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ENERGY TECHNOLOGIES AND ICT FOR AN ENERGY REVOLUTION

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7. *Appendix B: The IEA Implementing Agreement for a Program of Energy Technology Systems Analysis*

1. – Where is the global energy system going?

Exploring the scene with the WEM macro-economic model

1. Global Total Primary Energy Supply
2. Global Primary Energy Demand by Fuel Group
3. Global Primary Energy Demand by Region

Source: Reference Scenario to 2030 of the World Energy Outlook, International Energy Agency (IEA-WEO2008)

1.1 – Global Total Primary Energy Supply to 2030

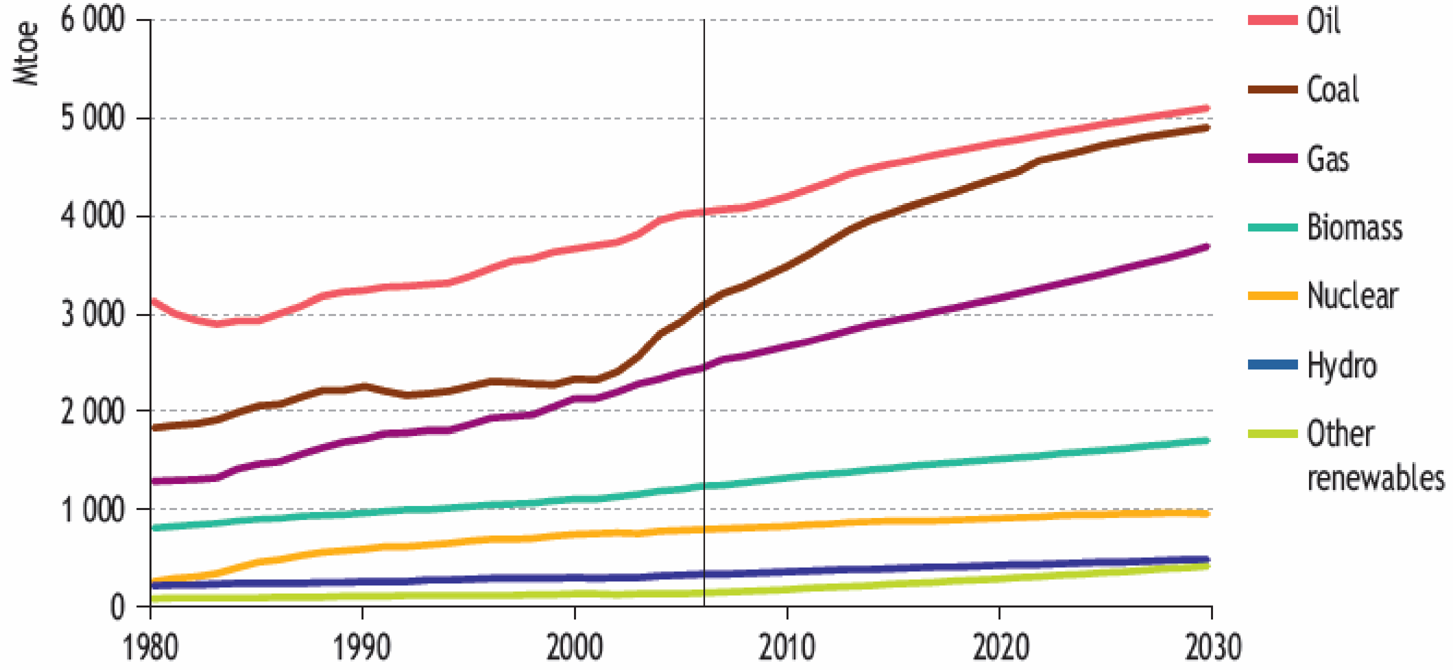
Table 2.1 • World primary energy demand by fuel in the Reference Scenario (Mtoe)

	1980	2000	2006	2015	2030	2006-2030*
Coal	1 788	2 295	3 053	4 023	4 908	2.0%
Oil	3 107	3 649	4 029	4 525	5 109	1.0%
Gas	1 235	2 088	2 407	2 903	3 670	1.8%
Nuclear	186	675	728	817	901	0.9%
Hydro	148	225	261	321	414	1.9%
Biomass and waste**	748	1 045	1 186	1 375	1 662	1.4%
Other renewables	12	55	66	158	350	7.2%
Total	7 223	10 034	11 730	14 121	17 014	1.6%

* Average annual rate of growth.
** Includes traditional and modern uses.

1.2 Global Primary Energy Supply by Fuel Group

Figure 2.1 • World primary energy demand by fuel in the Reference Scenario



1.3 – Global Primary Energy Demand by Region

Table 2.2 • World primary energy demand by region in the Reference Scenario (Mtoe)

	1980	2000	2006	2015	2030	2006-2030*
OECD	4 072	5 325	5 536	5 854	6 180	0.5%
North America	2 100	2 705	2 768	2 914	3 180	0.6%
United States	*1 809*	*2 300*	*2 319*	*2 396*	*2 566*	*0.4%*
Europe	1 504	1 775	1 884	1 980	2 005	0.3%
Pacific	467	845	884	960	995	0.5%
Non-OECD	3 043	4 563	6 011	8 067	10 604	2.4%
E. Europe/Eurasia	1 267	1 015	1 118	1 317	1 454	1.1%
Russia	*n.a.*	*615*	*668*	*798*	*859*	*1.1%*
Asia	1 072	2 191	3 227	4 598	6 325	2.8%
China	*604*	*1 122*	*1 898*	*2 906*	*3 885*	*3.0%*
India	*209*	*460*	*566*	*771*	*1 280*	*3.5%*
Middle East	133	389	522	760	1 106	3.2%
Africa	278	507	614	721	857	1.4%
Latin America	294	460	530	671	862	2.0%
World**	7 223	10 034	11 730	14 121	17 014	1.6%
European Union	*n.a.*	*1 722*	*1 821*	*1 897*	*1 903*	*0.2%*

* Average annual rate of growth.
** World includes international marine bunkers.

2. – What Global Limits are Apparent?

1. Economic
2. Energy resources
3. Environment – climate change
4. Technological
5. Social

Sources: *IEA-World Energy Outlook 2008*
IEA-Energy Technology Perspective 2008
IPCC-AR4, Summary for Policy Makers

2.1a – Economics of global energy systems, 2002
(for comparison: GDP=35 mp – 43 ppp US$T = US$1995 Billions)

2002 USD bill.	Coal	Crude Oil	Oil Prod.	Nat. Gas	Nucl.	Hydro	Bio-Mass	Elec. Other*		TOTAL
TPES	192	1056	0	456	47	46	112	6		**1915**
Transf	-136	-1053	2372	132	-47	-46	80	1259		**2562**
TFC	56	3	2372	589			192	1265		**4477**
Industry	39	3	317	206	-	-	24	333		**922**
Transport	1	0	1702	34	-	-	2	12		**1751**
Other	16	0	353	348	-	-	166	920		**1804**

TPES = Total Primary Energy Supply; TFC = Total Final Consumption;

Transf. = transformations, such as power & CHP plants, refineries, coke ovens,

Other indicates renewable sources: wind, solar, geothermal, etc.

Prices: oil=40$/bbl; coal=50$/t; n.gas=5$/GJ; elec=100$/MWh R&C, 50 ind, …

2.1a – Economics of global energy systems, 2006
(for comparison: GDP=38 mp – 58 ppp US$T = US$2000 Billions)

2006 USD bill.	Coal	Crude Oil	Oil Prod.	Nat. Gas	Nucl.	Hydro	Bio-Mass	Elec. Other*	TOTAL
TPES	546	2099		923	140	151	237	22	**4118**
Transf	-405	-2092	3050	-279	-140	-151	26	2235	**2243**
TFC	142	7	3050	644	0	0	263	2257	**6361**
Industry	114	7	548	262	-	-	41	708	**1680**
Transport	1	0	2044	41	-	-	6	37	**2129**
Other	27	0	458	341	-	-	215	1511	**2552**

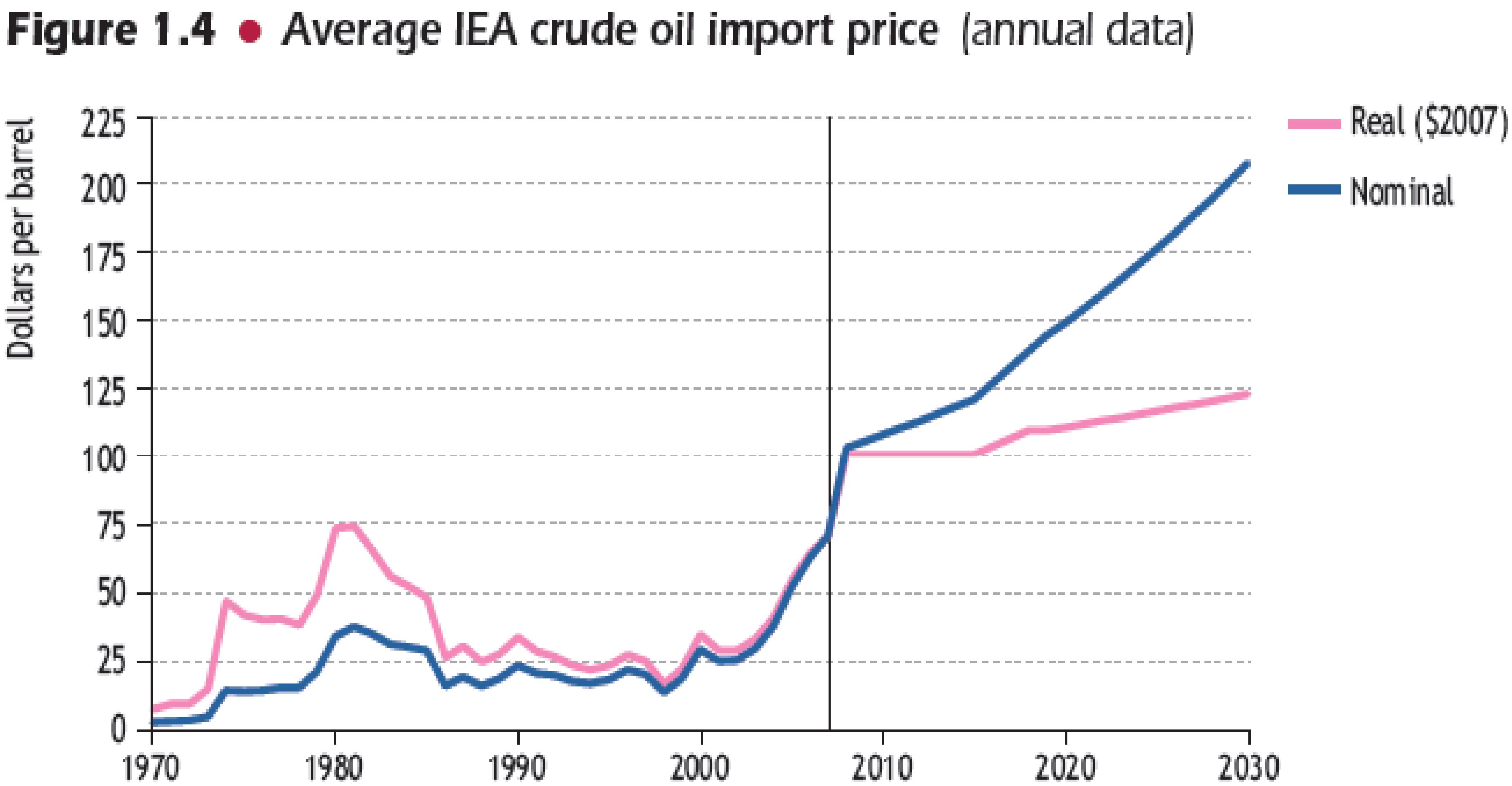
TPES = Total Primary Energy Supply; TFC = Total Final Consumption;

Transf. = transformations, such as power & CHP plants, refineries, coke ovens,

Other indicates renewable sources: wind, solar, geothermal, etc.

