# Energia, clima e sostenibilità: risorse, popolazioni e sviluppo

## Riserve di petrolio, di carbone, di minerali e loro evoluzione - 1

SSST

Torino, 5 Novembre 2010

Sala Principi D'Acaja - Università di Torino

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# Outline

**1 Introduction (1 hour):**

Course Overview

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**2 The economics of energy (2 hours)**

- Economic theory of the exploitation of exhaustible resources,
- Hotelling's rule and its limits
- Hartwick's rule, physical capital, natural resources and sustainable growth
- Resource Curse and Dutch Disease Economic
- Theory of renewable resources. The tragedy of the commons: individual efficiency and collective inefficiency

**3 Focus on Energy Sources: Prospects and Policy (3 hours)**

- Perspectives and specific policies for
- Coal (with and without carbon sequestration)
- Oil
- Gas
- Renewables
- Energy efficiency

# Introduction: energy and security- worrying about resource scarcity

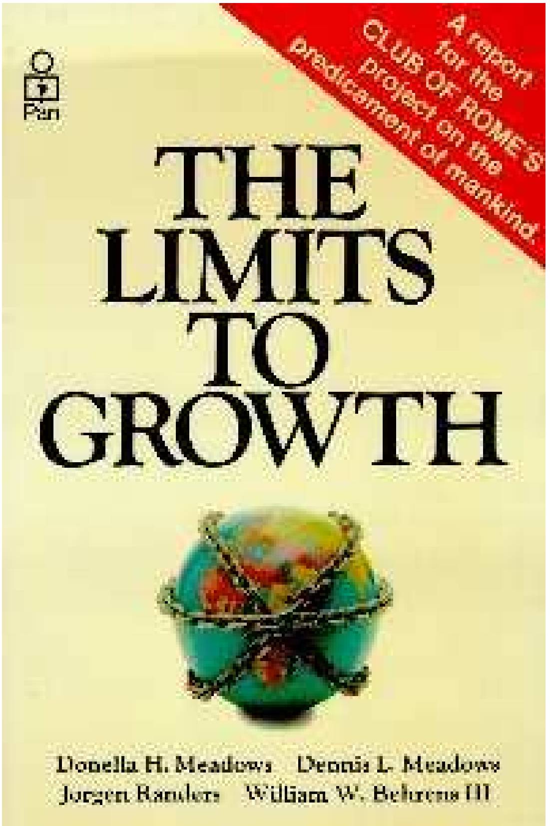
"The power of population is indefinitely greater than the power in the earth to produce subsistence for man."

"Population, when unchecked, increases in a geometrical ratio. Subsistence increases only in an arithmetical ratio".

"The cheapness of labour, the plenty of labourers, and the necessity of an increased industry amongst them, encourage cultivators to employ more labour upon their land, to turn up fresh soil."

THOMAS ROBERT MALTHUS
(1766-1834)

# Introduction: energy security - worrying about resource scarcity

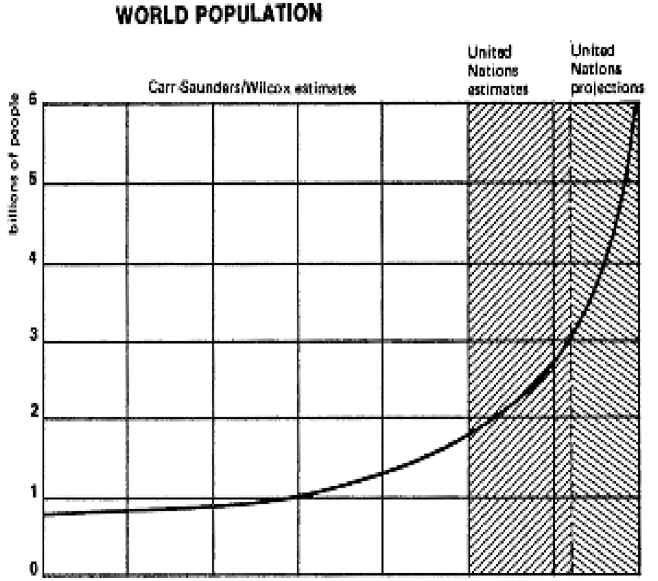



THE CLUB OF ROME

In the 1970's oil price shocks led to sharp price increases for many commodities. At that time many became alarmed at the rate of utilization of natural resources by mankind. It seemed that in just a few years real scarcity would become a major global problem.

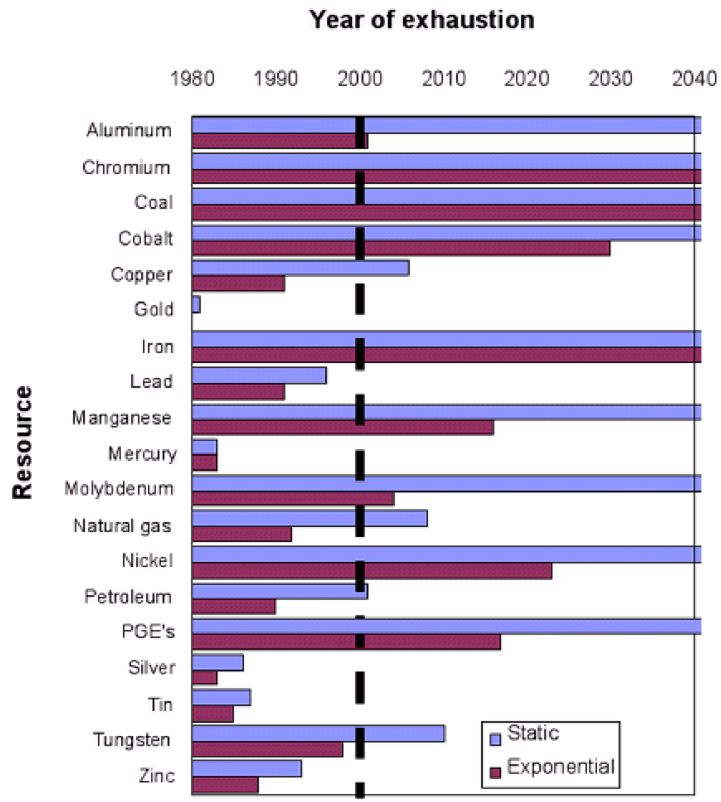
A clear reason for this alarm was the concept that certain natural resources are inherently limited in nature, and that current rates of use, or even the likely future rates of use would surely use them all up in the foreseeable future. The voice of this movement was the "Club of Rome", so named because they felt that western society, like ancient Rome, was doomed.

# Introduction: energy security - worrying about resource scarcity




*World population since 1650 has been growing exponentially at an increasing rate. Estimated population in 1970 is already slightly higher than the projection illustrated here (which was made in 1958). The present world population growth rate is about 2.1 percent per year, corresponding to a doubling time of 33 years.*

SOURCE: Donald J. Bogue, *Principles of Demography* (New York: John Wiley and Sons, 1969).



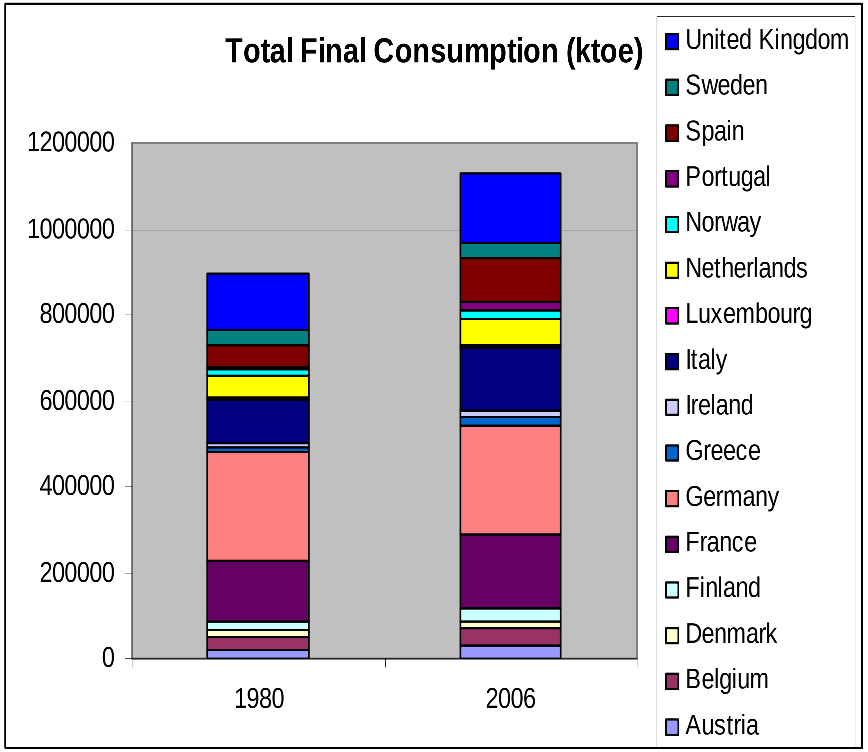

**Population growth and resource depletion according to the predictions of the Club of Rome**

# Introduction: energy and security - is there enough energy?

- **"By 2015, growth in the production of easily accessible** oil **and** gas **will not match the projected rate of demand growth. However, unconventional shale gas may solve part of the problem.**
- **While abundant** coal **exists in many parts of the world, transportation difficulties and environmental degradation ultimately pose limits to its growth.**
- **Meanwhile,** alternative energy sources **such as biofuels may become a much more significant part of the energy mix — but there is no "silver bullet" that will completely resolve supply-demand tensions."** **Source:** Shell energy scenarios to 2050 **(2008)**
- **Uranium is also abundant. The issues posed by nuclear energy are related to the risk posed: nuclear accidents, nuclear proliferation, long run waste disposal.**

# Introduction: energy and security - Energy consumption in Europe

- From 1980 to 2006, energy consumption has increased for the EU as a whole;
- The consumption share of each country has remained rather stable;
- The highest portion of energy consumption is ascribable to Germany, followed by France, United Kingdom and Italy;
- France, Italy and Spain registered the highest increase in energy consumption.



## Introduction: energy and security- Energy consumption in Europe

Energy Consumption by Fuel.

Energy mix mainly composed by oil, gas and electricity;

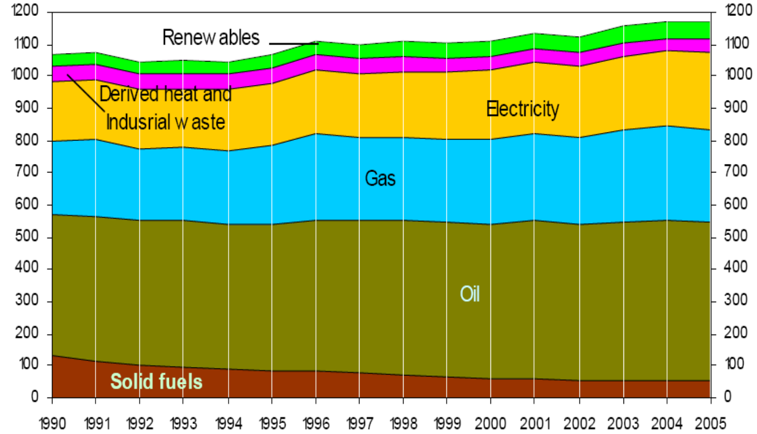
Solid fuels, renewables and industrial waste: limited share of total consumption.

Energy Consumption by Sector.

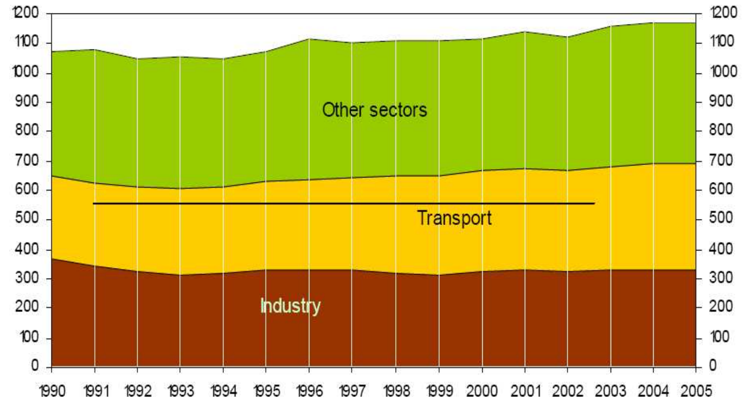
Largest share of total final energy consumption: households and service sectors (“other sectors”).

Final Energy Consumption EU27, Mtoe

a) by Fuel.

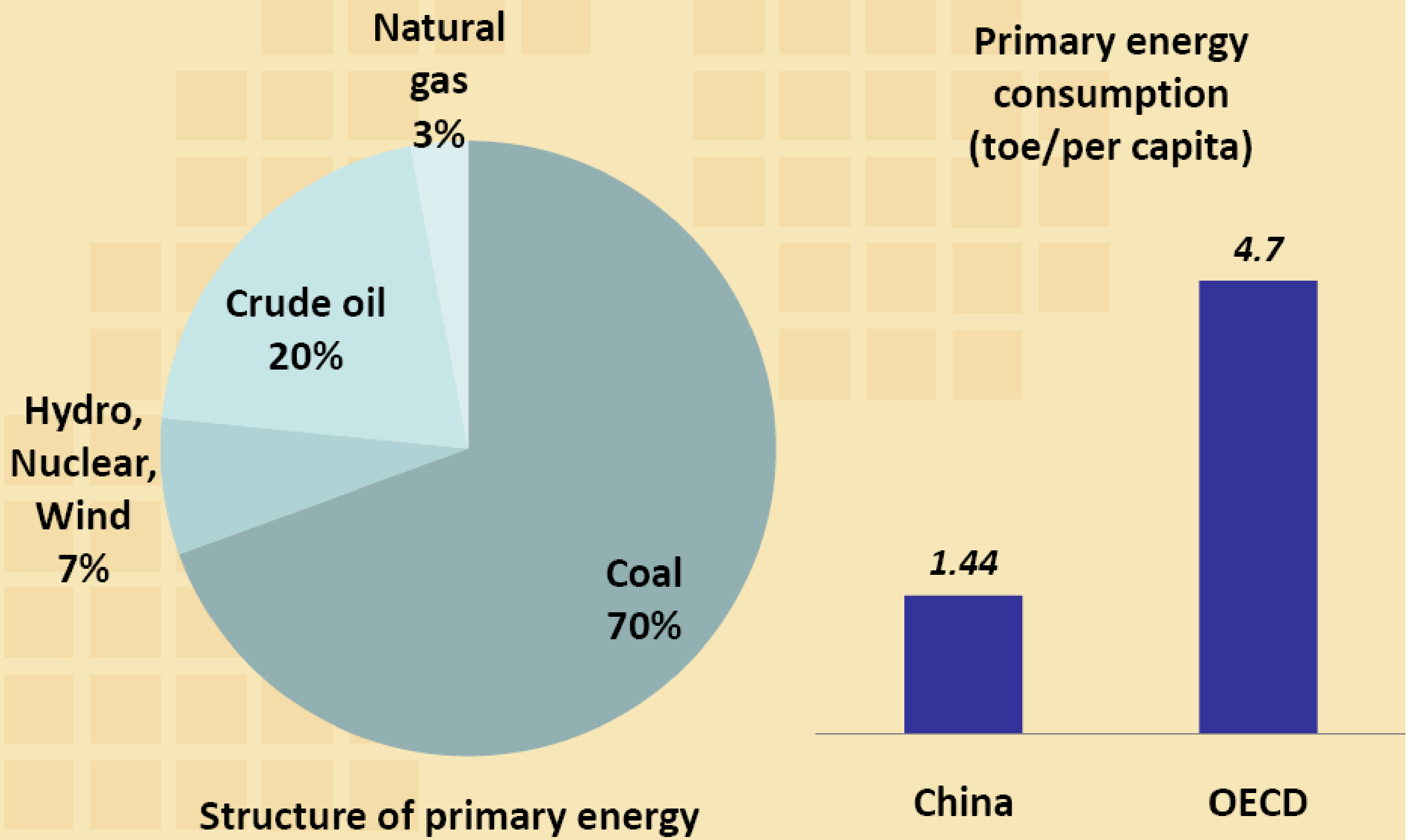



b) by Sector.



