity over the next 10-20 years; decommissioning of much existing, and ageing, EU nuclear capacity – especially after about 2015; and the increasing maturity of the North Sea oil and gas province such that output will peak and then progressively decline by 2020.

COMPETITIVE ENERGY PRICES AS A KEY COMPONENT OF THE SINGLE EUROPEAN MARKET

Competitive energy prices are being secured by measures such as the Directives to liberalise the EU electricity and gas sectors; reducing State Aids (especially for coal) and the market distortions created by them; and harmonising taxes on oil products. It is important to stress that liberalisation must be seen as a process and not as an isolated event. As energy markets are liberalised, structures and incentives will change. These may lead to a range of intended and unintended consequences. Oversight of progress towards liberalisation will also be necessary to ensure compliance with the directives and a level playing field across the EU. On occasions, it is likely that

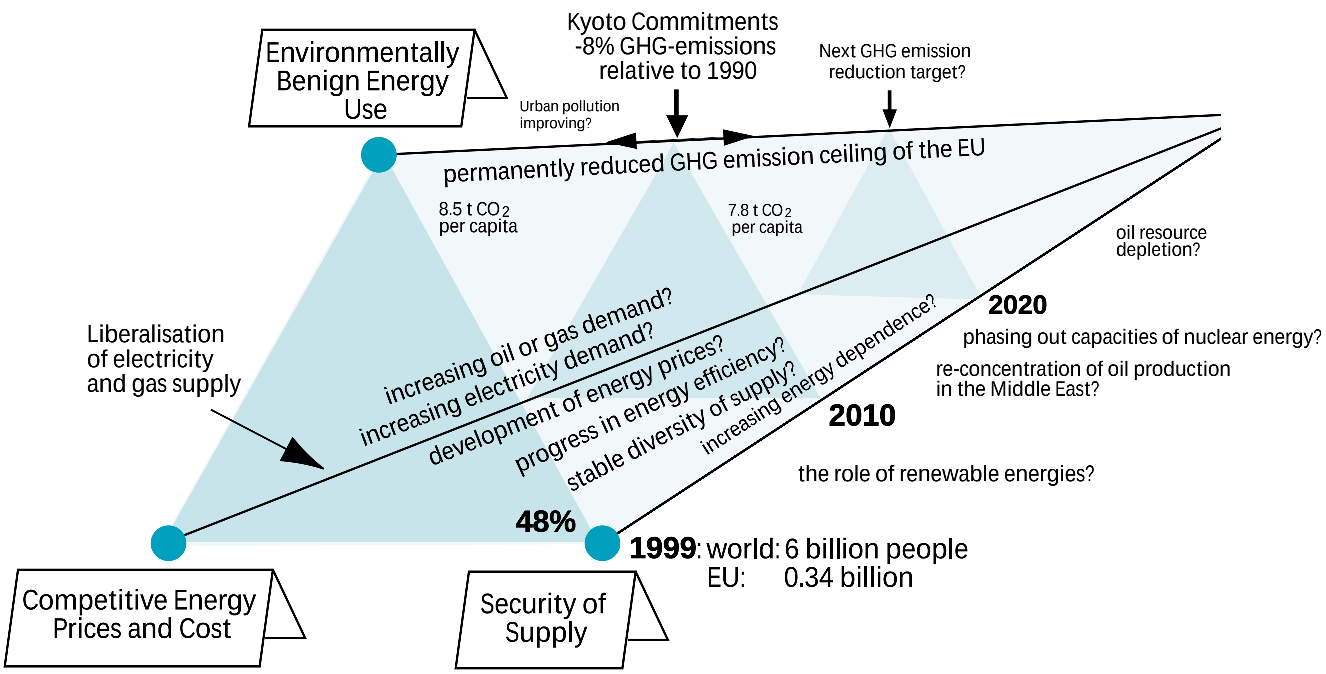


FIGURE 2-1: ENERGY POLICY OBJECTIVES AND NEW CHALLENGES AT THE COMMUNITY LEVEL

liberalised markets will require revised frameworks of conduct – e. g. to ensure adequate diversity of fuel supplies; and consistency with environmental and other policy objectives. This is particularly the case given the expectation of a period of lower real energy prices. Low prices could reduce market-based incentives for further investment in cleaner and more energy efficient technologies such as appliances, vehicles, combined heat and power generation (CHP) and renewable energy sources, and, thus, may not favour competitiveness at the energy end-use level.

EFFORTS TO REDUCE ENVIRONMENTAL IMPACT OF ENERGY USE

These measures are cumulative and now numerous. For the energy sector and energy system per se, the most important of these include the Large Combustion Plant Directive to combat acid rain; the commitments made following the Kyoto Protocol of December 1997 to curb emissions of a basket of six greenhouse gases – particularly carbon dioxide (CO_2); and the Integrated Pollution Prevention and Control Directive which requires the use of Best Available Techniques (BAT) to reduce releases of pollutants to air, land and water in an effective manner.

Whilst these three pillars have been at the heart of energy policy in the past, the context of policy making has often changed dramatically. For example, the last three decades have witnessed considerable changes in energy circumstances and, especially, in the "conventional wisdoms" which have dominated energy policy thinking.

- First, apparent scarcity has given way to apparent plenty. Rather than rising ever higher, as anticipated in 1973/74, international crude oil prices have fallen significantly in real terms since the mid 1980s. Natural gas, the use of which was once largely restricted to "premium" end-use applications, is now rapidly penetrating the large "crude heat" market – especially in power generation in the so-called "dash for gas". Without doubt, this changed wisdom is closely related to the changing perceptions about greater natural gas availability and to more pressing environmental concerns.
- Second, in the 1970s, constraints upon energy were perceived as internal to the energy sector: i. e. relating largely to supply security and depletion. Now, the constraints are increasingly perceived as external to the energy sector: i. e. relating primarily to global environmental impacts.
- Third, in the 1970s, energy policy was often narrowly equated with fuel supply policy and thus to the energy sector. Now, it is recognised that energy policy must be conceived in much wider terms: e. g. as regards competitiveness, economic and social well-being, and the environment; and thus must pay due regard to the role of the much wider energy "system".

These changes will inevitably influence both the scope and the style of energy policy making. *In the past, fixation upon the supply side* permitted energy policy making to be dominated by a single department in a Member State or a single Directorate General in the European Commission. *Now, concern for the wider energy "system"* requires more subtle and complex inter-relationships; greater co-operation and policy co-ordination; and, especially, more effective dialogue with a much wider range of stakeholders. In particular given liberalisation and, in some cases, privatisation, it appears likely that future energy policy will require greater attention to be given to (i) the demand side and hence (ii) the wider energy "system". To give but one example, acid rain could be tackled by policy measures targeted at a limited number of major emitters. Tackling greenhouse gas emissions requires a much more systemic policy response, based upon *dialogue with a wider group of stakeholders*, e. g. road and rail transport, city planning, recycling of energy-intensive materials.

SOME CORE POLICY IMPERATIVES

Bearing in mind these changes in policy focus, a *core of imperatives* can be identified as "ingredients" of a new approach to ensuring that the energy system plays its part effectively in the more sustainable development of the EU:

- provision of diverse and secure supplies,
  - site licensing and planning consents for investment in new energy supply capacity and energy infrastructures,
  - import dependence and net energy trade, including new regions like Eastern Europe and the CIS,
- provision of adequate, full cost, and low price, energy supplies,
  - frameworks for pricing, regulation and other financial controls, especially for natural monopolies such as the "pipes and wires",
  - taxation policy – especially taxes and duties on transport fuels; off-shore oil and gas tax regimes; and, more controversially, possible carbon or energy taxes,
- reducing the wide range of environmental impacts and controlling the speed of climate change at the global level,
  - issues relating to employment, safety and welfare for workers and the population at large,
  - research, development and technology choices, including long-term choices of clean coal or "clean nuclear",
- measures to stimulate more efficient energy use, especially at a time of lower real energy prices,
- industrial policy and plant procurement issues,
- social and health dimensions of energy use, given ageing populations and fuel poverty. In some EU countries, there is well-documented evidence of "fuel poverty" - the inability to afford adequate warmth, leading to excess winter deaths through hypothermia. Low incomes are one reason. However, major causes are the poor

thermal insulation of buildings and the continued use of inefficient heating equipment.

Some of these policy imperatives are quite specific to the traditional energy "sector". Others form significant components of macro-economic, fiscal, environmental, industrial, trade, social or transport policy in terms of the wider energy "system". These points imply that, in future, successful energy policy supporting sustainable development will be a more complex, subtle, inclusive and cooperative process. Emphasis will be on effective co-ordination (within the Commission services, between the Commission and Member States, and involving inclusive dialogue with numerous stakeholders – no longer merely with the traditional, powerful but vested interests in the energy supply industries).

2.2 NEW CHALLENGES OF ENERGY POLICY

The changing character of energy policy making has been discussed above. Here, we focus on specific shaping factors and issues likely to warrant more attention from policy makers. However, in some areas, the lead times to formulate – and especially to implement – effective and widely-supported responses are long. Preparedness is vital in policy making, as is the need for flexibility and the need to anticipate yet further somersaults in "conventional wisdoms". As a result, both policy making and its underpinning analytical capabilities must draw upon a range of multi-disciplinary advice and resources.

On a broad **geopolitical level**, the following factors will be important in shaping the EU and the wider, global, energy policy stance:

- The demand for energy is a derived one. Users in the energy "system" require the ***services* provided by energy use** such as heat, comfort, cooking, communication, movement and motive power. The role of the energy sector is to meet these various demands for services in a least-cost, yet environmentally-responsible, manner. These demands are stimulated by many factors, most of which are beyond the direct influence of the energy sector per se. This again highlights the pressing need for co-operative and integrated policy making across a wide front to implement commitments for more sustainable development of the EU economy.
- The main **factors driving global energy demand** will be increased economic activity, higher per capita incomes and population growth. The global population of 5.3 billion in 1990 (and 6 billion by October 1999) is presently expected to increase to 8.1 billion in 2020, 10 billion in 2050 and 12 billion in 2100. Over 90 % of this growth will occur in developing countries, particularly China, India, Africa and Brazil. In contrast, other than via expansion through new Accession States, the EU's population is expected to remain relatively stable.
- About one third of the world's existing population has ***no* access to commercial energy supplies** at present; many more have inadequate energy provision due to poor supply infrastructures and/or low incomes. Continued population growth will exacerbate these problems, especially in the poorest countries.
- Satisfaction of even basic human needs will require substantial growth in global **primary energy demand**. The latter was 5,900 Mtoe in 1974 and 8,500 Mtoe in 1998, i. e. an increase of 1.5 % per year. Recent projections anticipate growth in global energy demand of 50-80 % by 2020 (compared to 1990). As with population, most of the *in-cremental* energy demand growth will occur in developing countries.
- For the foreseeable future, global energy consumption will be **heavily based upon fossil fuels**. Even in the EU, in 1997 79 % of energy supplies comprised fossil fuels, 15 % nuclear power and only 6 % renewable sources (mainly hydro, biomass and wind). Whether at the EU or global level, the transition from fossil to renewable energy sources on grounds of sustainability will take place over many decades. Current, and expected, low fossil fuel prices will not make this transition easy to achieve.
- The consequence of these factors is that the **global environmental impacts** deriving from the energy sector and energy system will increase. These impacts take many forms. By no means are they confined to greenhouse gas emissions. The energy sector – whether by exploration, production, transportation, conversion, storage, final end-use, or waste disposal – imposes a very wide range of environmental impacts. These include: the upstream impacts of different fuel cycles (such as coal or uranium mining and waste tips); land use and visual intrusion on landscapes by generating plants, transmission lines, terminals, refineries, gas storage facilities and other plants; subsidence; noise; cooling water requirements, waste water from energy extraction and conversion facilities, and oil spills at sea; solid waste disposal; plant decommissioning; radiation and radioactivity; and gaseous emissions, especially of carbon dioxide (CO_2), oxides of nitrogen, and sulphur dioxide (SO_2).
- The **global economy** is becoming more interdependent. Especially since the changes in Eastern Europe and the former Soviet Union, traditional political divisions have ceased to have much of their historic relevance. However, the process of transition to liberalised, market-based economies based upon strong democratic foundations has not proved easy – whether in the former Soviet Union, Asia, Africa or Latin America. Yet the new world trade order and creation of free trade zones (such as the EU Single Market, NAFTA and

Mercosur) are transforming economic relations.

- Increasing **mobility** in industrialised and developing countries may become of major concern regarding oil dependence and ever increasing CO_2 emissions.
- Finally, despite the current global emphasis upon competition and liberalisation, it is the **responsibility of governments** and international agencies to shape the governance frameworks for markets and to reconcile complex policy trade-offs. Market forces have much to commend them. But human aspirations – whether for education, health, a clean environment, a sense of community, justice and peace – cannot and will not be satisfied by markets alone.

With these broad perspectives in mind, the main energy policy challenges for the EU are likely to include:

(1) *Security and diversity*: a policy of self-sufficiency or autarky in energy is not realistic. However, given the central importance of reliable and secure energy supplies in modern economies, continuing oversight of EU and global energy markets is essential. Through **ongoing international diplomatic efforts** the EU may further encourage free trade in provision of energy supplies; seek to reduce political instabilities which might threaten supply security; encourage further infrastructure development in gas and electricity within and without the EU; continue its significant dialogues with energy exporters and in global environmental negotiations; and seek – **through R&D, technology dissemination and other policies** – to encourage both diversity in energy supplies and the transition towards greater use of cleaner and renewable energy supplies. This may also involve CO_2 removal from coal use or new technological concepts of nuclear energy use, waste treatment and recycling to ensure diversity of supply.

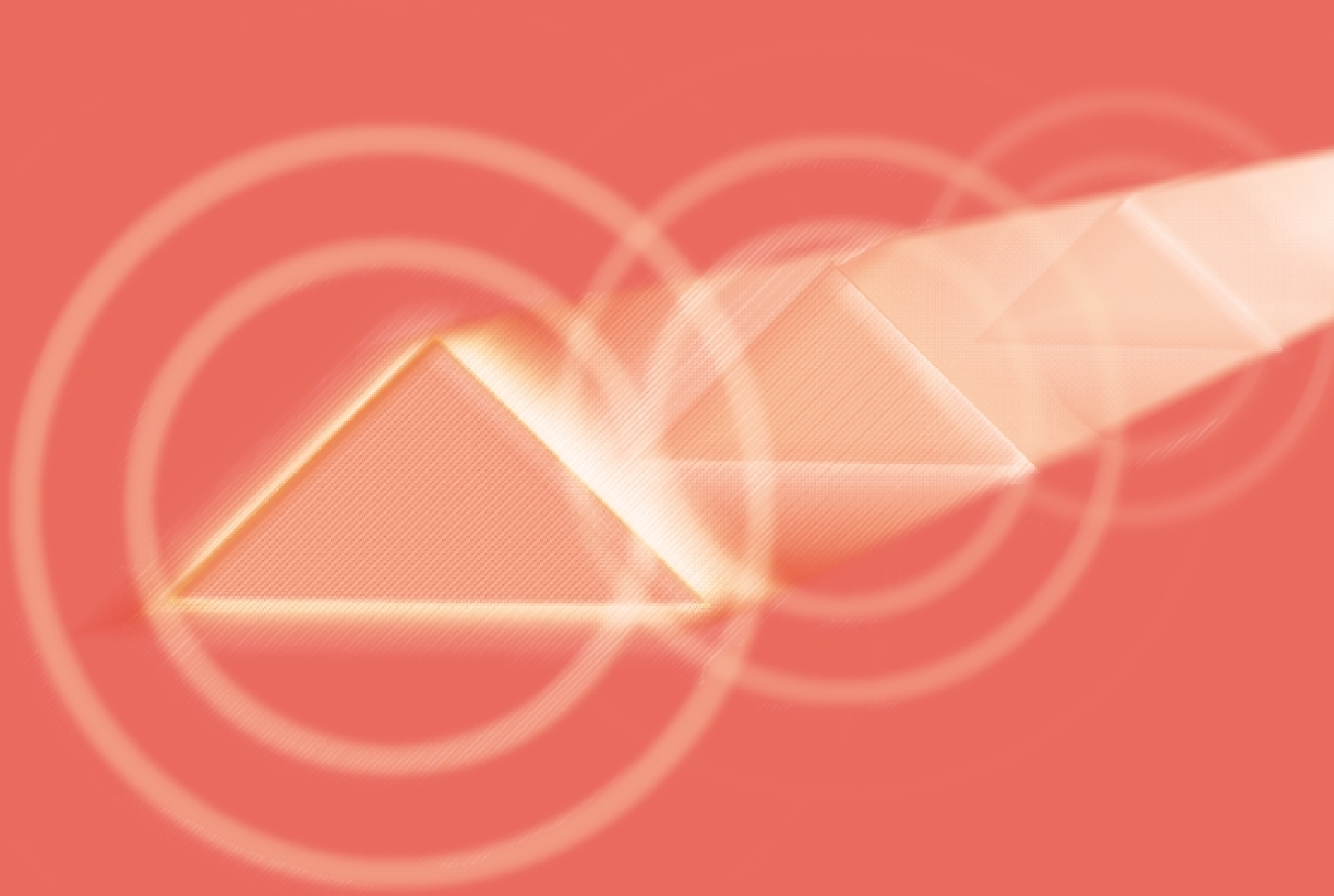
(2) *Competitiveness*: overseeing the removal of barriers to the creation of a competitive and responsive EU energy market will assist in meeting the wider objectives enshrined in the Treaties of the Community (e. g. competitiveness, employment, regional development, social cohesiveness, health, and sustainable development). Monitoring compliance with Gas and Electricity Directives, securing reductions in State Aids, co-ordinating national approaches to economic and environmental regulation of liberalised energy markets, and ensuring all final consumers are permitted the choice of energy supplier will therefore be necessary.

(3) *Cleaner, more efficient energy use*: continued development of **integrated policies** within the EU and globally is required, in view of the very wide range of environmental impacts imposed by energy production, transportation, conversion and use. In this context, it will be important to share the burden of higher expectations for reducing emissions across all relevant sectors particularly energy, commerce, industry, transportation and domestic consumers. The energy sector can play its part; but this must be co-ordinated with contributions from all other end-use sectors and applications. Lower real energy prices are expected to reduce incentives. Thus a wide range of other policy measures will be required: regulations; voluntary agreements; R&D, technology diffusion and technology transfer; equipment labelling and performance standards; taxes and subsidies; the newer flexibility instruments (emissions trading, joint implementation and the clean development mechanism). These measures should work with the grain of the market and thus stimulate (and not just penalise) energy users.

(4) *The Policy Approach*: given huge uncertainties about future EU and global developments over the next 20-30 years, **flexibility in policy making will be required**. A powerful lesson of the past is that established conventional wisdoms can (and will) be overturned all too easily. In particular, it is for the EU to identify where it is best placed to make a value-added contribution in consultation with Member States, local and devolved governments, numerous stakeholders and other actors. Greater consistency in future policy making – especially between the economic (or market conduct) and environmental regulatory regimes – is essential. Both on the demand and supply sides, the energy system of industrialised countries is characterised by long lead times, long asset lives and huge sunk investment. Whilst this implies that system inertia is considerable, it does not mean that progress is impossible. The skill in policy making will be to stimulate incentives, encourage initiatives and to provide stable, but demanding, regulatory frameworks. Such frameworks are most likely to emerge on the basis of co-operation, effective policy co-ordination, extensive dialogue with a wide range of key stakeholders and the utilisation of broad-based, multi-disciplinary analytical capabilities. This transition in policy making is likely to require **a period for searching and learning**. This will permit further analysis and dialogue as to which key elements of policy need to be revised and the most effective ways in which they can be integrated in new transparent and coherent policy frameworks.

The new challenges of the next decade are analysed in greater detail in Chapters 3 to 7. This is to help identify the relevant policy issues at the Community level, also taking into consideration the contextual situations in the Member Countries and the major shaping and driving factors arising from global developments.

PART III RECENT EU AND GLOBAL ENERGY MARKET TRENDS



The present situation and past trends of the energy system of the European Union, but also of the world regions, are useful and important pieces of information for analysing possible energy futures and designing new policies. To reflect on this basis of knowledge is the objective of this Chapter 3. Data on energy demand are mostly reported back to the basis of 1985, a time when the high energy price period from 1973 ended and the low energy price period of today began.

3.1 EUROPEAN ENERGY CONTEXT: PRESENT POSITION AND TRENDS

This section presents the current state and recent trends of the European energy system as background for the understanding of both, the results of the energy outlook presented in Chapters 4 and 5, and of the policy analysis (see Chapters 6 and 7). In the spirit of Shared Analysis, the material presented here is extracted from the "Annual Energy Review 1999" being published as a special issue of "Energy in Europe"[3].

3.1.1 PRIMARY ENERGY DEMAND AND SUPPLY

The European Union is the second largest energy-consuming regions in the world (see Table 3-1). In 1997, it used 1,407 Mtoe, or about 30 % of total OECD primary energy consumption and about 15 % of world consumption. The energy demand of the European Union increased slightly by a yearly average of 1.0 % over the period 1990-97[4] , with a period of relative stability between 1990-94, due to the economic recession in 1992-93 and the rapidly shrinking energy demand in the former German Democratic Republic. But primary energy use rebounded during 1995-96 due to economic growth and colder weather conditions in 1996. The resulting increase reached 3 % per year between 1994 and 1996. In 1997, energy consumption declined slightly by -0.3 % because of the mild weather.

The European Union has continuously decreased its primary energy/GDP ratio for decades; between 1985-97, the average annual change was -1.1 %. Differences of cold and warm weather may change the primary energy/GDP ratio by 2 %, which was the case in 1996 compared to 1995. The long-term trend of changes in the energy/GDP ratios varies among the different energy sectors. The EU industry reduced its primary energy/GDP ratio by 2.2 % per year on average since 1985 and the tertiary /domestic sector by 1.6 % per year, due to improved energy efficiency and structural changes in favour of less energy-intensive industry branches. Despite a continuous increase in thermal production, the power sector managed to stabilise its primary energy/GDP ratio since 1990, thanks to important efficiency gains and declining growth of electricity demand (see Chapter 3.1.3). On the other hand, until now, the transport sector has continuously increased its primary energy/GDP ratio by +0.7 % per year on average since 1985, although the first signs of stabilisation seem to appear since 1993.

TABLE 3-1: PRIMARY ENERGY DEMAND IN WORLD REGIONS, 1985-1997

	Mtoe				Annual growth rates (%)			Shares (%)			
	1985	1990	1995	1997	1985/ 1990	1990/ 1995	1990/ 1997	1985	1990	1995	1997
Western Europe	1286	1363	1413	1460	1.2	0.7	1.0				
European Union	1241	1314	1363	1407	1.2	0.7	1.0	16.1	15.3	15.1	14.9
EFTA	45	49	51	53	1.5	0.9	1.2	0.6	0.6	0.6	0.6
Rest of OECD	2578	2852	3124	3246	2.0	1.8	1.9				
NAFTA	2086	2260	2454	2542	1.6	1.7	1.7	27.1	26.4	27.1	26.9
OECD Pacific	452	540	607	633	3.6	2.4	2.3	5.9	6.3	6.7	6.7
Central and Eastern Europe	371	333	280	289	-2.1	-3.5	-2.0	4.8	3.9	3.1	3.1
CIS (1)	1272	1348	956	911	1.2	-6.6	-5.4	16.5	15.7	10.6	9.6
Africa	322	364	408	425	2.5	2.3	2.3	4.2	4.2	4.5	4.5
Middle East	191	237	296	329	4.4	4.5	4.8	2.5	2.8	3.3	3.5
Asia	1378	1732	2175	2351	4.7	4.7	4.5	17.9	20.2	24.0	24.9
Latin America	302	339	401	436	2.3	3.4	3.6	3.9	4.0	4.4	4.6
World	**7700**	**8568**	**9051**	**9447**	**2.2**	**1.1**	**1.4**	**100.0**	**100.0**	**100.0**	**100.0**

(1) Community of Independant States, including Baltic countries for statistical reasons

Source: European Commission, Annual Energy Review 1999

[3] European Commission, forthcoming publication.

[4] A comparison of the energy consumption in 1990 and 1997 eliminates the influence of differences in climate due to the comparable weather conditions during these two years for Europe as a whole.

TABLE 3-2: PRIMARY ENERGY DEMAND AND CO_2 EMISSIONS, EU15 (1985-1997)

	Mtoe				Annual growth rates (%)			Shares (%)			
	1985	1990	1995	1997	1985/ 1990	1990/ 1995	1990/ 1997	1985	1990	1995	1997
Total	**1241**	**1314**	**1363**	**1407**	**1.2**	**0.7**	**1.0**	**100.0**	**100.0**	**100.0**	**100.0**
Solid fuels	316	301	238	222	-1.0	-4.6	-4.3	25.5	22.9	17.4	15.8
Oil	512	545	576	588	1.2	1.1	1.1	41.3	41.5	42.3	41.8
Natural gas	198	222	273	302	2.3	4.2	4.5	16.0	16.9	20.1	21.5
Nuclear	147	181	201	213	4.2	2.1	2.3	11.9	13.8	14.8	15.1
Hydro & Wind	24	22	25	26	-1.8	2.5	2.2	2.0	1.7	1.9	1.9
Other energy sources	43	42	49	57	-0.2	3.0	4.3	3.4	3.2	3.6	4.0
Total CO_2 emissions (Mt CO_2)	2992	3076	3043	3047	0.6	-0.2	-0.1				

Source: European Commission, Annual Energy Review 1999

Total **oil demand** has steadily increased by 1.1 % yearly since 1990 in (see Table 3-2). The growth in consumption reached 34 Mtoe in the transport sector on a total of about 50 Mtoe, excluding statistical differences and 16 Mtoe for non-energy uses. This means that the European oil market is becoming increasingly dependent on two sectors (transport and petrochemicals) which accounted for 63 % of total demand in 1997. In other sectors or end-uses, oil as a fuel for power generation, space heating and process heat is declining and being replaced mainly by natural gas throughout Europe.

Primary consumption of **natural gas** increased by about 4.5 % per year on the average since 1990, demonstrating continuous growth. Increases were spectacular in three main markets; the power sector (+91 % or + 33 Mtoe), the tertiary/domestic sector (+31 % or +30 Mtoe) and industry (+17 % or +11 Mtoe). Resource availability, government energy policy and infrastructure development, all favoured increasing use of natural gas. Environmental and climate change policy also encourages gas use. Privatisation of the electricity sector and the ensuing widespread development of independent power production add another dimension of policy encouraging expanded gas use. Growth in natural gas demand is being accompanied by increased activity in terms of gas infrastructure, which will enable customers to diversify suppliers.

The use of **solid fuels** decreased in most Member States and sectors over the 1990-97 period. The slow down was particularly noticeable in France, Germany and the United Kingdom, all three historically identified as hard coal mining countries. They absorbed about 75 % of total European coal consumption in 1985 and still 71.3 % in 1990. The in-depth restructuring of the hard coal mining industry has suppressed protected markets in these countries and opened the door to competition from gas and oil products as well as from nuclear energy and imported coal. Consequently, the reduction in solid fuel use was 35 % in these three countries since 1990, one of the main reasons being the dramatic decline of lignite use in East Germany. In 1997 their share was limited to 62.7 % of total European consumption. On the contrary, since 1990, coal consumption has slightly increased in Denmark, Finland, Greece and Portugal due to imported coal mostly used in power generation and/or the iron making sector.

Nuclear energy increased gradually from 11.9% of total primary energy demand in 1985 to 13.8 in 1990 and 15.1% in 1997. The share of **hydro & wind** remained fairly stable, although this hides the strong growth in wind energy. The other energy sources (which include geothermal, other renewable energy sources - mainly biomass - and net imports of electricity) have grown from 3.4% in 1985 to 4% in 1997.

PRIMARY ENERGY SUPPLY

Domestic production of primary energy in the European Union as a whole seems to have slightly increased by 0.3 %/a with some fluctuations since 1985 (see Table 3-3). The different forms of primary energy carriers, however, showed substantial differences in their growth pattern during this period.

- Domestic production of **solid fuels** declined progressively until 1995 (a reduction of about 34 % since 1990), and seem to stabilise thereafter. This development was mainly due to the fast decreasing production of lignite in East Germany.
- **Oil production**, hit by a significant decline between 1985 and 1990 in EU Member States, showed an annual increase of 6.4 % between 1990 and 1995, driven by the application of more efficient and economical methods for offshore exploitation and reached a new peak in 1995. Despite a period of low oil prices, reduced production costs (from the development of offshore technologies such as floating platforms) maintained small field development profitable. Consequently, satellite developments from existing fields have been a significant contributor to an enlarged European production in the North Sea.
- **Natural gas** and nuclear energy became the main domestic sources of primary energy in the EU (23.9 % and 27.9 % of total primary production in 1997 respectively), with a continuous increase of 4.6 % and 2.3 % per year respectively over the period 1990-1997.

TABLE 3-3: PRIMARY ENERGY PRODUCTION AND ENERGY IMPORT DEPENDENCE, EU15 (1985-1997)

	Mtoe				Annual growth rates (%)			Shares (%)			
	1985	1990	1995	1997	1985/ 1990	1990/ 1995	1990/ 1997	1985	1990	1995	1997
Primary Production	735.2	703.3	738.2	761.5	-0.9	1.0	1.1	100.0	100.0	100.0	100.0
Solids	239.4	209.9	138.0	126.3	-2.6	-8.0	-7.0	32.6	29.8	18.7	16.6
Oil	150.9	117.0	159.7	158.3	-5.0	6.4	4.4	20.5	16.6	21.6	20.8
Natural gas	131.9	132.9	166.6	182.2	0.2	4.6	4.6	17.9	18.9	22.6	23.9
Nuclear	147.4	181.4	201.2	212.6	4.2	2.1	2.3	20.0	25.8	27.3	27.9
Hydro & Wind	24.4	22.3	25.3	26.0	-1.8	2.5	2.2	3.3	3.2	3.4	3.4
Geothermal	1.8	2.2	2.5	2.8	4.4	2.6	3.5	0.2	0.3	0.3	0.4
Other renewable energy sources	39.5	37.6	44.9	53.3	-1.0	3.6	5.1	5.4	5.3	6.1	7.0
Import dependence (%)	41.5	47.7	46.6	47.7							

Source: European Commission, Annual Energy Review 1999

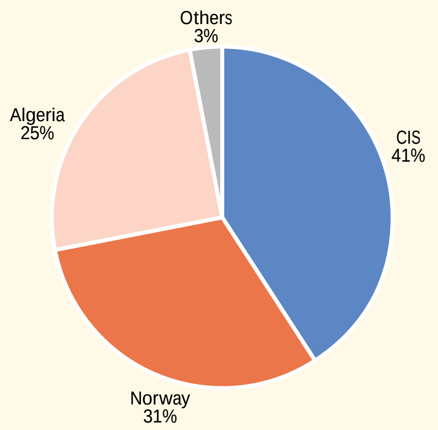
The recent increase in natural gas production has been most impressive (+4.4 % in 1995, +13.2 % in 1996) reaching 189 Mtoe or 209.6 bcm in 1996. This trend was mainly sustained by the United Kingdom, the first European gas producer since 1997, which has almost doubled its production since 1990, and by the Netherlands, which play the role of a swing producer[5] from their major Groningen gas field characterised by very low production costs.

- For its part, **nuclear energy** also performed well with production increasing as mentioned above by 2.3 % on average, while average capacity growth reached only 0.9 % during the 1990-1997 period. This implied an increasing utilisation rate that now exceeds 80 % for the European Union as a whole - one of the best plant operating performances in the world.
- In 1997, the contribution of **renewable energy** sources represented 10.8 % of total primary energy production in the Community and 5.8 % of gross inland consumption respectively[6]. Hydroelectricity and wind energy remained quite stable since 1995, and represented only 3.4 % of the primary production. Increasing production issued from wind power compensated a relative slowdown of hydro production linked to the poor hydraulic conditions these last years. Geothermal energy remained globally marginal. Finally, biomass (including refuse) whose use grew both for power generation mainly in the northern countries and for direct use mainly in the domestic sector showed an accelerating progression since 1990 to reach 7 % of total primary production in 1997. The situation, as regards renewable energy sources, varies widely from Member State to Member State. Renewable energy sources are mainly used in Sweden, Austria, Finland and Portugal with a national share of gross inland consumption ranging between 16 to 27 %. They are also used significantly in Denmark, Italy, France, Spain, and Greece, with a share of between 5 and 8 %. Their use remained almost negligible in the other Member States.

ENERGY IMPORT DEPENDENCY OF THE EU

The **energy import dependence** of the European Union as a whole has fluctuated since 1985 in parallel with domestic production: from 41.5 % in 1985, it increased to 49.8 % in 1992 to reach a level of 47.7 % in 1997, as in 1990 (see Table 3-3). Net imports of energy in the Union amounted to 691 Mtoe in 1997, and increased by 1.0 %/a on average since 1990.

FIGURE 3-1: SUPPLIERS OF NATURAL GAS TO THE EUROPEAN UNION, 1996



Source: European Commission, Annual Energy Review 1999

[5] The Netherlands reduced their gas production by 12 % in 1997 when confronted with a declining European demand due to warm weather conditions.

[6] A jump in the contribution of renewables to primary energy production from 1996 to 1997 is due to changes in the statistical conventions for renewables in some larger EU Member States.

For **solid fuels** some 44 % of total needs were covered by external suppliers in 1997 (24 % in 1985 and 29 % in 1990) reflecting the changed policy to reduce the state aid of EU Member States for expensive domestic coal production. In terms of **crude oil**, the European Union depended on external supplies for as much as 80 % in 1997 (75 % in 1985 and 85 % in 1990), including requirements for maritime bunkers. This mainly concerned crude oil, as net imports of oil products were quite marginal in 1997. The external dependency of the European Union on **natural gas** was 41 % in 1997 (35 % in 1985 and 42 % in 1990). The shares of the three major suppliers are around 40 % for CIS, 30 % for Norway and 25 % for Algeria (see Figure 3-1).

3.1.2 FINAL ENERGY DEMAND BY SECTOR

The year 1997 is of particular interest in the sense that it presents similar weather conditions as in 1990. In that way a lot of comparisons, mainly regarding energy and environment indicators, can be made excluding any distortion due to climatic variations. Since 1990, final energy demand has increased on average by 1.1 %/a while GDP growth was 1.6 %/a implying an elasticity of about 0.69 (see Table 3-4). In 1997 final energy demand in the European Union (930 Mtoe) declined by 0.8 % compared to 1996, mainly due to warmer weather conditions inducing a 12 % decline of degree-days. This compensated the increasing consumption induced in industry and transport by the sustained economic growth. The major developments thus, concerned the heating fuels with natural gas leading the way with a 5.2 % decline in consumption, followed by heating gas oil with a reduction by 4.5 %, solid fuels by 1.7 % and district heat by 1.3 %.

INDUSTRIAL SECTOR

Energy consumption in industry shows a contrasted evolution with three specific periods. During the second part of the 80's energy consumption remained stable, the 15 % increase of industrial production being compensated by energy efficiency and long-term structural change to less energy-intensive industrial structures. Between 1990 and 1994 energy consumption declined by 1.6% per year on average pushed by energy efficiency measures and declining industrial production. Since 1994, energy consumption grew at 1.6 % per year on average while industrial production increased by 2.0 % on average. Between 1985 and 1995, industrial production grew on average by 1.6 % per year, followed by a stabilisation in 1996 (+0.1 %) and a growth of 4 % in 1997 while energy consumption in 1985-1997 remained rather stable. Consequently the energy intensity improved by about 24 % since 1985. The recent evolution demonstrated that a sustained industrial production favoured additional intensity gains. This can be a consequence of higher utilisation rate of capacities conjugated with the continued development of small and medium-sized specialised in high value-added products (electronics, information technology, bioengineering etc.). The analysis of the energy intensity is complex: technological improvements happened but at the same time structural changes took place. The restructuring of the European industry continued and induced a further reduction of activity in energy-intensive branches, such as iron and steel, chemicals and non-metallic minerals.

In terms of **fuel mix**, significant changes have occurred since 1985 with the declining contribution of solids (1985: 23.9 % and 1997: 14 %). Coke consumption is decreasing below average at a rate of 1.9 %/a whereas hard coal and lignite consumption has declined by

TABLE 3-4: FINAL ENERGY DEMAND BY FUEL AND BY SECTOR, EU15 (1985-1997)

	Mtoe				Annual growth rates (%)			Shares (%)			
	1985	1990	1995	1997	1985/ 1990	1990/ 1995	1990/ 1997	1985	1990	1995	1997
Total Final Energy Demand	822.1	861.7	899.2	930.6	0.9	0.9	1.1	100.0	100.0	100.0	100.0
by fuel											
Solids	101.4	80.1	49.1	45.9	-4.6	-9.3	-7.6	12.3	9.3	5.5	4.9
Oil	373.6	396.8	419.6	430.1	1.2	1.1	1.2	45.4	46.0	46.7	46.2
Gas	161.4	178.2	205.7	215.9	2.0	2.9	2.8	19.6	20.7	22.9	23.2
Electricity	136.3	156.0	169.4	176.6	2.7	1.7	1.8	16.6	18.1	18.8	19.0
Heat	16.0	16.9	19.5	20.8	1.1	2.8	3.0	1.9	2.0	2.2	2.2
Renewable energy sources	33.3	33.7	36.0	41.3	0.2	1.3	3.0	4.1	3.9	4.0	4.4
by sector											
Industry	264.1	264.9	258.4	262.6	0.1	-0.5	-0.1	32.1	30.7	28.7	28.2
Transport	202.8	253.8	275.7	288.6	4.6	1.7	1.9	24.7	29.5	30.7	31.0
Tertiary-Domestic	355.0	342.6	364.7	379.0	-0.7	1.3	1.5	43.2	39.8	40.6	40.7

Source: European Commission, Annual Energy Review 1999

7.5%/a. Natural gas and electricity, which show a growth rate of about 2.2 % and 1.5 % respectively per year in the period since 1985, largely dominated the industrial energy market. Overall, the resulting shares of final energy changed over the period 1985-97 as follows: the share of oil decreased from 21 % to 17 %, while gas and electricity saw their shares increasing from 25 % to 33 % and 23 % to 28 % respectively.

TRANSPORT

Energy consumption in the transport sector grew between 1985 and 1997 at an average annual rate of 3 %. But in the period 1990-97, the growth was reduced to 1.9 %/a. In 1997, total energy demand in the transport sector (excluding marine bunkers) reached 289 Mtoe or 31 % of total final energy demand of the EU compared to only 24.7 % in 1985. This underlines the predominant contribution of the transport sector to the growth of final energy demand. Between 1985 and 1997, the increase of energy consumption for transport, about 86 Mtoe, represents 80 % of the total increase of final energy demand. But between 1990 and 1997, transport contributed 50 % to the total increase of final energy demand, the difference being absorbed by the tertiary-domestic sector. Since 1993 energy demand grew more slowly than before, and the energy intensity, measured against the GDP, diminished.

The volume of passenger traffic in the European Union has grown more rapidly than the overall economy since the beginning of the 1980s. This development has been largely uniform across most of the European countries. However, there has been a significant slowdown in the annual growth of passenger traffic in the 1990s when compared to the 1980s (2 % in the 1990s as opposed to 3.2 % in the 1980s). The volume of work-related traffic (journeys between home and workplace, university or school as well as business trips) has remained fairly constant. By contrast, leisure travel (attending leisure events, weekend excursions, holiday trips etc) has risen rapidly in recent years.

Freight transportion followed a path opposite to passenger transport. During the 1980s traffic increased on average by 1.9 %/a with a major expansion of road traffic that reached 4.0 %/a on average. Since 1990, as a consequence of the just-in-time industrial organisation to reduce stocks and working capital, goods transport increased by 2.8 % per year on average. Road transport grew by 29 % these last seven years, followed by (intra European Union) sea transport with a 22 % increase and inland waterways with a 10 % increase. At the same time the contribution of rail declined by 7 %.

Within the transport sector, **road transport** is the largest energy consuming sub-sector, accounting for about 83 % of total energy demand since 1985. The energy and environmental implications of road transport are increasing because the expected growth in traffic volumes is likely to more than offset the expected energy efficiency improvements in vehicle performance. Also, the rate of car ownership is steadily increasing, however at reduced speed: the number of cars in the European Union has increased by about 3 % per year on average since 1985, but only by 2.1 % since 1990. In addition, larger engines (over 1500 cubic centimetres) have increased their share of new registrations at the expense of smaller cars.

The share of diesel in total road consumption has increased continuously since 1980, growing from 36.7 % to reach 47.4 % in 1997. This evolution resulted from two main phenomena: the increasing volume of goods transported by road and the progressive increase of the share of diesel cars in the car fleet (reaching around 15 % in 1995).

The demand for aviation fuel grew on average by 4.6 %/a between 1985 and 1997, as a result of rising real incomes implying increasing leisure air travel combined with the recent liberalisation of air market that induced spectacular reductions in tariffs. These last two years kerosene consumption increased respectively by 5.7 % in 1996 and 4.9 % in 1997.

The **transport energy intensity** grew continuously by 1.5 % between 1985 and 1993, but has declined since then by 0.8 % per year on average. Without statistical disaggregation of private and freight transport, however, it is currently not possible to analyse in detail the determinants of this new trend. Many factors already described contribute to this evolution: the slowdown of the growth of passenger traffic associated with a stabilised contribution of the road traffic, technological improvement of the car fleet, the accelerated contribution of road for good transportation which was partially compensated for by a better utilisation of the goods vehicles and also technological improvement to increase efficiencies and reduce emissions.

DOMESTIC AND TERTIARY SECTORS

In 1997, the domestic and tertiary sectors used around 41 % of total final energy demand, almost the same proportion as in 1985 despite the warmer weather. **Energy consumption in the domestic and tertiary sectors** increased yearly by 0.5 % on average since 1985 under the pressure of a few continuously growing energy end-uses (e.g. electrical appliances, office automation) and growing living standard (e. g. more central heating and increasing dwelling or office size per capita). In fact, energy consumption in these sectors, although a function of population, number of households, private income and evolution of the services sector, is also highly dependent on weather conditions (space heating) and thus presents some marked fluctuations reflecting prevailing weather conditions. From this point of view it is very pertinent to compare 1997 with 1990 presenting similar climatic conditions. It must be stressed that between these two years energy consumption increased by 10.6 %, the tertiary-domestic sector contributing to 50 % of the total increase of final energy demand. Available statistics indicate that the energy consumption of the domestic sector has increased by 8.9 % since 1990 while tertiary consumption has grown by 14.4 %.

In terms of **fuel mix**, solid fuel use dropped by 77 % since 1985, and represents only 2 % of today's total energy demand. Heating oil demand dropped throughout the whole period but presented wide fluctuations due to weather conditions and stock variations, and still covers 27 % of the total demand in 1997 (compared to 34 % in 1985). Gas and electricity slowly increased their market shares to cover 34 % and 26 % respectively of the total energy demand of this sector in 1997 (compared to 27 % and 20 % in 1985). Since 1990, gas consumption increased by 3.6 % per year on average, gaining a substantial market share on the heating market to the detriment of heating gas oil and solids. Electricity demand which grew during the second part of the 80's at the same rate than the GDP increased 50 % faster than GDP since 1990. District heat progressively increased its market share and covers now more than 4 % of the total energy demand. The share of renewable energy remained stable at around 6 % since 1985.

3.1.3 ELECTRICITY DEMAND AND GENERATION

Electricity consumption, since 1985, shows an average increase of 2.2 %/a but the long-term trend of this growth was clearly oriented towards a progressive slowdown. During the second part of the 1980s, electricity growth still reached 2.7 % per year on average but this evolution must be compared to an average GDP growth of about 3.1 % per year. In the beginning of the 1990s a slower growth (1.3 %) was registered due to the economic slow-down of 1992-93. In 1995 and 1996, sustained by economic activity and colder weather conditions, electricity demand growth reached 2.6 % per year on average. In 1997, despite higher economic activity enhancing growth, warmer weather conditions limited the growth to 1.6 %. Consequently the average growth of electricity demand since 1990 reached 1.8 %/a to be compared to a GDP growth of 1.6 %/a. This means that the long-term elasticity of electricity demand versus GDP is now close to 1. The share of electricity in final energy demand increased significantly at the EU level from 16.6 % in 1985 to 18.1 % in 1990 and 19 % in 1997.

In 1997, **electricity generation** in the European Union reached 2,422 TWh (see Table 3-5), showing an average growth of 1.7 % since 1990. Despite a very limited increase in generating capacity since 1990 coming partly from capacity extensions in existing units when replacing steam generators, nuclear production showed the fastest growth (2.6 % per year on average since 1990). Its contribution reached a little over 35 % of the total electricity production in 1997 compared to just 30 % in 1985. The utilisation factor of nuclear units has increased continuously over the past ten years to reach 80 % on average at the European level.

Hydro and wind power together increased their production by 2.2 % per year on average since 1990 to generate 13 % during 1997. Since 1990 wind production has been multiplied by 10 but its contribution only represented 0.3 % of total production even if some European countries are amongst the largest world contributors: Germany, Denmark and Spain for example. Thermal electricity production showed a slower annual growth of 1 % on average since 1990, but still represented about 51 % of the total electricity generation in 1997 (54 % in 1990). Short-term evolutions demonstrate that nuclear contributed for the major part (about 50 %) of incremental production followed by thermal electricity generation (about 30 %) and hydro (about 20 %).

In 1997, the installed capacity for electricity generation was about 556 GWe, of which 56 % consists of thermal plants; the rest is divided between nuclear power stations, hydro and wind power plants.

TABLE 3-5: ELECTRICITY GENERATION AND GENERATING CAPACITIES, EU15 (1985-1997)

	Mtoe				Annual growth rates (%)			Shares (%)			
	1985	1990	1995	1997	1985/1990	1990/1995	1990/1997	1985	1990	1995	1997
Electricity Generation in TWh	1917	2156	2328	2422	2.4	1.6	1.7	100.0	100.0	100.0	100.0
Nuclear	575	720	810	860	4.6	2.4	2.6	30.0	33.4	34.8	35.5
Hydro & wind (including pumping)	299	276	314	323	-1.6	2.6	2.2	15.6	12.8	13.5	13.3
Thermal	1043	1159	1204	1240	2.1	0.8	1.0	54.4	53.8	51.7	51.2
Generation Capacity in GWe	481	523	539	556	1.7	0.6	0.9	100.0	100.0	100.0	100.0
Nuclear	87	117	120	124	6.0	0.5	0.9	18.1	22.3	22.2	22.3
Hydro & wind	103	112	118	120	1.5	1.0	1.1	21.5	21.4	21.8	21.6
Thermal	290	295	302	311	0.3	0.5	0.8	60.4	56.3	56.0	56.0
Average Load Factor in %	46	47	49	50	0.7	0.9	0.8				

Source: European Commission, Annual Energy Review 1999

TABLE 3-6: FUEL INPUTS FOR THERMAL POWER GENERATION, EU15 (1985-1997)

	Mtoe				Annual growth rates (%)			Shares (%)			
	1985	1990	1995	1997	1985/ 1990	1990/ 1995	1990/ 1997	1985	1990	1995	1997
Fuel Inputs for Thermal Power Generation	248.5	269.5	272.0	270.4	1.6	0.2	0.0	100.0	100.0	100.0	100.0
Solids	170.4	182.2	161.9	149.4	1.4	-2.3	-2.8	68.6	67.6	59.5	55.3
Oil	40.4	42.5	43.6	38.4	1.0	0.5	-1.4	16.3	15.8	16.0	14.2
Gas	30.1	36.6	55.2	69.8	4.0	8.6	9.7	12.1	13.6	20.3	25.8
Geothermal	1.7	1.9	2.1	2.4	2.0	2.7	3.9	0.7	0.7	0.8	0.9
Biomass	5.8	6.3	9.1	10.3	1.7	7.6	7.2	2.3	2.4	3.4	3.8
Average Thermal Efficiency in %	**36.1**	**37.0**	**38.1**	**39.4**	**0.5**	**0.6**	**0.9**				

Source: European Commission, Annual Energy Review 1999

Since 1990, installed capacity has increased by 33 GWe. New capacity, excluding repowering and conversion of existing units, represents about 57 GWe, of which: 9.4 GWe of nuclear units, 4.7 GWe for hydro power, 4 GWe for wind power plants, about 25 GWe of combined cycle units, 6.8 GWe of gas turbines and 3.2 GWe of internal combustion engines. About 50 % of combined cycle capacity was still located in the United Kingdom, although this technology is expanding rapidly in many other EU countries.

Concerning the **fuel mix in thermal power stations** (see Table 3-6) solid fuels remain the first contributor (55 % of total energy input in 1997 down from 68 % in 1990). Oil consumption, slowly increasing during the period 1990-95, declined by 4.5 % in 1996 and by 7.7 % in 1997. The share of oil declined from 15.8 % in 1990 to 14.2 % in 1997. The progression of gas consumption was very spectacular since 1990. Its share in fuel inputs quite doubled in seven years, growing from 13.6 % in 1990 to 25.8 % in 1997. Gas consumption grew by 4.0 % per year on average between 1985 and 1990 and by 9.7 % since 1990. This evolution was even accelerating with a growth by 26 % the last two years. As fuel inputs remained quite stable since 1990, this means that about 33 Mtoe of solid fuels have been substitute by gas since 1990. Although the participation of other sources (mainly urban and industrial waste) remained small (about 5 % of total inputs in 1997), their consumption, constant over the period 1985-1990, increased sharply after 1992 due to the development of incinerators and new landfill legislation in some Member States.

The last decade was also marked by the development of **combined heat and power generation**. In 1996, 9 % of total electricity production was generated in combined heat and power units. But there are substantial differences among EU member countries: The European leaders are Denmark (46 %), Finland (32 %), the Netherlands (28 %) and Austria (21 %). The low shares of co-generated electricity in France, Belgium, the UK and Southern European Member States reflect different energy policies in the past.

Replacement of out-dated units and the development of new technologies such as combined-cycle units, supercritical units and gas turbines, induced a continuous improvement of thermal efficiency of the power sector. This average efficiency, 39.4 % in 1997, was increasing by 0.9 % per year on average since 1990. This improving rate has accelerated these last two years reaching 1.2 % in 1996 and 2.3 % in 1997 as a consequence of the impressive commissioning of combined-cycle power plants.

The European electricity industry is likely to become increasingly integrated in the near future. In 1996, the Community adopted a Directive with the intention of progressively liberalising the electricity market and providing independent producers with greater access to the European power network (see Chapter 6.3).

3.1.4 ENERGY PRICES

The average **prices of energy for industrial consumers**, over the period 1997 to 1990, show an average yearly decrease of 7.1 % for steam coal, deeply influenced by the suppression of the "Kohlepfennig" in Germany in 1996, 0.1 % for heavy oil, 1.1 % for natural gas and 3.2 % for electricity considering a weighted average at the European level. In 1997, the difference between the average European price per toe of heavy fuel (€122) and natural gas (€119) diminished without reducing the important substitution operated in favour of gas. The more rapid decline of electricity prices also favoured electricity uses, increasing the competitiveness of electrotechnologies. Between Member States, the prices for the different energy sources show important discrepancies in both value and trends depending on supply conditions, market mechanisms and taxation. It must be stressed that the liberalisation of electricity and gas market in the United Kingdom resulted in impressive price reductions for both gas and electricity: 28 % for natural gas in only two years and 14 % for electricity.

Transport fuel prices increased regularly since 1990, by a yearly average of about 1 %. This growth accelerated in 1996 and 1997 as a consequence of higher crude oil prices even if the share of raw materials in final prices declined continuously under the pressure of tax increases. Large price fluctuations existed per Member State and per fuel. Furthermore, relative prices of gasoline versus diesel differed very sharply per country, inducing possible distortions in competition in the road transport sector.

Average **energy prices for the tertiary and domestic sectors** showed a general decrease since 1990 in the European Union as a whole but at contrasting rates depending on the fuel. The decrease remains limited for electricity: -1.2 %/a for the European Union as a whole with extremes going from +2.6 % in Sweden to –5.4 % in Greece. The most important price decrease concerns heating oil: -1.5 %/a on average while the average yearly decrease of natural gas prices is less significant: -0.6 % at the European level.

3.1.5 ENVIRONMENTAL TRENDS

CO_2 emissions are of primary importance in the current political debate. In general terms, CO_2 emissions in the European Union declined substantially in 1997 compared to 1996 (- 2.6 %), but were only about 1 % below the 1990 level. Since 1990, the per capita CO_2 emissions showed a reduction of 0.5 % per year on average and reached about 8.1 t of CO_2 per capita in 1997. The CO_2 emitted per unit of GDP demonstrated a more sustained reduction as it declined by about 1.7 % per year on average since 1990. These trends were favoured by the fact that the carbon intensity (t of CO_2 /toe) declined by about 1 %/a on average since 1990 due to the shift from oil and solids to natural gas and increasing use of carbon-free energies (nuclear, wind, biomass, etc).

In terms of absolute CO_2 emissions, Germany ranks first within the EU in spite of an average yearly decline of 1.9 % between 1990 and 1997 (see Table 3-7). Its share in total European CO_2 emissions reached 27 % in 1997 (34 % in 1985). The second Member State is the United Kingdom with a yearly decline of 1 % and a share at around 17 %. Italy comes third with a share of about 13 % but a yearly increase of 0.4 % on average and France fourth with a share of 12 % and a yearly growth by 0.2 %. These four Member States together accounted for 69 % of total emissions of the EU in 1997, compared to 75 % in 1985.

The short-term evolution of CO_2 emissions illustrates their sensitivity to weather changes. If the total energy consumption is corrected to take into account standard weather conditions then CO_2 emissions have been almost stable since 1990. Reduction of CO_2 emissions in industry (-10.5 % in seven years) and the power sector (-7 %) compensated an increase from the transport sector (+14 %). CO_2 emissions from all these sectors are almost independent of weather conditions. In the tertiary / domestic sector however, where energy consumption for heating dominates, CO_2 emissions are directly correlated with degree-days. The impact of temperature variations on CO_2 emissions in the tertiary / domestic sector can be estimated at +/-6 % following colder or warmer temperature extremes. The CO_2 emissions of the tertiary / domestic sector accounted for 21.1 % of total emissions in 1997, i. e. the weather effect on total CO_2 emissions can be estimated at +/-1.2 % at maximum compared to an average climate. This may be important from the perspective of the political EU objective of a stabilisation of CO_2 emissions in 2000 compared to the 1990 level.

The **stabilisation of the CO_2 emissions** corrected for weather fluctuations between 1990 and 1997 is the result of two main factors.

TABLE 3-7: ENERGY RELATED CO_2 EMISSIONS BY COUNTRY IN THE EUROPEAN UNION (1985-1997)

	Mt CO_2				Annual growth rates (%)			Shares (%)			
	1985	1990	1995	1997	1985/ 1990	1990/ 1995	1990/ 1997	1985	1990	1995	1997
Austria	51	55	57	59	1.5	0.6	1.1	1.7	1.8	1.9	2.0
Belgium	99	105	111	116	1.1	1.2	1.5	3.3	3.4	3.6	3.8
Denmark	61	53	60	64	-2.8	2.6	2.8	2.0	1.7	2.0	2.1
Finland	47	52	56	59	2.0	1.7	1.9	1.6	1.7	1.8	1.9
France	360	352	345	358	-0.4	-0.4	0.2	12.0	11.5	11.3	11.8
Germany	997	947	864	830	-1.0	-1.8	-1.9	33.3	30.8	28.4	27.2
Greece	57	71	78	79	4.6	1.9	1.5	1.9	2.3	2.6	2.6
Ireland	26	30	33	36	2.7	2.3	2.9	0.9	1.0	1.1	1.2
Italy	338	389	403	400	2.9	0.7	0.4	11.3	12.6	13.3	13.1
Luxembourg	10	11	9	8	1.2	-3.9	-3.2	0.3	0.3	0.3	0.3
Netherlands	141	153	167	169	1.6	1.7	1.4	4.7	5.0	5.5	5.5
Portugal	25	39	48	48	9.2	4.2	2.9	0.8	1.3	1.6	1.6
Spain	177	202	227	240	2.6	2.3	2.5	5.9	6.6	7.4	7.9
Sweden	58	51	54	52	-2.7	1.2	0.3	1.9	1.6	1.8	1.7
UK	544	567	531	529	0.8	-1.3	-1.0	18.2	18.4	17.5	17.3
EU-15	**2,992**	**3,076**	**3,043**	**3,047**	**0.6**	**-0.2**	**-0.1**	**100.0**	**100.0**	**100.0**	**100.0**

Source: European Commission, Annual Energy Review 1999

TABLE 3-8: ENERGY–RELATED CO_2 EMISSIONS BY SECTOR, EU15 (1985-1997)

	Mt CO_2				Annual growth rates (%)			Shares (%)			
CO_2 Emissions	1985	1990	1995	1997	1985/ 1990	1990/ 1995	1990/ 1997	1985	1990	1995	1997
Total	2992	3076	3043	3047	0.6	-0.2	-0.1	100.0	100.0	100.0	100.0
Transformation sectors	1057	1127	1091	1054	1.3	-0.6	-0.9				
Power generation	894	962	926	894	1.5	-0.7	-1.0	29.9	31.3	30.4	29.3
Other energy sector	163	165	165	160	0.2	0.0	-0.4	5.4	5.4	5.4	5.3
Final demand sectors	1935	1949	1952	1992	0.1	0.0	0.3				
Industry	613	568	517	509	-1.5	-1.9	-1.6	20.5	18.5	17.0	16.7
Transport	588	739	803	842	4.7	1.7	1.9	19.7	24.0	26.4	27.6
Domestic and tertiary	734	643	632	642	-2.6	-0.3	0.0	24.5	20.9	20.8	21.1

Source: European Commission, Annual Energy Review 1999

The increasing contribution of non-fossil fuels, mainly nuclear with smaller contributions of wind energy and biomass, and the larger penetration of natural gas both for power generation and in final energy use in substitution of solid fuels and oil products.

Looking at CO_2 emissions by sector at a European Union level (see Table 3-8), the largest sector in terms of emissions remained **power generation**. In spite of thermal production increases by 1 %/a since 1990, CO_2 emissions from the power sector declined by as much as 1 %/a on average. This resulted from both the efficiency gains in the classical conventional power stations and the development of combined-cycle power plants based on natural gas which associated high conversion efficiency with the fossil fuel having the lowest CO_2 content per unit of energy. Consequently the average thermal efficiency of thermal power stations increased by 6.5 % since 1990 and the carbon intensity (t of CO_2/toe) has been reduced by 13.2 %. The total share of emissions from the power sector declined steadily from 31.3 % in 1990 to 29.3 % in 1997.

Within the final demand sectors, **transport** was the only one with steadily increasing emissions since 1990 (1.9 % per year on average). The contribution of this sector has increased from 24 % in 1990 (20 % in 1985) to 28 % in 1997. The domestic and tertiary sectors stabilised despite the progression of natural gas and district heat on the heating market, replacing heating gas oil and solids. In fact, the development of low CO_2 content fuels (natural gas, electricity and renewable energy forms) compensated the behaviour-related factors increasing CO_2 emissions (e. g. larger heated surfaces). Industry presented the greatest decrease in CO_2 emissions since 1990 (-1.6 %/a) even if the reduction was limited to 0.8 % during the last two years.

TABLE 3-9: SO_2 AND NO_x EMISSIONS, EU15 (1990-1996)

	kt			Annual growth rates (%)		
	1990	1994	1996	90/94	94/96	90/96
SO_2	16499	11366	9856	-8,9	-6,9	-8,2
NO_x	12945	11780	11325	-2,3	-2,0	-2,2

Source: DNMI-EMEP, 1998 Major Review of Strategies and Policies for Air Pollution Abatement

Concerning other pollutant emissions, SO_2 and NO_x in particular, it can be assumed in spite of lacking complete statistical data, that the European situation is generally improving. As illustrated in Table 3-9, SO_2 emissions, of which 50 % originate from the power generation sector, are declining significantly as a result of different measures: the improvement of fuel quality by reduced sulphur content in diesel and heating oil, the environmental regulation in large industrial combustion installations and the substitution of solid fuels and oil products by natural gas. NO_x emissions are also decreasing, but to a lesser extent than SO_2 emissions under the pressure of both regulation in large industrial combustion installations (De-NO_x plants) and regulations concerning catalytic converters for new cars.

Overall, with regard to energy policy objectives, it can be said that the trends of the EU energy system supported sustainable development by diversifying energy supply, decreasing energy prices (in real terms), reducing conventional emissions, maintaining efficiency improvements and stabilising CO_2 emissions.

3.2 GLOBAL ENERGY CONTEXT: PRESENT POSITION AND TRENDS

In the 1990s, the global energy context has been marked by a number of **key trends**:

- Until the financial crisis of 1997-1998, the developing countries of Asia and Latin America accounted for most of the growth in world energy demand. After stalling in the early 1990s, with the economic decline of the FSU (Former Soviet Union) and Eastern Europe, world energy demand has started rising again. It is mainly fossil fuels that have satisfied the increasing demand, given the constraints to the development of nuclear (i. e. societal acceptance) and renewable energy (high capital costs and lack of profitability).

- Natural gas is now showing signs of becoming the fuel of choice for power generation in several world regions. The share of oil in the increase has been contained because oil demand growth is essentially governed by road and air transportation trends.
- Energy prices have been decreasing under the combined effects of technological progress in production and greater competition in the global and national energy markets.
- Contrary to conventional wisdom ten years ago, the dependence of the international oil market on OPEC and Middle East exports has scarcely increased in the 1990s. Energy security stakes have changed under the combined impact of diversification of supply and an increasingly globalised oil market.
- World-wide energy-related CO_2 emissions grew less rapidly (1.2 % per year for the period 1990-1996) than global primary energy demand.

Some of these trends have been contingent on the circumstances of the period, in particular the sharp economic decline of the successor states of the Former Soviet Union. The Asian financial crisis may have broken previous structural dynamics, while saturation effects, structural changes and prevailing efficiency improvements may be responsible for the changes observed in the 1990s in the developed economies.

3.2.1 RECENT FINANCIAL CRISIS AND WORLD ENERGY TRENDS

Before the financial crisis, the growth in world energy consumption was driven by the energy needs of the emerging countries, the latter increasing by 4.9 %/a between 1990 and 1997, compared with 1.5 %/a for the industrialised countries and 1.1 %/a for the European Union (see Figure 3-2). The share of emerging countries in world energy consumption thus increased from 29 % to 34 % over this recent period. The significant decrease in the requirements of the transition economies (about –450 Mtoe since 1990) has partially offset the increased needs of the developing economies (about +800 Mtoe).

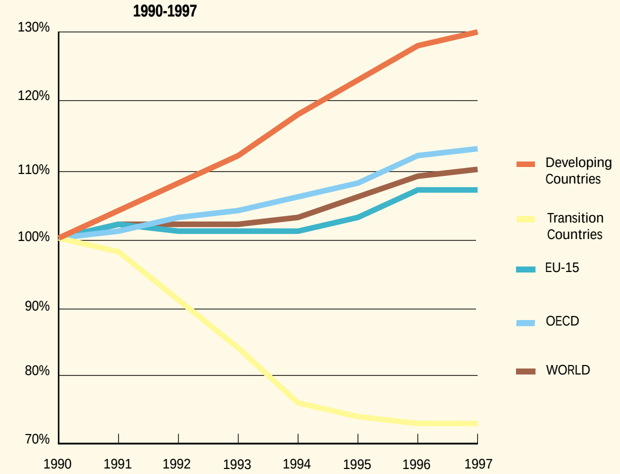
Some of the major recent trends in global energy development were interrupted by the financial crisis which occurred in certain developing Asian economies in late 1997, in Russia in August 1998 and in Brazil, in February 1999. In Russia, the economy was drawn further downward by the devaluation of the rouble and the collapse of the Russian banking system. In Asia, the deepening of the Japanese recession and the sharp decline in regional trade amplified mutual problems between Asian countries, but had only minor effects on China and India.

EASING OF PRESSURE FROM DEVELOPING COUNTRIES

The Asian financial crisis of 1998 affected the global economic situation, given that during the nineties, world economic growth has been driven essentially by the development of the emerging economies in Asia and the exceptionally steady growth of the American economy. The world-wide economic growth rate fell by a third compared with the 1990-97 period (2 %/a versus 3.2 %/a) and by half in comparison with the two preceding years (4.1 %/a; see Figure 3-3).

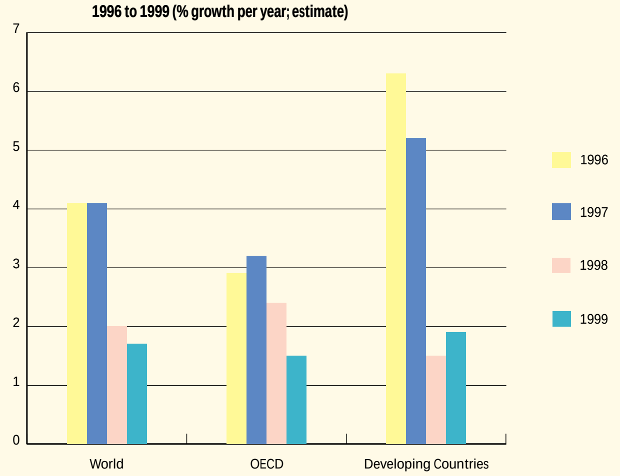
The financial crisis reduced energy consumption in the developing countries. Their oil consumption, representing half of global consumption, fell by 1.5 % in 1998, whereas it had increased by more than 4 %/a in the previous years. With the cumulative effects of the

FIGURE 3-2: Growth in primary energy consumption of world regions, 1990-1997



Source : European Commission, Annual Energy Review 1998

Figure 3-3: Economic growth rates of OECD, Developing Countries and World, 1996 to 1999 (% growth per year; estimate)



Rexecode, Paris, December 1998

economic recession, world energy consumption will be about 4 % lower in 1999 and 5.5 % lower in 2000 than it would have been without the financial crisis (according to POLES simulations).