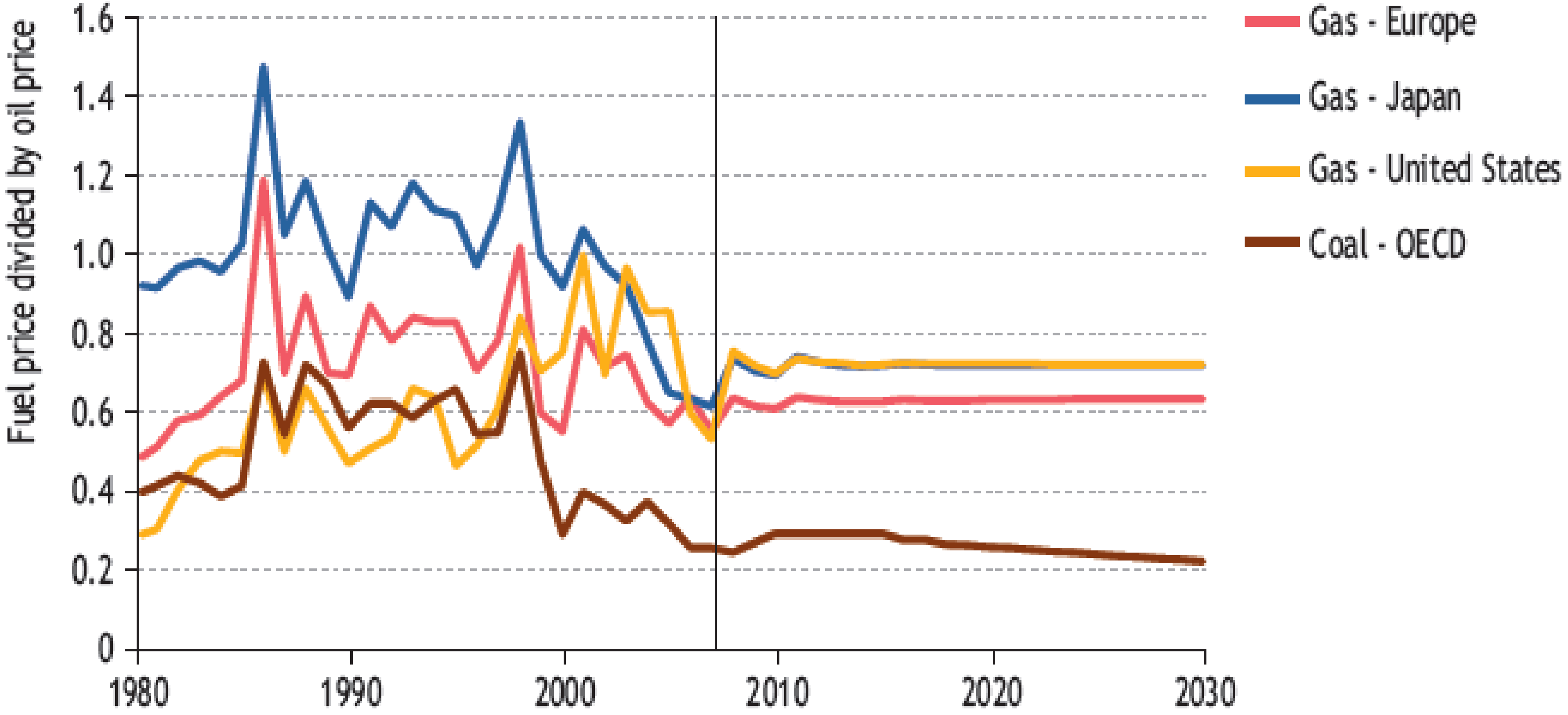
Prices: oil=70$/bbl; coal=35%; n.gas=75%; elc($/MWh)=140R&C, 90 ind, 50 gen.

2.1b – Price instability: oil



2.1c – Price instability: natural gas and coal

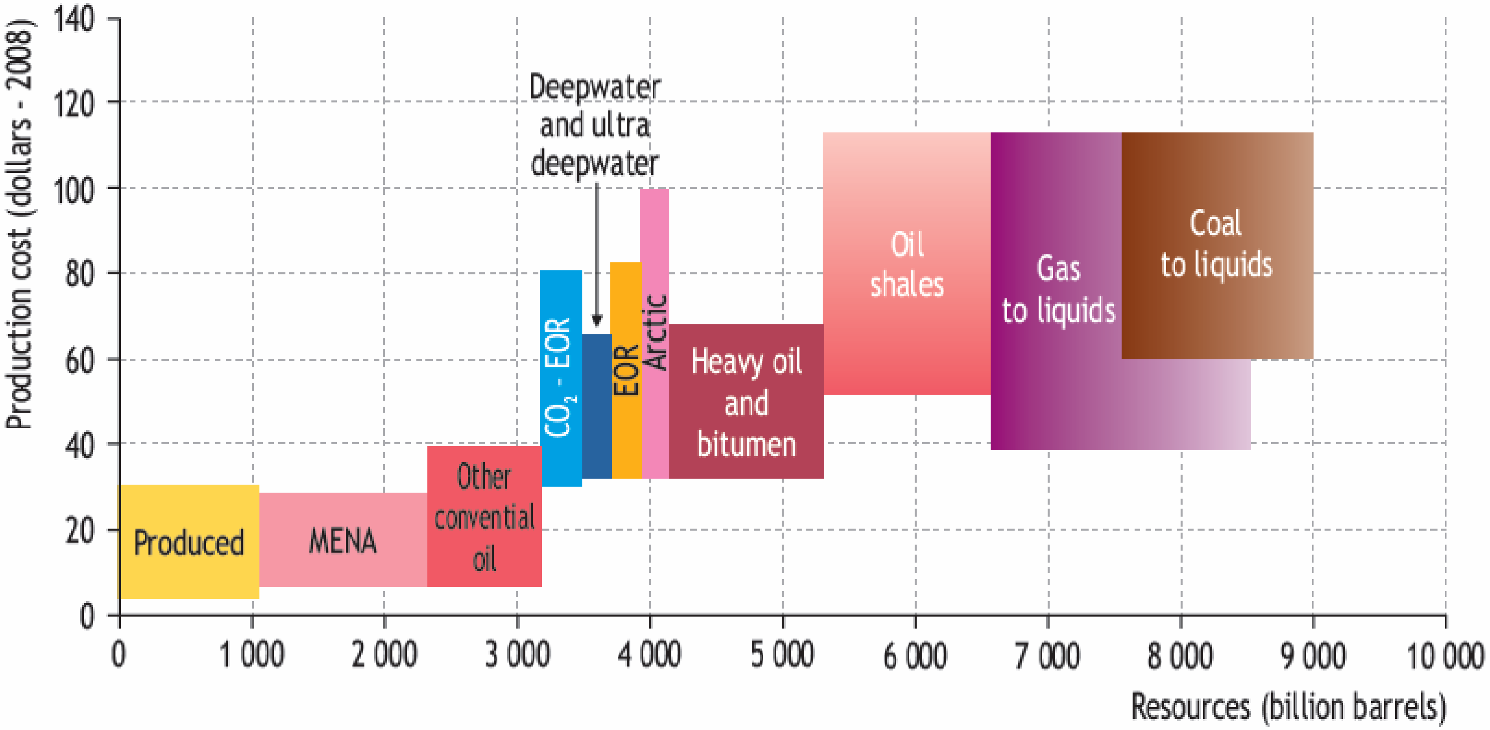
Figure 1.5 • Assumed natural gas and coal prices relative to crude oil*



* Calculated on an energy-equivalent basis using real-2007 dollars.

2.2 – Limited and concentrated oil resources

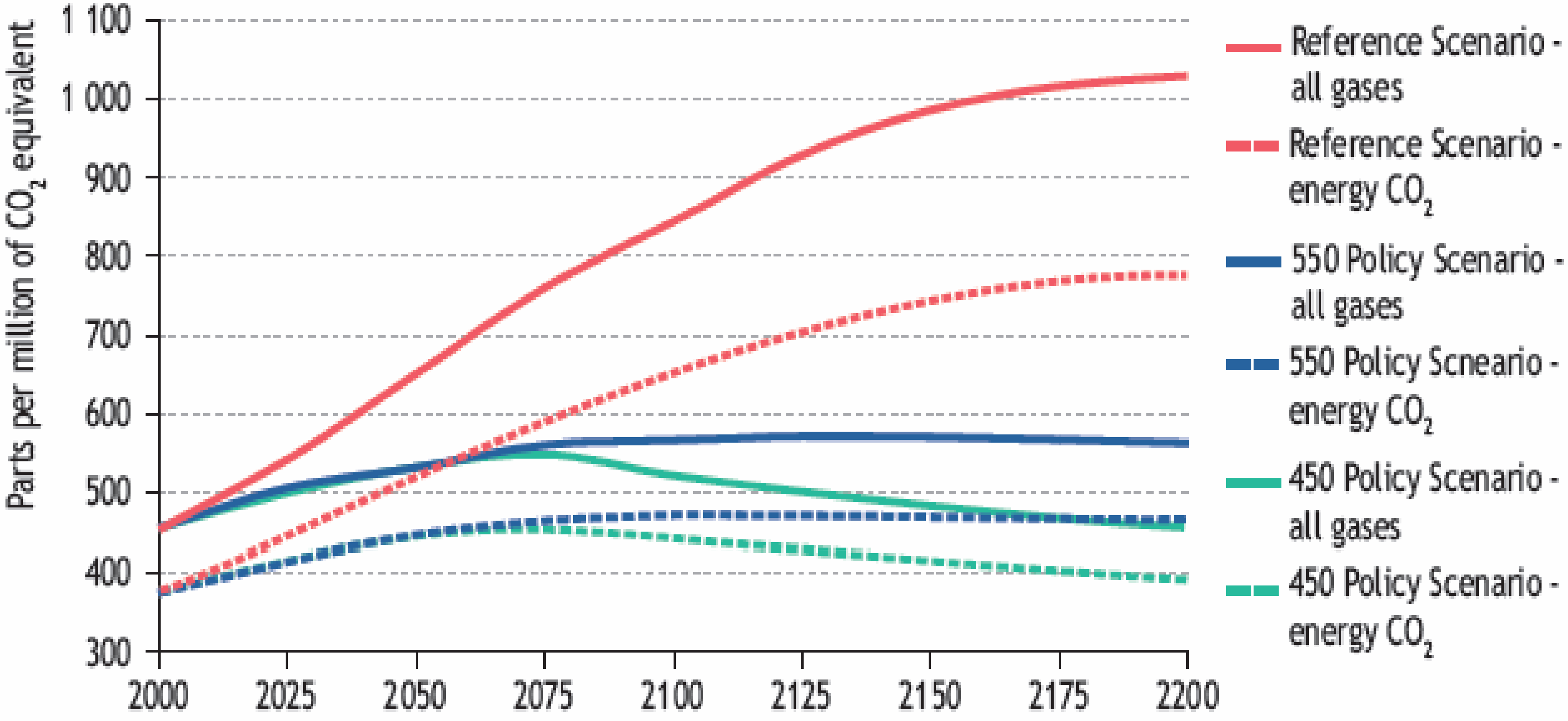
Figure 9.10 • Long-term oil-supply cost curve



Note: The curve shows the availability of oil resources as a function of the estimated production cost. Cost associated with CO_2 emissions is not included. There is also a significant uncertainty on oil shales production cost as the technology is not yet commercial. MENA is the Middle East and North Africa. The shading and overlapping of the gas-to-liquids and coal-to-liquids segments indicates the range of uncertainty surrounding the size of these resources, with 2.4 trillion shown as a best estimate of the likely total potential for the two combined.

2.3a – GHG concentrations: trends

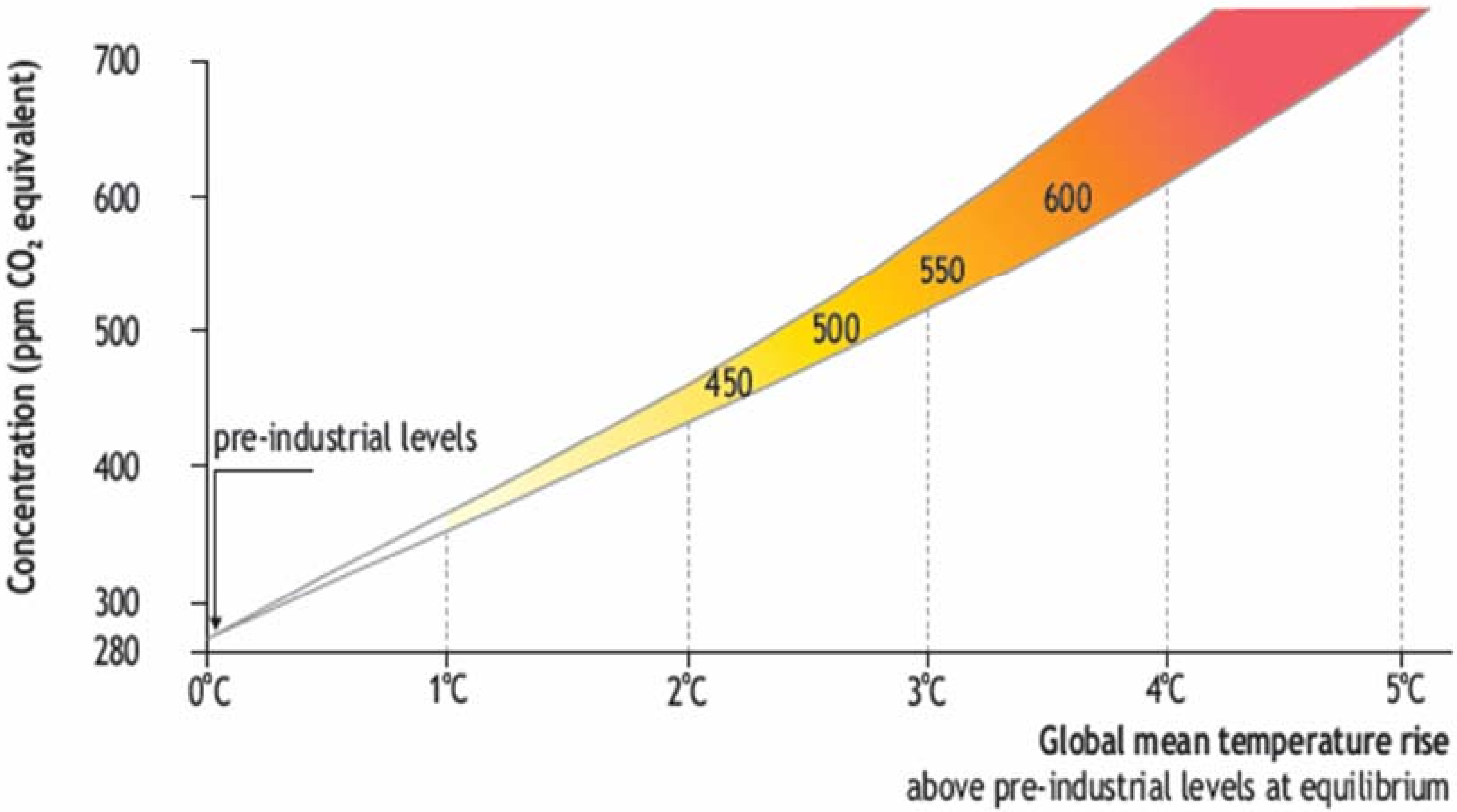
Figure 17.3 • Greenhouse-gas concentration trajectories by scenario