# Energy Consumption in China

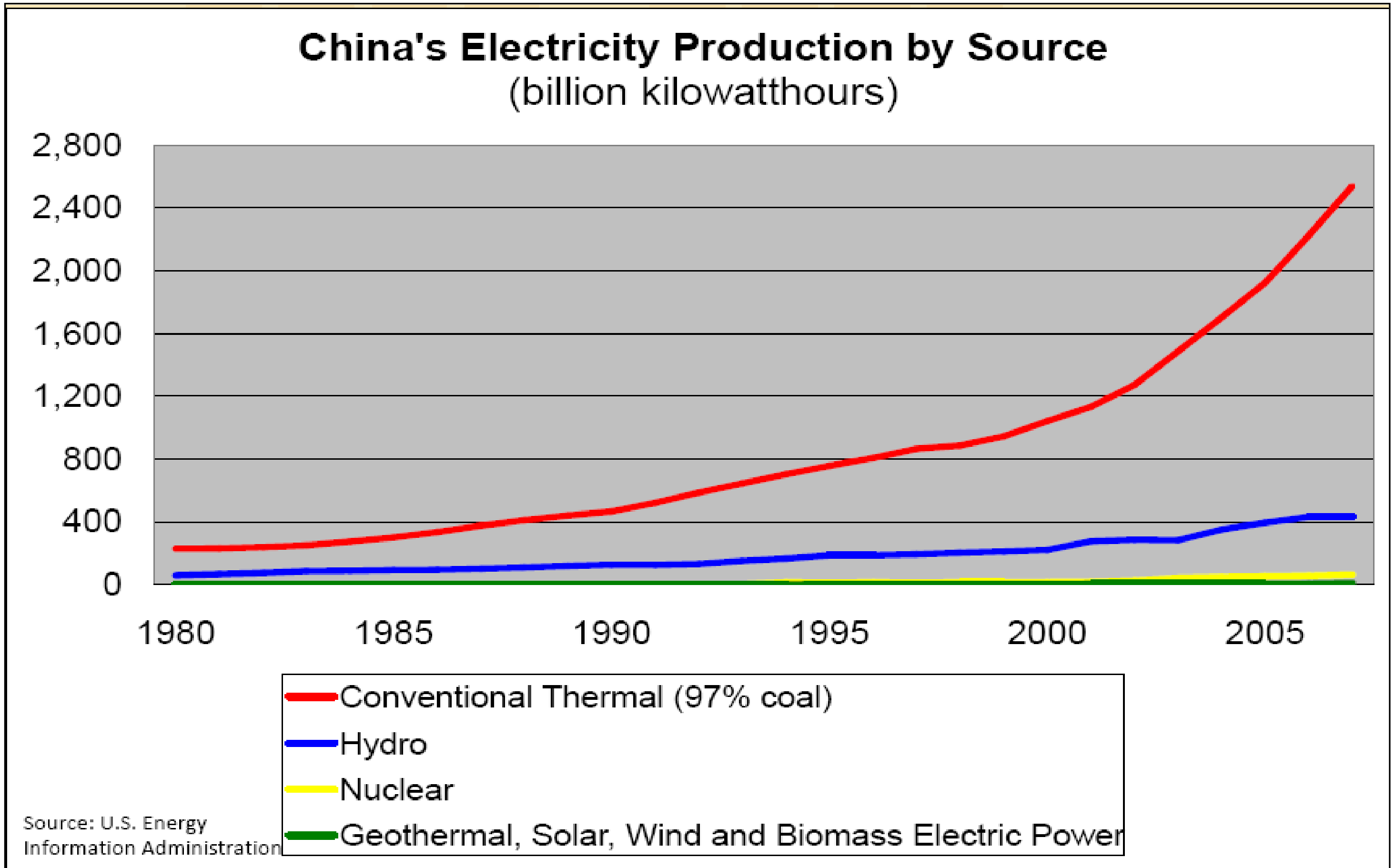
## China's energy system – the fundamentals




Structure of primary energy consumption

Source:Clingendael (2009)

## Introduction: energy and security- energy consumption in China

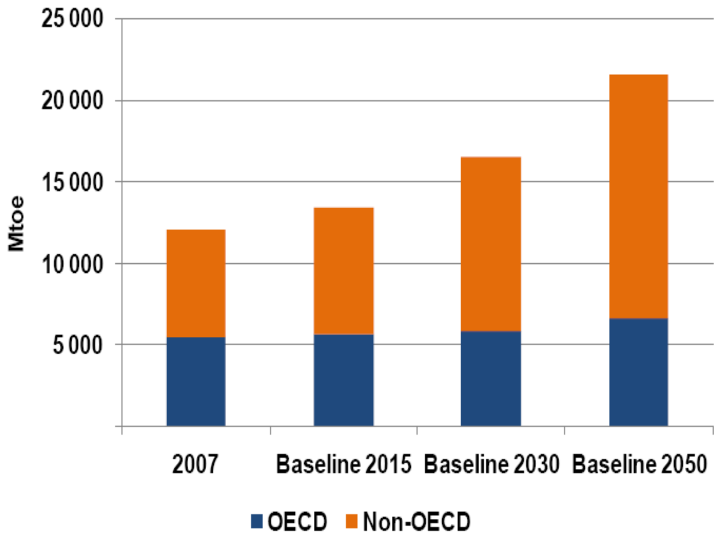


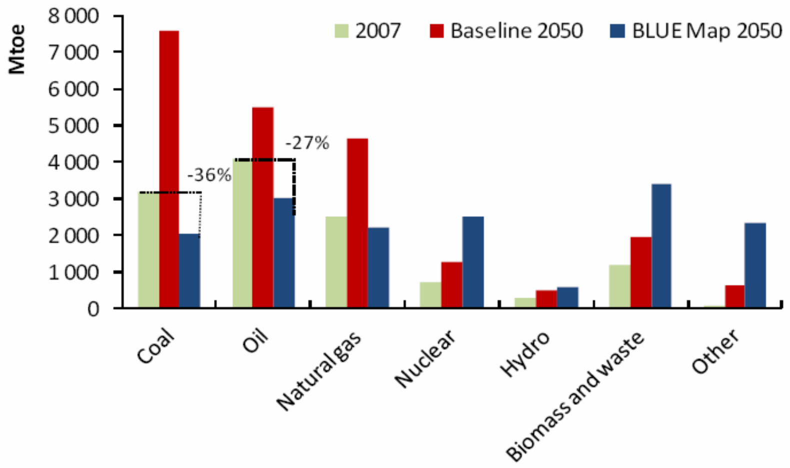





Source:Clingendael (2009)

# Introduction: energy and security- IEA’s primary energy demand projections








Source: International energy Agency, Energy technology perspectives, 2010

# Introduction: climate and energy security - twin problems

Between now and 2050, humanity have to face a twin problem:

- The growing scarcity for oil and gas (not for coal !)
- The accumulation of GHGs in the atmosphere

These « twin problems » cannot be considered independently as:

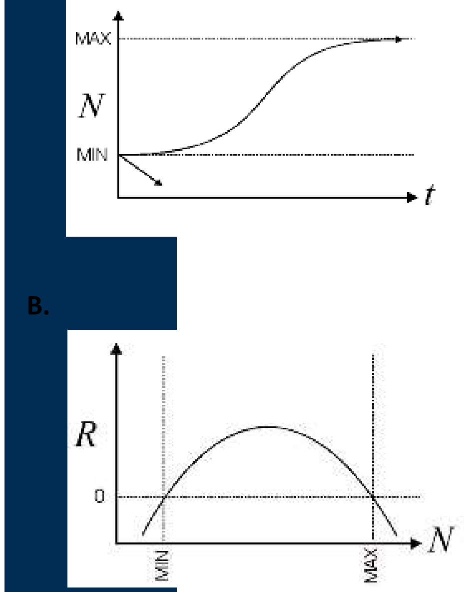
- Hydrocarbon scarcity paves the way to coal, and thus to increasing carbon emissions
- Conversely, climate policies open the path to low carbon societies, and to different ways to deal with energy needs

« Smart energy policies » thus have to deal with the two sides of the problem.

# Introduction: energy and climate - some definitions

- Externalities
- Renewable resources
- Exhaustible resources
- Sustainable growth

# Definitions : Renewable natural resources




Stock and harvest rate curves
for renewable resources.

**Renewable natural resources** are those that can regenerate themselves within human timeframes.

Consider the evolution of population (N) of a renewable resource with time. Above a certain minimum population, the population rises exponentially until the carrying capacity of the environment is reached at NMAX. Below the minimum population NMIN, the individuals cannot find each other to mate, or the population is otherwise spread too thin to survive. Above NMAX, the environment becomes overcrowded and population growth is negative. This implies a certain maximum sustainable catch as the population growth rate (R) has a maximum between NMAX and NMIN.

Negative growth rates for underpopulation imply that a species can be doomed long before the last one is dead. This is thought to be the case or nearly the case with a great many species today, including commercial ones (e.g. tuna).

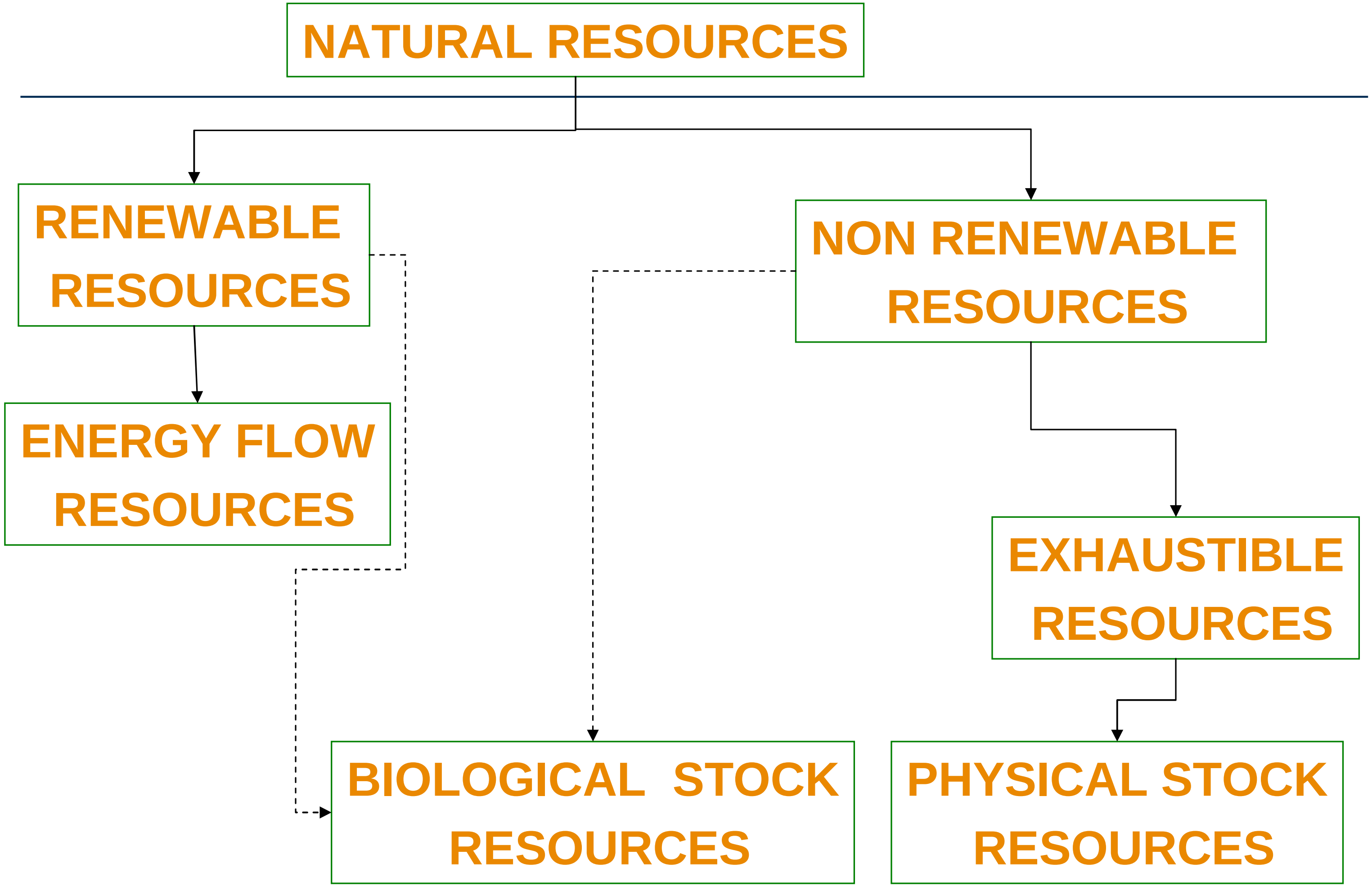
## Definitions : Non- Renewable and Exhaustible natural resources

**Exhaustible natural resources** are resources that even if left alone do not reproduce themselves – at least over any time scale relevant to humankind.

Of course, they are non-renewable. Though the geologic processes that created most types of nonrenewable resources in the past are still operating today, the time frames are too long compared with their use to be considered renewable.

A "renewable" resource may become non renewable, if the species approaches extinction. Non-biological renewable resources, including solar and hydro power do not have these restrictions.

Surprisingly, the economics of exhaustible resources extraction dictates that they hardly ever become exhausted – contrary to sadly many renewable ones.


NATURAL RESOURCES
RENEWABLE RESOURCES
NON RENEWABLE RESOURCES
ENERGY FLOW RESOURCES
EXHAUSTIBLE RESOURCES
BIOLOGICAL STOCK RESOURCES
PHYSICAL STOCK RESOURCES

# Definitions: Externalities

"An externality is present whenever the wellbeing of a consumer  or the production possibilities of a firm are directly affected by the actions of another agent in the economy".

*Mas-Colell et al. 1995*

Negative externalities can be viewed as overexploitation by individuals of some common resource (air, water, climate, biodiversity etc.)

# Definitions: sustainable development

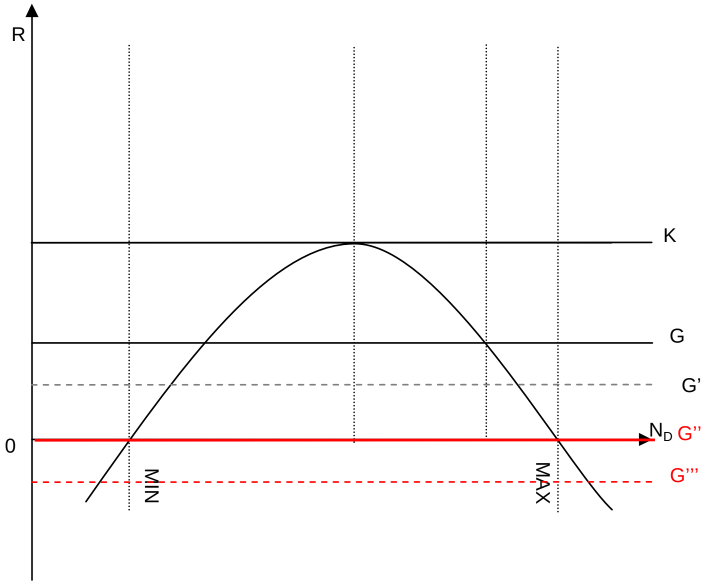
- The Bruntland Commission (1987) defined sustainable developments as those that "**meet present needs without compromising the ability of future generations to meet their needs**"(WECD, 1987).

- In strictly economic terms sustainable growth consists of an increasing path in real incomes or output that could be sustained for long periods of time. However this restricted definition is questionable also on economics ground – the ”green GDP” approach broadens the economic approach to growth by allowing for natural capital and ecosystem services.

# The economics of energy sources

- The tragedy of commons
- Optimal extraction of exhaustible resources
  - The Hotelling rule
- Sustainable growth and exhaustible resources
  - The Hartwick rule
  - Resource Curse and Dutch Disease

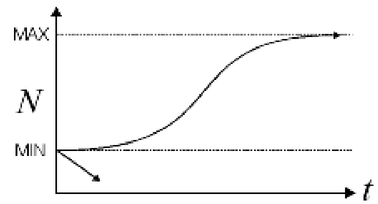
# How renewable becomes non-renewable:
# Geordie and the the Tragedy of the Commons




*Ah my Geordie will be hanged in a golden chain*
*'Tis not the chain of many*
*Stole sixteen of the king royal deer*
*And sold them in Bohenny*

*XVIII century English Ballad*

*Così lo impiccheranno con una corda d'oro*
*E' un privilegio raro*
*Rubò sei cervi dal parco del Re*
*Vendendoli per denaro.*
Fabrizio de Andrè, Geordie 1965




*The Tragedy of the Commons* (Hardin, 1968, Science)

The problem arises when property rights are not well defined.

