Power Transmission and Distribution

Electrical energy supply in the next 20 years with an outlook to 2050

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SIEMENS

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The development of the electrical energy supply in the next 20 years with an outlook up to 2050

Content

- Introduction
- Probable development of the power consumption
- Development of the consumption of resources
- Reserves and resources
- The role of the renewable energies
- Energy policies in Europe, USA and China
- Development of future technologies
- Electrical power supply scenarios for 2020 and beyond
- Summary

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1. Introduction

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Blackout in California 1998

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Blackout in Italy 2003

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Experience from the blackouts

The blackouts have shown:

- Despite the high standards our electrical power supply systems are vulnerable.
- The “liberalization” of the energy markets in the different countries has slow down the investment in the electrical supply systems. There is a good chance for further blackout situations if investments will stay at this low level.
- The expenses for research and development have dropped to an historic low level. There is the need to ramp up those investments to secure our energy supply systems and our energy future.

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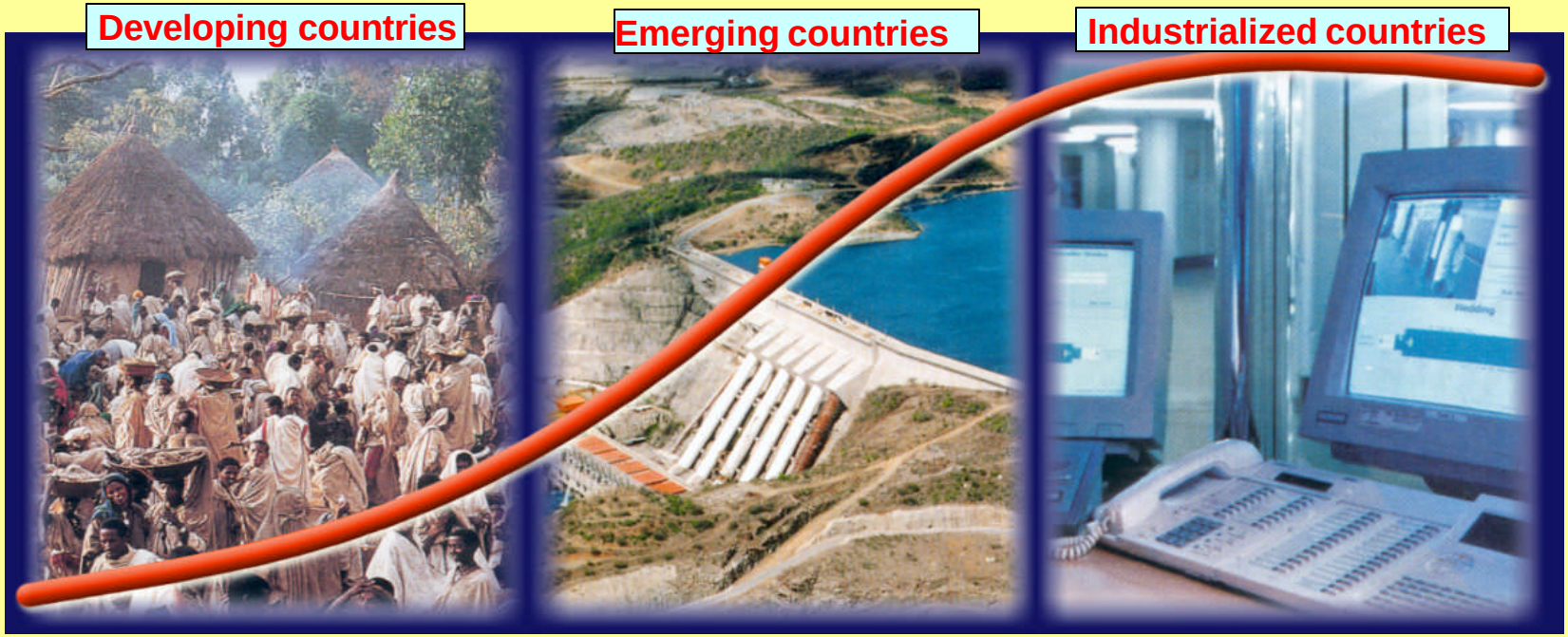
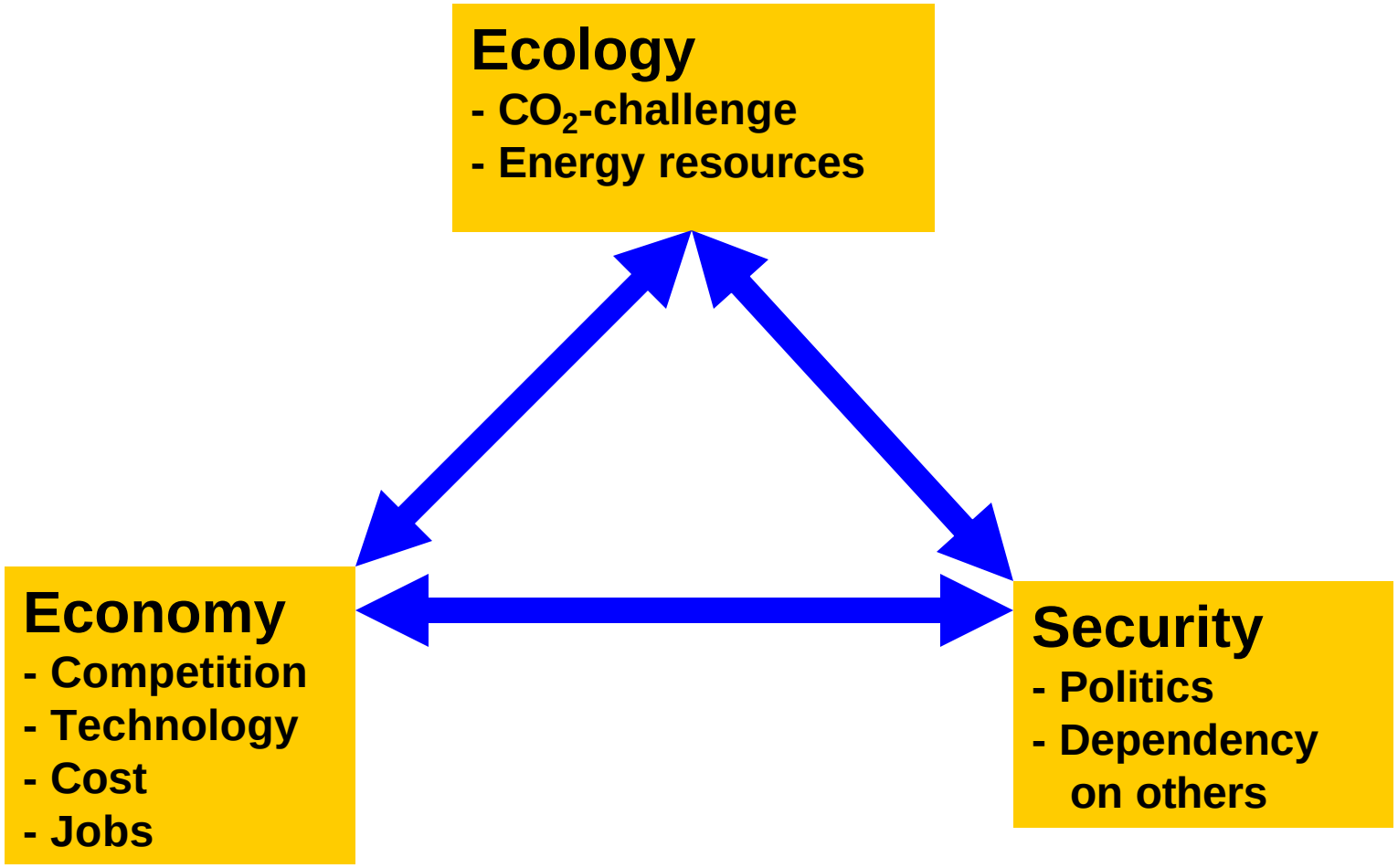
Development of power plants and nets in the different phases of human needs and situations

- 2 billion men have no access to electrical power until now
- Growing industrial activities and increasing requirements for the supply security
- Increasing prosperity and protection of the resources

- Solar power
  Diesel power
  separated networks
- Coal power plants
  Water power stations
  Interconnected networks
- Power plant mix
  Centralized and de-centralized networks



The optimization task: Economy vs. Ecology vs. Supply Security



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2. Probable development of the power consumption over the next 20 to 30 years

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Electrical power generation in some selected countries worldwide

Countries	DE	FR	UK	IT	ES	USA	China	JP	Indien
GNP in bill.USD	2,16	1,56	1,53	1,46	0,85	10,45	5,99	3,65	2,66
Inhabitants in Mio.	82,4	60,2	60,1	58	40,2	290,3	1287	127,2	1049,7
Installed Power in GW	123	115	77	80	61	905	320	265	115
Power Generation in TWh/a	597	560	315	265	225	3850	1450	1040	530
Power Generatio/capita in	7250	9300	5820	5430	5600	13260	1130	8175	505
Structure in %									
Coal	**51,1**	0,8	**32,0**	12	**35,0**	**53,0**	**74,0**	23	**73,0**
Gas	9,6	1,1	**38,0**	**37,0**	12	15		**25,0**	4
Oil	0,6	1,2	4	**27,0**		3	7	12	1
Nuclear	**27,6**	**78,0**	23		**32,0**	**21,0**	1	**30,0**	3
Hydropower	4,2	**17,0**		17	20	7	**17,0**	8	**19,0**
Renewables	3,8	1,9	3	7		1	1	2	
Others	3	0	0	0	1	0	0	0	0

Quellen: 1. Inhabitants and GNP: CIA(Hrsg.), The World Fact Book 2003, in: www.odci/cia/publications/factbook
2. Power statistic: Schiffer, Energiewirtschaftliche Tagesfragen 54.Jg.(2004) Heft 3

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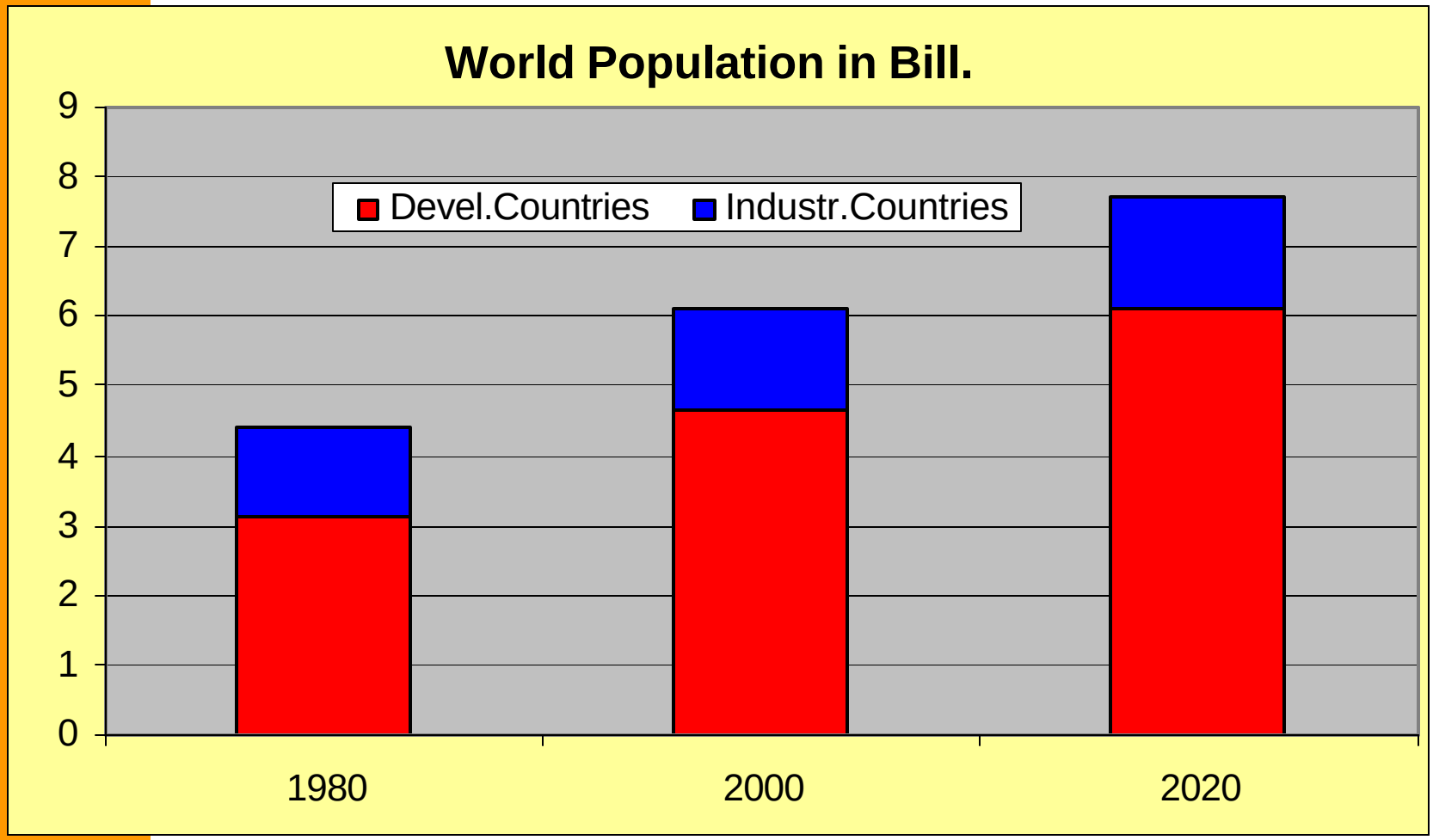
Development of world population



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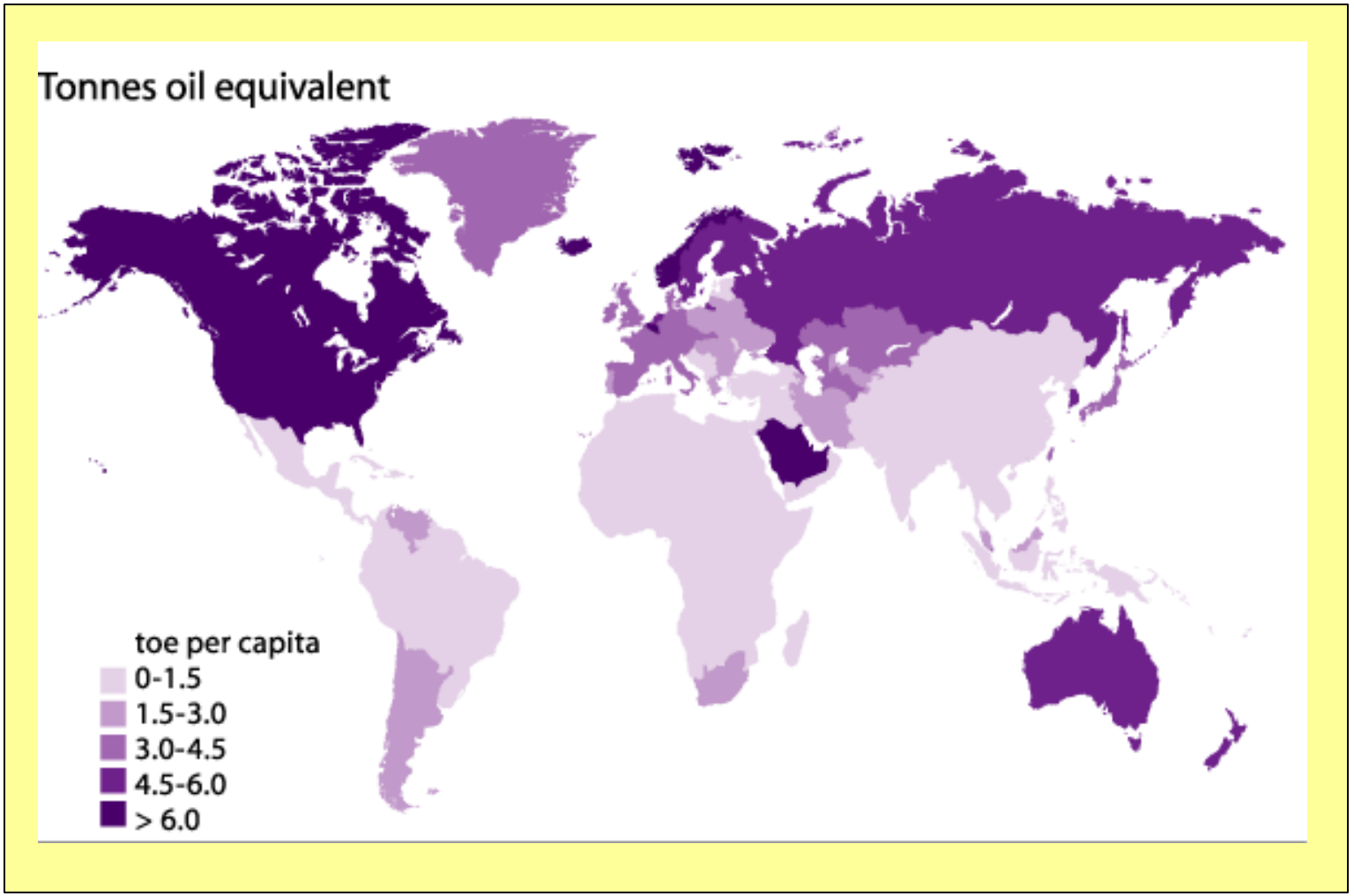
Primary energy consumption per capita