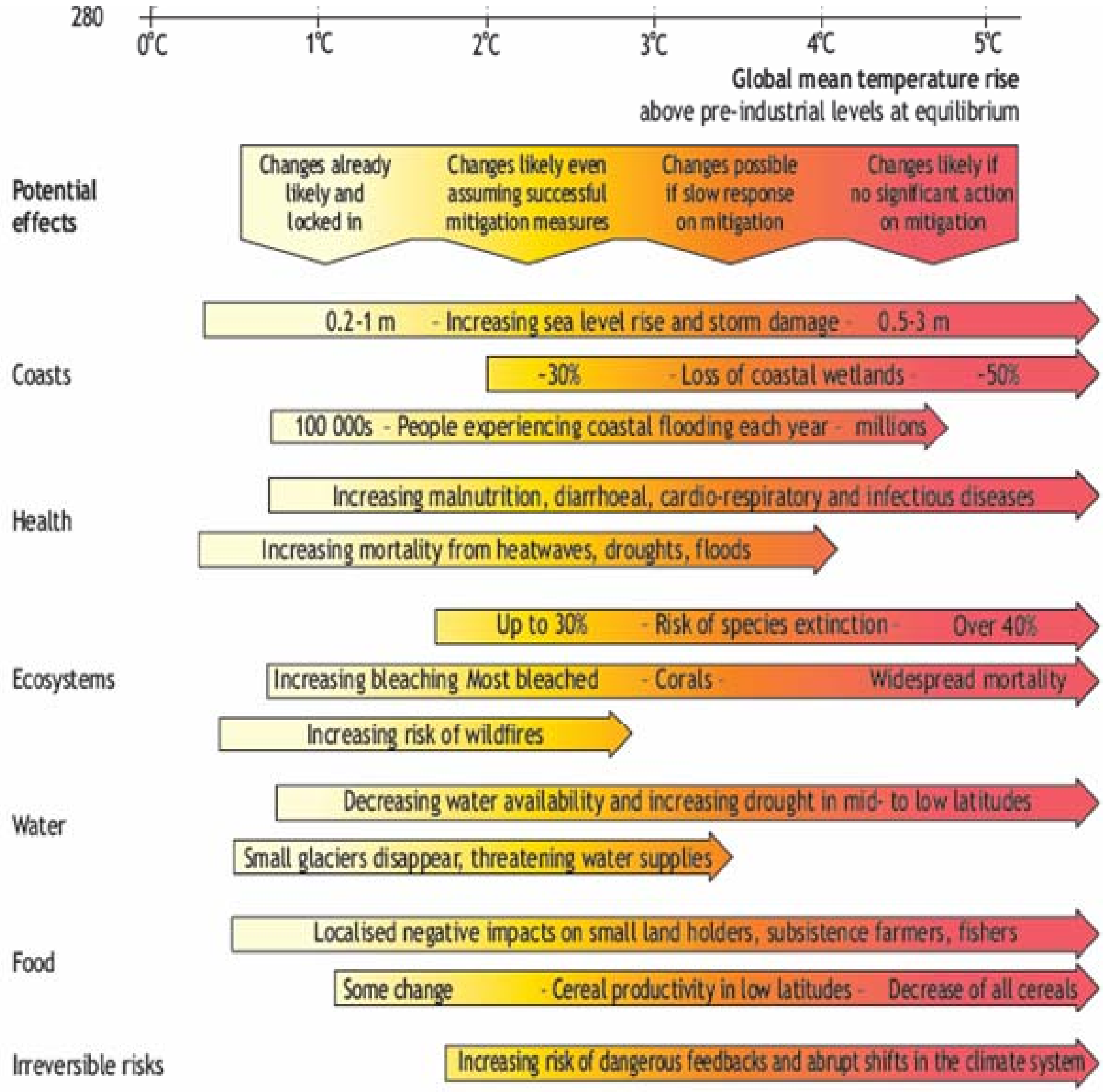
Note: We used MAGICC (Version 5.3)[7] to confirm that the projected emissions for all greenhouse gases to 2030 would result in concentration trajectories consistent with achieving stabilisation at around 700 ppm CO_2 (equivalent to around 1 000 ppm CO_2-eq) in the Reference Scenario, at 450 ppm CO_2 (550 CO_2-eq) in the 550 Policy Scenario and 380 ppm CO_2 (450 ppm CO_2-eq) in the 450 Policy Scenario.

2.3b – GHG concentration and temperature increase

Figure 17.1 • Potential effects of stabilisation of atmospheric concentrations of greenhouse gases at different levels



2.3c – GHG concentration and effects



Source: Adapted from IPCC (2007).

2.3d – Temp. increase, emissions and concentration

The relation between emissions and climate change according to Climate Change 2007, IPCC

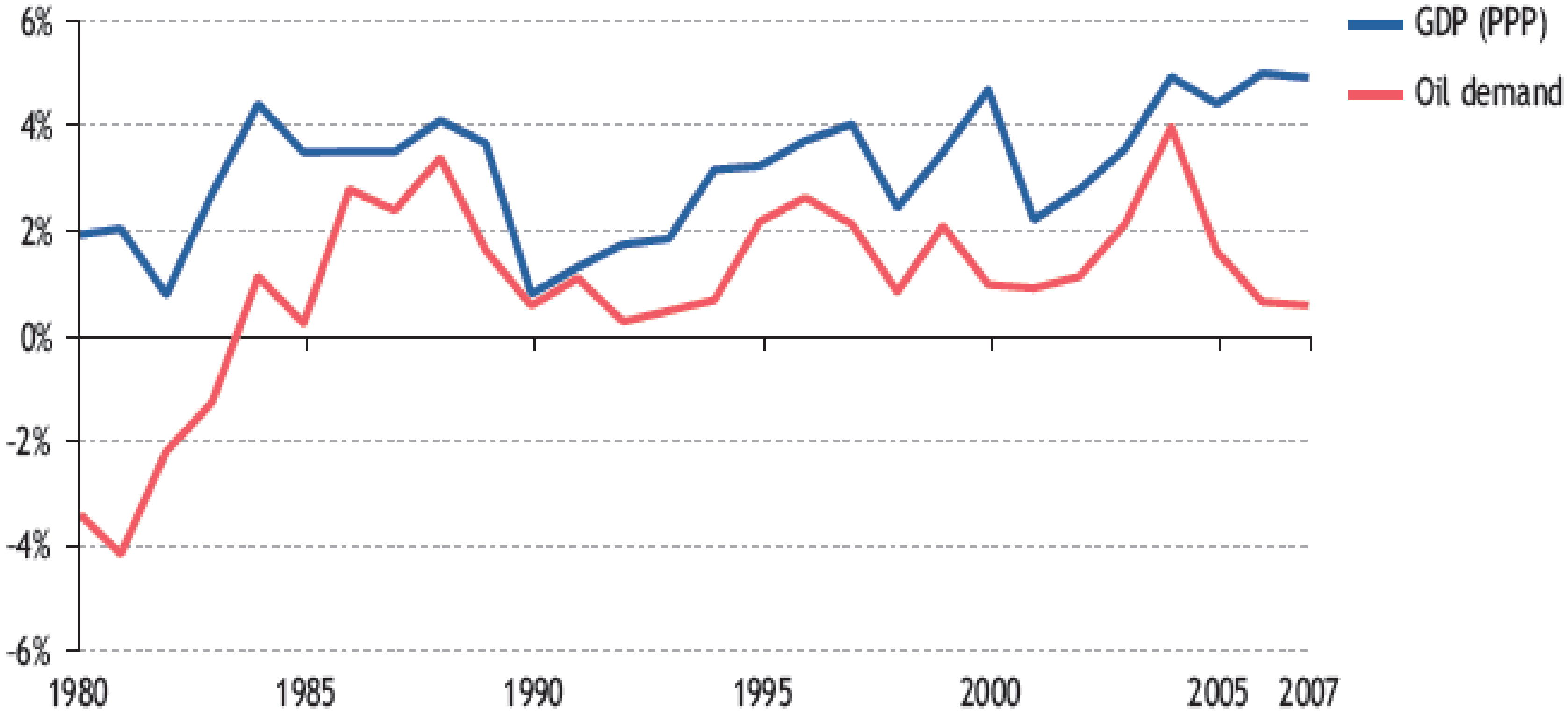
Temperature increase (°C)	All GHGs (ppm CO_2 eq.)	CO_2 (ppm CO_2)	CO_2 emissions 2050 (% of 2000 emissions) (%)
2.0-2.4	445-490	350-400	–85 to –50
2.4-2.8	490-535	400-440	–60 to –30
2.8-3.2	535-590	440-485	–30 to +5
3.2-4.0	590-710	485-570	+10 to +60

Source: IPCC, 2007.

Change in global CO2 emissions in 2050 as a function of global mean temperature increase above pre-industrial at equilibrium, using a climate sensitivity of 3°C (Table SPM.5 of [IPCC, AR4, WGIII, 2007]).

2.4a – Increasing wealth requires more oil

Figure 3.1 ● Change in world primary oil demand and real GDP growth



Chapter 3 - Oil market outlook

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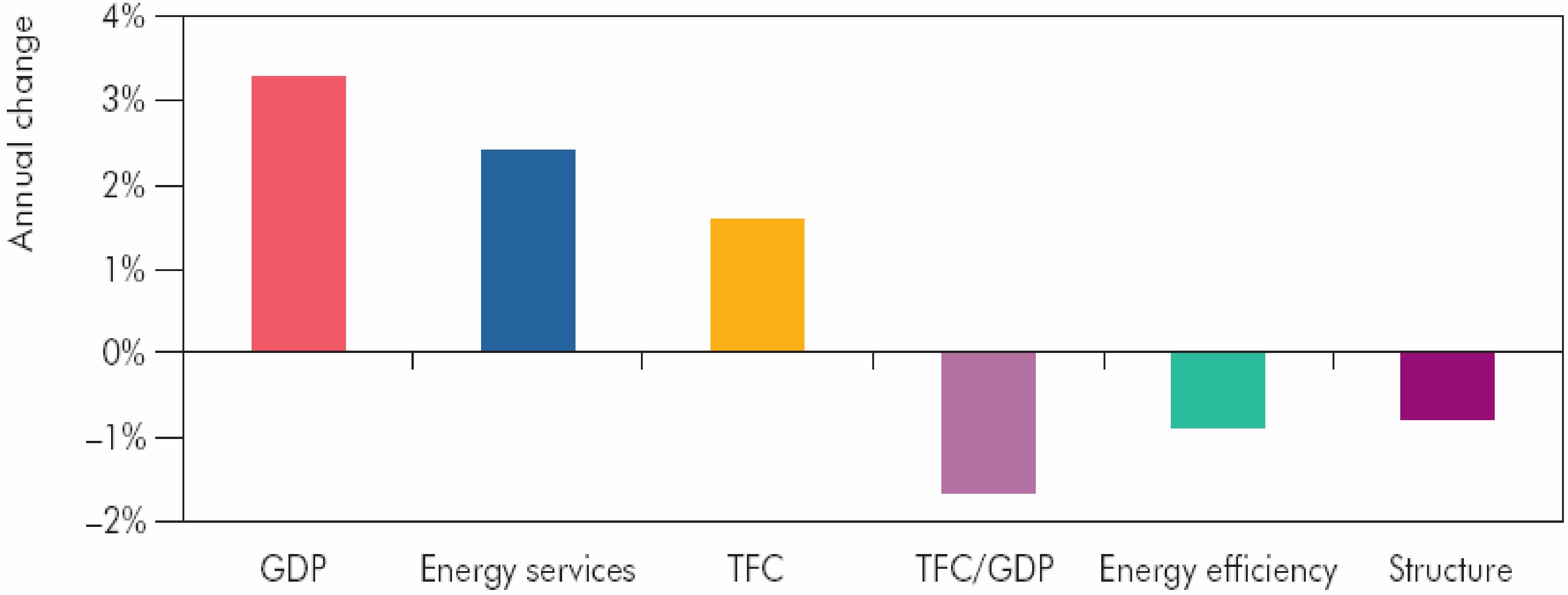
2.4b – Limited technological improvement

Figure 2.9 ▶ **Global trends in factors affecting final energy use under the Baseline scenario**



Note: The negative value for energy efficiency represents an improvement.