Consequently, the price of oil decreased from 18 $/barrel to an historic low of 10 $/barrel for several months in 1998-1999. In the countries and regions concerned, sudden surplus capacities (e. g. 180 million metric tonnes refinery capacity) led to the postponement or abandonment of a range of capital-intensive projects. Power generation units, liquefied natural gas chains and pipeline transport projects in emerging Asian countries were particularly affected. Uncertainties about oil prices also caused companies to cut back exploration and development expenditures in most regions of the world in 1998.

However, this situation appears to be temporary. The present financial crises in different countries are mainly adaptation crises in a difficult-to-predict pattern of financial instability accompanying rapid economic growth amidst financial globalisation. Thus, if structural measures to facilitate macroeconomic and financial adaptation are implemented, regardless of their social costs, the economies affected will probably resume fairly rapid growth within two or three years. Thus, after a year of negative growth (with the exception of Indonesia, Malaysia, Russia, and the Ukraine) an upturn can be expected in all of these economies (see Table 3-10). With the fairly rapid economic recovery of the emerging economies, and the end of the economic decline in the transition economies, world energy consumption is likely to return soon to its former path of growth.

TABLE 3-10: PROSPECTS OF ECONOMIC RECOVERY OF ECONOMIES AFFECTED BY THE FINANCIAL CRISIS (ANNUAL GROWTH RATE), 1997 TO 2000

	1997	1998	1999	2000
Brazil	3.2	0.2	-3.8	3.7
China	8.8	7.9	6.6	7.0
Korea	5.5	-5.5	2.0	4.6
ASEAN-4*	3.8	-9.4	-1.1	3.0
World	4.2	2.5	2.3	3.4

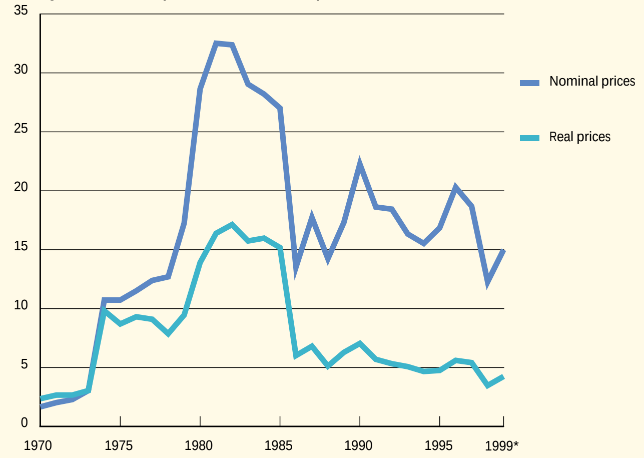
ASEAN-4: Indonesia, Malaysia, Thailand, Philippines

Sources: IMF, World Economic Outlook 1999

1998: AN EPISODE OF LOW PRICES IN A PERIOD OF MODERATE PRICES

The reduction in the oil price to 10 $/barrel, close to the pre-oil crisis level of 1973 in real terms (see Figure 3-4), was not only due to the economic crisis in Asia and Brazil. The steady increase in non-OPEC production, the resumption of Iraqi export activity and the increase of OPEC members' production quotas agreed in 1997 amplified the imbalance between oil supply and demand. However, after the limited effects of production restrictions introduced by some key OPEC and non-OPEC producers in 1998 (Saudi Arabia, Venezuela, Mexico, Norway etc.), the agreement between OPEC members in March 1999 to reduce production has enabled oil prices to more than 20 $/barrel again. But there are doubts as to the durability of the agreement in the near future, given present surplus capacities and continuing competitive forces (including increasing use of natural gas).

Figure 3-4: Oil Prices (nominal and real $/barrel), 1970 – 1998



Source : BP Amoco Statistical Review 1999

After the sharp decline in exploration and development expenditures, the upward trend of the oil price towards a level of 20 $/barrel in the third quarter of 1999 may not be strong enough to bring about a major change in the oil and gas business environment. The most striking example of this lack of confidence is the postponement of most of the oil export projects in the Caspian region. Projects in industrialised countries, and, in particular, in the North Sea, have also been scaled back.

At present, it is difficult to anticipate the situation of the international oil market once the Asian and Latin American economies have recovered which is expected to occur in 2000-2001. Two factors on the supply side can limit the possibility of a sustained price increase above the moderate level of 15-20 $/barrel. First, the technological progress which has helped non-OPEC oil supplies to erode the OPEC market share over the past decade will continue. During this time, non-OPEC oil supply has diversified increasingly: the North Sea and Mexico had already emerged as major producing areas in the 1980s, and much of the new production in the 1990s has come from the developing non-OPEC countries such as Angola, Argentina, Brazil, Columbia, China, Egypt, India, Yemen, Malaysia, Oman, Peru and Syria. These countries increased their market share in total world oil production from 13.3 % (380 Mtoe) in 1990 to 15.7 % (515 Mtoe) in 1997.

The significant reduction in exploration and production costs in difficult areas has contributed to the renewal of non-OPEC production, in spite of moderate prices. There is nothing to suggest that this effect will not continue to be felt. Moreover, non-conventional resources are becoming competitive. Second, the increasing opening up of oil upstream in the OPEC countries – particularly in the Middle East, Venezuela and Algeria – will make it even more difficult for OPEC to maintain its quota policy. Small producing countries, Ecuador and Gabon, left OPEC in 1992 and 1995 respectively to follow their divergent interests. This trend could be consolidated by Saudi Arabia, which appears to be on the verge of adopting a policy of low prices and an increasing high market share (which was limited in 1997 to 11.9 %).

3.2.2 WORLD ENERGY TRENDS

In the 1990s, world energy trends have been influenced by the growing importance of the developing countries. But, with their constant contribution of 50 % to global consumption, the ability of industrialised countries to stabilise their energy/GDP ratio, to diversify their energy mix and to develop their own resources, is likely to remain key factors in global energy trends.

FINAL ENERGY DEMAND TRENDS

The specific patterns of energy **development in the emerging economies** have been reflected in a certain number of **trends in final energy demand** since 1990.

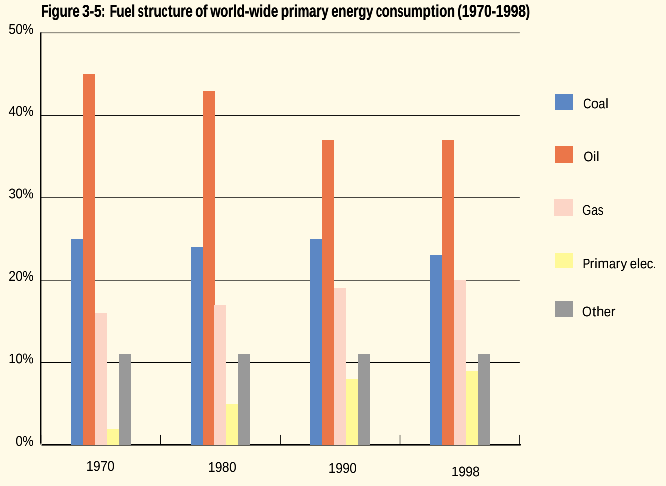
- Electricity is the most rapidly growing component of final energy demand: a growth of 2.3 %/a for 1990-1997 compared with 0.7 %/a for overall final energy. In some emerging countries, double-digit power consumption growth has accompanied the increase in revenues and industrial activities. This has made up for the small increase in electricity in industrialised economies (2 %/a). The increased share of electricity in final energy demand means that the power generation system is becoming increasingly important as a major converter of primary energy, but also as a source of greenhouse gases.
- Consumption of oil products increases essentially in relation to the development of the road and air transportation sector. The growth rate of 1.6 %/a in this sector largely reflects the high elasticity of transportation demand in response to economic growth and the very sustained increase of this demand in emerging regions (5 %/a in Asia and 3.7 %/a in Latin America since 1990).
- In sectoral terms, apart from the most dynamic sectors (domestic, tertiary and transportation), where growth is reflected in rising incomes, the global consumption of the industrial sector has been virtually stable and its share has decreased during the nineties despite the industrialisation of emerging economies. It has been supported by the sharp decline of transition economies (-6.7 %/a), as well as the effects of structural changes and technological progress (dematerialisation, new processes, etc.) in the industrialised countries. But will it continue in the future to compensate for the impact of increased industrialisation?

DEVELOPMENT PATTERNS OF PRIMARY ENERGY NEEDS

Despite low energy prices, the global trend toward reducing the energy/GDP ratio has been more marked in the 1990s (-1.2 %/a) than it was in the 1980s (-0.9 %/a). The major emerging countries (Latin America, China, South-East Asia) have shown a surprising trend (-1.8 %/a in the last sub-region), while the trend in most industrialised countries has been slower: between –0.3 %/a and –0.8 %/a for Australasia, the European Union and North America. World energy consumption per capita has remained stable during the 1990s. Alongside this evolution, trends in the energy mix have amplified the positive effects of the decrease in intensity on the global energy stakes (limitation of oil dependence, mitigation of CO_2 emission growth).

- In the 1990s, the share of **oil** in the primary energy balance has remained stable (around 37 %), with a more limited use in industry and power generation in the developing countries than was previously the case.
- The **natural gas** share has continued to grow slowly but steadily (19 % in 1985, 21 % in 1997), with increasing use in power generation and the take-off of gas consumption in the emerging economies in Asia and Latin America, where gas penetration is still low (8 % in non-industrialised Asia, 15 % in Latin America). Until the financial crisis, Asian consumption had risen by 6.7 %/a and accounted for all the growth in world trade with liquid natural gas (LNG).

Figure 3-5: Fuel structure of world-wide primary energy consumption (1970-1998)



Source : European Commission, Annual Energy Review 1999

- With a slow growth of around 1 %/a over the last 20 years, **coal** still accounts for 24 % of gross energy consumption with a slightly decreasing market share. Over half of the increase in demand has come from the electricity generation sector in developing countries and industrialised economies. In China and India, which have an increasing share in world-wide consumption (28 % in 1990, 38 % in 1997), coal is used in every sector and forms the basis of their economic development.

In electricity systems, the technology mix has benefited from the increase in non-fossil fuel power generation (2.2 %/a) which has maintained its contribution (36 %) to overall power generation. The increase in nuclear energy production in the 1990s has been made possible by better plant operating performance and the commissioning of some new reactors (30 GW). But with far fewer orders after 1980, the contribution of nuclear energy started to decline in 1997. Like nuclear energy, the development of hydroelectricity has been hampered by societal and environmental concerns, capital intensiveness and the competitiveness of other power generation techniques. In conventional electricity generation (2.5 % yearly increase in production), where natural gas has been gaining ground to the detriment of oil, solid fuels have remained dominant (around 58 % of fuel inputs). This is particularly the case of the coal-producing countries (USA, China, India, Australia, etc.), but the emergence of low-cost coal exporters (Australia, Colombia, Indonesia, South Africa, etc.) has facilitated the development of the coal trade for power generation in a growing number of importing countries.

3.2.3 INCREASING GLOBALISATION OF MARKETS

The world energy system is becoming increasingly integrated, as reflected in the more rapid increase in energy trade (34 %) than in energy consumption (8.3 %) between 1990 and 1997[7]. All the regions have contributed to this development, but the emerging Asian economies, with their poor endowment in terms of resources, have played a major role. Their energy imports have doubled and now represent 18 % of world energy imports in 1997. The share of the industrialised countries has decreased by 6 % thanks to the stabilisation of imports from other regions as a result of increased domestic production of oil (+13 % since 1990) and gas (+23 %).

World **oil trade** grew from 1,570 Mt to 2,020 Mt between 1990-1998, with an increase in imports by the USA (+118 Mt) and the developing countries (+300 Mt). The Middle East share, and more generally the OPEC share, remained stable during this period, due to the unexpected growth in non-OPEC production and exports, which kept pace with world-wide oil consumption (see Table 3-11)[8].

For importing countries, the question of oil dependence has been settled by market forces and the use by competitors of new technologies in exploration and development, which has helped increase NOPEC production. Moreover, in the new geopolitical context of **non-polarisation**, the increasing access to OPEC resources is enforcing the trend of the oil market to a commodity market and lowering the risk of dependence.

Gas trade, which has developed differently in the various regional markets because of high transportation costs, has been characterised by three major factors:
- the increasing integration of the North American market, with the growth in Canadian exports to the US market (from 26.4 Mtoe to 73.4 Mtoe between 1990-1997),
- the growth of European trade (4.4 %/a), resulting in particular from increased sales from the FSU (+10.6 Mtoe between 1990 and 1997),

TABLE 3-11: EVOLUTION OF OIL PRODUCTION AND TRADE IN THE 1990s (MT)

	OPEC production	Non-OPEC production excl. FSU	FSU production	World production	Middle East exports	World exports excl. Middle East	World Trade
1990	1,199 (37.7 %)	1,410 (41.5 %)	570.6 (17.6 %)	3,179.9	710.6 (45.2 %)	861.5 (54.7 %)	1,572
1998	1,480 (44.6 %)	1,677.6 (48.3 %)	361.3 (10.2 %)	3,518.9	935.1 (45.4 %)	1,084 (54.6 %)	2,019

Source: BP Amoco Statistical Review 1999

[7] To some extent, the increase in energy trade can be explained by structural changes (increased number of countries, in particular FSU, since 1990)

[8] Due to a decrease in internal consumption, the drop in FSU production (300 Mtoe between 1990-1997) did not result in a reduction in FSU exports.

Norway (+10.6 Mtoe) and Algeria (+ 4.4 Mtoe) to the European Union, which in the future could generate a degree of dependence on potentially unstable countries,

- the expansion of the Asian gas market (from 46.7 to 72.6 Mtoe of LNG between 1990 and 1997), with new LNG importers besides Japan (South Korea, Taiwan and, recently, the Philippines, India, China and Thailand) and new sellers outside the traditional Southeast Asian producers, in particular in the Middle East, where there are significant reserves.

World **coal trade** has developed rapidly with the establishment of low price, competitive producers (Australia, South Africa, Indonesia, Colombia and Venezuela), to the detriment of US exporters. These countries have exported increasingly to steel producers and power generating companies in all regions. As a result, trade in coke and steam coal increased from 190.4 to 248.6 Mtoe over the 1990-1997 period. Under the pressure of competition between producers, the coal market has become more integrated and is clearly influenced by price-making on the Asian markets and its effects on the other regional import markets, despite differences in costs.

3.2.4 GLOBAL ENVIRONMENT: STABILISATION OF CO_2 EMISSIONS REMAINS A DISTANT GOAL

Recent trends can shed light on the future requirements for industrialised countries to curb their CO_2 emissions and for developing countries to limit increases in emissions. The Kyoto Protocol may herald a new effort among industrialised countries to reduce their greenhouse gas emissions. But the objectives will not be easy to attain.

World-wide CO_2 emissions increased by 8 % between 1990 and 1997. If the FSU (Former Soviet Union) and CEEC (Central and Eastern European countries) are excluded, global CO_2 emissions rose by 19.6 % in the same period (2.6 %/a). This comparison highlights the significant economic decline of the FSU, which reduced its emissions by one third (corresponding to 6 % of global emissions in 1997). This drop partly offset the accelerating increase in emissions in the developing regions of the world (5.6 %/a in Asia and 4.2 %/a in Latin America since 1990) in the years prior to the financial crisis. The industrialised countries have begun to curb the growth of their emissions. It is noticeable that there has been a temporary stabilisation of emissions in the European Union, in particular due to the economic restructuring in East Germany and the power sector liberalisation in the UK. However an increase of 1.5 %/a has been observed for North America over the same period of time. The part of industrialised countries (roughly 50 %) in global emissions has thus remained stable. Obviously, compliance with the Kyoto Protocol would imply for industrialised countries to further curb their emission, involving for example a more effective reduction in energy intensity, particularly in the transport sector, and a substantial shift in the composition of energy sources away from high-carbon fuels.

In sectoral terms, the development of emerging economies has led to an increase in the contribution of the power generation sector to global CO_2 emissions (34 % in 1996 versus 28 % in 1980), due to rapid electrification and constraints to the development of non-fossil fuel electricity. At the same time, the contribution of the transport sector to CO_2 emissions has remained stable (20 % since 1980), while emissions in the industrial sector have fallen (with stable emissions between 1985 and 1995). Thus, the effects of industrialisation in the emerging countries have been completely offset by the structural changes in the economies of the industrialised countries (improvements in industrial equipment, the greater use of electricity and the move away from the most CO_2 intensive fuels).

TABLE 3-12: CHANGES IN CO_2 EMISSIONS (MT OF CO_2) OF WORLD REGIONS, 1985 TO 1997

	CO_2 Emissions			Annual Growth (%)		Shares (%)		
	1985	1990	1997*	1985-1990	1990-1997	1985	1990	1996
Industrialised Countries	9.60	10.28	11.06	1.37	1.05	51.3	49.7	49.6
of which EU	*3.08*	*3.18*	*3.17*	*0.66*	*-0.05*	*16.5*	*15.4*	*14.2*
FSU and CEEC	4.49	4.51	3.00	0.09	-5.66	24.0	21.8	13.4
Developing countries	4.61	5.87	8.25	4.96	4.99	24.6	28.4	37.0
World	18.70	20.66	22.31	2.01	1.11	100.0	100.0	100.0

* estimated values for non-OECD regions

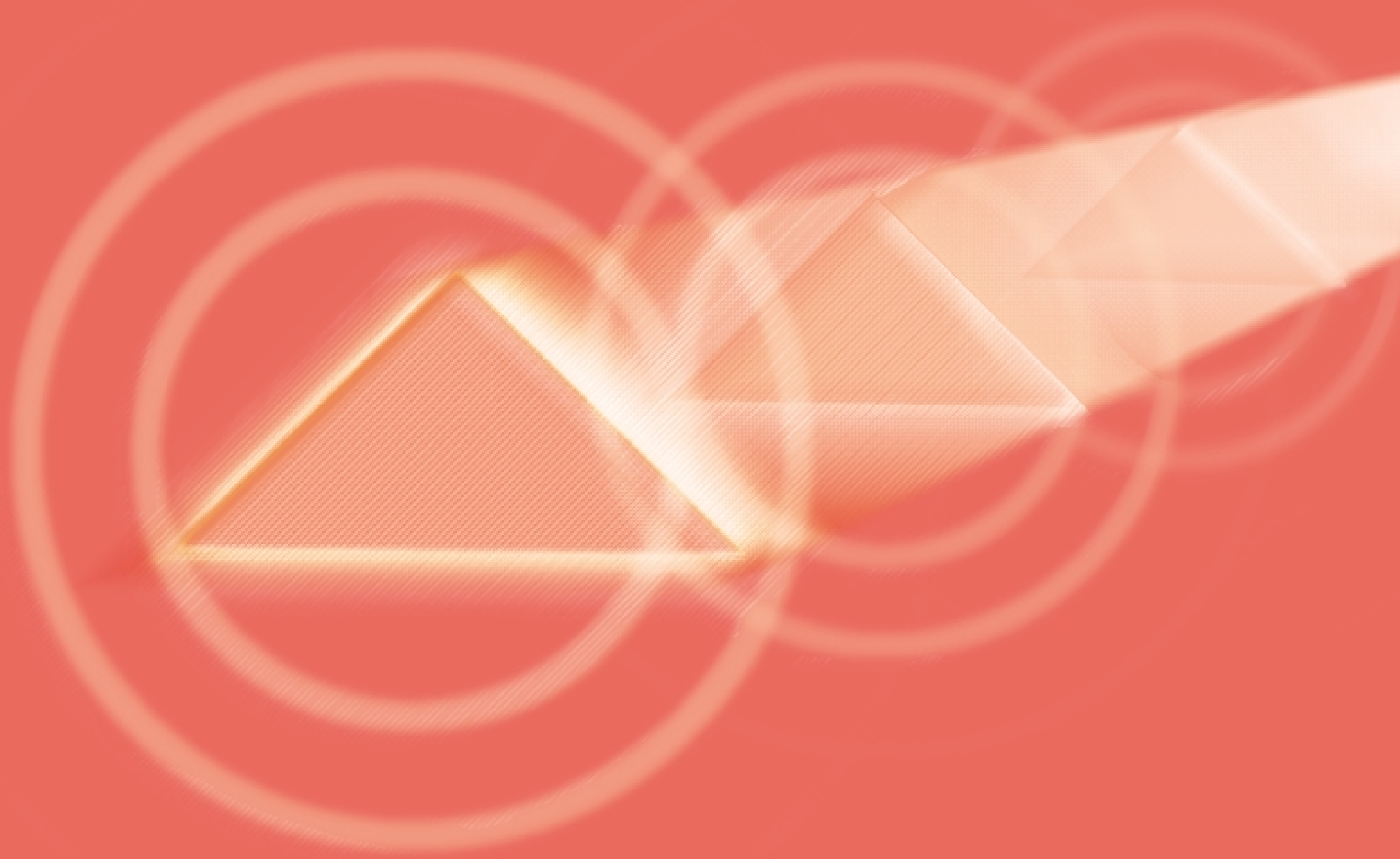
Source: European Commission, Annual Energy Review 1999

In the medium-term, it will be difficult to contain growth in world CO_2 emissions for a number of reasons: the strong limitations to the development of nuclear power generation in industrialised countries, the sustained growth trend in the road and air transportation sector in all regions and the economic development of the emerging countries, of which the major ones will base their development on carbon-intensive fuels.

A new balance in regional CO_2 emissions will of course result from differences in demographic and economic dynamics, given that per capita emissions are eight times higher today in industrialised regions than in Asia. Thus, the responsibility of the Annex B parties (developed countries having signed the Kyoto protocol) will remain the most important, not least because of their greater potential for reducing emissions.

PART IV

ENERGY PROSPECTS TO 2020



Energy demand is derived from various socio-economic activities. Future energy demand is therefore subject to the uncertainty inherent in future development of these economic and social driving forces (such as the rate and structure of economic growth). The design of alternative scenarios, i. e. the configuration of alternative developments of important drivers in a consistent way, is the methodological approach to explore possible energy futures, their contextual conditions and policy-relevant issues. The design of scenarios combines possible future developments of the boundary conditions and the techno-economic characteristics of an energy system by applying the scientific criteria of plausibility, consistency and interpersonal transparency. Energy-related scenarios can be designed using two basic options:

- the **exploratory approach**, which tries to identify the strongest shaping and driving forces that effect energy use such as: economic growth, structural changes, population development or new technologies. This approach has been used for designing the Baseline Scenarios at the world and EU level (supported by the two models, POLES and PRIMES respectively; see Chapter 4),
- the **normative or target-oriented approach**, which explores ways of meeting certain goals or objectives of society that might include some of the following examples: limiting energy import dependence, contribution to full employment, meeting CO_2 emission reduction targets. This approach has been used to design variants of the Baseline Scenarios (e. g. assumed CO_2 reduction targets, future of nuclear energy; see Chapter 5).

Both approaches assume that policy choices can be made and that their impacts on future energy demand and supply can be analysed.

The **time horizon** of the scenarios and their variants is 2020, accompanied with a more speculative outlook to 2030. These three projection years may also represent critical "turning points" in the evolution of the EU and global energy market. Although the EU is firmly expected to increase its Member States over this time horizon, the scenarios have been calculated with PRIMES for **EU-15** (see Chapter 4.2). More information at the aggregate level of West and Eastern Europe could be gained by the POLES model (see Chapter 4.1).

The **Baseline Scenario** follows the philosophy of conventional wisdom describing recent trends of the major drivers for the next 20 years. It is exploraory in character and takes into account energy and climate change policy decisions already made up to the end of 1997, e. g. the directives on liberalisation of electricity and gas markets, support of renewable energy forms and co-generation, policies for natural resources, waste disposal and acid rain pollution. The commitments of Kyoto, however, are not considered binding in the Baseline Scenario, but they have been analysed in variants of the Baseline Scenario in Chapter 5.2.

4.1 GLOBAL BASELINE SCENARIO

4.1.1 INTRODUCTION

This section summarises the most important assumptions on which the EU energy outlook, presented in later sections, is based. The section begins by presenting the global economic and energy context, which includes some discussion on international energy prices, and then proceeds to examine the EU's macroeconomic framework and other important assumptions.

While the link between energy demand and economic growth has weakened over recent years, it remains the most important determinant of energy trends. Since the focus of this chapter is the analysis of likely energy trends, the baseline macroeconomic projections presented below are not meant to be innovative. Rather, they have been constructed on the basis of consensus views among the most reputable international organisations engaged in such projections, such as the EC, the UN, the OECD, the International Monetary Fund (IMF) and the World Bank.

4.1.2 INTERNATIONAL CONTEXT[9]

The EU energy outlook is critically dependent upon that of the global economic and energy system development. The energy sector is, to a large extent, already operating within a world context and any regional analysis has to take into account international influences. One illustration of this is the oil market, which is globally integrated. It is simply not possible to examine future oil market trends in the EU without taking into account global supply and demand, which will determine future oil prices. Similar considerations apply in the case of natural gas. European gas prices and demand will depend not only on the developments in countries, such as Russia, that supply gas to the EU but also on countries as far afield as Asia. The pressure from the demand of the growing club of Asian gas importers could lead to future competition for access to the Middle East or Russian gas resources with the European importers after 2010-2020.

The environment is also an issue that often needs to be analysed in a context that is larger than the region of concern. In the case of the climate change problem, the issues are global and any policies and

[9] The material in this section is based on projections by the POLES model and draws heavily on work by Patrick Criqui of IEPE and Nikos Kouvaritakis of ECOSIM. POLES actually models 26 countries or regions. For further details see Volume 2 of the Shared Analysis Project and the model reference manual: *"POLES 2.2. European Commission, DG XII, December 1996".*

TABLE 4-1: GLOBAL POPULATION PROJECTIONS BY REGION, 1990-2020

	Million capita			Annual growth rates (%)			Shares (%)		
	1990	2010	2020	2010/1990	2020/2010	2020/1990	1990	2010	2020
World	5,249	7,027	7,893	1.5%	1.2%	1.4%	100%	100%	100%
OECD countries [11]	861	962	992	0.6%	0.3%	0.5%	16.4%	13.7%	12.6%
of which EU	364	383	384	0.25%	0.03%	0.18%	6.9%	5.5%	4.9%
Developing countries	3,979	5,603	6,414	1.7%	1.4%	1.6%	75.8%	79.7%	81.2%
FSU & CEEC	410	463	487	0.6%	0.5%	0.6%	7.8%	6.6%	6.2%

Source: UN and World Bank

measures undertaken by the EU must be seen in such a context. This section provides the international economic, energy and environmental trends within which European investment and policy decision makers are likely to operate over the next 20 years and beyond.

GLOBAL POPULATION TRENDS

The world population is likely to increase by about 2.5 billion people or 50 % in the period 1990-2020, with the bulk of this increase – almost 90 % - expected to take place in developing regions. However, a significant slowdown is projected in the rate of global population growth over the next 25 years. As can be seen from Table 4-1, this rate is assumed to decline from 1.5 %/a over the period 1990-2010[10] to 1.2 %/a in the following decade from 2010 to 2020. Major reasons for this deceleration include the low birth rates in OECD countries and the spreading of the demographic transition in developing countries.

Key features of this trend include a rapid growth of the African population and the slowdown of the demographic growth in emerging Asia (from 2.1 %/a over 1971-93 to 1.15 %/a after 2020) with the stabilisation of the Chinese population in the long run. The population of OECD countries is almost stable. The share of the EU in global population is expected to decline from 6.9 % in 1990 to 4.8 % in 2020 and 4.2 % in 2030 (benefiting of a small increment of 3.7 % on the period).

GLOBAL ECONOMIC OUTLOOK

The world economy is expected to grow by slightly above 3 %/a throughout the projection period (in terms of Purchasing Power Parities).[12] Growth is expected to recover after 2000, in spite of the recent financial crisis in some emerging Asian economies (February 97), Russia (August 98) and Brazil (February 1999). The world economic growth is assumed to increase from 2.5 %/a in the nineties to 3.6 %/a over the 2000-2010 period before slowly decreasing to 3.4 %/a over the 2010-2020 period[13].

TABLE 4-2: ECONOMIC GROWTH ASSUMPTIONS BY REGION (IN %), 1990-2020

	1990/2000	2000/2010	2010/2020
North America	2.4	2.4	2.1
Western Europe	1.8	2.4	2
OECD Pacific Countries	1.4	2.5	1.7
Former Soviet Union	-8.2	5.8	5.8
Central & South America	3.0	4.4	4.0
Emerging Asia	6.4	5.1	4.4
World	**2.5**	**3.6**	**3.4**

Source: POLES

[10] This rate of demographic growth decreases already from 1.6 %/a in the 1990s to 1.5 %/a over the period 2000-2010.

[11] The OECD countries as defined here correspond to the present OECD countries prior to the accession of Mexico, South Korea and new Central European members.

[12] POLES economic projections are derived from world baseline growth scenario that has largely used projections of the OECD Linkages project, adjusted for the currency values from Market Exchange Rate (MER) to Purchasing Power Parity (PPP) GDP growth rates. While most economic forecasts present variations in MER-GDP, the official currency rates reflect the prices of international tradable goods and services which are hardly representative of the total domestic economy. It is thus considered that the PPP-GDP is a better indicator for the energy consumption and energy intensity of GDP and is also more suited for international comparisons.

[13] The hypotheses of growth (3.3 %/a on 1992-2010 and 3.4 %/a on 2010-2020)) are slightly higher than those of the IEA (World Energy Outlook 98) with 3.1 % over the period 1995-2020 and those of the Energy-Information Administration-US DOE (International Energy Outlook 98) with 3.2 %/a over the period 2000-2020. The World Energy Council and the IIASA, which refer to MER GDPs, considered in 1995 a growth between 2.2 % and 2.7 %/a in their different scenarios which is slightly slowing down after 2020. The Shell scenarios consider the conditions for a long term sustained energy growth of 3 %/a.

TABLE 4-3: KEY GLOBAL DEMOGRAPHIC AND ECONOMIC ASSUMPTIONS

				Annual change (%)		
	1990	2010	2020	2010/1990	2020/2010	2020/1990
POP (M)	5,249	7,027	7,893	1.5	1.2	1.4
GDP (G$90ppp)	27,383	50,187	69,945	3.1	3.4	3.2
GDP/POP (k$90/cap)	5.2	7.1	8.9	1.6	2.3	1.8

Source: POLES

World economic growth is expected to be quite rapid after 2000 as the emerging Asia and Latin American economies return to their strong growth path and the former centrally planned economies, in particular Russia, are expected to recover from their recession. With the exception of North America, which has grown quite rapidly in the 1990s (+2.4 %), OECD countries are expected to grow at a slightly higher rate in the next decade. The dynamic Asian economies are expected to bottom out during 1999 with a modest growth rate, and to experience a period of sustained recovery beginning in 2000, reaching pre-crisis projected growth rates by 2003. This assumes the success of stabilisation and reform policies, which have been implemented in the countries in crisis. Latin American countries, especially Brazil, will follow a similar recovery path. However, there is some uncertainty regarding the speed of the Asian economic recovery and the ending of the long Japan's recession.

In the longer term, growth in all regions is projected to slow down after 2010. For example, growth rates in all OECD regions decrease to around 2 %/a, or below, after 2010. Non-OECD regions continue to experience average annual growth rates of more than 3.5 %. While the Chinese economy is assumed to decelerate to an annual growth rate of 4 % after 2010, the Indian economy will maintain a growth rate of about 5 % over the 2010-2020 period. Latin American will grow by 4.4 %/a over the 2000-2010 period and by 4 %/a after 2010.

In terms of per capita GDP, the projected annual growth rate is 1.8 % over the whole of the projection period. However, as the deceleration in the growth of population is especially noticeable in the longer term, a slight acceleration in per capita incomes is expected in most developing countries. This is especially significant for the energy consumption trends in a number of sectors for which the degree of wealth is an important factor.

ENERGY RESOURCES AND PRICE

The baseline projections presented here are based on the important assumption that global energy markets will remain well supplied at relatively modest cost throughout the projection period. Thus, in comparison to the gyrations of the past 25 years, the primary energy prices assumed here reflect the current consensus view that no supply constraints are likely to be felt at least in the period up to 2020. For these assumptions on primary energy prices, it is necessary to adopt an optimistic view on future discoveries of new oil and gas fields and on further advances in extraction technologies.

While the oil market is fairly integrated at a global level, this is not the case for gas and coal whose markets still retain a strong regional basis. The primary reason for this regional fragmentation is the high transport cost of gas and coal, relative to their production cost. This is expected to change progressively over the next 25 years under the baseline assumptions for energy prices.

OIL PRICE OUTLOOK

In the short run, oil prices depend on changes in global oil demand and on the productive capacities in Gulf countries, considered as the "swing producer" in the oil market. In the longer run, oil prices are likely to be influenced to a greater extent by the "fundamentals", i. e. the levels of oil demand and available reserves.

Given the remarkable improvement in the technologies applied to oil exploration and production in recent years, the size and geographic diversity of economic sources of oil supply have grown. While

Figure 4-1: World oil production

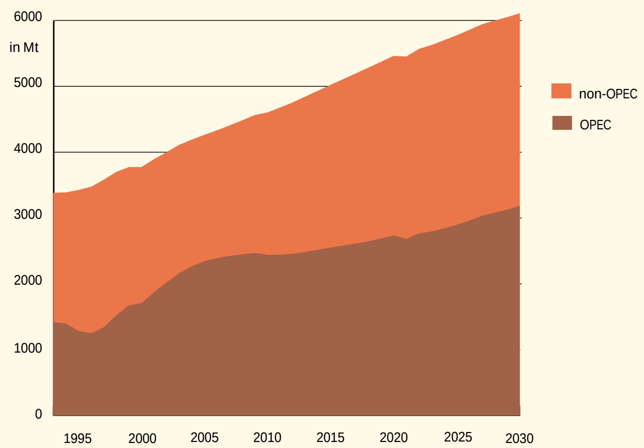
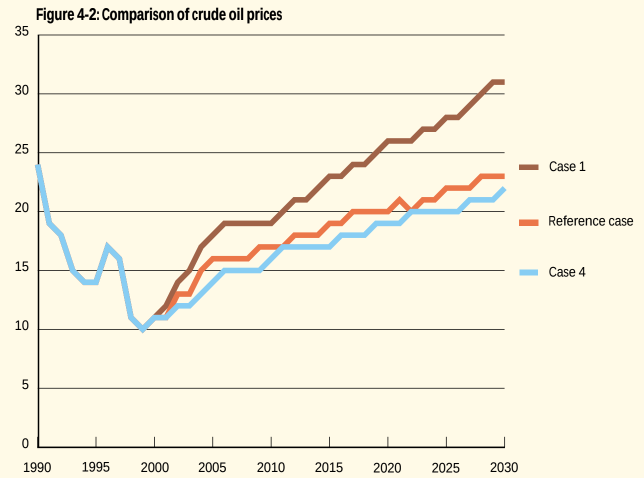


TABLE 4-4: OIL PRICE PROJECTIONS FROM POLES (IN $90/BARREL)

	1990	2010	2020
Reference case	23.8	16.9	20.1
Case1 (Moderate resources)	23.8	19.3	25.0
Case 4 (protracted crisis)	23.8	15.9	19.0
IEA* (WEO98)	23.8	17.0	25.0
DOE-EIA** (IEO98)	23.8	17.8	19.1

* Business as usual case ** Reference case

the vast reserves of the Middle East are still the most promising for assuring large-scale availability of reasonably-priced oil in the longer term, the reserve and production potentials of other areas have grown substantially in recent years. Thus, future growth in oil demand may be served by a large number of supply areas. In the very long term, unconventional oil resources will increasingly be exploited, as international oil prices rise and the costs of developing these resources decrease through technological progress.



Source : POLES

There is a great deal of uncertainty surrounding future oil prices partly due to the difficulties in estimating the size of the oil resources that are yet to be discovered and of technological progress. Table 4-4 presents a number of projections on oil prices for the period to 2020[14]. Under the POLES reference scenario, world oil resources correspond to the US Geological Survey's optimistic view of recoverable resources of 2900 billion barrels and the price of crude oil is projected to increase from around $17/barrel in 2010 to $20.1/barrel in 2020 (1990$)[15]. A protracted crisis could also alleviate the pressure of the demand of emerging economies (with an effect of - $ 1/bl in 2010 and 2020). If a less optimistic assumption on resources is used (1,400 billion barrels), the POLES model indicates that oil prices could increase to $19.3/barrel in 2010 and to $25.0/barrel in 2020[16]. In this case, oil prices are expected to return to around their 1990 level ($23.8/barrel) in real terms.

NATURAL GAS PRICE OUTLOOK

The factors affecting each of the regional gas markets will be somewhat different. As contractual gas prices are often indexed to netbacks on oil product prices, the slow increase of the oil prices is also likely to constrain future increases in gas prices, at least in Europe. The North American market, which is mature and fully competitive, will experience a more rapid price increase than the European market because of greater resource limitations.

TABLE 4-5: REGIONAL GAS PRICES IN THE REFERENCE CASE

	1990	2010	2020
World crude oil price ($90/barrel)	23.8	16.9	20.1
Gas import prices ($90/boe)			
American market	10.8	17.8	18.3
European market	15.2	15.2	19.8
Asian market	20.6	21.9	23.3

Source: POLES

The Asian gas market is largely dependent on liquid natural gas (LNG) imports to Japan and South Korea. Consequently, current gas prices in the Asian gas market are higher, by about $1/Mbtu[17], than those of the European market. The entry of new suppliers (in particular Middle East countries with significant resources), the development of some competitive forces and the technical progress of transport could limit the price increase in the long-run.

Gas prices have declined in Western Europe during the 1990s due to production over capacity, partial market liberalisation and low oil prices. In the longer run, the pressure of increasing demand, especially for power generation purposes, will make the importation of gas from a number of distant fields from Russia, North Africa and Middle East a necessity. This will require a modest increase in gas prices.

[14] Primary energy prices are endogenous in the POLES model

[15] This corresponds in 1999$ to a price of $20.3/barrel in 2010 and $24.1/barrel in 2020.

[16] This corresponds in 1999$ to a price of $23.2/barrel in 2010 and $30/barrel in 2020.

[17] The difference of 1$/Mbtu corresponds to 5.88 $/barrel of oil-equivalent and to 40.8 €/toe)

COAL PRICE OUTLOOK

International coal prices are expected to stay independent of oil prices and are projected to remain relatively stable. This is due to the rising number of competing projects for the production of low cost coal for export purposes in a number of countries such as Colombia, Australia, Indonesia South Africa, and Venezuela. This expected stabilisation of coal prices follows a significant decline from $60/t in 1980 to $40/t in the mid 1990s. The increasing coal demand of the three major consumers (China, India and USA) will be satisfied mostly from their abundant domestic resources, with only a small part supplied by imports.

CONVERGENCE OF THE REGIONAL FUEL PRICES

In general, the US is expected to maintain a comparative advantage over the EU in terms of fossil fuel energy costs. This is partly due to the well-established transport infrastructure in the US and the low costs of indigenous extraction. This does, of course, have some adverse effects as it has contributed to the greater energy and carbon intensity of the US economy. It should be noted that a greater integration of the regional gas and coal markets would be more likely in a world of very high primary energy prices as the costs of transport in such a world would be low relative to the overall cost of energy.

However, regional price differentials are expected to diminish over the next 20 years and beyond. For natural gas, the price in North America should increase after 2010 because of limitations in regional resources. Gas import prices in Asia should decrease after the development of more competitive LNG projects and cost reductions. European prices are not likely to increase dramatically as EU infrastructure is completed and as the market becomes more mature.

NEW PATTERNS OF ENERGY DEPENDENCE

Despite the assumptions of modest energy prices, the global demand projections that are presented in the following section imply a very large increase in the production of fossil fuels. For example, global oil production is likely to be close to 5.25 Gt by 2020, an increase of 55 % from its current level.

Oil trade is expected to increase quite significantly. This is partly because of the stagnation in the production of OECD countries, which will cover less than 20 % of the global oil output by 2020 (30 % in 1996), and partly because of the weak endowment of oil reserves in emerging Asia, which will consume 1.25 Gt by 2020 (0.5 Gt in 1996). Based on optimistic assumptions on non-Gulf oil resources, the share of the Gulf region in world production could increase from 26 % of global production at present to 40 % by 2020. Two thirds of the required global oil production increase is expected to come from this region where the reserve to production ratio is close to 100 years.

Global gas production will have to nearly double between now and 2020 in order to satisfy the rapidly increasing fuel needs (from 2,000 Mtoe to 3,500-4,000 Mtoe). This implies the increase of imports to the European and Asian markets by cross-border pipe-lines or LNG chains from volatile regions or countries. The doubling of the Western Europe consumption requires increasing imports from less politically stable countries (55 % of imports outside Norway in 2020). The dramatic increase of Asian gas needs, from 156 Mtoe in 1996 when Japan is excluded to 570-640 Mtoe in 2020, may also require imports from Middle East countries, Central Asia and East Siberia.

4.1.3 GLOBAL ENERGY CONSUMPTION OUTLOOK

FINAL ENERGY DEMAND

World final energy demand is projected to increase by 2.0 %/a over the 1990-2020 period (see Table 4-6). Growth in gas demand as a final fuel, at 2.6 %/a, is more modest than the demand growth as a primary fuel (3.0 %/a, see Table 4-8). Conversely, due to the rapid growth in transport demand, the demand for oil as a final fuel is somewhat stronger than as a primary fuel. The growth in final oil

TABLE 4-6: GLOBAL FINAL DEMAND BY FORMS OF ENERGY, 1990-2020

	Mtoe			Annual change (%)			Shares (%)		
	1990	2010	2020	1990/2010	2010/2020	1990/2020	1990	2010	2020
Final Energy Consumption	**6,057**	**8,740**	**10,884**	**1.9%**	**2.2%**	**2.0%**	**100%**	**100%**	**100%**
Solids	830	1,042	1,222	1.1%	1.6%	1.3%	14%	12%	11%
Oil	2,588	3,753	4,654	1.9%	2.2%	2.0%	43%	43%	43%
Gas	1,012	1,685	2,210	2.6%	2.7%	2.6%	17%	19%	20%
Heat	228	224	164	-0.1%	-3.1%	-1.1%	4%	3%	2%
Electricity	834	1,467	2,020	2.9%	3.3%	3.0%	14%	17%	19%
Renewables	564	568	614	0.0%	0.8%	0.3%	9%	6%	6%

Source: POLES

demand is due to the transport sector, which accounts for more than one fourth of the final world energy and for half of the world's oil consumption. From 1990 to 2020, the annual world-wide demand for oil in the transport sector is projected to increase by around 80 % (1.2 billion metric tonnes). Changes in transport efficiency may modify these trends. Transport demand growth will be much higher in the developing world than elsewhere. For example, Asian growth in transport energy demand is projected to be close to 4.5 %/a between 1990 and 2020.

In terms of final energy demand, the fastest growing final fuel by far is projected to be electricity. It will register an annual growth rate of 3.0 % over the period to 2020, almost in line with global economic growth. This is a reflection of continued electrification, a trend that is well established for a very long time. Indeed, electricity has often grown much faster than GDP on a global scale. Electricity demand is expected to grow by 7 %/a in dynamic Asian countries and by 5 %/a in other developing regions in the period to 2010. As the share of electricity in final energy demand continues to increase, the power generation system will have a growing weight as a major user of primary energy.

PRIMARY DEMAND BY REGION

The energy intensity of the world economy is expected to decline by 1.4 %/a in the period to 2010 and by slightly less than 1 % after that. As population growth decelerates after 2010 in most developing countries, per capita energy consumption will show a marked increase.

Total primary energy consumption is likely to increase by an average annual growth rate of almost 2 % in the 1990-2020 period, broadly in line with long term trends. Somewhat surprisingly, an acceleration in demand is projected in the latter part of the period. This is primarily due to the continued fast growth in most developing regions which, by 2010, account for the bulk of the increase in energy demand. Between 1990 and 2020, energy consumption growth in developing countries is projected to account for 72 % of the increase in world energy demand. In the same time period, the OECD countries will account for only 23 % of this increase. Consequently, whereas in 1990 energy consumption in the OECD countries exceeded that of the developing countries by 1,553 Mtoe, the developing countries will surpass OECD countries by an amount of 1,700 Mtoe in 2020. The share of OECD countries in global primary energy consumption will decline from nearly 50 % in 1990 to 37.7 % in 2020 while the share of the European Union will decline from 15.9 % in 1990 to 10.7 % in 2020.

China and South Asian economies will almost double their share in global primary energy consumption between 1990 and 2020 (see Table 4-7). The growth of primary energy in this region, by about 3,000 Mtoe, accounts for almost half of the global increase in energy demand and is more than double the increase in OECD countries. The Former Soviet Union is projected to experience an increase in demand after the solution of its restructuring problems and its level of energy demand is not expected to reach that of 1990 before 2015.

PRIMARY DEMAND BY FUEL

The global energy system will continue to be dominated by fossil fuels over the next 25 years. Indeed, as can be seen from Table 4-8, dependence on fossil fuels is likely to be close to 90 % by 2020, compared to slightly above 85 % today. In the context of the recent concerns about global warming, this is clearly an unwelcome development. However, given the consensus view of relatively low energy prices throughout the projection period as well as the concerns about nuclear power, fossil fuel energy is likely to maintain its competitiveness. New renewable forms of energy are likely to be badly affected by a period of sustained low energy prices.

One explanation relies upon foreseeable evolutions of the technology mix in the electricity systems. The renewable sources of electricity will continue to be dominated by large hydro plants. Their future development will be sufficient to maintain their share in total pri-

TABLE 4-7: GLOBAL PRIMARY ENERGY DEMAND BY REGION, 1990-2020

	Mtoe				Annual change (%)			Shares (%)		
	1990	2000	2010	2020	2000/1990	2010/2000	2020/2010	1990	2010	2020
OECD countries	4,066	4,714	5,196	5,621	1.5 %	1.0 %	0.8 %	49.1 %	44.5 %	37.7 %
EU	1,313	1,452	1,550	1,596	1.0 %	0.7 %	0.3 %	15.9 %	13.3 %	10.7 %
Developing countries	2,513	3,585	5,052	7,319	3.6 %	3.5 %	3.8 %	30.4 %	43.3 %	49.1 %
Emerging Asia	1,424	2,167	3,131	4,500	4.3 %	3.7 %	3.7 %	17.2 %	26.8 %	30.2 %
CEEC & FSU	1,694	1,047	1,421	19,66.3	-4.7 %	3.1 %	3.3 %	20.5 %	12.2 %	13.2 %
World	**8,273**	**9,346**	**11,669**	**14,907**	**1.2 %**	**2.2 %**	**2.5 %**	**100.0 %**	**100.0 %**	**100.0 %**

Source: POLES

TABLE 4-8: GLOBAL PRIMARY ENERGY DEMAND BY FUEL, 1990-2020

	Mtoe			Annual Growth Rates (%)			Shares (%)		
	1990	2010	2020	1990/ 2010	2010/ 2020	1990/ 2020	1990	2010	2020
Solids	2,182	2,916	3,920	1.5	3.0	2.0	26.4	25.0	26.3
Oil	3,182	4,407	5,323	1.6	1.9	1.7	38.5	37.8	35.7
Gas	1,682	2,813	4,035	2.6	3.7	3.0	20.3	24.1	27.1
Other	1,227	1,533	1,629	1.1	0.6	0.9	14.8	13.1	10.9
Gross Inland Consumption	**8,273**	**11,669**	**14,907**	**1.7**	**2.5**	**2.0**	**100**	**100**	**100**
Energy intensity (toe/k$90)	310.9	232.5	213.1	-1.4	-0.9	-1.3			
Energy per capita (toe/cap)	1.6	1.7	1.9	0.3	1.1	0.6			

Source: POLES

mary supply, but not in electricity generation, which grows much more quickly. The outlook for nuclear energy is one of modest growth (2518 TWh in 2000, 2721TWh in 2020), which is insufficient to maintain the share of nuclear energy in primary supply and electricity generation.

Thus, the electricity sector will continue to rely on fossil fuels. As already mentioned, natural gas will play an increasing role as a power generation fuel, especially in OECD countries. In developing Asia, the role of coal in power generation will remain predominant and by 2010, about 700 Mtoe of coal could be burnt in the thermal power plants of the region, 92 % of which in China and India. The situation is likely to be more balanced in other developing regions.

Apart from the decrease in the share of non-fossil fuels, the most significant change in fuel shares over the period to 2020 is the increase in that of natural gas. Due primarily to its cost advantages as a power generation fuel in combined cycle gas turbines, the consumption of gas is projected to increase by 2.6 %/a in the period to 2010 and by almost 3.7 %/a after that. Solid fuels will also increase their share a little as they manage to maintain their position in power generation in some of the most important markets, including China and India. Oil will lose some shares and become increasingly used for transport purposes.

4.1.4 CO_2 EMISSION OUTLOOK

Given the projections for growth in primary energy demand and the continued dominance of fossil fuels, it is not surprising that global emissions are expected to grow quite rapidly. Because of the rising dependence on fossil fuels, CO_2 emissions grow faster than primary energy consumption over the projection period, averaging an annual growth rate of 1.8 % between 1990 and 2010 and 2.7 % between 2010 and 2020. By 2020 they will be 86 % above their 1990 level.

The regional pattern of emission growth reflects the pattern of energy use and the fuels used in each region. Perhaps the most striking aspect of the figures presented in Table 4-9, is the singular importance of China and India (the dominant country in the South Asia region) for the future of global emissions. In both countries, the energy system is extremely dependent on solid fuels, the only primary energy form that is abundant in these countries and the most carbon intensive of fossil fuels. For the period 1990-2020, China and South Asia account for more than half of the increase in global emissions.

The share of OECD countries in global emissions could decline from 47.1 % in 1990 to 34.2 % in 2020. The restructuring of the energy systems of the economies in transition will lead to a sharp decline in

TABLE 4-9: GLOBAL CO_2 EMISSION OUTLOOK (IN MT C), 1990-2020

	Mt C			Annual growth rates (%)			Shares (%)		
	1990	2010	2020	2010/1990	2010/2020	2020/1990	1990	2010	2020
OECD countries	2,735	3,369	3,692	1.0	0.9	1.0	47.1	41.0	34.2
CEEC & FSU	1,292	957	1,335	-1.5	3.4	0.1	22.3	11.6	12.4
China and South Asia	846	2,069	2,994	4.6	3.8	4.3	14.6	25.2	27.8
Other developing countries	993	1,829	2,761	3.4	4.2	3.7	16.1	22.2	25.6
World	**5,806**	**8,224**	**10,782**	**1.8**	**2.7**	**2.1**	**100.0**	**100.0**	**100.0**
Change from 1990 (Mt C)		2,418	4,976						
Change from 1990 (%)		41.6%	85.7%						

Source : POLES

their emissions until the beginning of the next decade and their share in global emissions is projected to fall by almost half between 1990 and 2010. With the completion of the transition period, emissions from these countries are projected to increase rapidly to reach a 12 % share in global emissions.

By 2010 (the middle of the first budget period of the Kyoto protocol) global CO_2 emissions could exceed the 1990 level by 42 %. Emissions of Annex I countries (here approximated by OECD countries plus FSU/CEEC) will grow by 7.4 % in these baseline projections. Therefore, the overwhelming part (88 %) of the CO_2 emission growth by 2010 will come from developing countries, with China and South Asia accounting for 51 % of the global emission increase by 2010.

4.2 BASELINE SCENARIO FOR THE EU[18]

4.2.1 KEY ASSUMPTIONS

This section presents the most important assumptions on which the EU energy outlook is based. While, over recent years, the link between energy demand and economic growth has weakened, it remains one of the most important determinants of energy trends.

EU DEMOGRAPHIC OUTLOOK

Population is an important determinant both of overall economic performance and of energy trends, especially in the transport, household and services sectors. Total EU population will grow very modestly in the period from 1995 to 2010 by some 12 million people. The divergence in annual population growth rates among individual Member States varies from 0.04 %/a in Italy to 0.5 %/a in the Netherlands. Even this modest growth in EU population is likely to be due, to a significant degree, to immigration.

After 2010, total EU population will effectively stabilise and its level of 384 million people in 2020 will be only marginally higher than its 2010 level. Only Ireland, Sweden and the Netherlands show growth rates of more than 0.3 %/a in the period 2010-20 while Germany and Italy experience small declines in population over this period.

THE ECONOMIC OUTLOOK OF THE EU

The economic outlook presented below is based on a number of underlying assumptions. For example, the recent Asian crisis is assumed to be transitory and the longer term global international economic climate is assumed to remain generally positive in the medium term. Also, the EU is projected to benefit from a continued increase in world trade, as barriers continue to decline. Commodity prices and inflation remain modest.

TABLE 4-10: POPULATION TRENDS IN THE EU, 1995 TO 2020

	000 inhabitants				Annual growth rates (%)	
	1995	2000	2010	2020	1995/2010	2010/2020
Austria	8,047	8,144	8,326	8,443	0.2	0.1
Belgium	10,137	10,252	10,484	10,658	0.2	0.2
Denmark	5,228	5,321	5,452	5,526	0.3	0.1
Finland	5,108	5,178	5,290	5,350	0.2	0.1
France	58,139	59,179	61,387	62,831	0.4	0.2
Germany	81,661	83,123	83,000	81,200	0.1	-0.2
Greece	10,454	10,643	11,079	11,269	0.4	0.2
Ireland	3,601	3,625	3,760	3,909	0.3	0.4
Italy	57,301	57,455	57,633	56,543	0.0	-0.2
Netherlands	15,459	15,868	16,659	17,204	0.5	0.3
Portugal	9,916	9,993	10,293	10,513	0.2	0.2
Spain	39,210	39,544	40,372	40,307	0.2	0.0
Sweden	8,827	8,932	9,176	9,470	0.3	0.3
UK	58,606	59,269	60,146	61,038	0.2	0.1
EU14	**371,693**	**376,526**	**383,057**	**384,262**	**0.20**	**0.03**

Source: Primes

[18] This section is extracted from Chapter 3 of the study "EU Energy Outlook to 2020", European Commission – Directorate General for Energy, forthcoming, catalogue number CS-24-99-130-EN-C, ISBN 92-828-7533-4, 1999, which was carried out in the context of the Shared Analysis Project (Volume 5 of the project report).

SHORT RUN PROJECTIONS: THE PERIOD TO 2000[19]

Following a period of modest economic performance and rising unemployment, the EU economy started recovering after 1997. The recent economic crisis in a number of Asian economies and Russia is not expected to have a significant impact on European economies.

All EU countries are expected to participate in the sustained recovery in the period to 2000. Ireland will continue to expand at a rate that is around three times the EU average. Other cohesion countries will also experience strong annual growth (averaging more than 3.5 %/a) in the 1998-2000 period.

MEDIUM AND LONGER RUN PROJECTIONS: 2001-2020

Despite the generally favourable overall international context, the EU growth rate after 2000 is assumed to decelerate to levels that are consistent with long-term historical trends. In the period 2000-10, the annual economic expansion is projected to be around 2.4 % while in the period after 2010 it might not exceed 1.8 %.[20] It is assumed that the monetary unification will tend to reduce fluctuations in interest rates and will lead to a gradual convergence of prices. Additionally, a combination of monetary policy and the high intra-EU level of competition are assumed to keep overall price increases low and inflation below the 1995 rate.

One of the fundamental assumptions made for the purposes of the baseline scenario, which is important for the determination of economic growth projections for individual Member States, is that the process of convergence among European economies will continue throughout the projection period. The assumed degree of divergence among Member States from the average per capita EU GDP remains significant and, even by 2030, the convergence process is far from complete. Thus, despite the progress made by the cohesion countries, the per capita income in Portugal and Greece remain 46 % and 39 % respectively below the EU average. The Scandinavian countries, on the other hand, continue to be significantly richer than other Member States even though their relative wealth is reduced from its present level.

The long established trend of the restructuring of EU economies away from the primary and secondary sectors and towards services is assumed to continue, although the pace of change is expected to decelerate. Thus, following the period of substantial restructuring of the past 20 years, the industrial sector's share in GDP is assumed to decline only modestly. New industrial activities with high added value and lower material base are projected to emerge in most countries. For the EU as a whole, the share of industrial added value in the economy is assumed to decline from just over 28 % in 1995 to 26 % in 2020. Agricultural added value will decline by one percentage point over the same period and is limited to just 2 % of GDP by 2020.

TABLE 4-11: ANNUALISED PERCENT CHANGE IN GDP, 1980-2020

	Observed			Forecast				
	1980/85	1985/90	1990/95	1995/00	2000/05	2005/10	2010/15	2015/20
Austria	1.3	3.2	1.8	2.6	2.2	2.1	1.7	1.6
Belgium	1	2.9	1.2	2.6	2.3	2.2	1.8	1.7
Denmark	2.2	1.8	2.0	2.8	2.2	2.1	1.6	1.4
Finland	2.9	3.4	-0.7	4.3	2.4	2.3	1.8	1.6
France	1.4	3	1.1	2.6	2.3	2.2	1.9	1.7
Germany	1.2	3.2	1.8	2.3	2.5	2.3	1.8	1.6
Greece	1.5	1.7	1.6	3.3	3.9	3.4	3.0	2.9
Ireland	3.3	5.6	5.8	9.0	3.8	2.7	2.2	2.0
Italy	1.4	3	1.1	2.1	2.2	2.1	1.8	1.6
Netherlands	1.3	3.1	2.1	3.3	2.6	2.5	2.1	1.9
Portugal	0.8	8	1.6	3.8	3.8	3.6	3.1	2.8
Spain	1.5	4.5	1.3	3.3	2.9	2.8	2.4	2.2
Sweden	2.2	2.8	0.4	2.3	2.2	2.0	1.6	1.4
UK	3.5	3.3	1.2	2.4	2.6	2.5	2.0	1.7
EU Average	1.7	3.2	1.4	2.6	2.5	2.3	1.9	1.7

Source: Primes

[19] The main source consulted for the preparation of the projections for the period 1996-2000 was the DGII projections of Autumn 1998 for each Member State, from which GDP, private consumption, consumers' price indexes, GDP deflator, interest rate and exchange rate were taken. For sectoral projections the DRI study "Europe in 2001 - Economic analysis and Forecasts" were also used, for the six countries for which it contained information.

[20] These projections are within the high and low growth scenarios of OECD (1997).

POLICY ASSUMPTIONS

The baseline scenario presented here is based on the assumption that EU policies currently in place will be continued. Given that one of the objectives of this study is to assist policy makers in the evaluation of a number of alternative measures, it is appropriate that the baseline should form the benchmark against which the effectiveness of a number of alternative policies could be measured.

Barring any major unexpected occurrences, the major driving force of policy changes over the next 20 years is likely to be environmental concern. This is both because of increasing pressure from public opinion, especially in the more wealthy EU countries, and because of legal obligations. For example, in the Kyoto protocol the EU agreed to cut greenhouse gas emissions (predominantly CO_2) by 8 % below their 1990 level.

A second major influence on policy makers over the outlook period will be the objective of completing the single market and efforts to enhance European competitiveness through reduced energy costs that could result from greater competition and liberalisation. For the purposes of the baseline scenario, it has been assumed that the process of single markets for electricity and gas is continued as currently legislated by specific measures. However, it is most likely that a number of further steps will be undertaken over the next 20 years towards more competitive and integrated EU markets.

More specifically, the baseline scenario assumes:

- The liberalisation of electricity and gas markets will proceed in line with EC directives and is assumed to fully develop in the second half of the first decade.
- The restructuring is enabled by mature gas-based power generation technologies that are efficient, involve low capital costs and are flexible regarding plant size, co-generation and independent power production.
- Energy policies that aim to promote renewable energy (wind, small hydro, splar energy, biomass and waste) are assumed to continue, involving subsidisation of capital cost and preferential electricity selling prices.
- On-going infrastructure projects in some Member States involving the introduction of natural gas are assumed to gain full maturity in the first half of the first decade of the projection period.
- The baseline scenario takes into account the different policies in place of EU Member States as regards nuclear capacity. Countries like Austria, Denmark, Greece, Ireland, Italy and Portugal remain non-nuclear countries during the pro-jection period. Finland (with on-going construction of 250 MW of new nuclear capacity), Germany, the Netherlands, Spain, Sweden and United Kingdom do not further expand their nuclear capacity. Finally, for France (with on-going construction of new nuclear plants, 6.4 GW) and Belgium the assumption of further nuclear expansion, on the basis of economic criteria, is adopted for the period beyond 2010. Decommissioning of existing nuclear capacity occurs on the basis of technical lifetime (40 year) with the exception of Sweden for which a much stricter decommissioning program (based on political decisions) is adopted. It is worth noting that nuclear will cease to be exploited in The Netherlands beyond 2010 and that despite the recent anti-nuclear decisions in Belgium there is some reinvestment in nuclear under baseline assumptions beyond 2010 (without however an increase in total capacity).

For analytical purposes the baseline scenario assumes that no new policy measures will be undertaken in order to meet the Kyoto commitments. Such measures are considered within the CO_2 emission reduction scenarios that are presented and discussed in the next chapter.

4.2.2 OVERVIEW OF PRIMARY ENERGY OUTLOOK

PRIMARY ENERGY SUPPLY [21]

Production of primary energy within the EU is expected to continue to peak around 2000 and then to decline throughout the period up to 2020. The production of all primary fuels is expected to decline after 2000, except that of renewable sources of energy which are likely to receive a significant boost because of their environmental characteristics. The decline of solids and oil is especially noticeable, with oil projected to decline by more than a third and solids by half in the period 1995 to 2020.

The production of nuclear energy is projected to remain close to its 2000 level until 2010 and then to decline by some 10 % in the period to 2020. Trends in primary nuclear supply are driven exclusively by the requirements of nuclear power stations and are further discussed below in the section on power generation.

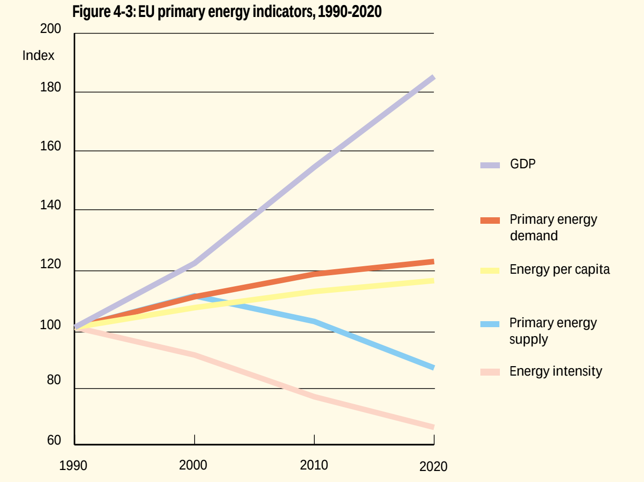
Given the modest decline of nuclear over the projection period and the growth in renewable sources, the role of non-fossil indigenous resources will become increasingly important to EU primary production. In fact if it were not for the assumed obstacles to further nuclear penetration after 2010, the decline in solids, which will decelerate after 2010, would be even bigger. Nuclear is projected to represent the biggest single source of primary energy by 2020, accounting for nearly a third of total production. Non-fossil fuels will

[21] Unless otherwise stated, all historical figures and growth rates used in this chapter are taken from the Annual Energy Review 1999.

account for nearly half of primary energy production by 2020, compared to a third in 1995. Hydro will grow very modestly over the period, since most major suitable sites for hydroelectric dams in the EU have already been developed.

It should be noted that the collapse of crude oil prices in 1998, which towards the end of that year approached €10 per barrel, is assumed not to have a long-term impact. If the recovery at the beginning of 1999 proves short lived and oil prices return to their 1998 level, this could affect the production of North Sea oil and gas in the medium term. However, unless low oil prices persist for a long period, they are unlikely to have a big impact on long-term output. The sharp reduction in the profitability of upstream companies that may result from low prices could lead to a reduction in exploration activity and to a delay in the start up of new projects. This, in turn, could reduce North Sea output in the next few years and lead to a further delay in the reaching of the peak of production .

Figure 4-3: EU primary energy indicators, 1990-2020



Source: PRIMES

PRIMARY ENERGY DEMAND

The annual growth rate in primary energy consumption is expected to be close to 1 %/a over the period to 2010 and then to decelerate to just 0.4 %/a until 2020. For the 1995-2020 period as a whole, EU energy demand growth will average 0.7 %/a.

Consequently, the baseline scenario projects a significant improvement of the energy intensity ratio. The implied annual energy intensity improvement is expected to average around 1.5 %/a throughout the projection period. The decoupling of energy from economic growth is also noticeable in Figure 4-3. It is due, first, to the changing sources of economic growth, i. e., high added value goods and services (and thus less energy and material intensive), and, secondly, to continued technological progress in the energy use and conversion, especially in the latter part of the projection period.

In per capita energy terms, EU primary energy is continuing to grow significantly, by 0.7 %/a, in the period to 2010. In the latter part of the period, however, per capita energy demand will slow down to just 0.3 %/a, as saturation effects become more pronounced. Concerning the development of the various energy forms, primary energy demand is characterised by the strong increase of natural gas, partially at the expense of solid fuels (see Table 4-12).