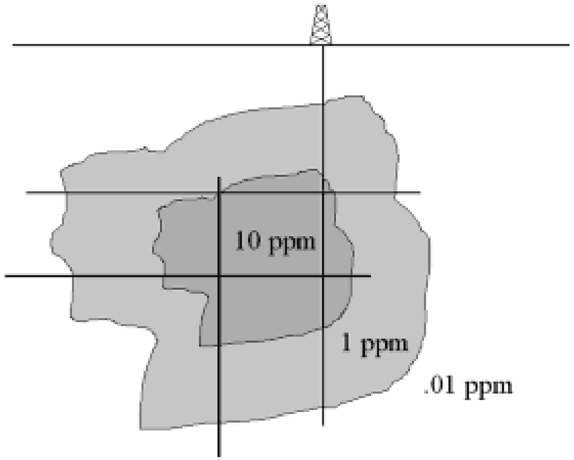
- private property then provides a mechanism to avoid externalities – he who owns (the king), cares about the property and controls its use and can exclude others (Geordie) from overusing it.
- private property is not the only available mechanism – regulations work as well (with legal system to enforce them).

# Finding exaustible resources

Estimating the amount of a natural resource is not a simple task, even for a single ore body.

The first consideration is the concentration of the material of interest, and its distribution in the rock.

Sinking exploratory shafts or diamond drilling combined with geochemical determination of the concentration (also called "**assay**") allow an estimate of the number of tons of rock in the ground at a given grade.

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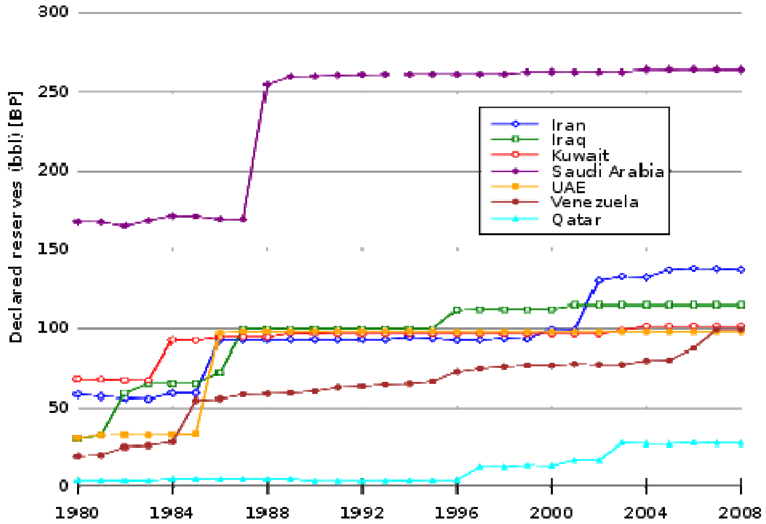
# Exhaustible Resources: defining reserves and resources

In the case of OIL there are three generally recognized categories.

1. Proven Reserves; "the estimated quantities of oil which geological and engineering data demonstrate with reasonable certainty to be recoverable in future years from known reservoirs under current economic and operating conditions." (BP)
2. EUR (Estimated Ultimately Recoverable) oil. This is oil that is infeasible to recover for reasons that are either economic or technical. This category also includes yet-to-be-found oil.
3. Non Conventional:oil from coal, oil shale, oil sands, tar sands, bitumen, heavy and extra heavy oil, deep water oil, polar oil and natural gas condensates.




| | World | OPEC |
|---|---|---|
| 2003 | 1213 | 819 |
| 2002 | 1031 | 819 |
| 2001 | 1028 | 814 |
| 2000 | 1016 | 802 |
| 1999 | 1034 | 800 |
| 1998 | 1019 | 797 |
| 1997 | 1019 | 789 |
| 1996 | 1007 | 777 |
| 1995 | 1000 | 770 |
| 1994 | 999 | 772 |

There is some arbitrariness in the classification, and the access to the real data is often considered a business critical information. The strategic use of reserves information is typical of OPEC countries.

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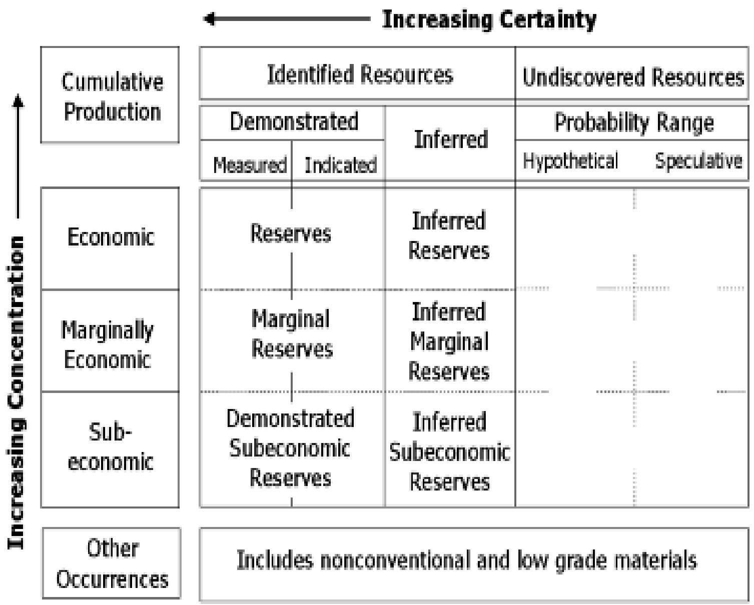
# Exhaustible Resources: defining reserves and resources

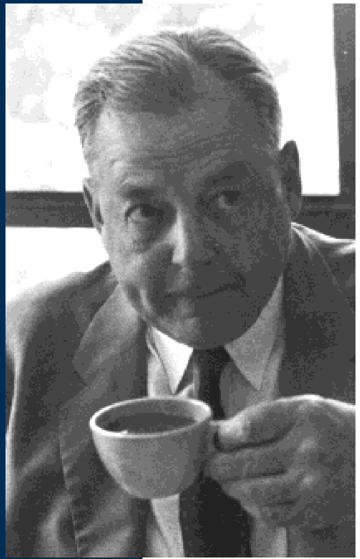
The next consideration is the technology of extraction. Only a certain amount of the ore is extractible, given the geometry of the ore body, its mineralogy and the accessibility of the surface location. These all factor into the **costs of extraction.**

The final factor is the price, which determines whether a given piece of rock below the ground is worth exploiting. Deposits are divided into economic and sub-economic depending on whether it is economically feasible to extract ore from them.




McKelvey diagram, USGS 1980

## Extraction of exhaustible resources: Hotelling's rule



Thus economic theory tells us that *coeteribus paribus*, the price of an exhaustible resource must rise. But how exactly?

Harold Hotelling (The Economics of Exhaustible Resources, JPE, 1931) proved that, *coeteribus paribus*, exaustible resource price rises at the market rate of interest.

Intuition: minerals in the ground are not so different from money in the bank.

# Extraction of exhaustible resources: Hotelling's rule

The extraction of an exhaustible resource can be seen in its simplest form as a simple profit maximization problem, for a society the same as for an individual. The society or individual face the same problem, namely that

$$\frac{dX}{dt} = -H(t)$$

where *X* is the stock of the resource and *H* is the "harvest" per unit time. The profit is (leaving costs aside for the moment)

$$\Pi = PH$$

Society maximizes its profit over all times, not just the present time. For this, the value of future profits must be *discounted* at a rate *r* that roughly equivalent to the interest rate. The maximization problem is thus :

$$Max \int_{t=0}^{\infty} \Pi\left(e^{-rt}\right)dt = \int_{t=0}^{\infty} PH\left(e^{-rt}\right)dt$$

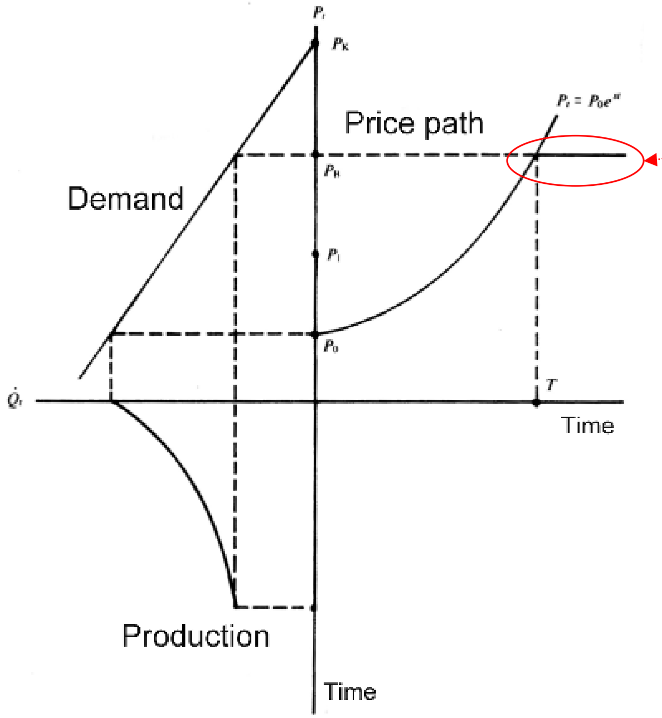
This is the fundamental problem in all of exhaustible resource economics. The almost trivial solution is that the maximum total profit is given by:

$$P_t = P_0 e^{rt} \quad or \quad \frac{dP}{dt} = r$$

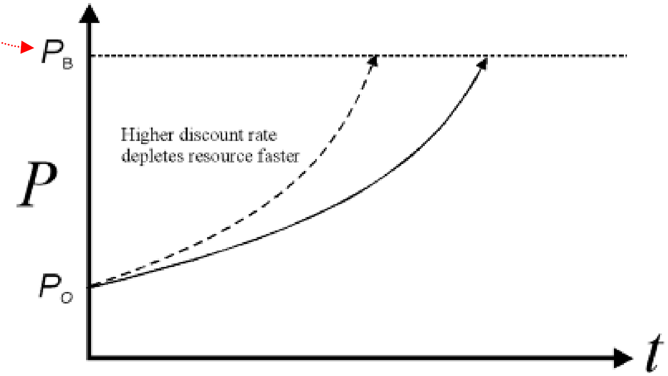
**A mineral deposit in the ground has the same significance as a bond, and is in some sense interchangeable with such a financial instrument. Proof: if not, then the price will rise either faster or slower than the rate of interest. If slower, then it is better to decrease extraction and invest in financial instruments that will by definition grow at the rate of interest. If faster, then it is better to invest in increased extraction, since the oil price is growing faster than the value of financial instruments. So, the equilibrium rate of extraction will keep the price rising at the rate of interest.**

# Extraction of exhaustible resources: Hotelling's rule

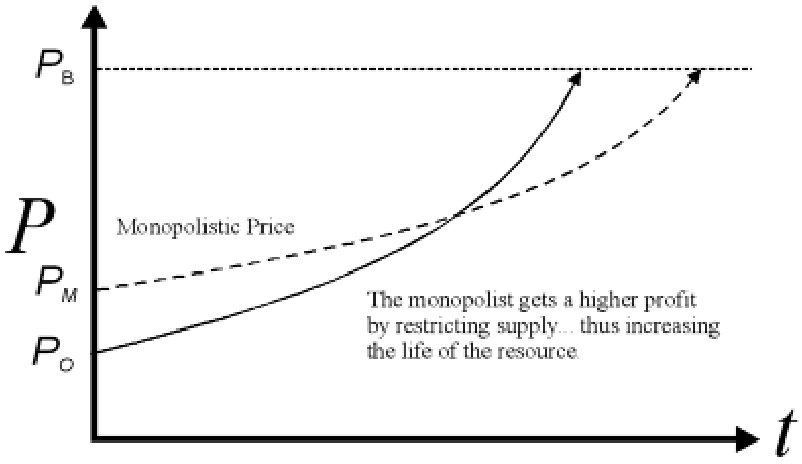
$$P_t = P_0 e^{rt} \quad or \quad \frac{dP}{dt} = r$$




backstop

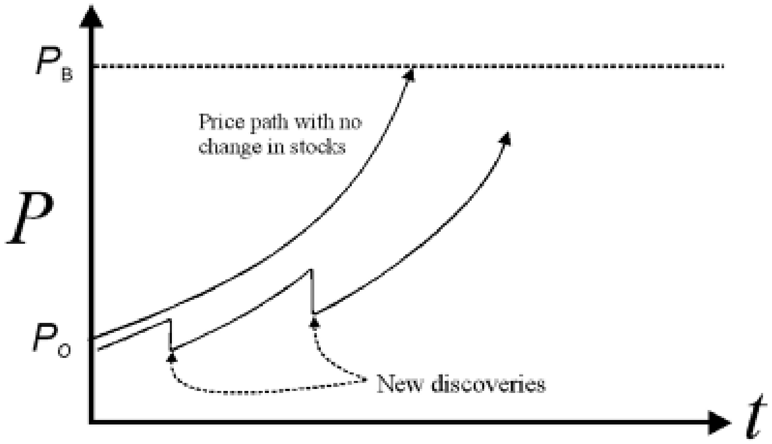



**exhaustible resources usually do not get exhausted!**



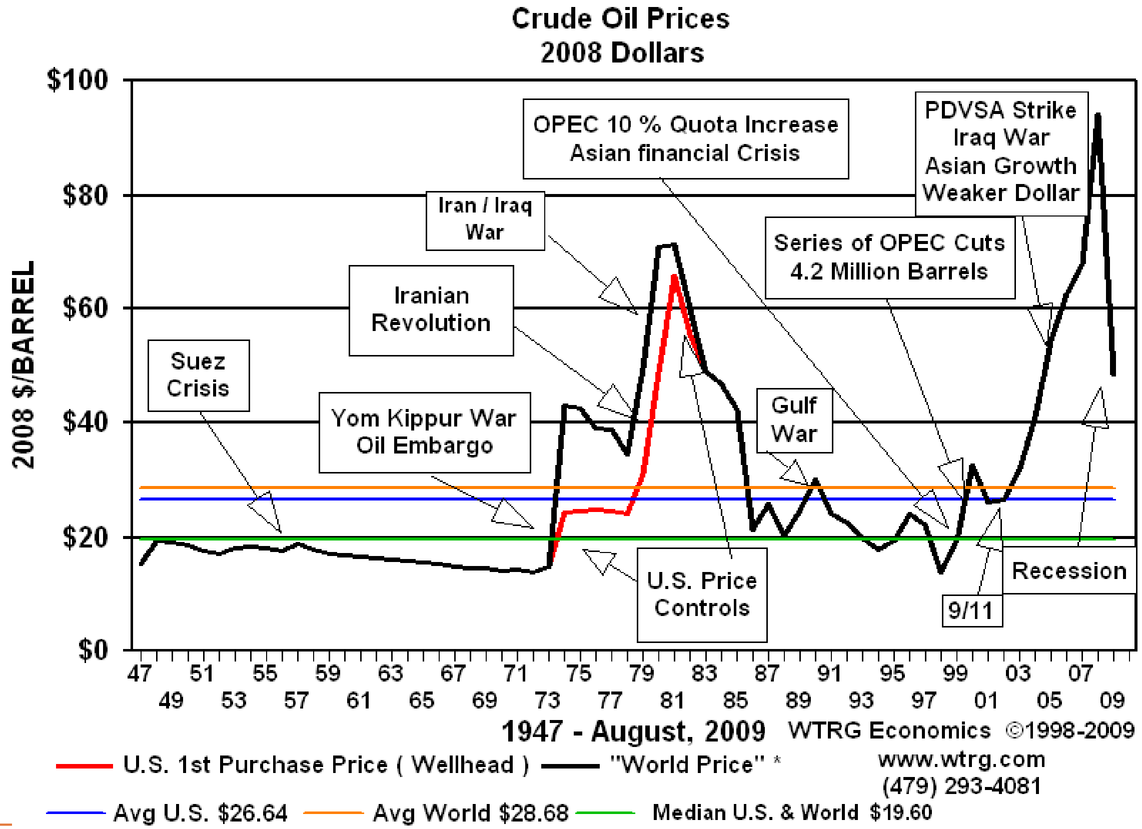

**The monopolist is the environment's friend (?)**

**What if resources are larger than expected?**



## Was Hotelling right?

Mineral resources' prices appear to be fluctuating or declining, rather than costantly soaring :




consider oil

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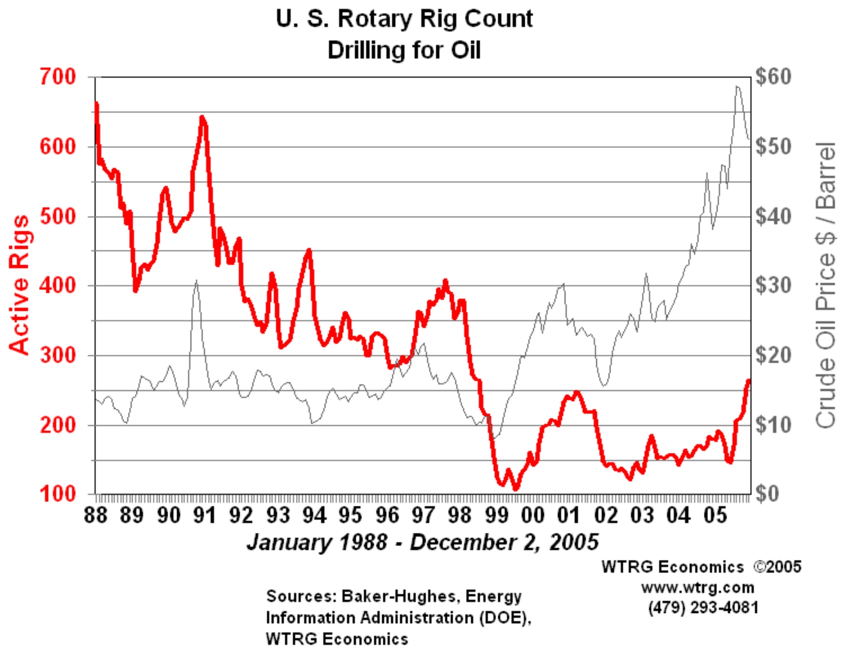
# Was Hotelling right?