Key point

A combination of energy efficiency improvements and structural changes are responsible for reducing final energy intensity under the Baseline scenario.

2.5 Social problems

The demand for energy services continues to grow in order to increase the utility of developed country consumers and ensure minimum social standards to developing consumers.

With present technologies those energy services are provided by energy vectors (natural gas, electricity, gasoline, etc.) very inefficiently (10-20%).

Using energy vectors depletes all kind of natural resources and changes the climate.

The resulting damages reduce the economic development and social standards.

In democracy, unavoidable technological disputes – particularly between suppliers and consumers – prevented so far from taking new courses.

3. – Is it conceivable to take a different course?

Exploring alternative paths with the technical-economic global multi-regional IEA-MARKAL model

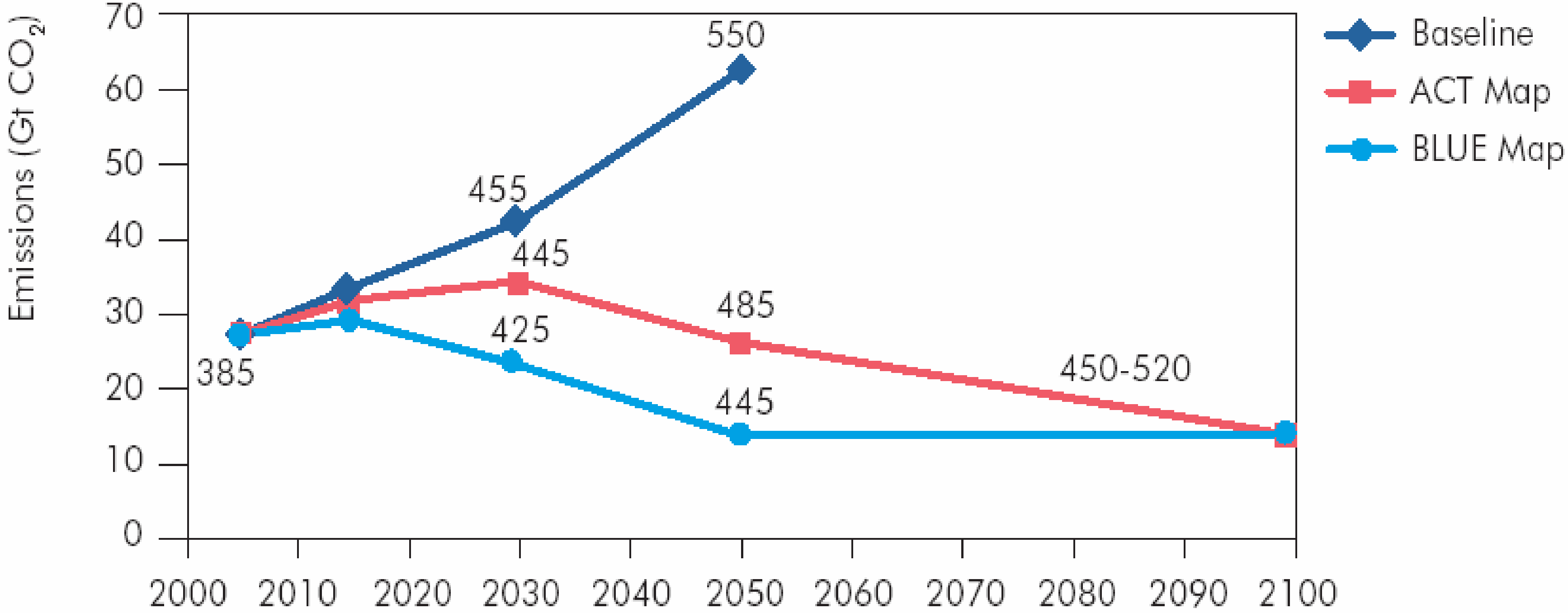
CO2 emission reduction:

1. paths
2. by sector
3. by technological option

Source: strong climate change mitigation policy scenario, IEA - Energy Technology Perspectives 2008: Scenarios and Strategies to 2050

3.1 – CO2 emissions reduction & concentrations

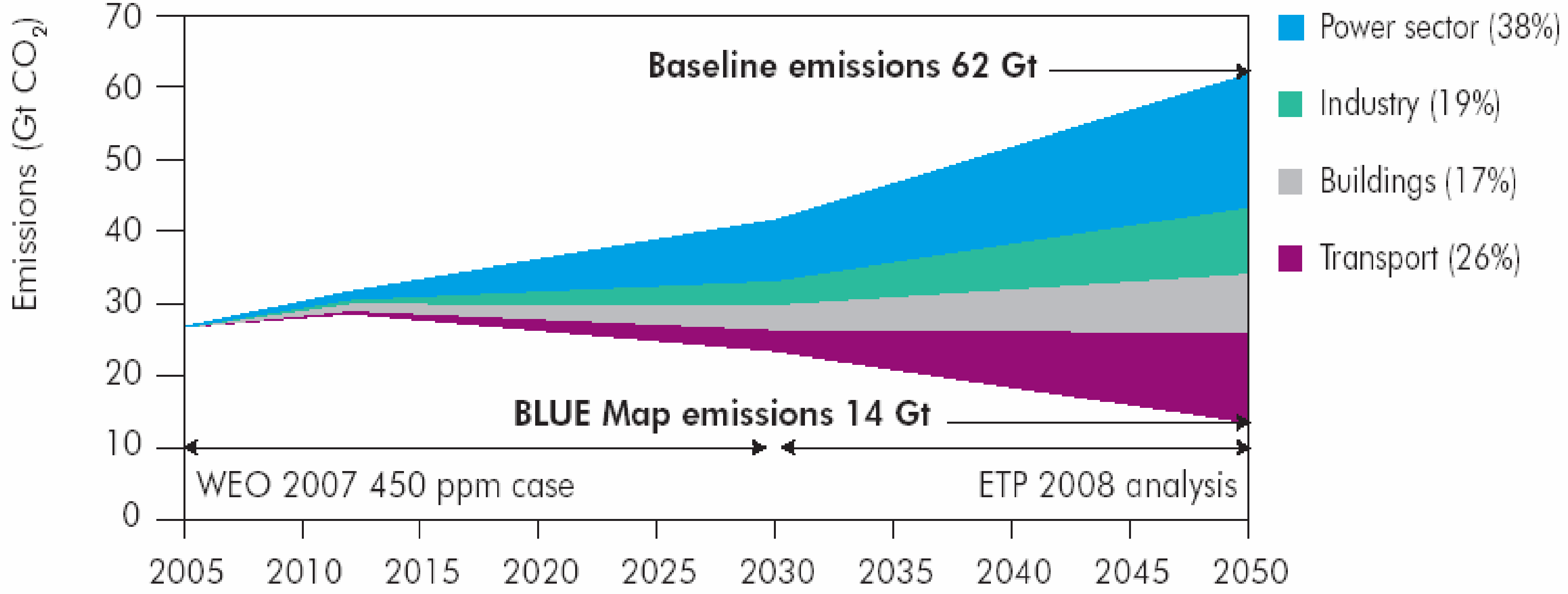
Figure 1.1 ▶ Energy-related CO_2 emission and CO_2 concentration profiles for the Baseline, ACT Map and BLUE Map scenarios



Note: Figures refer to CO_2 concentrations by volume (ppm CO_2).

3.2 – CO2 emission reduction by sector

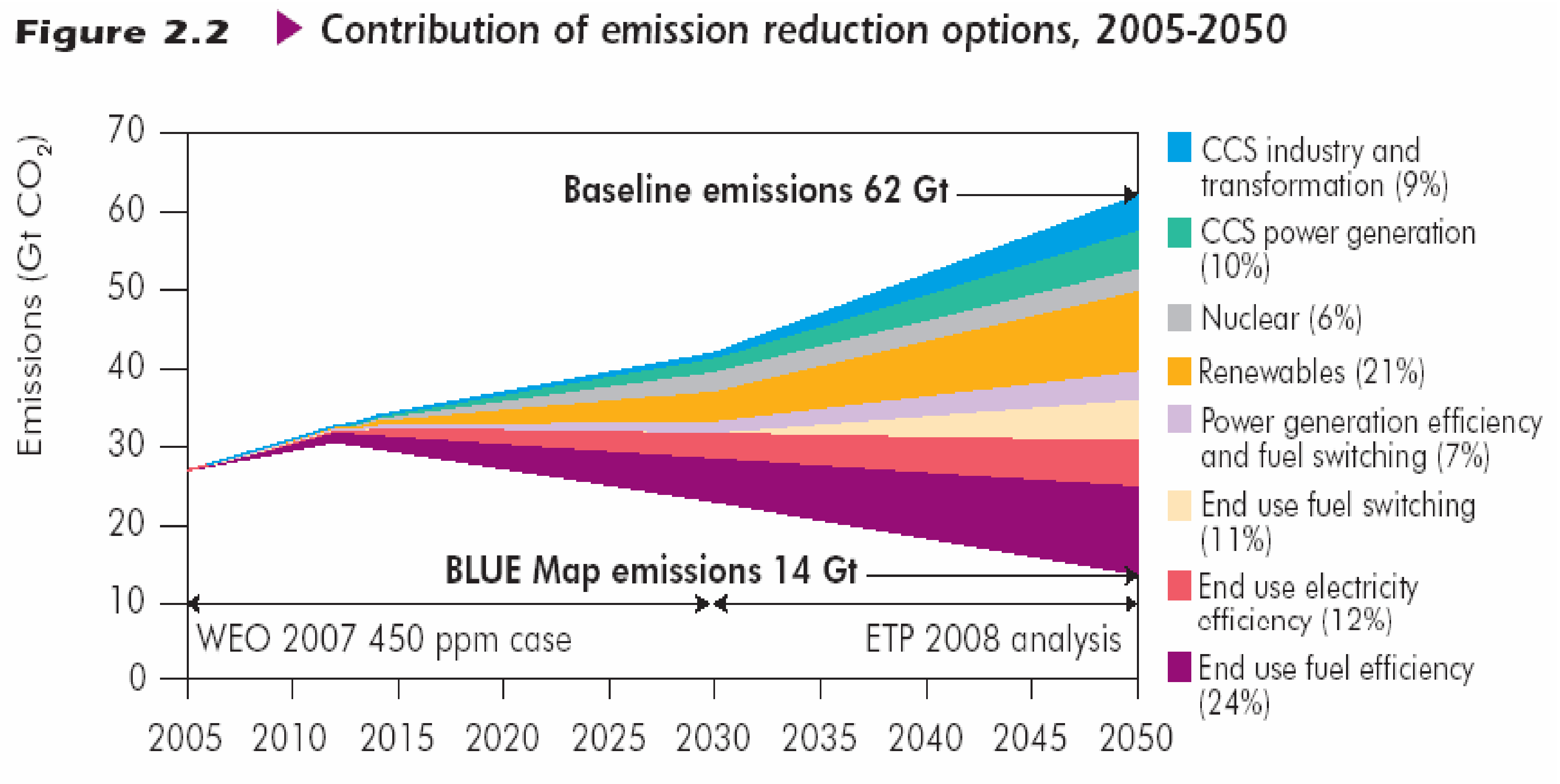
Figure 2.3 ▶ **Reduction of energy-related CO_2 emissions from the Baseline scenario in the BLUE Map scenario by sector, 2005-2050**



Key point

The share of end-use sectors in emission reduction increases between 2030 and 2050.