It is important to note that the EU energy system, on the demand side, will remain dominated by fossil fuels over the next 25 years. Indeed, the share of fossil fuels will rise marginally from just under 80 % in 1995 to 81 % by 2020. This is despite the significant pro-environmental policy assumptions adopted in the baseline.

TABLE 4-12: PRIMARY ENERGY DEMAND BY FUEL, EU-15 (1990-2020)

	Mtoe					Annual growth rates (%)			Shares (%)		
	1990	1995	2000	2010	2020	1995/ 2010	2010/ 2020	1995/ 2020	1995	2010	2020
Total	**1,318**	**1,368**	**1 ,454**	**1,556**	**1,612**	**0.9**	**0.4**	**0.7**	**100.0**	**100.0**	**100.0**
Solid Fuels	302	238	207	182	218	-1.8	1.8	-0.3	17.4	11.7	13.5
Liquid Fuels	545	578	606	655	663	0.8	0.1	0.5	42.2	42.1	41.1
Natural Gas	222	274	338	401	431	2.6	0.7	1.8	20.0	25.8	26.7
Nuclear	181	205	223	227	199	0.7	-1.3	-0.1	15.0	14.6	12.3
Electricity	2	1	1	2	3	2.7	1.2	2.1	0.1	0.1	0.2
Renewable En. Sources	64	72	79	88	100	1.4	1.2	1.3	5.3	5.7	6.2
Energy intensity (toe/M€90)	248	241	225	190	164	-1.6	-1.4	-1.5			
Energy per capita (toe/cap)	3.6	3.7	3.9	4.1	4.2	0.7	0.3	0.5			

Source: PRIMES

EU ENERGY IMPORT DEPENDENCY

In view of the above discussion on primary energy supply and demand, it is not surprising that the energy import dependency of the EU is projected to rise substantially over the next 25 years. It is expected that nearly two thirds of overall energy requirements will come from imports by 2020, compared to less than half in 1995. The decline in North Sea production after 2000 leads to almost 90 % dependence on imports for the satisfaction of oil requirements by 2020 (see Table 4-13).

TABLE 4-13: EU ENERGY IMPORT DEPENDENCY, EU-15 (1995-2020)

	%			
	1995	**2000**	**2010**	**2020**
Total Energy	**46.4**	**47.6**	**55.0**	**63.4**
Solid Fuels	39.5	46.7	52.8	67.8
Liquid Fuels	72.9	74.4	81.7	86.1
Natural Gas	39.9	39.5	52.4	67.3

Source: PRIMES

The better reserve situation of natural gas does not prevent a sharp increase in gas import dependency, from under 40 % in 1995 to more than 52 % by 2010 and to more than two thirds by 2020, due to the relatively rapid increase in gas consumption. An almost identical path to that of gas is followed by coal, the only solid fuel that is internationally traded. The increase in coal import dependency effectively reflects the phase out of most of the remaining subsidies and the consequent increase in the amount of cheap coal imports.

FINAL ENERGY

Final energy demand is expected to grow marginally faster than primary energy, rising by 1.2 % and 0.5 % in the 1995-2010 and 2010-20 periods respectively (see Table 4-14). This small differential between primary and final energy demand reflects the improved rate of conversion efficiency in power generation. The projected changes in the shares of various fuels over the next 25 years are relatively modest. The most notable change is the increase by nearly 4 percentage points in the share of electricity. This confirms one of the best-established long-term energy trends, namely, the gradual electrification of the energy system in developed countries. Even by 2020, however, electricity will continue to account for less than a quarter of total final energy consumption.

Under baseline technology assumptions, novel final energy forms, such as hydrogen and ethanol, do not make significant inroads, primarily due to cost considerations. Biomass will decline in absolute terms due to the decline in the number of agricultural households, the major users of wood. Other forms of renewable final energy forms, such as solar water heaters will grow quite rapidly but remain insignificant as a proportion of overall final consumption. It should be noted that the projected annual growth in electricity consumption, less than 2 %/a, is quite modest by historical standards – electricity has historically grown faster than GDP.

These trends in final energy fuels are, to a large extent, determined by the differential growth rates in the level of energy consumption and efficiency improvements of the major energy using sectors. For example, the sharp slow-down in oil demand in the latter part of the

TABLE 4-14: FINAL ENERGY DEMAND BY FUEL, EU-15 (1995-2020)

	Mtoe				Annual Growth rates (%)			Shares (%)		
	1995	**2000**	**2010**	**2020**	**1995/ 2010**	**2010/ 2020**	**1995/ 2020**	**1995**	**2010**	**2020**
Total Final Energy Demand	888	957	1,056	1,111	1.2	0.5	0.9	100.0	100.0	100.0
by fuel										
Solid Fuels	44	36	27	20	-3.2	-2.7	-3.0	4.9	2.5	1.8
Liquid Fuels	405	437	479	489	1.1	0.2	0.8	45.6	45.3	44.0
Natural Gas	178	198	212	213	1.2	0.0	0.7	20.0	20.1	19.1
Steam	70	74	89	102	1.6	1.3	1.5	7.9	8.5	9.1
Electricity	170	190	227	266	1.9	1.6	1.8	19.1	21.5	23.9
Hydrogen	0	0	0	0	-	18.3	-	0.0	0.0	0.0
Methanol - Ethanol	0	0	0	0	-	8.5	-	0.0	0.0	0.0
Renewable Energy Sources	22	22	22	21	-0.1	-0.4	-0.3	2.5	2.1	1.9
Biomass	22	21	21	20	-0.2	-0.6	-0.4	97.4	96.3	94.6
Other	1	0	1	1	2.2	3.5	2.7	2.6	3.7	5.4
by sector										
Industry	247	259	283	291	0.9	0.3	0.7	27.8	26.8	26.2
Residential	241	257	268	282	0.7	0.5	0.6	27.1	25.4	25.4
Tertiary	124	140	159	177	1.7	1.1	1.4	14.0	15.1	15.9
Transport	276	301	346	360	1.5	0.4	1.1	31.1	32.8	32.4

Source: PRIMES

projection period is simply the reflection of the lower growth in the energy demand of the transport sector, the major consumer of oil products in most developed economies. The increase in transport energy demand is actually identical to the increase in total demand for liquid fuels over the 1995-2020 period, implying stagnating overall oil consumption in the other sectors.

Energy demand in the tertiary sector is the fastest growing segment of final demand, reflecting the expected restructuring of the economy towards services. The modest growth in residential energy demand reflects the lack of growth in EU population and the small increase in the number of households. Overall, by 2020, the transport sector will account for almost a third of EU final energy consumption, followed by industry and the residential sector, which will account for 26 % each.

TRANSPORT SECTOR

Energy use in the transport sector is becoming an increasing policy concern within the EU both from energy and from an environmental point of view. The near complete dominance of oil products in the energy needs of this sector has identified, to a large extent, the security of oil supplies with the rising needs for transport purposes. Since most countries rely almost exclusively on imports for their oil needs, there are also significant trade implications. From an environmental perspective, worries about climate change have been added to longer standing problems of congestion, noise and urban pollution.

Passenger transport is projected to increase at an annual rate of 1.4 %/a over the next 25 years (see Table 4-15). This increase is lower than that of income and significantly lower than that suggested by historical trends. The bulk of passenger transport takes place on roads through the use of private cars. Road transport accounts for more than 89 % of total passenger travel and its share is expected to fall by a very small amount. Both public road and rail transport are in long-term decline, as a share of total transport, and most of the fall in the share of car travel will be absorbed by air travel. This is projected to grow annually at more than 4 %/a in the period to 2020. It has been the fastest growing mode of transport in the recent past and a number of factors will contribute to its future fast growth. These include the changing tastes towards more long distance travel, the much greater speed of air travel etc.

Energy consumption for passenger transport purposes is projected to increase significantly less rapidly than overall transport activity. This is especially the case for road transport, which accounts for the bulk of energy used in the transport sector. Energy demand in road transport is projected to grow by only 0.7 %/a, significantly below the corresponding travel activity. This substantial improvement in energy intensity is all the more impressive if the growing size and degree of comfort of future cars is taken into account. It is important to note that the baseline projections on passenger transport do not take into account the 1998 voluntary agreement between the EU Commission and the European car manufacturers. If successful in achieving its targets, this agreement could result in substantial energy savings for the EU and could contribute significantly to the limitation of CO_2 emissions.

Goods transport is closely associated with overall economic activity and, historically, this activity has grown at least as fast as GDP. Over the next 25 years, this trend is expected to be reversed and freight tonne kilometres (tonne-km) are expected to grow somewhat less than GDP. The main reason for this is the rapid growth in the service sector and the high added value manufacturing activity in the EU economy. These sectors are less freight intensive than the more traditional basic manufacturing and extraction activities.

Road freight is projected to broadly maintain its share in overall freight activity against the use of rail. Efficiency improvements in freight are expected to be more modest than in passenger transport.

TABLE 4-15: TRANSPORT SECTOR: PASSENGER ACTIVITY AND ENERGY DEMAND, EU-15 (1990-2020)

						Annual growth rates (%)			Shares (%)		
	1990	1995	2010	2020	90/95	95/10	10/20	95/20	1995	2010	2020
Travel per person (km/capita)	11,662	12,287	15,201	17,545	1.0	1.4	1.4	1.4			
Total passenger travel (Gpkm)	4,247	4,567	5,823	6,742	1.5	1.6	1.5	1.6	100.0	100.0	100.0
of which											
road transport	3,797	4,067	4,939	5,435	1.4	1.3	1.0	1.2	89.4	89.1	84.8
aviation	160	194	411	592	4.0	5.1	3.7	4.6	3.8	4.3	7.1
Total energy demand (Mtoe)	175	190	240	252	1.7	1.6	0.5	1.1	100.0	100.0	100.0
of which											
road transport	138	149	178	178	1.5	1.2	0.0	0.7	79.2	78.2	74.0
aviation	28	32	52	62	3.3	3.1	1.9	2.7	15.8	17.0	21.4

Source: PRIMES

INDUSTRY

Sectors that have been in long decline in the EU, like iron and steel, textiles and non-ferrous metals, are projected to show negligible or even negative energy demand growth over the period to 2020. From an energy point of view, by far the most important of these sectors is the iron and steel sector which, even after a long period of decline, still accounted for more than 20 % of overall industrial energy demand in 1995. Energy consumption in other energy intensive industries, such as chemicals and paper and pulp, will increase more rapidly than overall industrial energy demand. This largely reflects the extensive restructuring that has already taken place in these sectors over the recent past and the limited scope for further energy savings.

The differential trends in industrial sub sectors are reflected in the changes in fuel shares of the sector (see Table 4-16). Again, the most notable case is the rapid decline in the use of solid fuels, reflecting the decline in the iron and steel sector. Most other changes in fuel shares are relatively modest and reflect a broad trend towards cleaner fuels, such as electricity, natural gas and diesel oil. Residual fuel oil is declining for similar reasons.

Steam growth, which grows consistently faster than overall industrial energy demand, reflects the increased opportunities for co-generation and CHP, partly due to the assumed changes in market structure. However, the overall effect is small. In general, there is a "greening" of energy use by industry: Fuels that are carbon intensive tend to decline in absolute terms while "clean" fuels tend to grow. This applies also to the oil product mix.

TABLE 4-16: INDUSTRIAL ENERGY DEMAND BY FUEL, EU-15 (1990-2020)

	Mtoe					Annual growth rates (%)			Shares (%)		
	1990	1995	2010	2020	1990/ 1995	1995/ 2010	2010/ 2020	1995/ 2020	1995	2010	2020
Total	256	245	282	290	-0.9	0.9	0.3	0.7	100.0	100.0	100.0
Solid fuels	44.0	33.2	25.0	19.9	-5.5	-1.9	-2.3	-2.0	13.6	8.9	6.8
Liquid fuels	31.1	32.7	34.6	34.6	1.0	0.4	0.0	0.2	13.3	12.3	11.9
liquified petroleum gas	2.9	3.7	4.2	4.2	4.8	0.8	0.1	0.5	1.5	1.5	1.4
naptha	1.6	0.0	0.0	0.0	-100	-	-	-	0.0	0.0	0.0
diesel oil	9.4	9.6	12.2	13.0	0.4	1.6	0.6	1.2	3.9	4.3	4.5
residual fuel oil	12.4	11.0	11.0	10.5	-2.3	0.0	-0.5	-0.2	4.5	3.9	3.6
other petroleum products	4.7	8.4	7.2	6.9	12.1	-1.0	-0.4	-0.8	3.4	2.6	2.4
Natural gas	55.6	53.4	68.3	68.5	-0.8	1.7	0.0	1.0	21.8	24.2	23.6
Steam	55.1	54.3	66.4	73.3	-0.3	1.3	1.0	1.2	22.2	23.6	25.2
Electricity	69.8	71.3	87.5	94.2	0.4	1.4	0.7	1.1	29.106	31.04	32.435
Non-energy demand	81.0	92.9	108.7	116.5	2.8	1.1	0.7	0.9			

Source: PRIMES

RESIDENTIAL

Energy demand in the residential sector is expected to grow very modestly over the next 25 years primarily because of the relatively stable population in the EU and increases in energy efficiency. Thus, the annual growth in energy consumption in the 1995-2010 period is expected to be 0.7 % while, after 2010, the sector's energy needs are expected to grow by 0.5 %/a. The implied energy intensity[22] improvement of nearly 1.5 %/a is quite optimistic when compared to the recent past. It is partly based on the assumption of significant improvements in the energy efficiency of appliances and other energy using equipment of households.

Electricity use is expected to remain the fastest growing fuel in the sector although its differential growth rate, when compared to that of other fuels, will be significantly more modest. The increased penetration of air conditioning, especially in southern EU countries, as well as the greater number of electric appliances per household, are the main reasons for the fast growth in electricity demand. The use of solid fuels by households will drop sharply over the next 25 years mainly because of the decline in agricultural households.

[22] Energy intensity in households is computed using households income as the denominator.

TABLE 4-17: FINAL ENERGY DEMAND IN THE RESIDENTIAL SECTOR, EU-15 (1990-2020)

	Mtoe				Annual growth rates (%)				Shares (%)		
	1990	1995	2010	2020	1990/ 1995	1995/ 2010	2010/ 2020	1995/ 2020	1995	2010	2020
Total energy consumption	232	240	267	282	0.6	0.7	0.5	0.6	100.0	100.0	100.0
of which											
solids	20	8	1	0	-16.3	-10.9	-13.5	-12.0	3.4	0.5	0.1
liquids	64	62	67	67	-0.4	0.5	0.0	0.3	25.9	25.2	23.9
natural gas	76	89	101	105	3.2	0.9	0.4	0.7	36.9	37.6	37.2
new fuels	20	21	21	20	1.1	-0.1	-0.3	-0.2	8.8	7.7	7.1
steam	9	10	13	14	2.4	1.8	0.9	1.4	4.1	4.9	5.0
electricity	45	50	64	75	2.3	1.7	1.6	1.6	20.9	24.0	26.7
Income per household(€90)	22,765	23,073	29,694	33,798	0.3	1.7	1.3	1.5			
Energy Intensity(toe/M€90)	75	72	58	51	-0.6	-1.5	-1.3	-1.4			
Energy per capita (toe/capita)	0.64	0.65	0.70	0.73	0.2	0.5	0.5	0.5			

Source: PRIMES

SERVICES AND AGRICULTURE

The tertiary sector shows one of the fastest growth rates among all the final energy use sectors. As was seen in the discussion of future macroeconomic trends, much of the future economic growth is likely to originate from the service and trade sector, which already account for the bulk of the EU economy. The negative impact of the consolidation of the public sector, which is also included in this sector, is assumed to decline gradually.

Overall annual energy demand growth in the sector is expected to average 1.7 %/a in the period to 2010 and to decelerate to 1 % in the following decade as the overall economic growth rate moves to a lower level. An annual intensity[23] improvement of close to 1 % is projected throughout the projection period. This can be considered quite optimistic, as can be seen from the trends of the 1990-95 period when there was an actual increase in energy intensity.

Electricity, which already accounts for more than a third of the energy consumption of the sector, is projected to be the fastest growing fuel. This is due both to the continued penetration of electricity in space heating and cooling and to the increase in the number and variety of electric appliances, such as computers. Steam is also expected to continue to make inroads into this sector primarily due to the changing market structure. Solids will gradually disappear as a fuel for this sector.

TABLE 4-18: FINAL ENERGY DEMAND IN SERVICES AND AGRICULTURE, EU-15 (1990-2020)

	Mtoe				Annual growth rates (%)				Shares (%)		
	1990	1995	2010	2020	1990/ 1995	1995/ 2010	2010/ 2020	1995/ 2020	1995	2010	2020
Total energy consumption	**110.3**	**124.3**	**159.0**	**176.9**	**2.4**	**1.7**	**1.1**	**1.4**	**100.0**	**100.0**	**100.0**
Of which											
solids	6.7	1.5	0.3	0.2	-25.3	-10.2	-4.7	-8.0	1.2	0.2	0.1
liquids	34.8	37.5	39.5	36.7	1.5	0.4	-0.7	-0.1	30.1	24.8	20.8
natural gas	25.7	34.9	42.1	38.4	6.3	1.3	-0.9	0.4	28.1	26.5	21.7
electricity	37.9	43.2	65.8	86.6	2.6	2.8	2.8	2.8	34.8	41.4	48.9
steam	4.1	5.7	10.0	14.0	7.2	3.8	3.4	3.6	4.6	6.3	7.9
new fuels	1.2	1.5	1.3	1.0	4.4	-0.8	-2.5	-1.5	1.2	0.8	0.6
Value Added(000M€ 90)	3,244	3,589	5,348	6,492	2.0	2.7	2.0	2.4			
Energy Intensity(toe/M€90)	34.0	34.6	29.7	27.3	0.4	-1.0	-0.9	-1.0			

Source: PRIMES

[23] Energy intensity in services and agriculture is computed using sectoral value added as the denominator

TABLE 4-19: ELECTRICITY DEMAND BY SECTOR, TWH, EU-15 (1995-2020)

	TWh			Annual growth rates (%)			Shares (%)		
	1995	2010	2020	1995/2010	2010/2020	1995/2020	1995	2010	2020
Industry	858	1,046	1,122	1.3	0.7	1.1	42.3	39.1	35.9
Tertiary	503	765	1,007	2.8	2.8	2.8	24.8	28.6	32.2
Households	582	747	873	1.7	1.6	1.6	28.7	28.0	28.0
Transport	55	100	111	4.0	1.1	2.8	2.7	3.7	3.6
Others	32	15	10	-5.0	-3.8	-4.5	1.6	0.6	0.3
TOTAL	**2,030**	**2,673**	**3,124**	**1.9**	**1.6**	**1.7**	**100.0**	**100.0**	**100.0**

Source: PRIMES

ELECTRICITY AND STEAM GENERATION

Because of a number of favourable characteristics of electricity there is a well-established long-term trend towards increased electrification in most sectors of developed economies. These characteristics include easy controllability, precise measurement, cleanliness at the point of use and concentration of useful energy. Increasingly, a number of processes, appliances and applications can use energy only in the form of electricity. Overall, the use of electricity is expected to expand by 1.7 %/a over the projection period and its growth is expected to be especially rapid in the tertiary and transportat sector, though the latter is still of limited significance as an electricity market.

Steam demand is projected to grow by 1.3 %/a in the period to 2010 and by 0.9 %/a in the following decade. The industrial sector is the dominant user of steam. Households and the tertiary sector are potentially large users of distributed heat, mostly for heating purposes, but their distance from generation plants, where steam is a by product, and the difficulties involved in its transport, have prevented extensive use. It is only in countries such as Denmark, where specific incentives have been provided for the development of district heating systems, that steam plays a significant role outside industry. Partly because of the shift towards decentralisation, and partly as a consequence of technology progress allowing for smaller-scale distributed heat networks, steam applications in the tertiary sector are expected to grow quite rapidly over the projection period.

The bulk of the above electricity and steam requirements have to be produced within the EU and an allowance needs to be made for the significant transmission and distribution losses. Electricity imports remain negligible for the EU as a whole and they are usually significantly below 1 % of total consumption. Of course, electricity imports can be quite significant for individual EU countries and they are likely to adjust as the electricity markets become more integrated, at least at EU level. Transmission and distribution losses are expected to increase somewhat less than total electricity production due to better management. Steam losses as a share of steam production are expected to decline due to better insulation.

Total power capacity requirements for the EU will increase by some 300 GW to more than 50 % in the 1995-2020 period (see Table 4-20). Traditional coal and oil plants will decline very rapidly. Similarly, due to the decommissioning of older plants, there is a modest decline in the capacity of nuclear plants while nearly half of the thermal plant capacity currently utilised by independent producers is also expected to be scrapped. These declines in capacity are more than made up for by the dramatic increase in the gas turbine combined cycle

TABLE 4-20: GENERATING CAPACITIES IN GW, EU-15 (1995-2020)

	GW			Annual growth rates (%)			Shares (%)		
	1995	2010	2020	1995/2010	2010/2020	1995/2020	1995	2010	2020
Nuclear	132	135	117	0.2	-1.4	-0.5	23.1	18.8	13.4
Coal and Lignite	180	101	37	-3.8	-9.6	-6.1	31.5	14.1	4.2
Open Cycle multi-Fired	66	60	122	-0.6	7.3	2.5	11.5	8.4	14.0
Open Cycle of IPP	33	25	21	-1.8	-2.0	-1.9	5.8	3.5	2.4
GTCC and small GT	46	254	384	12.0	4.2	8.8	8.1	35.4	44.1
Clean Coal and Lignite	0	3	27	14.5	22.7	17.7	0.1	0.5	3.1
Biomass-Waste of Utilities	4	5	6	1.2	2.5	1.7	0.7	0.7	0.7
Fuel Cells	0	0	0				0.0	0.0	0.0
Hydro-Renewables	109	134	158	1.3	1.7	1.5	19.2	18.6	18.1
Total Capacities	**570**	**717**	**872**	**1.5**	**2.0**	**1.7**	**100.0**	**100.0**	**100.0**

Source: PRIMES

plants. These increase by more than 8 times over the projection period to reach 384 GW or around 45 % of the total installed capacity by 2020. This rather spectacular growth, brought on line by both utilities and smaller producers, is due to the significant cost and environmental advantages that this form of power generation has demonstrated in recent years.

Significant growth in generation by clean coal plants and biomass generation is also expected to occur over the next 20 years. However, these forms of power generation will still only account for less than 5 % of total generation capacity by 2020. The rate of growth in electricity generation from hydro power and other renewable energy forms is projected to be more modest. However, the increase in their capacity (nearly 50 GW between 1995 and 2020) will make a significant contribution.

Technological advances and changes in market structure will reduce the dominance of utilities in electricity generation. Thus, utilities are expected to own 78 % of the generation stock by 2020, compared to more than 90 % in 1995. This trend is clearly related to the widespread use of gas turbines since the economics of this form of generation indicate that economies of scale benefits are very limited above a rather modest size of a turbine.

The use of gas turbines in combined cycle mode will also greatly encourage the more widespread use of steam, especially by independent producers. CHP plants, usually through the use of GTCC, are expected to account for nearly three-quarters of steam generation by 2020.

A significant improvement is expected to occur in the efficiency of power generation. The efficiency of the overall generation system (including electricity production, as well as steam production from CHP plants and industrial boilers) is expected to increase by 12 percentage points to reach 66 % by 2020. The efficiency of electricity generation will improve from 34 to 45 % between 1995 and 2020. These projections are closely dependent on the projection of total new capacity requirements as well as on the expectation that the bulk of new capacity will be GTCC. This is because GTCC is much more efficient than established power stations and new single cycle coal plants. Thus, the greater the new capacity requirements and the proportion of GTCC in new plants, the greater the likely efficiency of the overall power generation system.

The trends in fuel use for steam and power generation purposes reflect the trends in the choice of fuel for new capacity requirements and trends in efficiency. The use of coal and lignite will decline quite dramatically between 1995 and 2010 but after that it will recover to reach, and marginally exceed, its 1995 level. This is due to the increased decommissioning of nuclear plants after 2010. Interestingly, the increase in gas consumption, rising by two and a half times over the projection period, is substantially less than the nearly tenfold increase in the use of gas turbines. This is due to the rising efficiency of GTCC but also to the use of gas not only for base-load generation but also for medium and peak load purposes, usually through the use of single cycle gas turbines. Oil use for generation purposes will decline by almost a third between 1995 and 2020 as many of the existing oil plants are kept only as part of the required reserve margin.

4.2.3 ENVIRONMENTAL IMPLICATIONS

THE OUTLOOK FOR CO_2 EMISSIONS

CO_2 emissions are projected to increase annually by 0.6 %/a in the 1995-2020 period. A comparison of these figures with those of total primary energy demand reveals that the carbon intensity of the EU energy system will decline in the first part of the projection period, by 0.3 %/a. However, CO_2 emissions are projected to increase marginally faster than energy demand after 2010. The main reasons for this are, firstly, the increase in the use of nuclear power in the period to 2010 and its decline thereafter and, secondly, the faster penetration of less carbon intensive fossil fuels in the period to 2010. Emissions from solid fuels will decline rapidly in the period to 2010 but rise almost as rapidly in the 2010-20 period. On the other hand, emissions from natural gas will increase more than twice as fast in the first part of the period, reflecting the "dash for gas" that is currently taking place in the power generation systems of most EU countries. In absolute terms, the increase in emissions from gas more than compensates for the sharp decline in emissions that results from the decline in the use of solid fuels.

Under the assumptions of the baseline scenario presented here, the EU will not manage to stabilise CO_2 emissions, let alone decrease them in accordance to the commitment undertaken at Kyoto. By 2010, EU emissions will be 7.1 % higher than they were in 1990. It is important to note that this increase takes place despite two unique occurrences that have led to a drastic reduction in post 1990 emissions in two of the largest economies within the EU, namely, the UK and Germany. In the latter, the reunification led to a sharp decline in the emissions of the eastern "Laender" as gas has replaced lignite-based town gas and as the economy of this region restructured drastically. In the UK there was a massive penetration of gas in the power generation system. Baseline CO_2 emissions in the EU are projected to continue increasing after 2010 and by 2020 they are expected to be 14 % higher than their 1990 level.

TABLE 4-21: CO_2 EMISSIONS BY FUEL, EU-15 (1990-2020)

	Mt CO_2				Annual growth rates (%)		Shares (%)		
	1990	1995	2010	2020	1995/ 2010	2010/ 2020	1995	2010	2020
Total	**3,079**	**3,037**	**3,298**	**3,508**	**0.6**	**0.6**			
Solids	1,093	870	664	819	-1.8	2.1	35.5	20.1	23.3
hard coal	616	547	397	569	-2.1	3.7	62.8	59.8	69.5
coke	125	93	64	52	-2.5	-2.2	10.7	9.7	6.3
lignite	280	210	199	196	-0.4	-0.1	24.1	29.9	23.9
Liquids	1,421	1,509	1,709	1 714	0.8	0.0	46.1	51.8	48.9
gasoline	354	350	424	425	1.3	0.0	23.2	24.8	24.8
kerosene	91	108	169	202	3.0	1.8	7.2	9.9	11.8
diesel oil	576	640	729	729	0.9	0.0	42.4	42.7	42.5
fuel oil	266	261	227	194	-0.9	-1.6	17.3	13.3	11.3
Gas	565	658	925	975	2.3	0.5	18.4	28.0	27.8
natural gas	483	591	873	934	2.6	0.7	89.8	94.4	95.8

Source: PRIMES

It is not surprising that, in the period to 2010, the sectors with the fastest increase in emissions are those where energy demand is expected to grow fastest, namely the tertiary and transport sectors. However, in terms of their absolute contribution to the increase in emissions it is the transport sector, which will account for more than two thirds of the overall increase in emissions between 1995 and 2010. After 2010, the transport sector will no longer be the main contributor to CO_2 emissions growth. This role will be taken up by electricity and steam generation, almost solely responsible for the increase in emissions between 2010 and 2020. By 2020, it will account for more than 40 % of EU emissions.

Given the stagnation of carbon intensity, CO_2 emissions do not grow at the rate of economic growth because of the improvement of energy intensity. Emissions could be higher by 2010 if the improvement of energy intensity were to prove slower than projected under baseline assumptions.

Energy intensity improvement is the major factor in moderating the rise of CO_2 emissions in the baseline projection for the EU. The impact of changes in the carbon intensity of fossil fuels will also be beneficial until 2010, after which the increased demand for coal leads to a rise in the carbon intensity of fossil fuels. The fossil fuel intensity of primary energy consumption actually contributes to a marginal increase in emissions as a result of the relative stagnation of nuclear and hydro.

4.3 ENERGY TRENDS AND UNCERTAINTIES IN CENTRAL AND EASTERN EUROPEAN ACCESSION COUNTRIES[24/25]

Following the collapse of most centrally planned economies in the late 1980s, Central and Eastern European countries are still currently undergoing substantial restructuring and reforms towards a market economy. The region as a whole experienced a sharp recession until 1993 after which a process of slow recovery began.

This analysis to date includes 7 of the candidate countries of Central and Eastern Europe, namely the Czech Republic, Hungary, Poland, Slovenia and the three Baltic States (Estonia, Latvia, Lithuania – for which separated historical data have not always been available for this analysis). These countries are called here **"accession countries"** solely for having a short name in the following analysis.

In response to the negative economic conditions gross inland energy consumption and indigenous energy production in central and eastern European **accession countries** followed a downward trend, declining in 1996 to 86 % and 81 % of their 1988 levels respectively. The biggest share in the decline in demand was that of solid fuels followed by oil while primary energy consumption of natural gas increased by about 30 % in 1988-1996. However, by 1996, solid fuels still dominated consumption although their share fell from 60 % in 1980 to 53 % in 1996. Oil and gas accounted for 21 % and 16 % of pri-

[24] Central and Eastern European accession countries include the Czech Republic, Hungary, Poland, Slovenia and Estonia. However, due to a lack of analytical historical statistics for the Baltic States, Latvia and Lithuania are also included in the accession countries.

[25] The discussion of recent trends in this section is based on the 1998 Annual Energy Review of the European Commission.

TABLE 4-22: PRIMARY ENERGY DEMAND, CENTRAL AND EASTERN EUROPEAN ACCESSION COUNTRIES, 1995-2020

	Mtoe				Annual growth rates (%)			Shares (%)		
	1995	2000	2010	2020	1995/ 2010	2010/ 2020	1995/ 2020	1995	2010	2020
Gross Inland Consumption	**187.2**	**192.9**	**221.0**	**254.6**	**1.1**	**1.4**	**1.2**	**100.0**	**100.0**	**100.0**
Solid Fuels	100.4	93.1	84.6	76.7	-1.1	-1.0	-1.1	53.6	38.3	30.1
Liquid Fuels	39.3	41.3	48.4	61.3	1.4	2.4	1.8	21.0	21.9	24.1
Natural Gas	29.0	38.2	65.5	91.9	5.6	3.4	4.7	15.5	29.7	36.1
Nuclear	11.2	11.8	12.2	12.3	0.5	0.1	0.4	6.0	5.5	4.8
Electricity	-0.2	-0.3	-0.7	-0.6	6.9	-0.6	3.8	-0.1	-0.3	-0.2
Renewable Energy Sources	7.5	8.9	10.9	13.0	2.5	1.7	2.2	4.0	4.9	5.1
CO_2 Emissions (Mt CO_2)	555	553	604	674	0.6	1.1	0.8			
Energy intensity (toe/M€90)	1,494	1,243	910	718	-3.2	-2.3	-2.9			
Carbon Intensity (t of CO_2/toe)	2.97	2.87	2.74	2.65	-0.5	-0.3	-0.4			
Import dependency (%)	17.5	28.3	44.2	55.5						

Source: NTUA estimates

mary energy consumption in 1996. Production from all fossil fuels also fell substantially since 1985 in the accession countries as a result of the restructuring of their economies. With a limited oil and gas resource base the countries of the region are net importers of crude oil and natural gas which they import mainly from Russia. In 1996, almost 95 % of total oil demand was covered by imports. Net imports of natural gas increased by 60 % between 1988 and 1996, from 15.8 Mtoe to 25.4 Mtoe.

As regards the future evolution of the energy system in this region, primary energy consumption is expected to grow annually by 1.1 %/a in the 1995-2010 period and by slightly more (1.4 %) between 2010 and 2020. The implied energy intensity improvement is expected to improve and to reach an annual rate of more than 2.9 %/a in 1995-2020 (see Table 4-22). The economic recovery after 1993, the industrial restructuring, the opening up to competition and the 'rationalisation' of the energy system initialised by the advent of economic reforms, as well as, the accelerated substitution of solid fuels with natural gas explain this change. The significant decrease of primary production, especially in solid fuels, will result in a growth of import dependency from 17.5 % in 1995 to more than 55 % in 2020.

The use of solid fuels is expected to decrease substantially in the projection period, both in absolute terms and as a proportion of total energy demand. The share of solids will drop from 54 % in 1995

TABLE 4-23: FINAL ENERGY DEMAND BY SECTOR AND BY FUEL, CENTRAL AND EASTERN EUROPEAN ACCESSION COUNTRIES, 1995-2020

	Mtoe				Annual growth rates (%)			Shares (%)		
	1995	2000	2010	2020	1995/ 2010	2010/ 2020	1995/ 2020	1995	2010	2020
Total Final Energy Demand	117.9	122.5	142.5	169.9	1.3	1.8	1.5	100.0	100.0	100.0
by Fuel										
Solid Fuels	31.4	27.1	20.4	16.2	-2.8	-2.3	-2.6	26.7	14.3	9.5
Liquid Fuels	27.5	29.2	36.9	48.4	2.0	2.7	2.3	23.3	25.9	28.5
Natural Gas	18.9	24.3	34.5	43.7	4.1	2.4	3.4	16.1	24.2	25.7
Heat	17.2	16.7	16.7	16.6	-0.2	-0.1	-0.2	14.6	11.8	9.8
Electricity	16.4	18.0	25.1	34.5	2.9	3.2	3.0	13.9	17.6	20.3
Renewable Energy Sources	6.4	7.2	8.8	10.5	2.1	1.8	2.0	5.5	6.2	6.2
by Sector										
Industry	42.3	43.0	47.5	52.9	0.8	1.1	0.9	35.9	33.3	31.1
Residential and Tertiary	58.2	60.8	69.5	79.5	1.2	1.4	1.3	49.4	48.8	46.8
Transport	17.4	18.6	25.5	37.5	2.6	3.9	3.1	14.8	17.9	22.1

Source: NTUA estimates

to around 30 % in 2030. This is to the advantage of natural gas which, spurred by its very rapid penetration in new power generation plants and on the demand side, will increase its market share by more than 20 percentage points in 1995-2020. The shares of oil and renewable energy forms in primary consumption show a moderate increase in the projection period.

Final energy demand in central and eastern European accession countries peaked in 1985 at close to 154 Mtoe and then declined sharply to reach 116 Mtoe in 1994. There was a moderate increase of about 2 % in the level of final demand in 1995, further accelerated to 5.6% in 1996. The main contributor to the decline was solid fuels, the consumption of which fell by 45 % between 1985 and 1996 due to the slowdown in the output of the steel industry and reductions in the use of solids for heating and cooking purposes. Oil, mainly a transport fuel exhibited a decline in consumption of "only" 3 % due to increases in the number of private cars. On the contrary, natural gas consumption increased by 35 % in the 1985-1996 period, due to its rapid penetration in the tertiary and household sector which occurred to the detriment of district heat. For the latter a decrease of more than 30 % was observed in 1985-1996. Finally, electricity demand remained quite stable in the 1985-1996 period.

Final energy demand is expected to grow marginally faster than primary energy (because of improved rates of conversion efficiency in power generation), rising by 1.3 % and 1.8 % in the 1995-2010 and 2010-20 periods respectively. The decline of solid fuels in final uses (-2.6 %/a between 1995 and 2020) is more evident than at the primary level as they are substituted by natural gas and electricity which rise by 3.4 % and 3.0 %/a respectively in the same period. Oil will become a fuel for transport. The increase in transport energy demand is actually greater than the increase in the demand for liquid fuels over the 1995-2020 period, implying a decline in oil consumption in the other sectors.

Energy demand in the transport sector is the fastest growing segment of final demand. By 2020, the residential and tertiary sector will account for almost half of final energy consumption, followed by industry and the transport sector, which account for around 30 % and 22 % of consumption respectively.

Electricity generation in central and eastern European accession countries, despite a peak of 303 TWh in 1989, followed a downward trend reaching a minimum of 261 TWh in 1994. It started recovering afterwards with an increase of 3.5 % in 1995 and 4 % in 1996. In 1996, thermal production was still dominant, with 80 % of total generation, despite the reduction of its share from 88 % in 1985. Thermal production in 1996 relied mainly on solid fuels (90 %) followed by gas (5.5 %) and oil (5 %), a fuel mix that has not changed significantly during the 1985-1995 decade. Nuclear and hydro generation increased both in absolute terms and as a share in total generation.

The use of electricity is expected to expand by 3 %/a over the projection period. District heat demand is projected to remain quite stable at its 1995 levels. Table 4-24 demonstrates the trends projected for the power and heat generation system of the Central and Eastern European accession countries. As this analysis does not include assumptions on policy shifts in the framework of these accession countries becoming members of the EU, there are no assumptions on the decommissioning of nuclear plants not meeting EU safety standards. Therefore, nuclear production is projected in

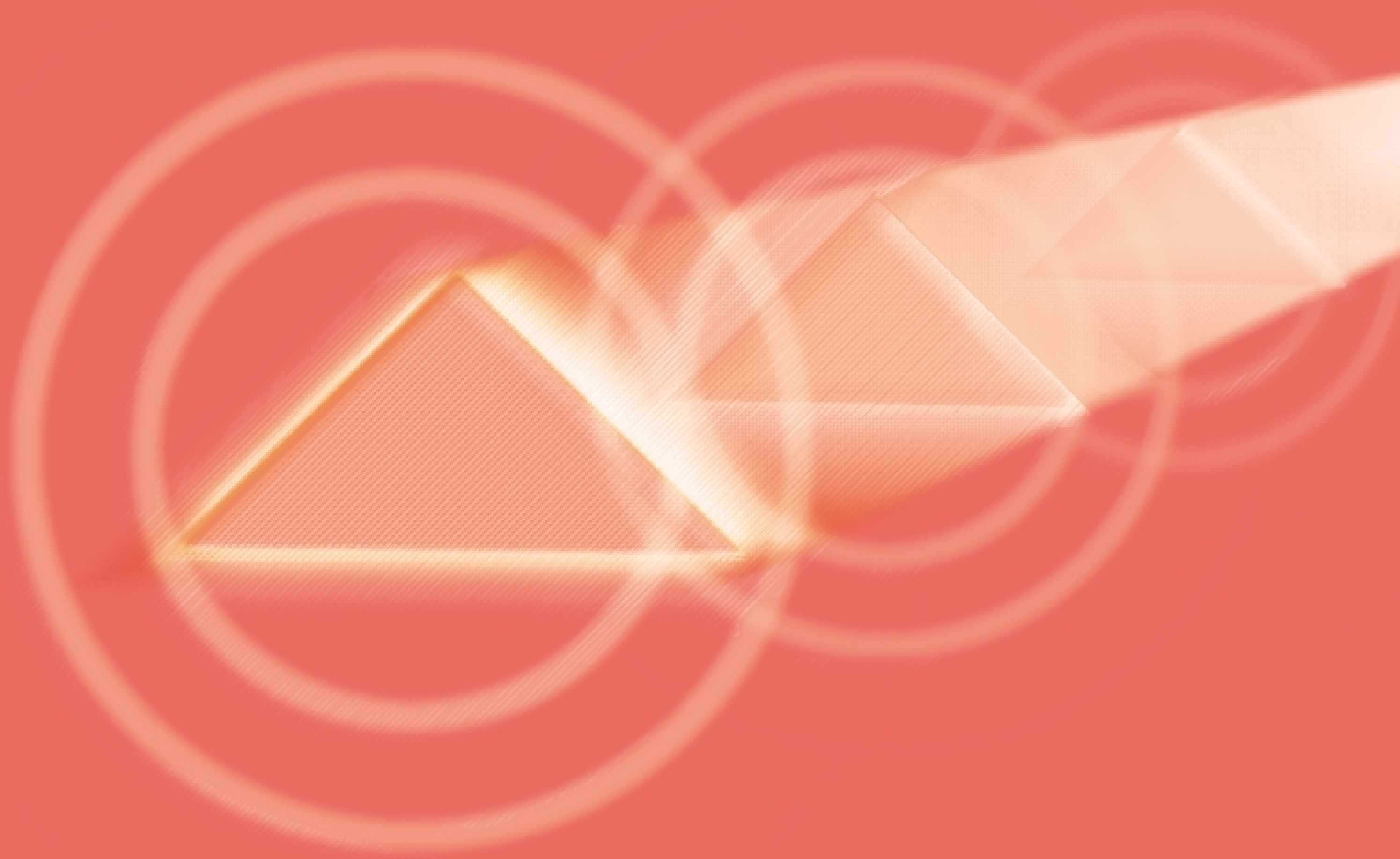
TABLE 4-24: POWER GENERATION IN CENTRAL AND EASTERN EUROPEAN ACCESSION COUNTRIES, 1995-2020

					Annual growth rates (%)			Shares (%)		
	1995	2000	2010	2020	1995/ 2010	2010/ 2020	1995/ 2020	1995	2010	2020
Electricity Generation in TWh	**270.5**	**291.4**	**354.9**	**449.1**	**1.8**	**2.4**	**2.0**	**100.0**	**100.0**	**100.0**
Nuclear	42.9	45.1	46.7	47.2	0.6	0.1	0.4	15.8	13.2	10.5
Hydro - Renewables	10.6	13.0	17.7	21.0	3.5	1.7	2.8	3.9	5.0	4.7
Thermal (incl. biomass)	217.0	233.3	290.5	380.9	2.0	2.7	2.3	80.2	81.8	84.8
Fuel Inputs for Power and Steam										
Generation in Mtoe	77.1	80.5	96.0	111.9	1.5	1.5	1.5	100.0	100.0	100.0
Solids	62.0	60.4	60.1	57.6	-0.2	-0.4	-0.3	80.3	62.6	51.5
Oil	6.5	7.0	5.4	6.4	-1.2	1.7	0.0	8.4	5.7	5.7
Gas	8.5	12.7	29.8	47.2	8.7	4.7	7.1	11.1	31.1	42.2
Biomass / Waste	0.2	0.5	0.6	0.7	9.5	0.8	5.9	0.2	0.6	0.6

Source: NTUA estimates

PART V

ALTERNATIVE SCENARIOS, VARIANTS AND SENSITIVITY ANALYSES



As future developments cannot be predicted, economic analysis considers alternative developments of the contextual conditions and of structure or technological changes in alternative scenarios. When only a few contextual conditions are varied and many assumptions of a scenario remain unchanged, these alternative projections are called variants of a given scenario. Finally, sensitivity analysis covers those projections where only one or two assumptions have been varied in order to analyse their particular implications on the energy system.

TABLE 5-1: STRUCTURE OF HYPOTHESES FOR ALTERNATIVE SCENARIOS ON THE WORLD ENERGY SYSTEM

Resources \ Economic growth	Economic recovery from Asian crisis	Protracted crisis
Standard resources (USGS mode) *	S1	S3
High resources (USGS 5 %)	Baseline	S4

(*) USGS: US Geological Survey

In this chapter, major attention is given to a few changes of important boundary conditions of the Baseline Scenario: at the global level, the influence of the energy resource availability and economic growth has been analysed, and the results are discussed together with other available projections on world energy demand. For the EU, alternative projections with PRIMES are used to analyse the implications of reducing CO_2 emissions according to the Kyoto commitments. In addition, sensitivity analyses serve to explore uncertainties regarding in particular the future of nuclear energy in Europe, the case of higher oil and gas import prices, the possible diffusion of more efficient new cars, and of different developments of structural change in the economy. These alternative projections give useful insights into the dynamics of the energy system and for particular sectoral and policy aspects.

5.1 ALTERNATIVE SCENARIOS ON WORLD ENERGY

Uncertainties surround the future dynamics of the world energy system, in particular those concerning the global and regional economic growth, technology development, the energy intensity trends and world oil and gas resources constraints. These factors determine the long-term oil price trend which, in turn, also influences the evolution of energy intensity, technological progress and substitution between fuels.

Scenarios based on different POLES model simulations allow the exploration of this interrelationship through some other energy futures around the baseline. The different scenarios have been simulated using the following crossed hypotheses on the economic recovery of the emerging countries from the financial crisis and on oil and gas resources (Table 5-1).

The comparison with other reference world energy outlooks to 2020 (IEA, US DOE) sheds some light on the impact of the resource constraints on long-term oil prices. Another comparison with the WEC-IIASA scenarios, which have a more ambitious goal drawing attention to the expanding range of options in the very long term (2020-2050), also helps to locate the baseline scenario in terms of technological orientation and business as usual growth of CO_2 emissions.

5.1.1 THE INFLUENCE OF GLOBAL RESOURCE CONSTRAINTS AND OF WORLD ECONOMIC GROWTH ON LONG-TERM OIL PRICE

POLES simulations present the originality of producing endogenous projections for international energy prices: oil and natural gas prices depend on the resource constraints as they are a function of the Reserves/Production ratios (R/P) in the long term[26].

The two driving forces for oil price trends are world economic growth and the degree of the resource constraint. The scenario of protracted crisis (S4), with a slow recovery lasting until 2007, shows that a lower level of global economic activity (losing around 7 % of GDP in 2020 in comparison with the pre-crisis scenario) has a small impact on the oil price (-1$/barrel in 2010 and 2020, by comparison to the reference case[27]).

One main question remains with the imminence of the pressure on oil and gas resources before 2020 and their eventual effect on respective prices. A more pessimistic view on the resource availability produces an energy market future quite different from the baseline scenario.

The level of recoverable resources derived from the US Geological Survey (USGS) depends on the probability of converting resources to proven reserves by discoveries and development, and on assumptions concerning the recovery rate increase over time. The reference case, which is based on a hypothesis of abundant resources, supposes a supplement in recoverable resources of 500 billion barrels (70 billion tonnes) on top of the 2,400 billion barrels (340 billion

[26] The model accounts for 20 production regions and assumes an increasing recovery rate with time; resources are transferred to reserves and cost of production increases according to endogenous functions.

[27] On the 1990-2020 period, the average rate of growth is reduced to 3.0 %/a, instead of 3.4 %/a.

TABLE 5-2: COMPARISON OF THE OIL PRICE TREND BETWEEN THE BASELINE SCENARIO AND THE MODERATE RESOURCE SCENARIO, 2010-2030

	2010		2020		2030	
	Abundant resource (Baseline)	Moderate resource (S1)	Abundant resource (Baseline)	Moderate resource (S1)	Abundant resource (Baseline)	Moderate resource (S1)
R/P Ratio (years)	37.4	36.0	32.8	29.9	29.4	25.6
Oil price ($90/barrel)	16.9	19.3	20.1	25.0	23.0	30.4

Source: POLES

tonnes) for the USGS "mode" estimate. Additional unconventional oil reserves of 1000 billion barrels are added when prices exceed $20/barrel. If the supplement of discovery is ignored, the oil price increases more rapidly than in the baseline scenario: +2.4 $/barrel in 2010, +5$/barrel in 2020[28]. The impact of the resource constraint is stronger in the following decade, creating a difference of $7/barrel in 2030 with respect to the baseline.

In its reference case the DOE's International Energy Outlook 1998 considers an exogenous price of $19.1/barrel in 2020, with an optimistic view on resources[29]. On the other side, because of the assumption of a more restricted endowment of the non-Gulf countries with cheap oil resources, the IEA's World Energy Outlook 1998 is more pessimistic with a $25/barrel price in 2020 in the reference case[30].

CHANGE IN THE DISTRIBUTION OF WORLD OIL PRODUCTION

The different assumptions on resources between the two POLES scenarios (baseline and S1) also shed light on the future distribution of world oil production in the case of moderate resources. The S1 scenario shows a reconcentration of production on the Gulf countries between 2000-2020 (from 26 % to 46 %, instead to 37 % in the baseline). On the other hand, the situation of abundant resources (baseline) would allow a more diversified oil production and trade with important discoveries outside the Gulf. This looks like a paradoxical evolution: lower oil prices and more non-Gulf oil production. But this can be easily explained, as oil is more abundant in every region, allowing higher level of production in non-Gulf regions, while the Gulf countries reduce their production as they behave as "swing producers" on the oil market.

In the "moderate resource" scenario S1, the non-conventional resources have, however, an important role to play by adding a substantial amount of competitive resources when the oil price increases beyond $20-25/barrel. The 2010/2020 period could be crucial for a significant contribution of unconventional oil to the world global oil supply[31], with a rapid technical progress and an improving recovery rate. They may reach a share of around 6 % in 2020 and 14 % in 2030 (instead of respectively 3.6 % and 10 % in the baseline).

An important feature to underline in the moderate resource scenario is that, given the location of the main unconventional resources in the West, the Gulf share in world oil production stays around the level of 46 % after 2020. Moderate conventional resources will thus not necessarily imply a dramatic concentration of world oil production on the Middle East.

TABLE 5-3: EVOLUTION OF THE DISTRIBUTION IN WORLD OIL PRODUCTION (MTOE), 1990-2030

	1990	2010		2020		2030	
		(Baseline)	S1	(Baseline)	S1	(Baseline)	S1
Gulf	815	1,750	1,920	2,020	2,390	2,440	2,830
Non-Gulf conventional	2,445	2,655	2,295	3,210	2,450	3,420	2,365
Non conventional	15	65	100	195	315	575	865
Total	**3,275**	**4,470**	**4,315**	**5,425**	**5,155**	**6,435**	**6,060**

Source: POLES

[28] In 1990$.

[29] Energy Information Administration (US DOE) – International Energy Outlook 1998, Washington: US DOE, April 1998.

[30] International Energy Agency – World Energy Outlook 1998, Paris, OCDE, 1998.

[31] Profitability appears at a price over $10 for Orinocco ultra heavy oil and $17 for tar sands.

TABLE 5-4: TREND IN PRIMARY FUEL PRICES ($90/BARREL), 1990-2020

		1990	2000	2010	2020
Oil	Baseline	23.8	11.2	17.1	20.2
	S1	23.8	11.1	20.1	25.5
Gas*	Baseline	15.2	9.8	15.1	19.8
	S1	15.0	10.0	17.3	24.9
Coal*	Baseline	10	8.9	9.6	10.2
	S1	10	9.0	9.7	10.4

* Price on the European market

Source: POLES

DIFFERENCES IN FUEL PRICE INCREASE

A conservative view on hydrocarbons resources influences both oil and natural gas price trends. Natural gas prices will increase more rapidly than in the reference scenario on the three regional markets. This change results also from the stronger resource constraint which provokes a quicker price increase in Europe between 2000 and 2020 for oil. It does not necessarily imply the continuation of contractual indexing of natural gas price to oil product prices in Europe: with the liberalisation of gas markets, the uncoupling of prices could occur but it is the pressure on regional gas resources which will increase gas import prices. This increase will logically be passed through to the final sales price, but with a compensating impact by the competitive pressure on the rent of pipeline companies.

As far as coal is concerned, a flat trend is assumed in both scenarios, leading international prices of coal to be disconnected from the oil and gas price growth, despite a higher use of coal in the scenario of higher oil price (see Table 5-5). The coal markets will be quite independent from the other fuel markets, even more than in the past.

THE LIMITED IMPACT OF HIGHER ENERGY PRICES ON WORLD ENERGY CONSUMPTION

World energy consumption growth is weakly influenced by the evolution of the oil price as the leading price. An increase to $25.5/barrel in 2020 instead of $20/barrel reduces world energy consumption by 0.4 Gtoe on a total level of 15 Gtoe (i. e. by 2.6 %) in 2020[32]. Oil may lose only 1.6 % of its market share in 2010 and 1.1 % in 2020 because of the parallel growth of oil and gas prices, and the already important share of taxes in the price of oil products.

Moreover, the energy market is increasingly divided into two parts with, on the one hand, oil products being primarily used in transport and the petrochemical industry and, on the other hand, power generation using coal, gas, nuclear, hydro and renewables. Because of

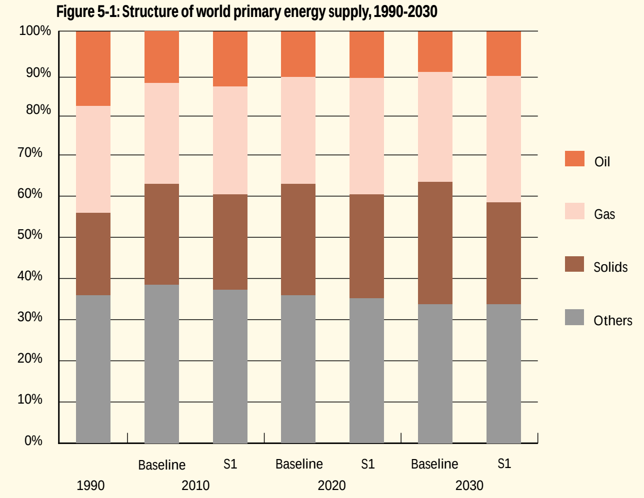
TABLE 5-5: INFLUENCE OF HIGHER OIL PRICES ON WORLD PRIMARY ENERGY CONSUMPTION, 1990-2030

	1990	2010		2020		2030	
		(Baseline)	S1	(Baseline)	S1	(Baseline)	S1
Total primary energy supply (TPES) (Gtoe)	8.5	11.75	11.54	15.0	14.6	18.8	17.9
Oil (Gtoe)	3.1	4.45	4.3	5.4	5.1	6.4	6.0
Share in TPES (%)	36.5	37.9	37.2	36.0	34.9	34.0	33.6
Gas (Gtoe)	1.7	2.9	2.7	4.1	3.7	5.5	4.5
Share in TPES (%)	20.0	24.7	23.4	27.3	25.3	29.3	25.1
Solids (Gtoe)	2.2	2.9	3.0	3.9	4.15	5.0	5.5
Share in TPES (%)	25.8	24.7	26	26	28.5	26.6	30.7
Others (Gtoe)	1.5	1.5	1.55	1.6	1.65	1.9	1.9
Share in TPES (%)	17.7	12.7	13.4	10.7	11.3	10.1	10.6

Source: POLES

[32] The WEC energy outlooks, which refer to a severe constraint on resources with a price of $40/barrel in 2020, consider a lower consumption of oil (4.5 Gtoe in the A2 scenario for a quite similar total primary energy consumption instead of 5.3 Gtoe in the POLES base case).

Figure 5-1: Structure of world primary energy supply, 1990-2030



Source: POLES

TABLE 5-6: LEVELS OF CO_2 EMISSIONS BY ANNEX B REGIONS IN 2010 (IN Gt C)

	1990	POLES**	WEO98**	IEO98**
OECD	2.73*	3.37	3.6	3.66
CEEC-FSU	1.29*	0.96	1.05	1.07
World	5.81	8.22	8.5	8.33

* approximate Kyoto targets ** base case

TABLE 5-7: INFLUENCE OF THE PRICE LEVEL ON WORLD-WIDE CO_2 EMISSIONS (IN Gt C)

	2010	2020	2030
Reference case	8.22	10.78	13.58
High price case	8.00	10.41	13.17
Reduction	-2.8 %	-3.6 %	-3.1 %

this situation, three points should be stressed:

- higher oil prices have a small impact on the market share of oil, given its dominant position in transport and petrochemicals;
- higher gas prices lead to more significant shifts in the market share of gas, favouring coal especially in power generation;
- higher oil and gas prices encourage non-fossil fuels only to a very limited extent.

5.1.2 FLEXIBILITY IN THE WORLD CO_2 EMISSION TREND

The POLES baseline is intended as a conventional wisdom case or a "business as usual" trend. It is not a normative outlook in that it does not integrate elements of post-Kyoto policies. Other world energy outlooks (IEO, WEO) demonstrate that, in the absence of supporting policies (in particular price signals and technological policies), the Kyoto targets for the commitment period and beyond will not be met. The impact of higher international fuel prices (+$5/barrel in 2020, +$7.4/barrel in 2030) on CO_2 emissions is not significant because of the weak elasticity of transport energy demand, and the independent pace of coal prices.

The comparison with other views of the long-term energy future sheds light on some key-variables for the determination of future global primary energy consumption and CO_2 emissions. However, the comparison of the central projections of the various exercises (DOE, IEA, WEC-IIASA) is not straightforward because global economic hypotheses, methodologies (determination of energy intensity trends) and accounting conventions are not the same[33]. Nevertheless, the comparison reveals a certain convergence of results concerning global energy consumption and CO_2 emissions in 2020 between the WEC scenario A (high growth), POLES, WEO98 and IEO98: world energy consumption will be in the range 14-16 Gtoe in 2020 (increase by 65-90 % since 1990) and CO_2 emissions in the range 10-11 Gt (increase by 70-85 % since 1990). It is then

TABLE 5-8: COMPARISON OF THE GROWTH OF CARBON EMISSIONS AND ITS DETERMINANTS IN 2020 IN DIFFERENT SCENARIOS

	1990	WEC A2	WEC C2	POLES Baseline	WEO98 Base case	IEO98 Base case
Economic Growth 1990-2020 (%/a)		2.7	2.2	3.3	3.1	3.1
TPES (Gtoe)	8.3	15.4	11.4	15.1	16.1	13.8
Energy Growth (%/a)		2.1	1.1	2.0	2.2	1.7
Total emissions (Gt C)	5.8	10.0	6.3	10.8	10.3	10.4

[33] The WEC-IIASA scenarios consider different global economic growth rates to 2020 (2.7 % in the scenario A, 2.2 % in the "middle course" scenario B, and again 2.2 % in the "ecologically driven" scenario) but with massive redistribution internationally in this case. Calculated in market exchange rates (MER) they are apparently lower than the POLES growth rate (3.3 %/a) and the World Energy Outlook rate (3.1 %/a) which are calculated in Purchasing Power Parities (ppp). But an economic calculation could demonstrate that the structure and the level of future world economic activity, assessed in MER in the WEC scenarios A, are quite similar to those of the POLES scenarios. In the purchasing power parity approach, the weight of developing regions increases more rapidly than in the MER approach. In any case these differences do not allow the comparison of the decrease of energy intensities between the WEC exercises and the other ones.

TABLE 5-9: REGIONAL DISTRIBUTION OF CO_2 EMISSIONS IN 2020 (IN GT C)

	1990	2020 POLES Baseline	IEO98 Base case	WEO98 Base case	WEC A_2	WEC C_2
World (Mt C)	**5.8**	**10.8**	**10.4**	**10.3**	**10.0**	**6.3**
OECD countries	47.1 %(*)	34.2 %(*)	39.2 %	39.0 %	38.0 %	30.0 %
Developing countries	30.6 %	53.4 %	49.0 %	49.0 %	47.0 %	54.0 %
(Developing Asia)	*(19.2 %)*	*(35.4 %)*	*(31.0 %)*	*(34.8 %)*	*(31.5 %)*	*(40.0 %)*
FSU-CEEC	22.3 %	12.4 %	11.8 %	12.0 %	15.0 %	16.0 %

(*) EU emission will decrease from 14.4 % in 1990 to 8.8 % in 2020.

obvious that scenarios compatible with long-run global warming concerns need to be set up to demonstrate a significant curbing of emissions by 2020 (see the WEC scenario C2).

The contribution of different world regions to global CO_2 emissions in each of these outlooks is different. In 2020, the POLES base case attributes 35 % of the emissions to the OECD countries, whereas the other outlooks attribute between 38 and 39 % of the emissions. Developing countries are supposed to emit an increment of 0.7-1 Gt C in POLES, which is mainly due to higher emissions in developing Asia, in particular in China and India (with an increment of 0.45 Gt C for the two countries). Power generation based on carbon-intensive fuels is indeed supposed to be dominant in the two countries.

Despite these differences, the above-mentioned scenarios converge clearly on the following messages:

- there will be no substantial change in the path of global CO_2 emission trends;
- demographic pressure and the need for economic welfare in the developing countries are so strong that they will account by 2020 for the larger part of CO_2 emissions;
- among the Annex B countries of the Kyoto protocol (countries with a quantitative reduction target for greenhouse gases), the industrialised countries will emit less in terms of their share in global emissions despite higher absolute emissions. This development will occur despite the slow recovery of emissions in the FSU/CEEC which will return to their 1990 emission levels only by 2020.

AIMING AT A REDUCTION OF CO_2 EMISSIONS: THE NEED FOR ACTIVE POLICIES

The long-term challenge is to reach an improvement of energy supply and availability, particularly in the developing countries, combined with a steady increase of the efficiency of energy use and conversion. The POLES simulations were not explicitly oriented towards exploring this direction. They show, however, quite an important world-wide energy intensity decrease of 1.2 %/a in the period 1990-2020, under the combined influence of economic structural changes, technological improvement and energy price, but this is not sufficient to curb CO_2 emissions autonomously, nor will such an improvement be sufficient to obtain a curbing of CO_2 emissions in the long-term.

In energy modelling, to construct CO_2 emission reduction scenarios one must im-pose binding constraints on emissions. It is strictly equivalent (dual in mathematical terms) to imposing the shadow value of this constraint (in other terms the marginal abatement cost) as an additional cost to all emitters of carbon. This technique is used for both the POLES and the PRIMES models. The so-called “carbon value” leads to adjustments in the behaviour and in the technology mix on the energy demand and supply side[34].

The energy and RTD policies which will be implemented in the Annex B countries for respecting their Kyoto commitments could affect the energy intensities of the GDP and the carbon intensity of energy (mainly by the promotion of renewables, energy efficiency improvements and the substitution of gas for coal). But the issue of the future commitments of non-Annex B countries for curbing the growth of their emissions will be raised by the fact that, even if the industrialised countries make a serious effort to respect their domestic commitments, global emissions will still continue to rise.

The POLES model exercise for CO_2 emission constraints also dealt with the hypo-thetical case of involving developing countries in the global reduction effort by using flexibility instruments at a world level. In such a hypothetical case, under global (world-scale) emission constraints, the developing countries would participate in the

[34] Briefly the basic methodological principle of the exercise on CO_2 emission constraints relies on the introduction of a "carbon value" in every region or country. The "carbon value" leads to adjustments in the final energy demand through technological changes and behavioural adaptations, and through substitutions of technologies in the energy supply system to the limit of equalisation of the marginal abatement cost to the tax. Its parametrisation allows to calculate the marginal abatement cost curve for each country: with that curve, we assess the total cost to reach an abatement target. Moreover the effects of an emission trading which would be activated by the differences of marginal abatement costs between countries can be simulated.

TABLE 5-10: EFFECTS OF THE POSSIBLE INVOLVEMENT OF DEVELOPING COUNTRIES IN EMISSION TRADING BY 2010

	Baseline scenario	No trading (Mt C)		Limited trading (Annex B only)		World level trading	
		Emission reduction to (Mt C)	Net cost (G$)	Emission reduction to (Mt C)	Net cost* (G$)	Emission reduction to (Mt C)	Net cost* (G$)
OECD countries	3,595	2,544	58.0	3,107	41.5	3,518	17.6
(European Union)	*(1,026)*	*(822)*	*(14.3)*	*(920)*	*(9.8)*	*(986)*	*(4.1)*
FSU-CEEC	797	797	0	484	- 23.2	546	- 7.0
Developing countries	4,163	4,163	0	4,164	0	3,690	- 4.2
Total	**8,345**	**7,504**	**58.0**	**7,754**	**18.3**	**7,754**	**6.4**

*The net cost is the cost within the countries less the trade value of permits. The value of the permit – at the market equilibrium - is 66.5 $/t C in the Annex B trading case and 22.5 $/t C in the global trading case.

Source : POLES

effort getting in return a compensation equal to the value of permits they would exchange.

This analysis has shown clear benefits for all parties from the involvement of developing countries in the global effort for emission abatement[35].

The emission abatement options of developing countries along their economic development path are wider in scope and cheaper than many abatement options in the industrialised countries. So an eventual extension of emissions trading to the world level (which simply implies granting these countries rights corresponding to any reductions that they are able to perform in relation to their reference projections) would be beneficial for all parties for the following reasons:

- The developing countries (in particular the major Asian countries) would have to reduce their emissions in 2010 from 4.16 Gt C to 3.69 Gt C (8.9 %), but would win a net value of 4.2 billion US$.
- The OECD countries could reduce their financial effort to respect their commitments: from 58 billion US$ without trading at all (or 41.5 billion US$ with trading inside Annex B) to 17.6 billion US$ when global emission trading is applied.

As a conclusion, 2020 does not appear to be the key turning-point for any major driving forces. Time-constants are too important for anticipating very contrasted energy futures at that time horizon. Therefore, concerning CO_2 abatement issues, only very active programmes and policies on both the energy demand and the supply could create significant differences by 2020, if they are undertaken both in OECD and in developing countries. Emission reduction commitments at this stage are undertaken only by industrialised countries who need to take the lead – but the environmental objective requires participation of developing countries at some stage taking into account their development requirements and trade.

5.2 ALTERNATIVE SCENARIOS AND SENSITIVITY ANALYSIS FOR THE EU [36]

5.2.1 INTRODUCTION

This section presents quantified analysis of energy system changes resulting from three scenarios that include a series of CO_2 emission reduction targets for 2010 and 2020 for the EU. The section also examines, through sensitivity analysis, the impact of a series of issues of special concern for energy and emissions.