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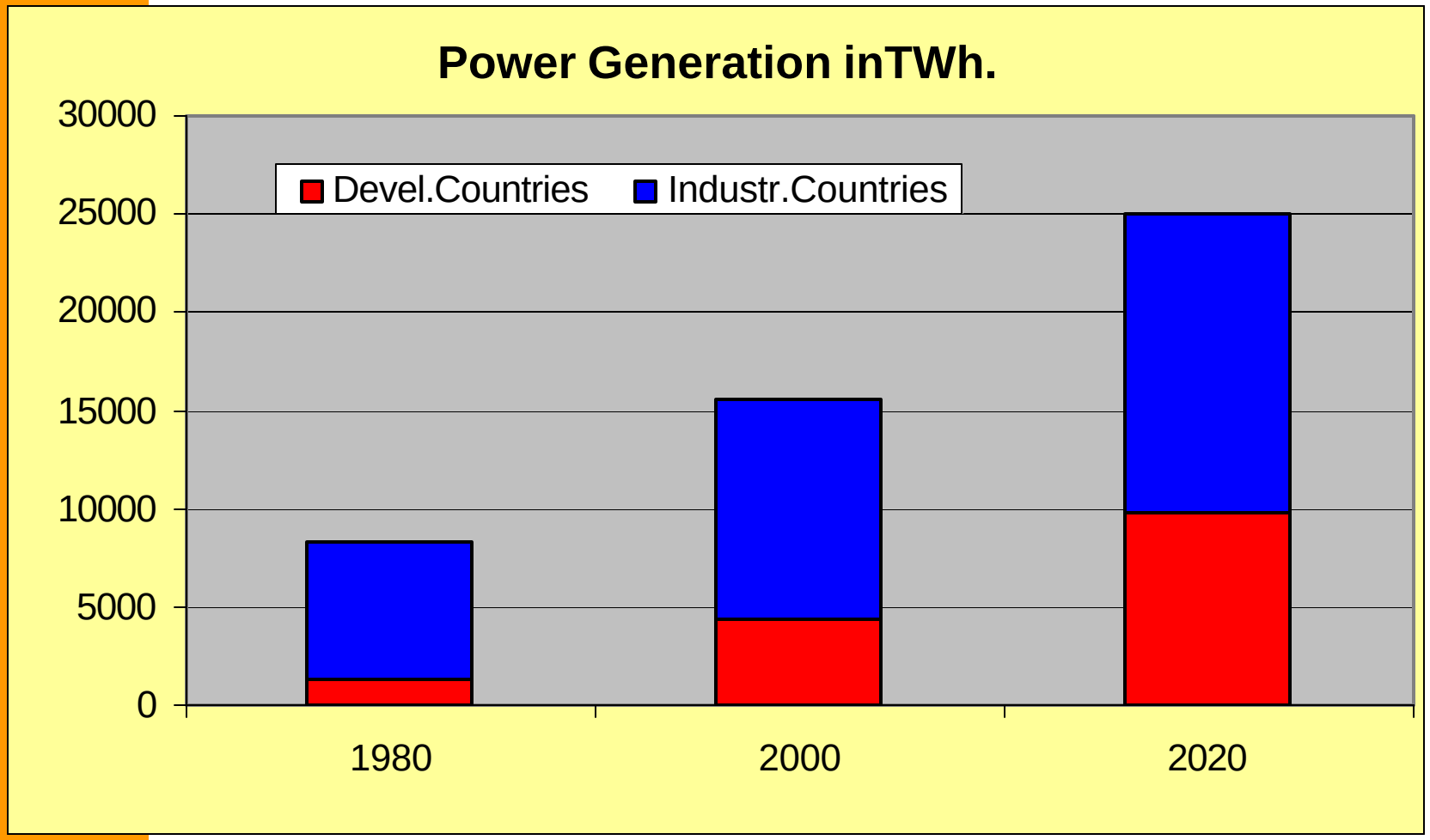
Worldwide electrical power consumption



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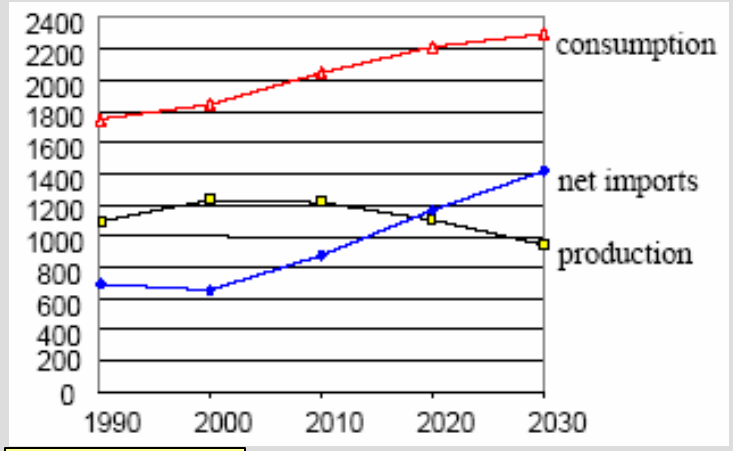
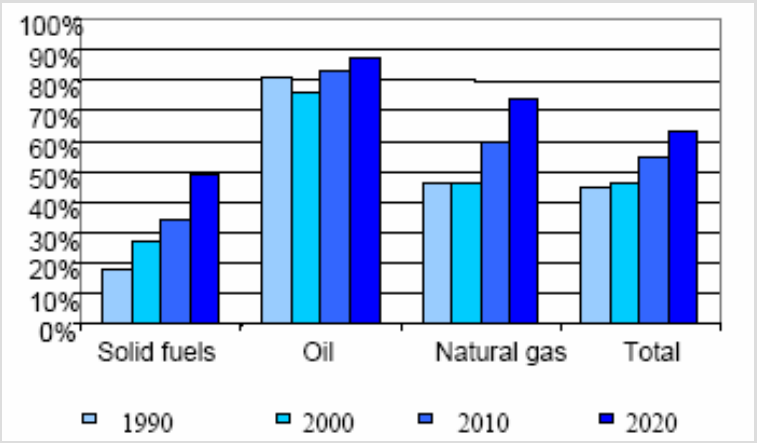
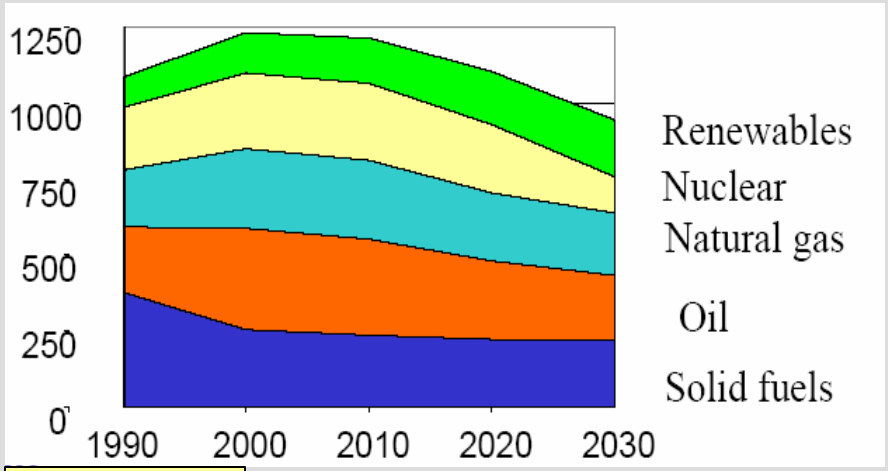
Electrical power consumption in Europe 30



Consumption



Dependency on others



Generation

- **The own production share falls**
- **The imports and the dependency on others increase**
- **The consumption will increase considerably**
- **The energy question must be discussed more intensive and now**

Europe 30 = EU 25+CH,BU,HR,NO,RO

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3. Consumption of the resources and CO2 challenge

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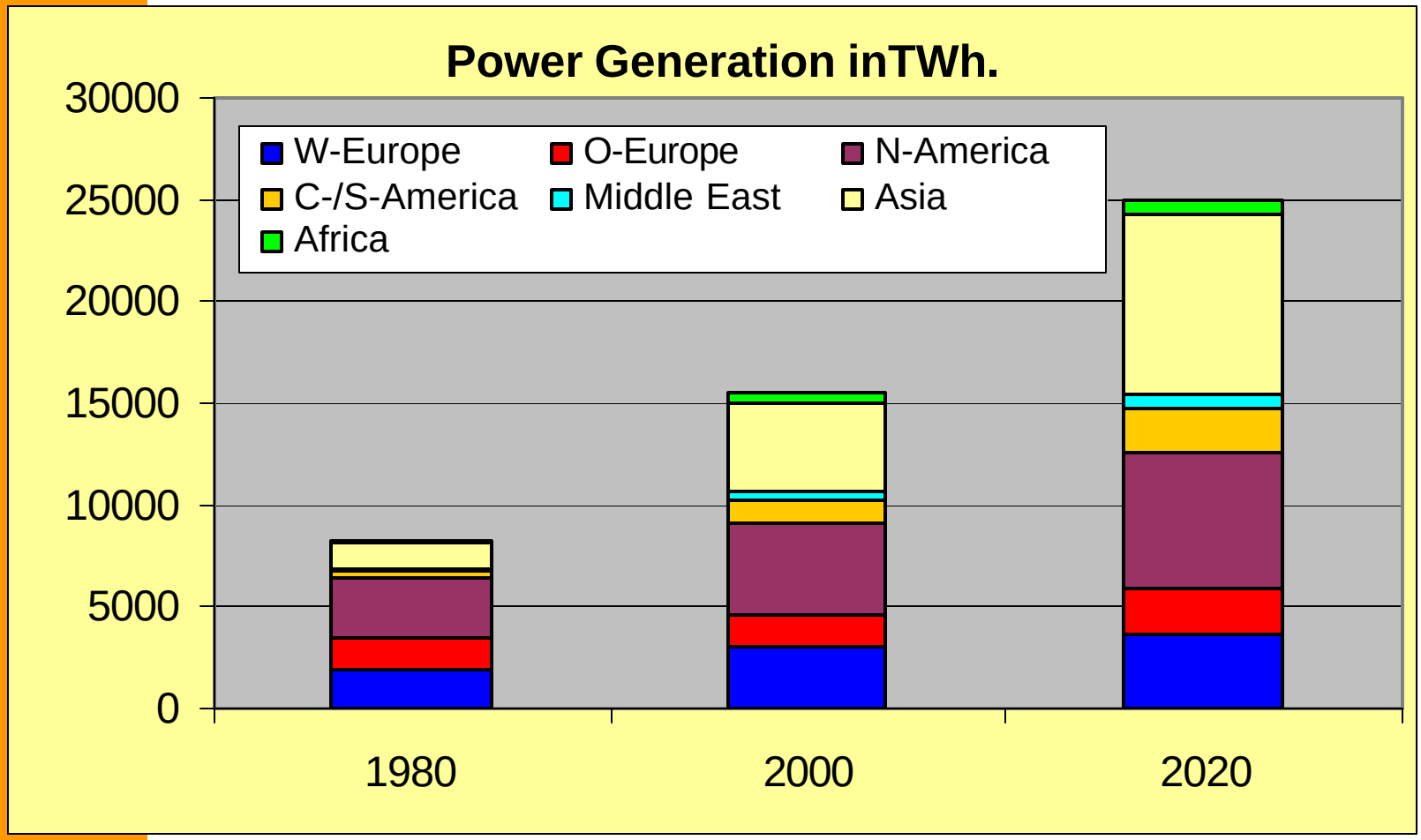
Worldwide power generation by regions



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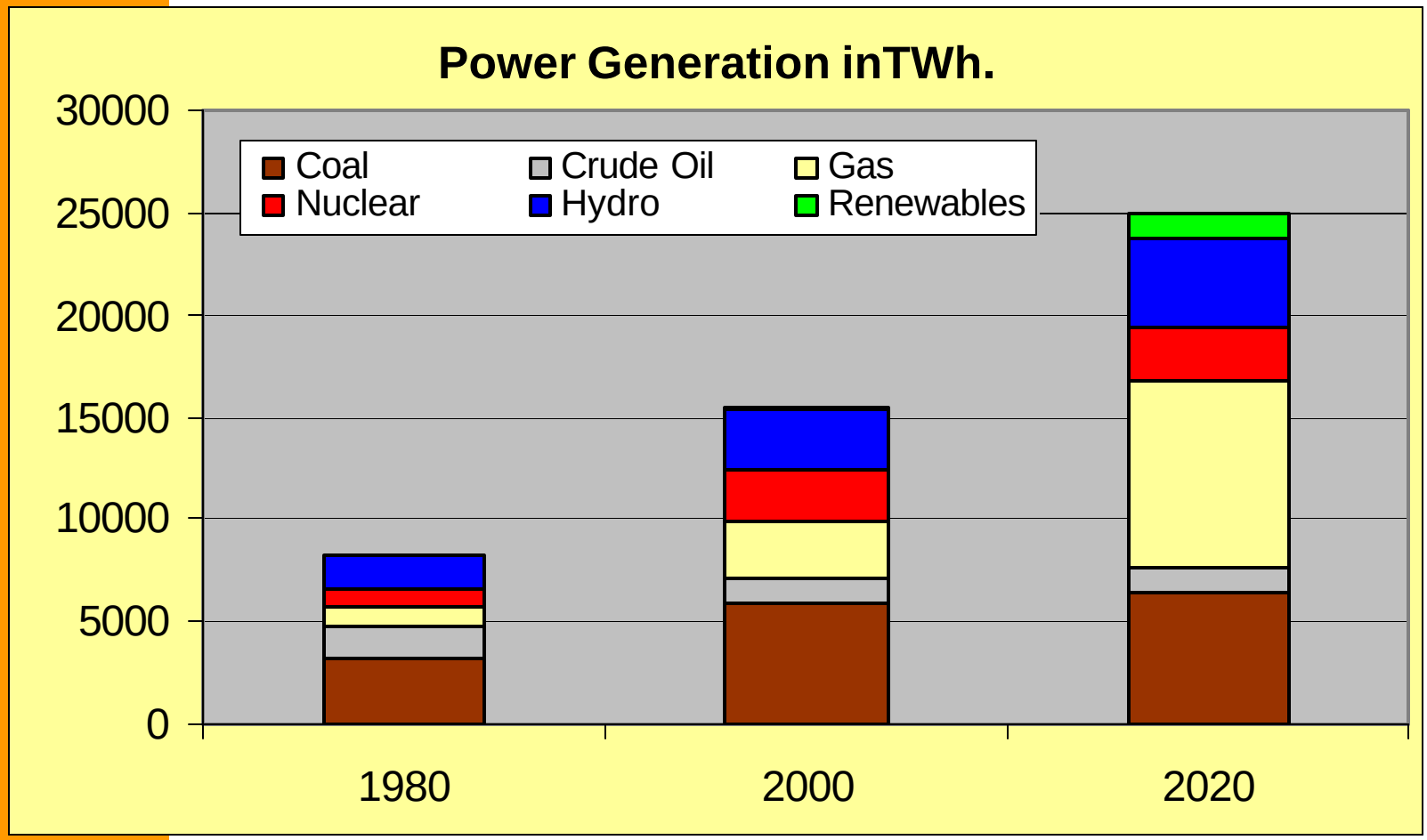
Worldwide power generation by resources



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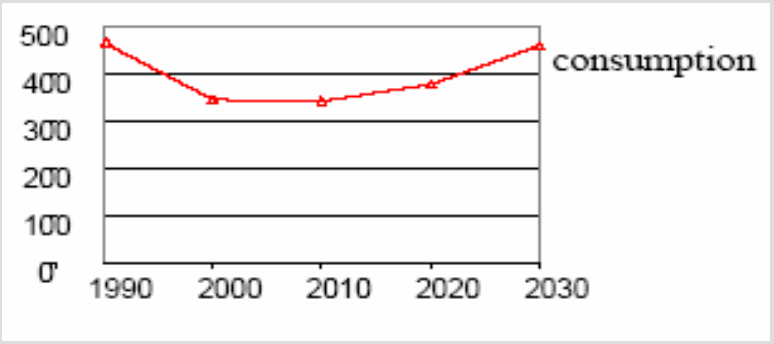
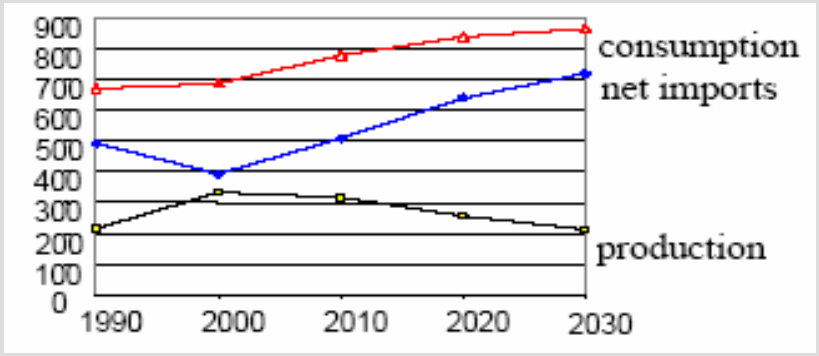
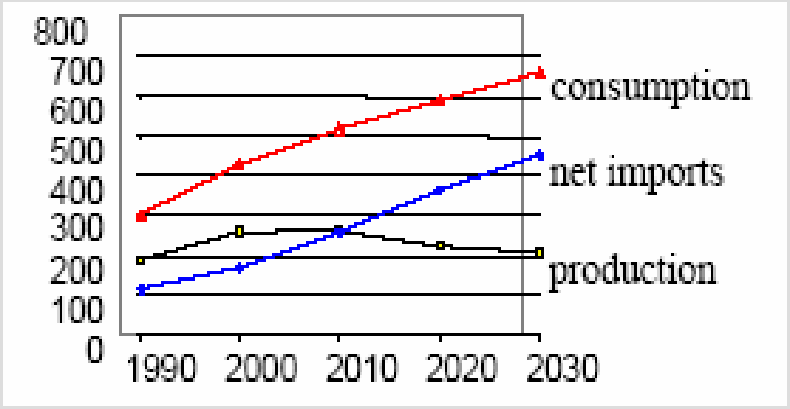
Resource consumption in Europe 30 in mtoe



