Lady, gentlemen and friends, good morning!

It is a real honor and pleasure for me to be here and many thanks to ICF for the invitation.

My presentation will consist of these parts:
1. Introduction
2. Energy Consumption
3. World Energy Resources
4. Electricity Production
5. Some comments on Transmission
6. Conclusions

Environment

- The key socio-economical factors affecting now our sustainable development are (not in order of priority):
  - Globalisation
  - Privatization processes
  - Liberalisation processes

  } Triumph of free market ideology

  - Technology

  ⇨ Uneven localization of primary energy resources and consumption areas

  ⇨ Health and Environment

  - The increasing North/South gap
  - Fanaticism/terrorism

As an introduction let us come first to the environment we are working in. Besides the key socio-economic factors, as outlined above, we must consider the following issues:

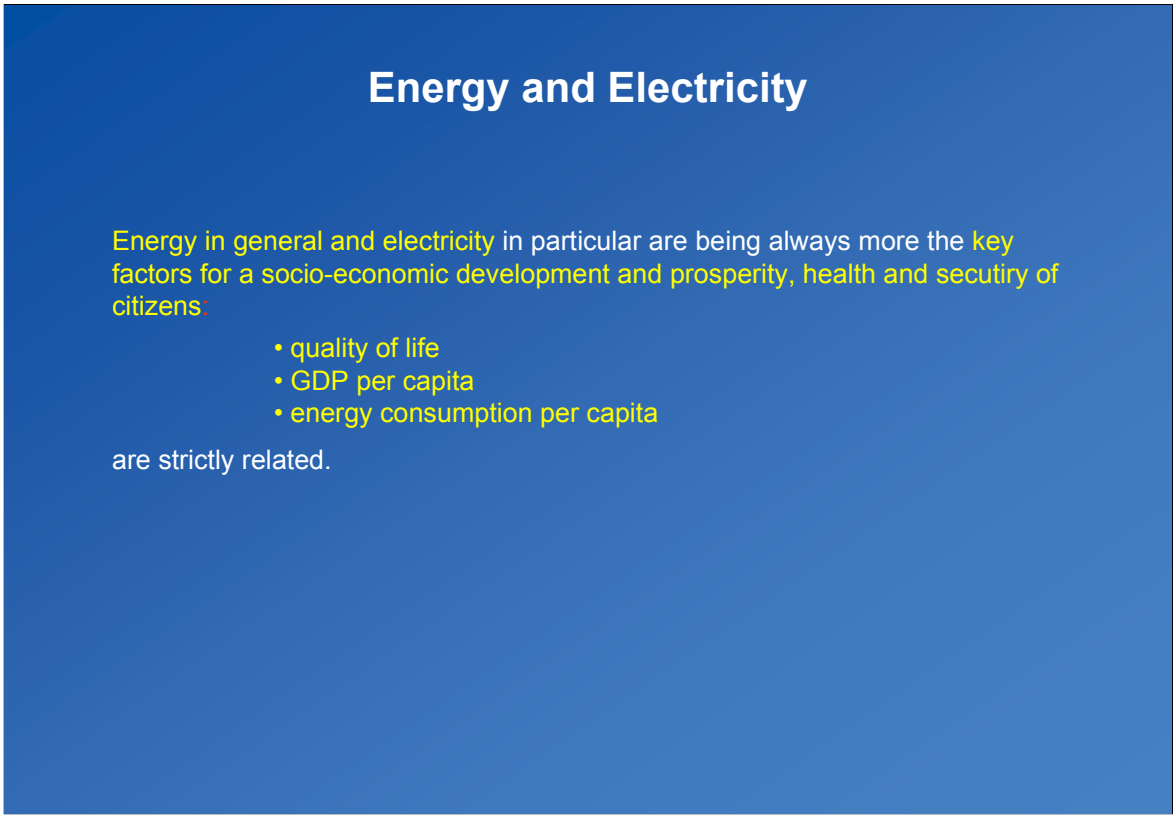
• With globalization /privatization /liberalization processes, the major efforts of companies have been /are being concentrated on strong cost reduction policies.

• In addition, the “company value” is mainly/only seen to day as the share value in the stock market with a focus on sending out “impressive” goals or actions (see personnel cutting) to the financial analysts (and alas to speculators).

• The ability/activity of communication seems sometimes to exceed the ability/activity to perform/to do.

• The considered returns on investments are always shorter and they are having a drastic effect on R, D&D (Research, Development and Demonstration).

• Concentration of investments on “non capital intensive” projects which in many cases are not in favour of sustainability and/or security of energy supply.



Now I would like to remember that the energy sector is a very peculiar one, characterized by very long cycle times. Energy is not a commodity.

• For a “new family” of HVDC (High Voltage Direct Current) converter stations, the global time from R.D&D (Research, Development and Demonstration), to engineering, construction and operation of “the family”, is of various decades.
• For a new family of NPP’s (Nuclear Power Plants) new reactors have a lifetime designed for 60 years and therefore considering licensing/decommissioning, the global cycle time is longer than one century (without taking into account the final waste disposal).

Energy problems and relevant effects on the environment are ever and ever attaining a global aspect and the subsequent energy and environmental policies of the countries involved and the penetration rate of different resources are more and more “interacting”.

An applied worldwide economic evaluation of the different environmental impacts would be a great help for the confrontation of the various “energies”. Efforts should be directed to an “engineering approach” which minimizes for each project the global cost of the four basic resources applied in any human activity, i.e. raw materials (including energy resources), labour, environment, capital.

Let us now come to the energy consumption.

	1995-2004 WORLD SITUATION											
	Population (Million)				Primary Energy (°) (MTOE)				Electricity (TWh)			
	1995	2004	Δ %	%	1995	2004	Δ %	%	1995	2004	Δ %	%
EUROPE	575	592	2.9	9.3	1803	1999	10.9	18.2	3068	3691	20.3	21.1
CSI	284	279	-1,7	4.4	959	966	0.7	8.8	1267	1345	6.1	7.7
N. AMERICA	296	326	10.1	5.1	2320	2585	11.4	23.5	4142	4742	14.5	27.1
LATIN AMERICA	474	541	14.1	8.5	524	651	24.2	5.9	770	1124	46.0	6.4
E. & S.E. ASIA	1926	2103	9.2	33.2	2151	2936	36.5	26.7	2611	4356	66.8	24.9
S. ASIA	1213	1420	17.0	22.4	525	689	31.2	6.3	493	787	59.6	4.5
MIDDLE EAST	149	181	21.4	2.8	319	475	48.9	4.3	339	583	71.9	3.3
AFRICA	707	869	22.9	13.8	438	557	27.2	5.1	364	535	46.9	3.0
AUSTRALASIA	28	32	14.2	0.5	113	138	22.1	1.2	211	285	35.1	1.6
WORLD	5652	6343	12.1	100	9152	10906	20.1	100	13.265	17.448	31.5	100
OECD	1088	1159	6.5	18.3	4891	5495	12.3	49.3	8521	10.145	19.0	58.1
EU 25	447	456	2.0	7.2	1594	1757	10.2	15.7	2632	3182	20.6	18.2