5.2.2 DEFINITION OF SCENARIOS[37]

As can be seen from Figure 5-2 and Table 5-11, the three new scenarios analytically examined and presented in this section are as follows:

- S0 scenario: Under this scenario, CO_2 emissions remain at their 1990 level throughout the projection period. Thus, under the carbon value imposed in this scenario there is effectively a stabilisation of emissions for the EU at around 3,068 million tonnes (Mt) of CO_2. In annual emissions of CO_2, this scenario results in a reduction of 222 Mt by 2010 and of 432 Mt by 2020 compared to the baseline.

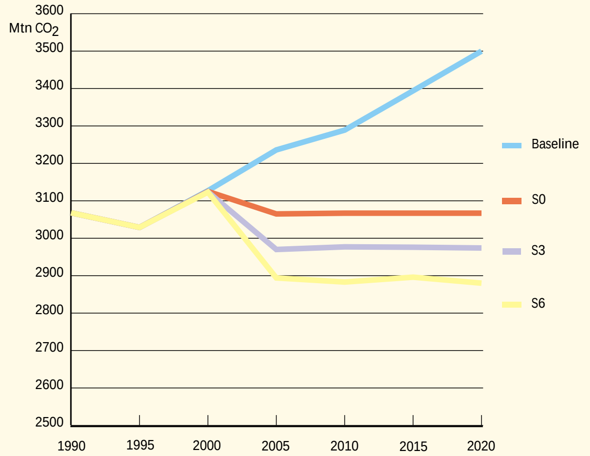
[35] Shared Analysis Final Report Vol. 2 (World Energy Scenarios).

[36] This section is extracted from Chapter 4 of the study "EU Energy Outlook to 2020", European Commission – Directorate General for Energy, forthcoming, catalogue number CS-24-99-130-EN-C, ISBN 92-828-7533-4, 1999, which was carried out in the context of the Shared Analysis project (Volume 5).

[37] These scenarios relate to the EU without Luxembourg.

- S3 scenario: Under this scenario, CO_2 emissions in 2010 and beyond amount to just under 3,000 Mt, representing a reduction of around 3 % from the level of emissions in 1990 and a reduction of nearly 10 %, or around 312 Mt, when compared to the baseline emissions in 2010. By 2020 the difference in CO_2 emissions between this scenario and the baseline exceeds 500 Mt.
- S6 scenario: Under this scenario, CO_2 emissions after 2010 amount to around 2,880 Mt of CO_2, representing a reduction of around 6 % from the level of emissions in 1990 and a reduction of just over 13 %, or around 406 Mt CO_2, compared to the baseline emissions in 2010. The difference in emissions by 2020 amounts to over 600 Mt of CO_2, when compared to the baseline.

Figure 5-2: EU CO_2 emissions in the baseline and the three scenarios, 1990-2020



Source: PRIMES

The selection of emission paths in the above scenarios spans the likely requirement set out in the Kyoto protocol for cost-effective reduction measures of energy-related CO_2 emissions taking into account cost-effective reductions of other greenhouse gases included in the Kyoto protocol (see Volume 11 of the Shared Analysis project and section 6.4.2). The use of flexibility mechanisms according to the articles of the Kyoto Protocol and the contribution of sinks would also alter the actual domestic reduction requirement to be accomplished within the EU energy system. The CO_2 stabilisation case (S0) is furthermore motivated by the commitment of the EU to stabilise CO_2 emissions by the year 2000 which implies that these emissions do not rise above the 1990 level in the years after 2000 (see section 6.4.2).

5.2.3 OVERVIEW OF RESULTS

CARBON VALUES

Given the technical features and design of PRIMES[38] the imposition of a global emission constraint is equivalent to the inclusion of an additional cost of carbon emission, which reflects all the economic costs imposed by the global constraint. In mathematical modelling imposing a global constraint is equivalent to imposing its shadow cost. As mentioned before we associate a "carbon value" to each emission reduction level for a given member-state and the carbon value is equal to the associated marginal abatement cost (measured in € per tonne of carbon avoided[39]). All emitters of carbon see the additional cost of emission (the carbon value) and adjust their behaviour, technology choice and fuel mix.

TABLE 5-11: CO_2 EMISSIONS AND CARBON VALUE FOR THE BASELINE AND THE THREE SENSITIVITY SCENARIOS 1990, 2010 AND 2020

	1990	2010				2020			
		Baseline	S0	S3	S6	Baseline	S0	S3	S6
CO_2 Emissions (Mt CO_2)	3,068	3,289	3,067	2,977	2,883	3,500	3,067	2,974	2,880
Reduction from Baseline (Mt CO_2)			-222	-312	-406		-432	-525	-619
% of 1990 level			100	97	94		100	97	94
Carbon value (€90/t carbon avoided)		0	50	78	102	0	59	81	115

Source: PRIMES

[38] The PRIMES energy system model formulates energy market equilibrium according to the mixed-complementary mathematical methodology, which roughly corresponds to the Kuhn-Tucker conditions that are dual to a mathematical programming problem. Consequently, the imposition of a global constraint on emissions is mathematically strictly equivalent to the inclusion of a shadow variable (a shadow cost) which appropriately affects all economic costs, proportionally to their emissions. This shadow variable is called here "carbon value". It represents the additional total costs for the energy system that are necessary for avoiding the emission of one additional tonne of CO_2.

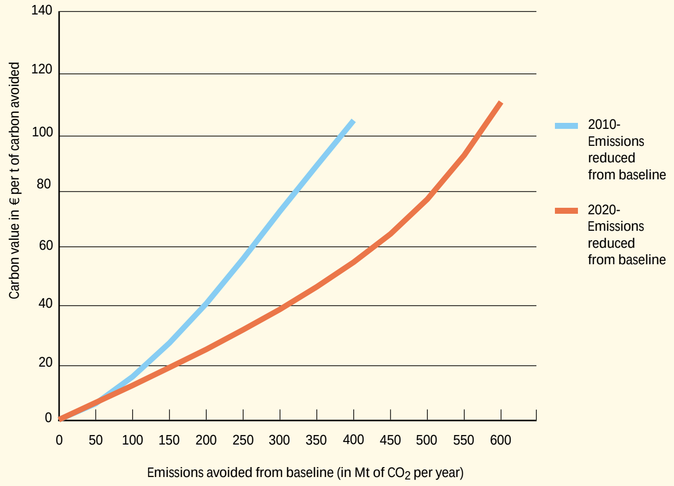
[39] One tonne of CO_2 emitted includes 12/44 = 0.272 tonnes of carbon. Therefore, if the carbon value is 1 € per tonne of carbon then the same value per tonne of CO_2 is equal to 12/44 €.

As can be seen from Table 5-11, the stabilisation of emissions that is achieved in scenario S0 requires a carbon value of €50 in 2010 and €59 in 2020 (all carbon values are given in terms of 1990 € per tonne of carbon avoided[40]). The carbon values for scenario S3 for 2010 and 2020 are €78 and €81 respectively while the corresponding carbon values for S6 are €102 and €115.

These figures indicate that whatever the emission reduction is in 2010, holding emissions at the same level beyond 2010 requires only a relatively small increment in the carbon value. This is despite the fact that emissions without the carbon constraint would tend to increase also beyond 2010, as underlying energy demand and carbon intensity would increase under baseline assumptions. For example, stabilisation of emissions in 2020 requires the reduction of an additional 210 Mt of carbon that would occur annually between 2010 and 2020. This is achieved with "only" an additional €9 of carbon value to its level in 2010. Similarly, the additional required reduction in emissions between 2010 and 2020, which is around 200 Mt, in the S3 and S6 scenarios is achieved with a relatively modest increase in the carbon value between 2010 and 2020. This tendency is likely to reflect the fact that, as we move further into the future, technological improvements make a reduction in emissions relatively easier than it is with present technologies.

In general, there is also a tendency for the degree of difficulty of reducing emissions (as represented by the level of carbon value) to increase non-linearly as the required level of emission reduction increases. The issue of non-linear costs in incremental reductions in CO_2 emissions has been discussed in Capros and Mantzos[41] in greater detail and for a far greater range of carbon values. It was concluded that there is a tendency for carbon values to increase non-linearly as the emissions target becomes more severe. This is

Figure 5-3: Carbon values and avoided CO_2 emissions compared to the baseline, 2010 and 2020



because "easy" carbon savings are achieved cheaply: but incremental reductions impose progressively higher costs.

PRIMARY ENERGY CONSUMPTION

At the most aggregate level of analysis, the economic system has two means of responding to the imposition of the carbon constraint while maintaining roughly the same level of GDP. It can either reduce the level of energy used per unit of GDP (the energy intensity); or it can change the fuel mix in order to reduce the carbon intensity of its energy sub-system. The division of the system's response between these two effects is an extremely important indication of where most of the flexibility in the system is to be found. A reduction in the carbon intensity of the energy system signifies that substitution opportunities among fuels are more cost effective than substitution of energy by other goods.

TABLE 5-12: IMPACTS OF CO_2 REDUCTION CONSTRAINTS ON PRIMARY ENERGY CONSUMPTION IN EU-15, 1990-2020

	1990	2010	% Difference from baseline in 2010			2020	% Difference from baseline in 2020		
		Baseline	S0	S3	S6	Baseline	S0	S3	S6
Gross Inland Consumption (Mtoe)	1,314	1,552	-3.3%	-4.5%	-5.7%	1 609	-3.5%	-4.8%	-6.1%
Solid Fuels	301	182	-23.3%	-30.8%	-40.4%	218	-53.5%	-61.7%	-67.1%
Liquid Fuels	544	653	-4.0%	-6.1%	-8.1%	660	-2.8%	-4.4%	-6.9%
Natural Gas	222	400	2.9%	3.5%	5.1%	430	8.6%	9.8%	10.0%
Nuclear	181	227	-1.1%	-0.3%	-0.5%	199	12.3%	11.9%	11.9%
Electricity	2	2	-2.2%	-3.0%	-3.7%	2	-2.6%	-3.6%	-5.3%
Renewable Energy Sources	64	88	8.6%	15.0%	21.1%	100	17.4%	21.6%	26.7%
CO_2 Emissions (Mt CO_2)	3,068	3,289	-6.7%	-9.5%	-12.3%	3,500	-12.4%	-15.0%	-17.7%

Source: PRIMES

[40] The figures must be multiplied roughly by 1.3 to obtain current €.

[41] P. Capros, L. Mantzos: "Energy System Implications of Reducing CO_2 Emissions: Analysis for EU Sectors and Member-States by using the PRIMES Ver.2 Energy System Model", Final report from ICCS/NTUA for DGXI of the European Commission, March 1999.

For the period up to 2010, in all three scenarios under consideration, nearly half of the overall reduction in emissions is achieved through a reduction in energy consumption. For example, under the S3 scenario, emissions are about 9.5 % less than in the baseline while primary energy demand has declined by only 4.5 % from its baseline level (see Table 5-12). Thus, considering the adjustment reactions of the energy system to the constraints implied by the three scenarios, it seems that, at the margin, it is as difficult for the system to reduce overall energy demand as it is to change the mix in primary fuels. The latter mechanism is, of course, somewhat weakened by the assumption that nuclear power generation will not be allowed to increase beyond the level assumed in the baseline irrespective of any carbon constraint imposed on the system.

The picture is somewhat altered when the figures for 2020 are considered. Compared to the baseline results, the reduction in primary energy in 2020 is similar to that for 2010, while the reduction in emissions is significantly higher. For example, under the S0 scenario the fall in primary energy consumption is very similar when compared to the baseline for both 2010 and 2020. However, the required overall reduction in emissions for 2020 (12.4 %) is nearly double that of its 2010 level (6.7 %). Given the significant gains observed under baseline conditions as regards energy intensity, the potential for further technological improvement, in the absence of a 'backstop' technology that would improve over time, becomes limited and very expensive. This effectively means that as we move further into the future the economic system finds substitution among fuels (i. e. reducing the carbon intensity) much more cost effective than reducing overall energy use (i. e. reducing the energy intensity).

In terms of primary fuels, the effects capture both the reduction in all fuels (as a result of the reduction in total energy demand) and the relative change in the demand for individual fuels which the imposition of the constraint would generate. By far the most significant impact is on solid fuel consumption for which both the above defined effects are negative. The demand for solid fuels, which are the most carbon-intensive of all primary fuels, declines not only because of the overall fall in energy consumption but also because their use is replaced by less carbon-intensive fuels. The reverse effect operates on gas and renewable energy forms, both of which increase if compared to their consumption level under baseline assumptions. The modest negative effect on liquid fuels is due mostly to a small reduction in overall demand rather than to substitution.

FINAL ENERGY AND EMISSIONS

Imposing carbon constraints (carbon values) affects all final demand sectors by reducing CO_2 emissions and energy consumption. However, the reaction of each sector is different, linked in particular to options for fuel switching

In terms of changes in final consumption, the impacts of the three scenarios are significantly different from those presented above on primary energy. Firstly, the difference between the reduction in final energy demand and the corresponding emissions in all scenarios is much less than is the case for primary energy demand (see Table 5-13). Thus, in 2010, the reduction in demand accounts for about two thirds of the overall reduction in emissions originating from adjustments in final energy, while in 2020 its contribution to emission reduction on the demand side reaches 75 %. Effectively, the role of changes in the fuel mix on the demand side is rather limited, a result strongly related to the significant changes of the fuel mix towards the use of less carbon intensive fuels already achieved under baseline assumptions.

The contribution of the demand side in the overall emission reduction accounts for around 40 % in 2010, further limited to 20 to 26 %, depending on the severity of the emission reduction target, in 2020.

TABLE 5-13: IMPACTS OF CARBON CONSTRAINTS ON FINAL ENERGY DEMAND IN EU-15 BY SECTOR, 1990-2020

	1990	2010	% Difference from baseline in 2010			2020	% Difference from baseline in 2020		
		Baseline	S0	S3	S6	Baseline	S0	S3	S6
Total Final Energy (Mtoe)	852	1,053	-3%	-4%	-6%	1,108	-3%	-5%	-6%
Industry	257	282	-2%	-3%	-4%	290	-3%	-4%	-5%
Tertiary	110	159	-7%	-10%	-12%	177	-6%	-8%	-10%
Households	232	267	-2%	-4%	-5%	282	-2%	-4%	-5%
Transport	253	344	-2%	-4%	-5%	359	-3%	-4%	-5%
CO_2 Emissions (Mt CO_2)	1,800	2,036	-4%	-6%	-8%	2,038	-4%	-6%	-8%
% of total reduction			39%	41%	40%		20%	23%	26%
Industry	424	378	-5%	-7%	-8%	354	-5%	-6%	-10%
Tertiary	193	220	-12%	-16%	-20%	203	-11%	-14%	-18%
Households	447	444	-4%	-6%	-8%	448	-4%	-6%	-8%
Transport	735	994	-2%	-4%	-5%	1,033	-3%	-4%	-5%

Source: PRIMES

Effectively, substitution at the primary level is easier to achieve than at the level of final energy demand.

The tertiary sector is most sensitive to the imposition of the carbon constraint with its energy demand declining by about three times the level of other sectors in 2010 and two times the level of other sectors in 2020, in the S0 scenario (see Table 5-13). At the more severe levels of constraint examined, the difference from other sectors declines although the tertiary sector remains the one with the strongest demand reaction. Moreover, the tertiary sector adapts to carbon values by speeding up electricity penetration which in a sense means the "export" of emissions to the power generation sector. As a result, reduction in carbon emissions is much faster than in energy demand.

In contrast to the tertiary sector, there is only a modest penetration of electricity in the transport sector. No new cost-effective fuels are expected to enter the transportation sector in the foreseeable future. Consequently, any emission reduction of the sector is likely to be due to a reduction in the energy demand of the sector, rather than to any changes in the fuel mix.

The most noticeable changes in the transport sector concern trains and aircraft. In both cases the average efficiency progresses, but trains gain market share while the share of air transport declines. The effects in the road sector mainly concern behavioural changes in car purchasing and use rather than in car technology itself. High emission reduction constraints are necessary to enable significant technology changes in the transport sector. It is interesting to note that fuels cells and electric cars do not significantly penetrate the EU transportation market in the period up to 2020. The main reason for this is that both electricity and fuel cells are still expected to be reliant on gas supplies, either directly or through methanol. Hence, under carbon constraints, cars that rely on these forms of energy do not gain a significant advantage over more conventional cars.

The industry and households sectors experience significantly faster declines in carbon emissions than in energy demand, suggesting a large degree of opportunity for further changes in the fuel mix in favour of electricity and gas.

In industry most of emission reduction comes from restructuring of industrial processes (e. g. more electric arc processing, more recycling of materials, etc.). Improved electrical technologies and heat pumps seem to be attractive and cost-effective options. In general, the degree of flexibility available to industry for reducing emissions is limited, when industry is considered at a very narrow sectoral level.

Like the tertiary sector, the household sector seems to have large possibilities for emission reduction both through adopting more efficient electric appliances and through reducing their thermal needs by improving buildings.

As the degree of tightness of the carbon constraint rises, the gap between the reduction in energy and emissions declines in the case of households and industry while it rises in the case of the tertiary sector. Fuel mix changes in the latter seem to become more cost effective when compared to further reductions in the sector's energy demand.

A major factor behind the differential changes in the various sectors is the different structure of energy prices that is generated by the imposition of carbon constraints. The end use prices for some users, such as the power generation sector and industry, are much closer to the underlying fuel costs than those of households and trans-

TABLE 5-14: IMPACTS OF CARBON CONSTRAINTS ON FINAL ENERGY DEMAND BY FUEL, 1990-2020

	1990	2010	% Difference from baseline in 2010			2020	% Difference from baseline in 2020		
		Baseline	S0	S3	S6	Baseline	S0	S3	S6
Total (Mtoe)	**852**	**1,053**	**-3%**	**-4%**	**-6%**	**1,108**	**-3%**	**-5%**	**-6%**
Solid Fuels	71	27	-13%	-17%	-19%	20	-14%	-19%	-26%
Liquid Fuels	378	477	-4%	-5%	-7%	487	-4%	-5%	-7%
Natural Gas	157	211	-4%	-6%	-7%	212	-3%	-5%	-7%
Steam	68	89	-1%	-2%	-2%	101	-2%	-3%	-4%
Electricity	156	226	-1%	-1%	-2%	265	-2%	-3%	-3%
Hydrogen	0	0	1%	2%	3%	0	2%	2%	3%
Methanol - Ethanol	0	0	-1%	-2%	-2%	0	0%	0%	0%
Renewable Energy Sources	22	22	4%	6%	8%	21	3%	4%	6%
Biomass	21	21	4%	6%	8%	20	3%	4%	6%
Other	0	1	4%	5%	7%	1	4%	5%	7%
CO_2 Emissions (Mt CO_2)	1,800	2,036	-4%	-6%	-8%	2,038	-4%	-6%	-8%

Source: PRIMES

portation. This is because of higher taxation on fuels in these two latter sectors. Consequently, after the imposition of carbon constraints, power generation and industry face much stronger incentives for altering their fuel balance.

The limited opportunities for substitution are reflected in the changes in individual fuels (see Table 5-14) and the comparison of these with the corresponding changes in primary fuels. The changes in most fuels are relatively similar to each other and the degree of similarity increases with the level of constraint. The exceptions to this are solid fuels and renewables, whose relative price changes are too strong. Even the use of electricity and steam declines, while that of natural gas declines by the same level as that of oil products. Thus, the increase in the overall use of gas at the primary energy level even for the S6 scenario is exclusively due to the shift towards gas within the steam and power generation sector.

ENERGY TRANSFORMATION SECTOR

It was seen above that changes in the level and fuel structure of final demand in 2010 account for about 40 % of total reduction in emissions imposed by the carbon constraints under the three scenarios considered here. Also, the corresponding figure for 2020 falls to between 20-26 %, depending on the severity of the scenario under consideration. Clearly, the bulk of the reduction in emissions originates from the process of transformation of primary energy into final energy. More specifically, the power and steam generation system of the EU appears to be the sector that can adjust in the most cost-effective way to emission constraints.

It is partly because the electricity and steam generation system is more flexible in the reduction of emissions that its output does not decline as sharply as that of other forms of final energy. As was seen in the discussion of final energy, electricity and steam consumption decline by less than half the amount of reduction in other fuels in scenarios S0 to S6. There are many reasons for this flexibility of the generation system. Firstly since nearly half of electricity generation takes place through the use of carbon free primary fuels, such as hydro and nuclear, a 1 % reduction in emissions in the system can take place with only half as much reduction in output – only the generation through fossil fuels needs to be reduced. Secondly, generation through carbon-free fuels can actually increase, although it is assumed that this will not be allowed to a significant extent in the case of nuclear power. Thirdly, the system can respond by increasing its overall efficiency of generation through fossil fuels. This can be achieved either by adopting improvements in the technology used for any given fuel (this effect is limited for 2010) or through alternative combinations of technologies and fuels, such as the greater use of CCGT as opposed to coal plants, or through changes in the allocation of the available plants in the merit order. Finally, the generation system can improve its overall efficiency by increasing the degree of co-generation of steam and electricity.

The operation of at least some of the above mechanisms can be seen from the sharp difference between the decline in the system's output and fossil fuel inputs. In all three scenarios examined, the decline in inputs is close to 4 times the corresponding decline in electricity and steam output for 2010 (see Table 5-15). This is amplified by increased electricity and steam generation from non-fossil

TABLE 5-15: IMPACTS OF CARBON CONSTRAINTS ON ENERGY INPUT/OUTPUT AND CO_2 EMISSIONS OF THE TRANSFORMATION SECTOR, 1990-2020

	1990	2010	% Difference from baseline in 2010			2020	% Difference from baseline in 2020		
		Baseline	S0	S3	S6	Baseline	S0	S3	S6
Electricity and steam output (TWh)	3,159	4,320	-1.3%	-1.8%	-2.3%	4,952	-2.4%	-3.3%	-3.9%
Nuclear	720	896	-1%	0%	-1%	787	12%	12%	12%
Hydro and Renewables	260	374	7%	8%	11%	461	12%	13%	16%
CO_2 Emissions (Mt CO_2)	1,212	1,201	-11.2%	-15.3%	-20.1%	1,418	-24.3%	-28.3%	-31.9%
% of total CO_2 reduction			60.5%	58.6%	59.6%		79.6%	76.5%	73.0%
Fossil fuel inputs in electricity and steam generation (Mtoe)	364	418	-5.5%	-6.9%	-8.8%	487	-11.7%	-13.4%	-15.2%
of which	%	%	%	%	%	%	%	%	%
Solids	54%	33%	25%	22%	19%	38%	16%	13%	11%
Gas	17%	40%	47%	49%	53%	39%	55%	58%	60%
Biomass/Waste	5%	7%	9%	10%	12%	7%	11%	12%	13%
Efficiency rates for electricity and steam generation	0.52	0.64	0.68	0.65	0.65	0.66	0.73	0.69	0.69

Source: PRIMES

fuels and by improvement of electricity and steam generation efficiency. For example, in S6, electricity and steam generation in 2010 is 2.3 % below its level in the baseline scenario while the corresponding generation inputs are 9 % below their baseline level. This effect is similar in magnitude for 2020. As stricter emission reduction targets are set the role of non-fossil fuels becomes more important, while efficiency gains become smaller. The latter occurs as a result of the decrease of electricity and steam production that leads to less investment in new generation capacity.

The flexibility of the power and steam generation sector to respond to carbon constraints is shown most dramatically by the changes achieved in emissions. In the stabilisation scenario, by reducing electricity and steam generation by just 1.3 % in 2010, the generation system reduces its emissions by 11 % - which accounts for two thirds of the overall system reduction in emissions - in order to reach the carbon constraint. Since, as was seen above, around half of this reduction is achieved through decrease in electricity and steam production, improved efficiency and an increase in the use of non-fossil fuels, nearly half of the overall reduction in emissions is achieved through changes in the generation fuel mix. This effect seems to become even stronger in 2020. In the S0 scenario, 2020 electricity output is reduced by 2.4 % when compared to the baseline. The resulting decline in emissions is 10 times higher.

One of the reasons for the growing scope of relatively cost-effective substitution in the power and steam sector after 2010 is that, under baseline assumptions, a large come-back of solids was projected to take place. This was on the basis of rising prices of gas. Under the carbon constraint scenarios, the impact of the increased relative price of gas is counterbalanced by the implicit cost of carbon, which results in a significant increase of the relative price of solids. Consequently, the power and steam generation system continues along its path to 2010, which involved the bulk of new generation capacity using gas as a fuel.

Furthermore, it is because of this switch between gas and coal in the generation system that the economic cost of the carbon constraint is limited, as will be seen below. The system is rather finely balanced between gas and coal, so relatively modest changes in the relative price of the two fuels can lead to very significant changes, both in the balance of fuels used and in emissions. It is primarily because of this that the cost of adjustment is rather low; it is also the reason why it is the power generation sector that is responsible for the bulk of cost-effective adjustments to the imposition of the carbon constraint.

While the role of the electricity and steam sector remains dominant in meeting the carbon constraint, there are indications that the relative difficulties increase, as the constraint becomes tighter. Thus, in 2020, the contribution of the sector declines from almost 80 % in the S0 scenario to 73 % in the S6 scenario. The reverse was observed, of course, for the contribution of final demand. Effectively, at low levels of the carbon constraint, the flexibility of the generation system and the available fuel switch options make it a convenient and cost-effective means to achieve emission reductions. As the constraint gets tighter, the options within the generation system become more rare, so final demand is required to make a more substantial contribution.

COUNTRY ANALYSIS

The emission reduction scenarios presented in the previous section can be interpreted, among several other ways, as if the European Union established a CO_2 permit market within the EU independently of any other international permit market. This allows the EU to gain in cost effectiveness, compared to the situation of every Member State acting alone, and leads to equal marginal abatement costs across the EU Member States. In other terms, according to the model-based evaluation, the marginal effort of emission reduction is the same in all member-states.

Other evaluations with the same model and methodology have shown that the marginal efforts and costs would substantially differ across the Member States if each country was to reduce emissions unilaterally according to the latest burden sharing agreement. In such a case the carbon values would differ, some countries experiencing a marginal cost that would be more than double the EU average, while some other countries would face a cost of only half the EU average. Of course, the marginal cost calculations carried out with an energy model provide only partial information for a burden sharing agreement, since other factors are also considered in such an agreement, as for example the carbon intensity experienced in the past, the prospects for economic cohesion or restructuring, the flexibility of the system (apart from its energy component) in adapting to emission restrictions, etc.

According to the model calculations, the cost effectiveness gains for the EU as a whole from equalising the marginal abatement costs across the Member States are substantial. The gains in terms of the average EU marginal costs are of the order of 40 %. The evaluation of the marginal abatement costs and the results regarding the differences among the Member States depend on the baseline scenario. Different evolutions under baseline conditions would lead to different conclusions regarding marginal costs and differences between the Member States.

Based on the baseline scenario adopted in the present analysis, the model-based evaluations show that there are large differences among EU countries in their response to the imposition of the emission constraints. For example, in the S6 scenario, 2010 emissions are nearly 24 % below their level in 1990 in Germany and 11 % in the UK, while in Greece and Portugal they are higher than in 1990 by more than 30 %. These differences reflect to a large extent the different dynamics in each country's energy system and industrial restructuring. The carbon intensity of the power generation system also plays a key role in the ease with which a country can adjust to the imposition of a carbon constraint.

While there is no exact correspondence between the share of different countries in 2010 EU emissions and the amount of emissions that they manage to avoid under the three scenarios, the two shares are not very different. For example, Germany's emissions in the baseline scenario in 2010 amount to 25 % of the EU total. Under the three scenarios under consideration, in 2010 Germany accounts for between 22 and 26 % of EU emission reduction. Overall, the shares of EU countries in 2010 emissions do not change significantly between the baseline and the three scenarios under consideration. This result can only be due to the relatively high degree of homogeneity of technological responses available for the EU countries (under the Single European Market) as is reflected in PRIMES.

However, there is a tendency for countries with high energy intensities and high carbon intensities in their power generation system to contribute more to the required emission reduction than their share in baseline emissions in 2010 would warrant. For example, under the S0 scenario, France, which relies to a very large extent on nuclear power for electricity generation, contributes only 8 % to the EU reduction while its share in 2010 emissions is close to 12 %. Greece, on the other hand, contributes 6 % to the EU reduction, significantly more than its 3 % share in 2010 emissions. Greece has the highest energy intensity and the highest carbon intensity in its generation system among EU countries.

The above differences between the country shares in 2010 emissions, and the corresponding contribution to the EU reduction, seem to get closer to each other for most countries as the level of constraint increases. For example, the contribution of Greece to the EU reduction falls from 6 % in the S0 scenario to 4 % in the S6 scenario, which is much closer to its share in emissions. Similarly, there is a tendency for the French contribution to rise. In other words, as the target of emission reductions increases, EU countries tend to reduce their 2010 emissions by a proportion not far from their share in emissions for that year under baseline assumptions. This is due to the fact that most of the differences among countries regarding the ease with which they can reduce emissions are exploited under the S0 scenario and, when the carbon constraint is tightened, the economic difficulties of adjustment are very similar among EU countries, in marginal cost terms.

ECONOMIC IMPLICATIONS OF THE EMISSION REDUCTION SCENARIOS' IMPACTS ON GDP

The imposition of emission reduction targets in the scenario results in an increase in energy system costs. The additional costs implied by a CO_2 emission reduction target is conveyed to the energy system through the carbon value, which represents the marginal abatement cost incurred by the system in avoiding the last tonne of CO_2 that is necessary in order to meet the reduction target.

As mentioned, the marginal abatement costs for the EU associated with the emission reduction targets examined, range from 50 to 102 € (all carbon values in 1990 terms[42]) per tonne of carbon avoided in 2010, depending on the level of the emission reduction target. The target of –3 % has a marginal cost of €78. The 2020 marginal abatement cost varies from €59, under the S0 scenario, to €115 under the S6 scenario. As mentioned earlier, the analysis reveals that the marginal abatement cost-curve for the EU is not linear i. e., beyond a certain amount of emissions reduction, additional reductions carry a disproportionate cost.

The economic interpretation of the costs for the economy arising from the above marginal cost is complex. The imposition of a carbon emission constraint induces an external cost to the economy compared to baseline conditions. Under such a con-straint, the system bears a net loss of welfare (compared to the baseline) for each tonne of CO_2 avoided equal to the marginal abatement cost corresponding to that tonne. Therefore the total loss of welfare implied by an emission constraint is equal to the area (the integral) below the marginal abatement cost curve (see Figure 5-3).

The PRIMES model, being an energy system model, provides a partial measurement of the marginal abatement cost curve and hence of the loss of welfare. For the whole economy the loss is likely to be higher, because of structural re-adjustment, stranded investments and other factors.

According to the partial evaluation with the model, the loss of welfare measured from the marginal abatement cost curve and corresponding to targets for 2010, under the three scenarios for the EU ranges from *1.5 to 5.5 billion €90 per year which represents between 0.02 % and 0.07 % of annual GDP*.

[42] All numbers in € of 1990 must be multiplied roughly by 1.3 in order to obtain € of 1999.

Because of the emission constraint, the economic agents will bear additional costs (from baseline) to obtain the same level of services obtained by using energy. Under an emission constraint the energy system (demand and supply) needs from the rest of the economy an additional expenditure to be allocated to energy investment and fuel purchasing, on top of corresponding expenditures under baseline conditions. The additional costs for the economic agents arising from the higher costs in the provision of the energy service do not necessarily represent a direct leakage from the economic system. However, under limited primary resources in the economy (i.e. capital, labour and funds from abroad), the additional expenditure will generate net costs to the economy, implying further loss of GDP, hence a loss of welfare. Such a loss might be larger than the abovementioned percentage. The evaluation of the impacts on GDP is complex. The additional expenditure allocated to the energy system is deviated from other sources that might have a higher multiplier effect on GDP. But also this expenditure involves the substitution of a partly imported commodity (fuels) by mostly domestically- (EU-) produced commodities, such as equipment and services needed to improve energy efficiency and change the fuel mix. Finally, the additional energy system costs also exert an upward pressure on domestic prices, weakening the competitiveness of European commodities, hence leading to less exports and more imports for all commodities. General equilibrium calculations with the model GEM-E3[43] have shown that the emission reduction constraints do lead to a net loss of economic welfare and GDP, but there are also accompanying economic policies that may partly alleviate the losses. According to this evaluation the distributional effects are the most noticeable, leading for example to severe implications for energy intensive activities.

According to the model estimates, the additional total cost[44] required by the energy system is of the order of 25 (stabilisation case) to 55 (-6 % case) billion €90 per year for the 2010 target.

In energy-intensive industrial sectors the increase in the average cost of sectoral output (industrial production) ranges from 3 % (stabilisation) to 7 % (-6 % case) in 2010, compared to the baseline.[45] The same increase in the output cost of non-energy intensive sectors ranges from 0.1% to 1%. In particular, the increase in the cost of energy for industry is higher, ranging from 14 to 30 % in energy-intensive sectors, and from 9 to 21 % in non energy-intensive ones. The energy cost for the service sectors increases from 3.5 % (stabilisation) to 9 % (-6 % case), however implying a small increase of total cost of the sector. Spending by households on energy fuel purchasing and energy-using equipment increases by roughly 3 % (stabilisation) to 10 % (-6 % case). Energy cost in the transport also rises, ranging from 0.5 to 2 % for passengers and from 1 to 4 % for freight.

The costs incurred by the power and steam generation sector relate to higher capital expenditures (more expensive plant technology), the costs induced from stranded capital, and the high fuel costs needed for fuel switching. The average power and steam generation cost increases from 9 % (stabilisation) to 18 % (-6 % case). The investment expenditures for power and steam generation also rise by a maximum of 8 %. Electricity tariffs increase from 6 to 22 %.

All the above costs are slightly higher in 2020 reflecting the higher carbon values needed in 2020 compared to 2010.

The total cost incurred by the average EU household for all kinds of energy services and related equipment increases from 2.5 % to 7.5 %, depending on the emission reduction scenario. In absolute terms this is equivalent to €50-150 per household per year. However, it must be pointed out that these costs do not include additional costs resulting from higher prices, e. g. for industrial goods in other sectors.

At this point it is useful to be reminded that the definition of the emission reduction scenarios (equality of carbon values) presupposes reaching emission targets at least cost. These assumptions significantly moderate the cost for the European Union economy for reaching the Kyoto targets. The costs could be higher in reality as a result of implementing carbon abatement measures in a non-optimal way.

Within such a range of emissions avoided, one of the main factors limiting the overall costs is the relatively low cost of switching between gas and coal in the electricity and steam generation sector, which accounts for the bulk of the reduction in emissions in all scenarios. Also, once the carbon value exceeds a certain level and the adoption of more energy-efficient technologies becomes marginally cost effective, their market penetration develops a strong momentum leading to the decline in the additional capital charges involved in the use of the new technology. In other words, the more a new technology is used the greater the reduction in its costs. In all sectors, the additional costs from paying for carbon emission abatement are largely offset by cost savings due to the adoption of improved technologies.

[43] See Capros P. et al. "Climate Technology Strategy", Two books published in 1999 by Springer Verlag, Germany.

[44] As mentioned these additional expenditures are recycled in the economy. They do not correspond to a net economic loss.

[45] In terms of total sectoral output the cost increases are rather low because important cost components (e. g. wages) do not change.

5.2.4 SENSITIVITY ANALYSIS

In order to examine the impact of a number of factors that are either highly uncertain - such as the long-term outlook for nuclear power - or highly critical for the energy and emission outlook, a number of sensitivities, or "cases", have been carried out. These include (a) case S36, which represents a more gradual imposition of scenario S6, (b) case SNUC, representing a nuclear renaissance in the circumstance of the S6 scenario, (c) case SHP, representing higher oil and gas prices than assumed in the baseline, (d) case ST, which includes a more efficient passenger transportation system than was assumed in the baseline, and (e) two cases involving alternative assumptions on the future structure of Germany and France.

MORE GRADUAL INTRODUCTION OF CARBON CONSTRAINTS

The sensitivity analysis carried out to examine the above issues is a combination of scenarios S3 and S6. Under the assumptions of the sensitivity, called S36, the S3 scenario was assumed to hold until 2010 and, for the period beyond 2010, the target is assumed to become more severe and to require that the EU system by 2020 emits 6 % less emissions than in 1990. Thus, instead of imposing directly the constraint implied by the S6 scenario, under this sensitivity a more gradual target is set until 2010.

The severity of the constraint of S36 is between that of the S3 and the S6 scenarios and the results are a reflection of this. While emissions are close to their level under the S6 scenario, this can only be achieved through a higher carbon value than in the S6 scenario since the adjustment period is significantly shorter. Thus, the required value for 2020 is around €120, compared to €115 under the S6 scenario. In other words, the lack of pertinent information on the severity of the emission reduction target misleads the economic actors. They first optimise on the basis of a relatively low emission reduction target in 2010 and then have to re-optimise so as to reach –6 % in 2020, which entails higher costs than aiming at the final objective right from the beginning. This case can serve as an illustration of the benefits of providing clear signals and stable framework conditions to the economic actors[46] . By 2030, the carbon values for the S6 scenario and the S36 sensitivity differ by only €3. All other results of the S36 case are between those of the S3 and S6 scenarios, as would be expected.

A NUCLEAR RENAISSANCE

Under the SNUC case, which imposes no restrictions on the scope of nuclear power within the countries that already use this form of energy, nuclear capacity is projected to increase to 181 GW by 2020 and to 212 GW by 2030. **The key factors that lead to the significant increase of investment in nuclear capacity relates to the assumption that existing obstacles as regards fuel transport, treatment and disposal, as well as higher safety standards, are overridden by technical progress**. The resulting expansion of nuclear power plants capacity is a quite significant one and is only comparable with what has taken place between 1960 and 1990. In view of the large decommissioning due between 2015 and 2030, in terms of new capacity under the assumptions of the SNUC sensitivity, almost 200 GW of new nuclear capacity will have to be built between 2015 and 2030.

The impact of this sensitivity on the EU energy economy is quite important. There is a significant decline in the required carbon value in order to achieve a reduction in emissions to 6 % below their 1990 level. Thus, by 2020, even though the level of emissions is similar in the two cases, the carbon value in the SNUC case is €75 compared to €115 in the S6 scenario - and the difference is even greater for 2030. As a result of this sharp decline in the required carbon value, the cost of using energy declines, while total primary and final energy increase to levels higher than those of S6. Similarly, the 6 % reduction from 1990 emissions is achieved in the SNUC case with a system cost that is about 10 % below that of S6.

One of the most interesting aspects of this case is the significant increase in the use of solids compared to the emission reduction case that does not involve nuclear expansion (case S6 for example). This takes place because the relative price of solids to gas has declined from its level under the S6 scenario due to the decline in the level of the carbon value when nuclear expansion is possible. In conclusion, nuclear power can play a very significant role in reducing emissions in the long term. However, this could only take place if nuclear power were to prove to be more acceptable as an energy form (through technical progress that would eliminate existing barriers) in the 2015 to 2030 period than seems to be the case at present.

[46] This result is related to the nature of the model PRIMES which involves myopic anticipation of economic agents. This feature mimics the reality which of course is always myopic regarding the prediction of the future. This implies that lock-ins are possible reflecting the fact that decisions taken today may not be the optimal ones if the whole future was known. Other models that assume perfect foresight of agents may produce different results regarding the implications from a gradual imposition of carbon constraints.

HIGHER PRICES FOR OIL AND GAS

Under the SHP sensitivity examined here, 2010 oil prices have been assumed to be nearly 30 % higher than in the baseline, approaching 20 €'98 per barrel. In 2020, oil prices are assumed to exceed €25 and to be more than 40 % higher than in the baseline. Gas prices are 25 % higher in 2010 and nearly 50 % higher in 2020, when compared to the baseline. The rationale behind these differential increases is the much greater increase in gas demand over the outlook period and the need for the additional gas demand to be imported from rather distant locations. Coal prices are not altered as the determinants of coal prices are rather different and there is a rather strong current consensus that developed coal resources are sufficient to cover any likely amount of coal demand over the outlook period without necessitating an increase in coal prices.

As would be expected **the impact of higher energy prices, even in selected fuels, is to reduce total primary energy consumption**. This reduction is quite modest as price effects are limited because large parts of primary energy (i. e. solids, nuclear, renewable energy) are not affected by higher oil and gas prices. On the demand side the sector which is most affected is the transport sector, as it uses almost exclusively oil. Transport energy demand declines by only 3 % in 2020.

Under the assumptions of this sensitivity, it was shown that even a modest increase in the cost of gas in the longer term is sufficient to significantly increase the use of solids. In fact, if the use of nuclear power was not simultaneously stimulated as a result of the increased price of gas, the resulting expansion in the use of solids and in emissions would be substantially higher. In other words, with higher oil and gas prices there can be an increase in CO_2 emissions (as shown in the modelling) because the fuel switching effect (encouraging solid fuels) can outweigh effects on overall energy demand following higher oil and gas prices.

A MORE EFFICIENT TRANSPORT SYSTEM

In 1998 a voluntary agreement was reached between the European Commission and the European automobile industry under the terms of which the industry is committed to reduce the average CO_2 emission figure for all new cars to 140 g/km by 2008.[47] This compares with a current level of emissions of about 186 g/km. An intermediate target was set for 2003 at 170 g/km. The industry has also undertaken to make cars available to the market by 2000 which emit 120 g/km, and to undertake further improvements beyond 2008. An initial target for the average of new cars was set at 120 g/km for 2012. The agreement assumes that the behaviour of non-EU producers will be compatible with the above targets and that EU policies will not hamper the implementation of the voluntary agreement. Of course, the agreement does not prevent the European Union authorities from using market based instruments and information schemes to reduce emissions further.

The above agreement was not included in the baseline presented earlier in this volume. The sensitivity analysis carried out to incorporate the voluntary agreement assumed that CO_2 emissions from new vehicles are reduced to 170 g/km in 2003, 140 in 2008, 120 in 2012 and to 100g/km by 2020. Reductions have been assumed to take place linearly in the intermediate years. The results of the implementation of the EU-ACEA agreement can be quite significant both for emissions and for the demand for oil products within the EU. It is assumed that the agreement takes place under baseline conditions. **By 2010, the impact of the voluntary agreement is to reduce oil demand by 28 Mtoe (or more than half a million barrels per day) in the EU, which is equivalent to more than 4 % of EU oil demand**. This decrease in demand corresponds to a decline of CO_2 emissions in the EU by 2.5 % when compared to the baseline. Therefore, the corresponding increase in 2010 from 1990 CO_2 emission levels declines from 7.2 % to 4.5 % in the baseline scenario. Since the agreement involves a reduction in the average CO_2 emissions only of new cars, it would be expected that the impact of the agreement would be more significant in the longer term, as the replacement of older cars is completed. The 2020 impact on oil demand is about double and is equivalent to a reduction in the required oil imports of the EU by more than 9 %. The impact of the agreement on emissions is more limited than on oil demand but very significant nevertheless. By 2020 CO_2 emissions in the EU decline by 4.6 % when compared to the baseline. The corresponding increase from 1990 level of CO_2 emissions drops to less than 9 % compared to 14 % in the baseline scenario.

The potential importance of the agreement can be discerned from its impact on the carbon value. Due to the fact that the 4.6 % reduction in emissions that is achieved through the voluntary agreement is quite a significant portion of the reductions required under the S6 scenario, **the required carbon value to achieve the reduction falls from €115 to €67.5 per tonne**. This reduction counterbalances to some extend - which cannot be exactly defined though modelling - the additional economic effort required by car manufacturers so as to satisfy the targets of the voluntary agreement.

[47] Much of the information on the agreement between the EU Commission and the European automobile industry is based on information available on the latter's web site as of 18 May 1999.

THE IMPACT OF ALTERNATIVE STRUCTURAL CHANGE ASSUMPTIONS

As has already been discussed, the baseline assumptions assume the continuation of the restructuring of the EU economies towards the service sector and, within industry, away from energy-intensive industries and towards more novel and higher value added industries such as electronics and telecommunication equipment. Unfortunately, the future structure of economic activity is extremely uncertain and there are very few alternative projections of good quality. This is especially the case for the long term.

In view of the period covered in the baseline scenario, it is important to note that the assumed economic structure for 2010 and 2020 is only one of many consistent alternative set of assumptions. In order to examine the possible importance of alternative assumptions of the future economic structure, two case studies have been considered. The first analyses the effects of an economic structure that is more optimistic from an environmental point of view and is based on a set of alternative assumptions provided by FhG-ISI for Germany. The second presents the impact of a different future economic structure, less optimistic (in environmental terms) compared to the baseline, for France based on a set of assumptions provided by ENERDATA[48]. As mentioned, both cases are presented here to illustrate the uncertainty involved in such kind of analysis for the future development of the energy system.

A CASE STUDY FOR GERMANY

Some of the most important differences in the assumptions of this sensitivity from those of the baseline include the reduction in value added of industry in 2020 by 3.5 %. The scenario involves reduction in German tonnage of steel production by 15 %, reduction in cement and petrochemicals production by 11 % and 13 % respectively and sharp reductions in other energy-intensive industries. It also involves reduction in freight by road and rail by 15 % and 11 % respectively; and a small reduction in road passenger transport. The sensitivity also includes a number of assumptions on technical progress and efficiency improvement that are more optimistic that those of the baseline. Finally, energy taxation is assumed to be somewhat higher in Germany over the outlook period than assumed under baseline conditions.

The results of the sensitivity analysis indicate a substantial reduction in German energy demand and emissions over the outlook period, although the impact for the period to 2010 is limited. By 2020, energy demand in Germany is limited to 322 Mtoe or 8 % below its level in the baseline. Energy demand by the transportation sector is 4 % below its level in the baseline, while the difference in other sectors is close to 10 %. Total emissions from the German energy system in 2010 are –15.1 % lower than in 1990, compared to –13 % in the baseline. Overall 2020 CO_2 emissions in Germany amount to 802 Mt, representing a 8.4 % reduction from baseline levels.

This sensitivity indicates that, in the case that future economic and technology developments lead to a less energy-intensive economy, the task of controlling German emissions would become easier. Nevertheless it should be mentioned that this would depend on the way energy-intensive goods are produced in other EU or world regions.

A CASE STUDY FOR FRANCE

In view of the discussion of the previous sensitivity it should be clear that the economic structure of the future could also prove to be less optimistic from an environmental point of view than that assumed in the baseline, at least for some sectors.

TABLE 5-16: IMPACT OF ALTERNATIVE ECONOMIC STRUCTURE ASSUMPTIONS, GERMANY

	Structural change scenario			
	2010	% Difference from baseline in 2010	2020	% Difference from baseline in 2020
Gross inland consumption (Mtoe)	343	-2.2%	322	-8.0%
Fuel inputs for generation (Mtoe)	98	-3.2%	104	-10.8%
Final energy demand (Mtoe)	231	-2.5%	224	-7.9%
CO_2 emissions (Mt CO_2)	807	-2.4%	802	-8.4%
Gross inland consumption/GDP (toe/M €90)	170.3	-2.2%	134.9	-8.0%
Carbon intensity (t CO_2/toe)	2.4	-0.2%	2.5	-0.5%

[48] For a discussion of the sensitivities and its rationale, as well as for details of the assumptions contained in the two case studies, the reader should consult Bertrand Chateau and Eberhard Jochem (Vol. 6 of the Shared Analysis Project). In running the sensitivity analysis, the differences between the baseline and the proposed "structural change scenario" were used, rather than the absolute numbers.

TABLE 5-17: IMPACT OF ALTERNATIVE ECONOMIC STRUCTURE ASSUMPTIONS, FRANCE

	Structural change scenario			
	2010	% Difference from baseline in 2010	2020	% Difference from baseline in 2020
Gross inland consumption (Mtoe)	275	1.5%	293	1.1%
Fuel inputs for generation (Mtoe)	26	-3.8%	38	-7.0%
Final energy demand (Mtoe)	167	2.1%	175	2.2%
CO_2 emissions (Mt CO_2)	404	3.6%	435	2.6%
Gross inland consumption/GDP (toe/M €90)	195	1.5%	174	1.1%
Carbon intensity (t CO_2/toe)	1.5	2.1%	1.5	1.5%

In the alternative set of assumptions examined here for France the value added for industry in 2020 as a whole is 8 % less than in the baseline but activity in many energy-intensive industrial sectors is higher than assumed in the baseline. Thus, French steel production in 2020 is nearly 20 % higher in this sensitivity than in the baseline while the production of the paper industry is more than 60 % higher. Similarly, the production of energy-intensive chemical sectors is almost 10 % higher than in the baseline, while the production of cement is almost 16 % lower. The overall impact of these assumptions leads to an increase of 1 % in energy use and related CO_2 emissions of the French industry by 2020, when compared to the baseline.

By far the most significant change in other sectors is that in the transportation sector. According to the case study examined here, the transportation sector in France will be more dominated by road than assumed in the baseline. For example, freight by road in 2020 is nearly 30 % higher than in the baseline while freight by rail is reduced by a similar proportion. Passenger transportation is also projected to be more road intensive. The result of these alternative assumptions is to increase transportation energy demand by 14 % in 2020, when compared to the baseline.

The alternative assumptions considered for France also included a significant reduction in the required building space. This reduction, which led to a sharp reduction in energy use by the tertiary sector in 2020, when compared to the baseline, mainly affecting electricity demand, which decreased by 1.6 % in 2010 and 3.2 % in 2020, compared to the baseline. In the tertiary sector, the decrease in electricity demand reached 12.5 % in 2010 and 15 % in 2020.

Total energy use in France under this alternative set of assumptions in 2020 is 2 % higher than in the baseline. Given the different allocation of this demand (more to industry and less to the tertiary sector) the carbon intensity of final energy use in France rises and CO_2 emissions in 2020 are 6 % more than under baseline assumptions. Total emissions from the French energy system in 2010 are 14.1 % higher than in 1990, compared to 10.6 % in the baseline. By 2020 they are 2.6 % higher than in the baseline.

It should be again emphasised that this projection for France is presented in order to illustrate the uncertainties. However, further analysis is necessary to extrapolate such developments to the whole of Europe.

5.3 CONCLUSIONS AND POLICY IMPLICATIONS

CONCLUSIONS ON GLOBAL ENERGY TRENDS UP TO 2020

Total primary energy consumption is likely to increase by an average annual growth rate of 2 % in the 1990-2020 period. The energy intensity of the world economy is expected to decline by almost 1.5 %/a in the period up to 2010 and by slightly less than 1 % after that. The global energy system will continue to be dominated by fossil fuels over the next 25 years. The dependence on fossil fuels is likely to be close to 90 % by 2020.

Given the projections for growth in primary energy demand and the continued dominance of fossil fuels, global emissions are expected to grow quite rapidly. As a result CO_2 emissions increase by around 40 % in 2010 and 85 % in 2020 from their levels in 1990. China and India account for almost half of the global increase in CO_2 emissions.

There are many uncertainties surrounding the future outlook of the world energy system. These include the level of global and regional economic growth, the degree of improvements in energy intensity and the level of world oil and gas resources, and hence price.

Scenario analysis indicates that a more pessimistic view on the resource availability than that assumed in the baseline, results in the oil price increasing more rapidly than in the baseline scenario: +2.4 $/barrel in 2010, +5 $/barrel in 2020. The impact of the resource constraint is stronger in the following decade, creating a difference of 7 $/barrel in 2030 compared to the baseline. Higher oil prices than those assumed in the baseline would only have a small impact on global energy consumption.

CONCLUSIONS ON EU ENERGY TRENDS UP TO 2020

Despite the evidence of some saturation effects for some energy uses in the EU, energy demand is expected to continue to grow throughout the outlook period even though at rates significantly smaller than in history. The growth rate in primary energy consumption is expected to continue to be close to 1 % over the period to 2010 and then to decelerate to just 0.4 %/a up to 2020.

The implied energy intensity improvement is gradually expected to improve and to reach an annual rate of more than 1.5 %/a towards the end of the projection period. Structural change on the demand side mainly explains this change. The role of energy technology is also important.

The EU energy system remains dominated by fossil fuels over the next 25 years and their share rises marginally from its level of just under 80 % in 1995. Nearly two thirds of overall energy requirements in the EU will be imported by 2020, compared to less than half in 1995. Import dependency will gradually increase for all fossil fuels and is likely to reach very high values in the longer run.

Under baseline technology assumptions, novel energy forms, such as hydrogen and methanol, do not make significant inroads, primarily due to cost considerations.

Final energy demand is expected to grow marginally faster than primary energy (because of improved rates of conversion efficiency in power generation), rising by 1.1 % and 0.5 % in the 1995-2010 and 2010-20 periods respectively. There are relatively modest changes in fuel shares over the next 25 years. Energy demand in the tertiary sector is the fastest growing segment of final demand reflecting the expected restructuring of the economy towards services. The modest growth in residential energy demand reflects the lack of growth in the EU population and the small increase in the number of households. By 2020, transportation accounts for almost a third of EU final energy consumption, followed by industry and the residential sector, which account for 26 % of consumption each.

Oil becomes almost exclusively a fuel for transport and petrochemicals. The increase in transport energy demand is actually greater than the increase in the demand for liquid fuels over the 1995-2020, implying a decline in oil consumption in the other sectors.

The use of electricity is expected to expand by 1.6 %/a over the projection period and its growth is expected to be especially rapid in the tertiary and in the transportation sector. Steam demand is projected to grow by 1.3 %/a in the period to 2010 and by almost half this rate in the following decade. The industrial sector is the dominant user of steam.

Total power capacity requirements for the EU increase by some 300 GW in the period 1995-2020. Traditional coal and oil plants decline very rapidly. Similarly, due to the decommissioning of older plants, there is a modest decline in the capacity of nuclear plants, while nearly half of the thermal plant currently utilised by independent producers is also expected to be scrapped. These declines in capacity are more than made up for by the dramatic increase in the gas turbine combined cycle plants (CCGT). These increase by more than 8 times over the projection period to reach 384 GW or around 45 % of the total installed capacity by 2020. This rather spectacular growth, brought on line by both utilities and smaller producers is due to the significant cost advantages that this form of power generation has demonstrated in recent years.

Significant growth in generation by clean coal plants and biomass generation is also expected to occur over the next 20 years, in particular towards the end of the projection period. However, these forms of power generation will still only account for less than 5 % of total generation capacity by 2020. A significant improvement is expected to occur in the efficiency of power generation.

Technological advances and changes in market structure will reduce the dominance of utilities in electricity generation. This trend is clearly related to the widespread use of gas turbines since, with this form of generation, economies of scale are very limited above a rather modest turbine size. The use of gas turbines in combined cycle mode will also greatly encourage the more widespread use of steam, especially by independent producers. Small-scale producers are projected to get between 20 and 25 % of the electricity market by 2020.

The use of coal and lignite declines quite dramatically between 1995 and 2010 but after that it recovers to reach, and marginally exceed (after 2020), its 1990 level. This is due to the increased decommissioning after 2010-15 of nuclear plants and the progressive rise in the relative price of natural gas.

The rising share of fossil fuels will lead to an increase in the carbon intensity of the EU energy system. Together with the modest increase in energy demand, this will lead to an increase in CO_2, which are projected to increase annually by 0.6 %/a in the period 1995-2010 and by 0.5 %/a after 2010.

Emissions of SO_2, NO_x and CH_4 from the whole EU energy system and especially from the power generation system are expected to decline quite rapidly over the outlook period as a result of environmental policy and fuel switching from solid fuels to natural gas.

CONCLUSIONS FROM SCENARIO AND SENSITIVITY ANALYSIS FOR THE EU

For the period up to 2010, in all three scenarios under consideration, nearly half of the overall reduction in emissions is achieved through a reduction in energy consumption. An even greater proportion of emissions reduction takes place through substitution in 2020. This effectively means that as we move further into the future the economic system finds substitution among fuels (i. e. reducing the carbon intensity) much more cost effective than reducing overall energy use (i. e. reducing the energy intensity) over and above the impressive energy intensity and more modest carbon intensity improvements already contained in the baseline.

The bulk of the change in carbon intensity of the EU energy system is due to the electricity and steam generation system. For the period to 2010, nearly 60 % of the overall reduction in emissions is achieved through adjustments in the power and steam generation sector. By 2020 this proportion rises to more than 70 %.

Renewable energies and nuclear also expand as a result of the imposition of the carbon constraints. The use of nuclear (if not constraint) expands substantially while the effect of renewable energy forms is rather limited. Similarly, the improvement in efficiency of generation in the three scenarios only accounts for a modest part of the reduction in emissions while the share of co-generated electricity from thermal plants increases modestly.

While the role of the electricity and steam sector remains dominant in meeting the carbon constraint, there are indications that the relative difficulties increase, as the constraint becomes tighter. Effectively, at low levels of the carbon constraint the flexibility of the generation system and the available fuel switch options make it a convenient and cost-effective way to achieve emission reductions. As the constraint gets tighter, the options within the generation system become relatively more difficult and final demand is required to make a more substantial contribution.

The total energy system cost of reaching the emission targets under the three scenarios for the EU in 2010 signifies a net additional cost for the rest of the economy, leading to a loss of welfare (of an order of magnitude of 0.02 % up to 0.07 % of annual GDP). The additional annual expenditure required by the energy system from the rest of the economy is significant but the macro-economic implications will depend on the adjustment flexibility of the European sectors in producing the additional commodities needed to implement the energy system changes. There is a significant increase in the cost of energy that the economic agents need to face under the emission constraints. The harmonisation of the effort in the EU (leading to equalising the marginal abatement costs across the Member States) and the exploitation of low-cost emission reduction potentials for non-CO_2 greenhouse gases, however, significantly reduces the cost for the EU, finally leading to a rather modest cost for meeting the carbon constraints considered. However, the macro-economic and especially the sectoral costs (energy intensive industries, households, cost of electricity) are not negligible and their consequences have to be further explored.

The outlook for nuclear power is one of the key uncertainties of this outlook. Nuclear can play a very significant role in reducing emissions beyond 2010. Its impact will depend on whether the massive amount of nuclear plants that are due to be decommissioned between 2015 and 2030 will be replaced by nuclear plants or by fossil fuel plants. Under the nuclear sensitivity, nuclear capacity is projected to increase to 181 GW by 2020 and to 212 GW by 2030. The impact of this sensitivity on the EU energy economy is quite significant.

Under the assumptions of the high oil and gas sensitivity, it was shown that even a modest increase in the cost of gas in the longer term is sufficient to increase the use of solids significantly.

The role of transportation is critical for the future increase in oil import dependency and significant for the future growth in emissions.

There is a great deal of uncertainty surrounding the future long-term structural changes that are likely to take place in the EU. Sensitivity analysis for Germany and France suggests that alternative economic structures than those assumed in the baseline could have significant impacts on future energy demand and emissions.

POLICY IMPLICATIONS

It was shown that under the baseline scenario assumptions for the period to 2010, it is unlikely that the EU will meet its Kyoto undertakings, at least through energy related CO_2 emissions. In the baseline case, instead of the 8 % reduction in emissions by 2010 a 7 % increase is projected for 2010, when compared to the level of CO_2

emissions in 1990. Depending on the outlook and policy measures for non-CO_2 greenhouse gases, such as CH_4, it is clear that a number of policy initiatives will have to be undertaken for the abatement of energy-related emissions.

It was seen that under the three additional scenarios CO_2 emissions could decline by between 222 and 406 Mt of CO_2. Whether these reductions are sufficient for the EU to meet its target will clearly depend on what measures are taken on other greenhouse gases and for CO_2 emissions from sectors other than that of energy. It also depends upon how severe new emission reduction targets are in the period 2010-2020 and subsequently. Finally, the future role of Kyoto flexible mechanisms and of sinks will be important in this respect.

The sensitivity analysis that was carried out earlier showed that a number of measures, other than the imposition of a global restriction on CO_2 emissions, could also be effective. However, many of these affect mostly the period beyond 2010. The one significant effect examined that is relevant for the Kyoto period is the potential contribution to emissions reduction from improvements in the efficiency of transport. It was seen that the implementation of the 1998 voluntary agreement between the EU and the auto manufacturers association could result in more than 80 Mt of CO_2 reduction by 2010, a very significant contribution.

The decrease of demand for energy, the fuel mix shifts towards gas and the changes in power and steam generation in favour of non-fossil fuels, contribute to considerable reductions of the emission of acid rain pollutants, under the three additional scenarios examined. The 2010 reduction in SO_2 emissions, when compared to those in the baseline, ranges from 23 % up to 33 % and those of NO_x range from 6 % to 10 %.

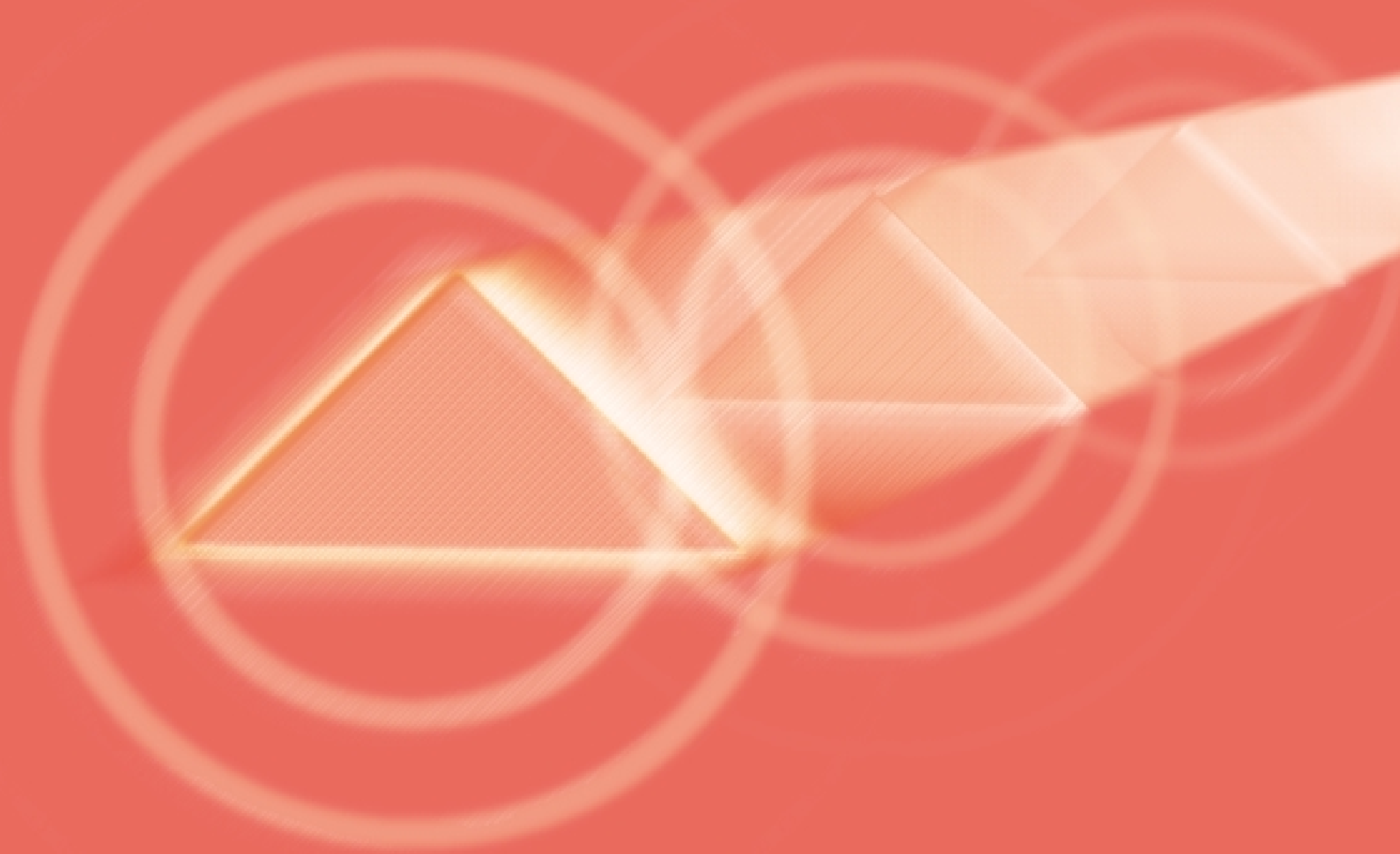
The imposition of emission reduction targets might also affect the ongoing process aiming at market liberalisation of electricity. In the case that carbon constraints impinge negatively on market liberalisation, additional policies may be needed so as to compensate for such effects.

One of the major conclusions to emerge from this chapter is the crucial role that the electricity and steam generation may be called to play in reducing emissions. Orchestrating this role may prove quite difficult in the circumstances of liberalised, mostly privately owned and competitive markets. It is important to recall that the reduction in emissions from the sector are not only due to market forces, such as the relative price of gas and coal, but also to a number of other factors many of which are influenced by policy. These include any non-fossil fuel obligations, subsidies for renewables (or other measures in support of renewables), difficulties of insurance for nuclear plants, fair tariffs for co-generation, R&D support for promising generation technologies etc. Thus, the task of the regulator and policy maker becomes even more important in monitoring and ensuring the implementation of a number of potential policy initiatives related to the sector.

Under the carbon constraint scenarios as well as under the nuclear and high price sensitivities, long-term import dependency improves for the EU but it remains a potential concern. Dependence on imported oil is not affected much by any of the alternative assumptions examined, and remains close to its baseline level in 2020.

The imposition of carbon constraints does indeed lead to a further penetration of renewable energy forms. This is due to their relative price becoming more attractive once fossil fuels have to carry the cost implied by the carbon value. However, their share in total primary energy remains below 8.4 % even under the S6 scenario for 2020. In general, the current EU target for renewable energy forms seems very difficult to reach in the absence of vigorous new policies. The cost gap between renewable energy and fossil fuels remains large even by the end of the projection period. The relative reductions in the costs of renewable energy, achieved through the imposition of carbon values which results in higher costs for fossil fuels, needs to be much more substantial than those suggested by the alternative scenarios examined here. Alternatively, technological progress must be much more rapid than assumed here.