3.3 – CO2 emission reduction by technical option



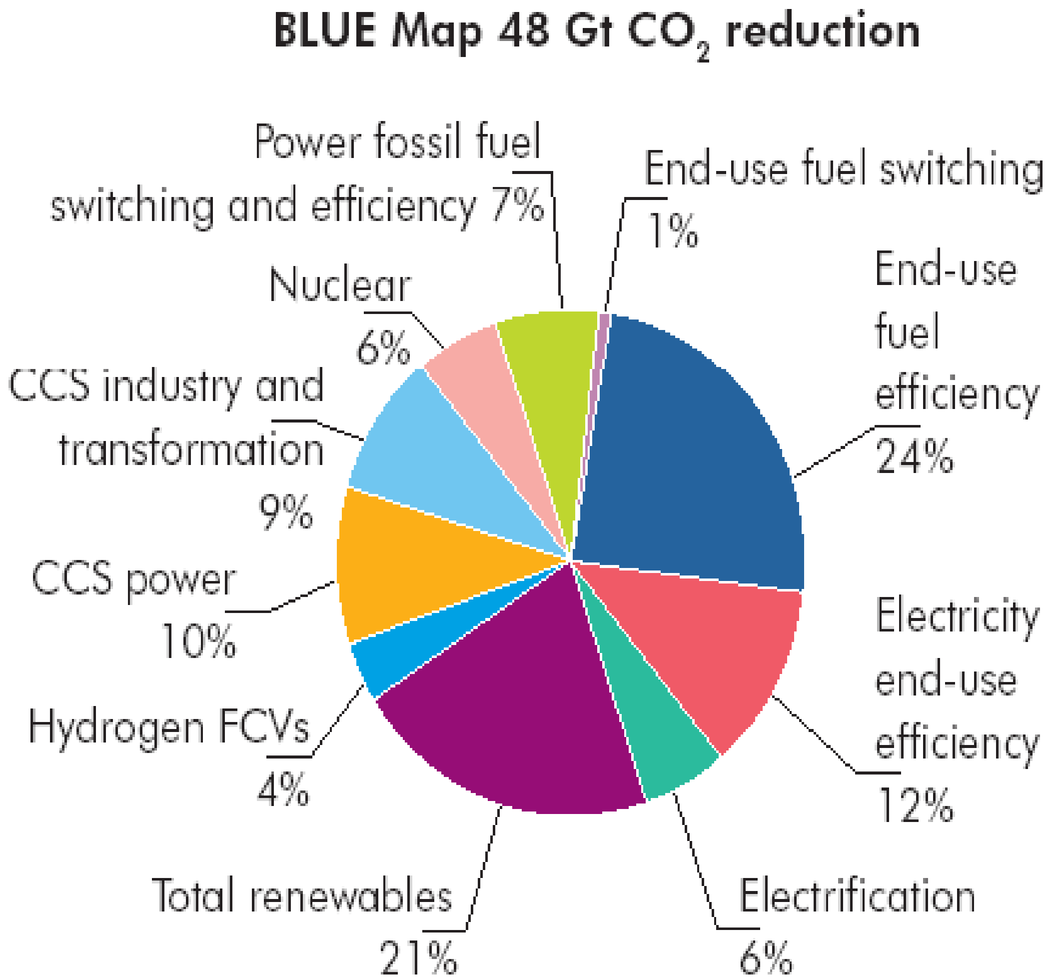
4. – What technologies for the energy revolution?

1. The analysis: share of emission reduction by energy technology group in 2050
2. The need: investments in energy technologies and infrastructures to 2030 and 2050
3. The reality: decreasing funds for energy research
4. The gap: traditional vs. innovative sectors

Source:

IEA-Energy Technology Perspective 2008, Scenarios and strategies to 2050

4.1 – The analysis: share of emission reduction by technology group in 2050



4.2a – The need: energy investments to 2030

Table 6.2 ▶ **Comparison of WEO and ETP investment needs for the Baseline scenario to 2030**

	USD trillion *World Energy Outlook*	**USD trillion** *Energy Technology Perspectives*
Production and transport		
Coal	0.6	0.6
Oil	5.4	5.4
Gas	4.2	4.2
Electricity generation, transmission and distribution	11.6	11.6
Subtotal	**21.9**	**21.9**
Demand side	n.a.	95.6
Total	n.a.	**117.5**

Global GDP in 2006 = 38 – 58 trillions USD2000

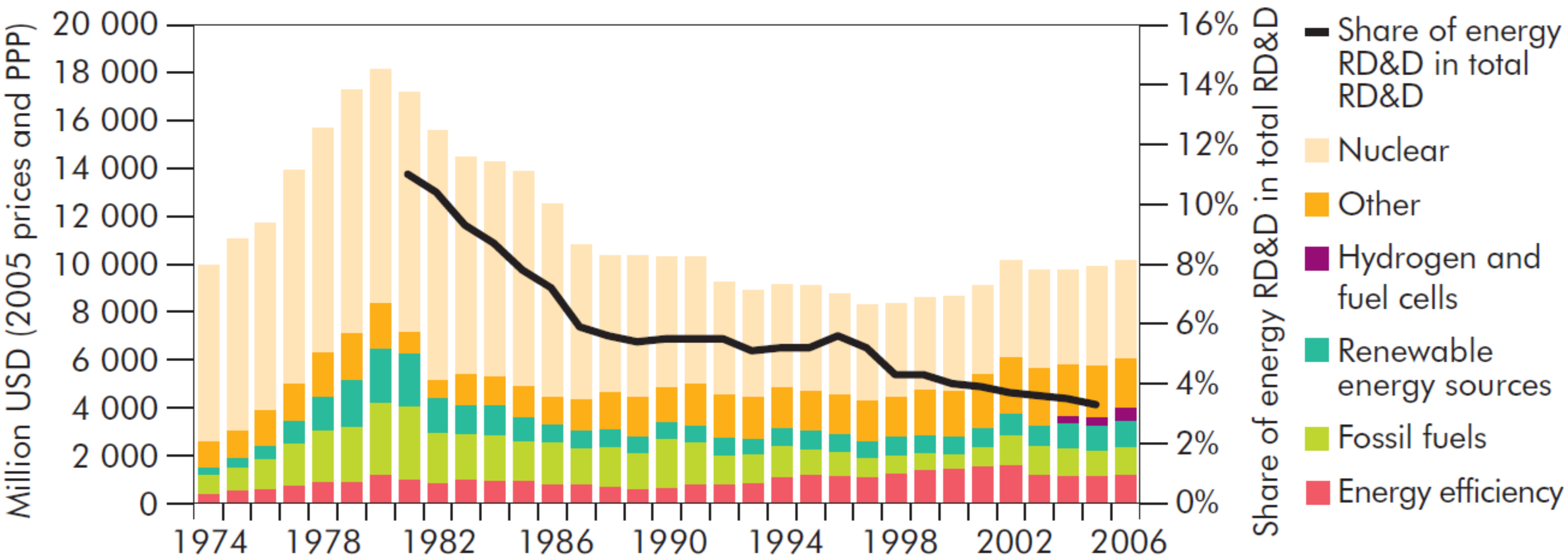
4.2b – The need: additional investments for mild and strong policy scenarios, 2010-2050

Table 6.1 ▶ **Additional investment in the ACT Map and BLUE Map scenarios compared to the baseline, 2010-2050**

	Increase/Decrease from baseline	
	ACT Map (USD trillion)	**BLUE Map** (USD trillion)
Transformation	–1.9	–0.6
Power plant	0.7	3.6
Transmission (electricity)	0.9	1.4
Distribution (electricity)	–2.7	–2.1
Industry	0.6	2.5
Transport	17.1	32.8
Residential	2.2	6.4
Services	0.4	1.0
Total	**17.3**	**45.0**

4.3a – Reality: public funds for energy R&D decrease

Figure 4.2 ▶ **Government budgets on energy RD&D of the IEA countries**



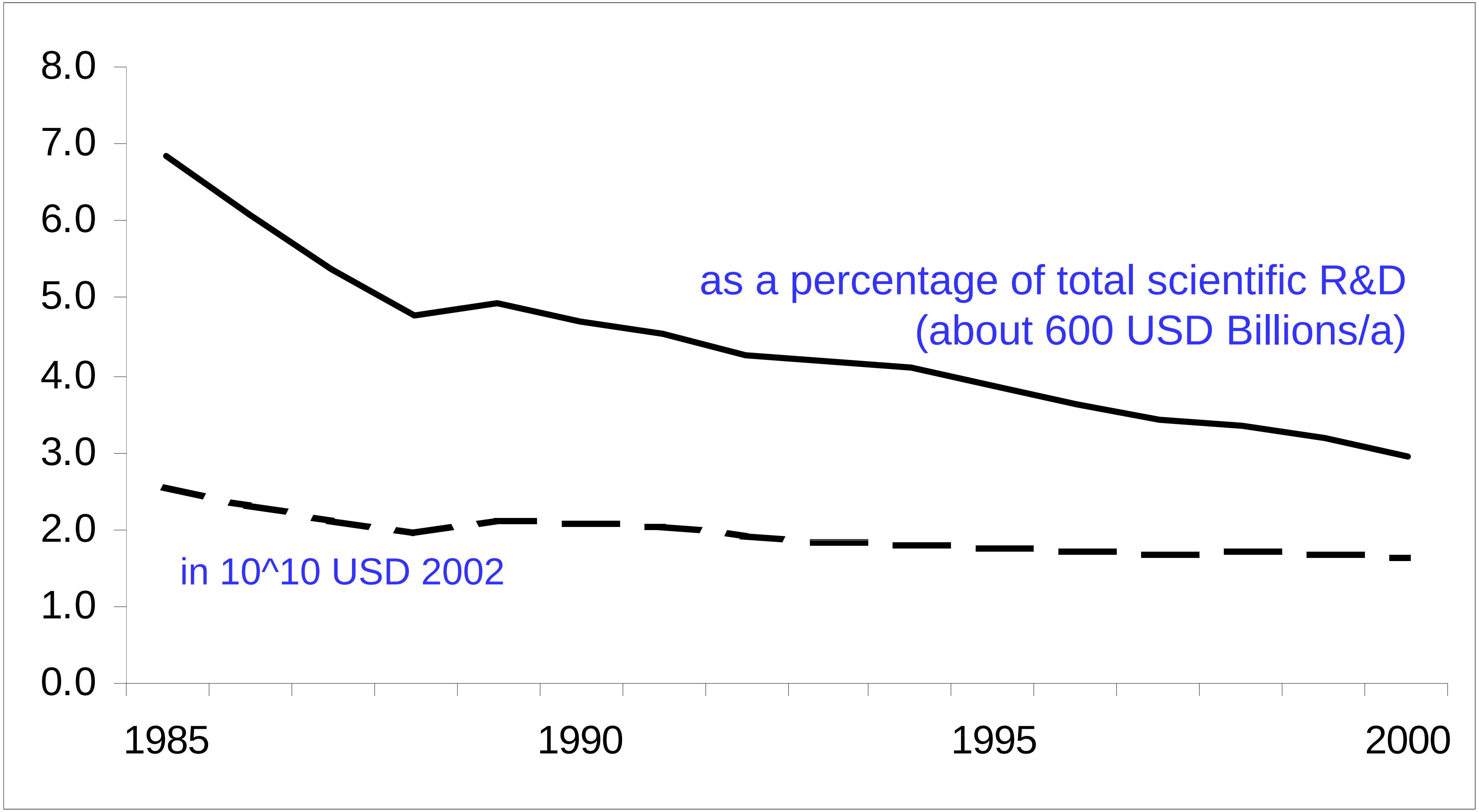
Note: RD&D budgets for the Czech Republic not included due to lack of available data.

Source: IEA 2007a, OECD 2007a.

Key point

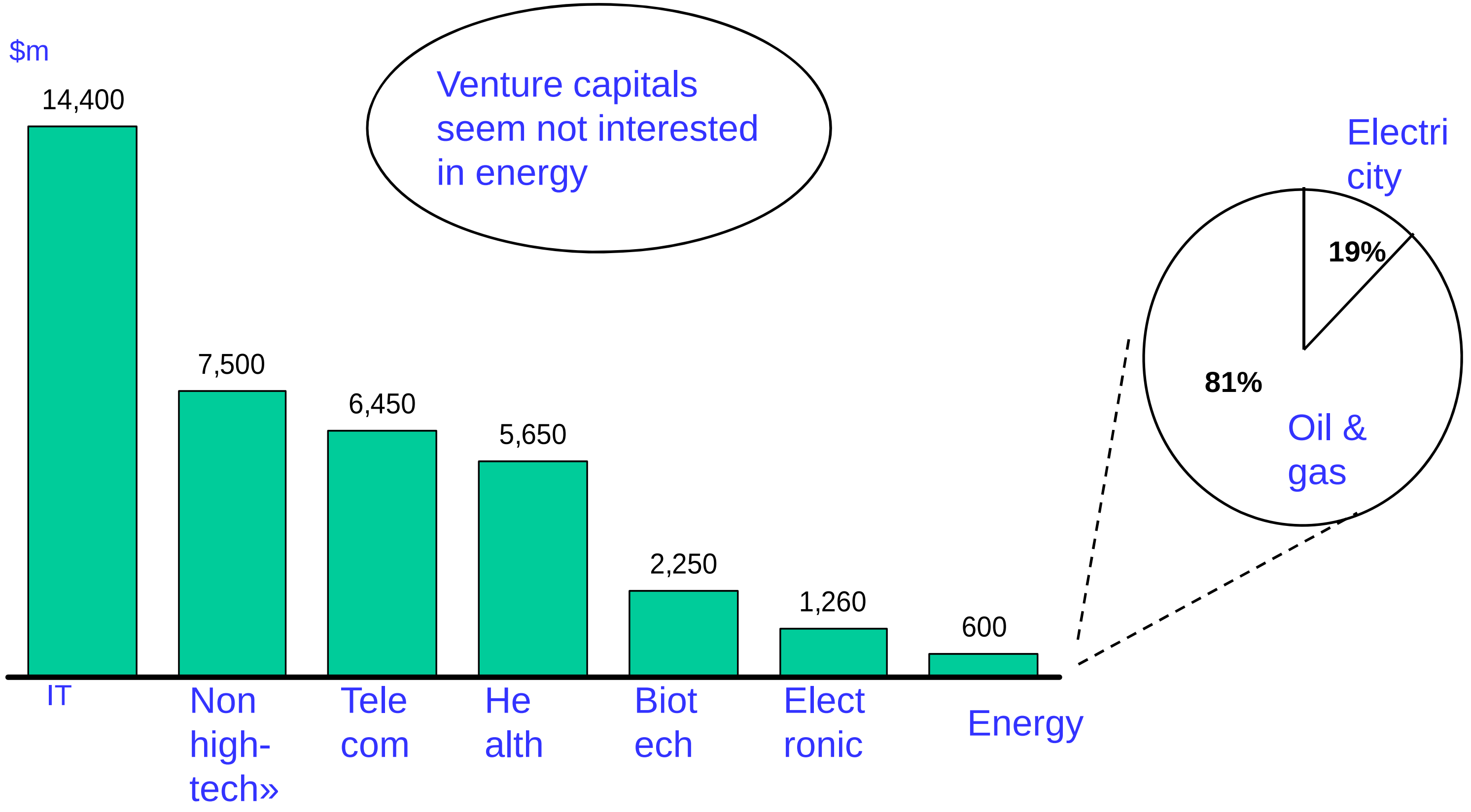
Government expenditures on energy RD&D have declined compared to the level seen during the late 1970s and early 1980s.