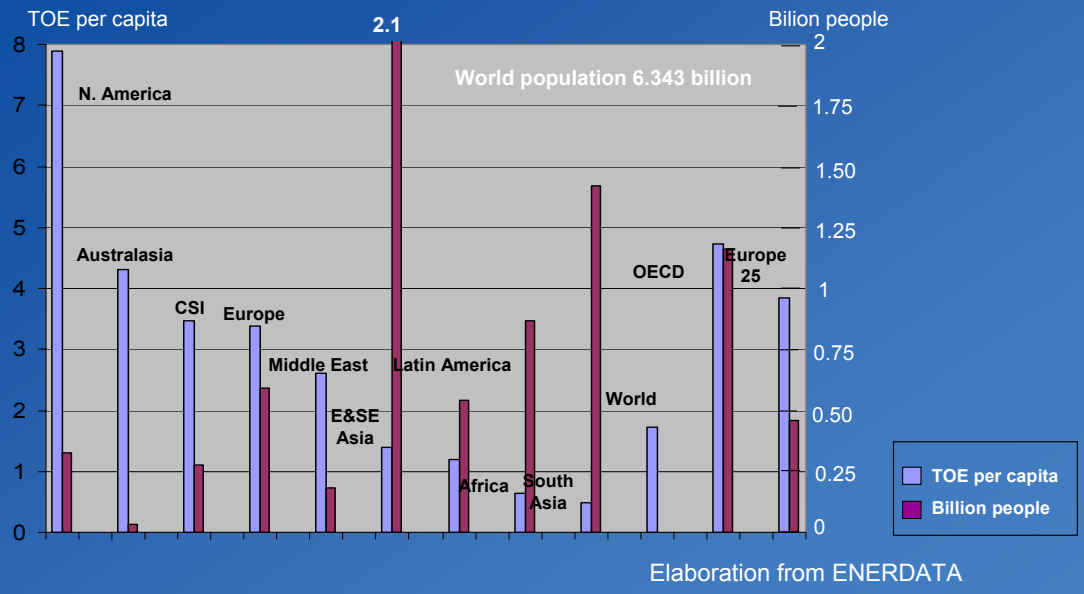
(°) Including wood and biomasses which account for 10% of global (more than 80% in Asia and Africa)

ELABORATION FROM ENERDATA

Considering the fact that electricity is produced by primary energies, it is fundamental to consider the present and future trends of global energy resources to have an idea on the future of electricity production.

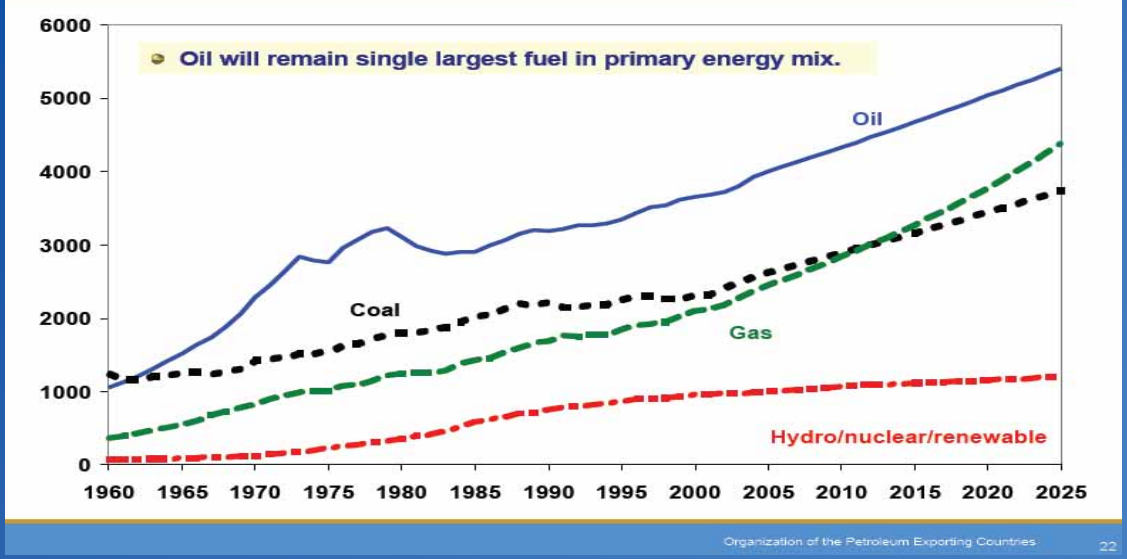
In the above table I will focus on the yellow colored fields. The world population in 2004 was 6.3 billion, with an increase of more than 12% in 10 years, but more than 30% in East Asia. The primary energy resources in the world are about 11,000 million tons oil equivalent (MTOE) with an increase of more than 20% in 10 years, but more than 30% in Asia.
Considering electricity generation we have more than 17,000 TWh in the world with an increase of 31.5% in 10 years, 1.5 times the rate of primary energy. In Asia the increase was around 60% in the last 10 years.

Large differences in primary energy per capita



There are large differences in primary energy per capita, from close to 8 TOE per capita in North America to 0.6 TOE per capita in South Asia.

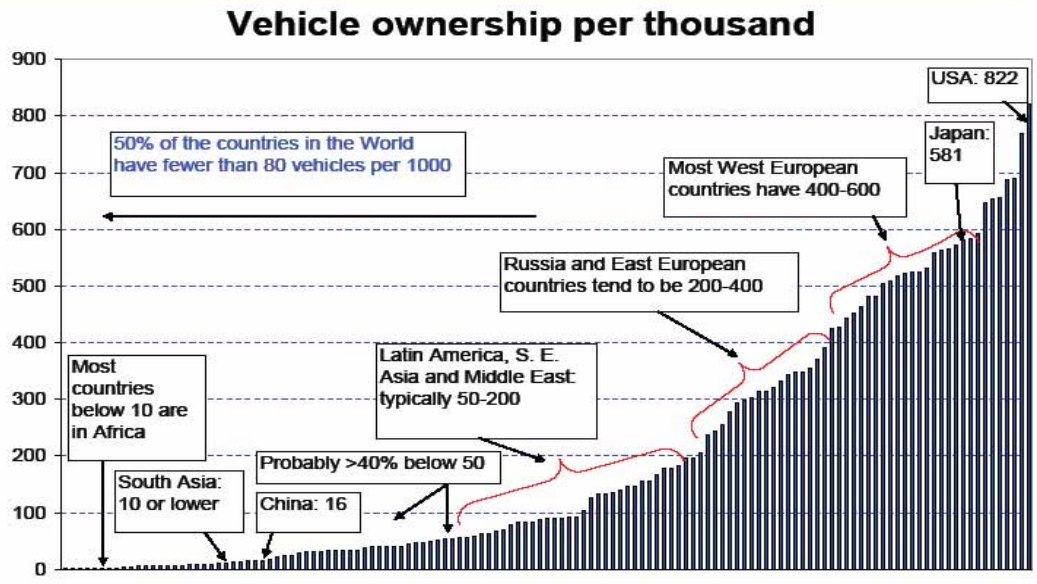
World energy demand by fuel type (mtoe)