Mineral resources' prices appear to be fluctuating or declining, rather than costantly soaring :


consider copper

# What Hotelling's Rule did not cover




Copper is not expensive relative to wages or prices and never has been. Throughout this time, the amount of proven reserves of copper has held nearly constant, even as production has risen tremendously.

Exploration (the identification of new proven reserves) is an expensive undertaking, and tends to occur primarily in times of rising prices - this puts a strong brake on the upward spiral in real terms.

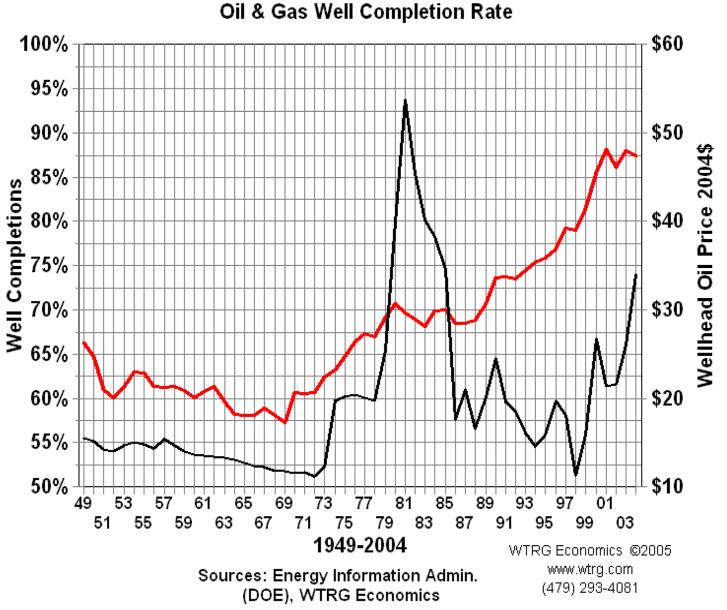
New methods of exploration and new methods of extraction have more than kept pace with demand over time, resulting in lower prices even though the producers are still turning a profit

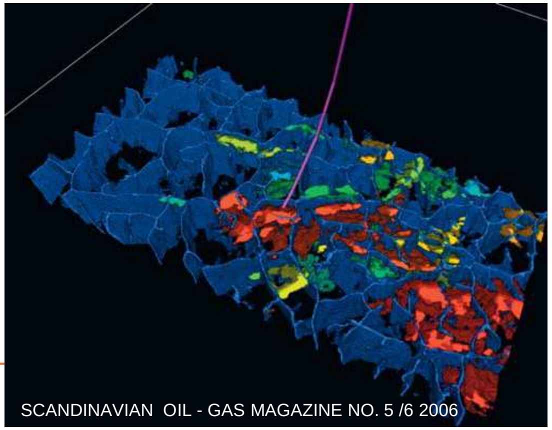
Petroleum companies have a strong incentive to explore and drill for new petroleum reserves, when petroleum prices are high:

Companies are exploring where extraction is much more expensive

- Extremely deep wells
- Extreme downhole temperatures
- Environmentally sensitive areas
- Allow extraction from the deep waters of the Gulf of Mexico or the cold Alaskan climate

# What Hotelling's Rule did not cover: technological progress




Technology has improved substantially in the mineral resource sector in the last decades. In the early days successful exploration was largely a matter of luck. Nowadays a significant fraction of oil wells drilled for exploration actually become production holes.

If the price is high, even a marginal hole may be put into production or completed if the expected production seems likely to at least cover the completion costs. This explains the rise in exploratory well completion throughout the seventies, but not the much higher rise in well completion in the nineties.

This increase is mainly due to advances on high-speed computing for the **3D imaging** of source and rocks in the subsurface.

Another technology advance is **directional drilling**, which allows a single hole to turn in any direction while drilling, even horizontal. Much more ore can be extracted, or a much larger region of an ore body using a single hole can be explored, with huge savings.

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# What Hotelling's Rule did not cover: Other issues

Hotelling's prices depend on the petroleum reserves being known and fixed, but **extracting companies do not know the location of all reserves**.

Demand for petroleum can change:

- Consumers reduce quantity demanded for petroleum products, and fossil fuels when prices increase;
- Innovation works also on the demand side: consumers can now buy more fuel efficient cars. New automotive and energy generation technologies are more fuel efficient than they were 20 years ago;
- Consumers can move closer to work.

Geopolitics: If a resource producing country cannot supply the market for political reasons, other countries can step in.

Strategic use of spare capacity.

# Resources and sustainable growth: the Hartwick's Rule

Although empirically questionable, Hotelling's rule has a fundamental role to play in terms of preserving the opportunity of future generations to live satisfactorily In then words of Sudhir and Sen (1994):

*"Preserving productive capacity intact is not, however, an obligation to leave the world as we found it in every detail. […]. But if society's broad stock of capital is to be maintained, we have to replace the non-renewable resources that are used up with something else. That has to be reproducible capital, whether physical or human"*

*[Hartwick] "showed exactly how much from the use of a depletable resource should be set aside and invested in reproducible capital so that the total return (i.e. income) could be sustained over time.*

***Hartwick's Rule says that if the entire competitive rents from an economy's use of a wasting resource are invested in reproducible capital, then it will be able perpetually to maintain a constant level of consumption****. The competitive rents, or pure return to the non-renewable resource, are given by Hotelling's (1931) classic result that the shadow value of the resource rises at a rate equal to the current marginal product of reproducible capital.*

***The accumulation of reproducible capital through investment of the Hotelling rents exactly offsets the (efficient) depletion of the exhaustible resource****. "*

**NB. 1) This is not just about oil, but about the whole resource stock!**

**2) Substitutability between natural capital, physical and human capital is far from perfect!**

# Resources and sustainable growth going wrong: the Dutch Disease

The Symptoms:

**Direct deindustrialization effect**: increasing labour demand for the resource sector and away first from lagging manufacturing sector and then from service sector.

**Spending effect:** extra revenues boost purchasing power of domestic labour and hence domestic demand for non-traded goods, for which prices will increase, and for internationally traded goods (different from resources) for which prices are set internationally and cannot change.

The **increased supply of foreign currency** would drive up the value of the domestic currency, which also implies an **appreciation in the real exchange rate** that **weakens the competitiveness** of the country's exports and, hence, causes the manufacturing export sector to shrink.

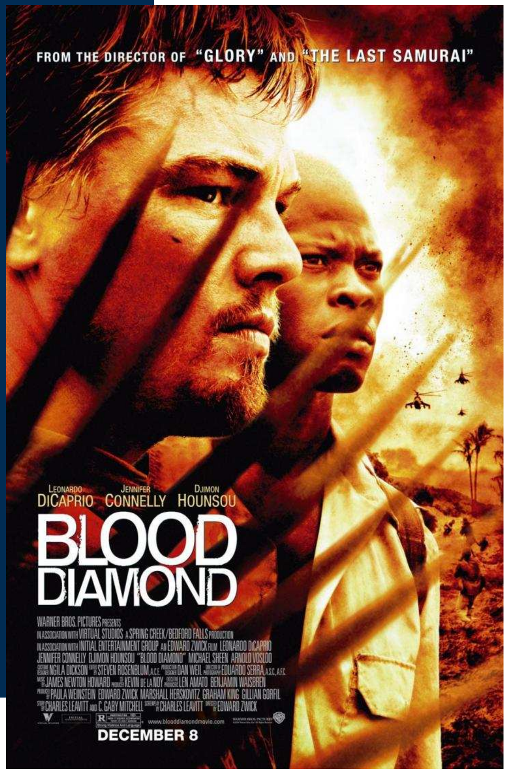
There will be increasing imports of traded goods and increasing exports of the extractive industry. But **this specialization is fragile** for an economic system once the reserves of natural resources deplete or if there's the chance of volatile prices. The countries that specialize in trade of natural resources are subject to **swings in terms of economic growth**.

**The cure:** active industrial policy promoting **diversification** of the productive sector ( mainly towards technologically advanced  production.



Source: POLINARES Project (2010), WP1

## Resources and sustainable growth going very wrong: the Resource Curse




Resource-abundance and international specialization in extractive sectors can do worse.

Natural capital intensity tends to crowd out capital, whether financial or human, thereby impeding economic growth.

Hence the definition of **resource-curse**, according to which countries that depend heavily on their natural resources tend to have less trade and foreign investment, more corruption, less equality, **less political liberty, less education, less domestic investment and less financial depth than other nations that are less well endowed with natural resources.**

With respect to Dutch Disease, the resource curse thesis involves also **poor quality of institutions and scarce human capital** (no clear causality).

Moene and Torvik (2006) identify the existence of a group of losers and a group of winners within the wider group of resource-abundant countries, build a model to explain the role of the initial level of institutions and verify that in fact an empirical positive relationship exists between **economic growth and the quality of institutions.**



**Source: POLINARES Project (2010), WP1**

**Focus on Energy Sources: Prospects and Policy**

- Introduction to energy security
- Perspectives and specific policies for
- Coal (with and without carbon sequestration)
- Oil
- Gas
- Nuclear
- Renewables
- Energy efficiency

## Is it "secure"?

IEA's define Security of Supply (SoS) as "*the availability of a regular supply of energy at an affordable price*"

The state of the art in the field of security of supply is dominated by a lack of precision and quantification.

Many disciplines have traditionally dealt with the issue of security of supply (economics, geopolitics, and engineering) so that under the label of "security of supply" many different visions and concerns need to be accommodated and a common ground established in order to arrive at a consistent, interdisciplinary framework.

Security of supply is more than the availability of enough energy.

Many indicators have been used to quantify security of supply , mainly in negative sense (in terms of of "dependency " and vulnerability").

# Dependency and Vulnerability

**Dependence** is a measure of how much the domestic economy relies on sources of energy that are not under its control. Physical measures of dependence include:

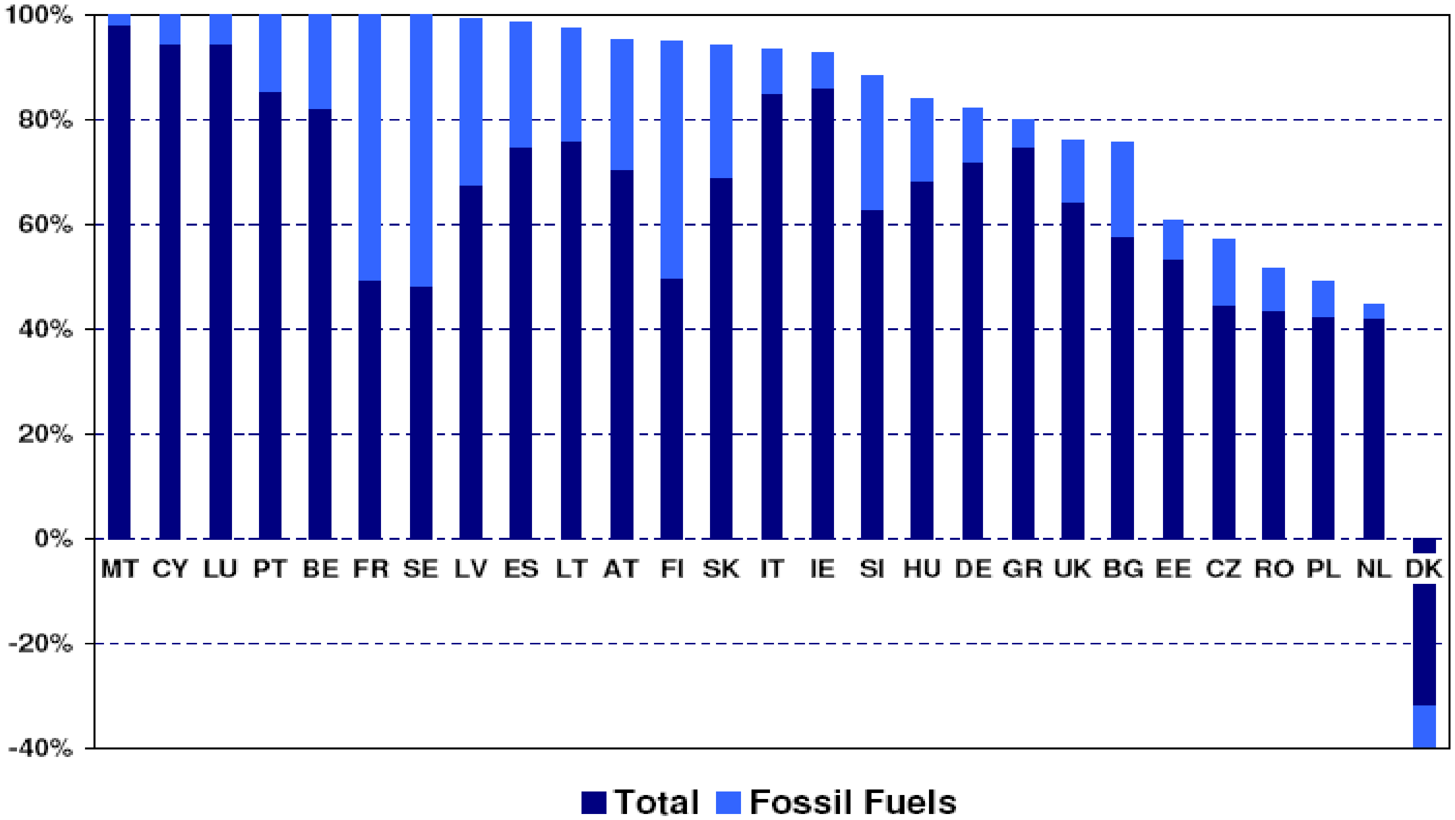
- imports of energy as a percent of total imports,
- oil imports as a percent of total oil consumption,
- gas imports as a percent of total gas consumption.

Economic measures of dependence are oil and gas consumption in physical units per $ of real GDP.

**Vulnerability** is a measure of the likelihood of domestic disruption in case some external energy source is reduced or cut off. Physical measures of vulnerability include

- the amount of imported oil used in transportation relative to total energy used in transportation,
- amounts of imported oil and gas fired electricity generation relative to total electricity generation,
- degree of supply concentration and
- the Shannon-Weiner diversity index.