PART VI KEY ENERGY POLICY ISSUES FOR EUROPE



The ultimate objective of the energy policy of the European Union and its Member States can be regarded in the spirit of the Amsterdam Treaty of 1997 to contribute to a sustainable development of society. This supporting role of energy policy can be achieved by providing the contextual conditions for a secure, competitive and environmentally benign energy system. The policy concept of sustainable development can be directly linked to the classical objectives of energy policy: security of supply, competitiveness of the energy system, and concerns for the environment (White Paper, 1995):

- sustainable development needs secure energy supplies; sudden disruptions of supply would be harmful;
- an energy system that is not competitive weakens the dynamics for economic growth that include change, for employment and welfare;
- environmental stresses and global climate change could destabilise the ecological balance and also weaken the development by high external cost.

These classical goals may have to be pursued with changing emphasis depending on the historical situation and emerging issues and constraints. The "golden 1990s" (see Chapter 3) were characterised by ample access to energy resources, decreasing energy prices, relatively low and secure energy dependence from foreign sources, declining SO_2, hydrocarbon and NO_x emissions and with a stabilisation of CO_2 emissions until 2000 in reach for the European Union. But, in a world of rapid change, energy policy has to be understood as a continuous process of alert observation, intensive learning and wise adaptation.

Within this spirit, this chapter reports on the results of the analyses of **major energy policy challenges** which are of particular interest at the turning point of this decade and century. Starting from general trends, which have been outlined in Chapter 3, and the quantitative projections of Chapters 4 and 5, the following part of the report covers contextual conditions (see Chapter 6.1), the policy-related results cover energy security and import dependence (Chapter 6.2), the prospects of future energy prices (see Chapter 6.3), the environmental and climate change policy aspects of energy use (see Chapter 6.4), the role of technological progress for the energy system (see Chapter 7), and finally, the priorities for and the value added of a European energy policy (see Chapter 8). Most of these topics are treated with a time horizon of around 20 years.

6.1 GENERAL TRENDS AND FRAMEWORK CONDITIONS

The analysis suggests that the external dimensions of EU energy policy are likely to assume significantly greater importance in future. Three dimensions are considered of particular importance in this analysis:

- First declining indigenous energy production and unfavourable market conditions for renewables are likely to **revitalise policy aspects of security of supply**; international co-operation in the energy field supported by globalisation of energy supply economies may well play an increasing supporting role.
- Second **the enlargement of the EU** needs further attentions given the severe challenges in the transition process of Eastern European countries.
- And third, continued **international diplomacy in the fields of environmental protection and climate change** should be seen as a priority.

In turn, the analysis concludes that effective resolution of external and internal policy dimensions will require the more effective integration of EU policy initiatives.

DECLINING DOMESTIC ENERGY PRODUCTION, UNFAVOURABLE MARKET CONDITIONS FOR RENEWABLES AND INCREASING ENERGY IMPORTS

The Baseline Scenario anticipates an increase in fossil fuel production in the EU over the period to 2005. However, thereafter **indigenous EU production is anticipated to decline**. The Baseline projections foresee that two-thirds of the energy requirements of the EU – or at least around 60 % in the alternative CO_2 reduction scenario – will have to be imported by 2020. This rise in import dependency is due to a combination of three major factors (see Chapter 4.2):

- Continued decline in **EU hard coal production** given high production costs, progressive removal of State Aids and competition from other forms of energy. Imported coal is sold cheaply; the supply curve for such coal is relatively flat (i. e. large volumes of coal will be brought on to international markets for a small increase in prices); and freight charges – though somewhat volatile – remain generally low. As a result, a steady increase in the share of imported coal is projected from sources such as Australia, Colombia, Indonesia, South Africa, and Venezuela. Also **lignite production** is likely to decrease given decreasing demand in the non-power sectors and increased investment risks due to liberalisation of electricity markets. As lignite has the highest specific CO_2 emissions it may lose competitiveness if EU greenhouse gas emissions have to be reduced further in a possible second commitment period 2010-2020. (This may well follow the first commitment period 2008-2012 for which a commitment was made in the Kyoto Protocol that the industrialised countries should reduce their greenhouse gas emissions by 5 %).

- The rapid increase in North Sea off-shore **oil and gas production**, witnessed since the early 1970s, is unlikely to be sustained given the growing maturity of the province. To date, the rising costs normally associated with development of smaller sized fields have been largely off-set by a range of technological innovations, such as 3-D seismic, deviation drilling, increased use of sub-sea systems, and better-designed and lighter off-shore platform structures. Whilst such technological momentum will be maintained (and, indeed, has been further stimulated by the recent fall in real oil prices), a slow but steady depletion of the North Sea Province is expected to reduce its overall production.
- The EU's installed **nuclear generating capacity** is ageing. Life extension of such plants is anticipated, where this is judged to be safe by nuclear licensing authorities. However, with the exception of France, public opposition to nuclear power remains strong at present. In addition, liberalisation of electricity markets and the abolition of formerly-protected utility geographical franchises are increasing investment risks and raising the cost of capital. These factors appear to disadvantage capital-intensive, long lead time generation options such as nuclear power, but to favour the move to smaller-scale generating units (Combined Cycle Gas Turbines and CHP) based upon natural gas. As a result, the EU's installed nuclear generating capacity is projected to decline – especially after about 2015 (see Chapter 4.2).

Partly influenced by these factors, the Commission has established a **target of 12 %** of the overall EU energy balance deriving from **renewable energy sources** by 2010 (KOM(97)87, final). In the light of lower real fossil fuel prices, and on the basis of existing policies, the analysis suggests this is likely to be a challenging target to achieve. As a result, greater attention may well have to be devoted to energy diversity and energy security issues in future. Key issues for the Commission and Member States to consider include:

- Qualitative changes in EU energy markets, especially the move towards natural gas and electricity and away from coal and oil. The latter two fuels are traditionally stored at the point of final use by consumers which, for technical reasons, is not the case for gas and electricity (other than small quantities of LNG).
- Increased **dependence upon imported natural gas** will lead to intensified appraisal of supply security risks and of means to ameliorate them. These might include expansion and reinforcement of pipe-line infrastructures, storage capacities and re-consideration of the changing dual-fuel capabilities of large energy users (especially in power generation and energy-intensive industrial sectors; see Chapter 6.3.2).
- **Enhanced energy research, development**, diffusion and innovation policies to increase diversity in the EU energy balance, reduce off-shore production costs in the North Sea and enhance market deployment of cleaner, more efficient energy technologies (see Chapter 7).

INTERNATIONAL CO-OPERATION IN THE ENERGY FIELD

Although the energy import dependence of the EU is projected to increase, a policy of energy autarky is not judged feasible or desirable. The resource and opportunity costs would be too high. This places a premium on **continued diplomatic efforts** to encourage global free trade in energy resources.

From the entrepreneurial point of view, the stability of world energy markets will be further assisted by increased overseas direct investment by EU and other energy companies, liberalising of energy markets by exporting countries, increasing mutual economic interdependence, and increased diplomatic dialogue and mutual understanding.

International co-operation in the energy field embraces numerous dimensions. The analysis suggests that under the auspices of the Energy Charter, negotiations should continue to conclude a multilateral Transit Framework to reduce risks of physical disruptions to pipe-line supplies. Likewise co-operation with a range of international institutions should continue – including the IEA, EBRD, World Bank, Mercosur and NAFTA. Bilateral negotiations will remain important with the OECD, Accession States, Central and Eastern Europe, the Gulf Co-operation Council, Mediterranean partner countries and individual developing countries and regional blocs.

ACCESSION COUNTRIES

Dialogue should continue with the Accession States given the impact eventual membership of the EU would have on the EU's energy balance. Comparing energy/GDP ratios of the EU and the Accession Countries, the differences are due to a very old capital stock in Eastern Europe and low energy prices over many decades. In many cases, energy was – and still is – subsidised, and environmental standards of energy converting technologies are lower than in the EU. There are many obstacles for energy efficiency such as lack of life cycle costing by investors, lack of market knowledge and up-front capital, traditions of wasteful behaviour and expectations of voters and stakeholders, the investor/user dilemma in the majority of buildings, or weak links of co-operation between universities and industry. West-East transfer of technology, know-how and policy experience in market economies open many opportunities for technology suppliers and the EU energy system. The EU may also consider defining a common commitment under Article 4 of the Kyoto Protocol.

INTERNATIONAL CO-OPERATION ON THE ENVIRONMENT

The analysis suggests that many of the efforts in the field of international co-operation on the environment will focus around the **implementation of a post-Kyoto strategy**. In this regard, the Commission will need to consider intensifying its dialogue with a range of other partners to ensure the Kyoto Protocol is ratified. This will need to include widening the scope of the Protocol over time, particularly to secure the trust and active participation of developing countries. This could be assisted by the measured development of mechanisms such as technology transfer, the Clean Development Mechanism and Joint Implementation. In addition, the Commission may ensure that emerging Member State experience with emissions trading is compatible both with wider EU and global emissions trading regimes. Given their significance in international diplomacy, it may be advisable to focus special efforts upon Russia, the USA, China, India and the Gulf Co-operation Council. High income developing countries such as South Korea, South Africa, Mexico and others may be asked to join the Annex B countries for the next commitment period. Particular attention of policy activities may also be given to urbanisation and transportation, harmonisation of taxes on jet fuels, support for decentralised economic development in Accession States and developing countries, as well as specific efforts of energy technology transfer and capacity building in developing countries.

INTEGRATION OF EU POLICY INITIATIVES

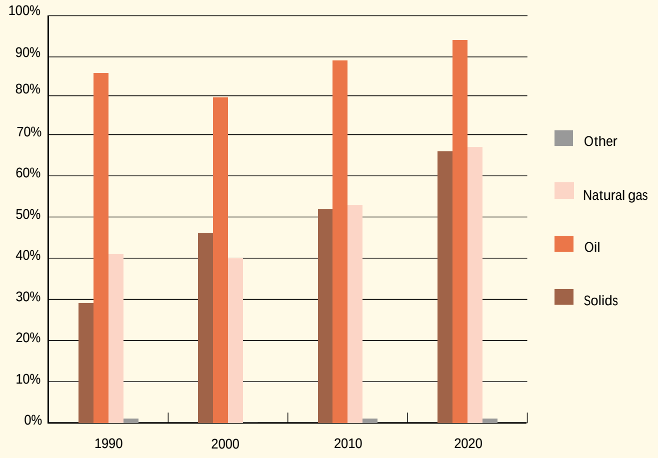
This analysis has highlighted the many complex facets of policy making in the energy field. In conclusion, it emphasises the need for increased co-operation and co-ordination of several policy areas as the focus shifts from narrow concerns of the energy sector per se to those of the wider energy system. In turn, this is likely to require new ways of thinking and new modes of operation. The Heads of State decided at their meeting in Cardiff to integrate energy, transport, and agricultural policies where possible.

Such policy integration – also with regard to sustainable development – could also be developed further to exploit opportunities for 'joined-up' policy making and to avoid duplication – or even partial compensation – of efforts. The key words here are coherence, co-ordination and transparency. As both the agenda and the process of policy making broaden, particular attention will be required to develop more meaningful fora for dialogue with a wider range of legitimate stakeholders. The existing system of consultation and dialogue has been based largely upon rather compartmentalised analysis of issues and policy responses. The new agendas are likely to require much greater 'joined up' thinking and cross-cutting styles of operation in the Commission and Member States. This could pose very significant challenges to the established procedures of the Commission, the Council of Ministers and the Parliament. In particular, the policy making process in future requires greater accountability, honest presentation of complex trade-offs, benchmarking of progress against agreed targets, and much less secrecy in policy deliberations.

6.2 ENERGY SECURITY AND IMPORT DEPENDENCE

According to the Energy Policy White Paper (1996), "the external dimension of energy policies is generally considered to be the most important vehicle for action of the European Union". A major challenge of European Energy Policy will be the re-emergence of security of supply in the agenda, given that the overall import dependency of the EU is expected to rise to almost 70 % for natural gas, 80 % for coal and 90 % for oil by 2020. At the same time the needs of the emerging economies will exert growing pressures in the international energy markets.

Figure 6-1: EU import dependence



But increasing competition on the **global oil market** will maintain the oil price at a moderate level in the future and accelerate the re-concentration of oil trade on countries with low-cost reserves, in particular the Middle East countries which account for two-thirds of proven oil reserves. This will result from the increasing normalisation of the oil market as a competitive market, under the effects of a deliberate strategy of Middle East producers to maximise their market share by limiting the development of oil competitors and energy substitutes. Low prices will thus slow down the development of new reserves in other regions such as the Caspian, or of the deep off-shore and unconventional resources. It will also delay the emergence of substitutes to oil products in transportation. The goal of Middle East producers is to reduce the risk of economic depletion of the abundant Gulf reserves before their technical depletion, a risk that they fear increasingly.

In the **gas sector**, the growing dependence will be potentially oriented towards the Russian supply which could reach 45 % of EU imports in 2020 according to POLES predictions, whatever the degree of liberalisation of the national markets and the level of prices. Beyond the importance of its reserves, the Russian gas strategy of maximisation of hard currency income and of export capacity creates a large potential of supply to the European market.

The interference between the European and the Asian gas markets will stay limited in the next three decades despite the rapidly emerging demand of gas of the major Asian regions (China, India, ASEAN). The geography will orient the development of Asian transboundary infrastructures towards specific gas provinces far from Europe (East Siberia, Central Asian republics, South-east Asian off-shore). Moreover the possible competition for access to the Middle East gas resources will be limited because of their abundance in particular in Iran and the probably weak pressure of the European demand which is geographically diversified.

In this context of changing energy markets, a permanent reassessment of risks is needed under the influence of two competing views: the "laissez-faire" view, which considers oil and gas as simple commodities, and the "interventionist" view which considers energy dependency as permanently risky at an economic and political level. As risks for oil and gas are not similar in type and magnitude, they have to be analysed differently (see Chapters 6.2.1 and 6.2.2).

6.2.1 INCREASING OIL DEPENDENCE AND SECURITY

The risks associated with re-concentrating oil supplies on the Middle East fall into two categories: the supply interruption risk and the market control risk.

SECURITY AND GLOBALISATION OF THE MARKET

The projected very high concentration of exports from the Persian Gulf (over 50 % in 2010 compared with 37 % today) would make world oil supplies very sensitive to any political disturbances that led to exports by major producers being stopped or export routes, such as the Straits of Hormuz, becoming unavailable for long periods of time. These risks must be appreciated when taking into account the globalisation of the oil market and the real political instability of the countries in the area.

The international oil market is currently both globalised and competitive, with many different sellers and buyers, and a spot market and its associated financial instruments. The withdrawal of a producer will not cause a break in supply to its regular customers, but will trigger a temporary price rise, as was the case in 1990 with the withdrawal from the market of two major exporters (Iraq and Kuwait). In this context of a "commodity oil market", there is no competition between national economies or regions for access to a specific resource: both supply and demand are addressed not to a specific country or region, but to the one "great pool" that the world market makes up. Existing intra-regional flows introduce only a limited friction in the market adaptations. This fact leads to two consequences:

- security of oil supplies is guaranteed on a world-wide scale, and the speed of adaptation to disruptions in the market depends on the quality of trading structures;
- research into privileged bilateral relationships with producers for guaranteed access to a specific resource is not of any great interest when confronted with strict rationing of supplies.

These observations should not lead to a confusion of all the situations. A significant long-term reduction in the contribution from one or two major producers, in the event of a major crisis, could exceed the market capacity to adjust in the short term. The responses to such a problem are known:

- industrialised nations must maintain an efficient **emergency reaction capacity** for dealing with a major destabilisation in world supplies, with co-ordinated management of strategic stocks; the European Union could decide to improve the sharing of risks between its members, to establish a publicly managed European strategic stock, and to act as a block outside the IEA co-ordination mechanism,
- a **foreign structural policy** aimed at political stabilisation and at economic development of the major exporting areas, in order to limit their macroeconomic dependence on oil revenues, would need to be defined.

UNCERTAINTIES ON MIDDLE EAST STABILITY

The re-concentration of the global oil supply on the Middle East raises the issue of the stability of the countries of this region. The Middle East is regarded as being politically unstable for several reasons. Successions of old monarchs and dictators in the near future are viewed as factors for possible future destabilisation. Highly dynamic demographics and high levels of unemployment could create social disequilibria. Fundamentalist movements and religious divisions could generate political turmoil. In the opposite scenario of too rapid democratisation, which would respond to repressed aspirations and pressures from the West, political opening would create instability. Moreover, potentialities of regional military conflicts still exist. Such views, however, have to be analysed carefully.

In these countries, there are already elements of national stability. Apart from the collapse of the Iranian monarchy twenty years ago, all the regimes in the Gulf have enjoyed long-term stability since the sixties. This is explained by the capacity of oil revenue to increase social well being, buy allegiances and maintain a large, repressive structure that allows the democratisation process to be limited. The lessons of the past have also been drawn on to counter and contain the risk of destabilisation through terrorism, as has happened in Saudi Arabia.

The future successors of the current leaders of the Gulf monarchies should not change the direction of oil policy or the attitudes towards the occidental military protection in any fundamental way, even if the future governments have reservations about this protection. The top-down decision-making process guarantees inertia of directions. Generally speaking, the successors will enjoy a considerable advantage over any potential competitor when they come to power. In dictatorial regimes the risks of instability will be higher, but the prior elimination of opposition means that the transitions will probably be very progressive.

It is expected that the effect of any democratisation in the present regimes will be to bring about a level of political instability. This instability does not convey, however, enormous risks to oil supplies, in view of the importance of maintaining oil income for financing public budgets.

At a regional level, there is, and will continue to be, a risk of conflict, especially if the Middle East peace process develops too slowly. Rivalry between regional powers could re-emerge after the lifting of the embargo on Iraq and the progressive abandonment of the United States' "double containment" policy towards Iran and Iraq. Two elements, however, must be taken into account when estimating this risk. Several conflicts have occurred in this region (Iran-Iraq, the Gulf War), without supplies or market stability having been affected in the long term. Territorial hostilities aimed at altering borders have been in vain. In addition, the United States' policy in the region, marked by the long-term presence of American troops, guarantees the safety of the member states of the Gulf Co-operation Council and, beyond that, the safety of oil supplies.

This being the case, there is still some risk that the major producing countries in the region will be destabilised. This could result from the competitive effect of the market on prices. In fact, the economic and industrial developments necessary for responding to demographic pressure will encounter difficulties in the financial budgets if international prices remain far below $ 20/barrel in the future.

A NEW RISK OF THE OIL MARKET BEING CONTROLLED?

The possibility of most oil business being re-concentrated on the Middle East carries the risk of market power being exercised, leading to a long-term increase in prices above their competitive level. However, the context of the oil market will be fundamentally different to that of the seventies and eighties, during which a group of states was able to control prices by concerted reductions of sales for two reasons:

- First, the re-concentration of trading in the Gulf will occur in the context of intense competition, maintained by technical progress, which will allow economic access to resources that are currently not easily accessible. Capacity for competition will therefore increase quickly if prices are too high.
- In the second place, in the increasingly competitive context, OPEC has lost part of the cohesiveness it demonstrated in the 1970s. Its influence on the oil price is decreasing and depends mainly on the systematic restrictive production policy of Saudi Arabia and occasional agreements with the largest non-OPEC exporters. OPEC operates more as an occasional safety net in case of too long-lasting price drops than as a permanent price-maker. The competitive nature of the market will be increased by the liberalisation, currently in progress, of access to all the oil-producing countries' resources. The last countries to remain impervious to such an opening (Saudi Arabia and Kuwait), or those prevented from opening by the American policy (Iraq, Iran), are now making developments in this direction. This opening will strengthen their rapid development policy by allowing the injection of the necessary capital and technology. The presence of companies will limit any possibility of building up market cartels or prevent price-making by regulation of quantities offered by a certain number of oil-producing states. Probable privatisation of national oil companies in non-Gulf regions would reinforce this trend. These two movements will have the effect of transferring the power of availability to international companies on a larger part of world reserves, including production from the Gulf countries. The latter will retain a certain control on the level of production, but it will not be large enough to influence the market.

To sum up, the development of world oil supplies in a greatly transformed world context will lead to changing risks. The concentration of most supplies in a single region will create a de facto vulnerability in global supplies while the strengthening of competition may affect the stability of some exporting countries by creating a long-term low-price trend. But the global, competition-based market will reduce greatly other risks.

6.2.2 INCREASING GAS DEPENDENCE AND SECURITY

While the progressive decline in North Sea production after 2005/2010 will lead to a high dependence (around 87 %) on imports for the satisfaction of oil requirements by 2020 (see Table 4-13), the better reserve situation of natural gas does not prevent a sharp increase in import dependency of the European Union from under 40 % in 1995 to more than 52 % by 2010 and to more than two thirds by 2020, due to the projected, relative rapid increase in natural gas consumption.

The risks associated with future developments in gas in Europe are not of the same nature as those related to oil development. First, trading in gas implies that a fixed capital intensive link has become established between the purchaser and the seller, which creates a relationship based on a common interest in making their investment profitable. Second, Europe's dependence on natural gas is evident in relation to three oil-exporting countries: Algeria, Norway, and Russia; it is therefore not in a largely competitive and world-wide market. Third the European regional market is a market of long-term regional contracts that concern, as of now, just a few sellers including the national companies of these three countries. The liberalisation of the European national markets will create a more competitive situation at the level of the regional oligopoly, which must be taken into account when analysing the risks.

There is a classic distinction between the short-term risk, which is essentially a physical risk of supply interruption, and the long-term risk, which is the risk that supply will not be compatible with demand.

THE SHORT-TERM RISK

The short-term risk is linked to the risk of accidents or weather phenomena. It can also be a political risk linked to the possibility of troubles in the exporting country or in transit regions, or more rarely a deliberate choice by the government of the exporting country. The current political instability in Russia and Algeria has therefore led to the consideration that an increase in purchases by the European Union from these two countries could increase the short-term risk considerably. This should be considered seriously given that Russia, which currently sells 70 billion cubic metres to the European Union, would have the capacity to sell up to 100-150 billion cubic metres in 2010, that is, 35 % of European needs and 60 % of imports. In the same way, purchases from Algeria, which currently total around 45 billion cubic metres, could reach 70 billion cubic metres in 2010. However, the uncertainty over Algeria and Russia must be kept in its proper place.

The risk of interruptions to supply, which has been studied in depth by the European Commission and the International Energy Agency[49], depends on the size and duration of the interruptions. A long-term interruption to supply, which carries the highest level of risk, could only result from longer-lasting political and military disorder, which is unlikely even in the event of a partial break-up of the states. Whatever the political regime, and its level of instability, may be, the need for currency and the requirement to attract and keep partners in trade is very likely to prevent any discretionary long-term breaks in supply – except in case of irrational behaviour of the leading staff.

There are several answers to these risks. Some have already been mostly put into practice, because of the maturity of the European networks. The importing states (France, Germany, Italy, etc) already have **storage capacities** that cover 20-40 % of their annual consumption. The inter-connections between the transport systems are being progressively reinforced, thus allowing each one to benefit from the back-up possibilities offered by the other systems with different supplies. In addition, the risk of interruption by transit countries can be limited by diversifying routes. In this way, Russia has recently made progress by building the new Belarus-Poland-Germany pipeline in order to reduce the exclusive dependency of its exports on the Ukrainian transit lines.

Diversification of supply sources, which is another means of risk reduction, has been operated more or less voluntarily by the importing companies (four supply sources in France, three in Italy and Germany, two in Spain and Belgium). In the future, this diversification could partly be carried out through the strategy of the oil companies that are exploring new opportunities around Europe by becoming more and more involved in the gas market. In this way, imports of liquid natural gas will, within the next few years, begin to be made from Egypt, Nigeria and Trinidad, and new Middle East exporters should soon follow suit. Finally, in the liberalised environment of the future, the development of short-term markets and transit facilities will open up new response opportunities allowing a replacement

[49] European Commission. *Gas supply and prospects in the European Community*, Brussels, Com(95) 478; and IEA, *Natural Gas Security Study*, Paris, OECD, 1995.

for an interrupted supply to be found quickly; the main restriction will be the availability of means of transport. In addition, the development of storage capacities by the distributors near the new consumers, in order to manage their "back-up" offer, will increase the overall flexibility of the system.

The big consumers (power generators, heat user, etc.) would have also incentives to avoid unique dependence from gas supply with the choice of multi-fuel equipment, in the face of the price volatility of short term markets.

The risk of short-term dependence can therefore be controlled in mature, properly inter-connected networks that are subject to market rules. It should not, however, be forgotten that the liberalisation of energy markets incurs a risk of interruption from its own construction because of the increased level of interdependence between the deregulated gas and electricity markets and because of the concomitance of peak demand on both markets. In the long term, gas from coal (e. g. hydrogen) is an option including removal and sequestration of CO_2 in aquifers or exploited gas and oil fields by contribute to further diversification of supply sources (see Chapter 7.1).

THE RISK OF CONTROL OF THE EUROPEAN MARKET

The associated risk of one of the exporters (particularly Russia) assuming a dominant role on the gas market of the European Union may seem important. Having joint ventures in several countries, and being in alliances with European companies enjoying a considerable presence in the gas industry, such as Shell, ENI or Ruhrgas, the Russian exporter Gazprom could rely on the liberalisation of national markets to gain as high a share in the market as possible by a low price strategy and thereafter to increase the prices. In truth, however, the existence of organised markets will limit the opportunity to influence market prices. In addition, the European companies whose only objective in forming an alliance with Gazprom is a selective one are very much encouraged to play the competition game throughout the value chain, given the progressive vertical de-integration of the gas sector under the effect of the Gas Directive.

As for the risk of formation of agreements between the small number of sellers outside the European Union, it will be minimal because of the difference of interests between exporting states or between companies concerned, and because of the competition rules within the Union. In any case, the setting of gas price levels will always be limited by the price levels of competing energy sources.

THE LONG-TERM SECURITY RISK

The long-term risk corresponds to a situation in which demand for gas could not be satisfied for political or economic reasons: contracting of insufficient quantities through underestimating the growth in demand, and lack of economic incentive to develop importation projects because price levels are too low. In European countries, this long-term risk has long since been considered to be sufficiently high to justify maintaining the monopoly position held by the gas pipeline companies. This position allows them to make long-term contracts by engaging in capital-intensive imports and to maintain a balanced division between various sources of imports and country-risks. In this way, it allows a reduction in the risk in long-term contracts outside OECD commercial and legal frameworks where shared rules and norms are weak.

Given the projected growth in demand, supplementary gas will have to be sourced from places increasingly far away from continental European countries. By increasing risks, the liberalisation of gas markets will question, in part, the possibility to develop new projects. Financial risks would have to be mitigated by sharing them mutually within consortia of buyers and by the expected continuation of take-or-pay contracts with the help of short-term markets for spreading the risk that can support the investment. Experience will demonstrate if confidence in market mechanisms is justified. Recent cases in which capital-intensive projects were completed without the protection of long-term contracts (Wingas in Germany, Interconnector), suggest that many import projects might see the light of day. No doubt less ambitious and more easily adaptable projects will be preferred to the major projects already carried out.

To sum up, given the importance of the future European dependence on natural gas, international gas security concerns are a serious issue in their own right. They are worthy of vigilance from the European Union and from the Member States. However, even though the market tends to be short-sighted by nature, its operation allows security to be maintained by improving levels of inter-dependence and short-term flexibility, and by opening new opportunities for imports. The Member States and the Community should oversee market developments to alert the operators in the event that purchases from a country outside the Union become too concentrated.

6.3 COMPETITIVE ENERGY PRICES

The two EU Directives on electricity and gas liberalisation, 96/92 and 98/30 will have a profound impact on the company structure and the entrepreneurial tradition of these two energy markets in Europe, which are in the middle of a transition period in most member countries. Traditional expectations, decision making and old paradigms are struggling with new concepts, new entrepreneurial understanding and new philosophies. Investors, experts and political institutions are expecting major changes due to the liberalisation of the electricity and gas markets and due to the internal market and the fall of the Iron Curtain. But one has to admit that the impacts of these initiated dynamics on the energy system and related policy areas are unknown and not without risks. The following two sub-chapters describe the current situation of transition and uncertainty.

In 1988, the Commission published the White Paper entitled "The Internal Energy Market" with the aim of establishing a single market by 1992. Clearly, the realisation of a single market for energy presented more serious obstacles than for other commodities. From that point on, liberalisation of gas and electricity markets has occupied an important place on the Commission agenda. The promotion of Trans-European Networks (TENs), e. g. for gas pipelines, as put forward in the White Paper "Growth, Competitiveness and Employment", added momentum to the political drive for liberalisation of EU energy markets. The first relevant Directive was passed in 1990 and was related to price transparency for industrial gas prices. Member States are required to inform the Commission about gas prices under clearly defined categories. The price transparency Directive and the gas and electricity transit Directive of 1991 can be regarded as the first, preliminary steps to the opening-up of the European energy markets to competition.

6.3.1 IMPACTS OF MARKET LIBERALISATION ON THE EU ELECTRICITY INDUSTRY [50]

The main objective of the European Directive 96/92, concerning common rules for the internal market in electricity, is to increase economic efficiency at the level of the whole EU-15 electricity sector. This objective is to be reached by creating or stimulating competition within and between the national electricity sectors. The increased competition is also expected to reduce electricity prices, to the main benefit of both industrial consumers (thus improving their competitiveness) and households. Furthermore, according to the Directive, the increased efficiency level is to be reached whilst keeping a satisfactory level of supply security and avoiding conflicts with the goals of environmental policies. The role of the latter condition is emphasized after the European Commission agreed to the Kyoto Protocol (December 1997). According to this Protocol, the greenhouse emission reduction targets for the EU and its Member States will also affect the energy-related greenhouse gas emissions (see Chapter 4.2).

Taking this background into account, an analysis of the effects of the electricity market liberalisation has to consider at least four different issues:

- the different institutional paths of implementing the Directive at the Member State level;
- the possible consequences of these differing paths on the market configuration of the electricity supply industry;
- the present and foreseeable reaction of the power firms to the liberalisation process;
- the coherence of the above mentioned issues with the dynamics required by the targets of the Kyoto Protocol.

THE IMPLEMENTATION OF THE DIRECTIVE

The implementation of the Directive was required by February 1999. Three countries were allowed a delay: one year for Belgium and Ireland, two years for Greece. An analysis of the provisions or legislative projects shows that all the EU-15 countries are currently liberalising their electricity sector or at least intend to liberalise the sector within the next years, in accordance with the requirements of the EU Directive.

Four countries (Denmark, Germany, the Netherlands, Spain) are fully liberalising their electricity markets, opening a much higher percentage of the market than required by the Directive. Eight countries liberalised or intend to liberalise their domestic markets by allowing a lower percentage of the market opening, which is closer to the threshold required by the Directive (of course, this distinction does not involve any value judgement about the behaviour of the countries). Clearly the UK, Sweden and Finland have already finished (or are finishing) the process of deregulating their power sectors, which was started independently of the Directive.

Not surprisingly the four countries plus Sweden, the UK and Finland (the 'liberalised countries' – LCs) are the ones where at the beginning of the 90's the electricity industry structure, both generation and distribution, was oligopolistic, either competitive or collusive (but legalised) through captive markets. The second group of eight countries, the 'slowly liberalising countries' (SLCs: France, Italy, Portugal, Greece, Austria, Belgium, Ireland, Luxembourg) is characterised by well-established, vertically integrated national electricity monopolies, de jure or de facto (Austria is the exception). Furthermore, the clauses of reciprocity are presently explicitly adopted by around half of the EU-15 countries, including three of the seven LCs. Then the role of potential competition from abroad might be less significant than expected, at least in the next years.

The analysis of the past experience of the countries, which have already liberalised their electricity market before the signing of the European Electricity Directive shows that electricity prices fall after liberalisation. Theoretically, quality of services for consumers should also improve, as non-price competition is a competition tool in oligopolistic markets. Furthermore, the overall efficiency of the energy

[50] This section is based on the study "Electricity Industry and Market Dynamics", European Commission – Directorate General for Energy, which was carried out in the context of the Shared Analysis Project (Volume 8).

system should increase, as competition pushes power generators to reduce production costs through the introduction of more advanced technologies.

However, some of the above mentioned benefits could be less than expected. Experience shows that the following development occurred:

- The starting conditions for promoting competition exert a strong influence on the liberalisation process. In England and Wales the existence of only two competitors at the generation side caused increasing rather than decreasing prices at the beginning of the 1990's.
- Electricity prices dropped in the UK (apart from Northern Ireland) after 1993. This is partly due to the electricity cost decrease, coming from both a better bargaining position vis-à-vis the domestic coal suppliers and the parallel ongoing liberalisation of the domestic natural gas market, which reduced gas prices. The latter issue underlines how important it is to analyse the effects of the liberalisation of the electricity market together with the expected evolution on the fuel input side, first of all natural gas. More generally, the reduction of prices in the UK experience might have been influenced by several factors (fall in international fuel prices, removal of historic cross-subsidies to coal and nuclear, autonomous technical change and so on): the weight of the spurred competition within the electricity supply industry is still unclear.
- The electricity price decrease for industry was stronger than for households.
- There is no clear evidence of an increasing quality of services (nor, indeed, of a falling off).

POSSIBLE CONSEQUENCES ON THE ELECTRICITY SUPPLY INDUSTRY

The differences between the "Liberalised Countries" and the "Slowly Liberalising Countries" together with the clauses of reciprocity, restrict the possibility for electricity foreign trade to trigger competition in the domestic markets. As the present Directive allows the national clauses of reciprocity over a seven year period, the evolution towards competition at the European level is gradual: however the start is important.

In the SLCs the former monopolistic power producers will become oligopolists with a dominant domestic market position. In a stagnating market and if the national monopolistic utility has already built up meaningful entry barriers or if the national government does not impose important reductions of its market share, the new entrants are likely to achieve only a marginal part of the power market. The dominant utility has relatively little concern about a decline of its domestic market share. Therefore it engages itself more actively compared to a pure oligopoly context in other markets, e. g. by investing in product diversification and acquiring shares of electricity companies abroad. In fact, the growth rates of the domestic electricity demand, the rate of replacement of obsolete plants, the incidence of peak load with respect to base load and the size of the potential market for district heating are currently key factors for the scope of entry of new power producers. If these are insufficient, it is possible that the electricity prices will drop sharply at the beginning of the liberalisation period, and stagnate after, as a witness to an obtained new low level of competition. Obviously the role of the regulator as a watchdog is very important in this period.

Since in the group of Slowly Liberalising Countries the share of 'eligible consumers' (consumers with free choice of supply) is low, the result will be that in the next years only large consumers in industry and the tertiary sector will be able to reap the advantages of liberalisation.

Of course, the expected effects of the electricity liberalisation are more positive in the group of Liberalised Countries. Oligopolies with relatively low entry barriers should become the most likely configuration of the domestic market. However, experience shows that there might be fewer new entrants than expected, while a large wave of mergers and acquisitions directed to existing small electricity producers, like municipalities, is already occurring: the level of concentration should increase. The new electricity generation, built up by new entrants, like Independent Power Producers (IPPs), or existing producers, should be based on small and medium power plants, as the early turbulence should induce risk-adverse behaviour, at least in the private investors.

STRATEGIES OF POWER COMPANIES

Until now, the response of the EU electricity companies to the electricity deregulation seems to lead primarily to mergers and acquisitions. Of course this does not exclude internal restructuring of these companies.

Cutting personnel within the electricity firms has been one of the immediate outcomes of the electricity reforms in England and Wales. The number of employees of the generation and transmission companies fell by 45 % between 1988/89 and 1997/98 (figures include Scotland as well), while in the regional distribution companies employment decreased by 30 % between 1988/89 and 1995/96. The new opportunities for many firms to jointly distribute electricity, gas and other services should enhance this effect.

In an oligopoly context, providing energy services should be part of the competition instruments (even if the UK experience suggests scepticism about the likely development of these services, the experience in other countries such as Sweden is more encouraging). A new 'customer approach' seems to become a common phenomenon among the power utilities in the EU. The main objective of this 'new customer approach' is to gain larger market shares through various marketing tools, such as proposing different types of electricity tariffs, providing consulting services, selling both electricity and gas (if possible) to be paid with the same bill. However, some words of caution are necessary. First, it is likely that this 'new customer approach' would be more directed to those electricity customers that can easily shift towards alternative electricity suppliers and not the households. Second, this kind of improvement in the quality of service is likely to occur more often where competition is more mature, i. e. in the group of Liberalised Countries' (however these services could be provided by specialised firms rather than by utilities). Third, there is the question of how this 'near to the customer' approach is financed. It seems that part of the former R&D expenditures are devoted to it.

As far as the effects of the liberalisation on the firms' R&D expenditures are concerned, two opposing opinions are often heard. First it is stressed that more competition leads to a higher R&D expenditure, because it will reduce the cost of generating (or distributing) electricity. Second, it is assumed that the bulk of the electricity sector research was carried out by the power equipment producers: the research within the utilities was only carried out as part of the intensive co-operation with the power equipment producers, as it was for nuclear and other large scale technologies. However, as the new competition context pushes firms to break off old, close relationships with the power equipment suppliers, it is generally assumed that the R&D efforts by the utilities become a cost factor, which they prefer to minimise. Furthermore, it seems that the attention of R&D in power companies is shifted to the improvement of technologies, which are directly improving services to the consumers.

As a consequence, the R&D expenditure could become a public responsibility, which has to be supported by society or by the whole power industry, for instance by adding a taxing fee upon the tariff for access to the grid. A third possible solution is the increase of R&D carried on directly by the power equipment industry. The net result of this shift of R&D expenditure placement is unclear.

So far the more obvious reactions of the electricity firms focus towards external growth of electricity sales through diversification and foreign acquisitions. It is easy to note that from a sample of 69 EU-15 utilities in 1997, describing their financial figures, 57 (82 %) are diversified. Major attention was paid to the internationalisation effort of the EU power sector. From 1996 to 1998, EU-15 electricity companies spent an average value of € 565 millions per transaction regarding partial or complete acquisitions of the shares of the firms, located outside the domestic country of the buying firm. The major destination of these investments (27 % in 1996 and around 38 % in 1997 and 1998) is the Western European market. Then a specific strategy of many European firms is the attempt to partially or totally control other European power utilities, thereby causing a concentration of the electricity industry within the EU.

CONSEQUENCES FOR KYOTO COMMITMENTS

Electricity liberalisation might have several impacts that are important for EU and national Kyoto Commitments:

- impact on fuel substitution (mainly substitution coal/gas);
- higher electricity demand as a consequence of lower electricity prices and lower electricity efficiency efforts at both supply and demand side;
- impact on renewables and on CHP.

IMPACT ON FUEL SUBSTITUTION

At a first look, the effects of both the liberalisation and the reaction of the firms to the EU and national Kyoto commitments with respect to fuel substitution seem easy to depict. The new market conditions oblige the utilities to pay more attention to the cost of production and to the risk of investment in new capacity. An analysis of the kWh costs of different electricity generating technologies (see Table 6-1) shows that electricity produced through gas turbines in combined

TABLE 6-1: COMPARISON OF COST RANGES FOR ELECTRICITY GENERATION BY NEW PLANTS, 1999 (IN €/MWh)

Source: Shared Analysis Volume 8 Size (MWh)	CCGT (gas)			Coal			Ratio CCGT/coal		
	low	medium	high	low	medium	high	low	medium	high
150	31.7	41.8	59.7	37.0	47.8	74.2	0.9	0.87	0.80
300	28.6	37.8	53.2	31.8	41.1	63.2	0.9	0.92	0.84
600	25.6	33.9	46.8	28.8	37.2	56.9	0.89	0.91	0.82

Source: DTI Size (MWh)	CCGT (gas)			Coal			Ratio CCGT/coal		
	low	medium	high	low	medium	high	low	medium	high
no distinction	26.9	29.8	32.8	38.8	44.8	48.5	0.69	0.66	0.68

cycles (CCGT) is less expensive than electricity produced through coal plants. The difference is around 10-15 % or more, depending on the assumptions[51].

The competitiveness of CCGTs with respect to coal plants is relevant to all capacities of individual plants for the power market. It is partly explained by the recent reduction of gas prices, and partially by the fact that new entrants are mainly investing in small or medium size plants. This is true for both Liberalised Countries and the Slowly Liberalising Countries. This means that the rates of liberalisation of the power markets do not affect this decision. It leads to the use of one fuel, namely natural gas, an increasing share of which is imported from outside the EU. With respect to the security of the EU supply, this trend should be monitored carefully.

The fact that the market decisions will lead to investment in less polluting gas technologies (rather than more polluting coal) in a competitive market is sheer luck. At a given size plant, the power generators may become indifferent towards the two types of technologies, if the price of natural gas increases 15 % with respect to the previously assumed price scenario for gas, other things being equal. (The DTI figures are more stable with respect to relative changes in gas and coal prices, given the fact that coal-fired plants are 31-34 % more costly). However, the evaluations carried out also take into account other issues, such as capital costs. So this development is also explained by the preference of the firms for facing variable costs rather than fixed costs.

ELECTRICITY PRICES AND ELECTRICITY DEMAND

The likely fall of electricity prices, because of the liberalisation of electricity markets, should stimulate the demand for electricity. This might increase for two reasons: either because other fuels could be substituted, or because, due to lower prices, energy efficiency for a given energy use could worsen. However, it is difficult to foresee how large these effects could be. First, it also depends largely on the price and availability of competing fuels in the final energy demand, mainly natural gas. Second, liberalisation could bring an end to the favourable contracts made by the public utilities to some kind of consumers, above all in the Slowly Liberalising Countries. Up to now they have benefitted from cheaper tariffs. If these contracts are substituted by others on the basis of higher electricity prices, the result could be a reduction of electricity consumption (or the search for a higher level of efficiency) in these consumer groups. This would compensate to some extent the increase in electricity demand in other consumer groups that benefit from lower prices. Third, experience shows that some of the governments of the countries which liberalised their electricity markets took advantage of the drop of pre-tax electricity prices to increase taxes, partially taking away from the decrease so that the impact on the consumers' behaviour was slightly softened. In fact, most of the European Member States (such as Germany, Italy and France) have recently introduced some form of energy/CO_2 tax, if they have not done so already (such as Denmark and Finland). Others, such as the UK, have a concrete proposal in the legislative process. Obviously, this gives a room for manoeuvre to the governments to reduce the undesired price effects of the liberalisation and to reduce charges on labour or to finance public expenditure aimed at increasing energy (and environmental) efficiency. In particular, enhanced R&D efforts are necessary to lower the costs of energy efficiency technologies further in order to maintain competitiveness in a world of lower electricity prices. Further, when competition will be shifted from lowering price levels to the quality of services provided, the role of energy efficiency might increase again in the portfolio of the companies in the form of energy services.

IMPACT ON RENEWABLES AND ON CHP

Of course, the role of the renewables in power production is important. In a liberalised context an increasing demand for renewables seems unlikely, as electricity generators have to pay more attention to the costs of generating electricity. According to our estimates, the medium and long-term production costs of the less expensive renewables, like mini-hydro or wind energy, are still around twice the kWh cost of electricity produced by CCGTs.

Therefore, the development of renewables is likely to be somewhat hampered by the liberalisation of the electricity market. In order to promote them, the portfolio approach (in which a certain market share is reserved for renewables) seems to be more coherent with the liberalisation. It introduces competition for the suppliers of electricity generated by renewables on the price basis, so stimulating efficiency. It also generates a market where they can evolve until full competition with fossil fuels. On the other hand, the REFIT model (characterised by a fixed subsidy for electricity fed back to the electricity grid; presently adopted in some countries like Germany, Spain and previously Denmark) provides for a larger initial market growth

[50] Table 6-1 shows evaluations of costs per kWh made through two different methodologies. The IEFE evaluation uses eight parameters which have been combined in order to build up three different scenarios (see Volume 8 of the Shared Analysis Project): the middle figures represents the most accepted estimate. Among the main assumptions, the range of interest rates is 8-10-12 %. For CCGTs the assumed natural gas prices are 0.103-0.134-0.165 ¤/m3. For coal plants the assumed steam coal prices are 37.2-46.5-58.1 ¤/t. Efficiency in coal plants is 42 % while for CCGTs it is a function of the size of the plants according to the results of a regression analysis on data from the US market. On the contrary, the DTI figures represent the responses made by individuals and organisations during a process of consultation decided by the UK Government in order to produce the Review of Energy Sources for Power Generation (presented to the Parliament in October 1998). In the cost range the middle figure represents the figure most quoted by the respondents. For this approach the assumptions are not specified.

for this kind of electricity. It grants an outlet to each of its suppliers. Critics argue that efficiency is not stimulated in markets such as this, although the evidence of the German and Danish markets in the field of wind energy does not support this. Rapid market growth has pushed generation prices down considerably, while pool markets, such as the one in the UK, are hampered in recent times by very small growth. Nevertheless, it seems necessary to gradually increase the competitive pressure on markets based on REFIT models and having achieved a certain size, in order to insure their future growth and to avoid continuous subsidising of the market. In conclusion, it appears that the two approaches, the portfolio and the REFIT approach, refer to two different objectives (to stimulate efficiency in supplying electricity generated by renewables or to increase the amount of the electricity produced by them in absolute terms). It seems useful (and more than obvious) to look for a "middle way". The current efforts to establish a frame directive for renewables that would allow each country to set up an approach that best fits the needs of its national market, are a step in this direction. For renewables that are still some way from being competitive, such as photovoltaics, larger subsidy programmes at the national level and perhaps EU level, will strongly influence their future development. Such programmes could compensate, at least for some time, for the more difficult position of renewables in liberalised markets.

On the contrary, a larger diffusion of CHP is likely because of electricity liberalisation (see Volume 5 of the Shared Analysis Project). This holds also for the south of Europe (with respect to industrial co-generation). However, it is likely that public support is still needed for medium and small firms, not only through incentives, but also through adequate taxing policies. It is possible, indeed, that the imposition of carbon (or environment) taxes increases the avoided cost for the buyers of heat and electricity produced by CHP, so increasing the price they can pay (and then the revenue on the CHP side).

CONCLUSIONS

In summary, some consequences of the electricity liberalisation in the EU area seem positive, but to a less extent than expected. Some other effects seem ambiguous.

The positive effects are the following:

- Competition will increase, as existing monopolies and captive markets are eroded. However, the role of the potential competition from abroad is hampered by the different degrees of liberalisation among countries and by the common recourse to the clauses of reciprocity (plus the lack of interconnection capacity). At the EU-level concentration may increase, due to the boost of foreign acquisitions. Such a behaviour has positive effects to the extent that the acquired firms are expected to increase their overall efficiency, but it can partially induce the acquiring firms to invest less in their own energy plants. Furthermore, it increases the short-term orientation of the management of the utilities that could be acquired.
- Electricity prices will fall with differences, however, between countries and among kinds of consumers.
- Electricity services (useful to increase efficiency at the consumer level) should spontaneously develop, however, with a less than expected spread and with less than expected benefits for the small consumers.
- Leaving aside the effects of the growth of the capacity, the level of emissions should decrease. The liberalisation of the electricity market spurs a higher efficiency in utilising fuels for generating electricity. However, it depends on the evolution of the gas/coal relative prices, and the new context is not spontaneously prone to develop the role of renewables and of electricity efficiency on the demand side, while the role of combined heat and power generation could be strengthened.

The ambiguous effects are the following:

- The effects on R&D efforts. On the one hand, they could increase as a tool to reduce costs (as a process innovation), on the other hand, they are expected to decline, because of the tendency of the utilities to save on costs and of the changed relationships with power plant producers.
- The 'Dash for gas' should go on, as sound incentives are provided by electricity liberalisation to increase the utilisation of this less polluting fuel. However, it is questionable whether this tendency is coherent with the supply security target (see the UK case) and will of course depend on the expected evolution of the gas prices relative to the coal prices.

6.3.2 IMPACTS OF MARKET LIBERALISATION ON THE EU GAS INDUSTRY [52]

Until 1990, the issue of gas market liberalisation did not feature significantly on the policy agenda of the European Commission. Its concerns were focused primarily on issues of security of supply. The gas industry was allowed to operate according to the individual wishes of each Member State. Perhaps because of the strategic importance of energy supply, no serious attempts were made to establish a free market in either gas or electricity, in spite of the EU objective of the establishment of a free market for other goods and services. The Transit Directive, which was passed in 1991, allows nominated gas companies the right to use the pipelines of other nominated gas companies, provided that gas crosses an internal

[52] This section is based on the study "Impacts of Market Liberalisation on the EU Gas Industry", European Commission – Directorate General for Energy, which was carried out in the context of the Shared Analysis Project (Volume 9).

European border. Later on, this was undoubtedly an incentive to the UK-Interconnector project. The discussion on further liberalisation of the gas markets continued and, after several years of debate, a political agreement on a new EU Gas Directive was finally reached in December 1997. After being adopted by the Energy Council with a unanimous common position, the EU Gas Directive was finally approved by the European Parliament in June 1998 and entered into force in August 1998.

GAS DEMAND TRENDS

After a period of moderate growth in the 1980's the demand for natural gas within the European Union is projected to rise substantially over the coming decades. Natural gas demand is said to be 'booming' all over Europe. The all-around optimism is fed by several economic and political developments. The main factors that have been restraining the use of natural gas are either no longer present or will be lifted within the foreseeable future.

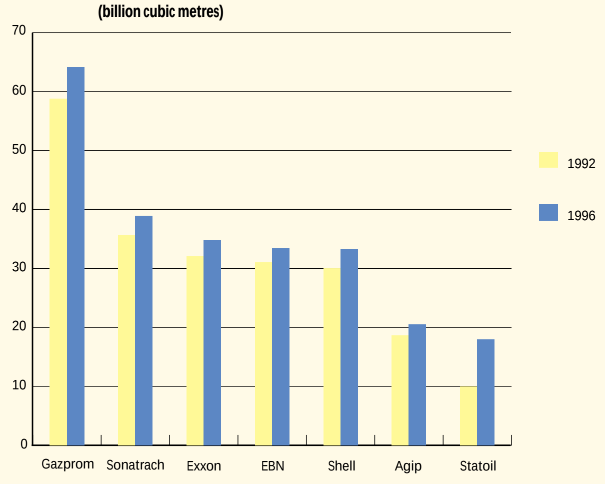
- It has become clear that natural gas resources, both on a European and on a world scale, are bigger than foreseen 20 years ago. In 1990 the European Union removed its earlier ban on burning natural gas to generate electricity. The fall of the Iron Curtain played a major role in this decision.
- Since 1985, natural gas prices have decreased. The fall in oil prices combined with the depreciation of the US$ has resulted in considerably lower end-user prices within all European countries.
- The low sulphur and carbon content of natural gas compared to other fossil fuels makes it an attractive fuel from an environmental perspective.
- The availability of highly efficient Combined-Cycle Gas Turbines (CCGT) and the liberalisation of the UK electricity market has stimulated the use of gas in the power sector. It seems likely that the ongoing liberalisation of the continental European electricity market will have a similar effect on the demand for CCGT and, hence, for natural gas (see preceding Chapter 6.3.1).

GAS SUPPLY

The ownership structure on the supply side of the European gas market can be characterised as an extremely complex oligopoly. In order to limit market risk, the search for and exploration of (new) gas fields is often executed in joint ventures with other gas companies. Although the management of a single gas field usually rests with one company, all partners in the joint venture are entitled to a part of the profit (loss) of the field. Additionally, many upstream companies have extensive interests in the downstream part of the market. The prime example is Shell, which holds an interest in at least 15 different transmission companies. The ownership structure of individual transmission companies can be very complex as well. For example, a consortium of four so-called 'pools' owns Germany's Ruhrgas. Behind each of these pools stands a consortium of upstream gas companies (exploration and production of natural gas), some of which have shares in more than one pool. In fact the upstream market is the most competitive part of the natural gas chain. About twenty major companies are involved in the exploration and production of natural gas for supply to the seven major consumer countries in the EU (Austria, Belgium, France, Germany, Italy, the Netherlands, and UK), see Figure 6-2 for the supplies of the major production companies.

In 1996, the biggest of those companies, Russia's Gazprom, had a market share of about 20 % of the West European market. In that same year, the top five companies Gazprom, Sonatrach, Exxon, Shell and EBN, supplied just over 60 % of this market. Although this points to a relatively competitive market, it must be noted that these figures are European averages. Taking a look at each of the countries separately we obtain a somewhat different picture. In some, one company or a consortium of companies holds a dominant market share. In the Netherlands, a consortium of Shell, Exxon and EBN supplies virtually the entire market. In Spain, Algerian Sonatrach supplies over half of the market. Moreover, many of the companies listed in Figure 6-2 do not compete with each other because of geographically separated markets. Seven out of the twenty companies listed are active only, or mainly, in the United Kingdom, whereas the two largest companies, Gazprom and Sonatrach, only compete with each other in Italy. The changes in market volume and share are illustrating the growing importance of non-EU producers.

Figure 6-2: Gas supplies to seven main EU consumer countries
(billion cubic metres)



TRANSMISSION OF GAS

The downstream part of the EU gas market (transmission and distribution) shows a completely different picture than the upstream part. In nearly every country, the transmission market is almost completely dominated by one company at present supplying virtually the entire market. The only exception is the German market where the share of the largest transmission company, Ruhrgas, is limited to 69 per cent.

The analysis has shown a reasonably competitive upstream market together with a nearly monopolistic downstream market. Hence, the conclusion seems warranted that any problems with market power will be confined to the downstream market only. However, the situation in the market for natural gas is more complicated than this simple analysis suggests. First, a number of the companies active in production and import of natural gas are working closely together. The main motive is that it allows cost savings and reduces risk. Horizontal integration also reduces the number of competitors in the market and, hence, reduces competition. Second, many of the upstream companies have interests in downstream companies. Although this vertical integration reduces risk and increases value added for a company, it also allows the upstream firm to 'shift' the battlefield to the less competitive downstream market and, hence, to evade competition. Furthermore, the fall in natural gas prices since the mid-eighties has been fully absorbed by the producers, while at the same time, the profits of the transmission companies have remained almost unaffected. Since the new companies Gazprom, Sonatrach and GFU (a Norwegian Joint Gas Negotiations Committee composed of Statoil, Norsk Hydro and Saga) have virtually no downstream interests, they have been hit much harder by the fall in natural gas prices than Shell, Exxon, EBN and ENI.

Construction of the UK-Interconnector with the Continent, with an initial throughput capacity of 20 billion cubic metres per year[53], was started in 1996 and completed in 1998. The first right to use the capacity was vested with the shareholders in relation to their participation. The shareholder group comprised of British Gas (35 %; British Petroleum, Elf, Gazprom and Conoco 10 % each; and Amerada Hess, Distrigaz, National Power, SNAM and Ruhrgas, with 5 % each). The Norwegian capacity to supply will experience a similarly impressive upward jump (throughput will increase from 44 billion cubic metres at present to about 77 billion cubic metres at the end of 1999), allowing the Norwegian producers to start competing with each other and with other supply sources. Furthermore, part of the UK-Interconnector deliveries are destined for Wingas, in Germany or elsewhere, thus diversifying this company's sources and improving the supply security of its deliveries. This should add to Wingas' competitive edge when it seeks to take additional market share from Ruhrgas and others.

In summary, we can conclude that the following factors are driving the EU gas markets towards more competition:

- growing gas share in energy demand and diversification of gas supplies and imports,
- emergence of large non-EU suppliers and overcapacity in gas supplies to the EU consumer markets,
- changing role of governments in the economy, and consequently their intervention in the gas markets,
- opening up of the German gas market by Wingas and Gazprom,
- the liberalisation of the UK gas market,
- construction of the Interconnector between UK and Belgium,
- implementation of the EU Gas Directive to accomplish an internal market for gas.

The **EU Gas Directive** aims to create a fully competitive market in natural gas through common rules for transmission, distribution, supply and storage. Central to this aim is the requirement to open up the transmission network and storage facilities to third-party access, so that eligible customers can buy gas directly from producers if they so wish. The Directive establishes minimum degrees of market opening. The initial market opening covers all power generators and all other consumers of more than 25 million cubic metres/year and a minimum of 20 % of each national market. The market opening rises to 15 million cubic metres/year and 28 % of the market after five years of the Directive taking effect in 2000; and to 5 million cubic metres/year and 33 % after ten years. The Directive also allows new entrants to build pipelines.

However, with a view on the future developments of the EU gas markets the implementation of the Directive raises several questions:

- How will the different Member States implement the Gas Directive and at what pace? Given the large differences between Member States with respect to available domestic gas production, dependency on imports and other economic and political features, differences in implementation can be expected. Will the implementation of the Directive indeed lead to an internal market for gas in the EU or in other words, will the Directive be implemented by the Member States beyond its minimal requirements?
- What are the responses of the different gas companies to the Directive and its implementation by the Member States? For example, can we expect a defensive or offensive response of the companies? How will the Member States and how will the Commission react to mergers or vertical integration of companies and to mergers or vertical integration of companies and to requests for derogations or/and violations of the rules by the Member States?

[53] The reverse capacity of the UK-Interconnector, i. e. gas flow from the continent to the UK, is 8.5 billion cubic metres per year

Clearly the outcome of the progressive liberalisation of the EU gas market and particularly the role of the Directive and the responses of the large companies in this process are, as yet, very uncertain.

Two scenarios of the impacts of the liberalisation of European gas

In order to cope with the large uncertainties of this process of the enforced liberalisation, the most relevant institutional driving factors influencing the emergence of more competition in EU gas markets are put into a scenario framework. This enables a more systematic analysis and assessment of the effects of this liberalisation process for the next decade. Two 'extreme' scenarios for the possible development of the relevant institutional framework (implementation of the Directive) and other key factors influencing (limiting and/or promoting) the development of more competition in the EU gas market are defined (see Box 6-1).

Box 6-1: Assumptions of two implementation scenarios of the EU Gas Directive

The key assumptions for both extreme implementation scenarios are as follows:

FULL COMPETITION (FC) SCENARIO

- Fierce upstream competition between large gas suppliers, such as Gaz de France, Gazprom, Shell, etc.
- Legal and effective unbundling of accounts and separation of management for trade, transmission, distribution etc. functions.
- Effective third party access (regulated Third Party Access will prevail) to the entire network, storage and distribution functions. Transparent access pricing is established.
- Pro-active operating regulators on the EU and Member State level not allowing any abuse of derogations, discriminatory access to the network, etc. in the Member States.
- Convergence of Member State regulations before 2010.
- Sufficient number and capacity of hubs, pipelines, storage at hubs/interconnector links (necessary for spot trading) facilities available in EU and optimally dispersed hubs, located across the EU.
- Spot trading will dominate the price setting for consumer markets.

SEMI-OPEN COMPETITION (SC) SCENARIO:

- Upstream suppliers form alliances and large vertical integrated companies are dominating the market (company response to implementation of the Directive).
- Administrative unbundling of trade, transmission etc. accounts of the vertical integrated companies.
- Discriminatory and limited access to network, storage, etc. (under a 'weak' implementation of a negotiated Third Party Access regime) still persisting.
- Ineffective and slowly reacting regulators with respect to settlements of tariff, access and other disputes.
- Large differences in deregulation between Member States due to differences in circumstances and different implementation of the Directive in the Member States.
- Insufficient number, quality and capacity of interconnectors/ hubs, pipelines, etc. for facilitating spot trade.
- Long run take-or-pay contracts still dominating and arbitrage and spot trade outside the UK is not yet emerging.

Finally for both 'institutional development' scenarios, we assume that full competition in the next ten years is only achievable in mature EU gas markets. Also, the oligopolistic characteristics of the EU gas market will continue in the next ten years in both scenarios. The following gas markets have been identified as mature: Austria, Belgium, France, Germany, Italy, Luxembourg, the Netherlands and the United Kingdom[54]. In addition, Ireland is considered to be close to maturity, and Denmark and Spain are expected to mature after a decade. Portugal, Sweden and Greece are new, emerging markets.

In summary the following impacts are envisaged.

For the Full Competition Scenario:

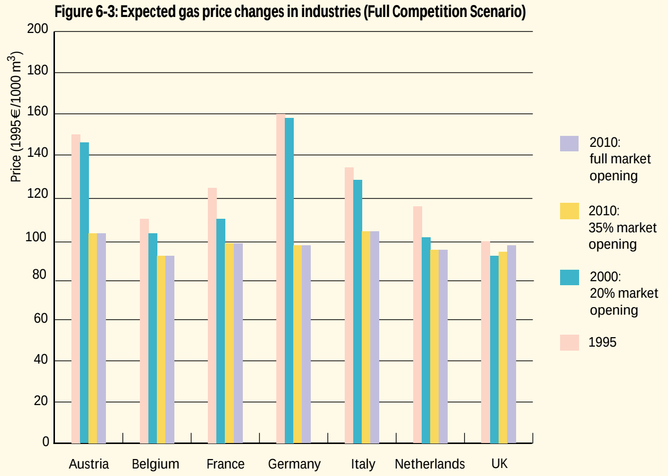
Achievement of an internal gas market in 2010 will have the following effects:

- Substantial lowering of natural gas prices in most of the mature EU countries except for the UK, see Figure 6-3 (industrial prices full competition).
- Convergence of gas prices across countries and between the different consumers due to arbitrage facilitated by emerging spot and future trading.
- Profits of gas companies will strongly erode.
- Transmission and production costs of gas are becoming relatively more important factors in the competition between supply companies. As one of the consequences there is a trend to more 'paper' trade and regionalisation of gas markets in Europe.

[54] For the classification, we have selected two main indicators, i.e. the share of natural gas in total primary energy requirements (TPER), and the number of years elapsed since the introduction of natural gas. The share of natural gas in TPER can give a rough indication of the number of buyers in a country and the importance of natural gas in a country's fuel mix compared to other fuels. The share of gas in TPER at the time of liberalisation was 22.9 per cent for the United Kingdom (in 1986) and 23.2 per cent for the United States (in 1985). This suggests that when the value of this indicator approaches 23 per cent, the natural gas market is mature enough for liberalisation, at least from a buyer's point of view. The number of years passed since the introduction of natural gas in a country gives an indication of the maturity of the gas infrastructure. In addition, it gives a rough indication of the investment costs to be recouped from the market, the expertise of the gas companies and policy makers.

• Substantial increase of gas consumption in most of the continental EU countries and particularly in the power sector.
• Growing number of multi-utilities and convergence of gas and electricity markets.

Figure 6-3: Expected gas price changes in industries (Full Competition Scenario)



Source: Shared Analysis Volume 9

Figure 6-3 clearly shows that after the industry customers are becoming eligible (market opening rising to 15 million cubic metres per year or 35 % in 2010) the gas prices for the industry are declining in most continental countries and particularly in Germany and Austria. However, in some member countries where gas prices for the industries are already relatively low (the Netherlands), or liberalised and thus low (UK), the gas price reductions are either very small or prices might even rise slightly due to the convergence of gas prices across the European gas market, which reflects the establishment of a single and full competition gas market in 2010.

For the Semi-open Competition Scenario:
Given the assumption of a minimum implementation of the Directive, of course the key objectives of the European Commission will not be obtained, because Member States will focus primarily on protecting their stake in national gas transmission and trade. Therefore we expect the following effects:
• Only small reductions in gas prices in the mature EU gas markets.
• Moderately increasing gas consumption in most of continental EU countries.
• Structural changes in the EU gas industry are limited.
• Unjustifiable price differences between countries and markets continue, particularly for small household consumers.
• Profits are constant or expected to increase slightly.
• Public support for the liberalisation process will decline.

CONCLUSIONS

Generally the analyses lead to the following **conclusions**:
• In order to realise full competition in the EU gas market (EU objective) it is necessary that all countries comply with the EU Gas Directive and beyond the minimal requirements. Thus preferably introduce regulated TPA and realise effective (preferably legal) unbundling of accounts of integrated gas companies engaged in both trade, production and transport of gas. If realised, substantial gas price reductions for all customers can be expected.
• Furthermore, to facilitate the emergence of gas-to-gas competition in the mature gas markets of the EU, it is also necessary that spot trading dominates price setting. This requires the establishment of a sufficient number of well-located hubs across the EU.
• In the downstream markets, one can expect that 'product differentiation' will increase. The exact form of this differentiation is still an open question. However, recent mergers of utilities indicate a trend towards the emergence of so-called multi-utilities, which are supplying a package consisting of electricity, gas, water and cable services to consumers.
• It is expected that the share of interruptible gas contracts, which today is relatively high in the UK (and was already high before liberalisation) might also increase in the Continental gas markets. This is because the former national transmission companies will also increase their flexibility of contracting sales to their customers in the next years. However, the picture will vary between Member States and type of customers.
• Trade via the pipeline network for transmission will relatively decline and be substituted by swap deals and other 'paper trade', thereby reducing the transmission costs for consumers. This is because these and other auxiliary (storage, quality, etc.) costs are becoming relatively more important in a fully competitive market.
• Consequently EU producers/suppliers such as Shell, Exxon, Agip/ENI, Winter-shall etc., which are closer to their customer markets than most of the non-EU producers, are the winners in the next decade of attaining full competition. Their production and sales will increase relatively more than the non-EU producers.
• It is expected that in the next few years the current gas oversupply situation will aggravate, because more pipeline capacity will become operational in the near future. However, after about 10 to 15 years, more expensive so-called non-EU 'long distance' gas supplies might be necessary to meet the growing EU gas demand. This might lead to small price rises at the EU border and perhaps also to small increases in end-user prices if the production costs of the EU producers also rise.
• The relative market positions of Russia and Norway will only gradually change in the long run, in favour of the lowest cost and most reliable producer of these two. Particularly in the EU, Russia's

Statoil, if the political situation in Eastern Europe does not change dramatically, and given their strong needs for hard currency export revenues. However, changing alliances and development of 'new alliances' between non-EU producers and EU trading companies (vertical integration to reach profitable consumer markets) might change this perspective substantially.