N.B. 2005 Global Consumption: 10GTEP excluding wood and biomasses

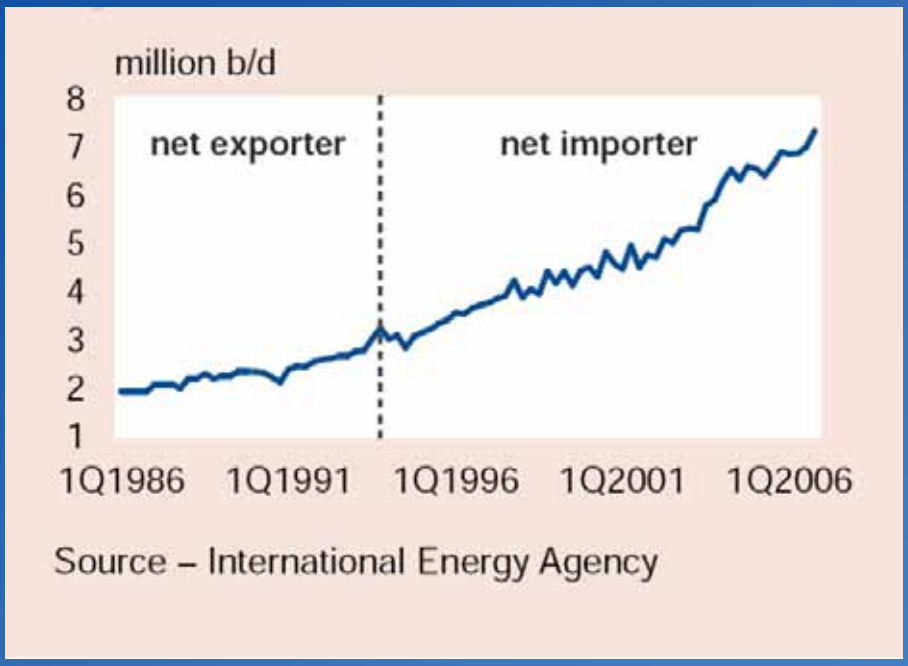
This slide shows the evolution of the world energy demand by fuel type. Oil is dominating as fuel resource. You can see that coal will be passed by gas around 2012.

Large differences in oil use per capita :



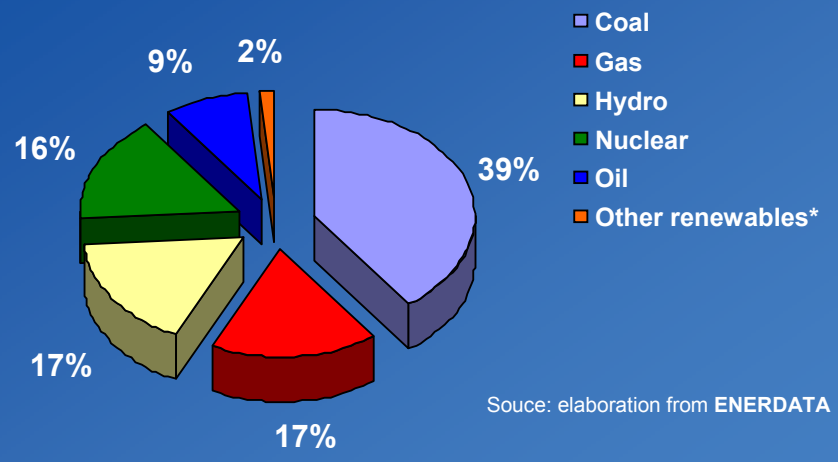
In the USA we have more than 800 cars per 1000 inhabitants, in Europe between 200 to 400, in India and China around 10 to 16.

Oil Consumption in China



If in 15 years China is reaching a value of one half of the current European value, imagine the millions of cars invading this country and how much oil will be consumed by driving these cars?

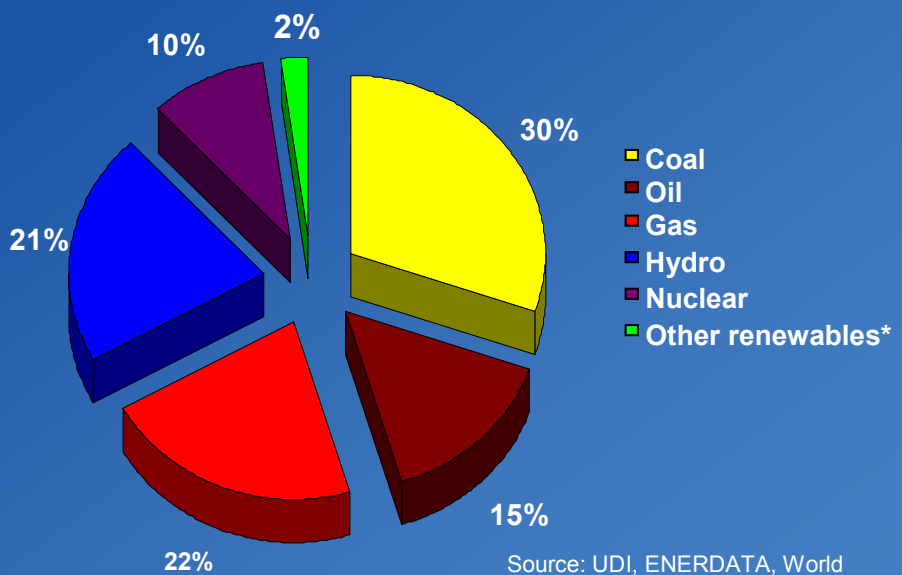
Electricity in the World (~ 16,000 TWh)