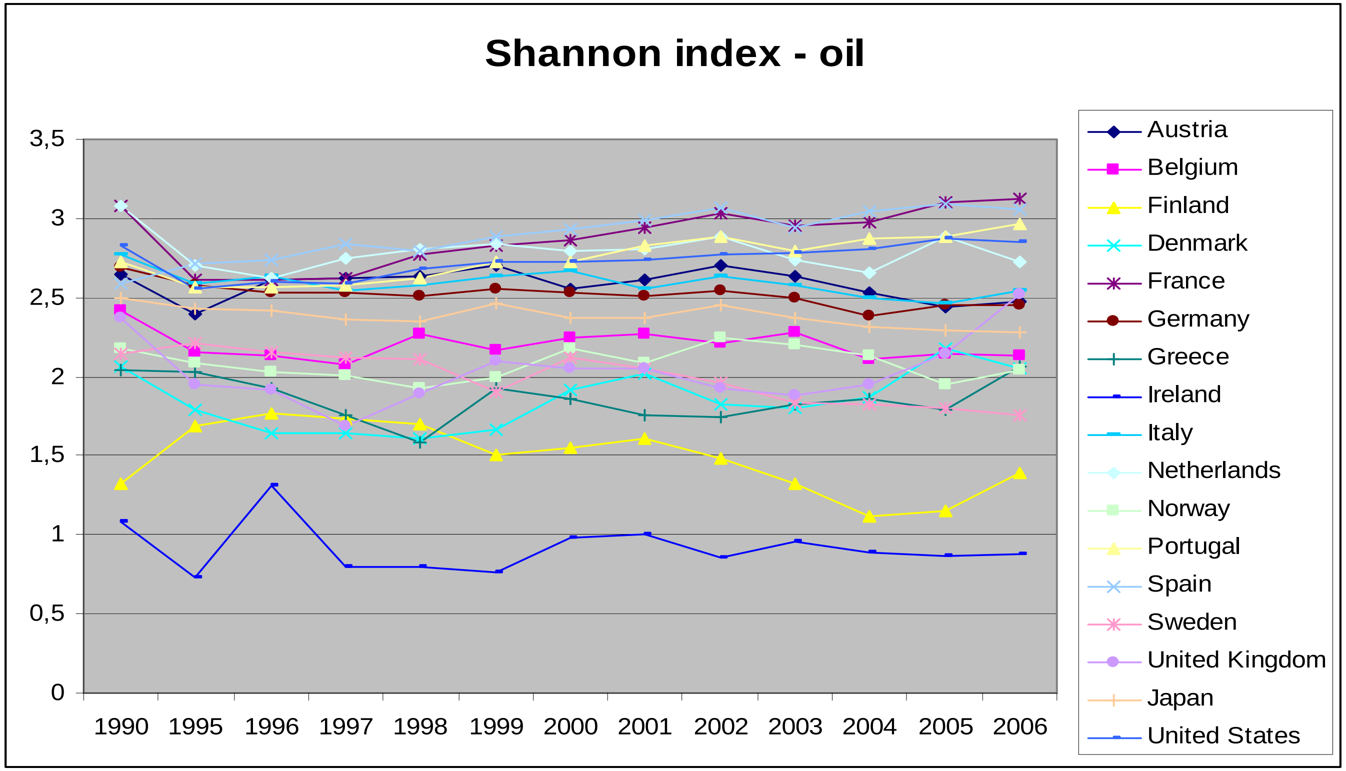
## SoS indicators: Dependency - Net Imports/Gross Inland Consumption




Source A. Pototschnig , Florence School of Regulation

## SoS indicators: Vulnerability- Shannon Weiner index

$$SW = -\sum_i x_i \ln x_i$$




The Shannon index places greater weight on smaller suppliers, the number increasing as the number of different suppliers increases. It reaches a max when all producers sell to the country under scrutiny, and they have the same size (in terms of oil sold)

source: SECURE project

# “Enough” for a given demand

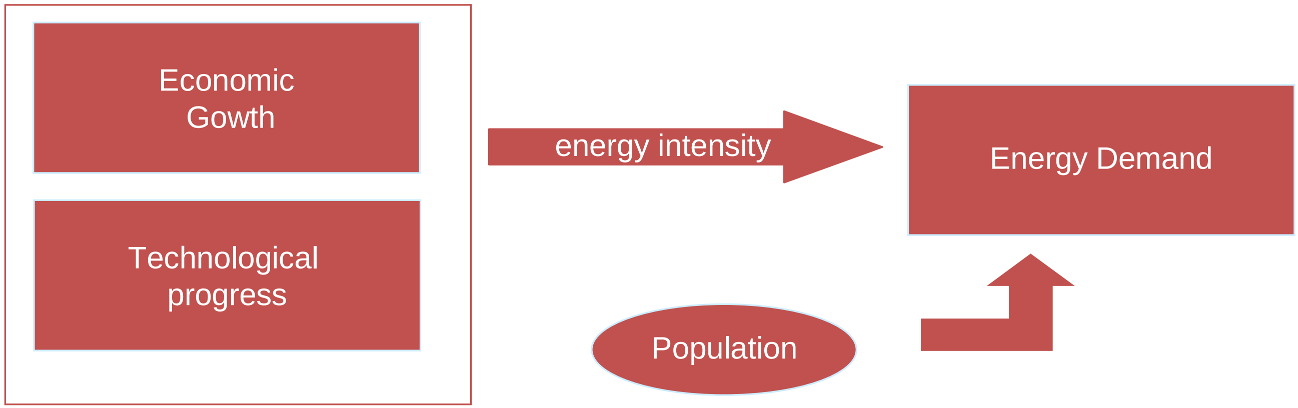
$$ED = f(Y, P, T)$$

“World population has more than doubled since 1950 and is set to increase by 40% by 2050.

History has shown that as people become richer they use more energy.

Population and GDP will grow strongly in non-OECD countries

and China and India are just starting their journey on the energy ladder.” **Source:** Shell energy scenarios to 2050 **(2008)**

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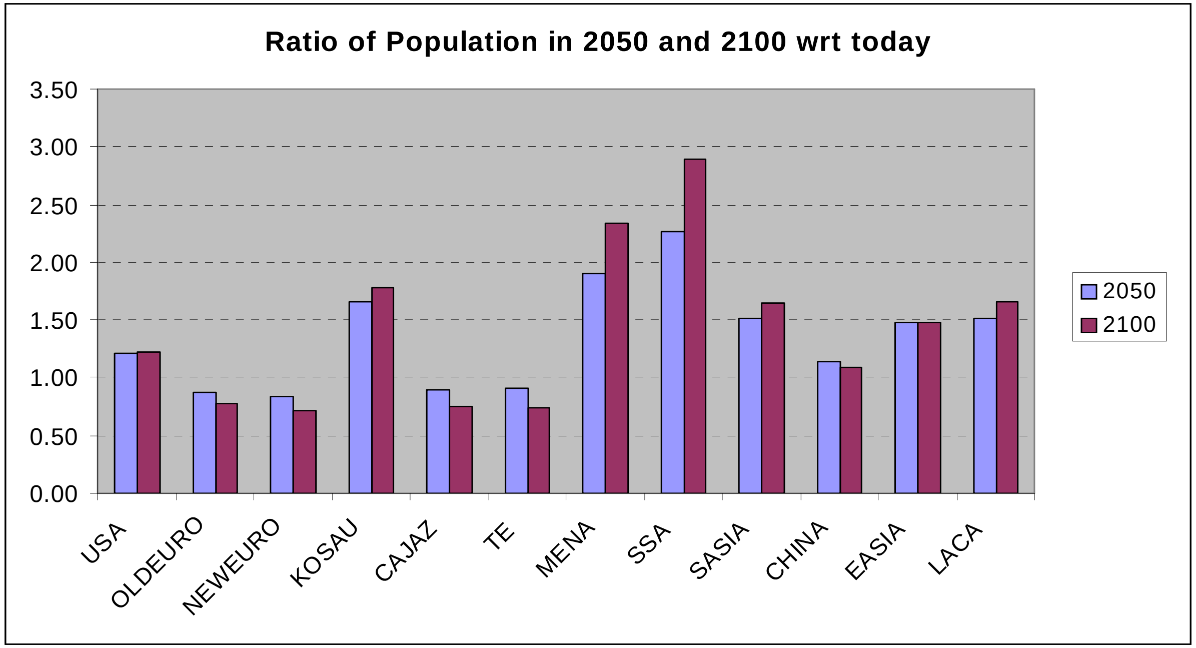
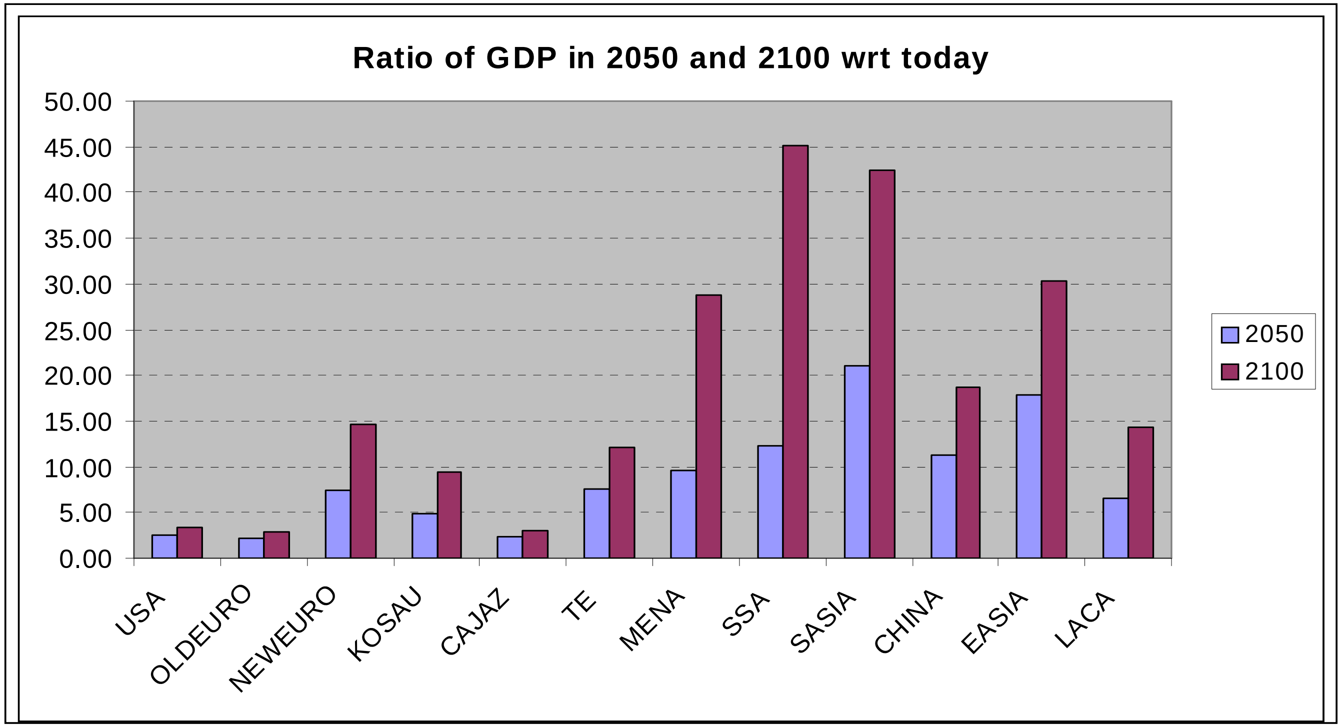
# Population




Source: WITCH (FEEM) elaborations based
on UN medium variant Word Population Prospects (http://esa.un.org/unpp/)

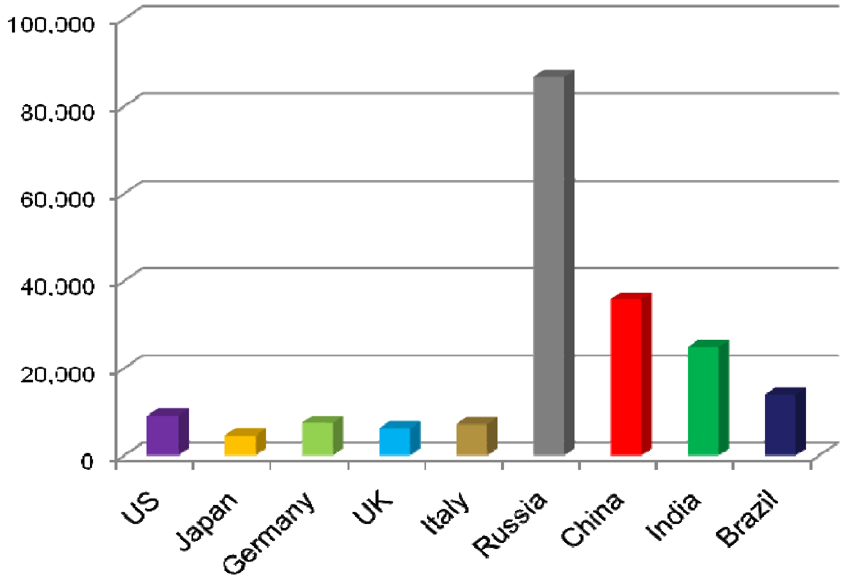
# Economic Growth



# Energy intensity: international comparisons

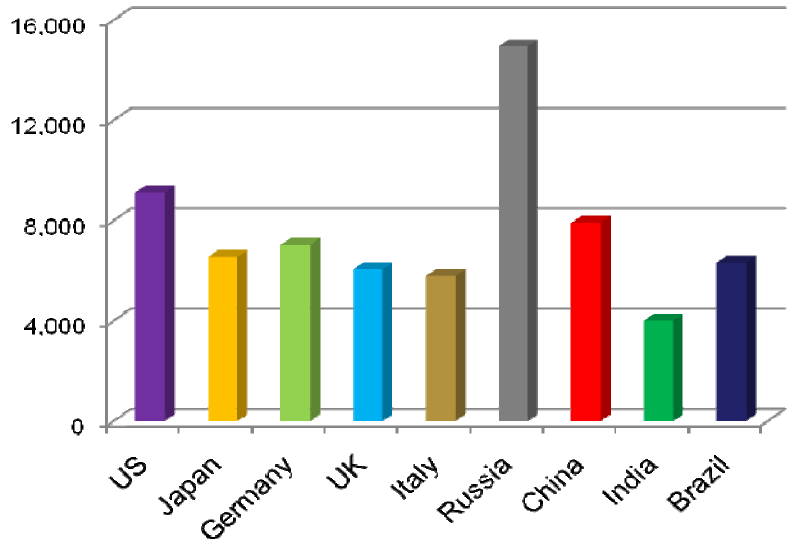
**2005 Energy Intensity of selected countries measured in MER**