- It is generally expected that due to the reduction of gas prices for the majority of the gas consumers in the EU member states, the consumption and share of natural gas will rise substantially in the next decades. Furthermore, it is expected that the penetration of renewables and the implementation of energy conservation measures, and therefore emission reductions, are hampered by the lowering of the gas prices. However, the increased substitution of gas for coal and oil in some Member States will lower their CO_2 and other emissions substantially which will largely compensate for any decrease in efficiency levels due to lower gas prices.

Consequently, we can conclude that in order to bring about a fully liberalised gas market in the EU and thereby harvest all the expected benefits - in particular a more efficient gas industry with a fair degree of gas prices for all customers - the Commission and the Member States will have to secure the following conditions:

- Harmonisation of the implementation of the Gas Directive in all EU Member States beyond the bottom-line requirements.
- Effective and thus legal unbundling of accounts and separation of management of the different functions of the gas market such as trade and network transmission, storage, etc. Otherwise large vertically integrated and/or national gas companies will continue to dominate the gas pricing, trade etc. in the EU.
- Secure effective and non-discriminatory access to entire network and particularly its auxiliary functions by realising regulated TPA for the entire network.
- Secure non-discriminatory access pricing, i.e. enforcing publication of tariffs and commercial conditions in advance.
- Establish strong empowered regulation authorities at the EU and Member State level, which have to co-ordinate their pro-active regulatory work in order to be effective.
- Minimise derogations for mature markets, particularly for take-or-pay contracts, public services, obligations and capacity reasons.

Clearly the developments in the next transition period of the EU gas markets are of great importance to all those involved. Therefore a close monitoring of events and market developments by policy makers at both EU and Member State level is expected.

6.4 ENERGY AND ENVIRONMENTAL PROTECTION

In a recent study, Environment in the European Union at the turn of the Century (EEA, 1999), the European Environment Agency established a diagnosis and a short-term projection (until 2010) for the European environment. The study concluded that despite more than 25 years of Community Environmental Policy general environmental quality in the EU is not recovering significantly, and in some areas, it is worsening, though other areas show a more encouraging development (see Table 6-2).

Most of the major challenges will continue over the next decade(s). These include significant societal developments (in GDP, population, consumption) and, despite some notable exceptions, a general failure to de-link these from environmental pressures; increasing environmental burdens from the growth of road and air transport, and general urbanisation and 'suburbanisation'; degradation of the rural environment; and increasingly significant risks to the valuable natural and biodiversity assets of Central and Eastern European countries, and those remaining in Southern and Mediterranean countries and in Northern and Western Europe.

The main goals of environmental policy in the near future appear to be (EEA, 1999):

- to pursue the sustainability objective from an environmental perspective, in particular by addressing the important problem of global climate change;
- to integrate the environment into more general sectoral policies;
- to cope with the enlargement of the EU in the coming years while maintaining environmental standards and adapting the economies of the enlargement countries to further tightening EU environment standards, taking into account the economic performance of the accession countries. Benefits from the enlargement are expected to be greater than the economic costs, although these are estimated to be considerable (EEA, 1999): they have been evaluated at about ¤100 billion or about ¤1000 per inhabitant of the accession countries. This cost is more than the total annual budget of the European Union and is of particular significance if it is remembered that the average income of these countries is one-third that of the EU. The process of enlargement thus poses questions regarding economy.

Integration of environmental policy into sectoral policies appears to be a key element in future environmental policy. It has been gaining increasing attention since the Maastricht Treaty and was reinforced by the Amsterdam Treaty which underlines its importance and defines it as a way to achieve sustainable development. The Kyoto meeting on climate change (December 1997) illustrated to the world the close links between environment and economic policy. In response to a request from the December 1997 Luxembourg European Council, the Commission came up with a strategy, set out in its May 27 Communication, for taking the environment more closely into account in other EU policies. This is in line with the provisions introduced by Article 6 of the Amsterdam Treaty.

TABLE 6-2:ENVIRONMENT IN THE EUROPEAN UNION AT THE TURN OF THE CENTURY

Pressures		Environmental issues	State & Impact	
Present	Future		Present	Future
+/-	-	Greenhouse Gases and Climate Change	-	-
+	+/-	Ozone Depletion	-	+/-
+/-	-	Hazardous Substances	+/-	?
+/-	+/-	Transboundary Air Pollution	+/-	+/-
+/-	+/-	Water Stress	+/-	+/-
-	-	Soil Degradation	-	?
+/-	-	Waste	-	-
+/-	?	Natural and Technological Hazards	+/-	?
+/-	?	Genetically Modified Organisms	?	✘
-	-	Biodiversity	+/-	?
+/-	+/-	Human Health	-	?
+/-	+/-	Urban Areas	+/-	+/-
-	-	Coastal and Marine Areas	-	?
-	?	Rural Areas	-	✘
-	?	Mountain Areas	-	✘

Legend:

+	positive development	+/-	some positive development but insufficient
-	unfavourable development	?	uncertain (partial quantitative/expert analysis available)
✘	no quantitative data available		

Assessment of progress over the past 5-10 years and trends up to 2010 (2050 for Climate Change and Ozone Depleting Substances). The indications about the pressures show how factors, such as emissions of pollutants or land use, which give rise to the problems, are changing. The information about state and impacts indicate how these pressures are feeding through into changing environmental quality.

Source: EEA 1999

Henceforth, such policy integration was no longer an option, but had become an obligation in Community law. The strategy is based on an inter-institutional partnership between the European Parliament, Commission and Council built around guidelines set out in the Commission's Communication. This thorough integration of environmental protection into other sectors was described in the Communication as "a long-term challenge that needs a gradual approach and one based on experience". At the Cardiff European Council (June 1998) the Commission Communication on Integration was endorsed and the Agriculture, Energy and Transport Councils were invited to report on integration progress at the following summit in Vienna (December 1998). For Vienna these Councils presented reports committing themselves to integration and reporting on the actions already taken. The European Council invited them to continue their work with a view to submitting comprehensive strategies in these sectors, including a timetable for further measures and a set of indicators, to the Helsinki European Council. In addition it invited the Development, Internal Market and Industry Councils to undertake work on the integration issue. Given this development, environmental policy is becoming "a policy of policies" as a main instrument for sustainable development (EEA, 1999).

At present, integrated strategies that include the environment in a sector's objectives remain rare, being absent from the Common Agricultural Policy treaty objectives, and absent from the EU common transport policy objectives. However, at least five countries (Austria, Denmark, the Netherlands, Sweden and the UK) have produced transport strategies that incorporate environmental objectives. The more heterogeneous industry and energy sectors are less amenable to overall integrated programmes, but climate change is now encouraging overall energy sector plans, turning the challenge of climate change into an opportunity.

Considering integrated policies, environmental fields of particular concern remain, from an energy policy perspective (see sections 6.4.1 and 6.4.2):

- the transport sector which receives a significant 'subsidy' in the form of externalised costs (estimated at around 4 % of EU gross domestic product). This encourages mobility beyond the optimum for society, especially for freight transport, which may sometimes be cross-subsidised by private car transport. **Urban transport** plays a particular role in that it contributes over-proportionally to the damage, despite the fact that there has been undeniable progress in emission reductions over the past decade.
- **environmentally damaging subsidies**, which are another example of failure to integrate environmental cost into market prices. They are in general declining, though still large in agriculture, industry and the energy sectors (particularly for **coal**); in total they still amount to some tens of billions of ¤. Tax concessions for car use and parking in some countries are another subsidy to private mobility.
- **global climate change**: The success of the sectoral integration policies as described above can be measured by the extent to which sectors decouple their economic activity from their environmental impacts, with associated increases in their 'eco-efficiency'. At the EU level, only air polluting emissions have shown a significant decoupling from GDP since 1990. By contrast, there has been only a relatively small decoupling of carbon dioxide and other greenhouse gases, and these trends continue to 2010.

6.4.1 REMAINING SUSTAINABLE ENVIRONMENTAL STRESSES: URBAN TRANSPORT AND COAL USE

URBAN TRANSPORT

TRANSPORT – A MAJOR CONTRIBUTOR OF ENVIRONMENTAL DAMAGES

In urban areas Passenger mobility and transport of goods contribute to a large part to the problems posed by the drift of the energy/environment balance of the transport system. Whatever the definition taken for accounting the energy consumption of the urban areas or for assessing the urban driving conditions, urban traffic consumes around 40 % of the total road energy consumption. This percentage is, however, worse for certain pollutants. Source-adjacent pollution is first and foremost an urban problem. Of all atmospheric discharge due to human activities, transportation is today responsible for 12 % of sulphur oxide emissions (SO_2), 69 % of nitrogen oxide emissions (NO_x), 64 % of carbon monoxide emissions (CO), 49 % of volatile organic compounds emitted (VOC's) and 33 % of suspended particles. Transportation is also the cause of one-third of the emissions of carbon dioxide (CO_2), the principal greenhouse gas (which has experienced an increase of 35 % in the transport share over the last decade). Therefore transport activities contribute significantly to environmental problems of climate change, acidification, tropospheric ozone and urban air quality.

2/3 OF TRANSPORT EXTERNALITIES COST OCCURRED IN URBAN AREAS

Although the transport sector contributes significantly to the functioning of the economy, it generates a certain number of damages to the environment in a broader sense – just like all human activities.

Damages are numerous, from accidents to the impact of noise, visual damage or space scarcity. Sometimes, they are specific to transportation (congestion, space scarcity), sometimes they contribute predominantly to a general evolution such as the emission of pollutants, either locally (air pollution) or globally (climate change). All these damages contribute to the "urban stress" caused by transport activities, but the focus in this section will be on damages related to energy consumption.

Many efforts have be carried out to monetarise the social costs, the so-called "externalities of the transport sector". Despite uncertainties about the methodologies used and the range of assessment for a given externality, these investigations have the merit of providing a broad estimation of the negative impact of transport activities. Nevertheless, these estimates are global and the breakdown by vehicle type or by type of traffic is often missing at the national level, a fortiori at the EU-level. Such an attempt has been carried out in France (Table 6-3, Orfeuil 1998) with the following main results by type of traffic:

- urban stress accounts for two thirds of the total externalities generated by transportation;
- local and global air pollution account for one fifth to one third of the total urban stress;
- car and light truck traffic contributes to the bulk (82 %) of the externalities in urban areas, whereas, the major contributors in rural areas are heavy trucks and cars.

Comparing the balance of the state income, mainly from transport fiscal policies, and the expenditures (infrastructure etc.) with the cost of the externalities, we may observe that the deficit (by km performed) mainly concerns car use in urban areas and trucks in long distance.

PAST AND CURRENT TRENDS IN POLLUTANT EMISSIONS STRONGLY DIVERGE ACCORDING TO THE TYPE OF POLLUTANTS

Past trends have been very diverse according to the pollutants and a basic distinction could be made between, on the one hand, pollutants which contribute to the air quality and, on the other hand, to global pollution such as CO_2.

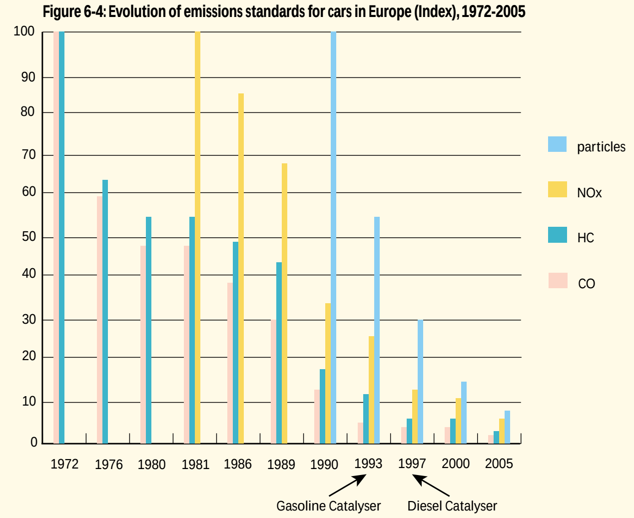
TABLE 6-3: EXTERNALITIES OF URBAN TRANSPORT IN FRANCE (HIGH ESTIMATE)

	Motor-cycles	Cars	Light trucks	Trucks	Busses	TOTAL
Externality due to			**Billion €$_{91}$[55]**			
Noise (1)	0.11	1.22	0.42	0.07	0.01	1.84
Local air pollution (2)	0.40	1.94	0.72	0.29	0.11	3.46
Pollution by CO_2 (3)	0.01	0.52	0.23	0.06	0.01	0.82
Accidents (4)	0.67	2.18	0.10	0.04	0.01	3.01
Congestion (5)	0.00	2.70	1.32	0.14	0.00	4.16
Total urban externalities (6)	1.20	8.55	2.78	0.60	0.16	13.28
Total non-urban externalities (7)	0.46	4.03	0.39	1.88	0.16	6.91
Total externalities (8)	1.66	12.58	3.17	2.48	0.32	20.19
			%			
% urban air pollution (incl. CO_2) in total urban externalities (2+3)/6	35	29	34	57	82	32
% urban externalities in total externalities (6)/(8)	72	68	88	24	50	66
% total air pollution (incl. CO_2) in total externalities	32	29	33	70	77	36

Source: Orfeuil 1998 , p. 41

Except for CO_2 and SO_2, little data is available at sectoral level for the EU (OECD Compendium 1997). To get an overview of the past trends, we propose to refer to the evolution of the emission standards applied at the EU-level (Figure 6-4, ADEME 1999). Clearly, a huge reinforcement of regulation occurred in all local pollutants, more than a factor 10 during the last 25 years. The same development can be shown for SO_2 and lead.

Figure 6-4: Evolution of emissions standards for cars in Europe (Index), 1972-2005



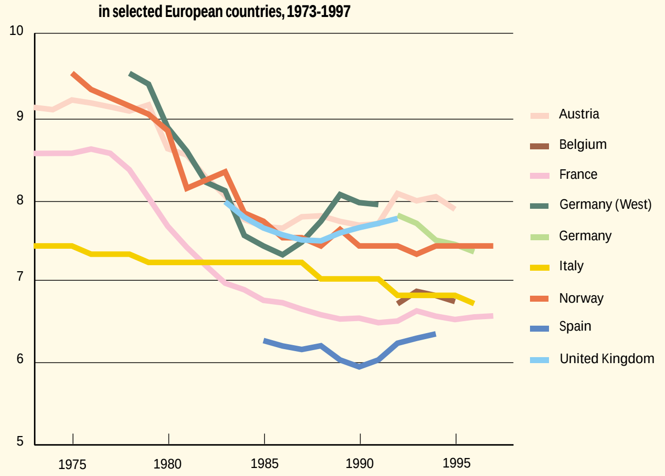
Source: ADEME 1999

Obviously, there exists a gap between the trends in regulation and the observed overall performances of the fleet, due to the requested delay for the fleet renewal and the traffic growth. During the period 1980-1990 the emissions of all pollutants emitted by mobile sources increased, mainly due to the increased mobility. Then, different trends according to the type of pollutants have been observed. NO_x and NMVOC have slightly decreased mainly due to the introduction of catalytic converters. Atmospheric lead concentrations have also been reduced due to the large-scale introduction of unleaded petrol. However, some issues such as the cold start problem for catalytic converters and emissions of particles in the growing Diesel-based vehicle market, remain.

The diagnosis for CO_2 is quite different and its trends are mainly influenced by the progress in energy efficiency, inter-fuel substitution and traffic growth. From the view point of energy efficiency and, by correlation, CO_2 reduction, the results were quite disappointing in Europe despite huge technological improvement in vehicles. Energy efficiency indicators of the transport sector (Bosseboeuf et al. 1999) show, at an aggregated level, a quasi-stabilisation of the transport energy intensity (i. e. the ratio of energy consumption of transport divided by the Gross Domestic Product GDP) from the first oil shock up to now. In general, energy efficiency actions were limited due to the complexity of this sector and the importance of non-technical factors: multiplicity of actors, consumer preferences for cars, special status of cars as a consumer good, etc. Nevertheless, at a more disaggregated level and for a certain period, significant improvements can be observed particularly during the high energy price phase at the beginning of the eighties. Nevertheless, a stabilisation or even worse a reverse trend can be observed after the

[55] The €-sign was also used here for the older European Currency Unit ECU.

Figure 6-5: Evolution of the tested specific consumption (l/100 km) of new cars in selected European countries, 1973-1997



Source: ODYSSEE Database 1999

counter oil shock. This was due to behavioural changes particularly in the transport sector. At least, undeniable technological gains of around 20 to 30 % in 25 years (Figure 6-5) were partly offset by the "rebound effect" (increased use of energy efficient cars as a consequence of lower spending on transportation fuels) and the strategies of car manufacturers which are sensitive to the customer demand. Performance gains since 1985 have been used to increase vehicle power, mass and comfort rather than to lower energy consumption. Clearly, technology is an option but not sufficient to tackle the CO_2 issue. So improvements in the organisation of the transport sector are needed as well. The current trend of energy consumption will remain strongly upward if drastic measures are not taken, leading to an increase in the order of 40 % by 2010 (compared to 1990 levels).

DRIVING FORCES

As distance travelled has increased due to the widening urban areas, urban pollution is primarily due to private cars. Freight transport in towns and cities, however, accounts for a significant share of pollutant emissions. Besides the fundamental social need to enlarge the "spatial expansion", the driving forces of the growing demand for transport energy are well known:

- traffic growth (practically a tripling of passenger mobility in 25 years and a doubling in freight, Table 6-4) in line with demographic and economic trends;
- urban spread due to a change in the localisation of activities and land use pricing leading to longer passenger trips;
- "dematerialisation" of the production, liberalisation of the haulage sector and change in logistic practices for freight have led to a decoupling between tonne and tonne-km trends, to an increase of the frequency of smaller parcels and the more frequent use of smaller trucks;
- lifestyle which led to a preference for faster, more comfortable transport modes;
- decrease of the running costs due to a drop in fuel and vehicle prices.

To summarise, people want to go faster and longer in less dense areas, leading to the use of faster modes which unfortunately consume more. In addition, transport policies particularly concerning the infrastructure development and sectoral policies (urban planning etc.), were counterproductive from an energy efficiency point of view.

FUTURE TRENDS: TECHNOLOGY SHOULD SOLVE LOCAL POLLUTION

Criteria of sustainability for pollutant emissions in urban areas such as SO_2, NO_x, VOCs, CO, and lowest levels for noise, could be reached by technology alone, pushed by regulation (see Figure 6-4) even under a pessimistic hypothesis of sustained transport demand and a road-oriented modal split. Appropriate technologies are already known as well as their timing for the industrial development and their market penetration. But criteria for CO_2 emission sustainability seems more difficult to reach solely by technological improvement.

TABLE 6-4: EVOLUTION OF PASSENGER MOBILITY (MILLION PERSON-KILOMETRES) AND CAR MODAL SHARE IN SELECTED EUROPEAN COUNTRIES, 1970 AND 1996

million person-kilometres	Cars 1970 10^6 pkm	Cars 1996 10^6 pkm	Annual variation (%)	Total 1970 10^6 pkm	Total 1996 10^6 pkm	Annual variation (%)	Car modal share (%) 1970-1996
Germany	351	748	3.2	438	890	3.0	80-84
Belgium	49	92	2.7	66	104	1.9	74-89
Spain	64	217	5.2	100	274	4.3	64-79
France	305	674	3.4	371	775	3.1	82-87
Italy	212	626	4.6	276	763	4.3	77-82
Netherlands	66	146	3.3	85	174	3.0	78-84
United Kingdom	297	589	2.9	387	665	2.3	77-89
Total	**1,344**	**3,092**	**3.5**	**1,724**	**3,645**	**3.2**	**78-85**

Source: CEMT 1998

Compensation by improvements in the organisation of the transport sector is still uncertain. But this issue will not only be determined by urban stress.

However, this scenario is somewhat simplistic. Emission abatement options of both the technology or transport demand side are sometimes in synergy with different pollutants or, in some cases, in contradiction, as illustrated by the following examples:

- catalytic converters reduce local pollutant emissions, but increases CO_2 (by 5-8 %);
- a compromise must be found between HC, CO oxidation and NO_x reduction;
- treatment of particles through the improvement of the combustion engine will reduce the mass of particles emitted, but can increase the number of small particles emitted;
- NO_x abatement supposes deep desulphurisation of diesel which can double the energy cost of diesel production in the refinery process;
- suppression of lead will increase emissions of benzene and aromatic-based pollution;
- speed limits reduce CO_2 emissions but may increases NO_x in some traffic conditions;
- by-passing urban areas can increase the CO_2 if it leads to an increase in distance;
- increased use of Diesel fuels could reduce CO_2, but increase NO_x and particle emissions;
- electric vehicle avoid urban pollution but may transfer CO_2 emission to the area of electricity production.

Although it is difficult to summarise the complexity of the phenomena, Table 6-5 presents the commonly accepted scenario of the evolution of pollutant emissions by type of area.

CONCLUSIONS

In order to reach sustainability of the transport system in urban areas, new policies are needed. These can be summarised as technology improvement, better transport organisation, inter-fuel substitution, economic instruments and taxation.

The environmental concern has led to new priorities for clean technologies where a compromise should be reached among pollutant abatement strategies. Clearly, for the main local pollutants, technological options, pushed by the regulation of emission standards, will conduct to more sustainably-oriented transport systems. For this

TABLE 6-5: SYNOPSIS OF THE EVOLUTION OF POLLUTANT EMISSIONS ACCORDING TO THE POLLUTANT

	Past			Future			Observations
	Total (1)	Total transport	Urban transport	Total (1)	Total transport	Urban transport	
SO_2	↓	↓↓↓	↓↓	↓↓	↓↓	↓↓	Technology improvement pushed by regulation, deep desulphuration leads to over consumption in refineries
CO	↓	↓↓↓	↓↓↓	↓↓	↓↓	↓	idem
NO_x		↓		↓	↓	↓↓	DeNO_x catalyst for gasoline, compromise with CO_2
HC/VOCs	↓	↓↓↓	↓↓↓		↓	↓↓	Compromise with CO_2
Particles	→	→	→	→	↓	↓↓	
O_3	↑	↑↑	0	?	?	0	Future uncertain; precursors of O_3 come from transport in urban areas, but O_3 appears in regional areas
SOx, NO_x, NH3							Acidification
CO_2	→	↑	↑	↑	↑	↑	Balance between technology improvement and traffic growth
N_2O		→					
CFCs	↓	↑	↑	↓	↑	↑	Air conditioning of vehicles
Lead	↓	↓↓	↓↓	0	0	0	Suppression by regulation, increase in benzene and aromatics

(1) includes industry, residential, tertiary , transport and other energy consuming sector

Source: ADEME 1999

purpose, **the European Commission's Auto-Oil Programme**, in which the European Oil industry association EUROPIA and the European car manufacturer association ACEA are involved, was aimed at improving air quality by means of evaluating cost-effective measures to reduce emissions from road transport (EEA, 1999). The process involved the car manufacturing industry and the oil industry and resulted in a number of Commission proposals in 1996, and final agreement in 1998 between the Council and the European Parliament on measures for passenger cars, light commercial vehicles and quality of petrol and diesel fuels. The measures are laid down in Directives 98/69/EC and 98/70/EC:

- a two-step tightening of vehicle emission limit values for passenger cars and light commercial vehicles, with the first step in the year 2000 and the second step in 2005;
- new environmental specifications for petrol and diesel fuels to take effect from the year 2000; very low-sulphur fuels to be mandatory from 2005;
- provision made for earlier phase-in of very low-sulphur fuels;
- leaded fuels to be phased out by 2000 (with the possibility of derogation up to 2005);
- proposals to be brought forward by the Commission for further complementing measures to take effect from 2005.

The estimated effect on road transport emissions of the Auto-Oil measures is substantial (Table 6-6). To evaluate the impact of the Auto-Oil measures on urban air quality in European cities and to assess possible further measures to reduce emissions from road transport, as well as non-technical local measures, the Auto-Oil 2 Programme was launched by the Commission. This is expected to result in Commission proposals by the end of 1999 (EEA, 1999).

In particular, a voluntary agreement was derived in the course of the Auto-Oil programme (proposed by the Association of European Car Manufacturers ACEA). It determines future specific energy consumption and CO_2 abatement targets which are ambitious, if realised. The average sales of new cars put into the European markets by the European manufacturers should reach the limits of 140 g

TABLE 6-6: ESTIMATED EFFECT ON ROAD TRANSPORT FROM THE PACKAGE OF MEASURES DERIVED FROM THE AUTO-OIL PROGRAMME (DIRECTIVES)

Pollutant	Pollutant Emissions in 2010 as % of 1990 level without Auto Oil measures	Pollutant Emissions in 2010 as % of 1990 level with Auto Oil measures
urban NO_x	37	23
urban PM	79	37
urban CO	20	10
urban VOC	23	23

Source: EEA, 1999

CO_2/km in 2008 and possibly 120 g CO_2/km in 2012 corresponding to a 25 % improvement compared with the current situation. The impact on transport energy consumption would be substantial (see Volume 5 of the Shared Analysis Project), although a considerable delay was introduced compared to the initial time schedule 2005 for the 120 g CO_2/km goal. Uncertainties remain, however, in the timing due to the inertia of transport infrastructures and the renewal of the fleet, as well as in the counterproductive consumer preferences towards larger and heavier cars with air conditioning, favoured by the car manufacturers through their sales strategies. There is the strong risk that this trend will prevent car manufacturers from achieving their goal. But in the event of the negotiated agreements with the European car manufacturers on reducing CO_2 emissions not coming to a successful conclusion, the Commission considers proposing the introduction of binding legislation. it is important not to wait until 2008 in order to take adequate action. Monitoring procedures have been set up, and it is the task of energy policy to recognise in time any non-compliance with the agreed targets and to initiate the corresponding political response.

The European Parliament wanted Member States to have greater fiscal flexibility to make clean fuels more attractive and had called for Commission proposals to this effect. Fiscal issues being - as always - a very delicate matter for the Member States, the agreement simply recalls that the Commission has already brought forward a proposal for an Energy Products Directive. This proposal has the objective of, amongst other things, allowing Member States to make more active use of fiscal incentives through differentiated excise taxation.

The diagnosis on CO_2 sustainability is far from being obvious. Due to the significant contribution which the transport sector must make to the attainment of the Kyoto targets, rapid progress in implementing "no regret" potentials is necessary and can have a significant contribution in the short and medium terms. These measures are expected to lead to significant economic and transport benefit, in addition to their other environmental benefits. Nevertheless more costly policies will have to be developed. More radical changes in the way the passenger are transported have to envisaged.

COAL USE

In recent years, many OECD governments have responded to concerns expressed about the implications for the global climate as a result of increasing concentrations of carbon dioxide (CO_2) and other greenhouse gases in the atmosphere by taking new policy actions. These decisions have the potential to affect the international market for coal. This also applies to air quality management strategies like regulations and air quality standards setting a maximum allowable rate of pollution output for each type of source (power plant, industrial boilers) by type of pollutant. A further distinction between type of source is made by fuel and often by technology. The most widespread use of uniform technology standards is for new facilities. In addition to national emission standards applied at a national level there are also regional, state and local standards which may be more restrictive in some aspects than the corresponding national standard. In siting power stations or industrial facilities these local standards can play a significant part in any new investment decision. In the OECD, local regulations are particularly important in countries with federal political structures (e. g. Australia, Belgium, Canada, Germany, the United States) as well as in other countries like Japan and Greece.

In many countries, emissions standards are being extended from new to existing facilities. Co-operation including both Western and Eastern Europe originally developed in the 1979 UN/ECE Convention on Long-Range Transboundary Air pollution. In a first protocol within the framework of this Convention, a number of United Nations countries committed themselves to at least a 30 per cent reduction in SO_2 emissions or their transboundary fluxes from 1980 levels by 1993 (Helsinki Protocol). A second SO_2 protocol was agreed in 1994. It includes a number of innovative control measures such as emissions trading among the signatory parties to the convention. A similar first protocol for NO_x emissions (the Sofia protocol) was signed on November 1988 by 35 nations including the United States, Canada and 20 European countries. The protocol undertook to freeze NO_x emissions at 1987 levels by 1995. The EC introduced a Directive in June 1984 on combating of Air Pollution from industrial plants (the "Framework Directive"). The directive called for a three-stage reduction from 1980 levels of SO_2 emissions from existing plant over 50 MW, with overall community targets of 25, 43 and 60 per cent reductions by 1993, 1995 and 2003 respectively. Belgium, Germany, France and the Netherlands are aiming at a 70 per cent reduction by 2003 while special dispensations for Greece, Ireland and Portugal allow 6, 25 and 79 per cent increases in emission levels by 2003. There is to be a simultaneous two-stage reduction in NO_x emissions for existing plant over 50 MW. The directive also introduces strict limits for particle, SO_2 and NO_x emissions from all new combustion plants authorised after 1 July 1987. On 24 November 1988, the Large Combustion Plant Directive 88/609/EEC was adopted by Member States. This was the first Directive to be adopted under the framework Directive 84/360/EEC. Council Directive 94/66 EC on the limitation of emissions of sulphur dioxide from large combustion plants amended Directive 88/609/EEC and set limit values for SO_2 emissions from smaller combustion plants using solid fuels, in particular, coal. It established limit values of 2,000 milligrams of SO_2 per cubic metre for some existing facilities and all new facilities with a capacity of between 50 and 100 thermal MW.

Table 6-7 demonstrates the summary of air emission limits for large new coal-fired boilers.

Coal is used mainly in power generation, in specific processes of industry and to a small extent in the residential sector. Demand in the non-power generation sectors has been decreasing in the OECD region for a number of years, but growing elsewhere. Consumption for power generation is growing world-wide. Two major factors will affect projections of coal demand. The first will be the outcome of competition between coal and natural gas in power generation. The

TABLE 6-7: SUMMARY OF AIR EMISSION LIMITS FOR LARGE NEW COAL-FIRED BOILERS

	SO_2 limits			NO_x limits		
	mg/Nm^3	g/GJ	lb/10^{9}Btu	mg/Nm^3	g/GJ	lb/10^9 Btu
Australia				500	175	410
Austria	200	70	165	200	70	165
Belgium	400	140	325	650	230	530
Canada	740	258	600	740	258	600
Denmark	400	140	325	200	70	165
Finland	400	140	325	145	50	120
Germany	400	140	325	200	70	165
Italy	400	140	325	200	70	165
Japan	223	78	180	411	145	335
Luxembourg	1700	595	1385	450	160	365
Netherlands	200	70	165	200	70	165
Portugal	400-2400	140-2400	325-1954	650	228	530
Spain	800	280	650	650	230	530
Sweden	285	100	233	145	50	116
Switzerland	400	140	325	200	70	165
Turkey	1000	350	815	800-1800	280-630	1465
United Kingdom	400	140	330	650	230	530
United States	1820	520	1200	570-740	200-260	465-605

Source: IEA Secretariat and country submissions second will be the choice of policies by governments to meet the greenhouse gas commitments of the Kyoto Protocol in 1997, and in particular the reduction of the remaining subsidies for coal in the EU.

Global demand for coal is projected to grow at an annual average rate of 2.2 %. Overall, OECD demand is projected to grow less than half the rate of non-OECD demand. Within the OECD, virtually all of the region´s total final consumption of coal is consumed in the stationary sector and is projected to decline slightly throughout the projection period. In OECD Europe, a return to average winter temperatures, from the warm winters experienced for most of the 1990s, is expected to result in a small short-term increase in coal demand. In the longer term, however, the switch to other fuels, principally gas, will more than offset this short-term effect. Coal demand for power generation is projected to increase in most world regions outside Europe, see Table 6-8.

TABLE 6-8: COAL DEMAND FOR POWER GENERATION, 1990/1995-2020

	World Energy Outlook 1998				POLES			
Power generation (Mtoe)	**1995**	**2010**	**2020**	**1995 – 2020 annual growth rate in %**	**1990**	**2010**	**2020**	**1990 – 2020 annual growth rate in %**
OECD	**719.6**	**921.7**	**1,039.5**	**1.5**	**665.3**	**844.4**	**1,015.9**	**1.4**
North America	456.1	604.3	784.8	2.2	410.6	631.3	729.0	1.9
Europe	197.9	235.9	166.9	-0.7	206.3	148.2	204.4	0.0
Pacific	65.6	81.5	87.8	1.2	48.5	64.9	82.5	1.8
NON-OECD	**586.9**	**1,038.4**	**1,413.7**	**3.6**	**521.6**	**955.7**	**1,554.4**	**3.7**
Transition Economies	163.9	210.5	212.3	1.0	235.8	152.7	185.6	-0.8
Africa	43.8	65.1	83.3	2.6	47.6	77.2	130.4	3.4
China	240.7	458.7	647.5	4.0	143.6	484.1	839.0	6.1
East Asia	33.5	87.1	157	6.4	28.9	52.7	86.4	3.7
South Asia	92.6	181.8	261.7	4.2	55.1	162.8	261.6	5.3
Latin America	8.3	24.3	36.1	6.1	7.7	25.2	50.2	6.4
Middle East	4.2	11	15.8	5.5	2.9	0.9	1.2	-2.9
World	**1,306.5**	**1,960.1**	**2,453.3**	**2.6**	**1,186.9**	**1,800.0**	**2,570.3**	**2.6**

Source: World Energy Outlook 1998, POLES

6.4.2 CLIMATE CHANGE POLICIES [56]

Over the past decade climate change has emerged as a critical international environment issue. Although the possible impact of increased concentrations of greenhouse gases on global climate is still not known in detail, the issue has been brought into sharp focus with the negotiations of the third Conference of the Parties (COP 3) to the United Nations Framework Convention on Climate Change (UNFCCC), the results of which were laid down in the Kyoto Protocol in December 1997. The principle of precaution is guiding the present and future energy policy in the light of the high share of energy-related greenhouse gas emissions and the enormous risks and future damages to many economies across the globe. Europe (see Chapter 6.4.3) and even global regions like North Africa may face substantial geophysical changes such as a change of the Golf stream or a growth of the Sahara desert (IPCC 1996). The results of the Kyoto process are seen by many as an interim step of necessary emission reduction targets of the countries having signed the Kyoto Protocol[57] within the decades to come.

In order to fully take into account the individual situation of each country or political entity, such as the European Union, a variety of flexibility mechanisms – concerning both domestic actions and measures abroad to reduce greenhouse gas emissions – were introduced by the Kyoto Protocol, of which the most important for the EU are

- burden sharing among the group of countries forming the European Union;
- burden sharing among different types of greenhouse gases and land-use changes;

[56] This section is based on the study "The Kyoto Target of the EU: Implications of the burden sharing and the greenhouse gas basket for CO_2-emissions in the Member States", European Commission – Directorate General for Energy, which was carried out in the context of the Shared Analysis Project (Volume 11).

[57] The so-called Annex-B countries, i. e. countries with a quantitative reduction target

- burden sharing among different sectors of the economy (transport, industry, energy conversion sector, residential and tertiary sector);
- flexibility instruments such as emission trading, Joint Implementation and Clean Development Mechanism (CDM) which allow greenhouse gas reduction measures abroad in countries having agreed to quantitative reduction targets in the Kyoto Protocol (so-called Annex-B countries) as well as countries without quantitative reduction target (so-called Annex-A countries);
- flexibility of emission reduction over time.

The first three of these flexibility mechanisms concern domestic actions while the fourth category aims at reduction measures abroad as a substitute for domestic actions. The fifth category might concern domestic reduction measures as well as measures abroad.

With the Kyoto Protocol the European Union Member States have committed themselves to reduce or limit their emissions of greenhouse gases by 8 % in 2010 compared to 1990. As a possible first step towards the long-term target to stabilise greenhouse gas concentrations in the global atmosphere in spite of drivers for further growth, a **basket of the six most important greenhouse gases** (in terms of their contribution to the greenhouse effect) or groups of greenhouse gases was defined in the Kyoto Protocol. These should be limited or reduced by countries with a quantitative reduction target (CO_2, CH_4, N_2O, hydro-fluorocarbons HFCs, per-fluorocarbons PFCs and sulphur hexa-fluoride SF_6). The decision also included changed land use which is of minor importance for the EU (1 %), but which stresses the possibility of carbon storage in biomass. On the

TABLE 6-9: OVERVIEW OF REFERENCE GREENHOUSE GAS EMISSIONS AND TARGETS FOR 2008-2012 AS AGREED IN THE BURDEN SHARING AMONG EU COUNTRIES IN 1998

	Greenhouse gas emissions 1990/1995		Emission target in 2010 (%)
	Mt CO_2 equivalent	per capita [1996]	
Austria	77.8	10.1	-13 %
Belgium	140.1	14.1	-7.5 %
Denmark	80.7	15.7	-21 %
Finland	64.7	13.0	0 %
France	500.8	8.8	0 %
Germany	1,214.3	15.3	-21 %
Greece	101.4	10.0	25 %
Ireland	56.9	16.2	13 %
Italy	551.6	9.7	-6.5 %
Luxembourg	14.0	36.9	-28 %
Netherlands	225.4	15.1	-6 %
Portugal	67.0	6.8	27 %
Spain	312.6	8.1	15 %
Sweden	66.5	7.8	4 %
United Kingdom	778.7	13.5	-12.5 %
EU total	**4,252.5**	**11.7**	**-8 %**

Note: Reference emissions for CO_2, CH_4, N_2O are those from 1990; reference emissions for HFCs, PFCs and SF_6 are those from 1995.

Environment Council in June 1998 a **breakdown of the EU target to the Member States** (burden sharing by country) was agreed (see Table 6-9). It leaves considerable flexibility to the individual country by setting targets ranging from –21 % for Germany and Denmark to +27 % for Portugal.

Regarding least cost options the Community has to consider the question of differentiated emission reduction possibilities and targets for its policies, because an equal reduction target for all six greenhouse gases could turn out to be more costly than otherwise. The additional consideration of sinks and land use changes effecting the storage of carbon makes the policy options of a European mitigation policy even more complex.

The **burden sharing among different sectors of the economy** has not been considered explicitly as a policy means to achieve the overall EU greenhouse gas reduction target of -8 %. However, all the studies carried out so far, including this work (see Volume 5), show that the different sectors will contribute unequally to the reduction target. While the transport sector will contribute less, given its strong growth of energy consumption, other sectors such as the power conversion sector and the industrial sector will contribute over-proportionally due to the shift from coal to the cleaner fossil fuel natural gas and increased efficiency levels in the first and structural changes to less energy-intensive industries in the latter.

The introduction of the **non-domestic flexible mechanisms** in the Kyoto Protocol

- emission trading among actors in countries with a quantitative reduction target (Annex-B countries),
- Joint Implementation projects between actors in Annex-B countries (essentially between OECD member states and countries in economic transition), and
- the Clean Development Mechanism (CDM), i. e. joint implementation projects between actors in Annex-B and Annex-A countries (without quantitative reduction targets),

also underlined the long-term aspects of climate change policy and, hence, the global search for least-cost options for reducing the greenhouse gas emissions. In this context the question arises whether domestic actions should constitute the larger contribution to the reduction targets of the EU Member States (as stipulated by the Kyoto Protocol with the claim that emission reduction through non-domestic flexibility mechanisms should be “supplemental” to domestic action) and what quantitative ceiling should be imposed on the percentage contributed by reduction measures abroad.

Flexibility of emission reduction over time was introduced into the Kyoto Protocol, by not fixing a single target year but a target period from 2008 to 2012 (for a more extended discussion of time flexibility over longer time periods, see Chapter 4 of Volume 13 of the Shared Analysis Project).

The following sections will investigate the implications of the basket of greenhouse gas emissions and of the ceiling on non-domestic reduction measures taking into account the burden sharing among the EU Member States. The burden sharing among sectors was already considered in chapter 5, at least concerning the largest contributor of energy-related CO_2 -emissions.

THE IMPLICATIONS OF THE BASKET OF GHG EMISSIONS AND BURDEN SHARING

An answer has to be given to the question as to what strategic position could be taken on the issue of burden sharing among greenhouse gases given the overall EU reduction target of –8 % until 2008-2012 on the basis of the emissions of the year 1990. Simultaneously, the analysis has also to consider the burden sharing among EU member countries which was decided by the Environment Council in June 1998. This tries to take into account the different situations of member states regarding the status of industrialisation, motorization and income as well as energy structures and their possibilities for change (see Table 6-9).

The basic hypothesis of this analysis is that energy-related greenhouse gas emissions may be less reduced than the total greenhouse gas emission. This is because some reductions of methane, N_2O and PFCs may exceed the average reduction target in most EU member countries due to other drivers and policies than climate protection policy.

The following results can be drawn from an in-depth analysis of the implications of the full basket of six greenhouse gases (see Volume 11):

The share in total GHG emissions of **HFCs, PFCs, and SF_6 is very small** and will reach – despite an increase of 40 % mainly due to HFCs – only 2.1 % by 2010 (all halogenated gases combined). Nevertheless, HFC substitutes as refrigerants and a recovery of SF_6 from insulating glazing are recommended mitigation options. Other reduction possibilities will be relatively costly.

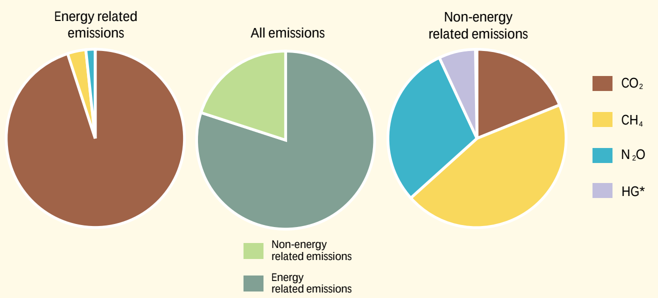
Up to 2010 **total CH_4 and N_2O emissions will decrease far more than the obligations of Kyoto for the EU of –8 %**. CH_4 could decrease to as low as 74 % of 1990 emissions and N2O to as low as 83 %.

In 1990, 23 % of total **CH_4 emissions** were energy-related and occurred mostly during the extraction and distribution of fossil fuels. This share was decreasing and reached 20 % of total CH_4-emissions in 1994. The non-energy related CH_4 emissions result mainly from the agricultural sector and landfills. Mitigation measures are underway in both the energy (e. g. renovating gas distribution networks, closing of coal mines) and agriculture and waste sectors (e. g. livestock digestive efficiency improvement, recovery of landfill gas). **Additional CH_4 emission reduction potentials are relatively small and costly** (Ecofys, 1998).

Some 82 % of total **N_2O emissions** were non-energy related in 1990 with a decreasing trend, and result mainly from agriculture and industry. Some smaller amount, though increasing, is also released from the transport sector due to the growing use of catalytic converters. N_2O is released because of an imperfect functioning of converters and engine regulation. Mitigation is undertaken mainly in the adipic and nitric acid production. Further mitigation is difficult and/or relatively costly.

In all, 80 % of total GHG emissions in 1990 were **CO_2 emissions** and their share is expected to grow to 84 % in a reference projection by the year 2010 (see Figure 6-6). About 95 % of total CO_2 emissions were energy-related. 28 % stem directly from the energy conversion sector, 20 % from transport, 21 % from industry and 11 % from the residential sector. Existing mitigation options are diverse and affect all sectors including substitution by natural gas and renewables for fossil fuels.

Figure 6-6: EU-15 GHG Emissions Excluding Land-Use Change and Forestry, 1990/1995



* HG = Halogenated gases including HFC, PFC, SF_6

Considerations of sinks seem to be of minor importance from an overall European perspective (11.6 Mt in 2010 or -0.27 % of the 1990 GHG emissions), but might have an importance from a regional perspective.

The above analysis shows that in addition to the reference projections to 2010 for all greenhouse gases together[58], emission reduction measures of some 320 Mill. t CO_2 are required for the EU in order to meet the targets of Kyoto by 2010. This additional reduction has essentially to occur in the energy sector This result implies a reduction of CO_2 emissions of some 178 Mill. t from the 1990 level or roughly –5.2 %. Expressed in terms of the target of -8 % for all greenhouse gases, CO_2 has to contribute 4.1 percentage points to the target, i. e. well below the average (see Figure 6-7). **This shows, on the one hand, how important the reductions of non-CO_2 emissions are likely to be and, on the other hand, how necessary it is to verify the projected mitigation options**. Nevertheless, as most of the cheaper non-CO_2 reduction measures (or measures triggered by environmental legislation or the decline of hard coal production) have already been taken, **the remaining effort has essentially to come from the energy system itself**.

The figures on which this analysis is based, still present a considerable degree of uncertainty, in particular concerning the non-CO_2 greenhouse gases (see Volume 11). Nevertheless, a sensitivity analysis shows that the approach chosen here is a relatively conservative one. If additional reduction measures are carried out in the coming decade compared to the reference development (for climate protection or other reasons), the pressure on CO_2 could be even more reduced.

NON-DOMESTIC FLEXIBILITY MECHANISMS AND SUPPLEMENTARITY

The Kyoto Protocol recognises the importance of domestic action by demanding that the use of these mechanisms "shall be supplemental to domestic actions (...)" (Article 6.1 d, Article 17). Furthermore Article 12.3 b of the Kyoto Protocol refers to the supplementarity issue by expressing that credits from projects carried out under the Clean Development Mechanism (CDM), i. e. projects carried out in countries without quantitative reduction target, may only be used for "(...) compliance with part of (...)" the commitment by a country with a quantitative reduction limit[59]. This reflects the concern of misusing the non-domestic flexibility mechanisms driving out domestic action.

However, the term supplementarity could not be defined in more detail during the negotiations of the Kyoto Protocol, since no agreement on the realisation had been reached. To implement supplementarity options such as:

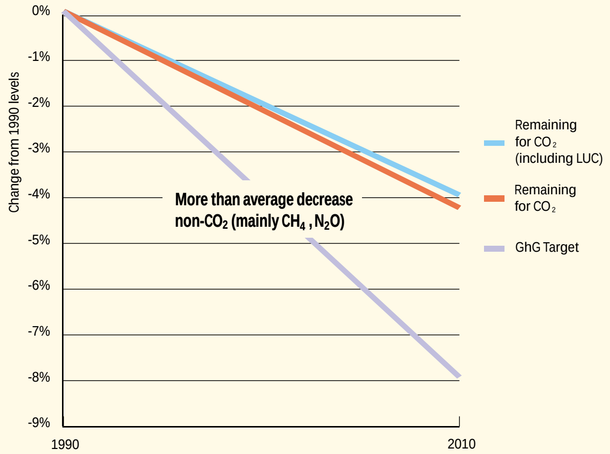
- a concrete ceiling (a quantitative limitation to the use of the non-domestic flexibility mechanisms) or
- qualitative criteria such as performance indicators for different sectors have been mainly discussed. On the international level it is envisaged that the sixth Conference of the Parties (COP 6) should agree in the year 2000/2001 on the principles, modalities, rules and guidelines for the Kyoto mechanisms. Consequently, this would then be most probably the decisive Conference of the Parties for the supplementarity issue.

THE CEILING ON NON-DOMESTIC FLEXIBILITY MECHANISMS

The EU has recently settled on a concrete proposal for a ceiling on non-domestic flexibility mechanisms (see Box 6-2). A ceiling is proposed for both the amount of domestic emission reduction that could be replaced by flexibility measures abroad, and for the supply of such options by countries which are below their reduction limit. An in-depth analysis of these formulae applied to the basket of the six gases allows the following main conclusions for the EU:

- Flexibility mechanisms can to a large extent replace domestic action. Based on the ceiling formulae recently agreed upon by the EU and based on the data set developed in Volume 11 for six greenhouse gases, **non-domestic flexibility mechanisms could cover up to 75 % of the gap between the 2010 reference scenario for all greenhouse gases and the 2010 target** (with the sum of all EU Member States taken individually, see Figure 6-8).
- **For the individual Member States there are large differences**, ranging from only 18 % of the difference between reference development and target in the case of Greece to 1250 % for France. All countries but Italy, Greece and Portugal have a ceiling close to or in excess of 50 %.

Figure 6-7: The impact of the reference development of non-CO_2 gases on the target to be achieved by CO_2



58 The reference scenario as defined here reflects the "With Measures Scenario" of the second national communications to the United Nations Framework Convention of Climate Change (UNFCCC), i. e. it includes all measures decided up to Kyoto Protocol (including measures decided but not yet realised). This explains differences with other scenario work established for non-CO_2 greenhouse gases (see EEA, 1999).

59 Annex I Party to the United Nations Framework Convention of Climate Change (UNFCCC).

• **Applying the ceiling to the EU bubble as a whole** (column "EU" in Figure 6-8), or limiting the ceiling of the individual Member States to no more than their actual gap between the 2010 reference scenario and the 2010 target (i. e. to 100 % in the case of France), would still lead to an overall ceiling in the range of 54 to 63 %.

• **Non-EU countries**, if they applied the EU ceiling proposal, would also be able to replace substantial amounts of domestic action through flexibility mechanisms (at least about 30 to 60 %). Nevertheless, the ceiling seems in general lower than for the EU. Another limitation could come rather from the amount of emission reduction that could be sold than from the ceiling imposed on the buyers.

Box 6-2: EU proposal for a ceiling on non-domestic flexibility mechanisms[60]

A concrete proposal for a ceiling in non-domestic flexibility mechanisms, on which the EU has recently settled, specifies that net acquisitions of emission rights by a country with a quantitative reduction limit must for all three Kyoto mechanisms together must not exceed the higher of the following two alternatives:

5 % of: its base year emissions multiplied by 5 plus its assigned amount[61] / 2

or

50 % of: the difference between its annual actual emissions in any year of the period from 1994 to 2002, multiplied by 5, and its assigned amount.

This is complemented by a ceiling on the net transfer by an Annex B Party (under current conditions mainly Russia and Ukraine) which for all three Kyoto mechanisms together must not exceed:

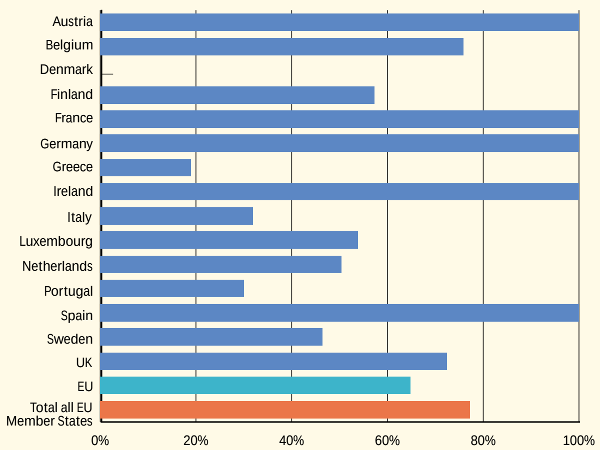
5 % of: its base year[62] emissions multiplied by 5 plus its assigned amount / 2

However, the ceiling on net acquisitions and on net transfers can be increased to the extent that an Annex B Party achieves emission reductions larger than the relevant ceiling in the commitment period through domestic action undertaken after 1993, if demonstrated by the Party in a verifiable manner and subject to the expert review process to be developed under Article 8 of the Kyoto Protocol (UNFCCC 1999, p. 6, 14, 20).

The **first formula** is only based on the base year emissions and on the target and can therefore already be calculated today. In the case of a flat target (2008/2012 emissions equal to 1990 emissions) this means that roughly 5 % of the base year emissions can be covered through non-domestic flexibility mechanisms and has to be compared for example with the 8 % EU reduction target. This means that at minimum about 60 % of the target can be covered by flexibility mechanisms under the conditions of the EU.

The **second formula** can only increase this minimum. In this formula the actual emissions between 1994 and 2002 enter the calculation of the ceiling, and the calculation can only occur a posteriori (i. e. given the data availability, the exact ceiling will probably not be available before early 2004). Therefore the outcome of this second formula depends on the reference development up to 2010.

Figure 6-8: The ceiling for EU Member States and the EU expressed as a percentage of the difference between the 2010 greenhouse gas reference scenario and the target [63]



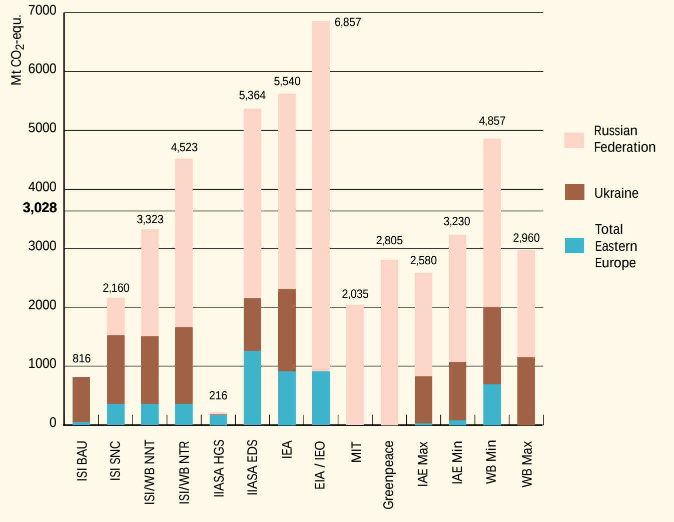
Regarding the **"seller side"**, all Eastern European Countries and the Former Soviet Union together are estimated to have a total of 3,323 Mt of CO_2 equ. of "hot air" (see scenario ISI/WB NNT[64] Figure 6-9) to be transferred in the first commitment period 2008-2012 (or 665 Mt CO_2 per year of the commitment period in the mean). A comparison with other "hot air studies" (see Figure 6-9) demonstrates that the estimates of the present study, based on data of the National Communications to the United Nations Framework Convention on Climate Change (UNFCCC) and the World Bank, are in the same range as the other studies. Moreover, the ISI/WB NTT scenario was almost equal to the average 3,028 Mt CO_2 equ.[65]. Figure 6-9 further illustrates the uncertainties in the estimates of "hot air" with a spread from single to triple. Main differences can be attributed to assumptions on economic recovery and efficiency progress in Russia, Ukraine and the Eastern European countries.

Divergent views exist in particular for Eastern European countries for which some scenarios conclude on a certain amount of hot air, while others see no hot air at all for these countries.

This amount would be limited to 1,556 Mt of CO_2 equ. due to the formula 3 of the EU ceiling proposal. **The ceiling would thus restrict the transferable hot air to about 50 % of the amount available**. Comparing the figure with the total amount of demand of industrialised countries which can be achieved via flexibility mechanisms (4,974 Mt CO_2 equ.), **the transferable "hot air supply" would be around 30 % of demand** (expressed as the sum of the ceilings of all countries exceeding their Kyoto target). The remainder has to be filled with additional domestic mitigation efforts or projects under the Clean Development Mechanism and Joint Implementation projects.

Given the divergent views on supplementarity a solution at the international climate change negotiations seems to be far away. Most likely packages including different divergent points will be negotiated at the end of the sixth Conference of the Parties to the UN Framework Convention on Climate Change (COP6), in order to reach an agreement on a minimal consent.

Figure 6-9: Comparison of hot air studies (sum over the hot air available in the five-years period 2008/2012 in Russia, Ukraine and Eastern European countries)



Sources: World Bank (WB) 1999 (for Russia only CO_2),
**International Institute for Applied Systems Analysis (IIASA) 1998,*
(HGS: High growth scenario, EDS: Ecologically driven scenario)
**International Energy Agency (IEA / OECD) 1999,*
**Energy Information Administration/international Energy Outlook (EIA/IEO)1999,*
**Massachusetts Institute for Technology (MIT), Ellerman et al. 1998,*
Greenpeace International (GP)1998, Institute for Applied Ecology (IAE) Herold, 1998.
** only including CO_2 emissionsPOLES*

THE MARGINAL MITIGATION COST OF COUNTRIES OR REGIONS WITH A QUANTIFIED GREENHOUSE GAS REDUCTION LIMIT ACCORDING TO THE KYOTO PROTOCOL (ANNEX B COUNTRIES)[66]

The integration of non-domestic flexibility mechanisms into the Kyoto Protocol was driven by the recognition that the marginal and total costs of greenhouse gas mitigation are not equal across the countries and regions. This is not only seen for developing countries without quantitative reduction target, but also within the countries having committed to such a target in the Kyoto Protocol (Annex B countries). Only Annex B countries are constrained by the commitment made at the Kyoto Conference. Their CO_2 emission reductions are calculated as the differences between the reference emissions for the different countries and regions in 2010 as projected by the world energy model POLES (see Volume 2) and the goals established at Kyoto for the constituent parties, as indicated in Table 6-10.

For the Former Soviet Union the level of CO_2 emissions is predicted to be 512 Mt C in 2010, which is below the aggregate level to which the FSU countries (Russia, Ukraine, and the Baltic Countries) committed at Kyoto (805 Mt). The difference of 293 Mt between the FSU commitment and predicted emissions could be exported by trading emission certificates to other Annex B countries. Central and Eastern Europe is not expected to have any remaining hot air[67], but the mar-

60 See chapter 5, Volume 11 of the Shared Analysis Project for an in-depth discussion of the proposal.

61 Target as defined in Article 3 of the Kyoto Protocol multiplied with five as the Kyoto protocol specifies 2008-2012 as the target period.

62 Or average annual emissions in the base period as provided for in Article 3 paragraph 5 of the Kyoto Protocol.

63 Note that the factor 5 is introduced from the fact that the period to consider is 2008/2012. The ceiling is expressed as the sum over those five years.

64 This scenario is based on data derived from 2nd National Communications except for Hungary, Slovakia, Russia and Ukraine which are based on World Bank projections. For Russia the NTT scenario assumes no innovations, energy subsidies at 1997 level and no additional regulatory measures for CO_2 reduction (World Bank 1999).

65 Since EIA/IEO, Greenpeace and the MIT projections did not include Eastern Europe, these studies have been excluded when calculating the average.

66 This section is based on the study "World Energy Scenarios" (established with the POLES model), European Commission – Directorate General for Energy, which was carried out in the context of the Shared Analysis Project (Volume 2).

67 The amount of "hot air" as calculated by POLES is in the higher range of the estimates of hot air in Figure 6-9 (around 5,370 Mt CO_2 for the period 2008/2012 excluding non-CO_2 gases). Concerning hot air from Eastern European countries, POLES comes up with no hot air for these countries, in difference to some of the hot air estimates for Eastern Europe, though it only comprises CO_2. The study presented in the previous section (see Figure 6-9) estimates hot air in the range of 99 Mt C for the period 2008-2012 (or 73 Mt CO_2 equ. annually), i. e. about 10 % of the hot air from the Former Soviet Union. This shows the sensitivity of these relatively small amounts of hot air to the underlying assumptions on economic growth in Eastern Europe, also illustrated by the range span up by the different studies compiled in Figure 6-9.

TABLE 6-10: CO_2 EMISSIONS (EXPRESSED AS CARBON EMISSIONS)[68], MARGINAL AND TOTAL COST CORRESPONDING TO THE KYOTO COMMITMENTS (ANNEX B COUNTRIES)

	2010 Reference (Mt C)	Kyoto Target (% of 1990)	2010 Kyoto Target (Mt C)	2010 reduction (Mt C)	Marginal cost ($/t C)	Total Cost (M$)	Effort (% of GDP)
USA	1,745	93	1,243	502	148.7	31,975	0.363
Canada	142	94	110	32	174.2	2,274	0.280
European Union	1,026	92	822	204	165.4	14,325	0.165
CEEC 4[1]	210	94	168	42	92.5	1,801	0.291
Rest of CEEC[2]	75	100	74	1	4.8	2	0.001
FSU[3]	512	100	805	-293	0.0	0	0.000
Japan	347	94	279	68	203.1	5,742	0.177
Australia & New Zealand	126	107	89	37	120.8	1,923	0.301
Total Annex B	**4,182**	**95**	**3,591**	**591**	**–**	**58,041**	**0.128**
World	8,345	132[4]	7,754	591		58,041	0.116

[1] Four main Central and Eastern European Countries (Poland, Hungary, Czech Republic, Slowakia)
[2] Croatia, Bulgaria, Romania and Slovenia
[3] Former Soviet Union (only successor countries with a quantitative reduction target, i.e. Annex B countries: Russia, Ukraine, Baltic countries)
[4] expected development, not a target

Source: POLES scenario S2 (see Volume 2)

ginal costs of abatement are substantially lower than in the other Annex B countries (see Table 6-10).

ANNEX B TRADING CASE: MUTUAL GAINS

Simulating emission trading (unrestricted by any ceiling) among Annex B countries by POLES, the price of the emission permits will be set at the level of 66.5 $/t C. At this market price, the OECD regions (USA, Canada, the European Union, Japan, Australia & New Zealand) are importers of permits and the Eastern European Countries and the Former Soviet Union are exporters. The Former Soviet Union accounts for nearly all of the exports (98 %), 75 % of which (293 Mt out of 389 Mt) consist of "hot air" with a zero cost. The remaining exports are generated by abatement undertaken to earn additional export profits up to the point where the marginal abatement cost equates the market price. It costs the FSU $2.9 billion to abate additional 97 Mt in excess of the 293 Mt, but all the permits representing the 389 Mt can be sold for $25.8 billion, which means a total gain from permit trading of $22.9 billion (see Table 6-11).

For the Annex B countries the cost of meeting the Kyoto commitment is reduced by $39.7 billion which represents costly domestic abatement avoided for the four OECD regions by importing permits, and the export earnings for the Eastern European Countries and Former Soviet Union. From the world-wide standpoint of the resource use, the aggregate cost of meeting the Kyoto commitments is much lower with Annex B trade ($18.3 billion) than without ($58 billion). The total gains from emission trading are $39.7 billion, split between the FSU ($22.9 billion) and the OECD & Eastern European Countries (Annex B) economies ($16.8 billion).

[68] The conversion factor from carbon to CO_2 emissions is 44/12 = 3.67

TABLE 6-11: GAINS FROM CO_2 PERMIT TRADING AMONG ANNEX B COUNTRIES

	Emissions (MtC)				Trading: Permit Price 66.5 $/tC				
Countries, regions	**2010 Reference (Mt)**	**2010 Scenario with trading (Mt)**	**Domestic effort (%)** [5]	**Trade (Mt)**	**Trade Value (M$)**	**Internal Cost (M$)**	**Total Cost (M$)**	**Effort (% of GDP)**	**Gains from trading (M$)**
United States	1,745	1,466	55.5	-222.9	14,822	8,699	23,521	0.267	8,454
Canada	142	125	52.3	-15.4	1,024	480	1,505	0.186	769
European Union	1,026	920	51.6	-98.4	6,545	3,267	9,812	0.113	4,514
CEEC 4 [1]	210	178	76.3	-10.0	662	1,013	1,675	0.270	126
Other CEEC [2]	75	66		8.3	-553	281	-272	-0.126	274
FSU [3]	512	417		388.7	-25,853	2,920	-22,933	-1.634	22,933
Japan	347	316	45.0	-37.5	2,495	951	3,445	0.106	2,296
Australia & New Zealand	126	102	64.9	-12.9	858	734	1,592	0.249	330
Annex B [4]	**4,182**	**3,591**	**55.1**	**(397)**	**(26,406)**	**18,345**	**18,345**	**0.075**	**39,697**

[1,2,3] see previous Table 6-10

[4] as some countries with smaller amounts of emissions (Switzerland, Norway and Turkey) have been omitted in the table, the total does not correspond exactly to the sum of components.

[5] Domestic effort measured as % of distance reference to target

Source: POLES

The gains from emissions trading for the Kyoto-constrained regions is distributed roughly in proportion to marginal cost and quantities to be reduced. The four regions with the highest marginal cost and the highest quantities to be reduced – Japan, the European Union, Canada and the United States – are the greatest winners of permit trading. Japan imports 55 % of its reduction requirement and reduces its cost by $2.3 billion. The European Union imports 48.4 % of its reduction requirement and reduces its cost by $4.5 billion.

This distribution of the gains from trade reflects an important feature of emission trading. Regions for which the marginal cost is farther from the trading equilibrium will import (or export) more than those regions with marginal costs which are closer.

PART VII ENERGY TECHNOLOGY SUPPORT FOR ENERGY POLICY

Given the policy challenges and issues described in Chapter 6, the role of energy technologies and energy efficiency in the end use sectors may be even more important than in the past two decades, particularly in a world of low energy prices and a re-concentration of world oil production in the Gulf Region.

Research and development as well as innovation policy will have to contribute to greater efficiency and reduce energy losses by process substitution, but particularly to reducing the costs of energy efficient technologies and of renewables (see Chapter 7.1).

Co-generation of heat and power (including fuel cells) as a highly efficient conversion technology and the use of renewables as long-term options to diversify energy supply and reduce pollution are important technological options which, however, face competition from two sides: low fossil fuel prices (and traditional conversion technologies) as well as improved energy efficiency, which often reduces heat demand in a given plant or city area. So, the competing potentials have to be analysed realistically and regarding their inter-linking dynamics (see Chapter 7.2).

Finally, efficient energy use in the final energy sectors does not only improve economic competitiveness, but it also opens up new opportunities for additional growth, employment and foreign trade (see Chapter 7.3).

7.1 RTD POLICY & ENERGY TECHNOLOGY OPTIONS IN A WORLD OF LOW ENERGY PRICES [66]

Energy R&D has always been an essential component of energy policy in the past 25 years at European and Member State level. An impressive number of research programmes covering energy technology development from basic research to demonstration and dissemination have been initiated (see Volume 10 of the Shared Analysis Project).