Souce: elaboration from **ENERDATA**

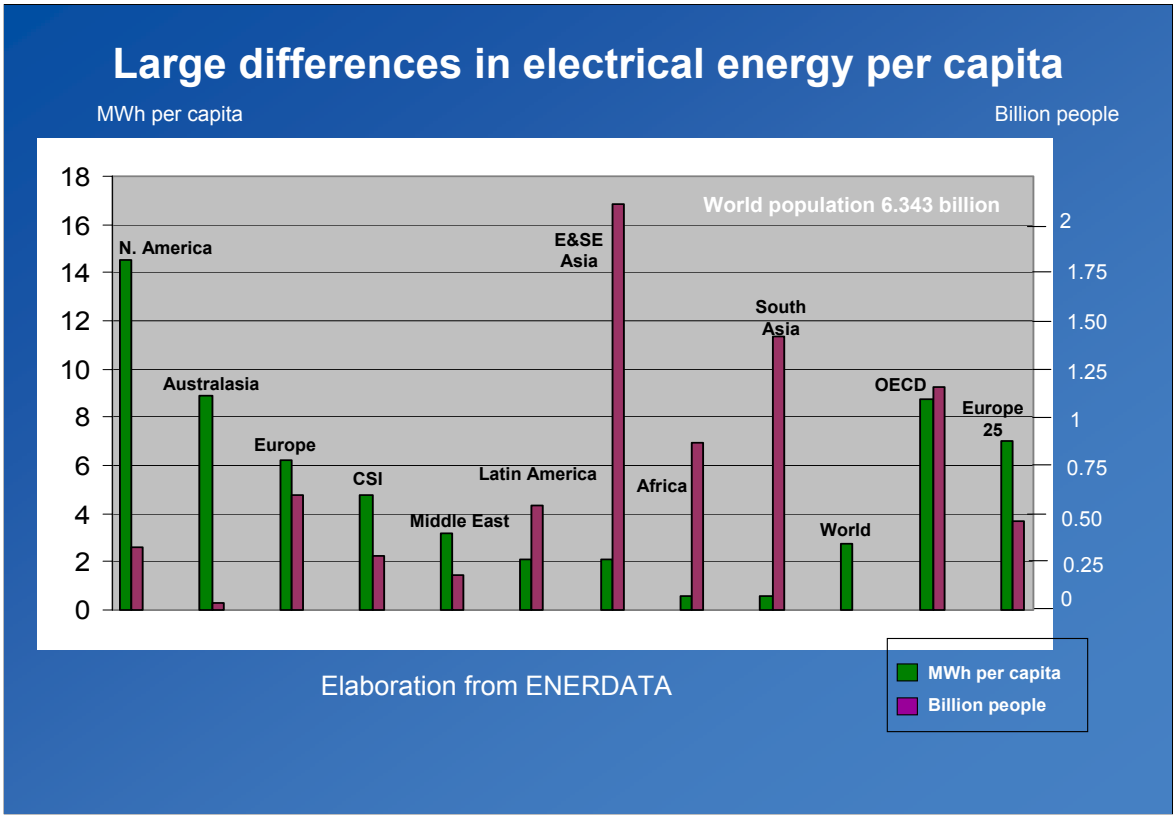
Please remember the 16,000 TWh of electricity in the world. This is the produced energy. About 40% of that is generated from coal.

World Installed Capacity (~3700 GW)



Source: UDI, ENERDATA, World Energy Database – WEC elaboration

This slide shows the installed capacity of about 3,700 GW.



With 13.8% of the world population, Africa consumes only 3% of the global electricity.
South Africa has only 5% of the total African population, but it consumes 47% of the global African electricity.

Source: ENERDATA, World Energy Database, WEC elaboration

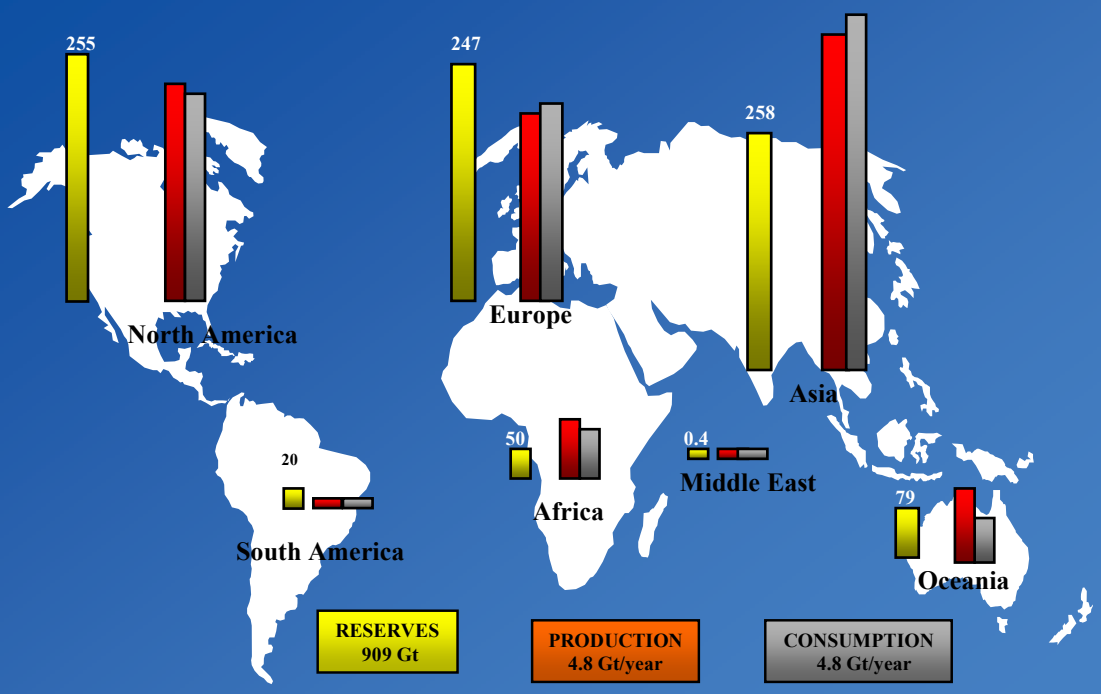
Now let us look at the world energy resources.

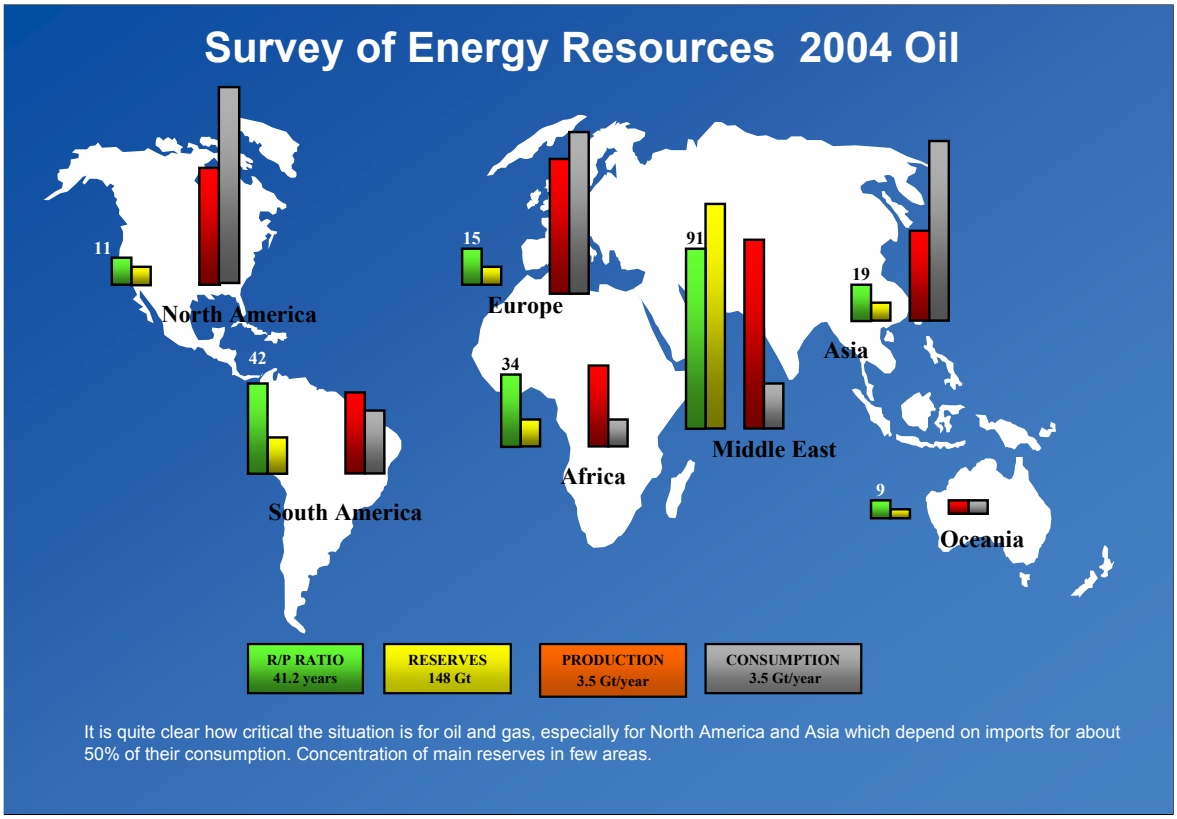
WEC Survey of Energy Resources (SER)