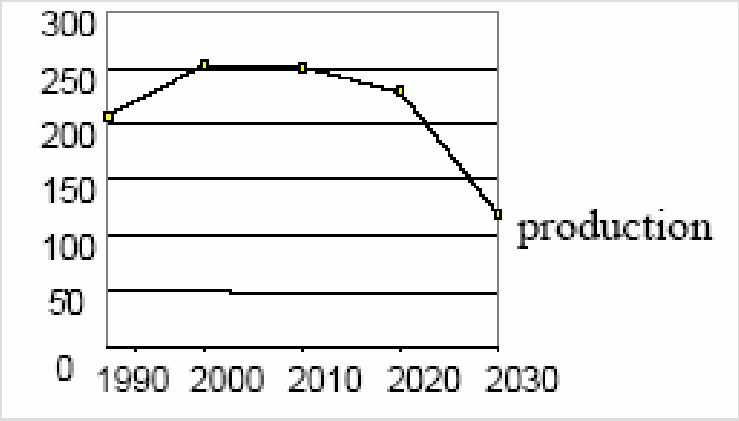
Coal



Crude oil



Natural gas



Nuclear

1 mtoe = 11,62 TWh

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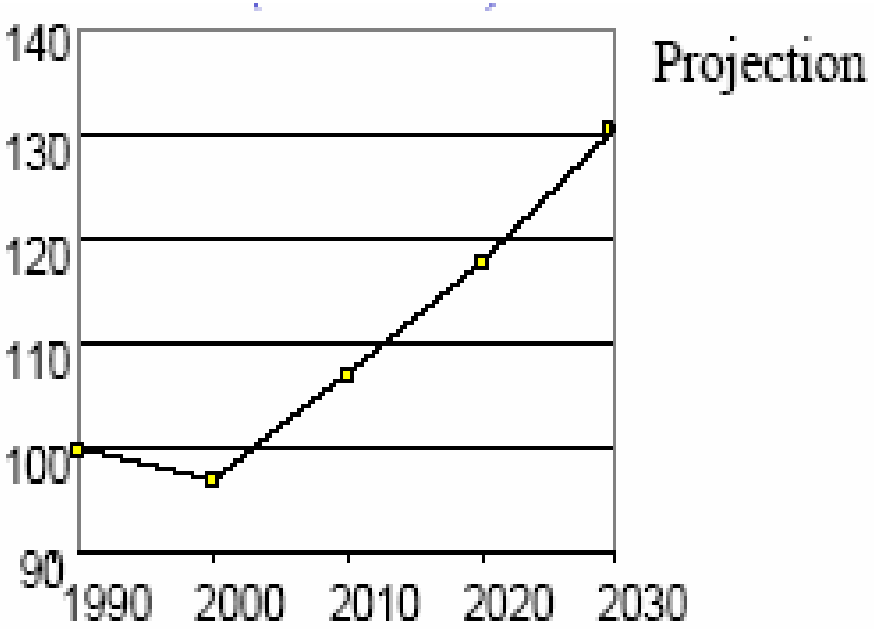
Development of CO2 in Europe

CO2 emissions (basis 1990 = 100)



- EU has committed itself to reduce the CO2 emissions by 8% until 2012 compared to 1990
- 92% of the CO2 generated by human activities stems from the energy sector.
- It seams that the Kyoto commitments will not be kept

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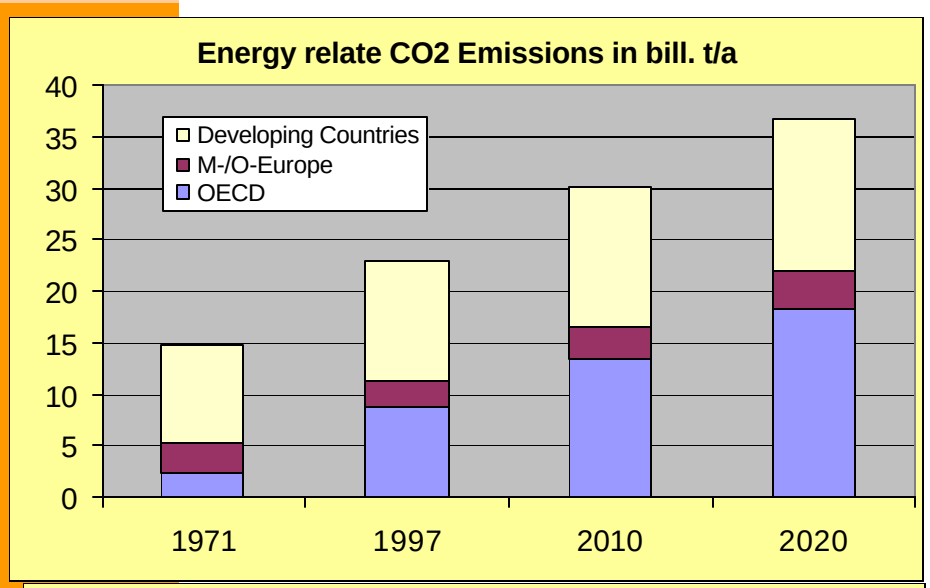
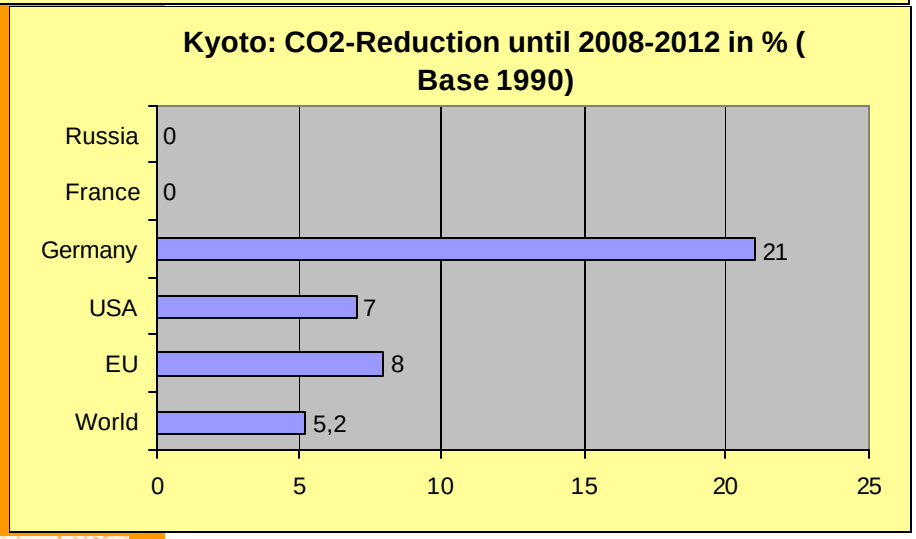
CO2 – challenge and potential solutions





Possible solutions for CO2 reduction (in the atmosphere)

- Increase of efficiency of the power plants
- Substitution of old by new, CO2 minimized power plants
- New technologies for separation and subterranean store of CO2
- Increased usage of renewables
- increased usage of nuclear power plants

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4. Reserves and resources

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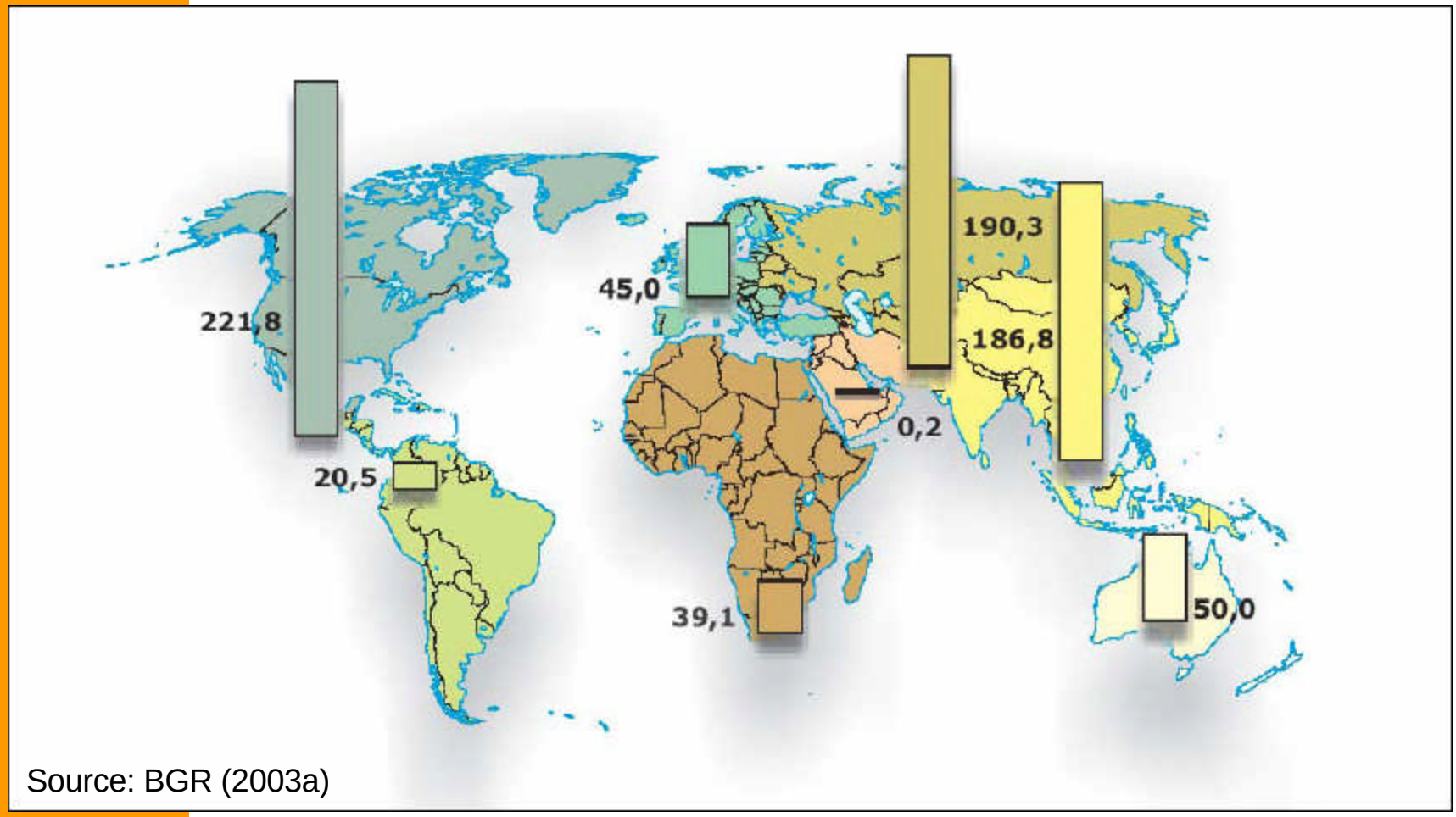
Reserves
Hard Coal in Gt



Source: BGR (2003a)

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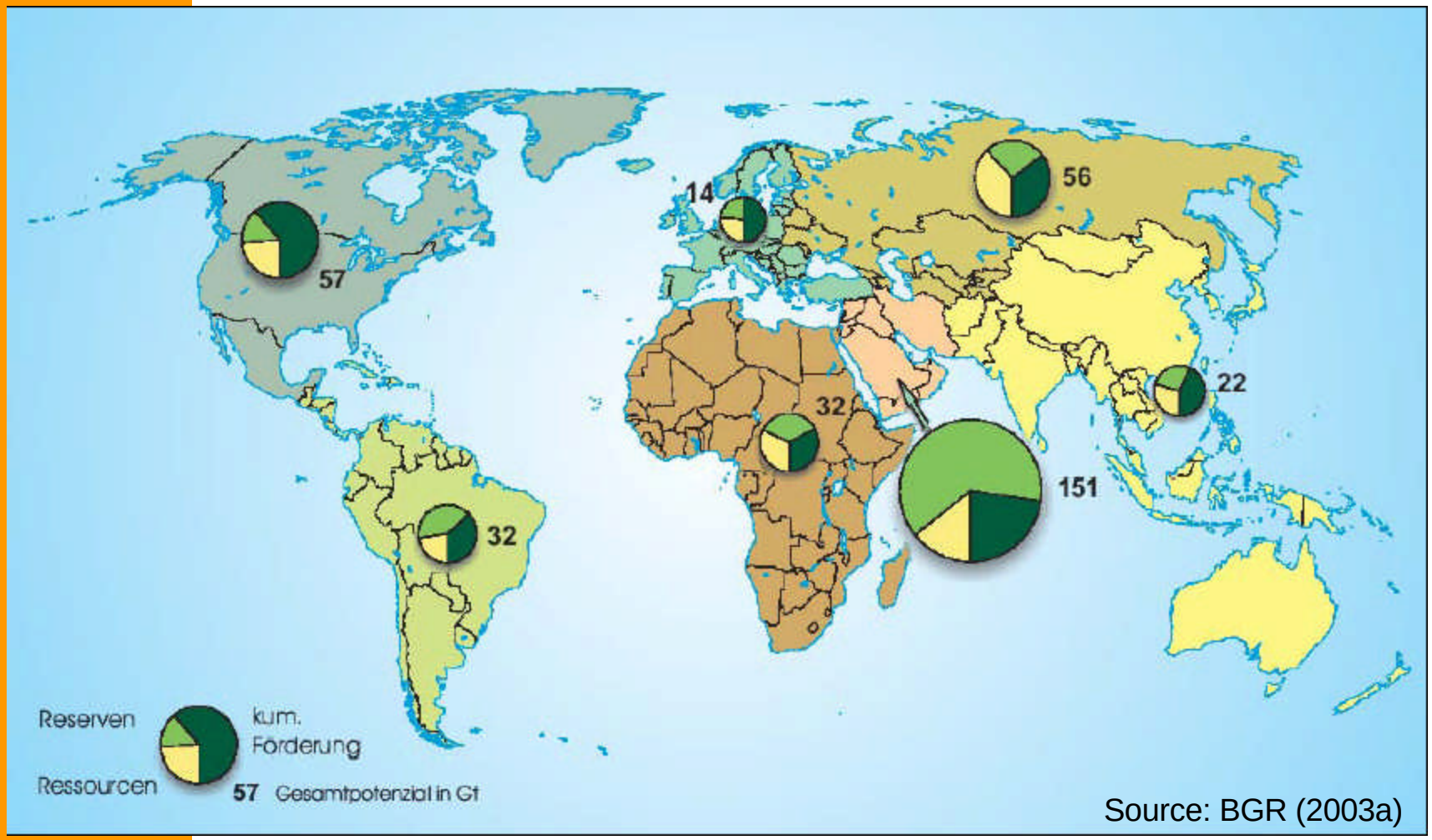
Reserves and resources
Oil in Gt



Source: BGR (2003a)

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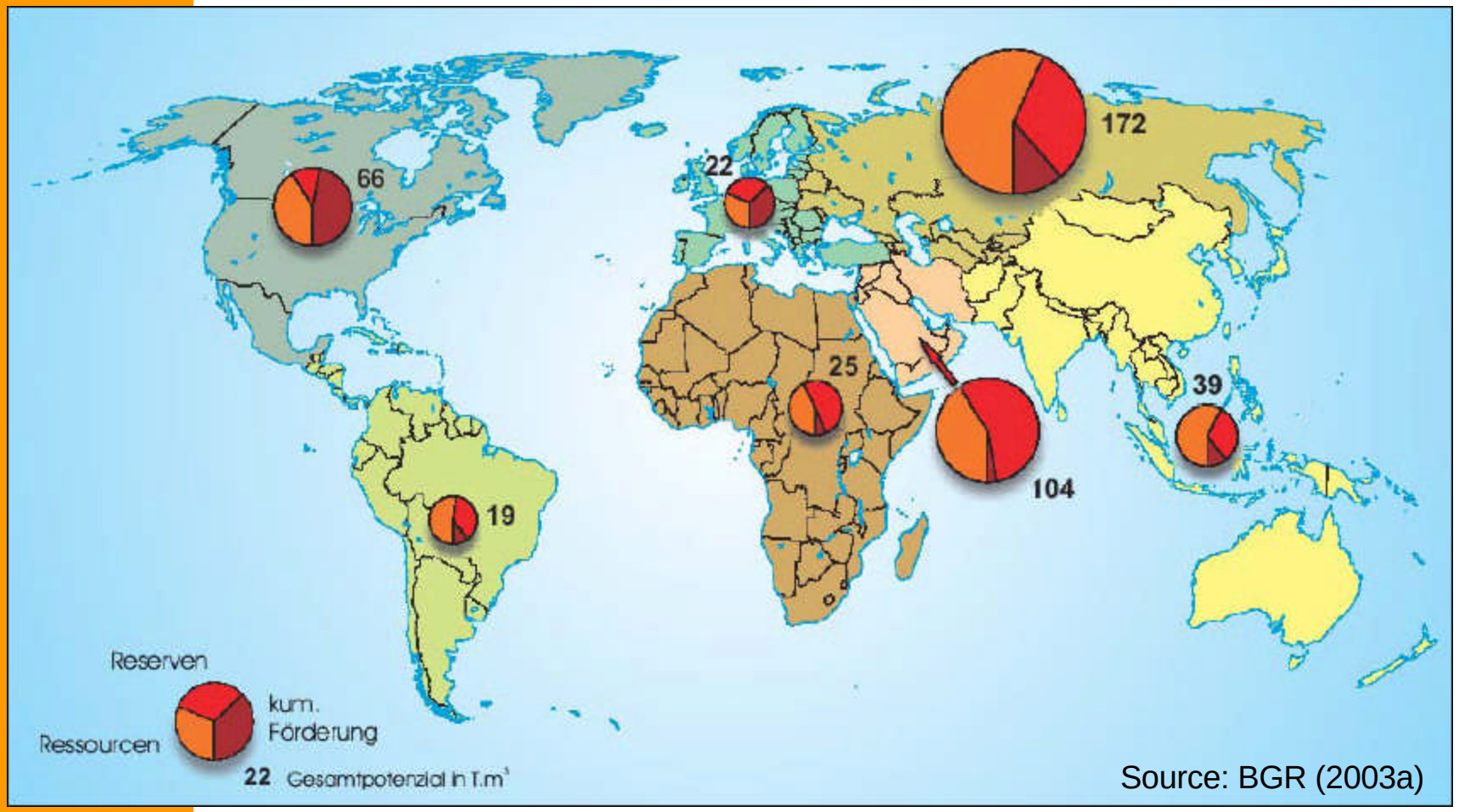
Reserves and resources
Gas in Tm^3