unit: Btu/$ in 2000 price




**2005 Energy Intensity of selected countries measured in PPP**

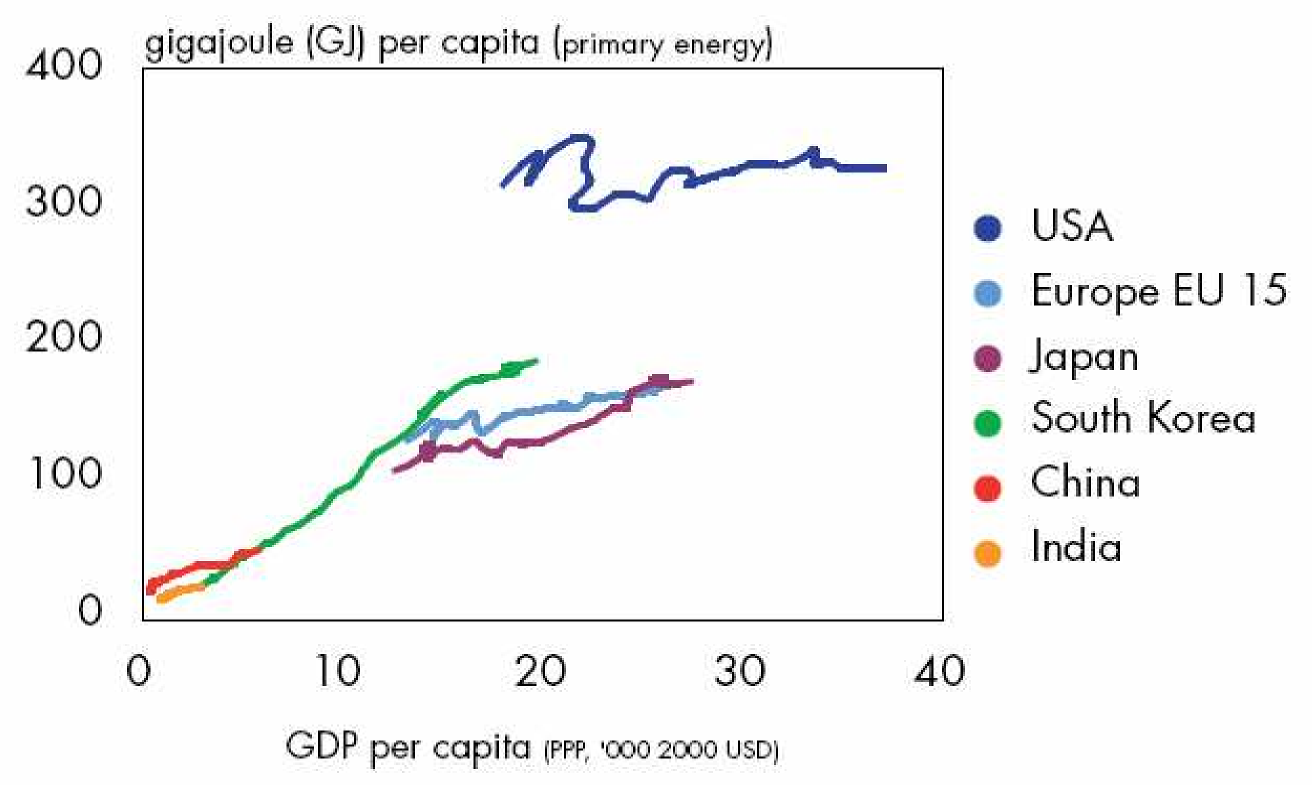
unit: Btu/$ in 2000 price






Data source: EIA, International Energy Annual 2007

## Per capita primary energy consumption vs per capita income 1970-2005






SSST

source:WEC 2009

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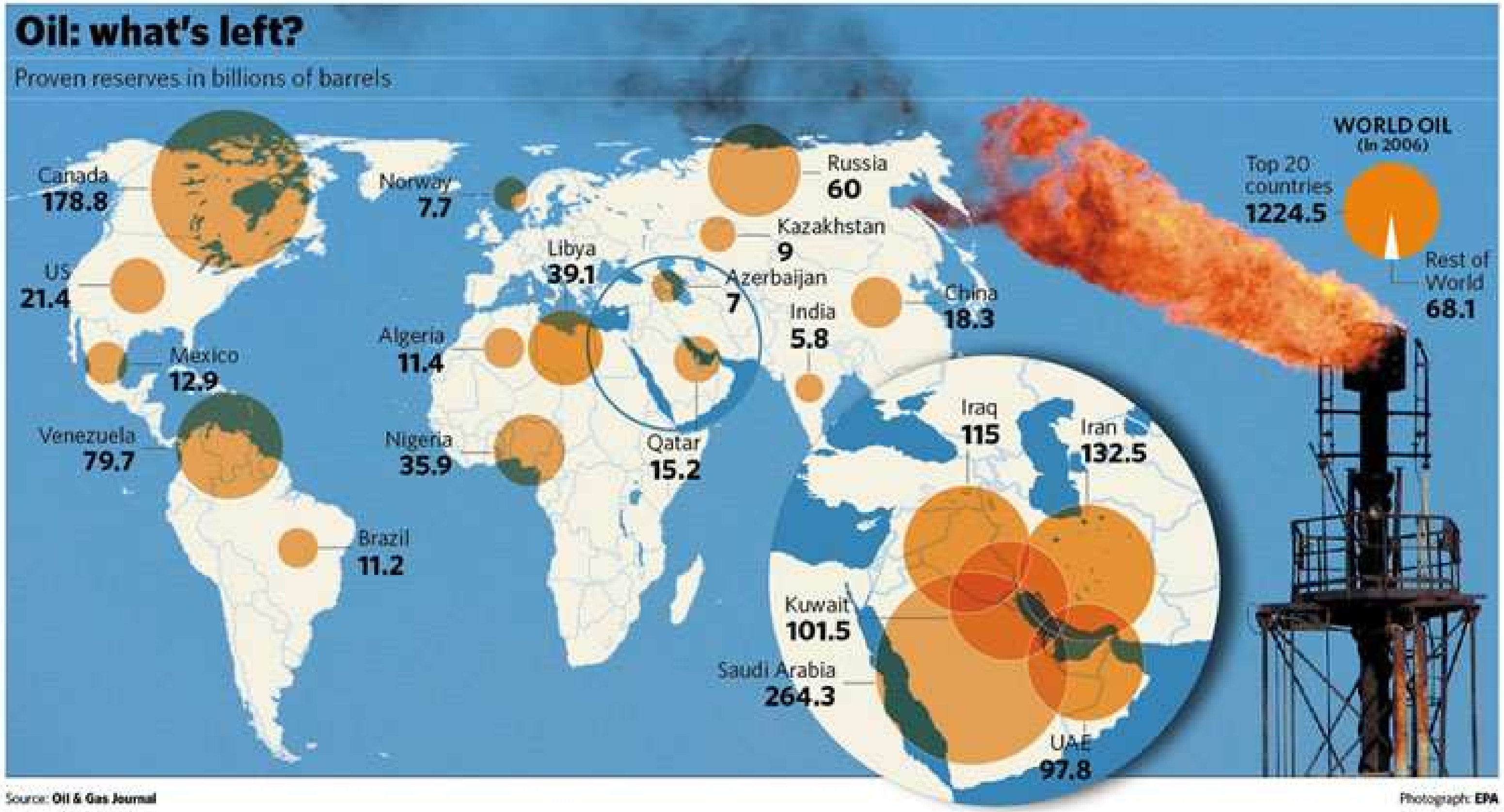
# Oil: proven reserves




"current oil reserve estimates should be downgraded from between 1150-1350 billion barrels to between 850-900 billion"

**Owen et al. The status of conventional world oil reserves--Hype or cause for concern? *Energy Policy***

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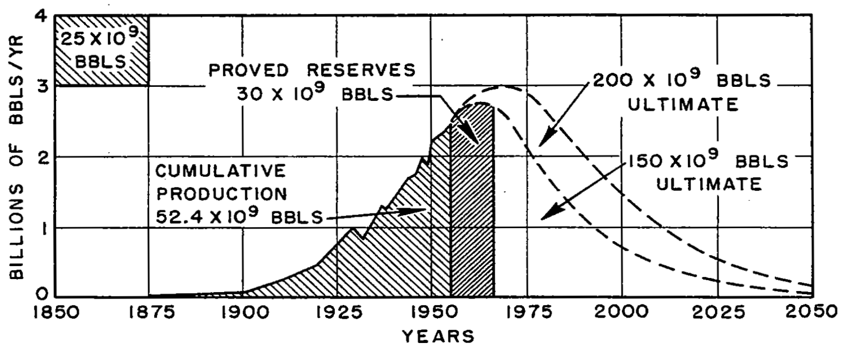
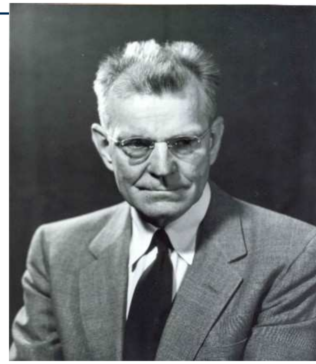
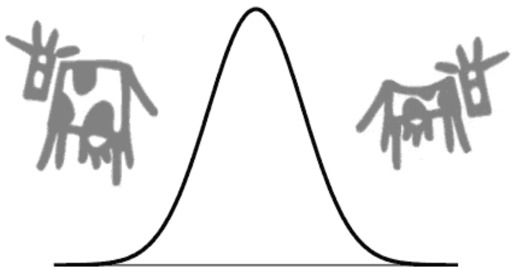
# Oil- Hubbert's curve

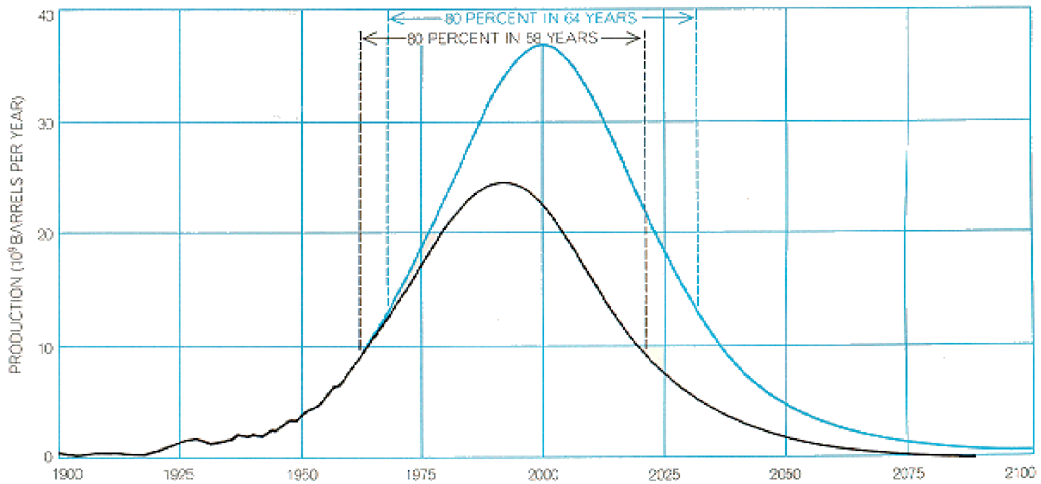


**M. King Hubbert**
1903 -- 1989

M.K. Hubbert's 1956 graph
Source: Nuclear Energy and the Fossil Fuels" Publication No. 95. Houston: Shell Development Company, Exploration and Production Research Division, 1956






CYCLE OF WORLD OIL PRODUCTION is plotted on the basis of two estimates of the amount of oil that will ultimately be produced. The colored curve reflects Ryman's estimate of $2{,}100 \times 10^9$ barrels and the black curve represents an estimate of $1{,}350 \times 10^9$ barrels.

from Energy and Power, A Scientific American Book, 1971, pg 39

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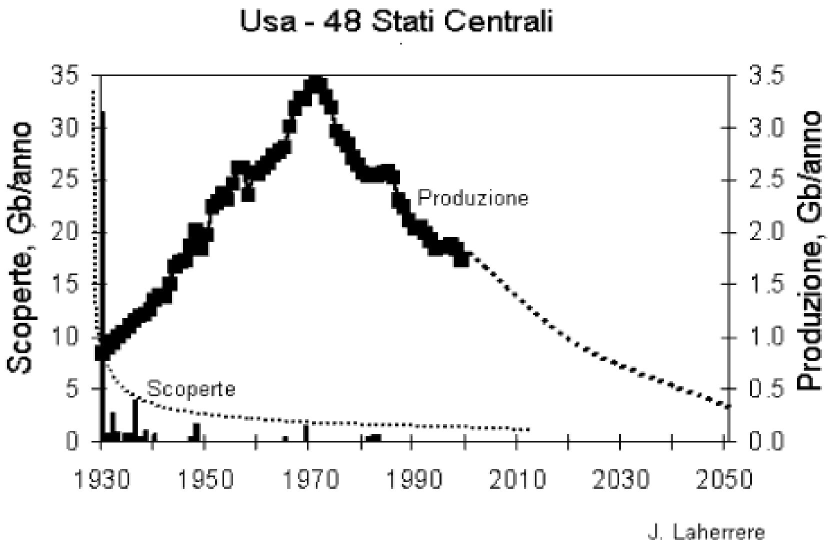
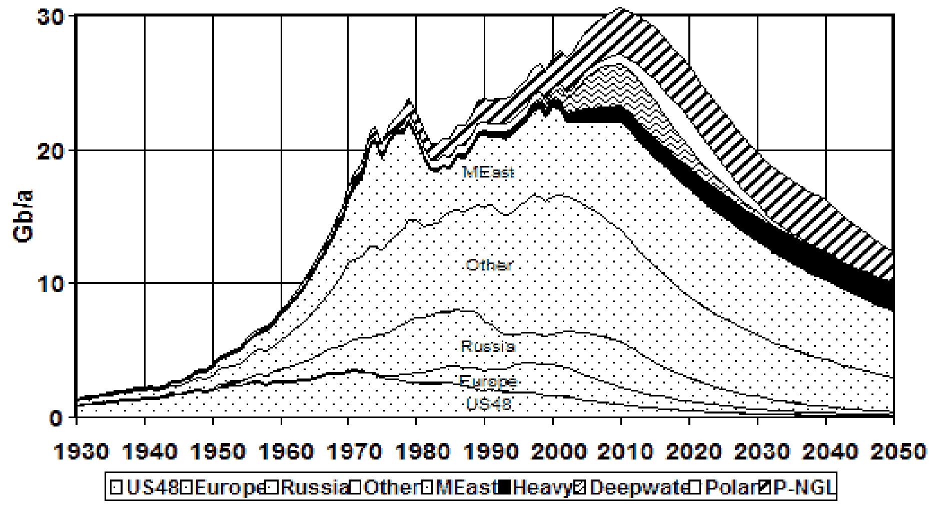
# Oil- Hubbert's curve



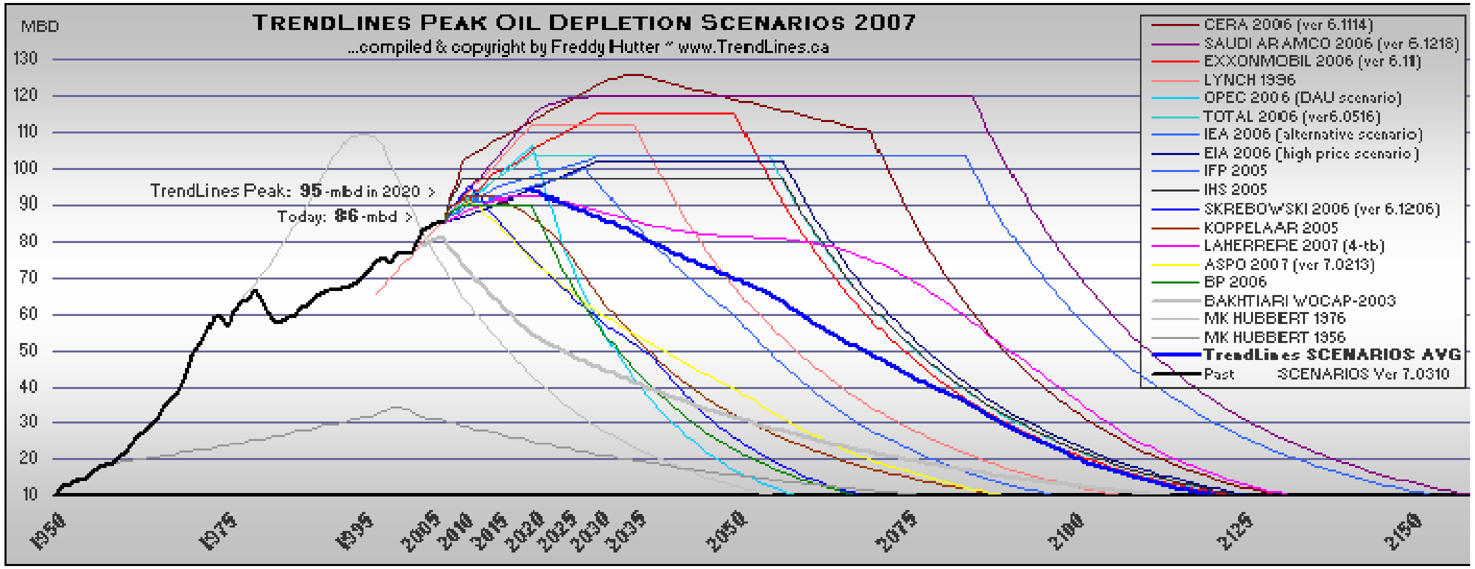

**Hubbert was right about the US**

**For the whole word the situation is less clear. This is one possible scenario…**



# Oil - The peak oil puzzle

…but many more have been proposed. There is uncertainty about when or (if) oil production will peak




Uncertainty stems from:

•reserves: how much oil is there in the ground, really?

•no major new discoveries, but

•recoverability: is it feasible and how much does it cost to recover unconventional oil? now it looks easier and cheaper.

•oil producers' behaviour: a single world market , but an oligopolistic one

## Natural Gas: Reserves (according to WEC – SER 2007)

"

**Since 1980, the world's proved reserves of natural gas have increased at an average annual rate of 3.4%** (compared with 2.4% for oil), owing to a number of exploration successes and improved assessments of some existing fields. At the present level, global gas reserves are equivalent to more than 56 years' production (net of re-injection) at the 2005 rate.

**Some 44% of total proved reserves is concentrated in about twenty mega and supergiant fields**, within which the world's largest non-associated gas field accounts for very nearly half. There is […] a high degree of consensus regarding most of the main players, notwithstanding differences in detail and in a few cases sharp disparities in definitions

**The amount of natural gas remaining to be discovered has been consistently and significantly underestimated.** …Gas exploration is at a less mature stage than that for crude oil. Many territories have been only partially explored. Improvements in the economics of transportation are opening-up access to hitherto 'stranded' deposits, while advances in technology will enable exploration and production activities to be undertaken in deeper and more complex horizons.