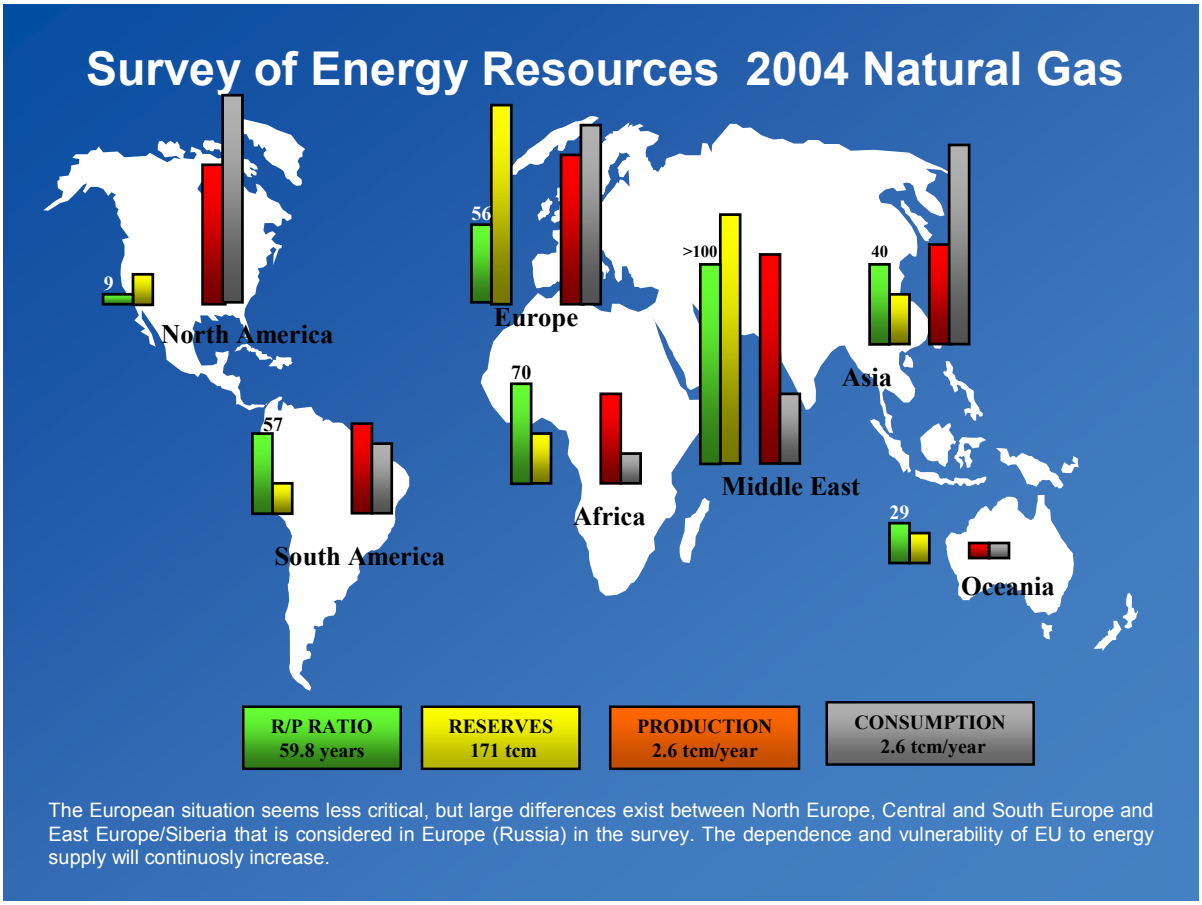
- Triennial Survey:
  - First Edition in 1934
  - 20th Edition in 2004 coordinated by me
- I give some few flashes updating some figures of the 2004 edition.

In the following slides relevant to coal, oil and natural gas, seven geographical areas are considered: **NA** (North America), **SA** (South America), **EU** (Europe, including also Siberia), **AF** (Africa), **ME** (Middle East), **AS** (Asia), **OC** (Oceania)

Survey of Energy Resources 2004 Coal



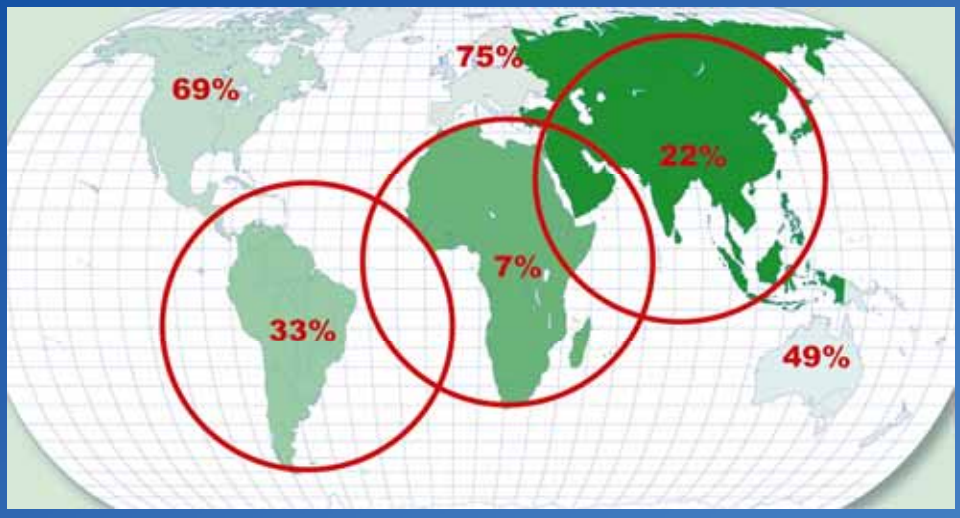

Survey of Energy Resources 2004 Oil
11
North America
42
South America
15
Europe
34
Africa
91
Middle East
19
Asia
9
Oceania
R/P RATIO
41.2 years
RESERVES
148 Gt
PRODUCTION
3.5 Gt/year
CONSUMPTION
3.5 Gt/year
It is quite clear how critical the situation is for oil and gas, especially for North America and Asia which depend on imports for about 50% of their consumption. Concentration of main reserves in few areas.