Source: BGR (2003a)

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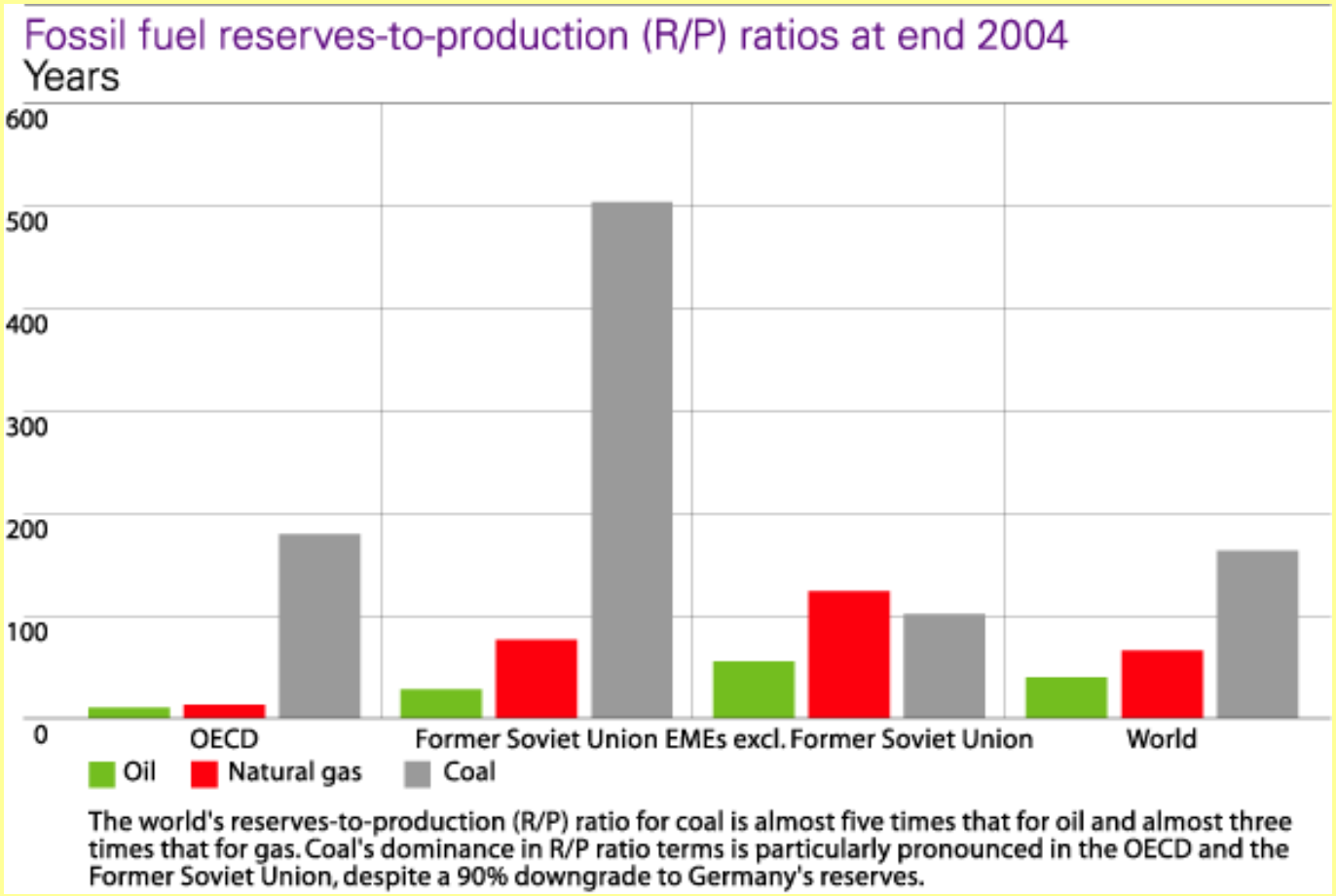
Fossil fuel reach in years



Source: BP, 2004

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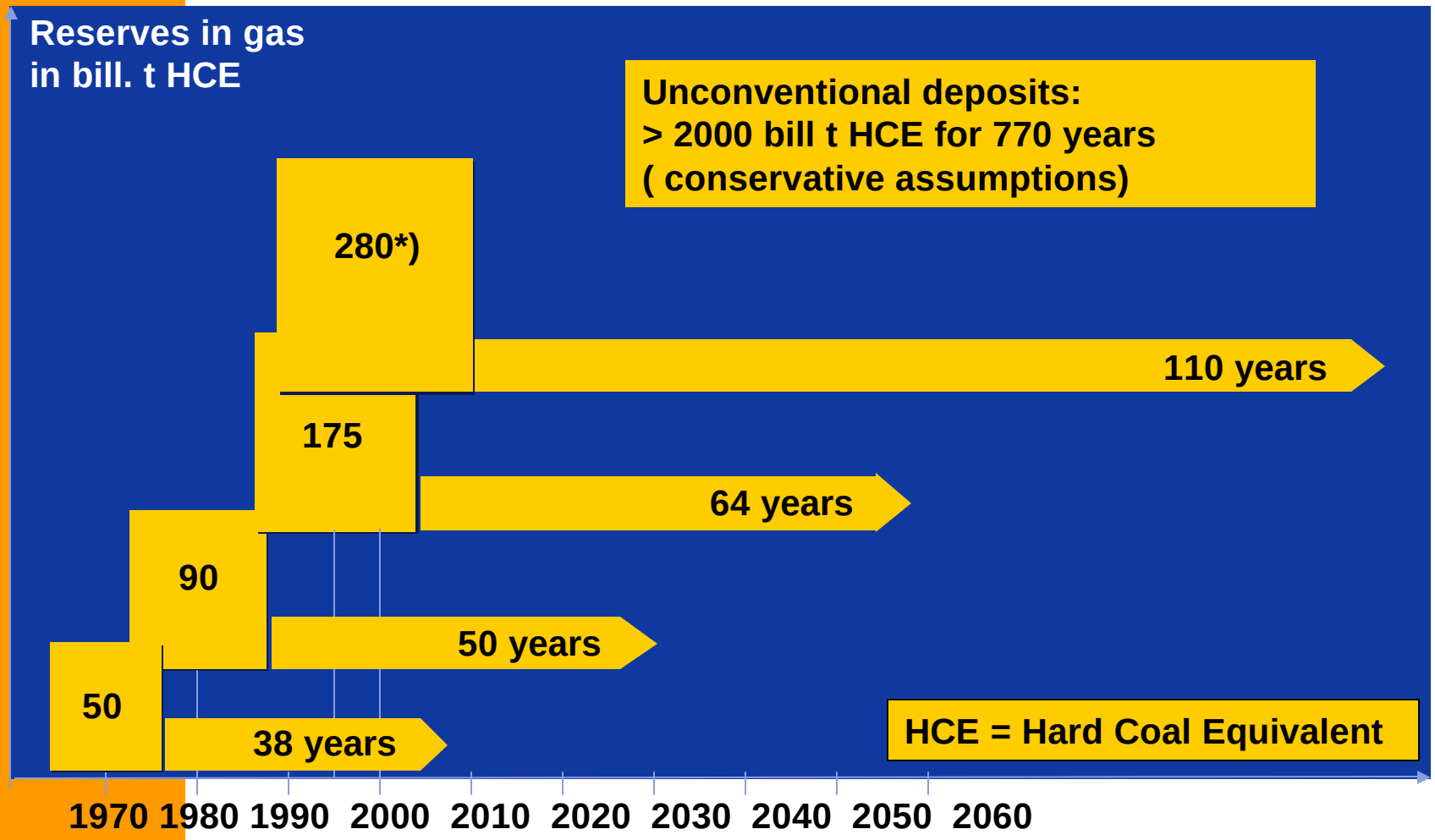
Gas reserves and reach



Source: KWU, BWK Bd. 51, *) IGU, World Gas Congress 6/2000

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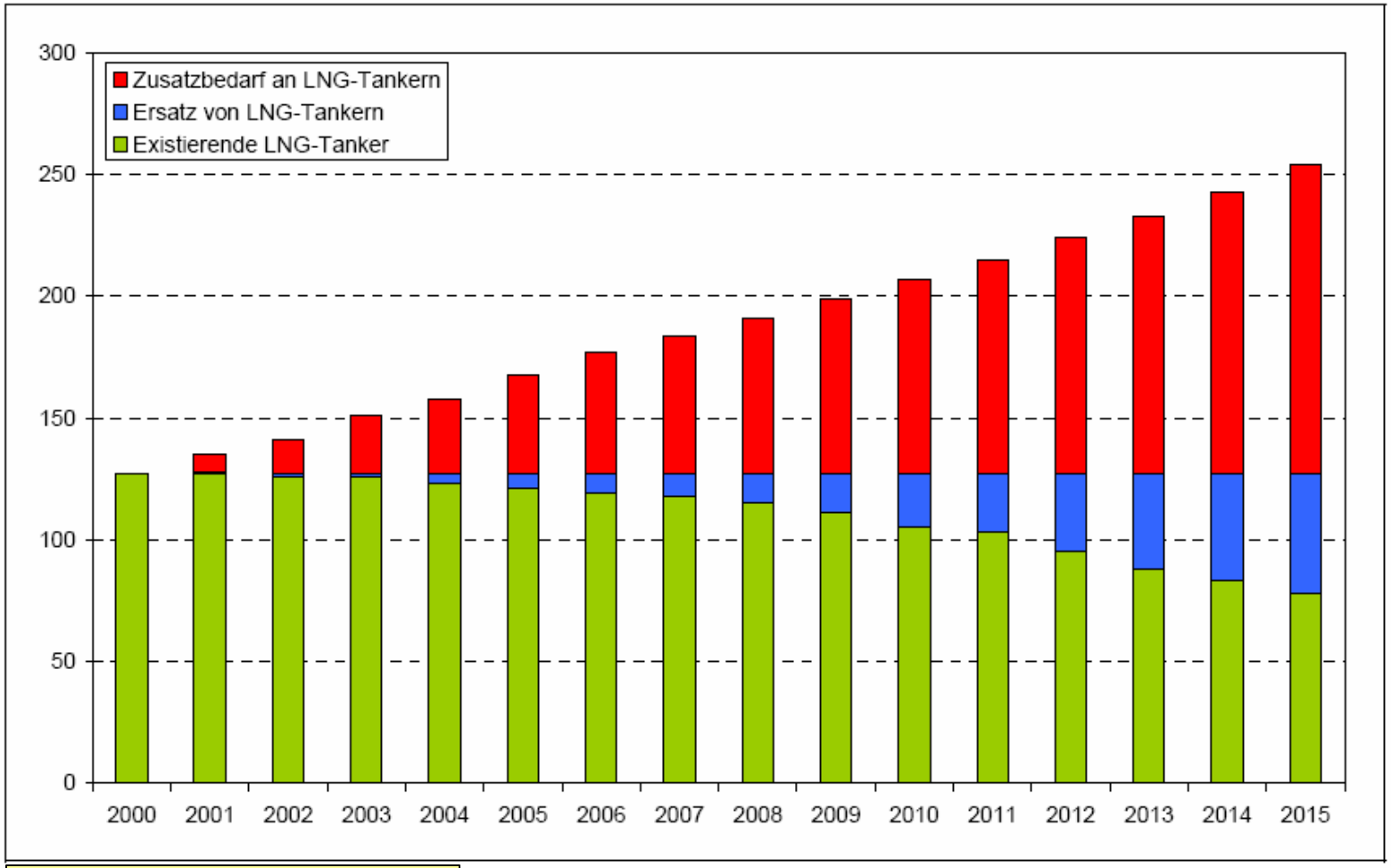
Development of Number of Liquid Natural Gas Tankers



Source: MOL (2003)

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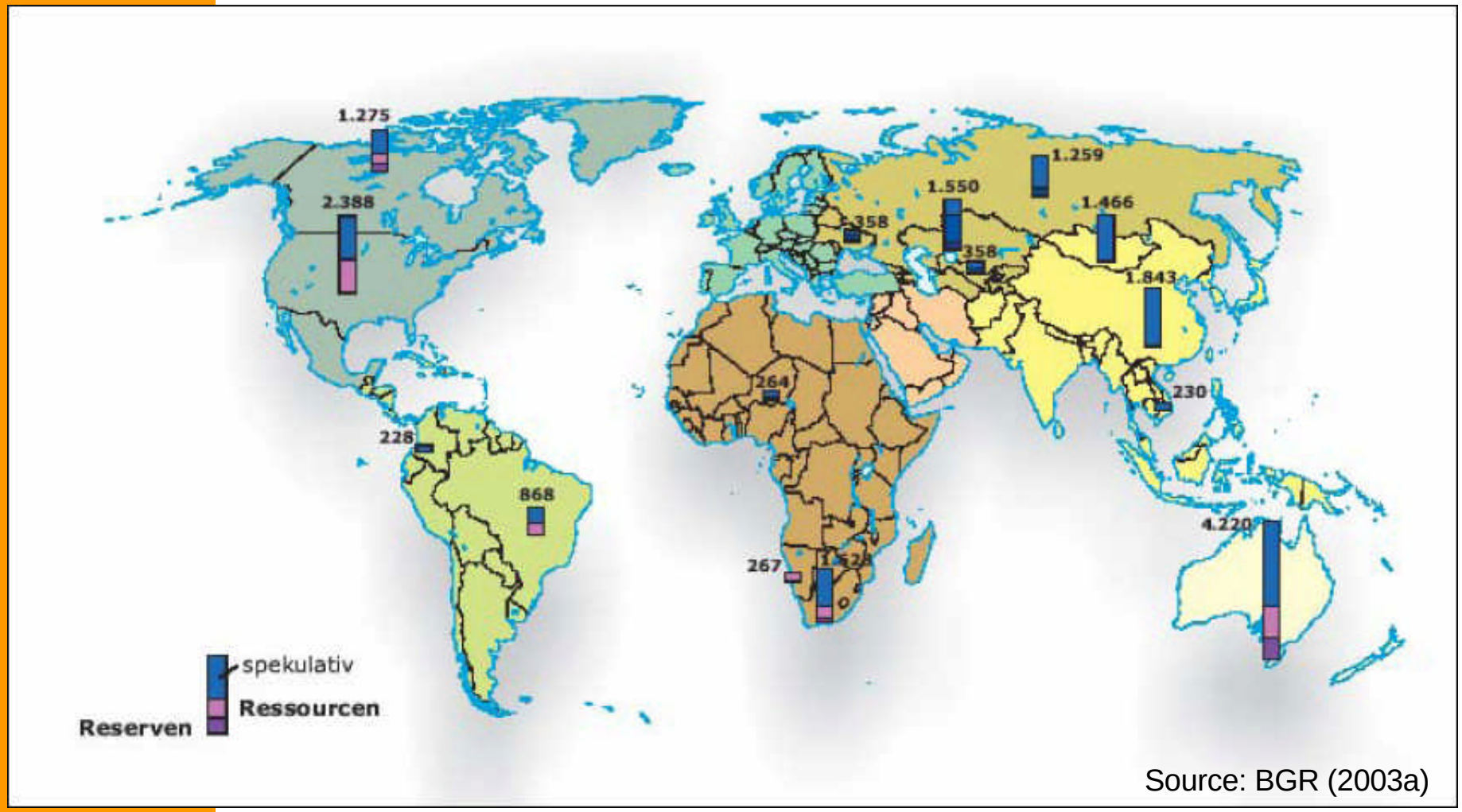
Reserves and resources
Uranium in 1000t



Source: BGR (2003a)

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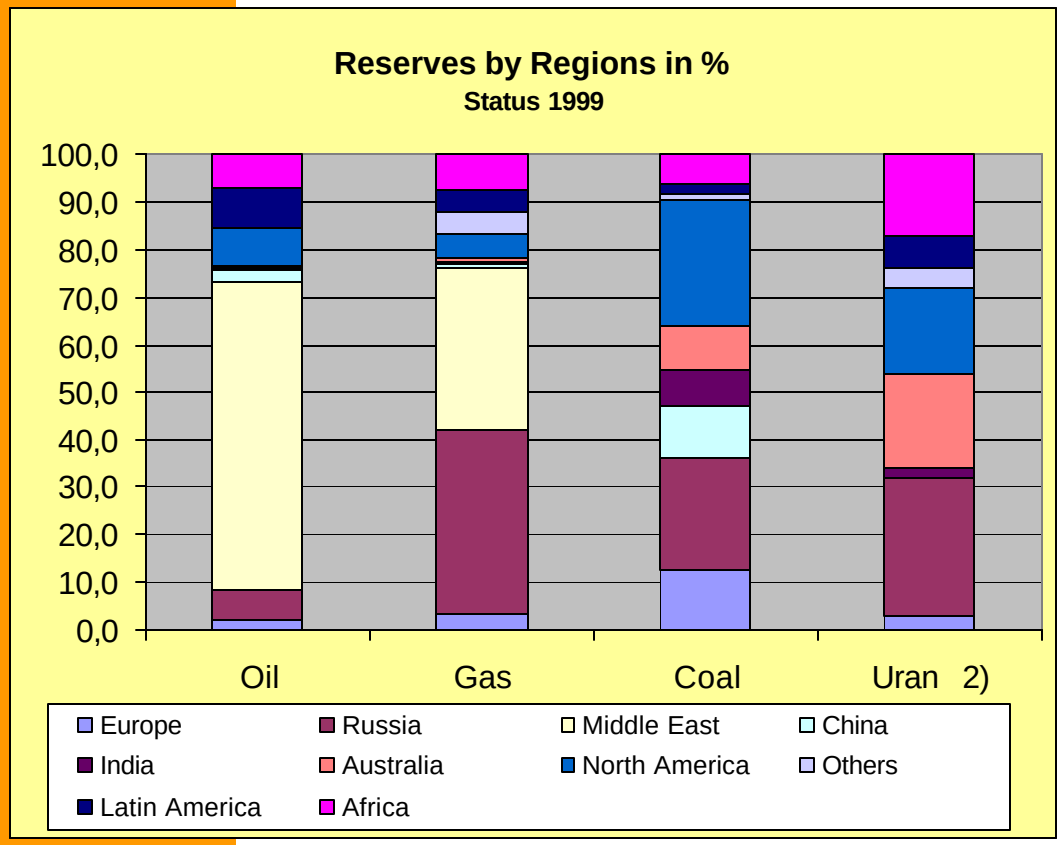
Reserves and reach