4.3b – The reality: decreasing funds for energy R&D



Energy R&D investments of USA, Japan, EU15 (source; www.izt.de/eurendel/)

4.4a – Venture Capital Investimenti by Sector, 1998



Venture Economics accounts for roughly 70% of all the deal flow. Source: NVCA

4.4b – Venture Capital Backed Revenue, 2006

Industry	Revenue at Venture Capital Backed Companies	Total Sector Revenue	Venture Capital Backed Companies' Share of Total Revenue
Computers and Peripherals	$533.3 billion	$681.2 billion	78.3%
Industrial/Energy	$302.4 billion	$6.5 trillion	4.6%
Software	$227.0 billion	$584.3 billion	38.9%
Retail/Distribution	$222.3 billion	$7.1 trillion	3.1%
Telecommunications	$165.4. billion	$467.6 billion	35.4%

Source: Venture Impact, The Economic Importance of Venture Capital Backed Companies to the U.S. Economy, 2007 (NVCA)ISBN: 0-9785015-4-3

5. – ICT contribution to the energy revolution

Waiting for the technological breakthrough – *the equivalent in the energy sector of integrated circuits instead of vacuum tubes, cars instead of coaches, cell phones instead of telegraphs* – ICT contributes:

1. Inside ICT, more efficiency

   Outside ICT:

2. Where in the energy system chains?
3. managing decentralised electric grids,
4. in the use of devices, efficiency and organization,
5. with innovative direct supply of energy services, and
6. diffusing the information.

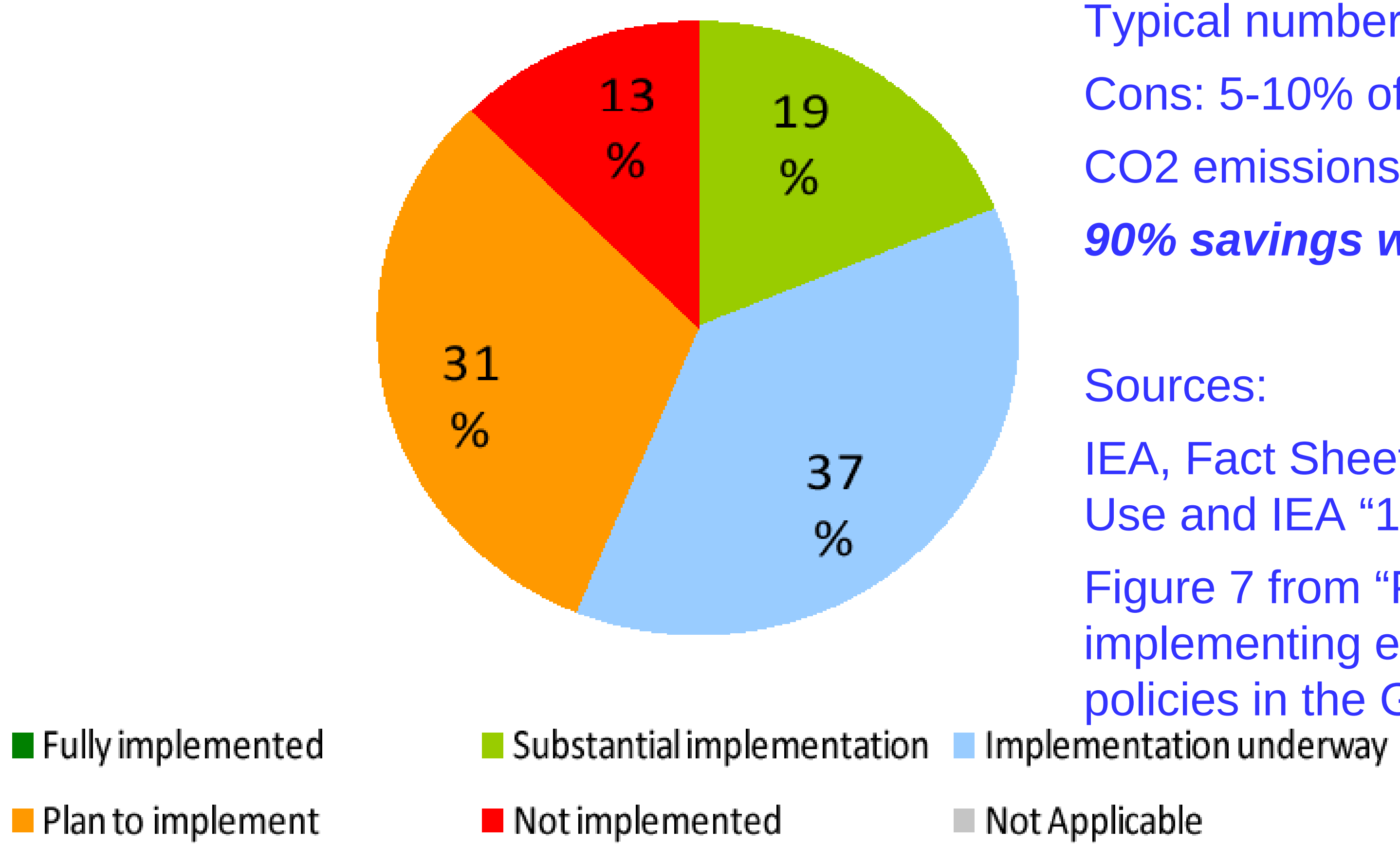
5.1a – More efficient ICT components & systems

"Currently, data volume transmitted through networks increases approximately by a factor of ten every five years, which corresponds to an increase of associated energy consumption by approximately 16 % – 20 % per year. Gartner estimates that the use phase of ICT equipment is responsible for 2 % of the annual carbon emissions. Other studies indicate that the share of the use phase of ICT in the worldwide energy consumption is closer to 3 %. This is comparable to the energy consumption of the aviation industry. When incorporating the entire life cycle, the share of ICTs is closer to 4 %. The exponential growth of ICTs, which will be required for reducing the energy intensity of the entire economy, is currently not sustainable." *[16-18% in 2030]*

Sources: EC, 2008, "Addressing the challenge of energy efficiency through Information and Communication Technologies"; and eMobility, , Dec. 2008, "Strategic Research Agenda" Version 7

5.1b – More efficient ICT: example standby power

Figure 7: Progress with implementing recommendations relating to standby power, all G8 countries



Typical power: .5-10 W; total

Typical number: 20 per house

Cons: 5-10% of dom. elc. Bills

CO_2 emissions: 1% globally

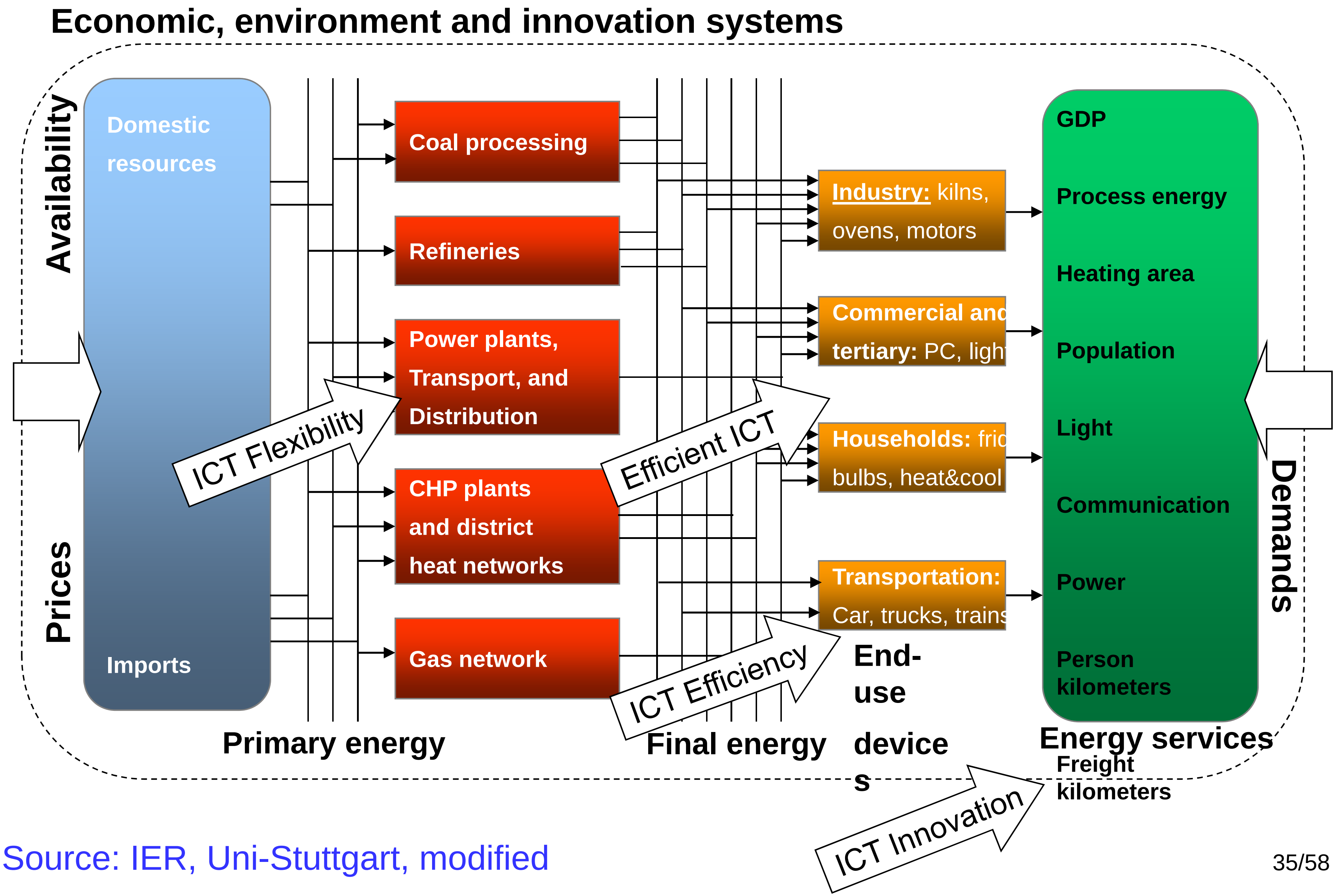
90% savings with new tech.

Sources:

IEA, Fact Sheet: Standby Power Use and IEA “1-Watt Plan” 2007

Figure 7 from “Progress with implementing energy efficiency policies in the G8”, IEA, 2009.

5.2 – Where in the energy systems?