Survey of Energy Resources 2004 Natural Gas
9
North America
57
South America
56
Europe
70
Africa
>100
Middle East
40
Asia
29
Oceania
R/P RATIO
59.8 years
RESERVES
171 tcm
PRODUCTION
2.6 tcm/year
CONSUMPTION
2.6 tcm/year
The European situation seems less critical, but large differences exist between North Europe, Central and South Europe and East Europe/Siberia that is considered in Europe (Russia) in the survey. The dependence and vulnerability of EU to energy supply will continuosly increase.

Large Hydro Power

- The major contributor in the renewable power sector for the foreseeable future
- Installed Hydro Power **750 GW** (10% of the global 3,700 GW) with production of **2,600 TWh/year** (16% of the global electricity production of 16000 TWh)
- Gross theoretical capability **> 40,000 TWh/year**
- Actual exploitable capability **> 16,000 TWh/year**
- Environmental concerns for large hydro plants plus long transmission systems to load areas.

Hydropower: Usage/Potential (2002)



North America and Europe have developed large hydros. In Africa there is a tremendous potential.

Uranium

- **Proved Reserves**
  - Recoverable at less than 80 $/kgU — 2.5 Mt
    Canada + Australia — ~ 50%
    Kazakistan + Namibia + Niger+ Uzbekistan + Russia — ~ 40%
  - Recoverable at more than 130 $/kgU — > 8 Mt
- **Production of Uranium in 2003** (50% of global reactor requirements)
  ~ 35,000 t

Secondary sources of uranium are affecting now the market price and the possible development of primary production centres. Possible periods of volatile spot prices connected to delays or interruptions of secondary supplies.
But for NPP's Uranium is a portion of fuel cost which accounts for some 10% of total kWh cost.

40-70 years at current consumption level worldwide with only known resources recoverable at less than 100 $/kgU around 150 years with known resources recoverable at more than 130 $/kgU.
Fast breeder reactor = multiplying factor of 60 at least for fissile resource.
Thorium ore is also a long term resource.

Nuclear

- 2004: 50th anniversary of the first delivery from the first reactor in Russia
- 441 nuclear plants in operation at Sept. 2005 ~ 368 GW
  2,600 TWh 16% of global electricity production
- Subdivision of installed power: EU 172 GW, NA 112 GW, AS 79 GW, SA 3 GW, AF 1.8 GW
- Trend: reduction of market share due to present and next future massive investments in gas and coal plants
- Nuclear plants less attractive in deregulated and low growth markets
- Economics and spent fuel and waste seem to play a role more important than safety. GHC emissions rules will play an important role for NPP development

Geothermal (end 2002)

- Electricity
  - 8,200 MW: US 25% + (Philippines, Mexico, Italy, Indonesia, Japan) 65%
  - 51 TWh
  - Potential 35 GW - 73 GW
- Direct use of heat: ~ 41 TWh

Wind

- Fastest growing energy technology with solar; average in last five years > 30% per year
- Europe 66% of global installed capacity
- End 2005: ~ 60 GW installed in the world (~ 120 TWh)

1. Germany 18.5GW (7% of el.en.)
2. Spain 10 GW (8% of el.en.)
3. US 9 GW (<1% of el.en.)
4. India 4.5 GW (1.5% of el. en.)
5. Denmark 3.1 GW (18% of el.en.)
6. Italy 1.7 GW (2% of el.en.)

NB: UK 1.3 GW and Ireland 0.5 GW (4% of el. en.)

Potential: Several times present global electricity demand but rising environmental opposition for land installations. The vast wind areas are far from loads:

- Grid problems/costs
- Off-shore developments and large size (5 MW each) are the future.

Solar Energy

- Annual solar radiation reaching earth ~ 60 times the global actual consumption of primary energy
- Photovoltaic capacity at end of 2005: 3.5 GW (4.0 TWh):

  20% off grid 80% grid connected
  N.B.: 1100 MW connected in 2005 (+40%)
- Cumulative installed capacity:
  - Japan ~ 1500 MW
  - Germany ~ 1250 MW
  - USA ~ 500 MW

  followed after a big-gap by India and China (around 100 MW each) and Australia and Netherlands (around 70 MW each)

Solar thermal electric power stations at end of 2005: 0.35 GW.
Thermal at the end of 2005: 300 million sqm. solar thermal collectors (80 GWh - 70 TWh)

China 65%
Europe 13% (Austria + Germany + Greece = 75%)
Japan 7.3%
Turkey 7.2%
Israel 4.4%

Marine Energy

Tidal energy: many sites technically suitable; whether the resource can be developed economically is yet to be determined. Potential energy production from the four most promising sites is ~ 50 TWh/year.
Wave energy: a plethora of ideas and designs of different devices. Few technologies ready to be deployed. Appreciable contributions expected only by the end of the century.
Ocean Thermal Energy Conversion (OTEC): to convert into useful energy the temperature difference between surface water and water at a depth ~ 1000 m is still expensive. A demonstative plant needed. Combination with potable water production.
Optimistic assumptions:

10 GW in 2010
20 GW in 2020
100 GW in 2050

Oil Shale - Natural Bitumen-Extra-Heavy Oil

Resources are mainly concentrated in :

USA (80% of oil shale)

Canada (60% of natural bitumen)

Venezuela (95% of extra – heavy oil)

They are enormous : by far more than 10 times the oil reserves.

Present production is minimal.

They may find a place in the world fossil energy mix in conjunction with diminishing resources of crude oil and relevant stable high prices.

Wood

- 1.8 billions tons per year : it is equivalent to more than 5% of global commercial energy consumption
- In Asia and Africa, the energy from wood is the dominant one for 2 billion people
- In Africa, countries excluding South Africa - Maghreb - Libya - Egypt, wood represents the 86% of energy sources

Biomass different from wood

- Agro fuels
- Fuels from municipal waste

Total contribution in 2005 ~ 500 MTOE

- Potential future contribution larger than present global energy consumption …. but not clear when

The drivers for electricity production

Not in order of priority they are:

- Cost of prime energy resources and relative differences
- Development of technologies and relevant costs
- Efforts/policies to stabilize climate change (e.g. Kyoto protocol/Europe)
- Public acceptance
- Local policies (e.g. China to use their coal)
- Financial environment/liberalization processes
- Energy efficiency/saving programs

In general for the electricity production it is essential to recall that:

• the “demand” diagram is varying daily (1 to 1.8 from night to daily peak), weekly and with seasons. Something could be done to flatten the diagram but not too much in the medium term

• it is therefore necessary to have an adequate mix of base-load plants, mid merit and peak ones;

• from the production side, some technologies are possible/economic only as base-load (e.g. nuclear), someone as peak (single cycle gas)

• some renewables (wind, PV) sources have no possibility of commitment to the “pool” of a firm capacity for the various hours of next day and cannot “stand alone” in the system. They cannot work without the “back up” of conventional generation and of a strong T&D system (with a clear additional cost to the normal costs usually provided).