	World Reserves 1)	World Production	Reach
	Gtoe	Gtoe	Jahre
Oil	140,8	3,45	40,6
Gas	134	2,1	66
Coal	328	2,1	156
Uran 2)	40-->2000	0,35	60-->3000 3)

1) economically to be developed

2) dependent on the technology

3) when consuming 0,65 Gtoe/a

Source: BP Amoco

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5. The role of the renewable energies

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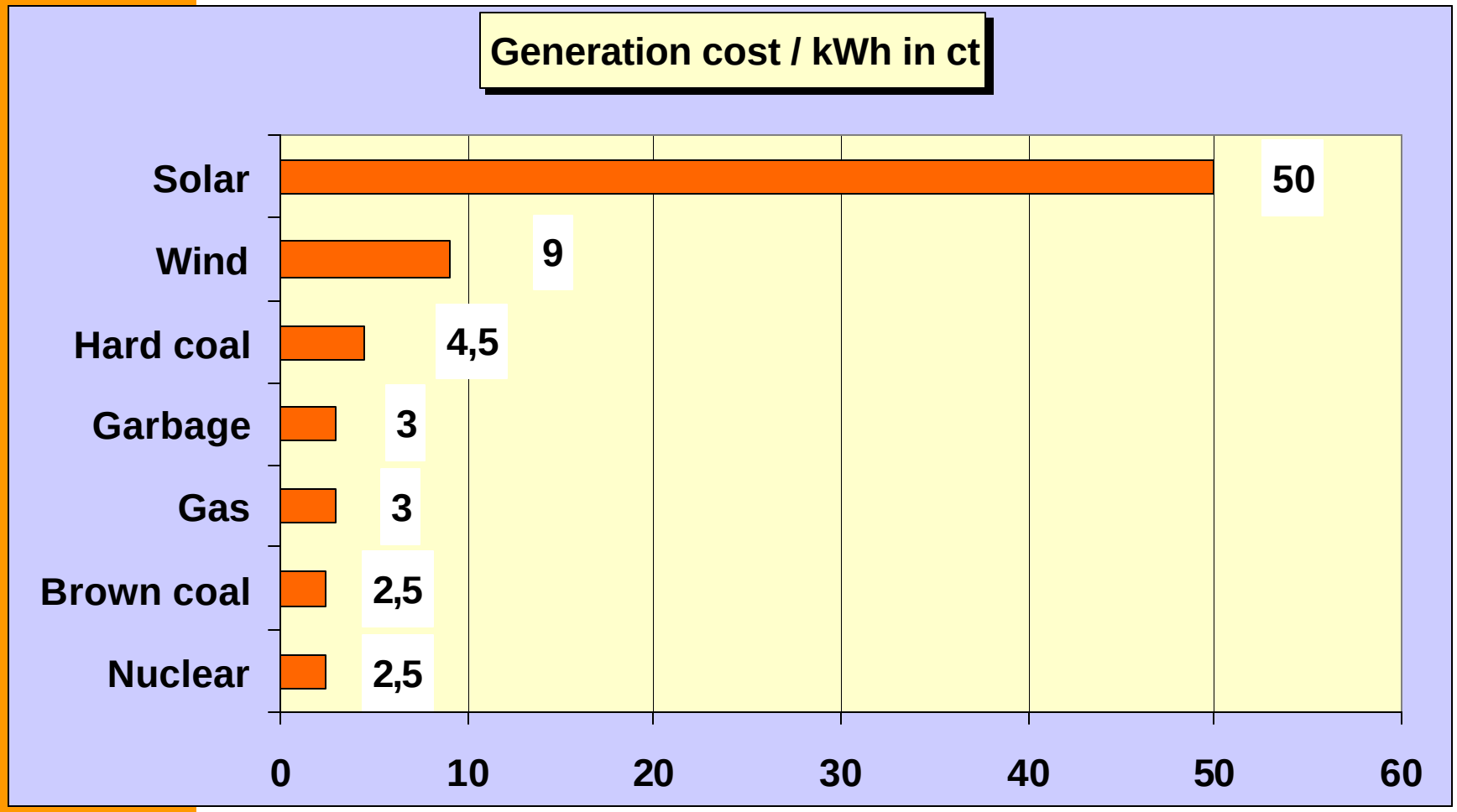
Renewable energies
Price comparison today in Germany



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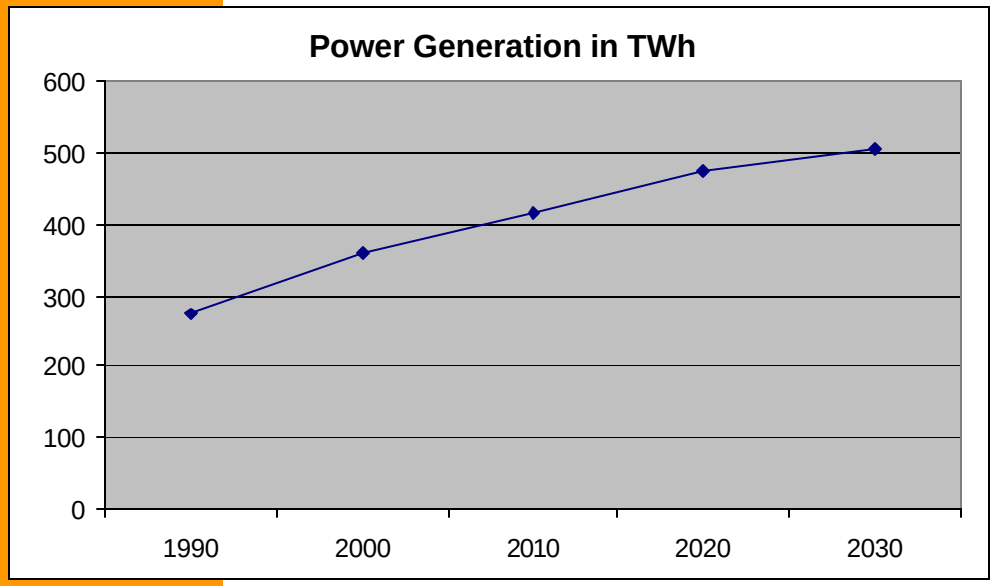
Development of Renewables in Europe-30



- The renewables will have a share of 12% of the power production until 2010 in Euope-30
- This is an increase of 2%/a starting in 2000
- Germany plans 12,5% until 2010 and 25% until 2020 in renewables, an increase of 6%/a
- Essentially renewables mean wind and water
- In the next 20 years solar will play an insignificant role
- The highest potential in renewables will play biomass and geothermal

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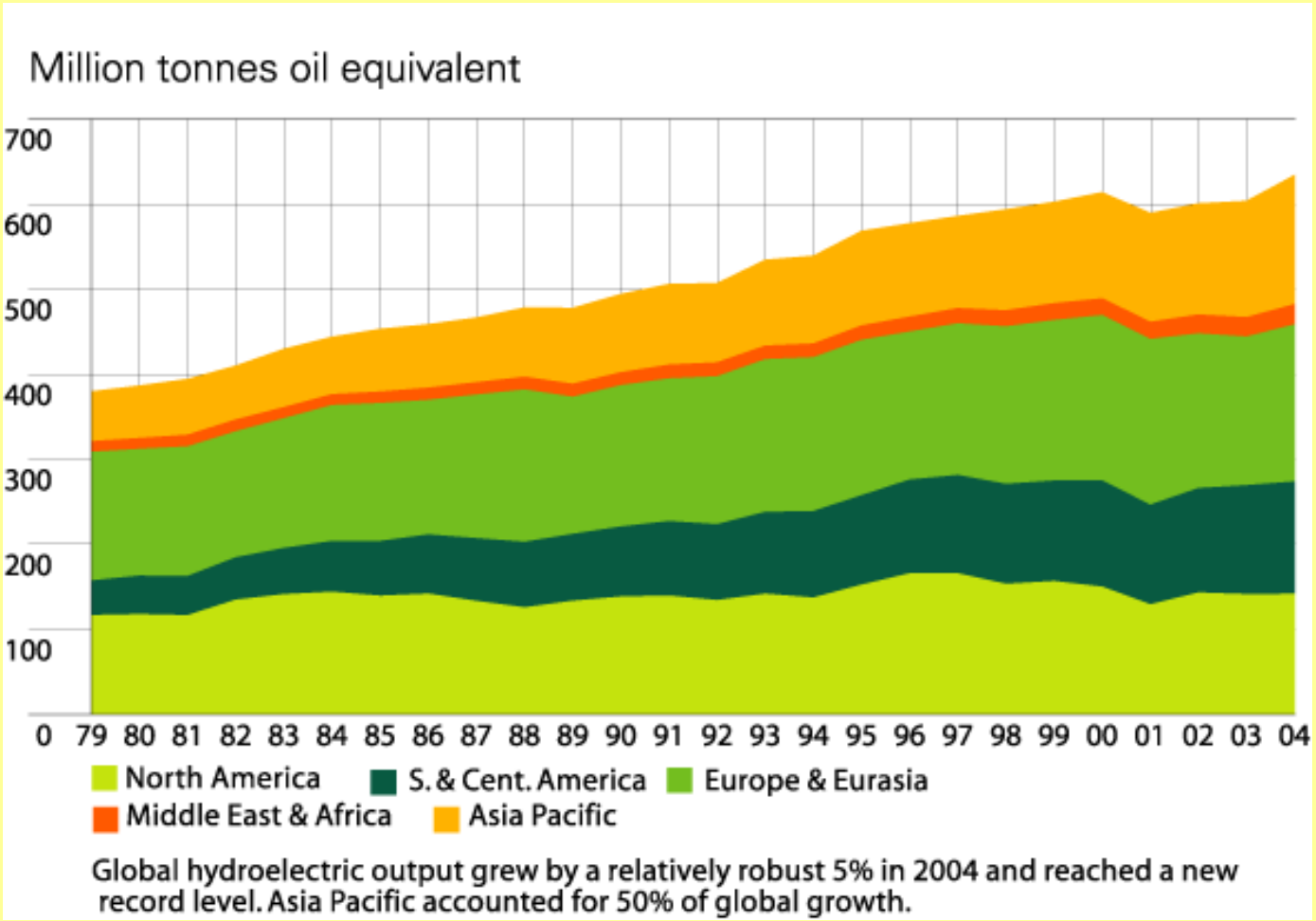
Renewable energies
Water – Hydroelectric power consumption by region



Source: BP, 2004

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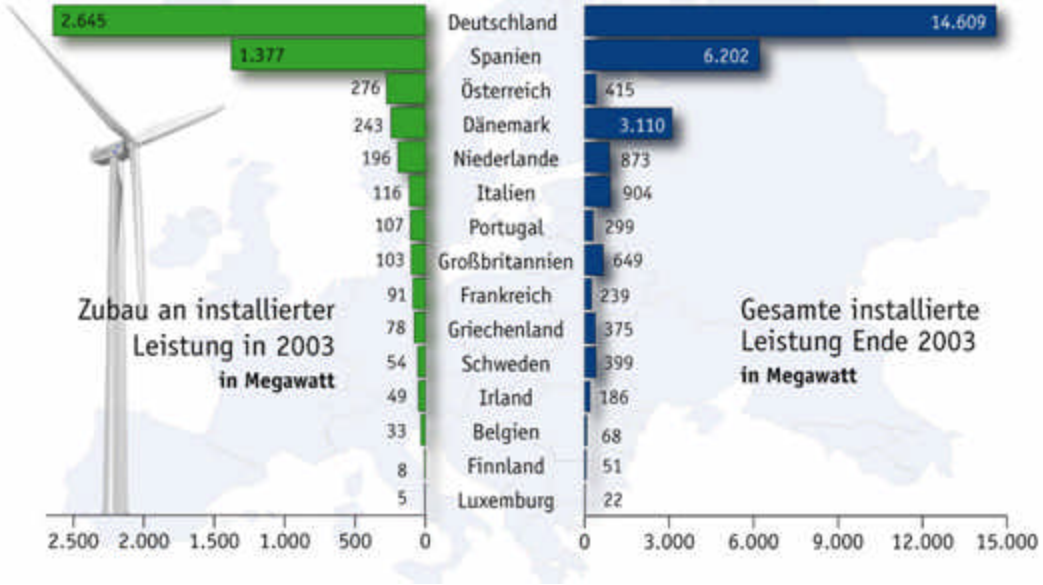
Renewable energies
Wind

Installed power



Technology development

		1980	1985	1990	1995	2000	2005
Power	MW	0,03	0,08	0,25	0,6	1,5	5
Rotor diameter	m	15	20	30	46	70	115
Height	m	30	40	50	78	100	120
Generation / year	MWh	35	95	400	1250	3500	17000
full load hours/a	h	1.167	1.188	1.600	2.083	2.333	3.400

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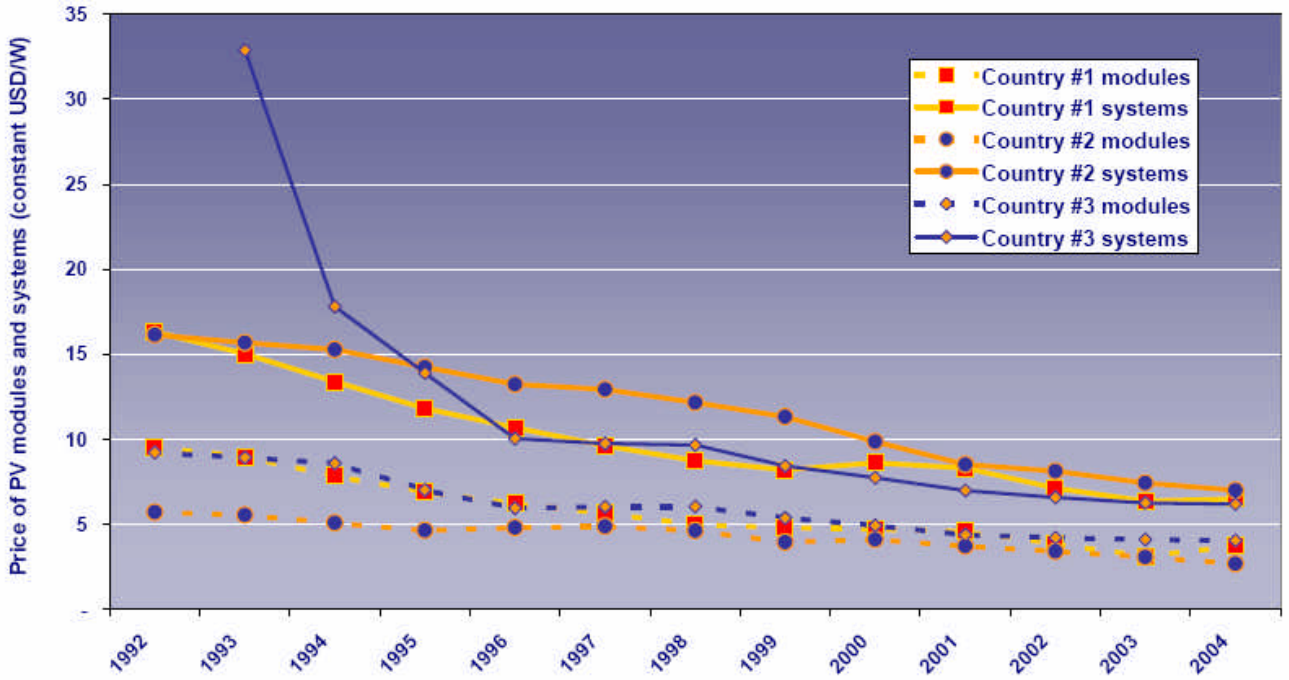
Renewable energies
Solar

Source: IEA, 2004

PV power (MW) installed in calendar year										
Country[1]	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
AUS	2	3	3	3,8	2,8	3,9	4,4	5,5	6,5	6,7
AUT	0,3	0,3	0,5	0,7	0,8	1,2	1,2	4,2	6,5	2,4
DEU	5,3	10,1	14	12	15,6	44,3	80,9	83,4	153	363
ESP[2]	0,8	0,4	0,2	0,9	1,1	3	3,6	4,8	6,5	10
FRA	0,5	1,5	1,7	1,5	1,5	2,2	2,6	3,3	3,9	5,2
JPN	12,2	16,2	31,7	42,1	75,2	121,6	122,6	184	222,8	272,4
NLD	0,4	0,9	0,7	2,5	2,7	3,6	7,7	5,8	19,6	3,2
USA	9	9,7	11,7	11,9	17,2	21,5	29	44,4	63	90



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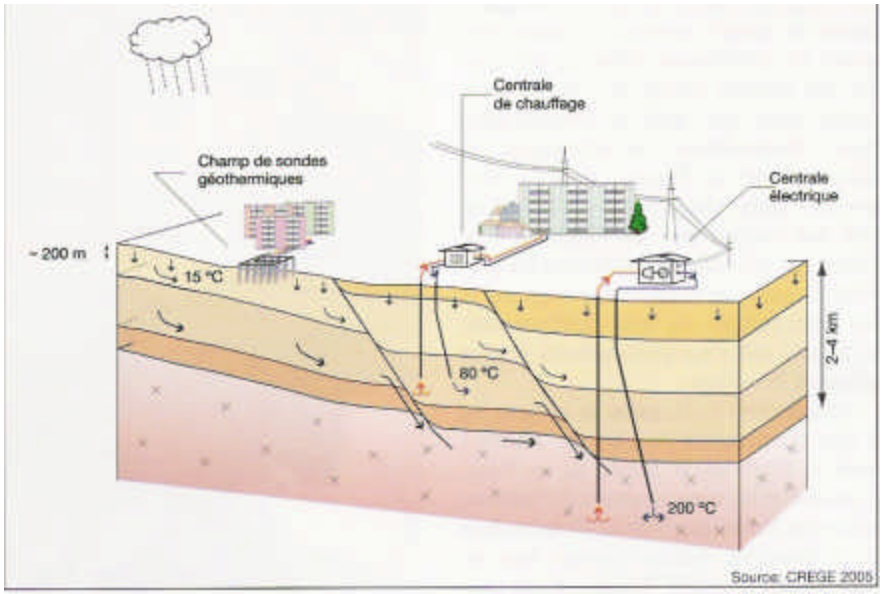
Renewable energies
Geothermal