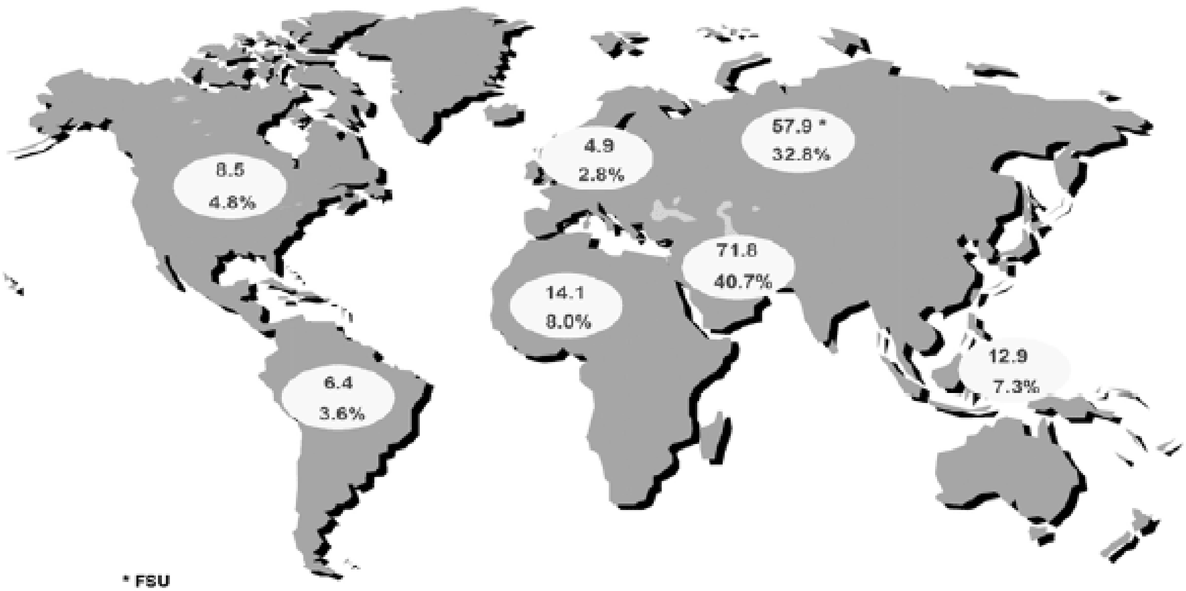
**Conventional sources of natural gas are already augmented by substantial quantities of coal-bed methane (CBM), and other non conventional sources** (e.g. tight gas sands, gas shales and possibly gas hydrates) will come to play a part in gas supply.

Cedigaz… give natural gas a lifetime probably in excess of 130 years, at the current rate of consumption.

"

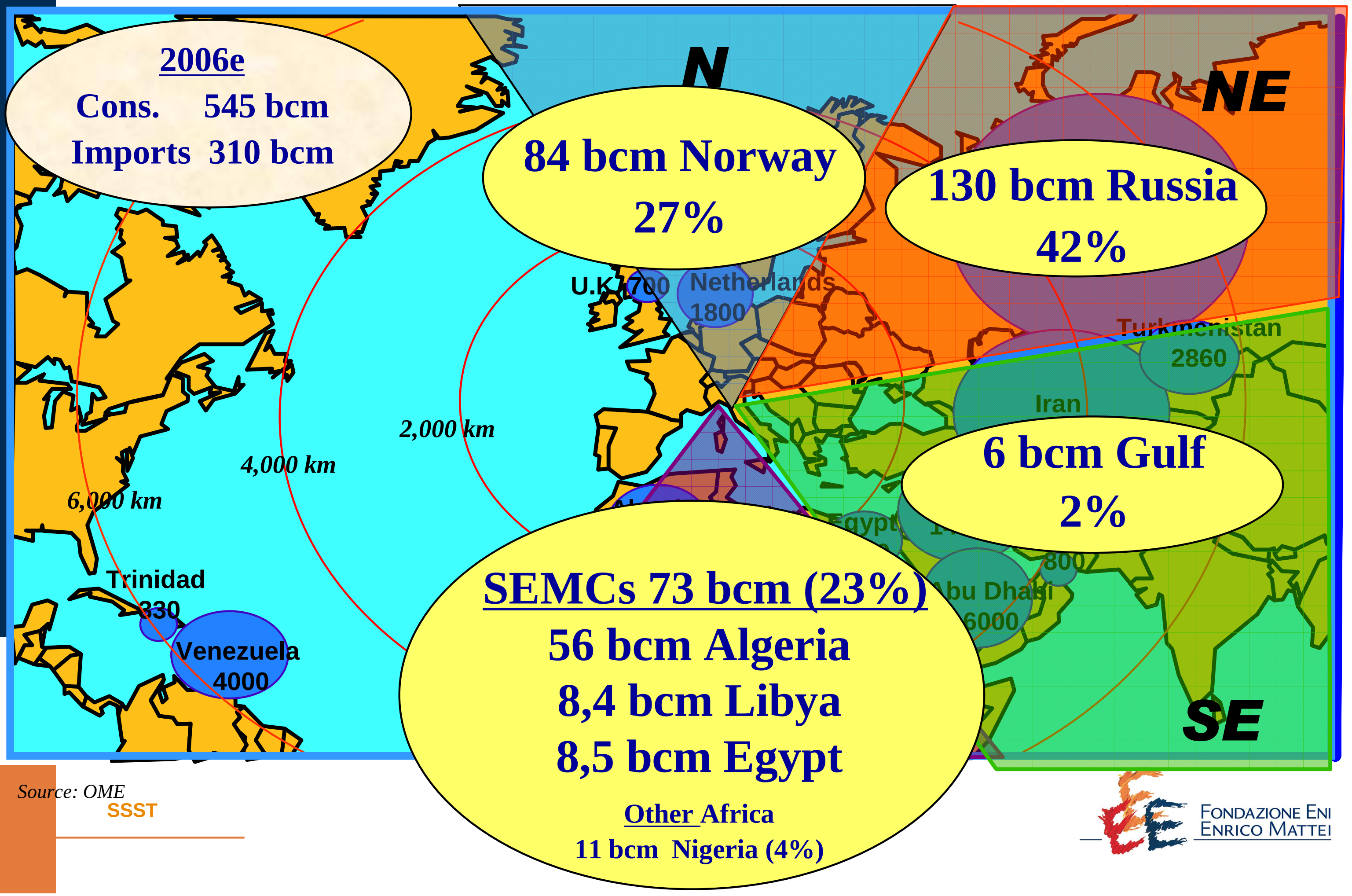
**Latest developments: demand decrease (7% in 2009) due to recession; more LNG; shale gas in USA. -> decupling gas prices and oil prices**

# Natural Gas Reserves




Proved natural gas reserves as at end-2005 (tcm and % of world)
Source: World Energy Council SER 2007

## 2006 : Gas Supply for EU-27




*Source: OME*



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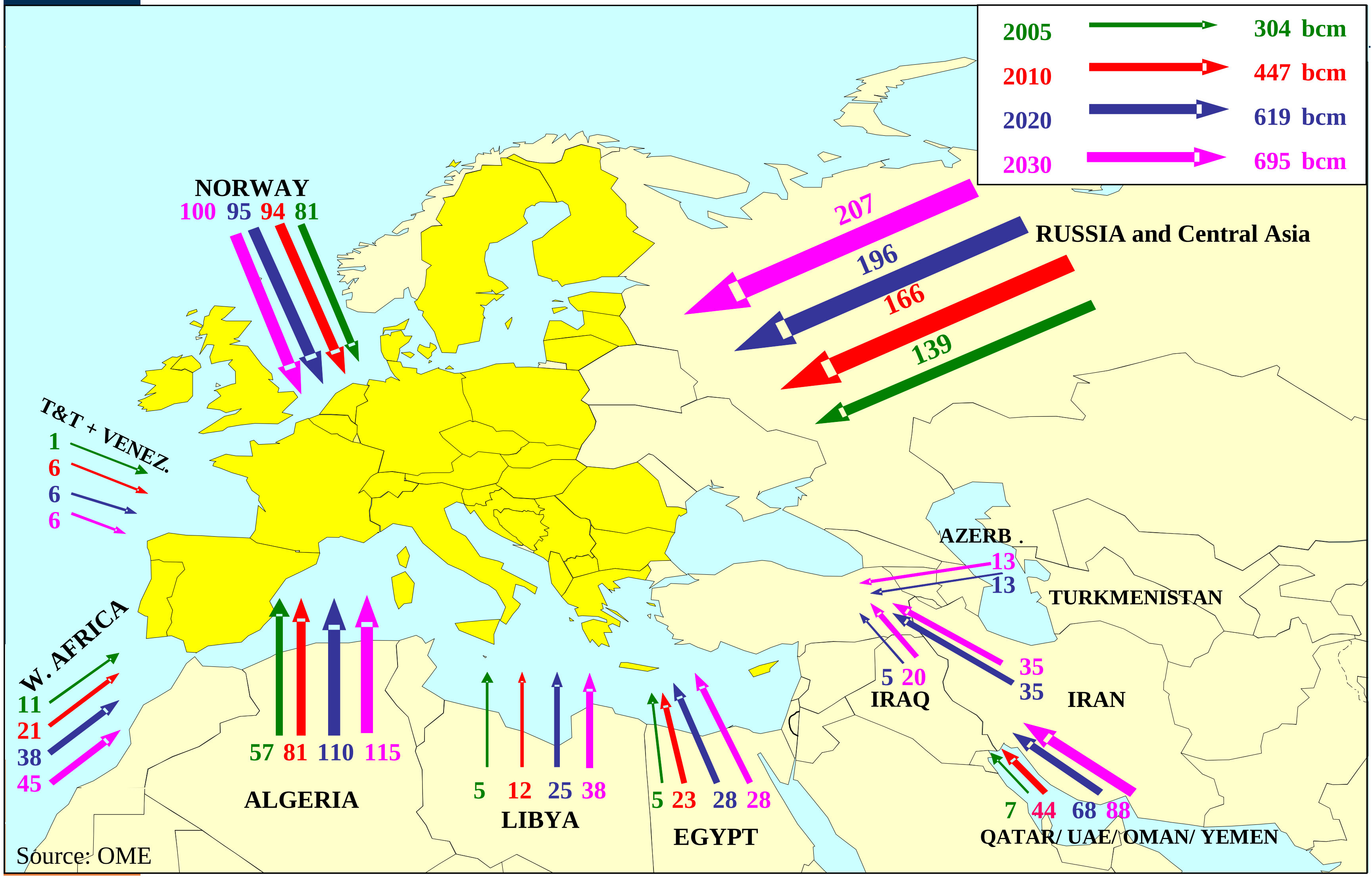
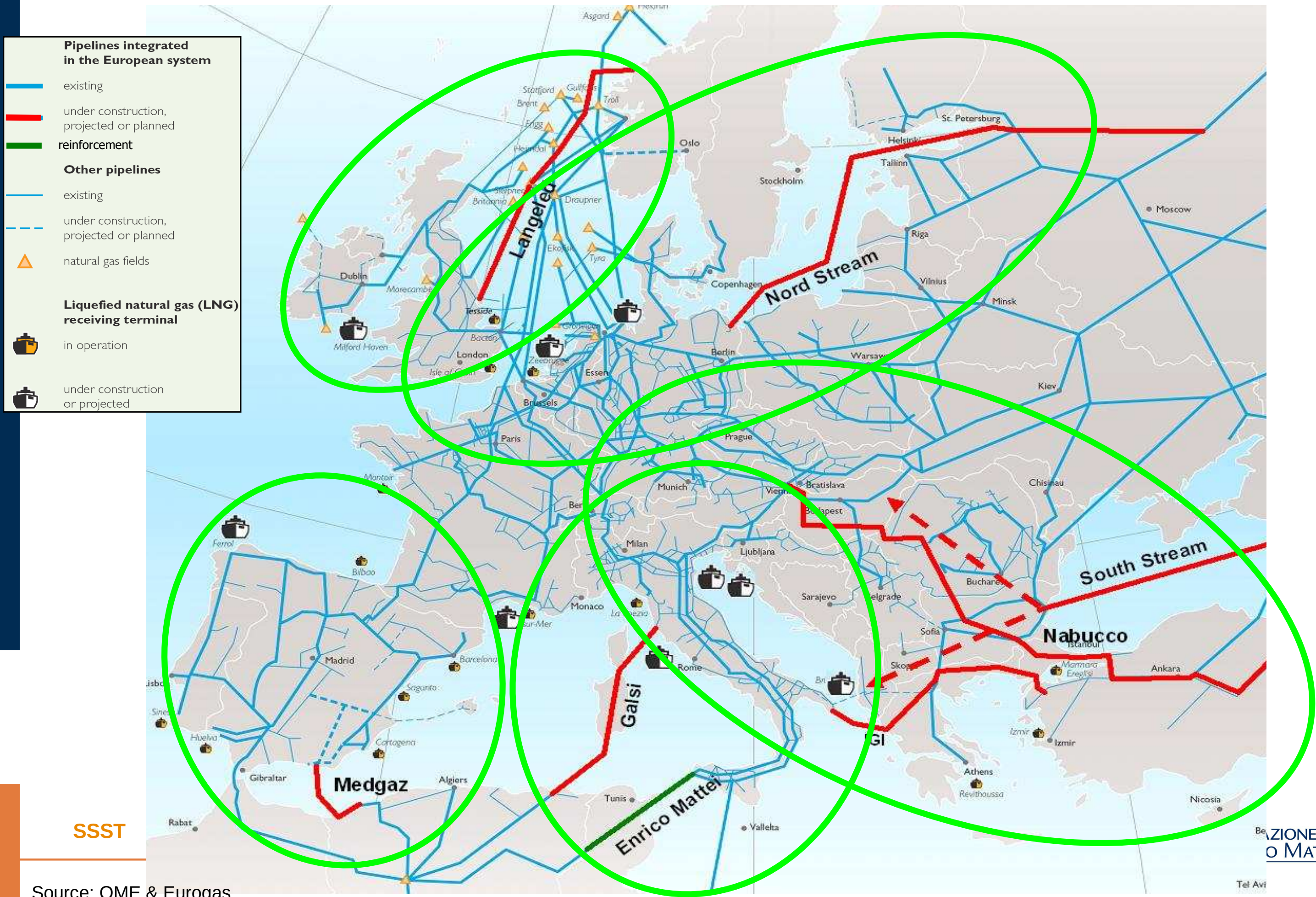
# Future gas export potential for Europe



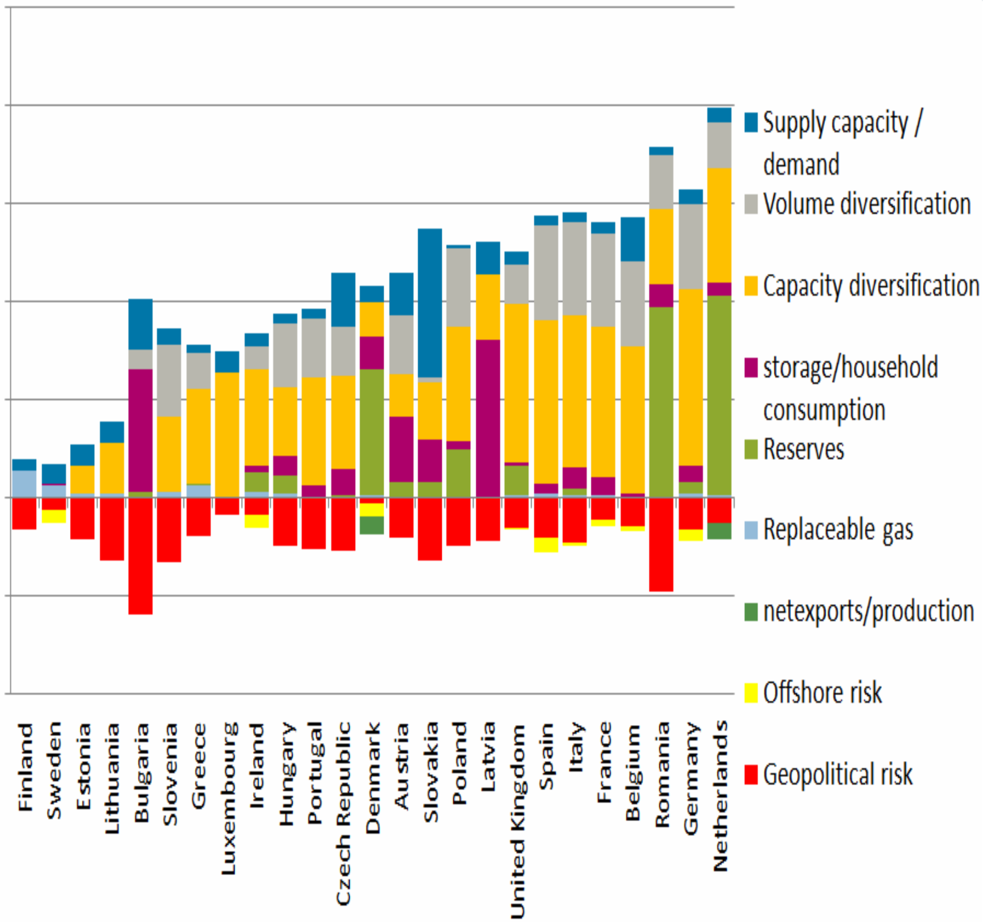
# Natural Gas: infrastructure- Pipelines




Source: OME & Eurogas

# Natural Gas

- Natural gas security is not only a question of the external dimension such as diversification of supply sources and routes. Demand side and internal factors are as important.
- Many parameters are at play – and these parameters can change over time e.g. as the consequence of policy
- Thus securing supply is a mix of measures and forward looking policies.