Taking care of what above, the development of energy storage systems, including electricity, could be an asset for future systems and for a better exploitation of some renewables.

The future for electricity production

Trend of demand up to 2030:

- Global energy increase: from 10 to 15 GTEP
- Electricity increase: from 16,000 TWh to 32,000 TWh

How to meet the demand: "centralized" generation / "distributed" generation / "hybrid" generation

- Fossil fuels (gas/coal; oil is mainly for transports)
- Hydro
- Renewables
  - Wind
  - Biomasses/biofuels
  - Geothermal
  - Solar
  - Marine/others
- Nuclear
- New vectors (e.g. Hydrogen)

Source IEA

Cost of generated kWh

Main components:

- capital
- fuel
- O&M

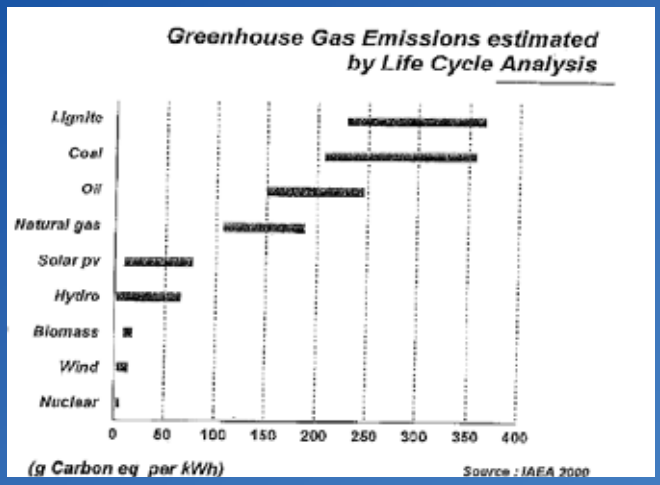
but also for a correct analysis:

1.front-hand costs (licensing, permits, logistics: important for nuclear and large hydro and in part for coal plants)
2.back-hand costs (decommissioning-final waste disposal, important for nuclear)
3.additional costs imposed to the system (important for "volatile supply" from some renewables)
4.emission costs

Range of cost per kW installed (new plants with present technologies)

	€/kW
Coal PC	800-1300
Natural gas CCP	400-600
Hydro	600-2000
Wind	900-1600
Solar Photovoltaic	3000-7000
Nuclear	1000-2000

Greenhouse gas emission
estimated by life-cycle analysis

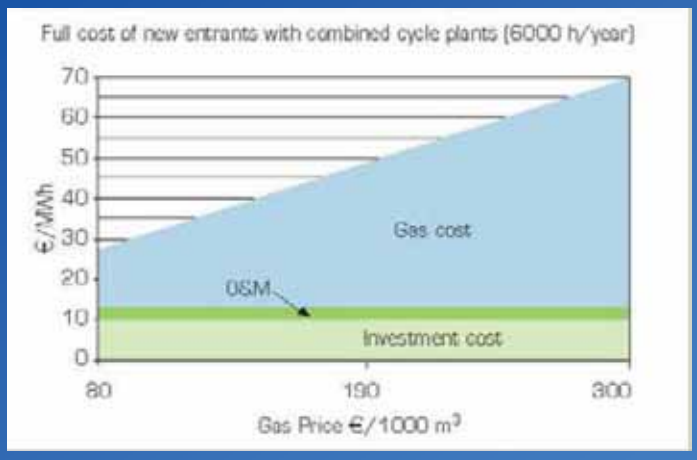


1 g carbon eq. ~ 3.7 grams of carbon dioxide

Carbon capture and storage - CCS

- Pre-combustion and post combustion technologies with target removal of ~85% of CO_2 are expected for commercialization around 2025
- CCS increases capital cost of power plants by between 30 to 100%
- CCS decreases efficiency of PPS (8-13 percentage points in existing coal fired plants and possibly 5 percentage point in future designs)
- CCS implies transportation and storage costs: at the end, the costs of the CO_2 removal is estimated at present from US$ 50 to US$ 100/t CO_2 with an effect on production cost of kWh between 30 and 100%.

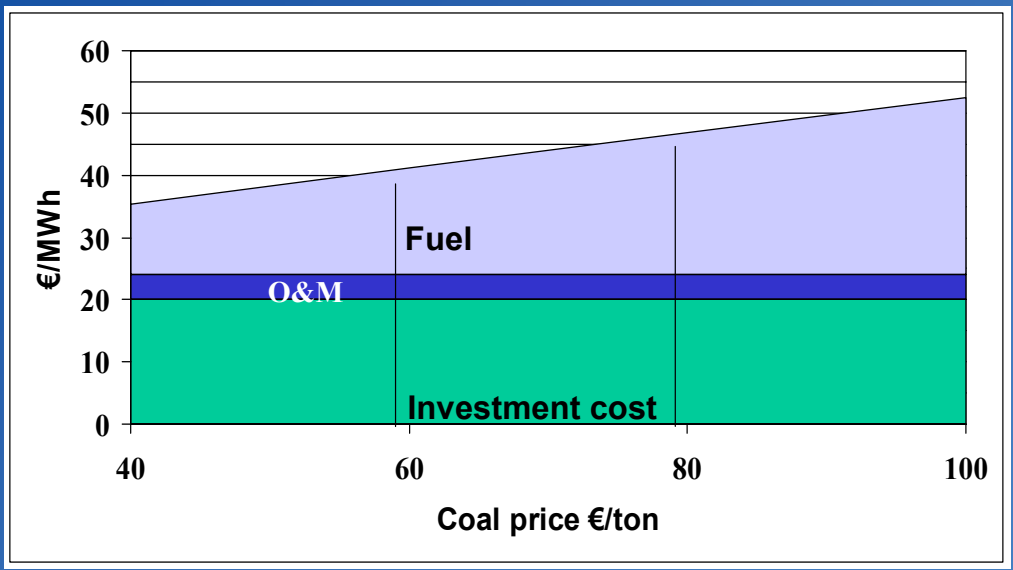
Full cost of electricity generated with CCGTP's versus gas price



Efficiency 57%
with carbon dioxide at 20 €/t CO_2, penalty of 6 - 8 €/MWh
today 300 €/1000 m^3 = 9.2 €/MBTU = 11.7 $/MBTU

Full cost of electricity generated with coal plants versus coal price

Full cost with hard coal plant (7,200 h/year, efficiency 44%)



with carbon dioxide at 20 €/t, penalty of 15 - 20 €/MWh

Some Comments on Nuclear

- Nuclear power is again becoming the subject of analyses and discussions. The possible recourse to nuclear power basically depends on:
  - environmental problems
  - its economic feasibility compared to other energy sources
  - public acceptance
- The possible security of supply of some primary energy resources and their price volatility is another factor in favour of better analyses on the nuclear option.
- The life extension/upgrading of the existing NPP's with their very cheap energy cost (~20 €/MWh) and zero CO2 emission is a must and many countries are considering that; a retirement according to initial scheduling/subsequent laws would be a great problem for many countries.