Principle:

- **Heat usage T <= 80°C**
- **Power generation T > 150°C**
- **resource: indefinitely large**



Applications:

Type de géothermie	Ressource	Profondeur (m)	Production	Technologie
Très basse énergie	Roches sèches	10...100	Chaleur ou froid	Sondes géothermiques verticales, géostructures énergétiques, tunnels, etc.
10...30° C	Aquifères peu profonds	10...1000		
Basse énergie	Aquifères profonds	1000...3000	Chaleur	Centrales de chauffage urbain, complexes de serres agricoles, thermalisme, pisciculture, etc.
30...90° C	Zones d'anomalie thermique à faible profondeur	100...1000		
Géothermie de moyenne énergie	Aquifères très profonds	2000...4000	Electricité et/ou chaleur	Centrales de production électrique et/ou distribution de chaleur couplée
90...150° C	Zones d'anomalie thermique à faible profondeur	500...2000		
Géothermie de haute énergie	Aquifères profonds dans des zones de gradient anormalement élevé	1000...5000	Electricité (et chaleur)	Centrales de production électrique (et distribution de chaleur couplée)
150...350° C	Systèmes géothermiques stimulés EGS			Centrales dès 2006

Source: SEV Bulletin, 8/ 2004

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6. Energy policies in Europe, USA, China

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Energy policy concepts
EU-25

- Further use of coal, developing an “emission” free power plant technology
- Use of nuclear power, but no common strategy within the union (e.g. France and Germany have fundamentally different approaches)
- Secure oil and gas reserves in Russia
- Increasing use of renewables
- Energy saving will be intensified by increasing efficiency of power use in products and in building

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Energy policy concepts
USA

- Intensive use of coal, developing an “emission” free power plant
- Use of nuclear power, developing new generation IV technology
- Secure oil reserves in the middle east
- Use of oil in Alaska and the oil sands in Canada
- Only modest use of renewables
- Energy saving will be intensified, e.g. day light saving time will be extended

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Energy policy concepts
China

- The most energy hungry nation in our days
- Will influence the world energy market extremely
- Intensive use of own coal
- Intensive use of nuclear power (e.g. 30 nuclear power plant in planning)
- Intensive use of water power
- Tries to secure oil in different places worldwide, has a strategic disadvantage until now
- Will start to use also renewables energies besides water

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The fight for the resources

- Energy will run short in the future.
- There will be a struggle mainly between Europe, USA, China and India for the resources.
- Energy prizes will rise considerably in the near future.
- A simple example for the electrical power consumption is presented to understand the situation:

Today (2001):

USA 14 MWh/person/year; 250 Mill. Persons
China 1 MWh/person/year; 1300 Mill. Persons

Tomorrow (2050):

USA 25 MWh/person/year; 300 Mill. Persons
China 14 MWh/person/year; 1600 Mill. Persons
Power Consumption Factor USA : 2
China: 18
both: 7

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7. The development of future technologies

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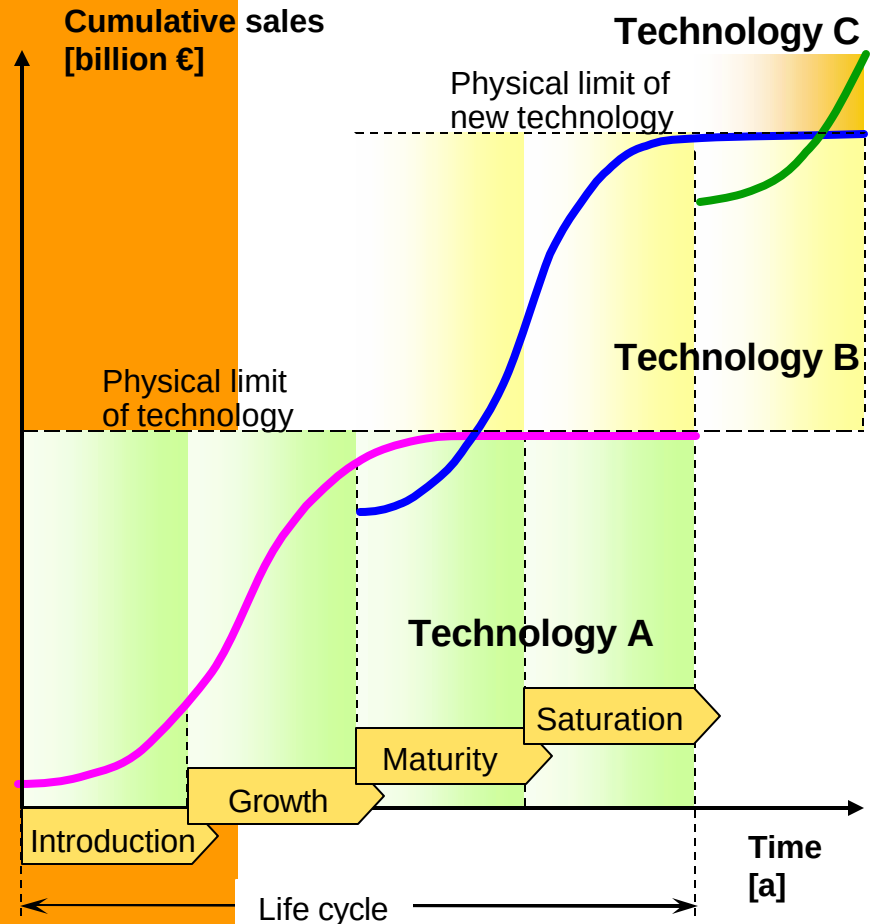
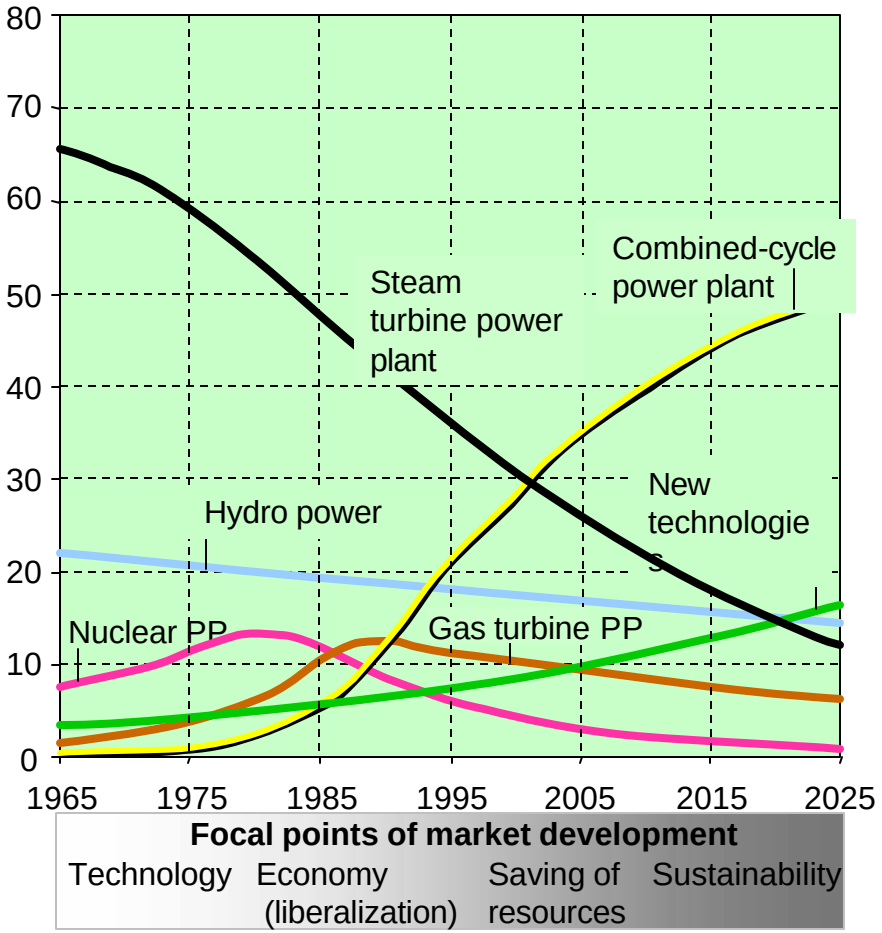
Technology cycles





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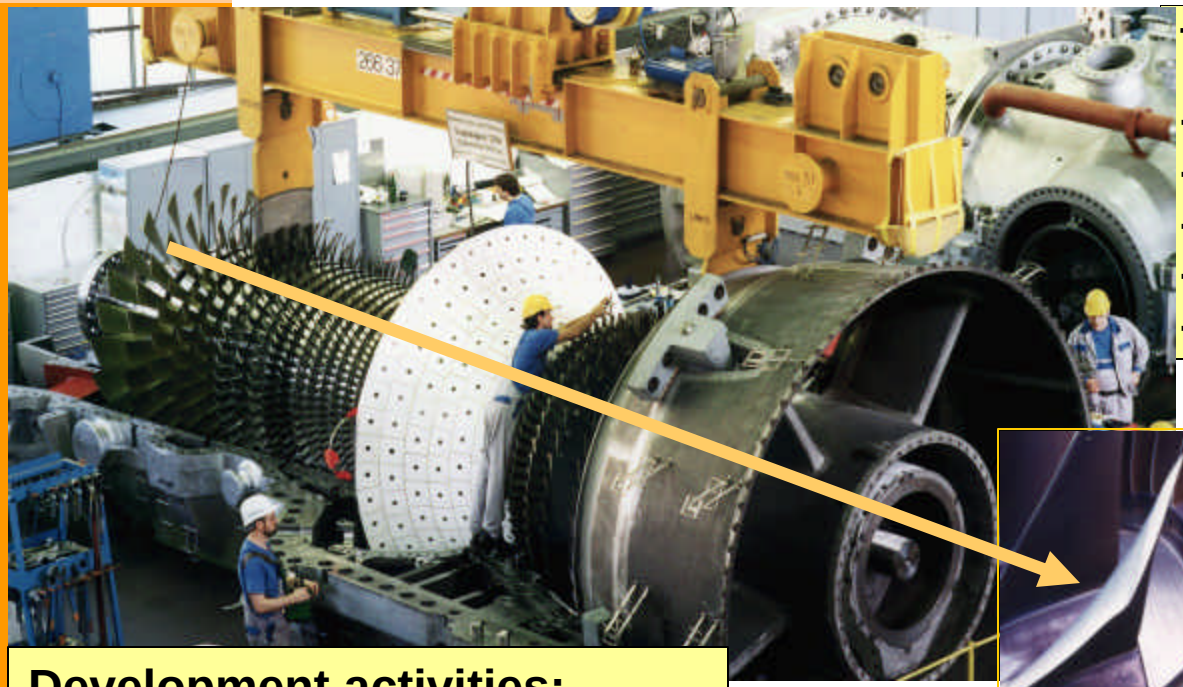
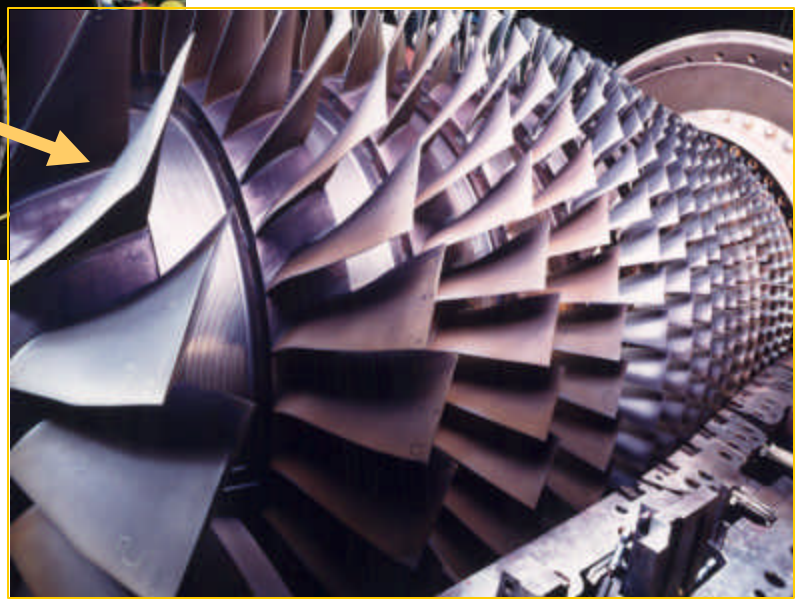
Future technologies
Gas power stations



Technical Data

- Power:	up to 300 MW
- spec.:	2 MW/Schaufel
- Temperature:	1250^{0}C
- Speed:	3600 U/min
- Efficiency.:	59%



Development activities:
- material improvement
- fluid mechanics

Goals:
- increase of power
- increase of efficiency
- reduction of costs

Source: Siemens

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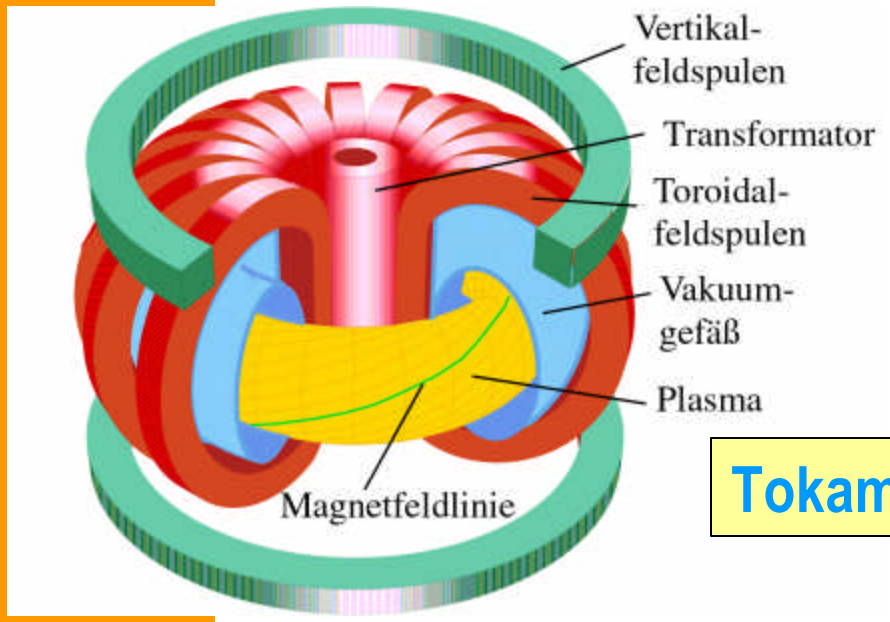
Future technologies
Nuclear fusion

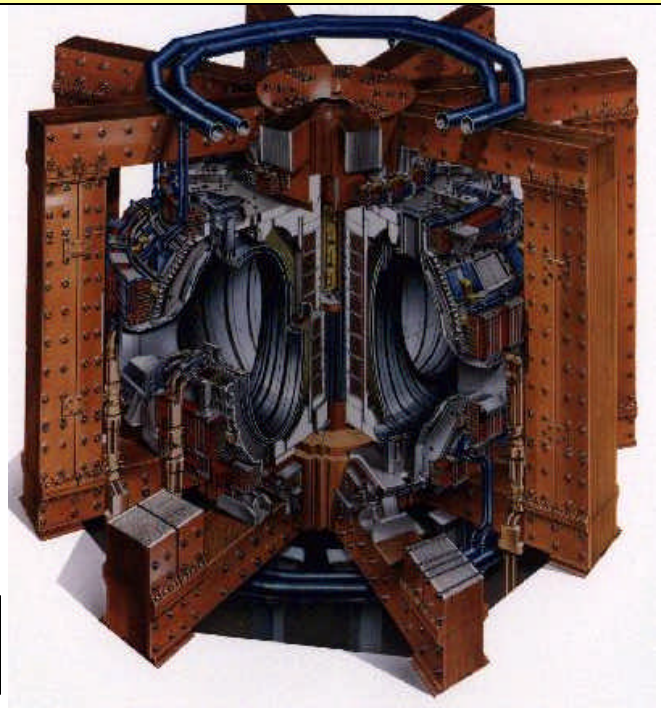
Nuclear fusion means the fusion of light atom kernels while releasing an enormous amount of energy: D + T → He + n + 100 Mio kWh / kg

JET = Joint European Torus

Today's performance: 16 MW Fusion power steady state for 2 sec while heating with 20MW.