From the 1980s up to now, the European Commission launched and carried out four R&D Framework Programmes (totalling funding of over 29 billion €) with the aim of improving the European Science & Technology base, and its industrial competitiveness. Within these pluri-annual Framework Programmes, the share of the total EU funding devoted to R&D in energy has fallen considerably, by over a factor of 2 for Member States and from 40 % to 20 % today, moving at the same time from conventional research themes to new technologies linked to the development of diversified energy sources. This is partly the expression of lower interest in energy R&D while energy prices were falling after 1985, but it also partly reflects the need to integrate new areas into the research programmes such as information and communication technologies, life sciences, material sciences, etc.

These efforts are continued in the latest energy RTD components of the 5th Framework Programme as well as through dedicated programmes such as the SAVE II and the ALTENER II programmes for the non-technical aspects of energy efficiency and renewable energy sources. These research programmes do not only cover technological aspects but also increasingly the socio-economic aspects of technology acceptance and diffusion.

Energy research is not very precisely identified as it is spread between R&D specifically devoted to energy and diffusing technologies. R&D efforts for energy efficiency in the end-use sectors is covered increasingly by research in material science, information technology, physical chemistry or biotechnology. More important energy R&D efforts are carried out in the private sector (e. g. the development of fuel cells) but industrial R&D is kept very confidential meaning that very little is known about actual efforts. Therefore more attention has to be paid to trends and not to absolute figures as some parallel development can be expected between public and private research (although mature technologies such as oil and gas exploration is a typical example where the public effort has been considerably reduced while private R&D has sustained substantial efforts).

Nevertheless, the background to energy-related R&D has considerably changed over time. Four main issues that have arisen over the past two decades determine changes in energy R&D and lead to questions on its role in the context of future energy policy.

- First of all, energy prices have been extremely low earlier in 1999. This raises questions about which type of technology is sensitive to low energy prices and will not enter the market for some time due to low energy prices. And, on the other hand, **which type of technology is insensitive to low energy prices** and should be focused upon in future R&D programmes.
- Second the **liberalisation of electricity and gas markets and the globalisation of industry has led to a considerable change in the boundary conditions for energy R&D,** in particular with respect to private expenditure for energy R&D. Is an increase in public energy R&D therefore necessary to compensate dwindling private efforts?
- The third change in the boundary conditions to energy R&D concerns the binding **Kyoto obligations and the pressure they put upon industrialised countries to develop new, innovative solu-**

[66] This section is based on the study "Energy Policy and Energy R&D in the European Union: Convergence or Divergence? A 2010 -2020 Perspective", European Commission – Directorate General for Energy, which was carried out in the context of the Shared Analysis Project (Volume 10).

tions in order to be able to achieve the self-imposed targets. How much can energy R&D contribute to fulfil the Kyoto targets and how much can it contribute beyond those targets?
- These changes in boundary conditions have to be seen in the context of the European Union's increasing energy dependence. This has always been the case in the past decades, but was attenuated for a short period of time after the second oil price shock due to important efforts to reduce oil dependence in the eighties. How can energy R&D contribute to slowing down this growing European dependence on external primary fossil fuel sources, especially oil and gas?

These four important changes give rise to questions as to how far the current patterns of energy R&D can contribute and are adequate to solve environmental problems (and resource problems in the longer term) and how can they contribute to increase competitiveness in liberalised markets and to enhance supply security. Given the increasingly limited R&D resources, the **timing of the development of different types of new technologies and their spread on the market** becomes of uppermost importance.

LOW ENERGY PRICES AND ENERGY R&D

Energy prices have been low in 1999 for different reasons depending on the energy source:
- Oil prices were falling in early 1999 (in real terms) to levels below those observed before the first oil price shock, although they have been recovering since then to levels above $20/barrel. However, while the oil price earlier in 1999 was mainly triggered by the lacking demand due to the economic crises in Asia, Russia and South America, and is unlikely to be representative for the long term, also the current (late 1999) oil price well above 20 $/barrel is most likely not representative for the long-term average oil price in the next decade, which is expected to be in the range 15 to 20 $/barrel (see chapter 4.1).
- Electricity prices, as a consequence of liberalised markets, have started to fall in 1999. In Germany for example, which has fully liberalised its electricity market for all consumers in a single step, electricity prices in late 1999 dropped by 30 % (and up to 50 % in certain cases). Although it is unclear currently , how much of this price drop is determined by short term strategies, and how much will be permanent, it is likely that future electricity prices will be lower than today (see chapter 6.3).
- Gas prices have been dropping, following oil price, and start to decrease - at least for some of the customers - as a consequence of the recent market liberalisation.

This more detailed discussion of reasons behind the lowering of energy prices shows that it is important to distinguish between short- and long-term trends in energy prices. Only the later could have any impact on long-term R&D (not taking into account short-term political considerations which, in the eighties, led to a rather parallel development of oil prices and energy R&D expenditure). In addition, there are trends to compensate, at least partially, the lower energy prices by increased taxes on energy products. Most EU countries have in fact already introduced in more or less recent times an energy or carbon tax, or are discussing the issue seriously. The pressure to shift the tax systems from labour taxing to energy/environment taxing is increasing, as it contributes to the solution of a variety of problems at the same time (unemployment, increased competitiveness of European industries both through lower labour costs and improved environmental performance, protection of the environment). Nevertheless, it seems generally agreed that at least for the next 10-15 years energy prices will at best remain at the current long-term mean levels, with the corresponding difficulties for new technologies to enter the market.

The most promising technology options for a sustainable energy system and their relationship with the competitive situation of the European industries have been investigated in a variety of European projects such as the ATLAS project (European Commission, 1997a), the European research project on *Energy RD&D Options for a Sustainable Future* (Blok et al., 1996), recent work on *European Energy Technologies - A Global Competitive Review* (Hagler Bailly, 1998), and by recent IEA work (1999b) on the *Role of Technology in Reducing Energy related Greenhouse Gas Emissions*.

These studies have shown that energy efficiency on the demand side is, other than fuel switching in its various forms at the supply and demand side, one of the low cost options to reduce CO_2 emissions even in an environment of low energy prices. This is reflected in the general consensus that energy efficiency will have to be one of the major pillars of a sustainable energy system. It is recognised by many researchers in the energy field (though not unanimously) that there is a no-regret potential for energy efficiency to the order of 20-25 %, which could be tapped at little or no cost.

With respect to a low-price environment promising technologies in the field of energy demand can be found in the following fields (see the Atlas project, European Commission, 1997a):
- *Energy efficiency in buildings*: heating and cooling technologies (e. g. heat pumps and condensing boilers), efficient lighting, building envelope improvements (window and insulation retrofits), building energy management systems, district heating and cooling systems, technologies that reduce "leaking electricity" losses;
- *Energy efficiency in industry*: process integration, high-efficiency motors, drives, and motor-driven systems, high efficiency separation processes, advanced end-use technologies;

- *Energy efficiency in transport*: efficient conventional vehicles, electric and hybrid vehicles, fuel cell-powered vehicles, biofuels;
- *Cross-cutting technologies*: combined heat and power, advanced gas turbines, sensors and controls, power electronics.

The role of R&D must be to reduce further the costs of these technologies in order to maintain them at a competitive position in a continued low-price environment.

In the building sector for example, it can be shown that through research and development no or very small additional costs had to be carried by house owners of new buildings despite an energetic improvement of about 60 % since the early seventies. Current technical developments give rise to the expectation that this will also be valid for the new generation of low-energy homes with energy consumption levels 30 % below current standards for new buildings. Even the so-called "Zero-energy houses" (houses relying entirely on renewable energy forms and passive solar use), have been shown that they can be built currently at additional costs of only 10 % to the user.

In the case of electric appliances little correlation was found in the past between energy consumption and price. More importantly, recent results from private R&D have shown that stand-by losses from televisions, video-recorders, radios, personal computers etc, which contributed in the past years to the increasing electricity demand, can be reduced by up to a factor of 50 without impact on performance or price at all.

Other examples can be found in the field of large energy-intensive processes where it can be shown in the case of many examples that new processes improved at the same time energy efficiency, environmental impact, productivity and lowered investment costs. It seems contradictory that companies often carried out R&D on such processes only under the pressure of environmental legislation and were not driven by considerations concerning competitiveness. This can, however, easily be explained by a variety of barriers existing in companies towards environment and energetic improvements.

In the case of the transport sector private R&D to improve the energetic performance of vehicles is very important, especially in the context of the voluntary agreements between the car industry and the European Commission on the reduction of CO_2 emissions from the new car fleets. It can be expected that more energy efficient cars can be developed without raising costs, as already today there is very little correlation between the energy consumption of a car and its price.

In a low-price environment, the question should also be allowed whether some technologies which – due their importance for the environment – must be promoted through R&D despite the fact that they might be less economic under today's price conditions (because of long development and investment cycles). In this case, appropriate market mechanisms have to be developed for their introduction. Such types of technologies might comprise for example insulation of the existing building stock at the demand side, and PV and other more expensive renewable energy options.

Last but not least non-price aspects of technologies contributing to a more sustainable energy system have to be enhanced. This can include for example PV facades or day-lighting systems as design elements in commercial buildings. Other, non-price driven developments are the boom in thermal solar energy systems for hot water systems in Germany, Austria etc. which - since the beginning of the nineties increased more than fourfold despite a low-price environment. It is likely that new techniques integrating these elements without much additional costs into new buildings might have contributed to the boom, but non-price elements have certainly played an important role

THE IMPACT OF LIBERALISATION OF ELECTRICITY AND GAS MARKETS ON ENERGY R&D

Liberalisation of electricity and gas markets and the globalisation of industry have led to a considerable change in the boundary conditions for energy R&D, mainly on the supply side (on the demand side essentially end-of-pipe technologies are concerned, not integrated energy efficiency technologies as just discussed, which generate little or no additional cost. On the long-term it is questionable whether end-of-pipe technologies should be strongly promoted through R&D given their limited potential to reduce energy consumption and their limited additional benefits).

Liberalisation affects, first of all, energy R&D by lowering electricity prices (see chapter 6.3), contributing thus to the already discussed general low-price environment, but also with respect to the R&D expenditure of firms. The views on the impact of liberalisation on this second issue are not uniform: some stress the fact that higher R&D expenditure will help to decrease, for example, the cost of generating (or distributing) electricity and will become a tool in the competition for a more efficient structure. Further, there will be an increasing demand for information and communication techniques for energy services and related R&D demand, also the result of liberalisation. At the same time, companies which were in a monopolistic or quasi-monopolistic position have not permitted some technologies to emerge in the past, because they were not in line with their global policy. Others, however, assume that the bulk of electricity sector research was carried out by power equipment producers, while research within utilities was only carried out as part of the intensive co-operation with these power equipment producers, and so the new competition context is pushing firms to break off relationships with power equipment suppliers. It is generally assumed that R&D efforts by the utilities are a cost factor that they would prefer to minimise as much as possible if price competition is to be an important factor.

It is important in this context to prevent markets of environmental friendly technologies which have been established for quite some time (co-generation) or grown recently (wind energy) to be swept away by short-term turbulances of the market opening. It is certainly not the idea to create new, heavily subsidised markets on the long term. But market opening for those technologies must occur gradually by setting adequate boundary conditions so that R&D carried out by equipment suppliers and users of those technologies can hold the pace with the pressure on prices and the trend of utilities to reduce their own R&D.

KYOTO AND THE PRESSURE ON INDUSTRIALISED COUNTRIES TO DEVELOP NEW, INNOVATIVE SOLUTIONS

It is clear already today that the contribution of future energy R&D to meet the Kyoto objectives can only be minor. This hypothesis is essentially based on two arguments:

- First, the lead times for the development of most technologies are simply longer than the decade that separates us from the target period. This does not yet take into account the fact that many new technologies will penetrate the market only during the reinvestment cycles, when it comes to replacing old equipment, which will add an additional delay. **The technology for the Kyoto targets is therefore essentially already in (or near) the markets and is based on R&D carried out one or two decades ago**.
- More important, however, is the second argument that new R&D is not necessary to meet the Kyoto objectives. The previous chapter 6.4.2 as well as Volume 11 have shown that to meet the Kyoto target, around minus 5.4 % relative to 1990 is necessary for CO_2 in the European Union as a whole due to the reduction in CH_4 and N_2O emissions. This has to be compared with the baseline and climate change scenarios developed for energy-related CO_2 in chapters 4 and 5 as well as in Volume 5, which foresees an increase for CO_2 in the range of 5-8 %. Closing the gap may therefore be possible with existing technology (see chapter 5) and the development of new technology may not be so relevant for 2010. In addition, a recent Council Decision of the European Union would allow up to 75 % of this gap to be covered by measures under the non-domestic flexibility mechanisms, not taking into account that non-European industrialised countries such as the United States are fully opposed to any cap on Kyoto flexibility mechanisms. The main conclusion to be drawn from this is therefore **that if R&D is successfully performed and new technologies sufficiently introduced into the markets, the time between 2010 and 2020 (and beyond) should be considered as the most relevant period for R&D implications (not 2010 and Kyoto)**. A technology strategy for reducing greenhouse gas emissions must start today, but must focus simultaneously both on the short term and the long term.

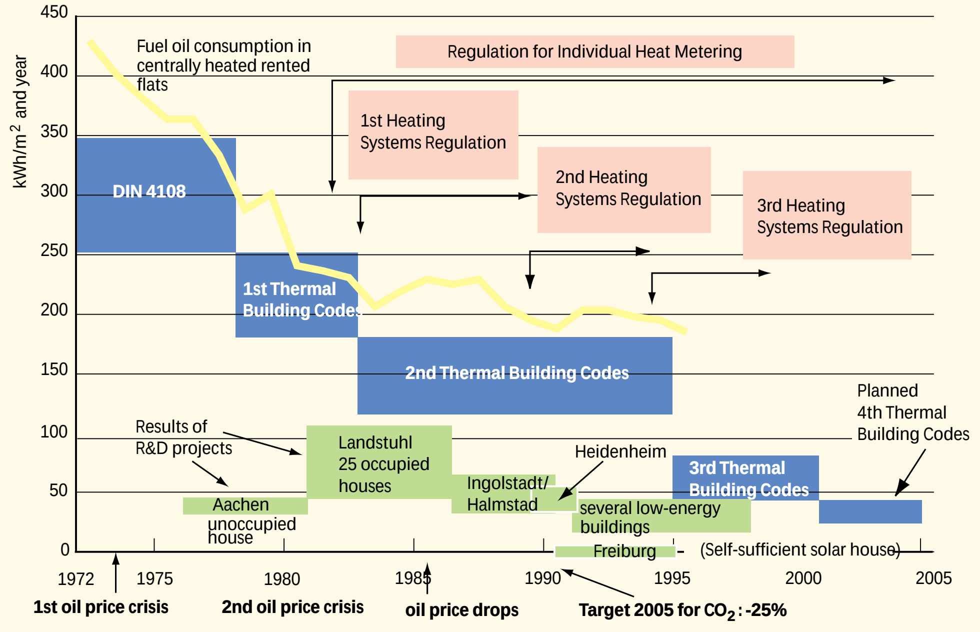
Consequently, in the short term and in the light of the Kyoto targets, enhanced market introduction of already existing technologies is the major challenge. *In a comparative analysis of energy RTD programmes and market observation systems in the USA, Japan and Europe* InnoTec et al. (1996) conclude that while in the past the major focus of technology-oriented RTD was on RTD programme planning and implementation, the highest benefits on the global market place for the competitiveness of European industries stem from market-oriented RTD. They recommend the implementation of a European Task Force on Strategic Energy Research and Development, including all interest-groups (officials from the EU and national governments, industrial executives, leading scientists, experienced consultants). This task force should assess the current market situation, analyse market trends in energy technologies, analyse the potential of innovative energy technologies and make recommendations for strategic priority-setting in future market-oriented RTD.

On the other hand, the link between energy R&D and the instruments of energy policy, which are currently characterised by many contradictions, must be improved to enhance the market introduction of technologies. Any energy policy makes use inter alia of a mixture of regulations, tax incentives, and R&D orientations and funding. Regulations have a major impact on technologies and constitute a major tool that is used by the EC and the Member States. Tax incentives are presently not available for the EC and this somehow makes it difficult to draw up a coherent energy policy at the EU level. It must be recalled that most Member States want to keep decision-making on energy policy at national level and have not adopted new competencies for the EU in the Amsterdam Treaty. However, the prime role of EU regulations over national regulation gives a strong role to the EC. Successful examples at the national level such as the interaction between research to lower costs of energy efficiency options, demonstration and regulation in the case of thermal building codes in Germany (see Figure 7-1) show that successful energy R&D needs a counterpart in future energy policy. Contradictions in signals such as carrying out R&D for renewable energy sources and subsidising fossil fuel and nuclear options have to be solved.

TIMING OF THE DEVELOPMENT OF DIFFERENT TYPES OF NEW TECHNOLOGIES AND THEIR SPREAD ON THE MARKET

Taking into account the above changes in boundary conditions, other more specific questions can be raised for future R&D policy in the context of future energy policy. In particular it must be asked at

Figure 7-1: Interrelation between research to lower costs, proof of technical feasibility and regulation using the example of Thermal Insulation Ordinances and Heating Systems Regulations in Germany



Source: BMBF 1996

what time certain technologies should be available to renew the energy system, and which amount of budget should be devoted to them while R&D budgets are limited:

- Are the efforts by the EU and its Member States in energy R&D in its various energy sectors adequate with the anticipated evolution of European dependence on energy sources (in the short or long term) and the possible contribution of each technology to renew the energy system in a sustainable manner? In other words and for example, is it reasonable to devote more than 50 % of the energy R&D budget to the nuclear sector, considering its potential weight in 2010 of about 15 % and less beyond?
- More specifically is it reasonable to devote 67 % of the EU nuclear R&D budget and about 20 % of the total R&D budget of the EU and its Member States to nuclear fusion, considering that no application can be foreseen on a larger scale before probably 2050 and more likely 2080, while global environmental problems will become more and more severe in the first half of next century?
- Taking into account the involvement of Member States in R&D devoted to the design of new, safer, cleaner and smaller nuclear reactors will it be necessary to devote some additional EU money to such research? Will European industry be strong enough to invest in this domain, taking into account the low visibility of nuclear equipment programmes?
- Will the RTD funding effort be adequate enough in gas, gas combustion or gas combined combustion technologies, considering their remaining efficiency potential and their increasing importance in the medium and long term future? Or is the strong commitment by private and also military R&D on jet engines etc. in this field a guarantee for the provision of improved technical solutions?
- Is research to win gas from coal (e. g. hydrogen) and the removal and sequestration of CO_2 in aquifers or exploited gas and oil fields sufficiently present in energy R&D as an option, contributing thus to further diversification of supply sources?
- Will the budget share of RTD on renewable energies in general and in biomass in particular be justified or adequate considering, on one hand, their perspectives in the future European energy balance (see the baseline development in chapter 4.2) and, on the other hand, their potential high contribution to solve environmental problems and the EU target of doubling the share of renewables to 12 % by 2010?

In order to answer these question, it is useful to develop "road maps" of anticipated energy technology products for different time horizons, e. g. 2000-2010 and 2015-2030 or longer as illustrated in Table 7-1. They present a balanced mixture of supply and demand options. In a more detailed manner, such "roadmaps" to a sustainable energy system can set the operational basis for energy technology R&D at different time horizons. A possible procedure to establish them could be the Delphi-Method. It is clear that such a "road mapping" covering perhaps up to half a century might have - despite all care - a preliminary character. Especially in the time frame 30-50 years further away they might sometimes have more the character of visions

TABLE 7-1: POSSIBLE "ROAD MAPS" OF ENERGY TECHNOLOGY R&D 2000-2010 AND 2010-2030

2000	2005	2010	2015	2020	2025	2030
1 kWh/day refrigerator standard	Fuel cells for providing combined heat and power in commercial buildings	Widespread use of hybrid lighting, combining light concentrators, efficient artificial sources, and fibre-optic distribution systems	Widespread production of chemicals from biomass feedstocks	Phase-change building materials with storage capacity and adaptive release rates	New system: Mass-produced customised buildings with integrated envelope and equipment systems designed and sized for specific sites and climates	New system: Broad-based biomass industry with new crops and feedstocks producing food, transportation fuels, chemicals, materials and electricity
Advanced turbine system for industrial co-generation (80 % combined efficiency)	Electro-chromic windows	Direct reduction for steel making	Hydrogen fuel cell vehicle	New system: widespread application of industrial ecology principles to industrial systems, with linked industries and energy cascading	Travel demand reduction through real-time information systems	New system: Energyplexes that integrate the fossil-fuel based production of power, fuels and chemicals from coal, biomass and municipal wastes with low carbon emissions
Advanced membrane technology for chemical separation	Advanced inert anode cell for the production of aluminium	Closed-cycle papermaking technology	Superconducting generators for utility systems	Production of hydrogen from solar conversion of water	Advanced geothermal hot dry rock and magma energy systems	Utility scale photovoltaic systems
Advanced systems for combustion of black liquor and for drying paper in pulp and paper mills	Thin-strip casting of steel	Advanced conventional vehicle with three times the fuel economy of conventional vehicles	Diesel fuels from natural gas	Simultaneous gas hydrate production and carbon dioxide sequestration	New system: Mature hydrogen supply infrastructure enabling multiple modes of hydrogen-based transport	New system: Fission reactors with proliferation resistance, high efficiency and lower costs
Advanced sensors and controls for optimising industrial processes	New energy-efficient catalysts for chemical synthesis	Life-time extension strategies for products, intensification of product use	Photovoltaics for distributed and peak-shaving utility systems	Feasibility of oceanic sequestration established		Enhanced natural carbon dioxid absorption
Direct injection stratified charge gasoline engine	Gasoline/electric hybrid vehicle	Hybrid fuel cell advanced turbine system or power generation with 70 % electric efficiency)	Further closing of recycling loops at different levels (materials, components, products)			The E=mc2 society
Advanced heavy duty diesel	Clean diesel for light duty trucks and sport utility vehicles	Biofuels competing with petroleum-based transport fuels				
Low energy-house standard for new buildings (30-50 kWh/m2)	Co-firing biomass/coal	Clean coal technologies (e. g. pressurised fluidised bed combustion, integrated gasification combined cycle) increase efficiencies to 55 %				
High efficiency motors	Wind turbines of 3-5 MW on the market	Superconducting transformers and industrial motors of 150 kW and higher				
Larger off-shore wind energy fields	Life extension and generation optimisation technologies for nuclear plants	Injection of carbon into aquifers				
Increase recycling rates for plastics, metals, paper, glass and other materials	Superconducting cables for underground transmission					

Energy Efficiency

Clean Energy

Carbon Sequestration

Clean Energy and Carbon Sequestration

Material and Product Strategies

Source: IEA (1999b), Atlas project: European Commission (1997a) than of a precise look to the future. By their sheer presence they would, however, help structure the future and the debate, while getting more precise in the short term. Such road maps could be inspired by long-term goals, based on a problem analysis evaluating risks and uncertainties (e. g. 80 % reduction in energy consumption by 2080), and would set intermediate milestones which can be measured against the observed development.

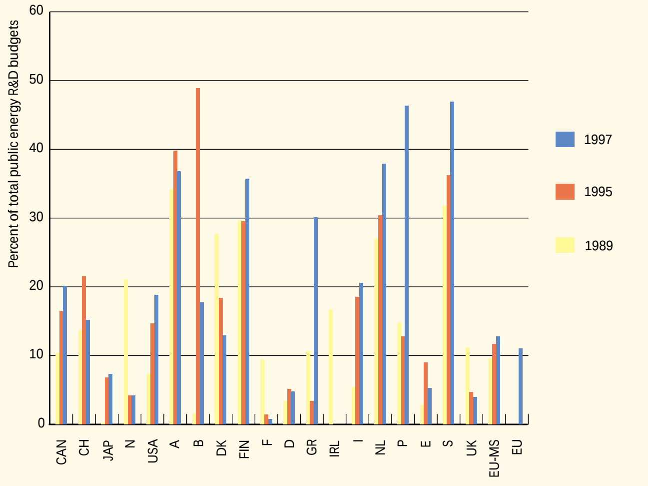
POSSIBLE FUTURE ORIENTATIONS FOR ENERGY R&D ON THE WAY TOWARDS A SUSTAINABLE ENERGY SYSTEM

What are the possible future orientations for R&D to allow Europe to fulfil its needs for an economically viable energy supply, address the supply security issue under international instability and environmental issues, and who will carry out the necessary R&D?

A first observation is that there will be a need to **control energy consumption more efficiently**, which still is still tending to increase, because of economic growth, and ever increasing road and air transportation. A significant reduction in the emission of greenhouse gases is another major objective. All final energy sectors have achieved major progress in the rational use of energy. However, in some sectors such as the transport and the residential sector, technical progress has been (over)compensated by changes in the lifestyle and behaviour favoured by low energy prices. In industry, low energy prices have led many energy-efficient technologies which were cost-effective at the time of higher energy prices to not being economically viable today given the low energy price levels. New technologies addressing improvements in energy efficiency and in environmental impact are nevertheless envisaged. Many of these are cost-effective, even under today's situation of low energy prices, but there is still a need for public support for such R&D to lower costs further and to develop new opportunities. Major contributions can come from the **transport and building sectors**. In transport, R&D should be devoted to a new organisation of transport, in particular in urban areas, and to low consumption and emission vehicles.

In flagrant contradiction with the consensus on the role of energy efficiency manifested in many studies and political speeches is the share of public energy efficiency R&D which is, at the EU-15 level, still only between 10 to 13 % of the overall energy R&D budget (see Figure 7-2[67]). Compared to international standards this is less than the USA and Canada but more than in Japan, due to its huge nuclear research programme. There has been some increase over the past decade which was more pronounced outside the EU. Within the EU, there are large differences across the EU Member States: While some of the larger Member States stagnated at a low level, or even decreased the energy efficiency R&D budgets, most show an increase over time. Despite the above mentioned fact that part of R&D efforts are covered in other areas and that private sector R&D budgets are largely unknown, it is more than likely that developments in the private sector are similar given the low level of attention devoted to energy efficiency in private industries.

Figure 7-2: Share of public energy efficiency R&D expenditure in total OECD government expenditure on energy-related R&D, 1989, 1995 and 1997



Source: IEA, Energy Policy Review of IEA countries (various years), Shared Analysis Volume 10

The production side is also a major cause for concern. Energy demand model simulation forecasts that fossil fuels will keep playing a major role for the next twenty years. This clearly indicates that there is a **market for clean fossil fuel technology**, at least in the short and medium term and for up to several decades. Companies play a major role in gas R&D. However, industrial R&D seems to be strongly linked to energy prices but also to growing pressure from liberalised markets, and there is a potential danger of a lack of continuity in industrial efforts, especially in high-risk areas. More investigation of cleaner fossil fuel routes will be required than at present through the **conversion of fossil fuel to hydrogen combined with the sequestration of CO_2** in large storage systems.

There is further a need to support research on energies which have a lower impact on the greenhouse effect than fossil fuels. The overall public R&D budgets devoted to certain **renewable energies** such as photovoltaics in Europe can be considered to be relatively high compared to the anticipated role of such energies within 20 years and the potential for energy efficiency improvements in end-use sectors. A specific effort is required in this domain to comply

[67] EU-MS represents here the sum of Member States, EU represents EU's own budget

with environmental issues. The fact that **considerable multidisciplinary R&D investment is necessary to boost a technology** (e.g. continuous decrease along the learning curve, using the effects of economies of scale) is well-known and also that industrial and market results may be delayed. Efforts should be related to the total maximum contribution of each type of energy to meet European needs and to the maturity of each technology. On this basis, wind R&D could be probably less support than biomass R&D.

Of particular importance is to investigate, both for fossil fuels and renewables, a **decentralised production of energy** which would allow the building of flexible systems. These may be better adapted to the demand and may also be safer than larger units. This is particularly important for developing countries in the context of their still small electric grids.

Fusion energy will arrive on the market, in perhaps 50 years, if ever. The EC could consider partly shifting its efforts from fusion to fission R&D and support new R&D incentives for the next generation of advanced design nuclear plants, including new designs. Given general budget constraints it is, however, clear, that new **risky technology routes implying high R&D costs have to be carefully evaluated** before committing substantial funds which reduce expenditure elsewhere.

In conclusion, there are still many issues facing Europe in the field of energy are still numerous. Fossil fuels will continue to play a major role in the short and medium term, and incremental innovation will be unable to solve environmental problems. There is a need for more radical innovations in a whole set of technologies, at least in the medium term after 2010. If progress beyond the European Kyoto commitments is to be achieved, the European Union should define ambitious technical/economic targets for the medium and long term, as the USA did, for example, with the Vision 21 programme for electricity production. All available policy tools should be mobilised to reach such targets. **Regulations** have a strong short-term impact on industry investment and research, and the European Union can play a major role in this domain. **Tax incentives** also play a significant role, and Member States are the main actors in this field. **Public R&D programmes and funding are very important in the medium and long term**. Both national and Community actions are necessary in this domain, in particular given the fact that **industrial energy research, as a result of liberalisation, will be mainly driven by short term considerations** with R&D budgets possibly cut under the pressure of competition. National programmes try to give a competitive advantage to their economy and to solve societal issues which are specific to the national context. Community action can better take into account the diversity of Europe and build a global strategy. Examples of technologies which need to be further studied are given in the ATLAS report, and the 5th Framework Programmes and associated work plans provide guidelines for the next 5 years for R&D to be supported by the EC. Developments in the past have shown that in the energy field there is no single option that can fulfil all requirements in terms of supply security, environmental protection and economic competitiveness. This is why **energy research, like energy supply has to be sufficient diversified and broad in order to cope with changing attitudes and the acceptance of the different options over time**. Limited public money for R&D and dwindling private R&D impose, however to establish priorities amongst the various options based on a careful evaluation of the potential of each technology and the most likely dynamic development of the energy system as a whole in the long term.

7.2 INTEGRATING THE POLICY OBJECTIVES FOR EFFICIENT HEAT USE, CO-GENERATION AND RENEWABLES [68]

In the Communication from the Commission to the Council and the European Parliament of October 1997 "A Community strategy to promote combined heat and power (CHP) and to dismantle barriers to its development" (COM(97) 514 final), it was stated that "CHP is one of the very few technologies which can offer a significant short- or medium-term contribution to the energy efficiency issue in the European Union and can make a positive contribution to the environmental policies of the EU." The simultaneous generation of heat and electricity by CHP offers one of the major opportunities for energy-related CO_2 emission reduction as the overall efficiency of these systems is around 90 % compared to 65 to 75 % for separate generation of heat and electricity. At present, less than 10 % of the electricity generation in the EU resulted from combined production, although there are significant variations among Member States, ranging from more than 30 % in the Netherlands, Denmark and Finland to less than 5 % in the UK, France, Greece and Ireland. These differences are not only due to different climates, industrial structures and indigenous energy resources, but also to traditional market structures of electricity supply and the national or regional energy policies in the Member States.

Most recent projections indicate an additional economic potential of CHP, that it would be possible for it to double its present share in electricity generation. This potential includes CHP for both industrial steam and heat production as well as district heating and cooling.

[68] This section is based on the study "Energy policy responses to the climate change challenge: The Consistency of European CHP, Renewables and Energy Efficiency Policies", European Commis-sion – Directorate General for Energy, which was carried out in the context of the Shared Analy-sis Project (Volume 14).

The increased energy efficiency in industrial processes and space heating, however, is likely to reduce heat demand. As the profitable operation of CHP depends on the heat densities of the local heat markets or the electricity-to-heat ratio of a production site or a large office building, hospital or hotel complex, there remains the question as to what extent the increased implementation of CHP and of efficient heat use in the end-use sectors entails conflicting objectives.

"District heating" traditionally refers to public networks combining many property sites, while a similar heat distribution network for several buildings within the same property site may not be considered to be district heating. In the last decade, however, small heat supply networks for a few buildings or industrial plants have also come to be considered as district heat generated by new small gas turbine- or engine-driven co-generation units. In Denmark, for instance, the warm water-based heating systems of many blocks of flats and large institutions were transferred to district heating systems without much additional investment in piping during the 1980s.

Although specific heat density is likely to decrease in the future, the share of electricity from CHP could still increase significantly. New technologies such as the combined cycle gas turbine – or fuel cells in the next decade – have a larger power-to-heat ratio than the current average.

New technical building code requirements, increasing opportunities for low energy houses or solar passive houses, refurbishing the existing building stock with a lower heat and cooling demand in the next decades, and reduced specific heat demand in industrial processes as well as structural changes to less energy-intensive products are likely to reduce heat demand in urban areas, cities and at industrial sites. The demand for cooling in urban areas is likely to increase (and equalise the seasonal variations in demand by supplying cooling via absorption technology), but may not compensate the decrease of demand for heat. This trend may be supported by solar heat collectors for warm water supply and for supporting heat generation in sunny regions during the heating period.

CONSISTENCY OF TARGETS AND RELATED POLICY INSTRUMENTS

In the light of the potentials of both the heat demand and the heat supply delivered by CHP and solar thermal energy, the question arises of the consistency of policies for further promotion of CHP, thermal solar energy use and energy efficiency. The answer to this question of consistency has many aspects: the dynamics of changes in the present building stock, the existing networks and industrial sites, new technical options of co-generation, further cost reductions of co-generation and district heating networks, decisions of building owners, policies of local and regional governments and the exact legal framework of the liberalised electricity and gas markets in the member states, including energy tax regimes.

THE DYNAMICS IN INFRASTRUCTURES AND THE ROLE OF LOCAL GOVERNMENTS

Neither CHP, district heat networks, nor widespread heat savings in buildings and industrial sites will be introduced or reduced in the short term. Energy conservation in buildings or new building constructions will depend on a large number of individual and collective decisions – often in connection with a change of ownership or occupants. The re-investment cycle of buildings may be in the order of 100 years and refurbishing buildings only takes place after several decades. The dimensioning of CHP units and district heat networks depends on these long-term changes.

The opportunities provided by synergy between the different measures during implementation may be far more important than the risk of inconsistency. The development of new built-up areas and urban renewal, for example, offers essential opportunities for the simultaneous implementation of heat saving and CHP-based district heating. The instruments to achieve such synergies are proper urban planning and the appropriate regulation of property developments by local governments. The national policy traditions influencing local governments vary widely, and there is little effort being made for a European harmonisation in this area. In those countries where the penetration of CHP has been most significant (Denmark, Finland and the Netherlands), there have been sustained co-ordinated policy initiatives for both CHP and efficient heat use over the last two decades.

NEW TECHNICAL OPTIONS OF CO-GENERATION AND FURTHER COST REDUCTIONS

If the heat density of a city area or a production site is declining, the consistency of policy objectives will also be sustained by a declining cost of combined heat and power generation or of heat distribution networks. There are several technical developments which support this perspective of further cost reductions:

- the combined-cycle gas turbine (CCGT) has made medium-scale CHP economically more attractive. Further development of CCGT on a very small scale (e. g. using small gas-driven turbines, engines or, in the next decade, fuel cells) might also make large-scale CHP or district heat systems less attractive; these small CHP units also have a substantial potential for cost reduction. Large-scale systems could still be an option for competition between primary fuels. An important aspect of the new technologies is a much larger power-to-heat ratio, i. e. about 1.0 for new CCGT or gas engine-driven units compared to 0.4 for traditional gas turbines and CHP plants a decade ago. Thus, the same heat demand will become the basis for increased electricity generation and, hence, improved profitability.

- Further potentials for increased efficiency and cost reductions of district heat systems can be found in optimising heat flows and temperatures. The introduction of heat-driven cooling-by-absorption technology during the summer months would increase load factors and utilisation time. Increased competition for equipment, construction and operation of grids may further increase overall productivity and reduce costs. The use of municipal wastes in CHP plants on the basis of environmental legislation may also improve the economics of district heating structures in urban areas.
- Competitive tendering or sub-contracting for the operation and maintenance of heat sources and grids may also open up opportunities for innovative thinking and higher productivity levels. This may lead to technology transfer via supranational international ownership and out-sourcing routine operation to internationally-operative specialist firms.
- Finally, commercial benefits can be gained from electricity spot markets by the management of generation units and heat storage to sell peak-load electricity. CHP generators that are supported by favourable long-term contracts for the sale of electricity may increase the overall efficiency of the electricity market by secondary trading on a power exchange if the hourly spot market price for electricity is higher than their short-term marginal cost. This is likely to occur in electricity markets that are influenced by hydro or wind power or by big customers or groups of customers with fluctuating electricity demand.

THE CONTEXTUAL FRAMEWORK OF LIBERALISED ELECTRICITY AND GAS MARKETS

Given the present surplus capacity of supply in both the electricity and the gas market in most Member Countries (see Chapter 6.3), these two final energies will be offered at marginal cost basis and may threaten CHP-based district heating networks (as can be observed in German municipalities). Electricity and gas supplies tend to have shorter payback periods, given the higher risks in privatised and liberalised markets. As the externalities of separate electricity and heat production are higher than those of co-generated electricity and heat, the question of levelling the playing field may require adaptations of some regulations in order to reflect the environmental advantage of CHP and related district heat networks.

During the first period of liberalisation, the intensive competition among electricity suppliers may also lead to a closing down of industrial CHP and, hence, cause stranded costs. On the other hand, the falling price of natural gas may limit these negative implications.

CONCLUSIONS

Whether the policies for more efficient heat use, co-generation, CHP-based district heat and solar thermal energy imply conflicting objectives cannot be answered in quantitative terms. But the substantial differences in the present use of CHP in the different member countries and existing low-energy settlements supplied with small co-generation units suggest that there seem to be substantial efficiency potentials for both heat demand and heat supply by co-generation, particularly in those member countries where co-generation has small shares in the total electricity supply.

It cannot be excluded that former monopolies of electricity supply will try to hinder co-generation investments in industry and the tertiary sector. There might, therefore, be a need to re-regulate markets to some degree at the EU or national levels to avoid such market imperfections. Such a regulatory approach may be of special importance during the first period of liberalisation, i. e., during the next half decade when surplus capacity of electricity and gas will be offered to customers in a very competitive environment before new market structures emerge at the end of the next decade. At that point in time, the question of conflicting objectives with regard to efficient heat use, co-generation and thermal solar energy may have become more pressing. The answer is likely to depend to a large extent on further commitments of the EU in the climate change policy process with regard to the year 2020.

7.3 RESOURCE-EFFICIENT TECHNOLOGIES AND ENERGY SERVICES AS A ROUTE TO STRENGTHEN COMPETITIVENESS

This section attempts principally to examine the role of resource-efficient technologies in strengthening the economy and as a stimulus to foreign trade, both of which are linked to employment.

ENERGY SERVICES AND RESOURCE-EFFICIENT TECHNOLOGIES

Increased competition following the liberalisation of the EU gas and electricity sectors is widely expected to take the form of price competition based upon bulk 'commodity' kWhs - at least initially (see Chapter 6.3). However, liberalisation will force suppliers to become more consumer-orientated, to increase marketing and sales activities, and to develop a range of services to retain the loyalty of existing customers and attract new ones from rivals. It is the derived character of energy demand that provides the intellectual rationale for the development of a widening range of such services. Consumers do not require electricity or gas: they do require process heat, light, cooling, cooking, communication, movement and motor power. Such services can take many forms:

- *Multi-utility services*: provision of more than one utility service to exploit economies of scale and scope, such as dual-fuel (gas and electricity); or either/both of these combined with water, district heat, or telecommunications.
- *Contracting*: (or building and facilities management): usually restricted to larger commercial and industrial consumers including provision of surveys, audits and best-practice bench-marking; installing, commissioning and operating CHP or other energy-intensive off-sites and facilities; competitive energy purchasing; provision of finance.
- *'Active' energy services*: consumer- and household-specific energy advice and audits; more efficient appliances, metering and control technologies; and (as required) the necessary finance to provide these for smaller consumers.
- *'Passive' energy services*: generalised advice on energy efficiency via telephone call centres and mailing shots, with utility bills or via libraries, post offices, exhibitions, conferences etc. This may be mandated in licences, or regarded as good business practice, although less practised in liberalised markets.
- *Non-energy services*: billing and meter reading frequencies; aggregation of accounts (e. g. for a chain of shops); bills for minority languages; special services for the blind and physically handicapped. Most of these are mandated in utility licences, or covered by good business practice.

Given the derived character of energy demand and the anticipated low growth in basic gas, electricity or district heat sales in heavily saturated EU markets, utilities (or other suppliers) will need to think of innovative ways to increase sales revenues and corporate profitability. The provision of 'active' energy services is clearly one such route to further business evolution and growth. However, as yet, this study (see Volume 12) has found little evidence of their emergence in practice. Further work, funded jointly by the Directorate General for Energy and Eurelectric, is now in progress to explore these issues with a range of utilities, regulators, consumer groups and other stakeholders.

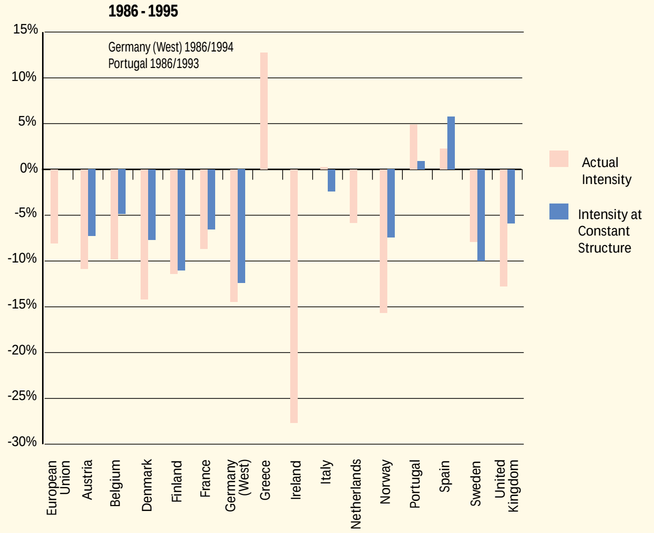
Similarly to the emerging concept of energy services, even if they are more mature, the definition and characterisation of energy-efficient technologies are not definitively consensual. Comprehensive lists of these technologies are available through national studies (e. g. IKARUS in Germany, Icarus in the Netherlands) or at the EU level (Atlas). In this section, the emphasis is on end-uses technologies, even though they are often less well documented than energy supply technologies (see also sections 7.1. and 7.2).

IMPORTANT ENERGY EFFICIENCY IMPROVEMENTS HAVE BEEN ACHIEVED IN EUROPE

The ecologically beneficial role of energy efficiency is widely accepted today. Whatever the level of analysis taken (macro, sectoral or by energy equipment and products), the assessment of the past achievements of energy efficiency trends clearly shows that EU countries have drastically improved their performances at the end-use level. The final energy intensity (final energy consumption per € of GDP) has decreased by 1.5 % annually or more over the period 1973-1997. Except for a few countries (Italy and Spain), structural changes (tertiarisation of the economy: more services and less energy-intensive industrial production) account for at least 10 % to 25 % of this improvement (Figure 7-3). Most of the gains stem from improved efficiencies in equipment and products (see examples for steel production in Figure 7-4, cement production in Figure 7-5 and for cars in Figure 7-6).

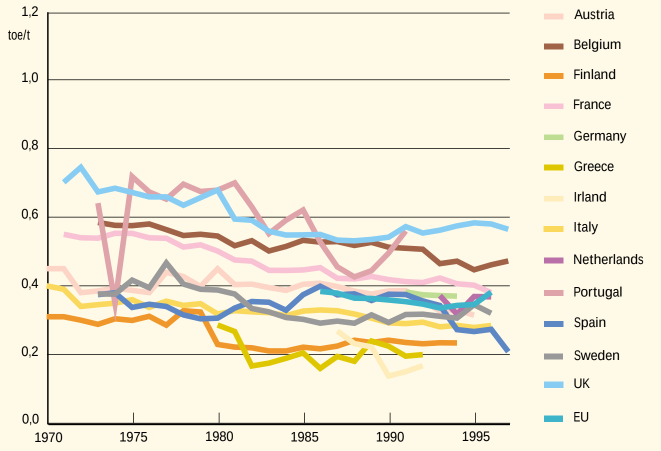
Nevertheless, since the 1986 counter oil shock, behavioural changes have lowered the pace of improvement and have sometimes reversed trends. This was mainly due to the combined impacts of energy price drops, the slowing down of energy efficiency policies and economic slow-down in Europe. In addition, results were more significant in energy-intensive industries and the residential sector (thermal regulation in new buildings) rather than in transport (despite huge technological improvement) or services. Nevertheless, recent trends reveal a revival of energy savings as a result of recent initiatives linked to the climate change policies in the Member countries.

Figure 7-3: Progress of the Final Energy/GDP - ratio of Western European Countries, 1986 - 1995



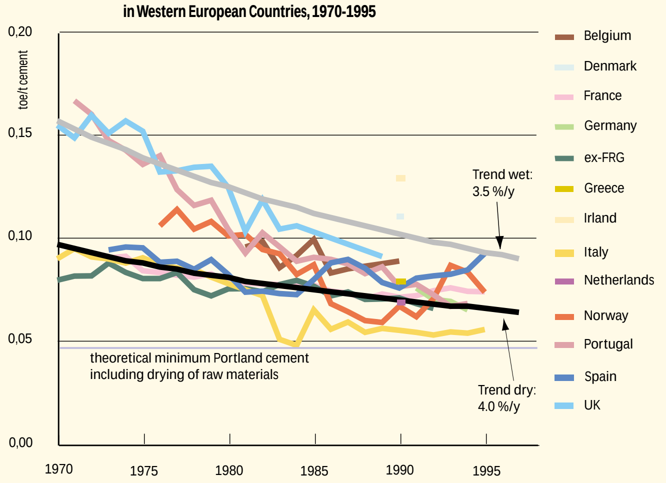
Source: ODYSSEE-SAVE Database

Figure 7-4: Specific fuel consumption for steel production in Western European Countries, 1970-1995



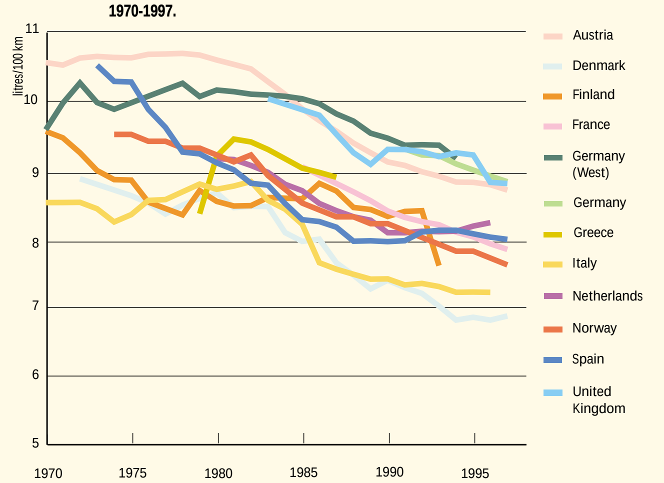
Source: ODYSSEE-SAVE Database

Figure 7-5: Specific fuel consumption for dry and wet cement production in Western European Countries, 1970-1995



Source: ODYSSEE-SAVE Database

Figure 7-6: Specific fuel consumption of the car stock in Western European Countries, 1970-1997.



Source: ODYSSEE-SAVE Database

ENERGY-EFFICIENT TECHNOLOGIES AND ENERGY SERVICES SPUR ECONOMIC GROWTH AND STRENGTHEN ECONOMIC COMPETITIVENESS

The beneficial economic effects of energy-efficient technologies are still not well-analysed either at macro or micro levels. At a first glance, national or international studies show that a huge technical energy efficiency potential still exists. Nevertheless, the doubt about the possibility of exploiting this potential economically still remains, reflecting a lack of understanding about the possibilities to reduce existing obstacles and market imperfections as well as costs by learning and economy of scale effects in the future.

Making new environment and energy technologies available is an important factor in industrial competitiveness. Nevertheless, for most advanced technologies, it is hard for businessmen to assume these cutting-edge technologies alone, given the technological risk and time required for their integration into industrial or commercial applications: pre-competitive status, generic research, often federating a range of partners, dual focus on basic and industrial research to name the most important problem fields.

The situation of energy-efficient technology suppliers is obviously very diverse, depending on the *maturity of the market*, the *nature of public policies* and *contextual conditions*. One of the main features of this emerging market is that part of its development is sustained by public policies as can be seen in the following examples :

- thermal building regulation requires more insulation products and intelligent building design;
- emission standards lead to clean cars, improving the competitiveness of car makers, automotive equipment manufacturers and providers of transportation alternatives to road vehicles;
- most household appliances are subject to highly inflexible production constraints and conditions of economic profitability that make any evolution difficult, outside regulatory measures and energy labels. More stringent regulations of the energy performance of electrical equipment in households and offices, would create conditions for a broad distribution of high-performance appliances and equipment;
- tariff structures determine co-generation or renewable markets which show huge differences in the share of co-generated electricity (Finland/France) or of wind-energy based electricity (Denmark/Sweden);
- financial incentives for initial consulting, voluntary agreements, technological procurement or energy taxation could accelerate the replacement of inefficient equipment.

The market development of efficiency investments also depends on *sectoral policies* in favour of the construction sector (both new building and retro-fitting work), of small and medium-sized companies or

TABLE 7-2: PRESENT (1995) AND FUTURE (2010) MARKETS AND ENERGY SAVING POTENTIAL AT EU AND WORLD LEVELS

Technology areas	Parameter	EU market (1995)	World market (1995)	EU technical potential (2010)	World technical potential (2010)
Insulation	**M€/a sales**	**3,000**	**25,300**	**90,000**	**925,000**
	Indicative Mtoe/a saved	46.6	229.0	101.2	1,030.0
Glazing	**M€/a sales**	**10,500**	**87,000**	**20,200**	**140,000**
	Indicative Mtoe/a saved	19.1	93.2	39.4	334.4
Lighting	**M€/a sales**	**443**	**3,029**	**8,500**	**61,000**
	Indicative Mtoe/a saved	0.5	3.1	12.1	86.0
Heating and cooling	**M€/a sales**	**1,524**	**5,700**	**5,850**	**40,000**
	Indicative Mtoe/a saved	8.2	31.1	31.5	2,221.7
Building management systems and controls	**M€/a sales**	**1,600**	**13,500**	**17,000**	**231,000**
	Indicative Mtoe/a saved	2.2	11.5	23.8	168.4
CHP	**M€/a sales**	**3,500**	**70,500**	**13,200**	**255,000**
	Indicative Mtoe/a saved	5.3	107.5	25.0	482.6

Source: Atlas Project, European Commission 1997a

of information and telecommunication as infrastructure of an economy. The effectiveness of these policies depends partly on the consumer's preference for such products or services. As far as the penetration rate of efficiency products into the market increases and the liberalisation of the energy market becomes a reality, these factors will influence the above-mentioned development of the energy system in a complex manner.

ENERGY EFFICIENCY SPURS ECONOMIC GROWTH

Whatever the reasons for this market development and the specific efforts made by public authorities to sustain a competitive, empirical studies show that the level of production of situation of energy efficiency products is growing very rapidly - more rapidly than that of the average sector of equipment goods or consumption goods in general. This is not surprising due to the fact that this production follows a typical take-off phase of a logistic development curve at low levels of the total market. However, one could argue that this market is far from being negligible. For instance, the construction sector constitutes the second largest sector of activity in Europe, after the industrial sector. It has experienced massive job losses in the last few years due to a decline in new construction and renovation work. During the same period, repairs and maintenance (including both major repairs and routine maintenance), accounting for 53 % of activity, have come to present the bulk of work in the construction sector. The overall market in France, for example, of efficiency products and labour in the residential sector is estimated at 5 billion € in 1992 and the domestic market of 16 energy efficiency products amounts to 2.5 billion € in 1998.

Similar results have been found in other Member Countries; for instance, the production of 12 energy efficiency products in Germany (burners, boilers, double/triple glazing, heat exchangers, control equipment for efficiency) has increased 50 % above the average of total industry production since 1976. Or over the period 1990-1998, the production growth of the energy efficiency goods grew substantially faster (29 %) compared to the equipment goods branch (16 %) and of the production growth of industry (11 %) in France.

The market for energy efficient products in the building sector was estimated by the Atlas Project (European Commission, 1997a) to be of the order of 20 billion € in 1995 (see Table 7-2), while the world market for these products was about ten times larger. Derived from a technical potential, the market estimate for 2010 was more than seven times the 1995 markets on both the EU and the world level.

What has been observed for energy efficiency products can also be said for products or investments taken in a broader sense of ecological products and services. The world-wide market for environment-related investments represented a turnover of 400 billion € in 1994. It also shows that the prospects for market growth outside Europe are very high. The turnover and the market growth potential is concentrated in non-EU countries. Although in OECD countries, the growth rate is around 4 %, but reaches 17 % in Asia and 12 % in South America.

Improved energy efficiency helps to spur economic growth by cutting waste, and cutting energy costs. Business can introduce products or services on to market with less investment in fuel and electricity. The consumer spends less on fuel or environmental protection costs, but more on investment or maintenance. But as long as the efficiency investment is economical, the energy consumer saves net energy costs. These savings may be spent by the companies to expand the markets, or by the private consumer to pay for other goods and services. The economic gains are modest, generally visible in the longer term, but not negligible.

Business increasingly sees addressing environmental concerns as a vital competitive advantage. Nevertheless, quantifying the exact economic growth generated by energy efficiency is difficult, if not impossible, because energy efficiency is part of complex production and consumption processes. Decision-making is more and more a multi-criteria process, for instance, in new or improved industrial processes which can also be more efficient in terms of labour, capital, environment, new materials or quality products. The production of manufactured goods, using raw materials and energy, engenders polluting discharges and wastes. Thus, it becomes more and more difficult to distinguish the savings from improved energy use from all other net savings of resources, labour or capital in cases of process or product substitution.

ENERGY EFFICIENCY TECHNOLOGIES AND RENEWABLES PARTICIPATE TO IMPROVE THE TRADE SURPLUS

Most *energy conservation products* are manufactured domestically; they are all planned, installed and maintained locally. Thus, improved energy efficiency helps to stabilise the balance of foreign trade. Nevertheless, this reasoning should be elaborated on slightly depending on the type of products. For instance, office equipment, electronic and household appliances and lighting fixtures which are nationally marketed are produced by multinational corporations sometimes located outside Europe.

The export of energy saving products tends to exceed the average growth for exports as a whole. In West Germany, exports of 12 energy saving products have increased by 8.3 % per year since 1982 - about twice as fast as all exports of industrial products, which increased by almost 4 % per year. Between 1992 and 1994, the trade surplus of energy efficiency capital goods more than doubled from 170 million to 360 million €.

Renewables have a natural place in the perspective of sustainable development with little or no emission of pollutants and limited local environmental impacts. European suppliers have been similarly successful in net exports of technologies using renewable energies, enhancing the reliability of components and systems, elaborating first standards and quality assurance systems. They can then take advantage particularly of the third world market, if a range of products adapted to particular climates or to foreign-made equipment can be supplied. European manufacturers may make a transition from a niche market strategy to volume strategies in the near future for some technologies.

EFFICIENCY TECHNOLOGIES AND THE USE OF RENEWABLES IMPROVE THE IMPORT ENERGY BILL AND OTHER MACROECONOMICS INDICATORS

Countries which are net importers of energy can substitute domestically-produced efficiency goods and services for imported energy. All the benefits of a greater balance of trade accrue to countries that practise energy efficiency: reduced inflation, improved competitiveness, investment in research and development, and more control over prices. Lowering energy costs also enhances the competitiveness of energy-intensive products. This is particularly true for products which are easily tradable and have a relatively high value-to-weight ratio such as steel, primary aluminium etc. Improving energy efficiency in the production of these energy-intensive products reduces vulnerability to energy price increases.

The share of energy costs in gross production in West German raw material goods, for instance, dropped from 6.1 % in 1982 to 3.1 % in 1997. The share of the energy cost of the cement production dropped from 31.7 % in 1981 to 14.4 % in 1997, of iron and steel from 13.4 % to 10.6 %, of pulp and paper from 11.8 % to 8.1 % and of the chemical industry from 5.9 % to 3.4 % respectively.

IMPLICATIONS ON EMPLOYMENT

Improvement in competitiveness and foreign trade may induce job creation. In fact the positive gross employment effects induced by energy efficiency improvements must be considered against the counter-balancing negative employment effects because consumers need less energy. Generally speaking, the balance still swings in favour of a positive outlook for of creation in the order of some 3500 new jobs per Mtoe saved.

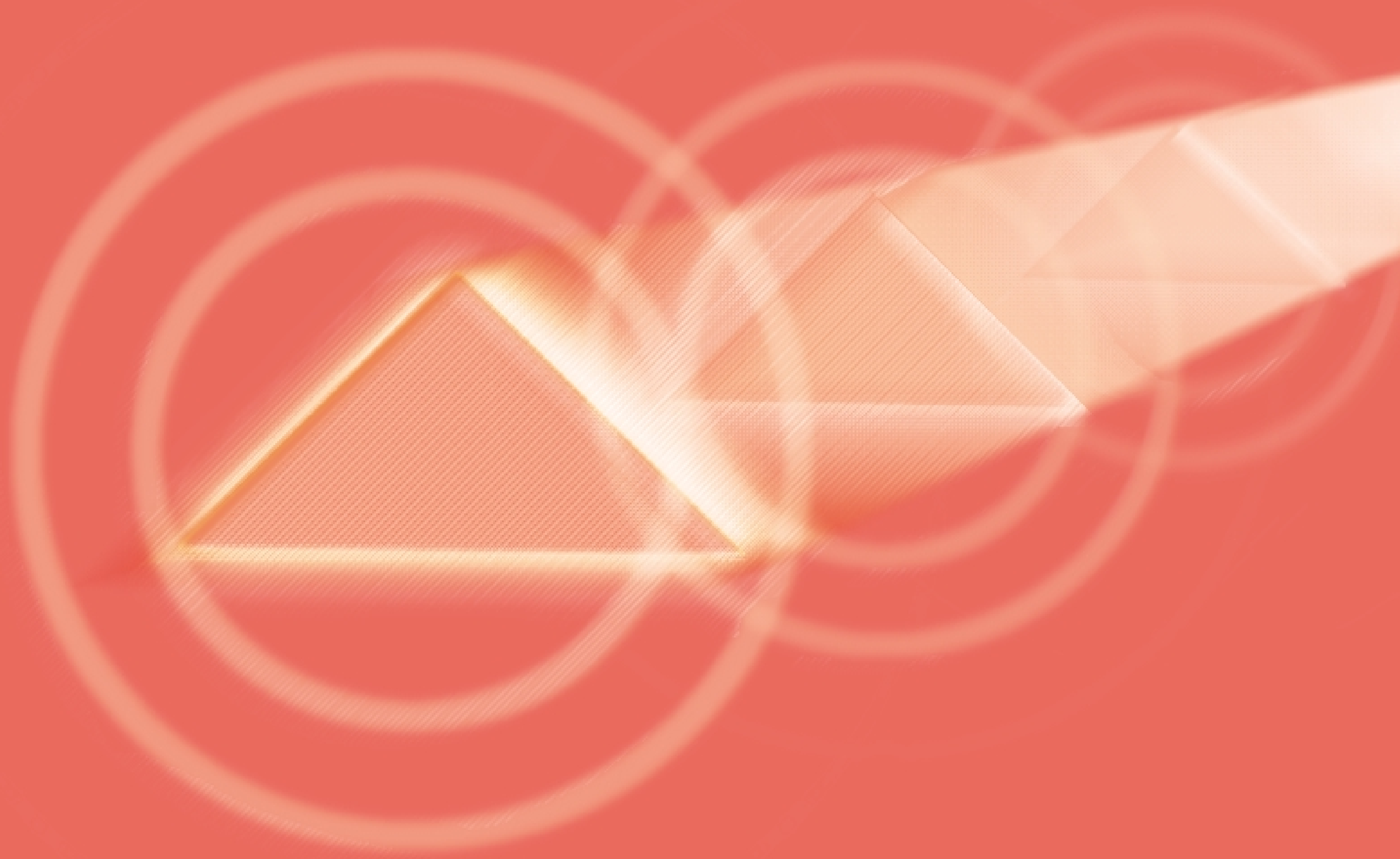
New jobs have been created not only in the manufacturing industry but also in the building sector, in installation, planning, maintenance, consulting and other services. The level of job creation depends on the amount of reduction in energy imports, labour-intensity in industries benefiting from energy savings, the degree of reduction of energy costs, which depends on the profitability of energy efficiency investments.

Along these lines, energy efficiency and the use of renewables could positively contribute in reducing today's unemployment. Clearly, the characteristics of job creation induced by energy efficiency are different from the energy supply side. They are mostly concentrated on the investment period. The changing time scale of job creation is apparent. An analysis made of the future of six key energy efficiency technologies, suggested that energy efficiency related jobs are also more evenly distributed within a country than jobs depending on energy supply.

CONCLUSIONS

Experience with energy efficiency shows that it serves all four macro-economic goals: employment, economic growth, well-balanced foreign trade, and price stability. This may occur if obstacles are removed and market imperfections are alleviated. This development has been observed in the last two decades in several Member States - and is likely to continue if governments and companies search to overcome existing barriers and market imperfections and to take advantage of present and future opportunities.

PART VIII THE WAY FORWARD



Given the long-term challenges and related policy issues described in Chapter 6 and 7, but also the principle of subsidiarity, the analysis suggests that the tasks of the Community's energy policy will increase; and that the Community may pursue a broader political approach in the next decade than in the past:

- International and diplomatic activities will be intensified, in particular as regards co-operation with energy-producing countries and in the negotiations on climate change policy (see Chapter 8.1);
- There are possible threats and opportunities for EU energy policy such as shocks or surprises in energy markets, the need to regulate the boundary conditions of liberalised energy markets, or the full exploitation of energy efficiency potentials to minimise conflicting objectives of energy policy (see Chapter 8.2);
- Conflicting objectives and their perhaps complex solutions require more emphasis upon developing a consistent and transparent policy framework; and broader policy co-ordination and integration (see Chapter 8.3);
- Finally, Chapter 8.4 summarises some proposals for the EU's energy policy role taking into account new challenges and the principle of subsidiarity.

8.1 PROMOTING THE ROLE OF THE EUROPEAN UNION IN THE INTERNATIONAL ENERGY FIELD

In the global context, the European Union is using its economic influence to ensure its interests with respect to energy supplies given the projected rise in import dependence. This includes developing its own proposals with regard to the oversight of the common assets of the planet, such as stability of the climate.

8.1.1 ADDRESSING EXTERNAL ENERGY POLICY ISSUES

As stressed earlier, a major challenge could be the re-emergence of security of supply on the energy policy agenda. With a dependence of 90 % in oil imports and 55 % in gas imports foreseen by 2010, the European Union will have to give more importance to energy issues in its relations with the rest of the world. But the globalisation of oil markets, the future liberalisation of the European gas markets, and the new international geopolitical context create a context significantly different from that at the time of the 1973 and 1979 oil shocks. Competitive markets provide greater flexibility and adaptability; and new market arrangements, such as spot and derivatives markets, reduce the risk of pervasive oil market control by a group of sellers. However, the analysis suggests that energy supply security issues should be kept under regular review.

The progressive emergence of the Common Foreign and Security Policy may well influence the geopolitical situation over the next decade. Since this policy is likely to concentrate initially on ensuring wider regional stability, this analysis suggests it could perhaps usefully focus on the security of gas supplies from large exporters on the European periphery; and then on means of securing world oil supplies in close co-operation with the United States.

The current, limited mechanisms for projecting external energy policy, and the globalisation of markets, means that action by the European Union is currently conceived as an indirect action; and, essentially, involves relying on market mechanisms or by integrating the objective of energy security into broader policies for foreign co-operation. Some of the response options to 'internal' EU strategies are well-known. These include the search for greater flexibility from the development of short-term markets, encouraging closer integration of national energy markets, and strengthening the physical links (pipelines and grids) between Member States.

8.1.2 ASSUMING A LEAD ROLE IN CLIMATE CHANGE NEGOTIATIONS

In the continuing international negotiations on climate change, the European Union is playing a leading role, especially by maintaining its position as regards the necessity to act effectively to mitigate this threat to the world environment. Importantly, the EU governments share common views on the need for the precautionary principle. The perceived costs of meaningful, and cost-effective, efforts to reduce the risks of climate change should not be viewed as a justification for delay in formulating a response strategy. This is because of the potential importance of the risks and the long lead-times necessary to put responses in place. The Member States are also agreed on the moral imperative that industrial countries should actively reduce their own greenhouse gas emissions.

The European Union has the opportunity to act in such international negotiations. The Single European Act of 1986, which confirmed the important community-wide status of environmental issues, has established an effective institutional authority for the Community on these issues. Accordingly, the Community is a signatory to the Framework Convention on Climate Change. Moreover it is well-recognised that global environmental issues cannot be addressed by national administrations exercising sovereignty and by operating alone. As a result, the European Union is acting as a coalition of countries which have agreed internal compromises, such as 'burden-sharing', despite the inherent complexities of policy-making which make such initiatives difficult.

The European Union has thus been able to exert effective influence in the course of the global environmental negotiations that led to the agreement on quantitative mitigation commitments. It was under its influence that the Berlin Mandate of 1995 recognised the limitation of Annex 1 parties' commitments; that the United States was obliged in 1996 in Geneva to accept the binding character of these commitments; and that the Kyoto Protocol in 1997 included quantitative commitments after the European announcements of reduction goals. Since Kyoto, in the complex negotiations on the flexibility mechanisms, the European Union has also sought to defend its conception of equity by seeking to limit the scope of these mechanisms through the proposed ceilings.