For possible new plants, the technology exists now and it is called generation 3"; large reactors (1000 MW and above, which are the cheapest one) are offered by the world main suppliers and are not causing "unit size" problems in the "strong" EU and North American systems.

The final cost of MWh produced by NPP's depends largely on the discount rate/internal rate of return considered, on the number of units per site and series effect (and this is very large in the nuclear sector) and on possible "local institutional frame" for site allocation and "final waste disposal".
Investment cost could vary from 1200 €/kW (large series effect) to around 2000 €/kW (first of a kind).

The preliminary conclusions of a WEC WG I am chairing, provides the following data:
• O&M costs are in the range 6 - 9 €/MWh (excluding special case local taxes)
• Fuel prior to electricity production is evaluated for the next years at 3.5 - 4.5 €/MWh for Light Water Reactors
• Fuel Cycle back end (Temporary waste management + reprocessing+ final disposal) is considered by new investors 1 - 4 €/MWh
• For decommissioning, they have deferred costs that do not contribute substantially to the total kWh cost, even if the actual values may be high (e.g. 250-1000 $/kW);the range of cost is 0.5 - 1 € / MWh

Total production cost

In conclusion, the total production cost could range (excluding special case local taxes):

- for a single unit order:
  from 25-35 euros/MWh with Finland approach
  to 50-60 euros/MWh for higher IRR

- for a multiple unit order, as considered by some large utilities, the value is 35 to 45 euros/MWh

Construction time length

Apart from the time for licensing, site definition/preparation and final authorizations:

From the first concrete poured to connection to the grid (excluding FOAK) total construction time is in the range of 3.5 to 5 years.

In any case with no institutional/governmental intervention on:

site allocation
risk insurance for major accidents
final waste disposal

it is practically impossible in liberalized market to borrow money ("NPP's are very likely non bankable projects").

Some comments on emissions

• Kyoto protocol is not ratified by US and not applied to countries as China and India. Not clear Kyoto 2.
• Some countries of EU are complaining the inefficiency and social costs of CO_2 emission penalizations/allowances.
• CO_2 ET (emission trading) market has revealed to be schizophrenic in Europe (up to 30 €/t with collapse to 12). Not yet clear the penetration rate of CDM (clean development mechanism) and JI (joint implementation) schemes. Possible speculations distorting the market.
• Green certificates (now 100 €/MWh in Italy)/white certificates/different subsidies to renewables, have not got a rational/common application and risk to distort the market.

Conclusions on electricity production expected for 2030

- Considering the great development of coal plants in China and India (in China in 2005 entered into service 70 GW of new plants and more than 85% of them are coal ones!)
- Considering that the most of investments in liberalized markets (low capital cost) is in CCGTP's (great gas increase in electricity production)
- Considering that the developments of wind in particular and of PV are impressive in terms of installed capacity but, by far, less in term of energy due to their reduced hours of utilization (2000-2500/year for wind and 1200-1500 for PV)

Considering large hydro are having strong impact on environment and investors do not like "elephant investments" (expected share reduction from 16% to 9%).
Nuclear is appealing for kWh cost and CO_2 emissions, but considering the long time from initial "thinking of a plant" to site definition and permits and to final commissioning of new nuclear plants, it will loose share from 16 to 8%.
Considering the long time of penetration of new technologies (distributed generation and micro-cogeneration, CCS, eventually H_2).
Even considering the strong reduction of oil share in electricity generation (from 9 to 4%) the fossil fuels (mainly coal and gas) will contribute with around 85% to the global electricity production in 2030.

Now let us talk about transmission.

Some comments on Transmission

- Very few electricity is traded between countries (less than10% in EU) and regions and therefore there are not real large electrical markets due to lack of transmission capacity and there are a lot of "local vulnerabilities" on energy supply which could be avoided with a strong network.
- To increase interconnection capacities, "private interconnectors" should be implemented, availing exemption of third part access (TPA) … but the TSO's are perceiving these private investments more as a competition to their "local power" than an aid to an opening of the market and to an increased trading. The concept of "natural monopolies" (what is the meaning?) should be revised.
- In a liberalized market transmission is much more important than in a centralized market where a central planning/operation of generation and transmission was /is done. Real large markets will exist only if a large transmission/interconnection capacity exists giving at each instant the possibility to convey to the loads the energy coming from the cheapest plants.
- Stronger interconnections will reduce also local reserve capacity margins.

Transmission accounts for a small portion of global cost of electricity to final clients; technologies (cables, HVDC, FACTS) are available to overcome the critical problems due to local oppositions and the technical problems arising form the operation of very large/extended alternating current (AC) systems. Investments in transmission are the best ones for security of supply of energy and for a real competitive and cheap market.

With reference to the overcome of the unpredictable electricity supply from wind generators and on the other hand to increase interconnection capacity between countries, the "European offshore supergrid proposal" is bringing together the latest technologies of wind generation and electricity transmission.

10,000 MW of wind generators interconnected, are making more reliable and predictable the energy supply and providing off-shore supergrid interconnections between regional networks (UK, Germany and Netherlands in first phase with possible future expansion to France, Spain and Mediterranean sea). It is a clear example of technologies and energy sources.

Conclusions

- No shortage of global energy resources: no limits to human ingenuity
  R/P ratio for fossil fuels:
  - Oil 40 years
  - Natural Gas 60 years
  - Coal 200 years
- Uneven distribution of strategic resources around the world
- Consumption areas do not all coincide with production areas
- Environmental issues/rules will play a strategic role in sustainable development
- Growing short-term focus of liberalized energy markets
- Substantial increase of non-hydro renewables, but total share only some 10% in 2030 (with wind and bioenergy very likely the leading players) - Fossil fuels will still contribute for around 85% of the global electricity production (mainly centralized)

Thank you for your attention.

Environmental aspects, security of supply in a world always more eager of energy, the present and possible future high prices of fossil fuels (especially oil and gas) the technology developments and the long times involved in the energy business are pushing all the energy stakeholders to consider open all the possible options. In this view, nuclear is coming back and a “nuclear renaissance” is foreseen by many experts.

Key question is:
How can be compatible in a liberalized market an energy policy which takes care of security of supply, environment and competitiveness without imposing “special costs” to the community (incentives, stranded costs, etc…)?

Deliverability of energy resources more than availability is the problem. Information and communication for public acceptance/reduction of planning time of energy projects and for a real spread of energy efficiency are a must.