Source: IER, Uni-Stuttgart, modified

5.3 – ICT manages decentralised electric grids

ICT can make it possible the transition

- from a highly centralize system with very few options
- to a highly decentralised system with as many options as “prosumers”

1. Power balance in Western Denmark, 1990-2010
2. The transition from high to medium voltage generation
3. Decentralised electric grids: Cell Controller functionalities.
4. ICT vs. energy: divergent cost development patterns
5. Towards the “internet of electricity: intelligent grids”

Sources

1, 2, 3: Per Lund, Energinet.dk: “The Danish Cell Project - Part 1: Background and General Approach”, IEEE, 1-4244-1298-6/07

4, 5: Friederich Kupzog, “Frequency-responsive load management in electric power grids”, PhD thesis, TUVienna, 2007

5.3.1 – Power balance, Western Denmark, 1990-2010

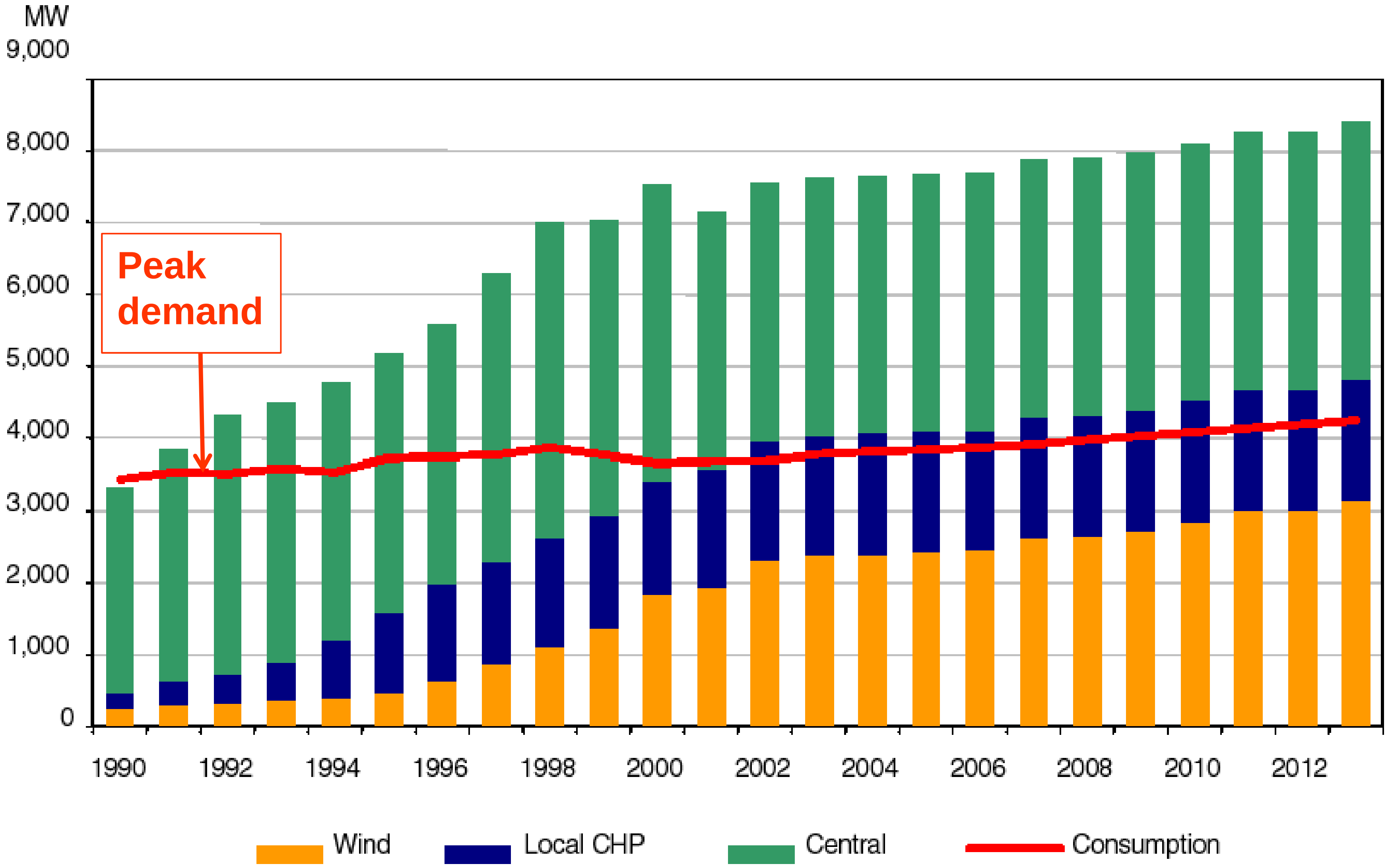


Fig. 3. Development of the power balance in western Denmark

5.3.2a-Transition high to medium Voltage generation

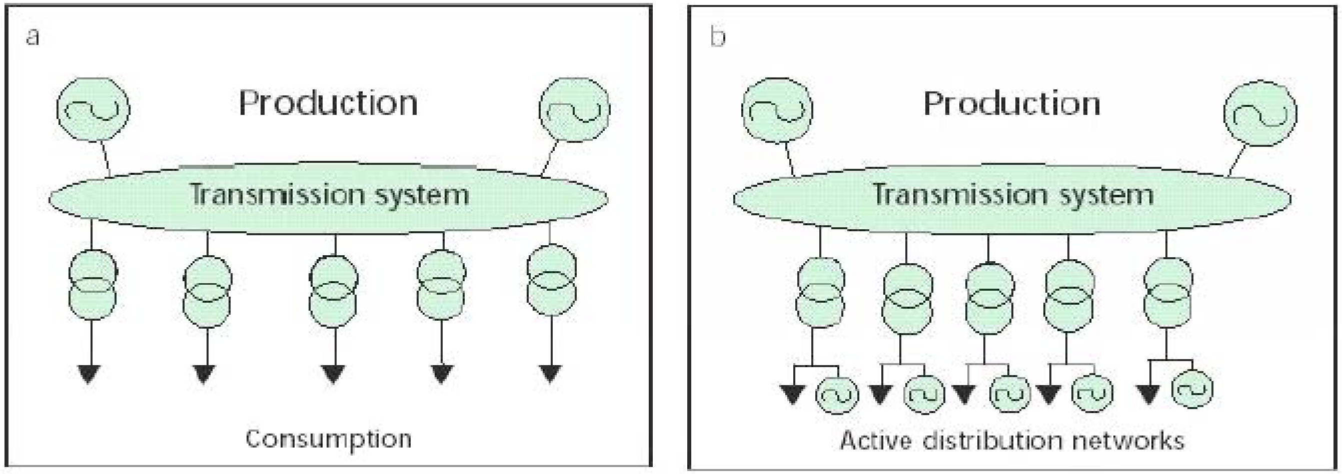


Fig. 2. The transition from primary production (a) to local production (b)

5.3.2b-Transition high to medium Voltage generation

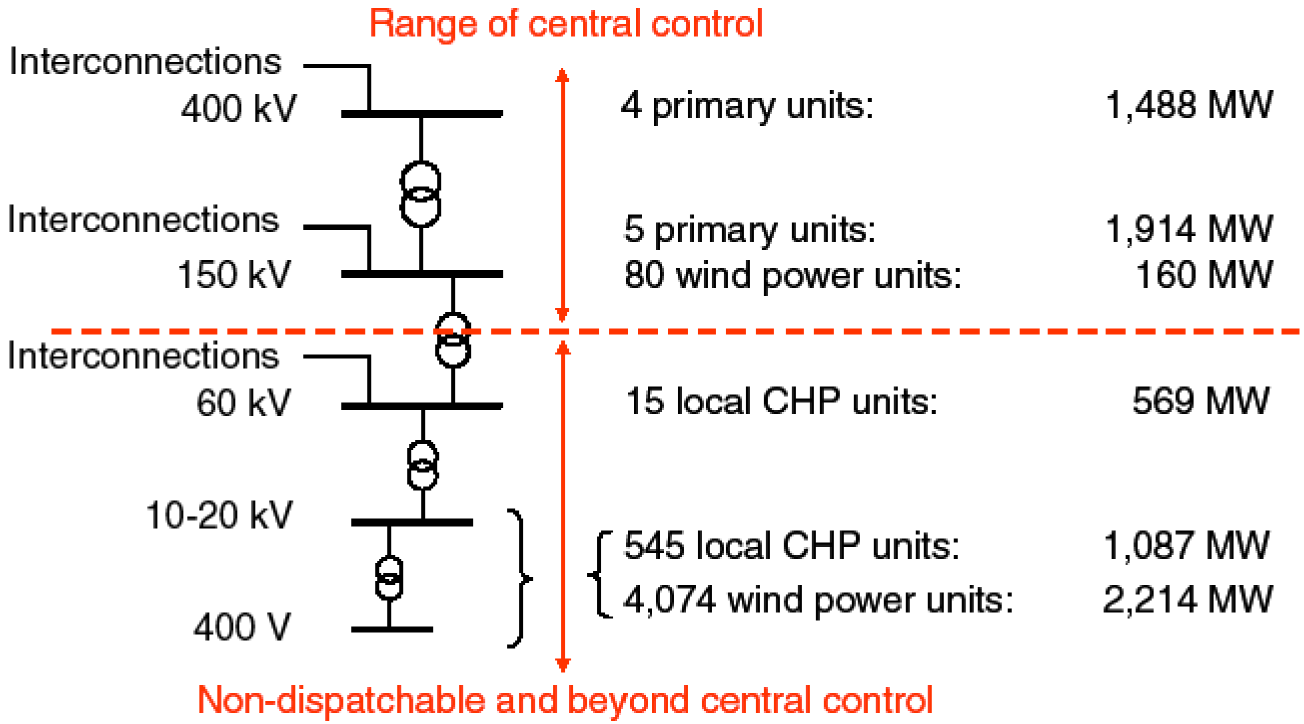


Fig. 4. Production capacity per voltage level in Western Denmark

5.3.3 – Cell Controller Functionalities

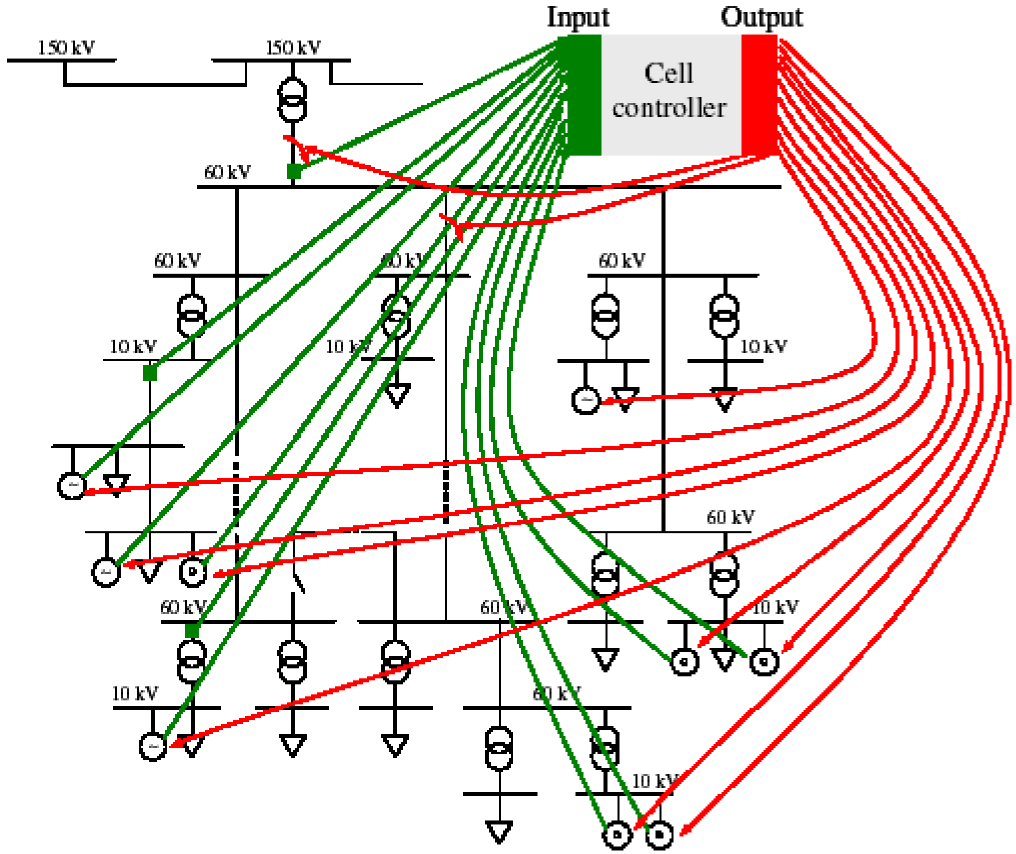


Fig. 7. Cell Controller functionalities. Measuring and monitoring of load and production indicated by (green) arrows pointing towards the Cell Controller. Control actions on generators, load feeders and main power circuit breakers indicated by (red) arrows pointing away from the Cell Controller.

5.3.4 – ICT vs. energy cost development projections

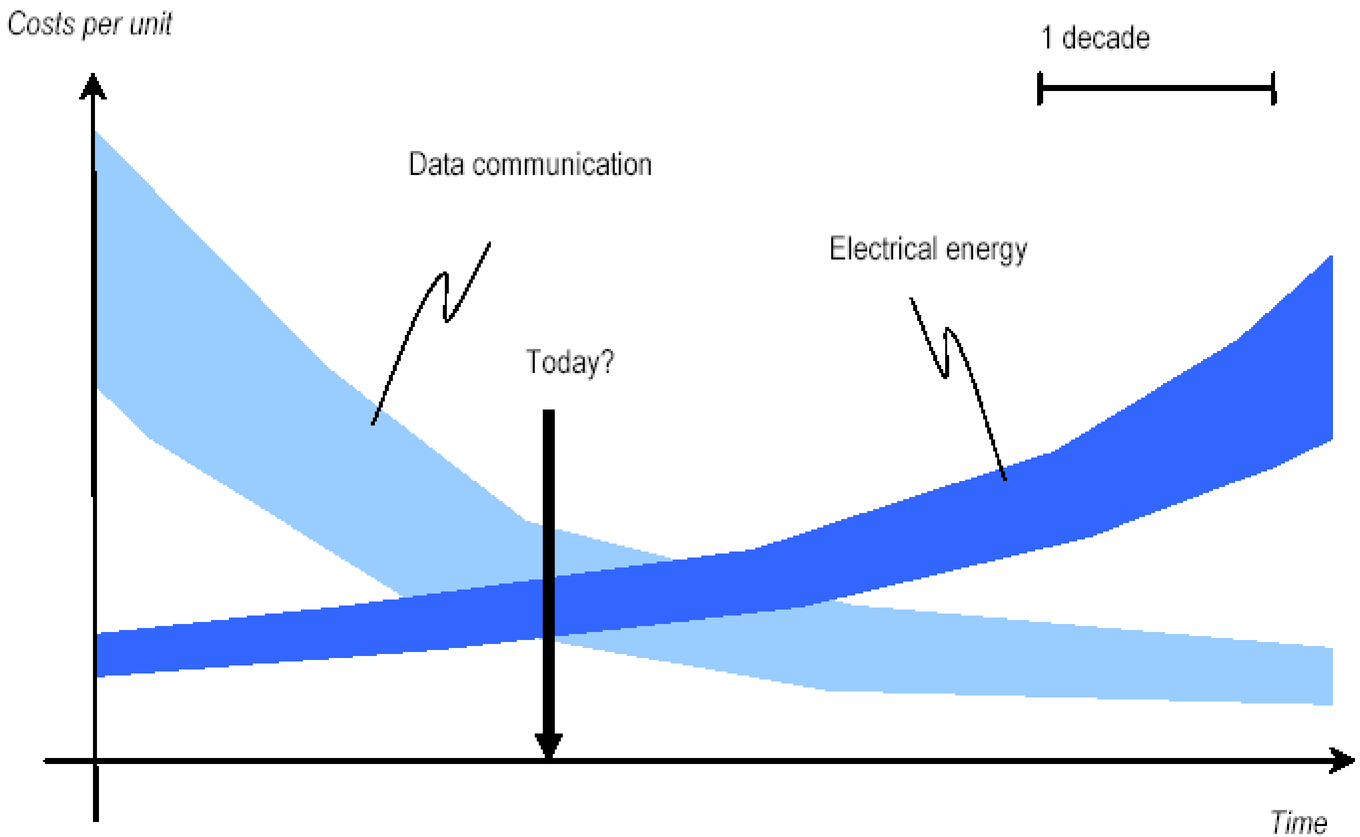


Figure 8.2: Estimated development of costs for communication and energy

5.3.5 – Internet of electricity and intelligent grids

Electric grids were designed as passive infrastructures, virtually “blind” on the medium and low voltage levels. How to supply more users, with more power, from myriads of dispersed generators?