An important dimension of the diplomatic role of the European Commission is to promote the position of the European Union in the definition of greenhouse gas trading schemes and the Clean Development Mechanism. Within the logic of this international position, both the Community and its Member States must provide themselves with the means of fulfilling as much as possible of their Kyoto commitments by 2008-2010 to ensure credibility in the next COP negotiations. Together with the common policies and measures co-ordinated by directives or recommendations (directives on renewables, promotion of co-generation, energy efficiency, transport, etc.), the reconsideration of the European proposals to tax energy and abolition of the tax exemption on aircraft fuel would allow the consolidation of national incentive schemes through tax. In addition, the Commission should seek to facilitate the development - and the supervision - of the frameworks required to establish effective permit markets between and within countries.

8.2 POSSIBLE THREATS AND OPPORTUNITIES FOR EU ENERGY POLICY

The past three decades have witnessed huge somersaults in conventional wisdom about energy market prospects. The 1960s were characterised by discoveries of large oil reserves, falling real oil prices, high economic growth, rising real incomes and surging ownership levels of appliances and vehicles. This complacency was shattered by the two oil price shocks of 1973/74 and 1979/80. These led to huge deflationary pressures, recession, growth in unemployment, balance of payments difficulties and disruption of global financial markets. Since the fall in oil prices from 1986, international energy markets have been more relaxed. Much indigenous, high-cost energy capacity has been closed in the EU and elsewhere.

Given the comparative tranquillity of international energy markets, the supply security concerns of the 1970s have diminished. The period since 1986 has provided an opportunity for governments to withdraw somewhat from detailed oversight of energy markets; and has witnessed the moves to liberalise and to privatise the energy sector. Effective liberalisation has yet to commence in some EU markets. Whilst continued oversight of progress is required by the Commission, it is unlikely that liberalisation will exercise such dominance of policy agendas in future. On the other hand, concerns about sustainability have grown. Given the expectation of lower real energy prices in particular, this suggests that policy may need to intensify. This is essentially because liberalisation is intended to exert downward pressure on costs and prices. Yet these lower prices are widely expected to reduce market-based incentives for greater energy efficiency and wider deployment of renewable technologies. In addition, policy could aim to exploit the opportunities provided by new, more efficient, and cleaner technology in both home and export markets - providing important benefits in terms of competitiveness and employment.

The focus of this Report is primarily on the period to 2020. Shocks and surprises are inherent in energy markets. Indeed, during the course of the Shared Analysis project, the world crude oil price has fallen from US$20/barrel to US$10/barrel and risen again (in early October 1999) to some $23/barrel. Since its launch in January 1999 the Euro has also fallen slightly against the dollar, in which oil prices are denominated. Thus, in Euro terms, oil prices have risen somewhat further. Of one thing we can be certain. Further shocks and surprises will occur over the next two decades. Should any consensus or conventional wisdom about the future emerge, it is most likely to prove wrong in both substance and detail. This places a premium on monitoring emerging energy market trends, high quality research, and flexibility in policy making.

On the other hand, despite these uncertainties, decisions still have to be made – whether by energy suppliers, energy users or policy makers. The energy system is characterised by long investment lead times, by huge sunk investment in equipment and infrastructures and by long-term contractual relationships. Key requirements, therefore, are clear and consistent policy frameworks, and the measured introduction of new policies.

8.2.1 SOME REALITIES FOR POLICY MAKING

As this analysis has revealed, global energy resources are highly concentrated. The Middle East accounts for two-thirds of proven oil reserves. Together with Russia, the Middle East also accounts for some 70 % of proven global gas reserves. Particularly for the EU, import dependence for oil and gas will increase to 2020. Coal reserves are somewhat more evenly distributed, but the largest deposits are in China, Russia and the USA.

Whilst proven reserves of fossil fuels are immense – even at the lower real prices now projected – so is the rate of consumption. But some 90 % of current global oil production is from fields more than 20 years old, and some 70 % from fields over 30 years old. These geological realities imply that supply security concerns should assume a higher priority, particularly given the EU's increased import dependence over the next two decades. This growing import dependence arises from gradual depletion of North Sea oil and gas reserves, the phasing out of high-cost EU coal production, and the progressive retirement of existing EU nuclear capacity over the period to 2020. New and renewable energy technologies will seek to penetrate (with some difficulty) newly-liberalised markets with lower real energy prices, greater market risks, higher discount rates, and shorter planning horizons.

World energy consumption is dominated by the three fossil fuels – oil, coal and gas – with a combined share of 80 % in 1998, the remainder being nuclear and hydro-electricity, biomass (such as wood) and other renewable sources (non-commercial energy excluded). Similarly in the EU, fossil fuels also comprise 79 % of energy supplies in 1997, with 15 % from nuclear power and 6 % from renewable sources (hydro-electricity, biomass and wind). For the foreseeable future, global energy consumption will be heavily based on fossil fuels. Any transition away from fossil to renewable or nuclear energy sources will take very many decades. Given growth in energy demand, and planning and construction lead-times, even a shift of only 5 % from fossil to non-fossil fuels is likely to take well over a decade to achieve at the global level. The feasible pace of change may thus be quite slow, even if all appropriate policies are in place.

Whereas the developed, industrialised OECD countries accounted for 60 % of total world energy consumption in 1974, this share fell to under 50 % in 1996. It will now continue to fall steadily. Energy demand growth has declined since 1990 in the Former Soviet Union as a result of economic and political dislocation. It may remain at lower levels, even with economic recovery, given structural adjustment from heavy industries and the huge scope for replacing inefficient capital stocks. On the other hand, energy demand growth has been rapid in Asia and South America – at least until the recent economic dislocations.

Satisfaction of even basic human needs will lead to substantial growth in global energy demand. Recent projections from numerous agencies anticipate growth in global energy demand (depending upon assumptions) of some 50-80 % by 2020 compared to 1990. Most of this incremental energy demand growth will occur in developing countries as they industrialise and expand private transport. However, even by 2020, per capita energy consumption will still vary markedly between countries; and, on average, consumption in most developing countries will be well under half that in Europe.

The consequence of these factors is that global environmental impacts deriving from the global energy system will increase in any 'trends continued' or 'business as usual' case. There is a danger that such environmental impacts might, perhaps, be too narrowly equated with CO_2 emissions and the debate about global warming. Other environmental impacts arising from the energy sector include noise, visual intrusion, facility land use, transmission lines, oil spills, waste disposal, other gaseous emissions (e. g. resulting in acid rain and ozone depletion); plant decommissioning, especially of older nuclear reactors and off-shore oil rigs; and high pollution levels in giant urban concentrations. Environmental policy responses require a broad front. Yet the responses so far proposed by the EU and the rest of the industrialised world fall short of those required to stabilise emissions or to address other environmental challenges.

In the OECD countries, at least, acid rain issues are being tackled largely via the twin routes of fuel switching (away from coal) and 'end of pipe' technologies such as Flue Gas Desulphurisation (FGD). Global warming presents far more severe challenges. Unlike the responses to acid rain, ozone depletion and atmospheric lead, there are no known easy 'technical fixes' to reduce global CO_2 emissions. This is because this gas is emitted whenever fossil fuels are burnt. The well-established options available within the energy system to curb global greenhouse gas emissions, especially CO_2, are:

- Lower energy demand growth through much enhanced energy efficiency efforts, including improvements to supply-side conversion and transmission of primary fuel inputs in power stations, grids and refineries. However, the major contributions from efficiency arise in end-use applications such as buildings, electric motors, lighting, appliances, vehicles and changing transport modes (from private to public provision); and
- Switching to less polluting fuels in two ways. In the medium term (say over 20 years) switching within the fossil fuels from coal towards natural gas (natural gas is hydrogen, not carbon, rich); and, in the longer term, away from fossil fuels to renewable energy sources and to nuclear power (should the latter option finds favour with public and political opinion).

Carbon emission targets introduce a new dimension to the debate. Given the current expectation of lower real energy prices, unless Governments have some additional policy levers to influence energy consumers, they may be powerless to deliver their evolving international commitments to 2010 and especially to 2020. The intensity of policy intervention – especially in liberalised markets – will need to increase, not diminish. Yet it is not clear that this paradox is sufficiently appreciated by policy makers.

At the heart of this debate is the term sustainability itself. In essence, the dilemma to be faced can be stated quite simply: how to give greater weight now to the future. Issues of sustainability impinge on inter-generational equity. It may not be in this generation's interests to respond sufficiently, or sufficiently rapidly. This generation may well have 'no regrets'. But future generations cannot be consulted. To economists, the cost of capital and the appropriate discount rate are central in this context. If consumers continue to use high discount rates (or seek short paybacks, typically of 2-4 years) for energy efficiency investments, it is most likely they will make inaccurate assessments of the present values of both costs and benefits. These paybacks on the demand side remain considerably shorter than those sought on the supply side. Thus, despite the preference for market-based instruments (such as energy or carbon taxes), a judicious mix of 'sticks and carrots' is likely to lead to more socially optimal decisions. All investment in new energy supply capacity attracts investment allowances against tax, but only some investment in energy efficiency is similarly assisted (e. g. not usually in the public sector or in households). As a result, least-cost solutions may not be readily identified. This illustrates how policy responses should be developed across a wide front using numerous policy measures.

This requires much greater imagination in the development of portfolios of policy instruments, some of which should be targeted at specific sectors and groups of end users. It may also require more flexibility in public accounting conventions than has been seen to date. This includes greater willingness to 'ring fence' (or hypothecate) taxation and to direct revenues via incentives and subsidies. For example, private motorists may well be more convinced of the case for higher road fuel taxation if it is clear that some of the incremental tax revenues will be used to improve public transport. Levies and taxes on industrial fuel use will probably be more acceptable if they are used partly to increase grants and tax relief to stimulate more efficient energy use. Such an approach is more likely to be acceptable to energy-intensive users than the use of such tax revenues to reduce labour taxes. This is because energy-intensive users also tend to be capital intensive, with small labour forces.

Energy efficiency incentives for the domestic sector need special attention. This is because increased competition from liberalised energy suppliers focuses almost exclusively upon price competition. Yet lower real energy prices provide a difficult platform from which to argue for more responsible energy use. Reconciling the effects of liberalisation with concerns about environmental protection and sustainable development could prove more difficult than many suggest. Without measures such as active energy services, minimum energy efficiency standards, levies and taxes, and well-targeted capital allowances, it appears most difficult to resolve this policy conundrum.

8.3 THE NEED FOR EFFECTIVE POLICY INTEGRATION

8.3.1 THE CHANGING MARKET AND POLICY CONTEXT

Earlier chapters of this Report have identified the need for policy intervention and integration at various levels. Here we draw together some issues which warrant more consideration by policy makers when shaping appropriate response strategies.

The process of liberalisation, and the impacts of greater competitive forces in energy markets, will result in profound changes. It is difficult to assess these changes at present. They include changing relationships with customers; industry financing; technology choice; funding of RD&D; new regulatory regimes; corporate realignments and restructuring; and the forging of quite new relationships (especially for formerly nationalised companies) with governments, and fuel and equipment suppliers. For many companies – and their newly-liberalised customers – these changes are without historic precedent. They represent a new order and a 'brave new world'. This new order will create – in quite unforgiving ways – both winners and losers. Anticipating the consequences of these changes is dominating much corporate and government thinking, as well as that by the consumer, financial, environmental, trades union and academic communities. Liberalised markets may need to be guided by appropriate policy frameworks. The key questions are why, when, where and how is any intervention justified.

At the same time, another demanding and unprecedented set of issues also requires resolution. These relate, first, to defining more sustainable pathways to development in the next century, and, second, to devising means to re-align liberalised economies towards these pathways. It is this confluence of these two huge policy agendas which lies at the heart of this Shared Analysis project and this Summary Report, and which, in many crucial ways, determines the core messages for policy makers.

These two dominant shaping and driving factors for the energy system – market liberalisation and sustainable development – need not always be in conflict. But it is idle to pretend they will not greatly influence the future agendas of policy makers. To take but one example: consumers in the more liberalised energy markets of the EU are receiving tens of competing offers for electricity, gas and dual-fuel supply. All announce that prices for these 'new commodities' have fallen; and will fall further. But, policy makers and analysts argue that 'business as usual' – and, especially, 'business as usual with lower real energy prices' – will not be consistent with sustainable development. A more consistent course must be steered. Thus the first targets for integration by policy makers should be reconciling market messages and policy messages.

Many desirable developments will flourish in more competitive markets which stimulate creativity and innovation in individuals, social attitudes, corporate thinking and new technologies. But, at present as liberalisation unfolds, uncertainty about the speed, and especially the benevolence, of such developments is immense. It is only when a view on these is taken that the form, extent and rigour of further policy and regulatory intervention can be assessed. Those who have unlimited confidence in market forces will see little need for re-regulating newly-liberalised markets. Others, for whom sustainable development is an absolute imperative, will wish to reinforce market messages with substantial policy resolve.

It is likely that new, more demanding, targets will be set early in the next decade to maintain momentum towards sustainability. Thus time is unlikely to befriend the policy maker. The EU and its Member States made binding commitments at the Kyoto Conference. Since then, Member States have allocated these commitments between themselves via the 'burden sharing' process. These must be delivered within a single decade – the Kyoto commitment period of 2008-2012. Whilst current commitments might appear tough, they will become progressively more difficult in future.

Whilst time is no friend, luck has been kinder. Large volumes of relatively cheap natural gas are available in, or near, the EU. New technologies, especially the Combined Cycle Gas Turbine (CCGT), are available. An important contribution towards the Kyoto commitments can be expected from utilising this natural gas in high-efficiency generating plants. This process commenced a decade ago and, as this Report highlights, will accelerate over the next decade. Power generation absorbs about one-third of EU and global primary energy demand and is thus a key 'swing' sector in the adjustment process. To this extent, liberalisation, and the 'dash for gas', are consistent with sustainable development and the Kyoto commitments. Whether such heavy dependence upon increasingly-imported gas is sustainable for more than 1-2 decades is at present a moot point. Post 2010-2015, the electricity sector's contribution will become less obvious, as by then its carbon intensity is projected to increase.

8.3.2 POLICY CO-ORDINATION

Other market-driven developments, such as more efficient appliances and further structural change away from energy-intensive heavy industry, are also projected to be consistent with sustainability and Kyoto imperatives. However, in most other areas – and especially in end-uses such as transport – markets and policy imperatives will not be easily reconciled against a background of lower real energy prices. As a result, a key message of this Report is that policy makers must now place much more emphasis upon developing a consistent and transparent policy framework to achieve the targets and the multiple policy objectives they have set. This requires a clear rationale; sustained political will over many decades; fair allocation of responsibilities – by country, agency, fuel and sector; effective policy co-ordination; prompt reconciliation of 'market' and 'policy' messages; simple but consistent signals to the energy system and final consumers; and a wide range of publicly-acceptable measures. Target-setting policy makers must close the 'logic loop' between the commitments they have agreed at Kyoto (and elsewhere) and the weaker market-based incentives likely in a period of lower real energy prices. Their targets, their policies and, above all, their progress will be subject to intense scrutiny.

The Kyoto commitments are primarily those of the Member States who agreed to them as signatories to the Protocol. Following political agreement to the Electricity and Gas Directives, the responsibility for monitoring and enforcing Member State compliance with these directives is that of the Commission. Other roles, in supply security, diplomatic dialogue, RD&D, employment, social cohesion, environmental protection, etc are increasingly shared between the EU and Member States following the Amsterdam Treaty. This will require greater co-ordination of efforts by Member States and the Commission; and between different Commission services.

As stated earlier, the need for such co-ordination increases as the policy response focuses less upon the narrow energy 'sector' and much more upon the wider energy 'system'. Crucial policy frameworks, such as those for economic and environmental regulation, the fiscal regime and the scientific and technological base, must be integrated. Policy integration will severely challenge the flexibility, imagination, innovation and co-operation of very many institutions. The central aim should be to identify and then to implement least-cost, but effective, responses.

8.3.3 CONSISTENCY OF POLICY RESPONSES

This is not the place to rehearse all the policy instruments and their likely consequences. Many of these have been identified earlier in this Report and in the supporting research volumes. However, criteria need to be established to guide the complex, multi-agency and multi-instrument response which is required. Such criteria are, no doubt, numerous. But some crucial criteria include the following:

- **Flexibility**: The future remains uncertain. 'Optimising' the policy response, given likely somersaults in emerging conventional wisdoms, is thus a forlorn endeavour. Economic and political uncertainties are great, the mood of public opinion could shift and the global demand/supply balance is difficult to predict over 2-3 decades or longer. The future will contain many shocks which will reveal the folly of strong belief in any present certainties or projections. History has taught powerful lessons in this regard.

- **Precaution**: Scientific consensus, likely any other consensus, should remain subject to searching challenge and scrutiny. But, at present, the scientific consensus about climate change and sustainability must be heeded. 'Business as usual' is no basis for future policy making. The precautionary principle is thus one key element likely to influence policy choices. But the policy measures identified in this Report should also be examined for their cost effectiveness and their contribution to other policy goals such as competitiveness and social cohesion.
- **Feasibility**: Political feasibility (or social acceptability) is an important test of policy packages. Some policy measures suggested in this Report (e.g. taxation and tougher regulation) will confront – and affront – powerful vested interests. They will respond. But vested interests, whilst given all reasonable opportunities to register their concern, must not (as on some occasions in the past) be permitted to exercise any veto. Saying 'no' to policy proposals is not sustainable: well-considered alternatives must be proposed in their place. Many other policy measures outlined here might well enjoy wide support: information campaigns; introduction of standards and regulations for appliances, buildings and vehicles; and voluntary agreements. Some other policy measures are as yet available in outline only, such as the flexibility mechanisms. Much further work is required before some newer instruments are fully evaluated by policy makers and stakeholders.
- **Environmental effectiveness**: Policy instruments, individually or in packages, must contribute to the imperative of sustainable development. The effectiveness of such instruments should be well-established, documented and credible; and consistent with a wide range of economic, energy, environmental and social objectives. Such instruments should aim at a hierarchy of responses, such as reducing carbon intensity; increasing energy efficiency; and accelerating the penetration of renewables, CHP and other low-emission and clean technologies. This Report has stressed the many environmental impacts, other than greenhouse gas emissions, which derive from the energy system. But, for example, reductions in carbon intensity might well prove a useful 'first hand' proxy for evaluating the environmental effectiveness of many policy instruments.
- **Cost effectiveness and economic efficiency**: The policy objectives set by the EU and Member States result from a process of political negotiation, and tough evaluation of trade-offs. Politics is the art of the possible. But the possible must also be evaluated on rational economic grounds. Resources are constrained and desirable objectives are manifold. Especially in newly liberalised markets, policy instruments should – wherever possible – work with 'the grain of the market'. Incentives are more likely to achieve support than penalties. In the event, both may prove necessary. If so, long-established principles of public finance may need to be re-examined, especially those of 'ring fencing' (or 'hypothecating') revenues so that these are re-invested in adjacent policy fields. For example, higher taxes on private transport may well be more acceptable if the incremental revenues are used to improve public transport. In addition, cost effectiveness is best assessed against a level playing field. Otherwise least-cost solutions might not be identified. For example, the relative cost effectiveness of nuclear versus renewable capacity expansion should be evaluated on the basis that all insurance risks are borne fully and fairly by both technologies without dependence upon public finance. Perspective is all when assessing cost effectiveness.
- **Market compatibility**: Policy instruments should reflect market realities such as consumer and market expectations; huge sunk investment in equipment and human skills; slow turnover of energy using capital stocks (aircraft, cars, freezers, power stations); the respect for freely-negotiated contracts, especially long-term ones; the resource losses imposed by stranded assets and contracts; increased competition in EU and global markets; the possibility of reduced incentives for long-term RD&D by the private sector etc.
- **Social and economic equity**: Burden sharing across countries, sectors and end-users should be equitable. Inevitably, some instruments will have undesirable side-effects, such as on income distribution, employment and personal choice. These side-effects must be evaluated with care. In some cases, compensation might be required to achieve social acceptability. Packages of measures should aim to ensure that side-effects are as low as possible and that adjustments are smoothed wherever this is feasible. Abruptness in policy implementation imposes higher costs than when individuals and markets are given adequate time to anticipate and to adjust. This also suggests there will be no merit in further delay.

8.4 THE VALUE ADDED OF EUROPEAN ENERGY POLICY

The range of policy issues likely to face the EU and Member States over the next 20-30 years has been reviewed above. Earlier sections also highlighted the considerable changes in energy circumstances and in the conventional wisdoms which have dominated energy policy thinking. It has been argued that changes, such as liberalisation of energy markets and the greater weight now placed upon environmental issues, will influence the scope and style of energy policy making. The case for greater co-operation, effective policy co-ordination between numerous DGs, extensive dialogue with a wide range of key stakeholders and the use of broad-based analytical capabilities has also been made. Here the primary focus is upon identifying major elements of a distinctive and value added role for the EU and the Commission.

8.4.1 THE EVOLUTION OF THE COMMISSION'S ROLE IN ENERGY POLICY

The historical record of Commission initiatives in the energy field was set out in a 'Compendium of Legislation' published in February 1995. This reproduced from the Official Journal all the relevant legislation under five main chapters. These were: General (statements of energy policy objectives); Solid Fuels; Gas, Oil and Electricity; Nuclear Energy; and Rational Use of Energy and Renewable Energy Sources. This document includes some environmental measures such as those for reducing the lead content of petrol, and the sulphur content of fuels. It does not, however, include all the important, wider legislation deriving from the competition, transport and environmental powers of the Commission which also impact upon the energy sector and wider energy system.

Many evaluations of Community efforts in the energy field have been published by other bodies. These record that there have been several attempts to formulate a common energy policy but that these have met with only limited success in the past. The primary impediment was the continued reluctance of Member States to surrender or to 'pool' sovereignty in this highly sensitive policy area. In the past, the main division was perhaps between energy 'consumer' and 'producer' countries; and the key issue was to keep the Commission *out* of any significant role in energy policy. This was then seen to be a matter of national legal competence.

More recently, factors such as market liberalisation, globalisation, falling commodity prices, more relaxed global energy markets and the present concern about energy-related climate change have shifted the focus of policy attention somewhat away from *security of supply* – an issue in which national sovereignty was judged to be of supreme importance by many Member States. To the extent that security of supply is now lower down the agenda, but issues such as liberalisation and climate change higher up the contemporary policy agenda, the EU now has more 'action space' in which to shape policy making. This is not to say that medium- to long-term supply security issues should be neglected by either Member States or the EU – especially given the prospective reductions in EU energy self-sufficiency over the next 20-30 years (see Chapter 4.2). However, neither is supply security likely to be seen as such a narrowly national issue in future.

The EU has committed considerable political efforts and investment resources in reinforcing electricity inter-connectors and gas and oil pipeline infrastructures. Ownership and access rights to these are governed by international law or by facility-specific legal instruments or treaties. If energy market disruptions were to occur in the future, the very existence of these 'common and shared' facilities reduces the scope for purely national responses to security threats. National sovereignty is also significantly constrained by agreement to emergency oil sharing arrangements.

Recently an additional dimension of policy has come to the fore – *market liberalisation* – where, in the past, the main division across the Member States was between the 'protectors' and the 'liberalisers'. In this area, many countries now see that active Community participation could bring real benefits, essentially by dismantling obstacles to trade and investment in other parts of the Community; and hence expanding market opportunities for their own companies (as energy suppliers, or as energy equipment suppliers). In this new era of transformed relationships between energy producers and suppliers, and of changed perceptions of the energy market, the Commission has rarely been better placed to make an impact on policy. After all, subsidiarity can have little significance when establishing the framework of *common* market rules within a single market especially for basic commodities (energy supply) and mass-produced energy-using appliances, equipment and vehicles. Other than buildings, these cover most energy demand by the energy 'system'.

The second major thrust is *the environmental agenda*. The Commission's interest in the environment is long standing. This interest grew after the Stockholm Conference in early 1972 when there was a formal Community commitment to an environmental policy. The evolving European environmental policy agenda has extended well beyond the narrow confines of the energy sector (e. g. to include chemical wastes and the quality of drinking water). But, particularly given the heavy fossil fuel dependence of the EU energy sector, the Community's measures to cut energy-related emissions of particulate matter, NO_X, SO_2 and – since the early 1990s – CO_2, have had profound effects. The important Community-wide status of environmental issues was confirmed in the Single European Act where they formed a separate chapter of the Treaty.

Diplomatic efforts with energy suppliers have also increased (e. g. the Energy Charter, and regular dialogue with OPEC, the Gulf Co-operation Council and FSU states). Dialogue is also in progress with the potential Accession States, as their membership of the EU will – in due course – have a significant impact on issues such as EU energy balances, liberalisation, environmental emissions, nuclear plant decommissioning etc. Particularly through environmental negotiations and subsequent legislation (e. g. the Large Combustion Plant Directive, and the limits on lead and sulphur content in road transport fuels), and as a signatory to the Framework Convention on Climate Change and the Kyoto Protocol, the EU is now exercising very considerable influence upon the development of the EU energy system. But, in other areas – for example in the national determination of measures to enhance security of supply and diversity – the principle of subsidiarity still remains significant.

This is not the place to record all the recent initiatives in the energy field. But, for the record, other than the Electricity and Gas Directives (96/92 and 98/30), major developments include a White Paper on Energy Policy (COM (95) 682); a White Paper on Renewable Energy (COM (97) 599); a Communication on Combined Heat and Power (COM (97) 514); a Communication on the Energy Dimension of Climate Change (COM 96) 196); progress in harmonising taxation of energy products, (though not in introducing a carbon/energy tax); development of TransEuropean Energy Networks such as gas pipelines and electricity interconnectors; increased provision of energy loans by the European Investment Bank and use of Structure Funds; significant funding for energy RD&D under successive Framework Programmes; and creation of bodies such as an Energy Policy Consultative Committee and expert groups drawn from national administrations. Many of these initiatives were summarised in 'An Overall View of Energy Policy and Actions' (COM (97) 167), April 1997.

In combination, the Single European Act, the Single Market proposals, the Electricity and Gas Directives, international environmental negotiations and – most recently – political agreement on a Single Currency have revitalised the EU's role. These political initiatives have raised awareness of the EU dimensions of policy in an ever-wider range of fields. The proposed progressive extension of the EU, subject to satisfactory political agreements with the Accession States, will further extend the scope for Commission activity in the energy policy sphere.

8.4.2 SUBSIDIARITY AND POLICY IMPLEMENTATION

Within the EU Member States the main energy policy actors, and their roles, differ widely. This is partly because of differing energy resource endowments; industrial structures; ownership patterns; administrative and governance styles or traditions; and the extent of devolved powers. In some countries, public ownership of much of the energy supply sector is seen as of crucial – even strategic – importance. In other countries, even though ownership is primarily or wholly in the private sector, very significant shareholdings are held by the public sector (e. g. in the case of municipal utilities in Denmark and Germany). In yet others, ownership has recently been transferred fully to the private sector. In some countries, many national responsibilities in the energy policy field are exercised centrally, by central Government departments or regulatory agencies. In others much more weight is placed upon regional autonomy and devolution.

The principle of subsidiarity remains of great political importance in some EU Member States. But whether it can survive liberalisation of energy markets and the growing cross-border ownership of energy companies will be a key question over the next decade. It has been suggested above that factors such as liberalisation, environmental protection and sustainable development will all reinforce the EU's role.

On the other hand, there is much pressure to identify additional roles for some policy activities at the local or municipal level (e. g. Agenda 21, integrated transport systems, land use planning, integrated waste recycling, and innovative 'climate change cities'). These may assume much greater importance for the implementation of national and EU energy policy goals in the future. After all, 'think global, act local' is the *leitmotiv* of many NGOs and pressure groups. This is an example of the countervailing, **centrifugal forces** which might be at work to re-allocate primary responsibilities for some dimensions of energy-related policy. These pressures for devolution and subsidiarity recognise that detailed *implementation* is often best handled at the local level, especially to exploit location-specific synergies or climatic requirements (e. g. town planning, integrated transport, recycling, building regulations).

The key point is that, where economies of scale or scope can be identified, policy should be established at the highest level. This is to minimise distorting trade barriers impinging on the Single Market, often resulting from – for example – inconsistent national appliance safety regulations and equipment standards, or State Aids. This supports the need for policy measures such as energy market liberalisation Directives, appliance labelling schemes and co-ordinated responses to international climate change negotiations to be handled at the European level.

It is often suggested that liberalisation will reduce the role of Member State governments and the Commission in energy markets. But the market by itself will not wholly satisfy what are termed 'public interest obligations', 'externalities' or 'strategic' policy concerns such as environmental protection, climate change, supply security, health and safety, international diplomacy and regional development. A wide range of environmental imperatives such as climate change and sustainable development will require a *more* interventionist policy stance – ironically because of the price effects of market liberalisation. The EU and Member Governments are conscious of the need to periodically encourage and/or coax energy markets by setting out their own strategic perceptions, particularly over longer time periods than energy markets unaided might normally consider. The post-Kyoto commitments, and the policy measures now being put in place to secure them, remind us all of this enduring characteristic of the energy system. Tackling such environmental concerns in the 'low energy price world' now foreseen is one of the most immense challenges faced by policy makers. However, liberalisation and privatisation will clearly have a major influence on the *instrumentality of policy* (i. e. why and how Governments and/or the Commission can intervene, even if they choose so to do).

8.4.3 POSSIBLE CRITERIA AND SHAPING FACTORS

The preceding evaluation suggests that the following factors will be of great relevance in shaping an EU energy policy response:

- Policy measure should be more *systemic* in character and involve efficient burden sharing (covering all major sectors of the EU economy, and not just the energy supply sector, and especially not just the electricity sector). This will place more emphasis on effective co-ordination of policies across Directorates General (e. g. Transport, and other DGs overseeing those sectors which generate the derived demand for energy).
- Transport technologies and fuel demand remain one of the greatest uncertainties for future policy. A major contributor to *incremental* growth in overall EU final energy demand and CO_2 emissions over the period to 2020 will be the transport sector. This growth could offset much of the CO_2 emissions reductions arising from all other demand sectors. Thus, in future, transport should be considered as being at the heart – and not, as now, at the periphery – of an integrated EU energy policy.
- Regulatory policy should aim to become much more 'seamless' especially as regards ensuring greater consistency between economic and environmental policy and regulation. The energy system is characterised by slow turnover of energy-using capital stocks and by long investment lead times. It is thus necessary to ensure that policy evolves smoothly over time with realistic 'adjustment' periods. Otherwise, there is a very real danger that abrupt changes in policy could lead to stranded energy-using assets and perhaps stranded fuel supply contracts.
- Uncomfortably for policy makers, there are no easy 'technical fixes' for reducing CO_2 emissions, unlike those of particulates, NO_x and SO_2. This again reinforces the need for the response to be systemic in character. In turn, this means that the demand side, not just the supply side, will feature effectively in the process of dialogue and policy formulation. Parts of the demand side are consulted at present, but these are mainly powerful industrial interests in energy-intensive sectors such as chemicals, aluminium and steel. In the past, both Member States' and the Commission's policy making in the energy field has tended to be '*supply side dominated*'. This asymmetry of access, dialogue and (occasionally) of effective policy veto may need to be addressed.
- Energy efficiency, CHP and renewable energy technologies will need to play a much bigger role. This means that the traditional interests in the conventional fossil fuels and bulk power generation will have to accommodate themselves to a new and much wider range of players; and expect less dominant influence in national and EU policy making circles. The combination of growing environmental concerns, the prospective increase in energy import dependence, and increased competition in international trade suggests that the Member States and the EU could usefully review the economy-wide benefits of integrated and consistently applied energy efficiency programmes over the next decade.
- More controversially, without a significant component of nuclear power generation in the EU plant mix, achievement – or maintenance – of a significant CO_2 reduction on the 1990 level in the period after 2015 appears more difficult. It is most likely that, after further international negotiations, the present 8 % reduction target for EU greenhouse gas emissions will become even more demanding. The economic case for new nuclear investment in a 'low energy price' world appears poor. Public opposition in many countries remains strong. This will require efforts to secure significant 'life extension' of existing nuclear reactors, if this can be achieved safely. This is a key area for fuller dialogue between the Commission and national regulatory agencies for nuclear power.
- The case for higher taxes upon energy requires more evaluation. There is an expectation of low real international fossil fuel prices over most of the next 20 years, as well as of price reductions arising from liberalisation and competition. The Commission will also have a key role in overseeing Member States' adjustments in energy taxation to avoid distortions in the Single Market.
- The Commission should closely continue to monitor the changing incentives for, and the 'architecture' for delivery of, energy RD&D and technological change. Member States have reduced energy RD&D funding, preferring to leave more of it to the 'market'. But newly-privatised energy companies have cut their RD&D heavily (as they no longer have to carry the 'state interest', unlike their nationalised predecessors). Privately-owned companies in more competitive markets have also cut RD&D (as a means of preserving short-run profit margins); and oil companies have reduced RD&D because of lower real oil prices. This may be a pessimistic evaluation, but is based on empirical observation. If neither national governments nor the 'market' fund adequate RD&D, this may imply a greater role for the EU. New world trading rules, and single markets such as the EU and NAFTA, are causing the opening up of procurement within the formerly protected energy supply sector. These rules are accompanied by significant structural realignments through mergers and acquisitions across national frontiers in many industrial sectors (e. g. heavy electrical equipment). Together, they may have undermined the logic of using national 'product champions' (whether state-owned enterprises or their major – once nationally based – equipment suppliers) in the development of national energy RD&D and technology policy. Much nationally-funded RD&D may thus now be prey to the 'free rider' effect, with the result that it is difficult (if not impossible) to identify narrow *national* economic benefits from given volumes of publicly-funded energy RD&D. Whilst such industrial realignment amongst equipment and appliance suppliers has integrated economies (e. g. in the EU), and perhaps reduced wasteful duplication of research within national boundaries, many such industries are no longer

based on the boundaries of single nation states. Over time, this may well change the balance between the case for national and for super-national RD&D funding.

- The energy sector is perhaps the most capital-intensive of all economic sectors in a modern economy. This remains true despite much lower specific (i. e. per kW) capital costs in CCGTs and despite significant capital cost reductions in off-shore oil and gas projects. The continuing disparity between the returns sought for new investment on the supply and demand sides of the energy system threatens very poor capital productivity and a continuing misallocation of resources. Given its interests in competitiveness, liberalisation of energy markets, rational resource allocation and environmental imperatives, this suggests the Commission should review the implications of the very different discount rates used on (i) the supply versus the demand sides and (ii) in nationalised monopoly versus competitive, privately-owned utilities; and be prepared to propose measures to 'level the playing field'.
- This analysis suggests that EU energy policy should be located firmly within a long-term global vision. This is because international energy markets are interdependent and EU energy dependency is forecast to rise significantly. Likewise many environmental threats have wide spatial consequences. Export and technology transfer opportunities for energy conversion and efficiency equipment are huge.

8.4.4 THE ENERGY POLICY APPROACH: SOME RECOMMENDATIONS

The analysis suggests that the Commission, acting in concert with Member States, may need to establish further guidelines and legislation if wider societal objectives are unlikely to be fully addressed by market forces operating within the existing framework. Any new initiatives should recognise crucial market realities: in particular, the long investment lead times on the supply and demand sides of the energy system, the slow turnover of energy-using capital stocks, as well as the new opportunities provided by technological change.

It is also essential to ensure that the additional requirements imposed upon the supply and demand sides of the energy sector are commensurate with those being applied to other economic sectors. This requirement reflects the derived character of energy demand, the need to balance obligations across many different sectors, and the fact that least-cost solutions to policy conflicts and trade-offs are unlikely to be found in the energy sector in isolation. It will be important to ensure consistency in the emerging legislative and regulatory framework which impinges upon the energy sector. This is especially the case with regard to the economic (or market conduct) and the environmental regulatory regimes. The demand and supply sides of the energy sector have a significant contribution to make in satisfying wider economic, social and environmental objectives. They will best make their contribution if it is clear that these obligations are widely shared with all other sectors; and if policy makers have a well-grounded appreciation of the costs, incentives and the timely opportunities of meeting them.

The Commission and Member States have a particular responsibility to evaluate alternative policy instruments and measures which may contribute to assist the energy (and all other) sectors in resolving conflicts and trade-offs in meeting multiple objectives. These should be carefully considered and costed, openly discussed with those liable to be affected by them, given an adequate democratic mandate; and introduced in a manner which minimises wasted resources or unduly threatens competitiveness.

Finally, the Commission – in discussion with Member States, local and devolved governments, consumers and all other actors – should continue to identify those areas where it is itself best placed to make a contribution. In some areas, there may be genuinely limited opportunities for Commission action. In others, Member States and devolved governments may choose to jealously preserve their discretion and own scope for action. But, in others, there will be a ready willingness for the Commission to act – and to be seen to act – where a distinctive value added is apparent. The desire for subsidiarity, and the process of market liberalisation, may well influence instrumentality (i. e. when and how the Commission seeks to intervene). But there will also remain numerous opportunities for the Commission to co-ordinate the efforts of others in well-judged ways.

8.4.5 SOME SUGGESTED VALUE ADDED ROLES FOR THE COMMUNITY

In the light of the factors and criteria set out above, areas where there appears to be genuine 'value added' roles from such an EU-wide approach include:

- Maintaining momentum aimed at removing barriers to the creation of a competitive and responsive EU energy market to assist in meeting the wider objectives enshrined in the Treaties (e. g. competitiveness, employment, regional development, social policy objectives and sustainable development); ensure diversity and security of energy supplies (to minimise impacts of supply disruption on the EU economy); and support the development of the physical infrastructures which are a prerequisite for a competitive market. This includes assisting the development of a liberalised European energy market within an appropriate regulatory framework. This will require overseeing developments in, and monitoring compliance with, the Gas and Electricity Directives, as well as securing reductions in inappropriate and market distorting State Aids (e. g. coal). The Commission should also ensure greater consistency between Member State and EU frameworks for (i) economic and (ii) environmental regulation; and that these evolving regulatory frameworks work 'with the grain' of the market. This includes co-ordinating and, where possible, harmonising national approaches to the economic regulation of liberalised utilities to ensure the success of liberalised energy markets. There is little logic in developing distinctive national systems of utility regulation within the emerging and converging European single market for energy. Detailed administration of an EU-wide regulatory regime could remain a national prerogative. It also includes ensuring that all final consumers of energy are permitted the choice of energy supplier, and provided with sufficient information to permit an informed choice by improving the publication of timely, accurate and comparative energy price information.

- Contributing, together with other EU economic sectors, to the objectives of a cleaner environment. This includes analysing, and seeking to overcome, possible inconsistencies and conflicts in different policy thrusts (e. g. liberalisation v. environmental protection). This is intended to address the core questions of when, where and why policy intervention might need to intensify.
- Ensuring that future energy policy making gives due weight to the demand side and harmonising energy efficiency regulation (e. g. standards, labelling and voluntary agreements, for mass-produced appliances and vehicles, boilers and burners, electric motors, fans, pumps, ventilators etc., and, where appropriate, national building regulations). In liberalised markets the levers available to Governments and the Commission on the supply side may be much reduced. In future, more policy influence may well be exercised via demand side measures than was true of the past tradition of policy making. It is likely to require much greater collaboration and co-ordination of policy responses across different Directorates General. In particular, the transport sector should be placed much more fully at the heart of EU energy policy. This theme also includes means of obtaining a more rational allocation of investment resources between the demand and supply sides; and between publicly- and privately-owned enterprises. Tax incentives for energy efficiency investment as for some energy supply investment, including renewables, may be necessary in a period of lower real energy prices.
- Co-ordinating and funding energy RD&D and technology policy, especially to assist more rapid market diffusion of cleaner and more efficient technologies which have wide market applicability (e. g. renewables, CHP, internal combustion engines, electrical appliances).
- Fulfilling a lead role in international diplomacy in the energy field (e. g. with energy exporters, Accession States and in global environmental negotiations); encouraging global free trade in the provision of energy supplies; and, through diplomatic and other means, to aim at reducing political instabilities which may threaten EU and global energy supplies, or free trade in them. One important dimension of this diplomatic and facilitating role could include that of assisting to develop and to oversee the frameworks necessary for greenhouse gas trading schemes within and between Member States; and between the EU and other nations or trading blocs. Another is to ease the accession of new Member States by ensuring convergence of their energy-related policies.
- Maintaining its own, and effectively utilising other, analytical and modelling capabilities to provide rigorous and timely evaluation of major EU and global trends and their policy implications; and to provide well-analysed options for consideration by the European Parliament, Commission services, Member States and a range of other important actors and stakeholders. This will necessitate pooling and sharing of analysis of economic, market, political, social and technological trends in order to develop consistent policies for the energy sector and the wider energy system.

PART IX CONCLUSIONS

Achieving sustainable development in its broadest sense requires that economic, environmental and societal objectives should work together to ensure improved welfare for the European Union and the world at large. The classical objectives of energy policy are intended to support this evolution towards more sustainable development. These objectives include:

- Assuring continuity of supply of different energy sources by enhancing the Community's trading relations with producers; by improving energy efficiency and by diversifying the primary energy balance;
- Improving the competitiveness of European industry and thus strengthening employment, economic efficiency and improved foreign trade opportunities;
- Looking to the environmental dimension of energy policy to contribute towards better local, regional and global environmental conditions.

During the 1990s, the energy system of the European Union responded to a number of useful and successful actions. Technological improvements and the commercial expertise of oil and gas companies increased the indigenous supply of key resources and reduced the costs of exploration and production, a trend favourable to improving the competitiveness of European industry. Markets began to be liberalised in the electricity and gas sectors and the first improvements in economic efficiency are now becoming visible. Environmental conditions have improved following the substantial decreases in some traditional pollutants, including sulphur dioxide, methane and nitrogen oxide. The Community set itself the ambitious target of stabilising CO_2 emissions at 1990 levels by 2000 and current forecasts suggest that this objective is within reach.

Thus history may consider this decade as the "golden 1990s" of the European energy system. However, the results of the Shared Analysis Project suggest that a number of these favourable conditions and trends will be under substantial pressure in the coming decade. As a result, energy policy at both Community and Member State levels will have to be much more creative and forceful in ensuring that the next decade will be just as positive in continuing along the path of more sustainable development.

In particular, three major challenges are highlighted by this analysis:

- Declining EU indigenous energy production is likely to accelerate with the consequent increase in EU energy dependency from its current level of some 50 % to some two-thirds of total energy consumption by 2020.
- Lower energy costs will strengthen the Community's industrial competitiveness in global markets. However, the remaining EU indigenous energy production, often high cost, will come under substantial competitive pressure from the keen prices for fossil fuels available in the world market. This will have important implications for expensive (and often subsidised) indigenous production; and it may be that its decline will accelerate as world fossil fuel prices become even more competitive.
- The commitments made by the European Union and its Member States in Kyoto to reduce total greenhouse gas emissions by 8 % by the commitment period 2008 to 2012 relative to 1990 represent a major challenge. Energy accounts for some 80 % of the Union's total greenhouse gas emissions. Consequently energy policy, relating both to production but perhaps more importantly to end-use, will need to reflect this specific challenge.

These are by their nature complex and long-term challenges. They impact on the three traditional pillars of energy policy and their potential contribution to sustainable development. As an analytical contribution to assist in meeting these challenges, the Shared Analysis Project suggests energy policy needs to pursue a broader political approach in the next decade:

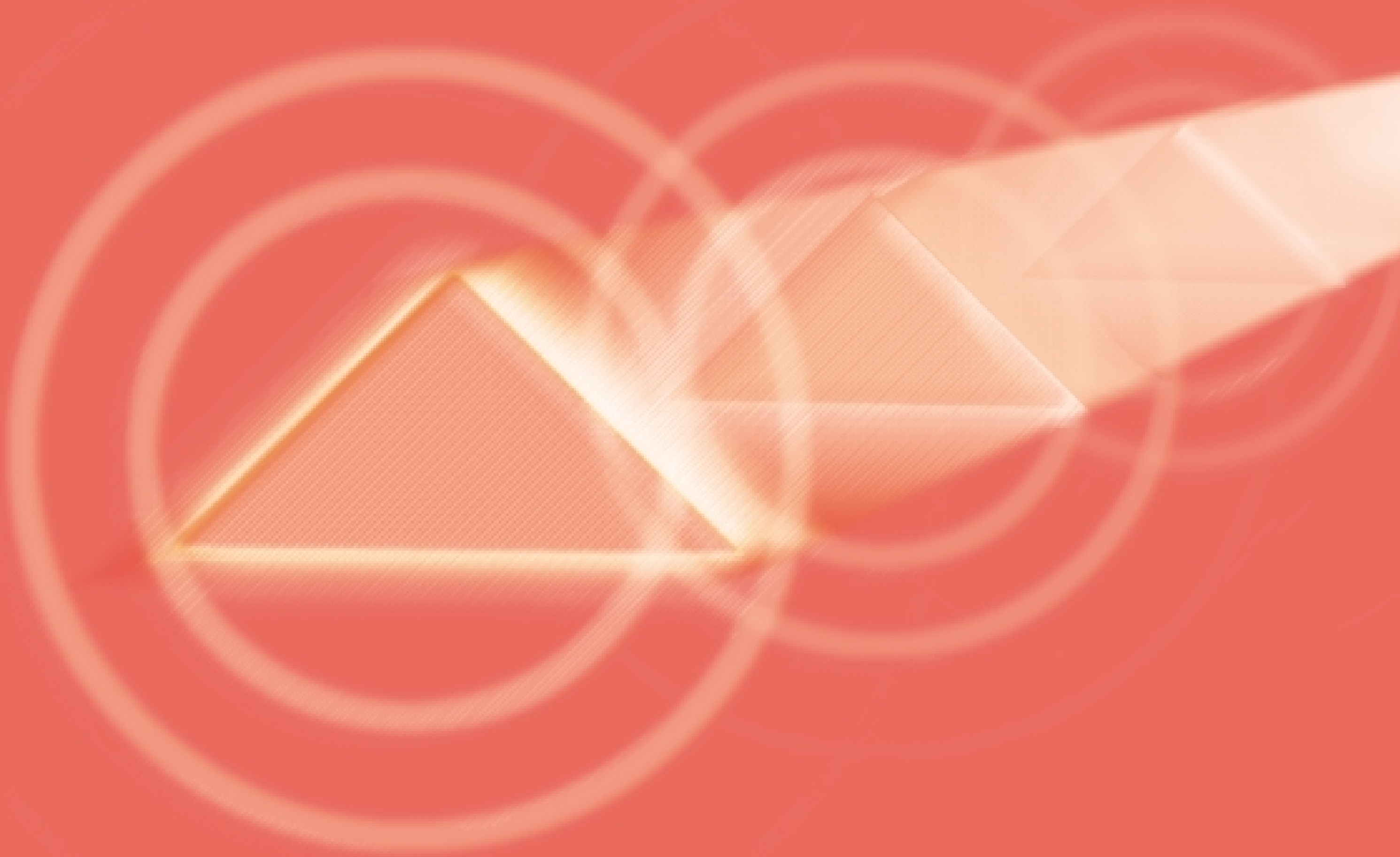
- addressing the energy system, including end users, their needs for energy services and the impact these have on energy supply; and how, and under what circumstances, citizens will require energy to be produced to meet their growing environmental concerns;
- integrating a wider range of interrelated policies, e.g. transport, urban city planning and climate change; and
- broadening and deepening dialogue and co-operation between Member State governments, institutions, stakeholders, and the wider policy milieu.

Above all, the analysis from the Shared Analysis Project identifies that the energy system of the world is in a period of transition, with many uncertainties, opportunities and risks. Many of these driving forces and shaping factors will impact on Europe's response to the globalisation of trade, changing market structures with growing emphasis on liberalisation in the gas and electricity markets, and on behaviour and expectations. In turn these, and other important, factors will influence the response to be defined for implementing the EU's demanding commitments under the Kyoto Protocol.

The core issues at the heart of the energy agenda, and the Community's own contribution to the development of policy, will need to take into account growing import dependency, enlargement of the European Union, the dynamics of the Internal Market, cern for the environment and climate change, and the challenges and opportunities presented by increased globalisation of trading activities.

These emerging challenges guarantee that energy futures will be no less exciting than in the past! They are likely to be accompanied by changes in policy emphasis and, indeed, witness further summer-saults in underlying conventional wisdoms. Above all, the Shared Analysis Project concludes that flexibility is a key requirement in developing the European Union's future energy system. This is because the uncertainties over the period to 2020 and beyond remain considerable. In particular, policy initiatives will need to respond both to the complex dynamics of rapidly changing markets and to citizens' legitimate expectations for more sustainable development.

REFERENCES



Annual Energy Review (1999): 1999 - *Annual Energy Review 1999*, Energy in Europe. Special issue December 1999 (forthcoming). European Commission, Office for Official Publications of the European Communities, Luxembourg 1999

Blok K., Turkenburg W.C., Eichhammer W., Farinelli U., Johansson T.B. (eds.): *Overview of Energy RD&D Options for a Sustainable Future*, Office for Official Publications of the European Communities, Luxembourg 1996

BMBF (1996): *4th Energy Research and Technology Programme*, German Federal Ministry for Education, Science, Research and Technology BMBF, Bonn 1996

Bosseboeuf D., Eichhammer W., Lapillonne B., Landwehr M.- 1999- : *Energy efficiency indicators : the European experience*, ADEME éditions, Paris 1999

BP Amoco (1999): Statistical Review of World Energy 1999, British Petroleum Company, London 1999

Capros P., Mantzos L.: *Energy System Implications of Reducing CO_2 Emissions: Analysis for EU Sectors and Member-States by using the PRIMES Ver.2 Energy System Model*, Final report from ICCS/NTUA for DGXI of the European Commission, March 1999

CEMT (1998): Conférence Européenne des Ministres du Transport

Ecofys (1998): Hendriks C. A. / Jager de D. / Blok K., *Emission Reduction Potential and Costs for Methane and Nitrous Oxide in the EU-15*, Interim Report, ECOFYS M717, Utrecht (order of DG Environment)

EEA(1999): *Environment in the European Union at the turn of the century*, European Environmental Agency, Copenhagen 1999 (http://www.eea.eu.int/frdocu.htm)

EIA (1998): *International Energy Outlook 1998*, Energy Information Administration (US DOE), Washington, April 1998

EIA (1999): *International Energy Outlook 1999*, Energy Information Administration (US DOE). Washington D.C (http://www.eia.doe.gov/oiaf/ie099/pdf/048499.pdf)

Ellerman, A. Denny / Decaux, Annelène (1998): *Analysis of Post-Kyoto CO_2 Emissions Trading Using Marginal Abatement Curves*, MIT, Boston.

EU Council (1999): *Council Conclusion on a Community Strategy on Climate Change*, Document No. 8280/99, 17 May 1999, Brussels

European Commission (1995): *Gas supply and prospects in the European Community*, Brussels, Com(95) 478

European Commission (1997a): *Energy Technology. The Next Steps. Summary findings from the Atlas project*. Directorate General for Energy, Brussels December 1997

European Commission (1997b): *A Community strategy to promote combined heat and power (CHP) and to dismantle barriers to its development* (COM(97) 514 final)

Greenpeace International (1998): *Greenpeace Analysis of the Kyoto Protocol,* Greenpeace Briefing Paper, Bonn, [http://www.greenpeace.org/~climate/].

Hagler Bailly (1998): *European Energy Technology* – A Global Competitive Review. Final Report: STR/1313/97, May 1998

Herold, A. (1998): *Hot Air and the Kyoto Protocol, Institute for Applied Ecology, in: Forum für Umwelt und Entwicklung* / WWF (Ed.): *Emissions Trading in International Climate Protection*, Workshop Bonn / Germany, 25/26 June 1998

IEA (1995): *Natural Gas Security Study*, International Energy Agency/OECD, Paris, 1995

IEA (1998): *World Energy Outlook 1998*, International Energy Agency/OECD, Paris, 1998

IEA / OECD (1999a): *A Preliminary Analysis of the EU Proposals on the Kyoto Mechanisms*, International Energy Agency, Paris 1999

IEA / OECD (1999b): *The role of Technology in Reducing Energy Related greenhouse Gas Emissions*, International Energy Agency, Paris May 1999

IFM (1999): *World Economic Outlook 1999*, International Monetary Fund, Washington D.C. 1999

Innotec et al. (1996): *Comparative analysis of energy RTD programmes and market observation systems in the USA*, Japan and Europe. Final Report Contract STR-0042-95-DE), Berlin December 1996

International Institute for Applied Systems Analysis (IIASA) (1998): *The Kyoto Protocol Carbon Bubble: Implications for Russia, Ukraine and Emission Trading*, Laxenburg

IPCC (1996): *Climate Change 1995. Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analyses*. Contribution of Working Group II to the second Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press 1996

Nakiçenovic, N., Grübler, A., McDonald, A.: *Global Energy Perspectives*, Cambrigde University Press, 1998

ODYSSEE Database (1999): *Database on European Energy Efficiency Indicators*, sponsored by the SAVE II Programme of the DG for Energy (see http://www.enerdata.grenet.fr/odyssee)

OECD Compendium for the Environment, OECD Paris 1997

Orfeuil (1998): Transport Externalities and Traffic conditions, Agence Française de la Maîtriese de l'Energie, Paris 1998

Revue de Rexecode, n° 61, 4e trim. 1998

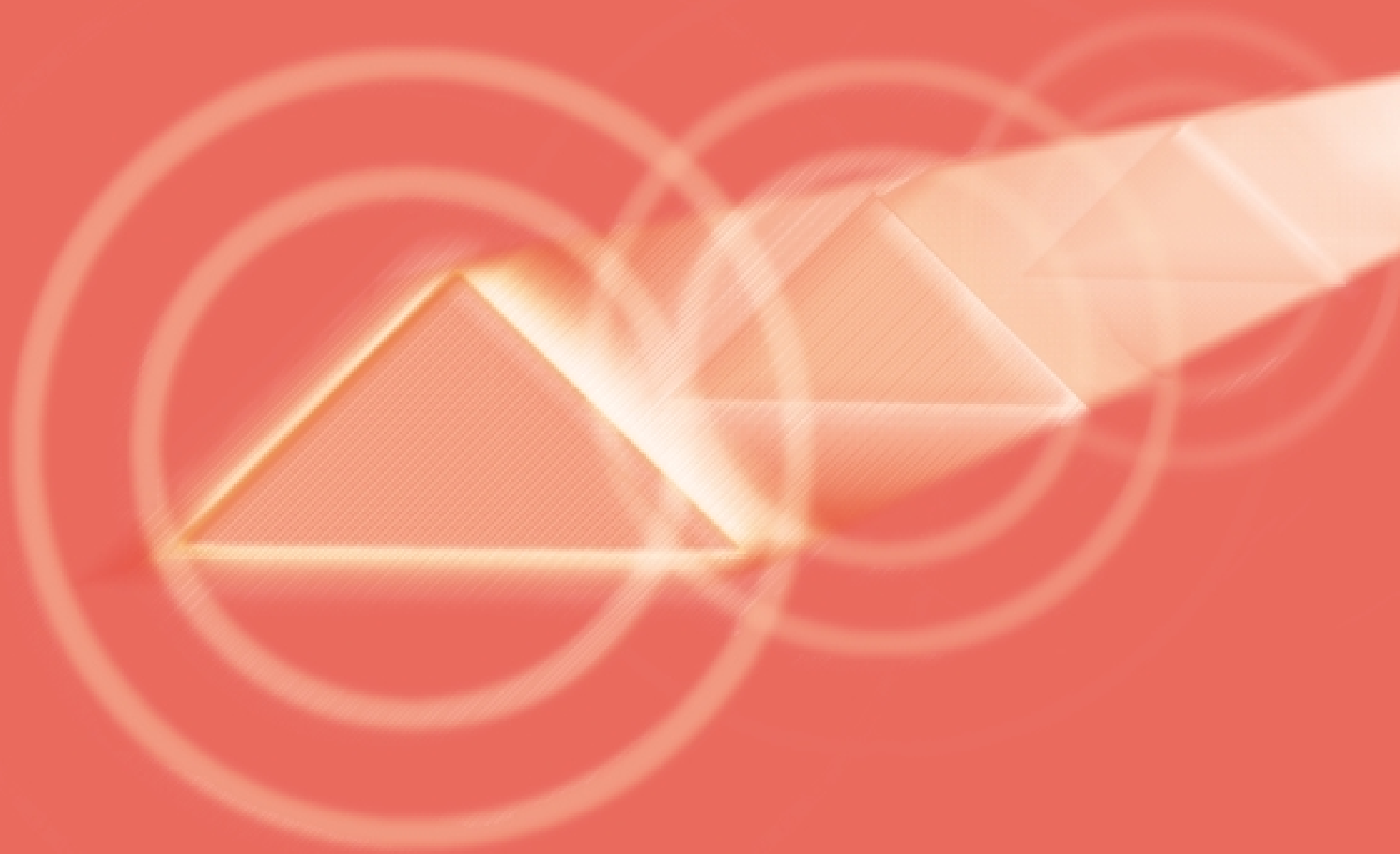
World Bank (1999): *Study on Russian National Strategy of Greenhouse Gas Emissions Reduction*, Moscow

LIST OF SHARED ANALYSIS VOLUMES

The following is the list of the volumes prepared in the Shared Analysis Project. They are available through an Internet site dedicated to the project (http://www.shared-analysis.fhg.de), through Compact Discs (CDs) and on printed matter on request from the Institute responsible for the Volume (for addresses see the section The Shared Analysis Project Team).

N°	Title	Institute
1	The Shared Analysis Project - Economic Foundations for Energy Policy (Joint Final Report)	All
2	World Energy Scenarios	IEPE/IER
3	World Energy under the Pressure of the Emerging Countries : the Asian Energy Thirst and its Consequences for Europe	IEPE
4	The Shared Analysis Approach	SPRU
5	EU Energy Outlook to 2020	NTUA
6	Part 1: Uncertain Driving Forces for Changes in the Energy Systems Part 2: The Interaction of Analysis Instruments for Energy System Modelling	ENERDATA/FhG-ISI
7	The Energy Outlooks of the EU Member States	IER/Ademe
8	Electricity Industry and Market Dynamics	IEFE/SPRU
9	Impacts of Market Liberalisation on the EU Gas Industry	ECN
10	Energy Policy and Energy R&D in the European Union: Convergence or Divergence? A 2010 -2020 Perspective	ESSOR EUROPE
11	The Kyoto Target of the EU: The Implications of the Burden Sharing and the Greenhouse Gas Basket for CO_2 Emissions in the Member States	FhG-ISI
12	New Instruments of Climate Change Policy and the Possible Role of EU Energy Policy	SPRU
13	Costs of Mitigation Options and Response Strategies to Climate Change	FhG-ISI
14	Energy Policy Responses to the Climate Change Challenge: The Consistency of European CHP, Renewables and Energy Efficiency Policies	RISOE

THE SHARED ANALYSIS PROJECT TEAM



CORE GROUP

PROJECT CO-ORDINATOR
FRAUNHOFER INSTITUTE FOR SYSTEMS AND INNOVATION RESEARCH (FHG-ISI)
Breslauer Str. 48
D - 76139 Karlsruhe
Germany

PROJECT STAFF:
E. Jochem
W. Eichhammer
R. Betz
K. Ostertag
J. Schleich
M. Schoen
R. Walz

CONTACT:
Mister W. Eichhammer
Tel. 0049/721/6809-158
Fax 0049/721/6809-272
Email: ei@isi.fhg.de

WITH CONTRIBUTIONS FROM:
Minh Ha-Duong, J.-Ch. Hourcade, F. Lecocq, B. Simon (CIRED, Paris), and
Ph. de Montgolfier, J.-P. Husson, N. Marin (Essor Europe, Paris)

NATIONAL TECHNICAL UNIVERSITY OF ATHENS (NTUA)
E3M-Laboratory
42, Patission Str.
GR - 10682 Athens
Greece

PROJECT STAFF:
P. Capros
L. Mantzos
D. Petrellis
E. Panos
K. Delkis

CONTACT:
Mister P. Capros
Tel.: +30-1-77 23 641
Fax: +30-1-77 23 630
Email: kapros@central.ntua.gr

WITH CONTRIBUTIONS FROM:
E.L. Vouyoukas (Consultant) and
J.-F. Guilmot (ESAP, Brussels)

SCIENCE POLICY RESEARCH UNIT (SPRU)
University of Sussex
Mantell Building
Falmer
E Sussex BN1 9RF
UK

PROJECT STAFF:
J. Chesshire
J. Watson
J. Surrey
M. Parker

CONTACT:
Mister J. Chesshire
Tel.: +44-1273/68 67 58
Fax: +44-1273/68 58 65
Email: j.h.chesshire@sussex.ac.uk

STEERING GROUP

AGENCE DE L'ENVIRONNEMENT ET DE LA MAÎTRISE DE L'ENERGIE (ADEME)

27, rue Louis Vicat
F - 75737 Paris Cedex 15
France

PROJECT STAFF:	**CONTACT:**	
D. Bosseboeuf	Mister D. Bosseboeuf	
A. Morchoine	Tel: -	33-1-47 65 23 55
J. Noppe	Fax: -	33-1-40 95 74 53
	Email:	bosseboeuf@ademe.fr

WITH CONTRIBUTIONS FROM:

B. Chateau (ENERDATA, Grenoble)

NETHERLANDS ENERGY RESEARCH FOUNDATION (ECN)

Policy Studies on Energy and Environment
Westerduinweg 3, P. O. Box 1
NL - 1755 ZG Petten
The Netherlands

PROJECT STAFF:	**CONTACT:**	
F. van Oostvoorn	Mister F.van Oostvoorn	
M.G. Boots	Tel.:	+31-22456 - 44 38
R. Aalbers	Fax:	+31-22456 - 33 38
F.A.M.Rijkers	Email:	oostvoorn@ecn.nl
M.A.Uyterlinde		

ISTITUTO DI ECONOMIA DELLE FONTI DI ENERGIA (IEFE)

Università Commerciale L. Bocconi
Viale Filippetti, 9
I - 20122 Milano
Italy

PROJECT STAFF:	**CONTACT:**	
A. Ninni	Mister A. Ninni	
E. Fumagalli	Tel.:	+39-02/5836 3810
S. Indigenti	Fax:	+39-02/5836 3890
I. Maschio	Email:	augusto.ninni@uni-bocconi.it
T. Prina		

INSTITUT D'ECONOMIE ET DE POLITIQUE DE L'ENERGIE (IEPE)
Université des Sciences Sociales de Grenoble
BP 47 X Centre de Tri
F - 38040 Grenoble Cedex
France

PROJECT STAFF:
D. Finon
P. Criqui
S. Avdulaj – Mima
D. Cavard
M. Chatelus
C. Locatelli

CONTACT:
Mister D. Finon
Tel. +33-4-76 51 42 40
Fax: +33-4-76 51 45 27
Email: finon@iepe.upmf-grenoble.fr

WITH CONTRIBUTIONS FROM:
F. Lantz, D. Babusiaux (IFP, Paris)

INSTITUT FÜR ENERGIEWIRTSCHAFT UND RATIONELLE ENERGIEANWENDUNG (IER)
Universitaet Stuttgart
Hessbruehlstr. 49a
D-70565 Stuttgart
Germany

PROJECT STAFF:
C. Kemfert
G. Schmidt
Ch. Böhringer
P. Schaumann
E. Läge
Ch. Schlenzig
U. Fahl
A. Voss

CONTACT:
Mrs. C. Kemfert
Tel. +49-(0)711-780 61-67
Fax. +49-(0)711-780 3953
Email: ck@ier.uni-stuttgart.de

RISØ NATIONAL LABORATORY
Systems Analysis Department
Building 110, P. O. Box 49
DK - 4000 Roskilde
Denmark

PROJECT STAFF:
P. Grohnheit

CONTACT:
Mister P. Grohnheit
Tel.: +45-46 77 51 07,
Fax +45 46 77 51 99
Email: poul.erik.grohnheit@risoe.dk

THE SHARED ANALYSIS PROJECT TEAM

INSTITUT D'ECONOMIE ET DE POLITIQUE DE L'ENERGIE (IEPE)
Université des Sciences Sociales de Grenoble
BP 47 X Centre de Tri
F - 38040 Grenoble Cedex
France

PROJECT STAFF:
D. Finon
P. Criqui
S. Avdulaj – Mima
D. Cavard
M. Chatelus
C. Locatelli

CONTACT:
Mister D. Finon
Tel. +33-4-76 51 42 40
Fax: +33-4-76 51 45 27
Email: finon@iepe.upmf-grenoble.fr

WITH CONTRIBUTIONS FROM:
F. Lantz, D. Babusiaux (IFP, Paris)

INSTITUT FÜR ENERGIEWIRTSCHAFT UND RATIONELLE ENERGIEANWENDUNG (IER)
Universitaet Stuttgart
Hessbruehlstr. 49a
D-70565 Stuttgart
Germany

PROJECT STAFF:
C. Kemfert
G. Schmidt
Ch. Böhringer
P. Schaumann
E. Läge
Ch. Schlenzig
U. Fahl
A. Voss

CONTACT:
Mrs. C. Kemfert
Tel. +49-(0)711-780 61-67
Fax. +49-(0)711-780 3953
Email: ck@ier.uni-stuttgart.de

RISØ NATIONAL LABORATORY
Systems Analysis Department
Building 110, P. O. Box 49
DK - 4000 Roskilde
Denmark

PROJECT STAFF:
P. Grohnheit

CONTACT:
Mister P. Grohnheit
Tel.: +45-46 77 51 07,
Fax +45 46 77 51 99
Email: poul.erik.grohnheit@risoe.dk