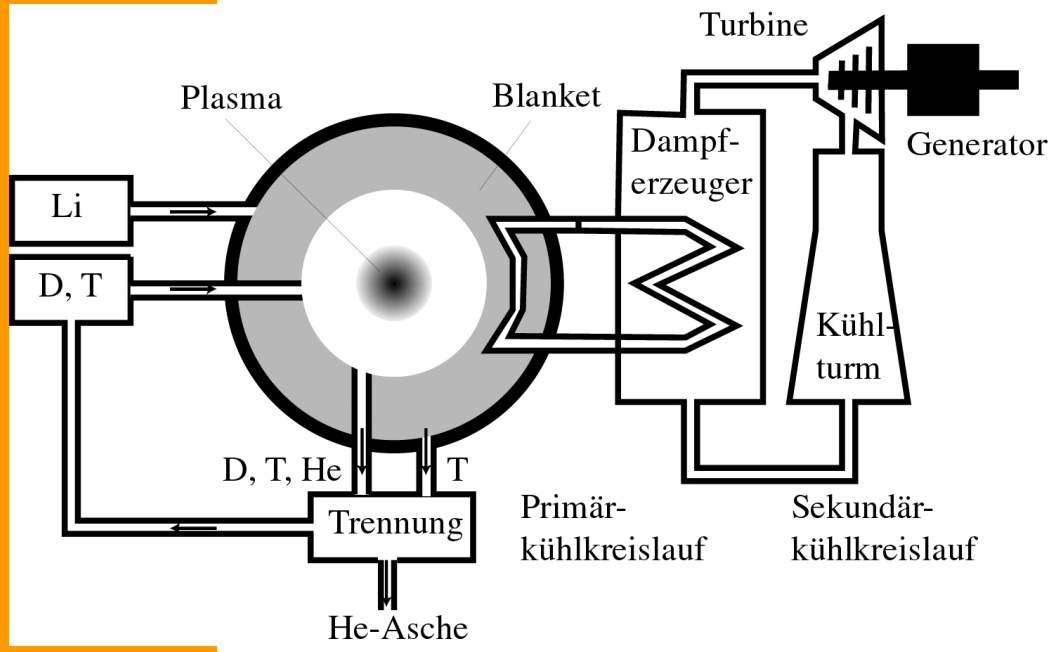
Tokamak Typ



Quelle: MPP IPP

Future technologies
Nuclear fusion

How does a fusion reactor look like ?



Source: MPP IPP

Next steps:

Project ITER

- **Start of construction: 2005**
- **Start of experiment: 2015**
- **Built in Carderache / France**

Possible Demonstration reactor DEMO

- **Start of planning: 2025**
- **Start of operation: 2045**
- **Power: 2GW$_{el}$**

Future technologies
Wind power stations

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Achieved in Germany:

- Installed power in 2003: 15,4 GW
- Generated energy in 2003: 18 TWh

Current developments:

- Wind power module : 1 MW → 5 MW
- Parks offshore: 20 MW → 1000 MW

Challenges:

- Transport of energy over long distances
- Load management
- Reserve management

Quelle: BMU

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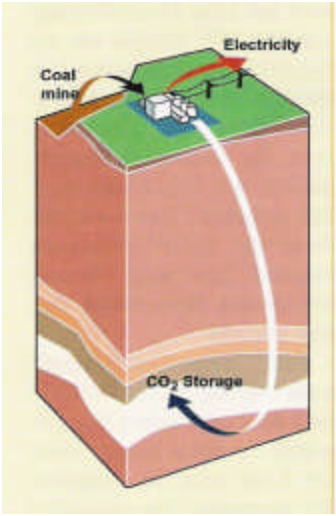
Future technologies
Solar

Situation today:

- **Cost still very high**
- **Efficiency could be improve**
- **In many countries subsidized to promote the technology**
- **Economically applicable in cases where the public power supply not available or a connection too expensive**
- **Goals: - further increase of efficiency**
  - Higher volumes for unit cost decrease

Future technologies
Geothermal power plant

Principle



- Worldwide only a few prototypes
- Investment cost high
- Resource is huge and is flowing steadily
- Everywhere in the world
- Needs much R&D investment

Prototype

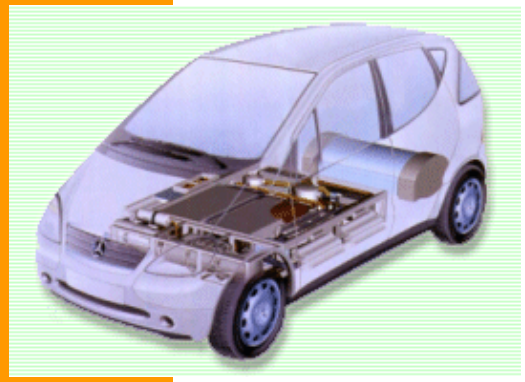
Braunkohle-Kraftwerk Schwarze Pumpe. Daneben entsteht die Pilotanlage für ein CO_2-freies Kohlekraftwerk (Bilder Vattenfall).

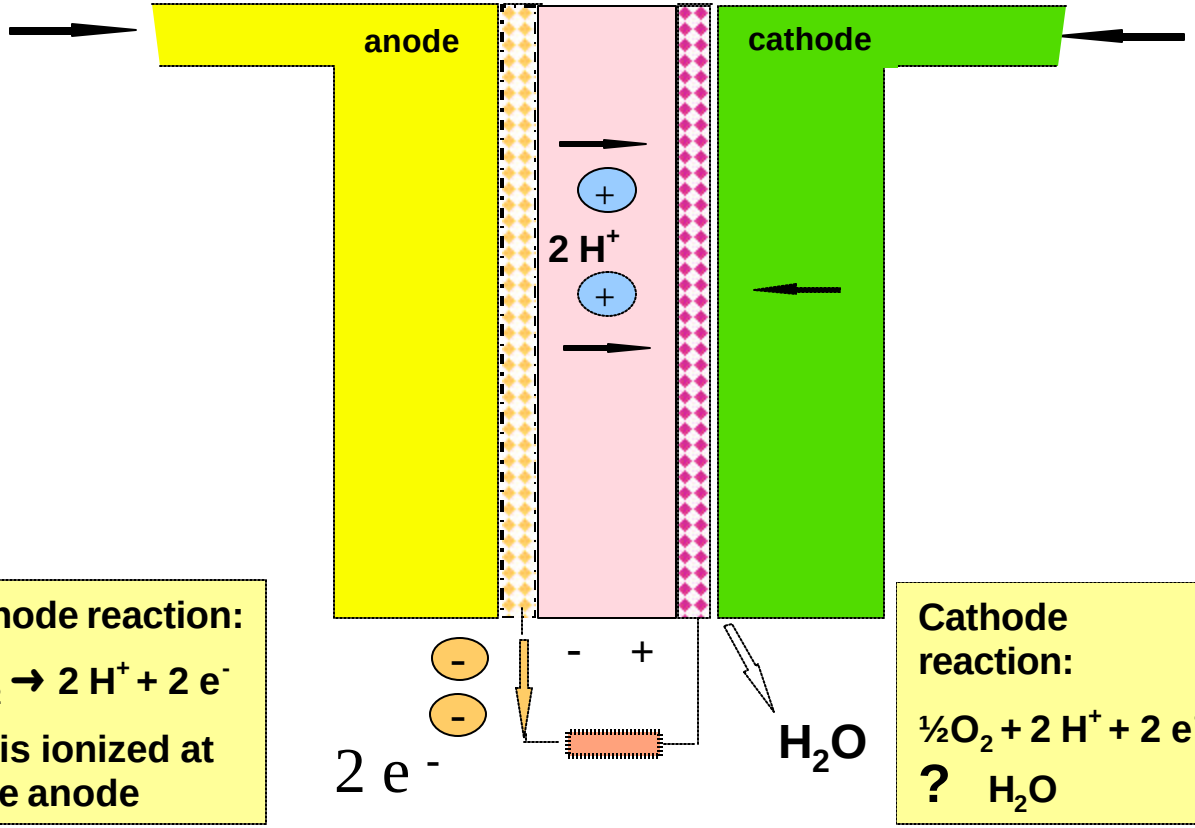
Future technologies
Fuel cells

Natural gas, Methanol → H_2

- PEM-foil, protons conductive
- conductive on both sides

O_2





Anode reaction:

$H_2 \rightarrow 2\ H^+ + 2\ e^-$

H is ionized at the anode

Cathode reaction:

$½O_2 + 2\ H^+ + 2\ e^-$

? H_2O

PEM = Proton Exchange Membrane

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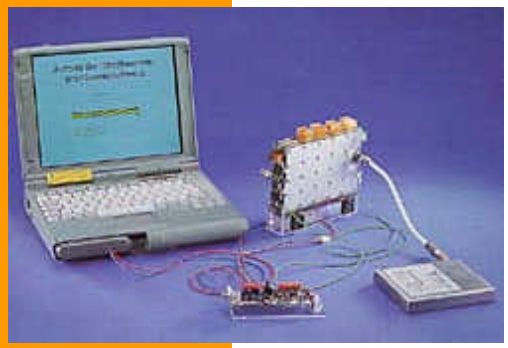
Future technologies
Fuel cells



For all systems needed:
- Reduction of manufacturing costs
- Increase of power density

Low temperature systems:
- Reduction of platinum consumption
- Development of high temperature membrane (ca. 180 °C)
- Simplifying of the gas preparation
- Reduction of the parasitize consumption
- Increase of life cycle

High temperature systems:
- Development of cheap steadfast materials
- Increase of life cycle
- Reduction of the size

The development of the electrical energy supply in the next 20 years with an outlook to 2050

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8. Electrical power supply scenarios for 2020 and beyond

Example Germany (1)
Development of the 3 scenarios

- **Scenario 1 „ Current German Energy Policy“:**

The initiatives of the government were integrated in one consistent szenerio. Starting on the data of 2003 all government decisions on the promotion of the renewables and the exit of the nuclear power plants were put together to one “picture”. The consumption is based on the experience of the last 10 years.

- **Scenario 2: „Cost optimal“**

Different from the scenario1 the nuclear power will be reduced only by 50% using only the modern plants.The renewables will be ramped up more slowly. The fossil power plant will contribute at the same level as today

? **Goal: Optimization of investment while fulfilling the Kyoto goals .**

Example Germany (1)
Development of the 3 scenarios

Scenario 3: „Environment optimal“

The nuclear power will be used on the same level as today, the renewables will be ramped up according to the plans of the government. The use of hard coal will be stopped (no subsidies any more), instead brown coal will be used more intensively. The gas imports will be increased on a lower level than in scenario 1.

? **Goal: Reduction of CO2 emissions while reducing the import dependency**

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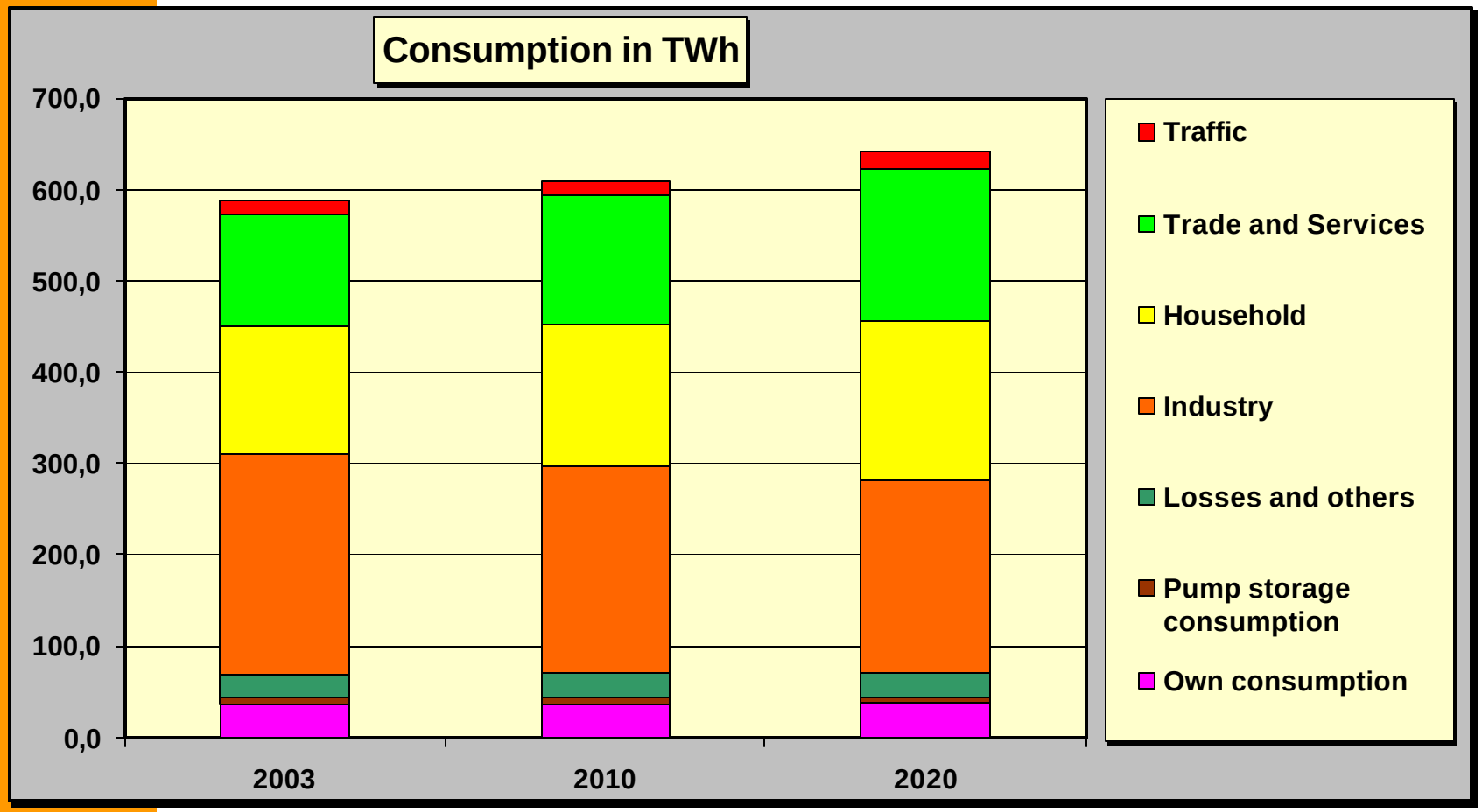
Example Germany (1)
Development of demand



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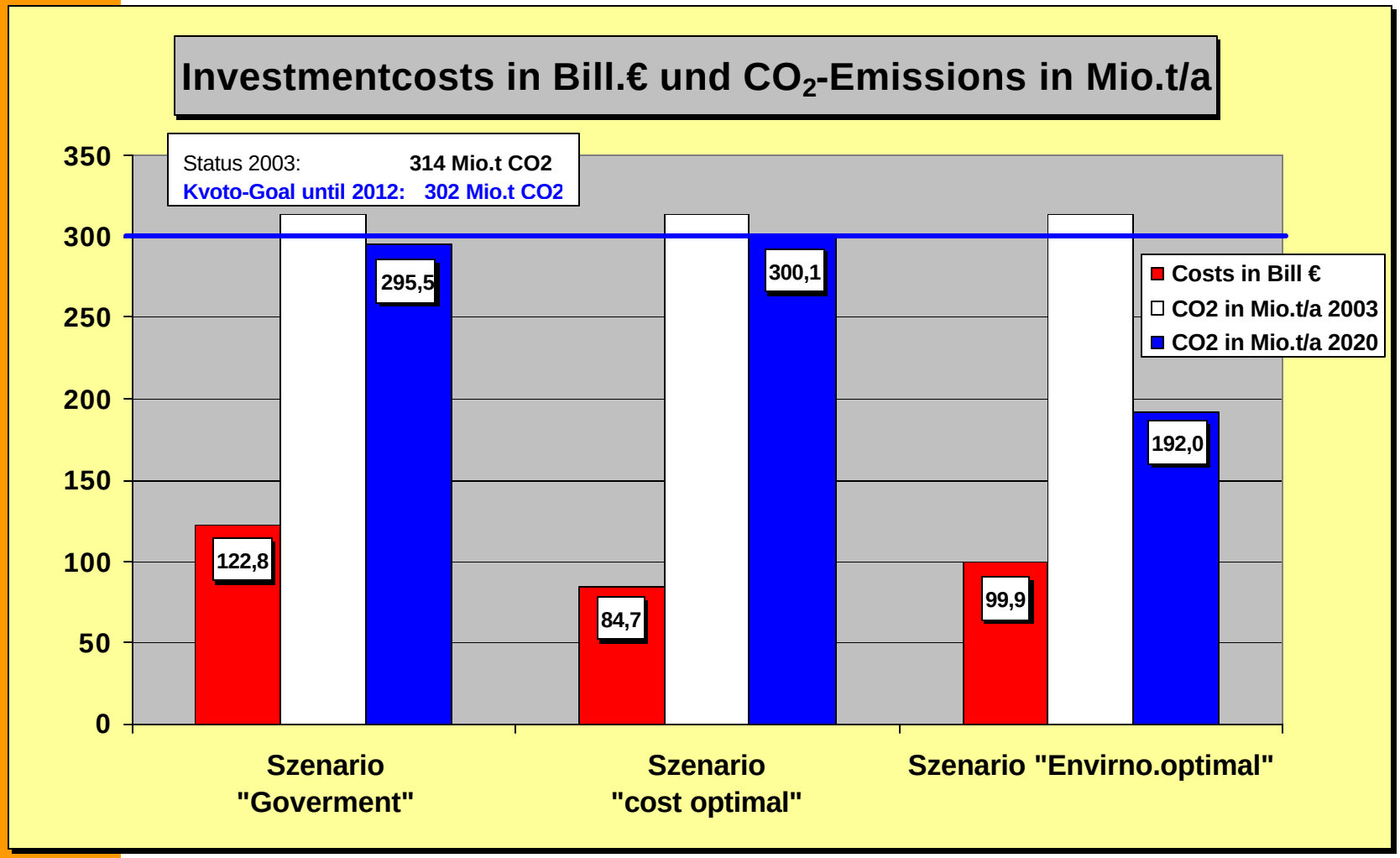
Example Germany (1)
Investment cost and CO2 emission for the 3 scenarios