Instead of investing into “more of the same”, the problem is tackled by installing comparably inexpensive ICT systems and controllers. Infrastructures are paralleled by sort of “internet” of the grid, connecting sensors which measure on-line data of the grid (such as voltage, current, frequency, power, energy, flicker, harmonics, other data).

“Intelligent” controllers associated to every user, transformer, plant, up to the GW level, exchange billions of data and ensure reliable power balance at each knot.

5.4 – Efficient management of efficient devices

Inside end-use devices ICT maintain optimal performance level of engines, motors, ovens, etc.

Outside optimal management of

- *Transport vehicles*: travel info, traffic management, on demand buses, etc.
- *Home appliances*: tele-control, load shifting devices, occupancy sensors, etc.
- *Industrial production*:

5.5 – Direct supply of energy services

In an energy system, the greatest losses are incurred in the last step of the chain, when useful energy (heat, power, movement) satisfies the requested service. Examples:

Why moving 1000 kg to transport 100 kg? Progress:

- reached: to move information instead of materials

- to be reached: move intelligence instead of people

Why cooking/heating a container for the content? Progress:

- reached: microwave ovens for inductive cooking

- to be reached: heat / cool people, not houses

5.6 – Diffusion of the information

With ICT centralised information is being gradually complemented by decentralised information and communications. This gives more possibility to establish micro-democracy.

In the field of energy, ICT facilitates Transparency, Truth telling, Fairness, and Openness to learning. This can gradually open the market to several win-win options (no/low cost efficiency) and behavioural changes.

Eventually consumers are associated to the decisions process, now dominated by suppliers. This paves the way to taking decisions optimal in the longer term and improves the “governance of the energy revolution”.

6. The International Energy Agency – IEA (Paris)

1. Intro
2. Member Countries
3. Secretariat
4. Implementing Agreements

6.1. What is the International Energy Agency?

The International Energy Agency (IEA) is an intergovernmental organisation which acts as energy policy advisor to 28 member countries in their effort to ensure reliable, affordable and clean energy for their citizens.

Founded during the oil crisis of 1973-74, the IEA's initial role was to co-ordinate measures in times of oil supply emergencies. As energy markets have changed, so has the IEA. Its mandate has broadened to incorporate the "Three E's" of balanced energy policy making: energy security, economic development and environmental protection.

Current work focuses on climate change policies, market reform, energy technology collaboration and outreach to the rest of the world, especially major consumers and producers of energy like China, India, Russia and the OPEC countries.

With a staff of around 190, mainly energy experts and statisticians from its 28 member countries, the IEA conducts a broad programme of energy research, data compilation, publications and public dissemination of the latest energy policy analysis and recommendations on good practices.

6.2 Member Countries

The International Energy Agency (IEA) is an intergovernmental organisation which acts as energy policy advisor to 28 member countries in their effort to ensure reliable, affordable and clean energy for their citizens.

Australia	France	Republic of Korea	Slovak Republic
Austria	Germany	Luxembourg	Spain
Belgium	Greece	The Netherlands	Sweden
Canada	Hungary	New Zealand	Switzerland
Czech Republic	Ireland	Norway	Turkey
Denmark	Italy	Poland	United Kingdom
Finland	Japan	Portugal	United States

6.3 Secretariat

Office of the Executive Director
Nobuo Tanaka
Richard Jones

Energy Statistics Division

Office of the Chief Economist

Office of the Legal Counsel

Communication and Information Office

Information Systems Division

Personnel and Finance Division

Directorate of Global Energy Dialogue (GED)
Neil Hirst

Directorate of Energy Markets and Security (EMS)
Didier Houssin

Directorate of Sustainable Policy and Technology (SPT)
(currently vacant)

6.4 Implementing Agreements

7. The Energy Technology Systems Analysis Program

1. Program
2. Objectives
3. Strategy
4. Tasks - Annexes
5. Participants
6. Cost and advantages
7. ETSAP tools users

7.1. The Programme of Energy Technology Systems Analysis

… is a multilateral international agreement, promoted and sponsored by the International Energy Agency (Paris).

This cooperation started after the first oil crisis, in order to understand through systems analysis, whether:

- alternatives to oil were technically feasible, economically and environmentally sustainable;
- solutions were global or dependent on national circumstances;
- global energy RD&D paths were possible or advantageous.

After two years of analyses (1976-77), since the tools available at the time were not sufficient to provide answers, the group developed a new tool, the MARKAL model generator.

7.2. Objectives

ETSAP experts assist decision-makers in assessing policies intended to meet the challenges of

- energy needs,
- technological progress,
- environmental concerns, and
- economic development,

… by carrying out

- a programme of co-operative energy technology systems analysis, and
- modelling studies of possible developments.

7.3. Strategy

The objectives are achieved through a twofold strategy:

1. ETSAP has established, and now maintains / enhances the flexibility of consistent multi-country energy / engineering / economy / environment analytical tools and capability (the MARKAL TIMES family of models), through a common research programme.

2. ETSAP members also assist and support government officials and decision-makers by applying these tools for energy technology assessment and analyses of other energy and environment related policy issues. In fact they implement several economic-equilibrium technology-explicit models of global, regional, national, and local systems.

7.4. Tasks (Annexes)

	1976-77	Analysis of existing tools for evaluating R&D strategies
	1978-80	MARKAL Model generator development (US-BNL, GE-KFA)
I.	1981-83	Energy Technology Systems Analysis Project
II.	1984-86	Information Exchange Project
III.	1987-89	International Forum on Energy Environment Studies
IV.	1990-92	Greenhouse Gases And National Energy Options: Technologies & Costs for Reducing GHG Emissions
V.	1993-95	Energy Options For Sustainable Development
VI.	1996-98	Dealing With Uncertainty Together
VII.	1999-02	Contributing To The Kyoto Protocol
VIII.	2002-05	Exploring Energy Technology Perspectives
IX.	2003-05	Energy Models Users' Group
X.	2005-08	Global Energy Systems and Common Analyses
XI.	2008-10	JOint STudies for New And Mitigated Energy Systems (JOSTNAMES) (annual fee: 20k€ per participant)

7.5. Participants

Country	CP/Institution	Country	CP/Institution
Belgium	FPP/VITO-KUL	**Italy**	CNR-IMAA
Canada	NRCan/GERAD	**Japan**	
Denmark	DEA/Riso	**Korea**	KEMCO
EC	DGRTD	**Netherlands**	ECN
Finland	VTT/TEKES	**Norway**	IFE
France	DGEMPEDAD/ADEME-EDMP	**Sweden**	STEM/Chalmers
Germany	IER / Uni-Stuttgart	**Switzerland**	PSI
Greece	CRES	**UK**	BERR/AEAT
Ireland	SEI / Uni-Cork	**US**	DOE/BNL

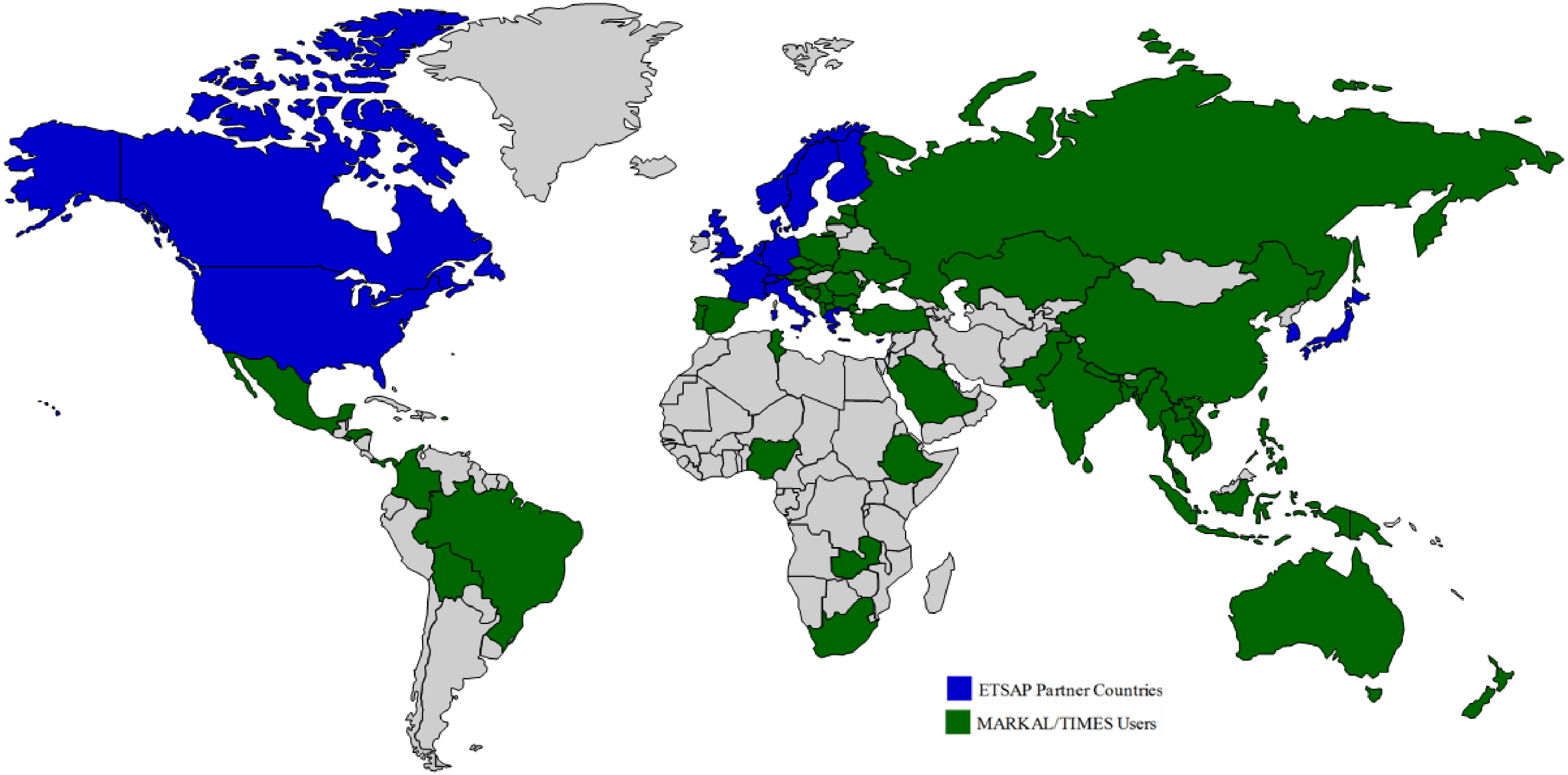
7.6. – Cost and advantages

Advantages:

- Free access to users' interfaces;
- Participation to the decision process;
- Full access to the ETSAP-TIAM (TIMES Integrated Assessment Model): a multi-region partial equilibrium model of the global energy systems covering the entire World, with endogenous trade of energy and CO2 permits, stochastic variables and climate equations; it includes a procedure to subtract a country from its region and add it as a separate region.

Cost: 20 000 Euros per year

7.7. MARKAL–TIMES users across the world (>200)



Only those countries with at least one MARKAL/TIMES modelling team active during the Annex are "painted."

Thank you

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www.etsap.org

Recent models and studies that use MARKAL-TIMES are exemplified in the report ***"Global Energy Systems and Common Analyses"***, downloadable from http://www.etsap.org/official.asp