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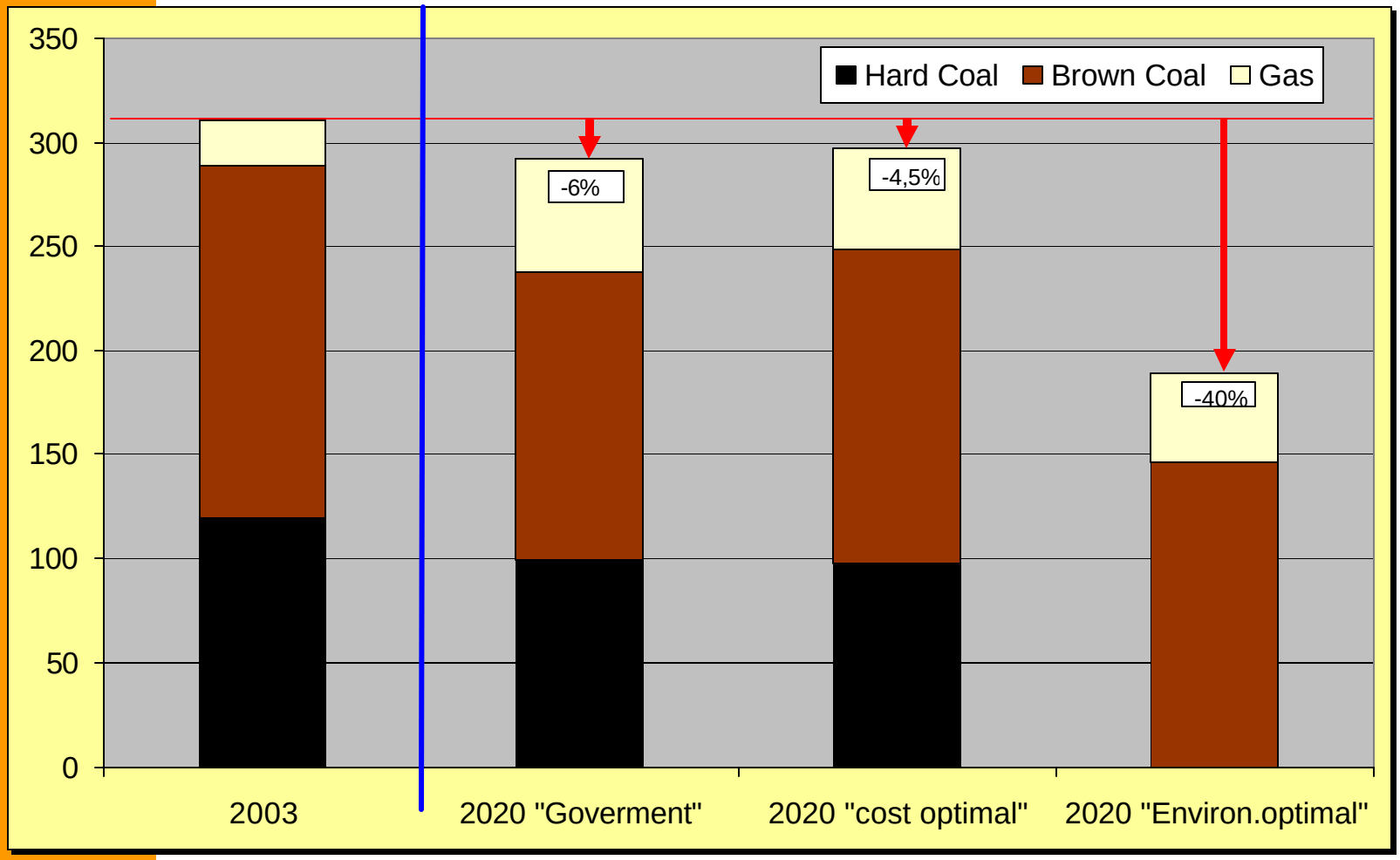
Example Germany (1)
Development of CO2-emissions for the 3 scenarios until 2020



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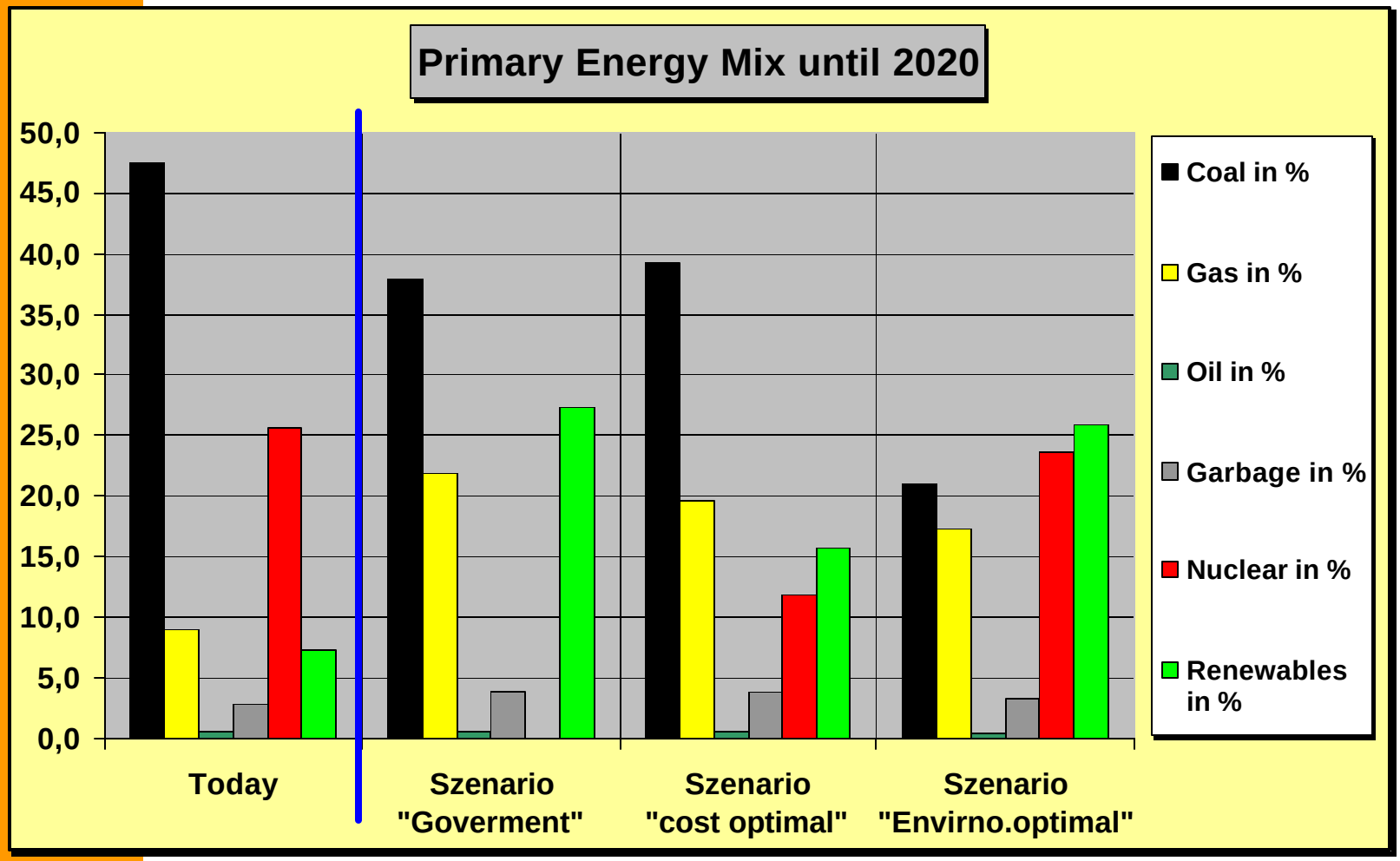
Example Germany (1)
Energy Mix in %



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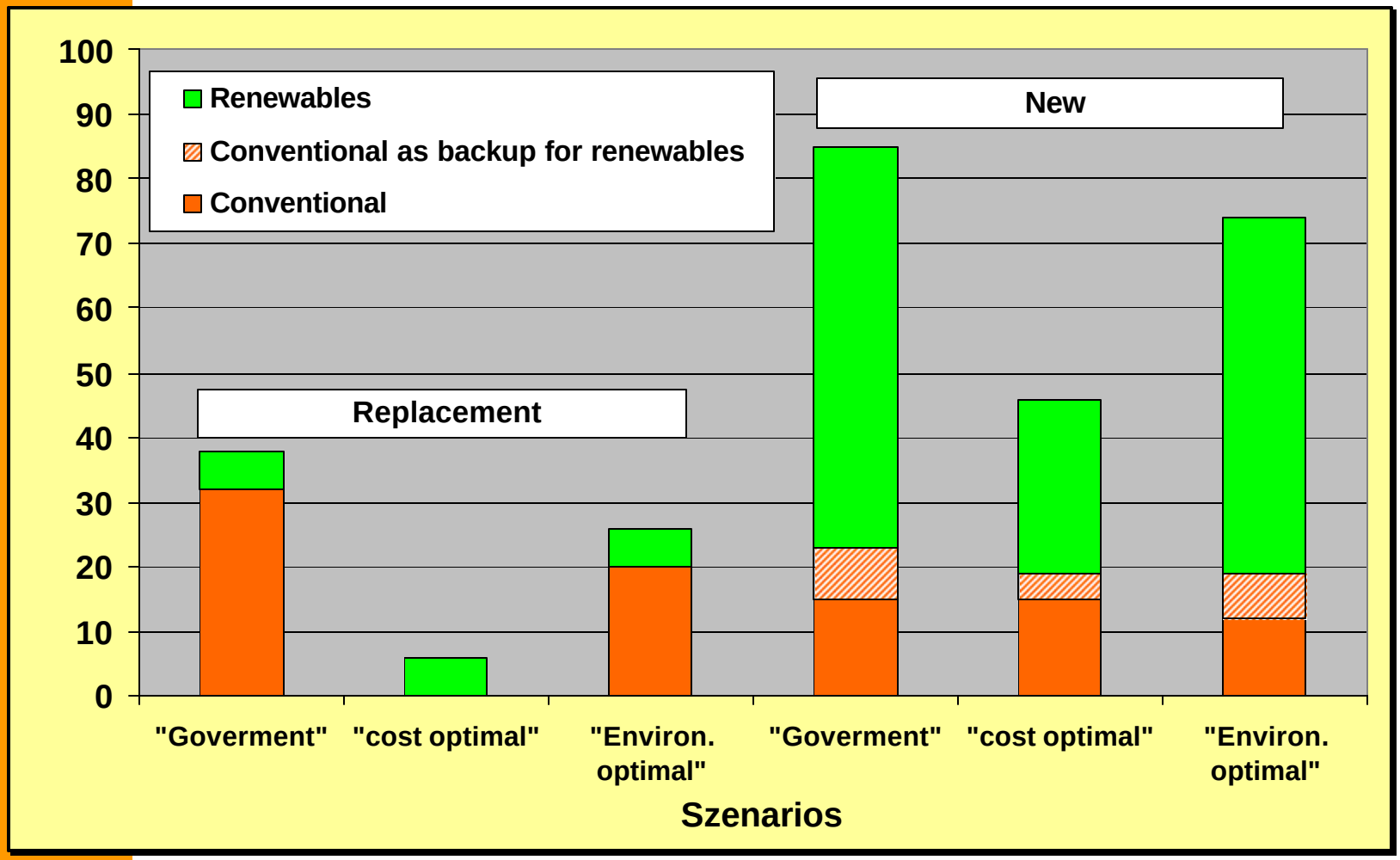
Example Germany (1)
Investment cost for power plants until 2020 in bill.€



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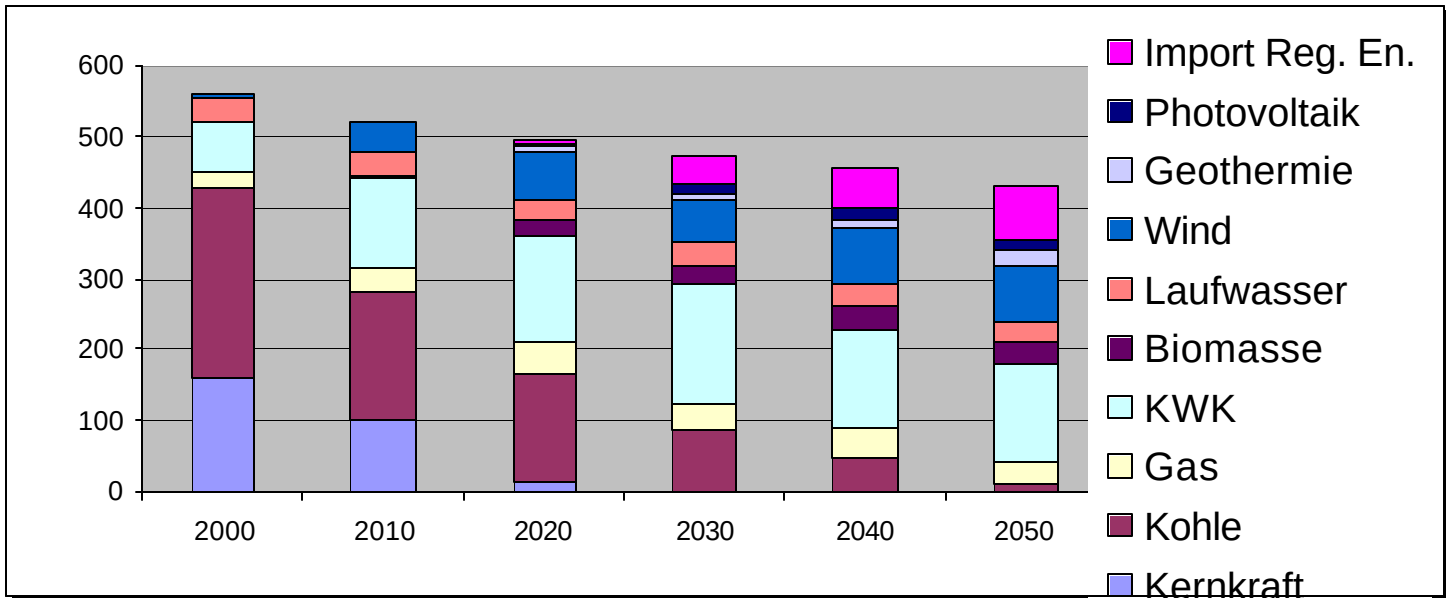
Example Germany (2)
Long term scenario of German Environmental Agency

Assumptions

- Power consumption will fall despite increase of economic **growth**
- Shut down of all nuclear reactors
- Expansion of renewable energies and combined-cycle power plant
- The scenario follows the **concepts of the current German government**



2050:
-20% Demand
53% Renewables
17% Reneweable Imports

Source: Fischedick,M;Nitsch,J. u.a.: Langfristszenarien für eine nachhaltige Energienutzung in Deutschland. Untersuchung im Auftrag des Umweltbundesamtes

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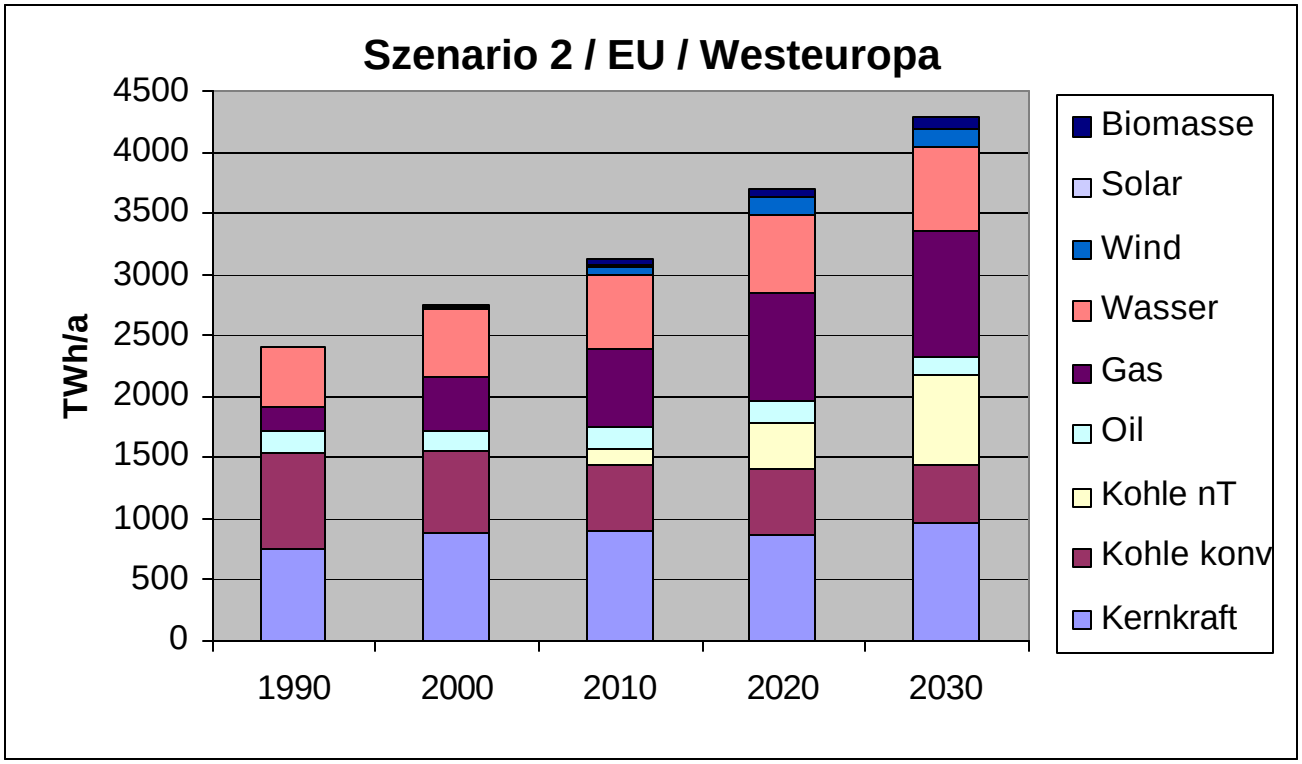
Example EU
Outlook to 2030

- Power demand increases by 1,5% / year
- The renewables play an increasing but still modest role in the EU outlook
- By using sophisticated technologies coal will still be the backbone of the supply



Source: European Commission: World energy, technology and climate policy outlook 203- WETO- Directorate General for Research: Energy, 2003

The development of the electrical energy supply in the next 20 years with an outlook to 2050

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9. Summary

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Summary

- This century will be the century of energy not of information.
- The fossil resources will come to an end.
- We need an balanced mix of energy source.
- The role of the renewable will steadily grow.
- The nuclear energy will experience a renaissance.
- Energy prizes will rise steadily.
- The fusion technology will come to application by the middle of the century
- There will fights for energy sources

→ We have to find energy solutions if we want to survive