Source: Ramboll Secure SoS index

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# Natural Gas

There is enough gas around Europe to secure the EU gas supply to 2030 – the issue is investment upstream as well as infrastructure

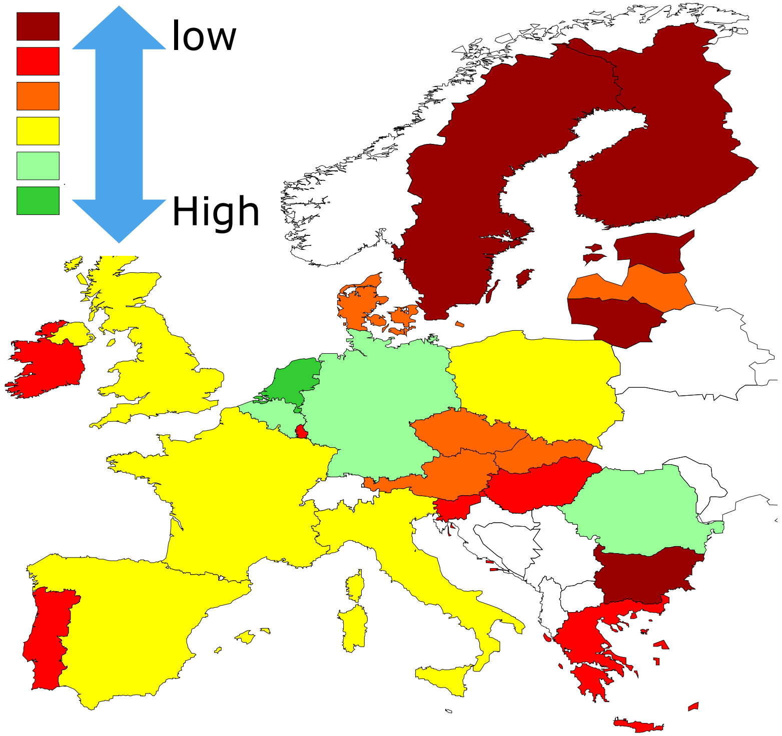
But what about after 2030?

- Will the EU be prepared for a post gas peak in many of its current suppliers, and how?

Gas security has to be addressed in a global perspective, and throughout the gas chain.

**=> Need to promote healthy relations between producers, consumers, transit countries and between national and international companies.**

Level of Security of supply in EU




Source: Ramboll Secure SoS index

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# Coal

**The real issue in European supply security regarding coal is not the resource availability, but the absence of an economically and politically sustainable use of coal** for electricity, liquefaction, gasification, industrial applications etc., **due to obstacles in the implementation of a CCTS (carbon capture, transportation, and storage) value-added chain.**

Upstream, there are little worries about the supply security of (steam) coal

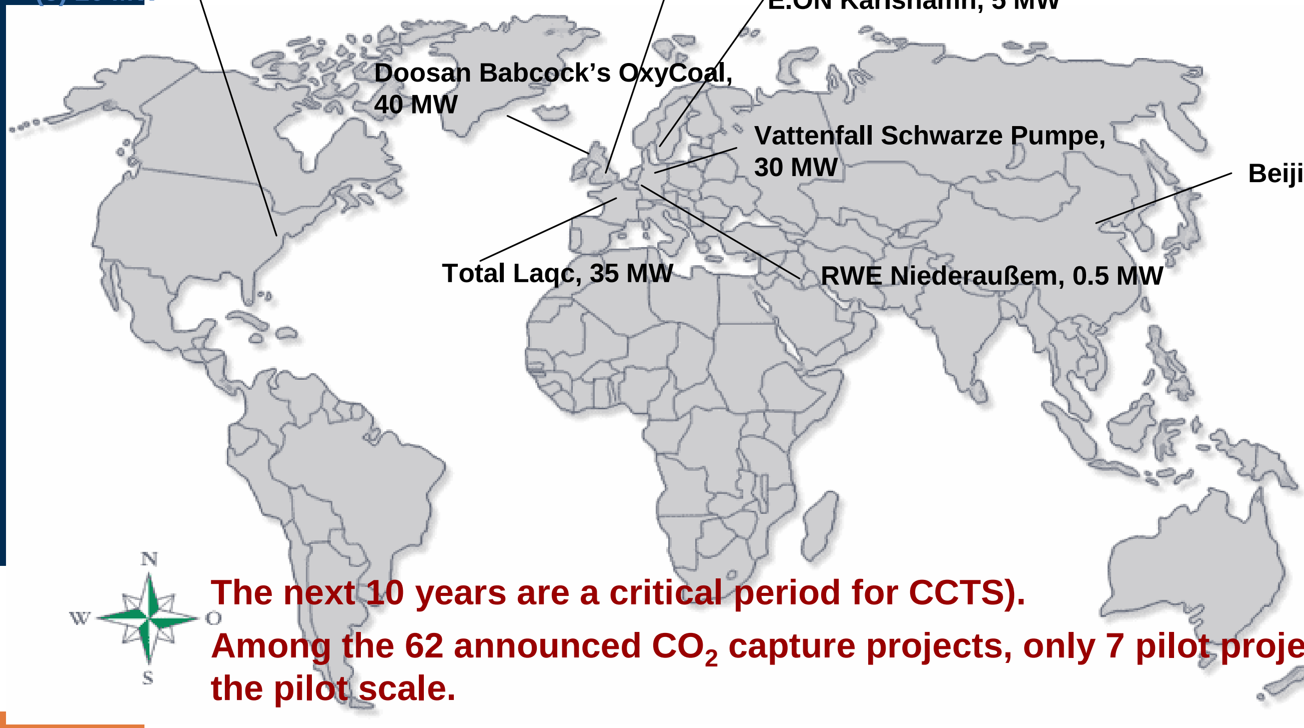
- Market monitoring should be continued, in particular on developments and prices in specific regions (e.g. China)
- Competition authorities should continue to monitor international coal markets, with a special focus on mergers & acquisitions of "Big Coal"



source: SECURE project

# Investment needs for CCTS

The IEA Blue Map Scenario outlines a need of 100 serious CCTS demonstration projects until 2020!




**The next 10 years are a critical period for CCTS).**

**Among the 62 announced $CO_2$ capture projects, only 7 pilot projects are operating on the pilot scale.**

**Assuming that all of the announced projects are realized by 2050 there still remains a gap of 40 projects to reach the IAE blue map scenario.**

source: SECURE project

## Coal: CCTS

- **There is a real danger that the ambitious development plans in CCTS demonstration over the next decade will not be met; policies should aim on the acceleration of the development process.**
- **The real bottleneck towards CCTS is the transport and storage infrastructure. Legal and technical uncertainty needs to be resolved.**
- If industry does not respond to current incentives, the level of incentives needs to be raised to a reasonable level or pilot and demonstration projects should be carried out by public research institutions.
- Due to the lack of an inherent value of $CO_2$ the revenue stream strongly depends on future regulatory decisions; these should be made explicit as soon as possible.





source: SECURE project

# Nuclear energy

**In order to respect climate policy goals, also nuclear needs to play an increasingly important role in worldwide and EU long term energy balances**.

However, according to IEA and EC energy scenarios, the EU nuclear share is expected to reduce by half between now and 2030. As nuclear is presently providing two thirds of all low carbon electricity in the EU, this will create an even larger strain on fulfilling CO2 targets.

In fact, the so often announced nuclear renaissance is having a difficult birth: With 148 aging reactors in operation in 15 member states, there are presently just 4 reactors under construction in the EU (Finland 1, France 1, Bulgaria 2).



source: SECURE project

# Nuclear energy

Reasons for the stalling renaissance of nuclear energy are:

**social acceptability** (political opposition) for a technology which is perceived as dangerous and for which the permanent waste disposal issue has still not been solved,

**lack of human capacity** (Europe's industrial capacity of building nuclear power plants is said to be limited to maximum 4 per year, other regions seem to have the same problem of aging workforce) which is expected to worsen over the next years as specialists retire;

**strongly increasing investment cost for nuclear power** due to, among others, improved safety and environmental standards. And contrary to the general energy capital cost index which has fallen by 20-30% since its peak in 2008, nuclear costs do not seem to have fallen over the last year ;

**technical problems** with the new 3rd generation designs of all major manufacturers resulting in huge cost-overruns for the first realizations of the new designs;

the **difficulty to finance hugely capital intensive plants in a market environment** and in particular after the financial crises;

the increasing uncertainty on construction costs raise some doubts on the ability of nuclear power to foster a decrease in prices.



source: SECURE project

# Renewable energy sources (RES)

By definition, not depletable; however some may have limited potential in many countries due to geographical, orographic, meteorological conditions (e.g hydro, wind, solar)

According to IEA (http://www.iea.org/textbase/papers/2006/renewable_factsheet.pdf) they can be divided into first, second and third generation RES:

- **1$^{st}$: mature technologies like hydropower, biomass combustion, and geothermal power and heat**
- **2$^{nd}$: technologies recently developed but commercially viable (at least in some countries and in some case with government support: solar heating and cooling, wind power, modern forms of bioenergy, and solar photovoltaics.**
- **3$^{rd}$: are still under development and include concentrating solar power, ocean energy, enhanced geothermal systems, and integrated bioenergy system**

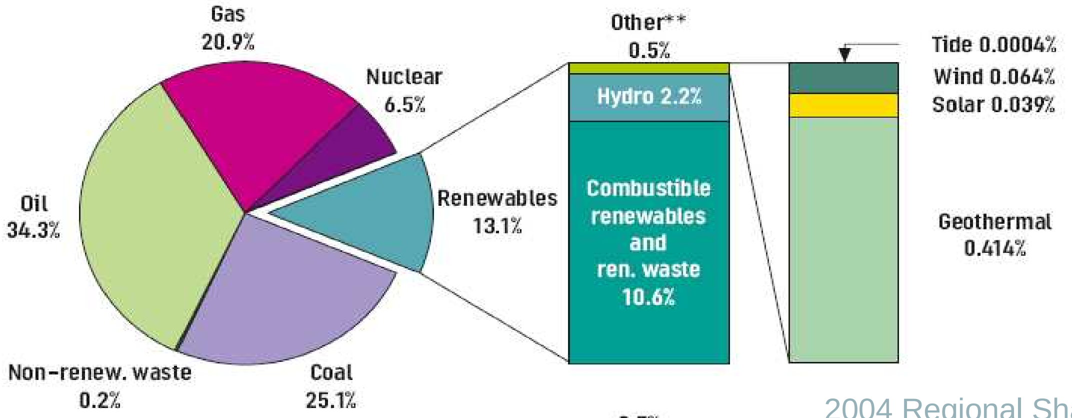
**The key is their cost compared to traditional fossil energy sources**

**Also as they are mostly emission free, they interact with the sustainability issues; however there is no impact-free energy source:**

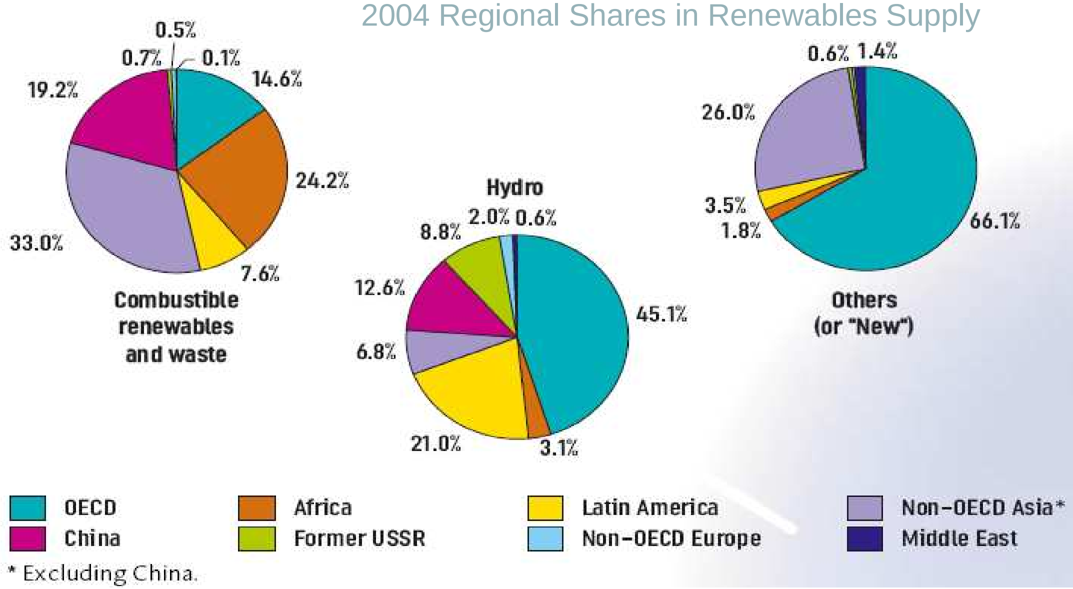
- **hydro: water use, quality and water rights; land use; local pollution**
- **biomass: $CO_2$ efficiency varies with crop; competition with food crops, cattle, forests**
- **wind: landscape impacts; migratory birds, LCA emissions**

# Renewable energy sources (RES)

2004 Fuel Shares of World Total Primary Energy Supply

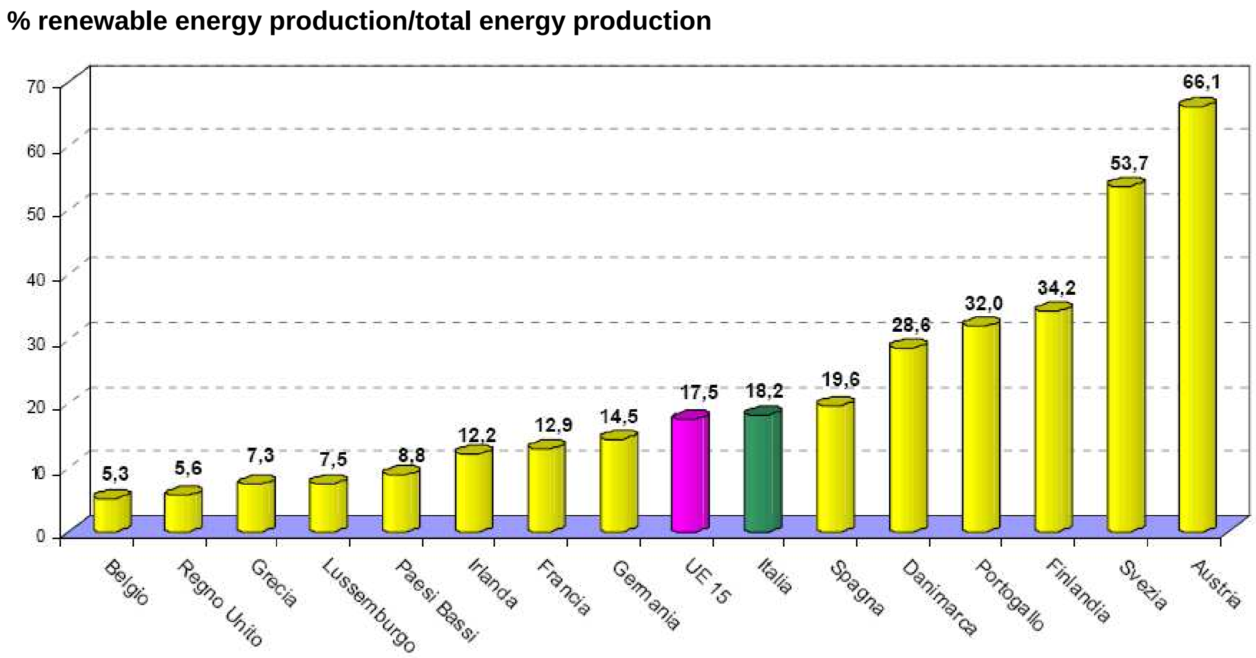



2004 Regional Shares in Renewables Supply



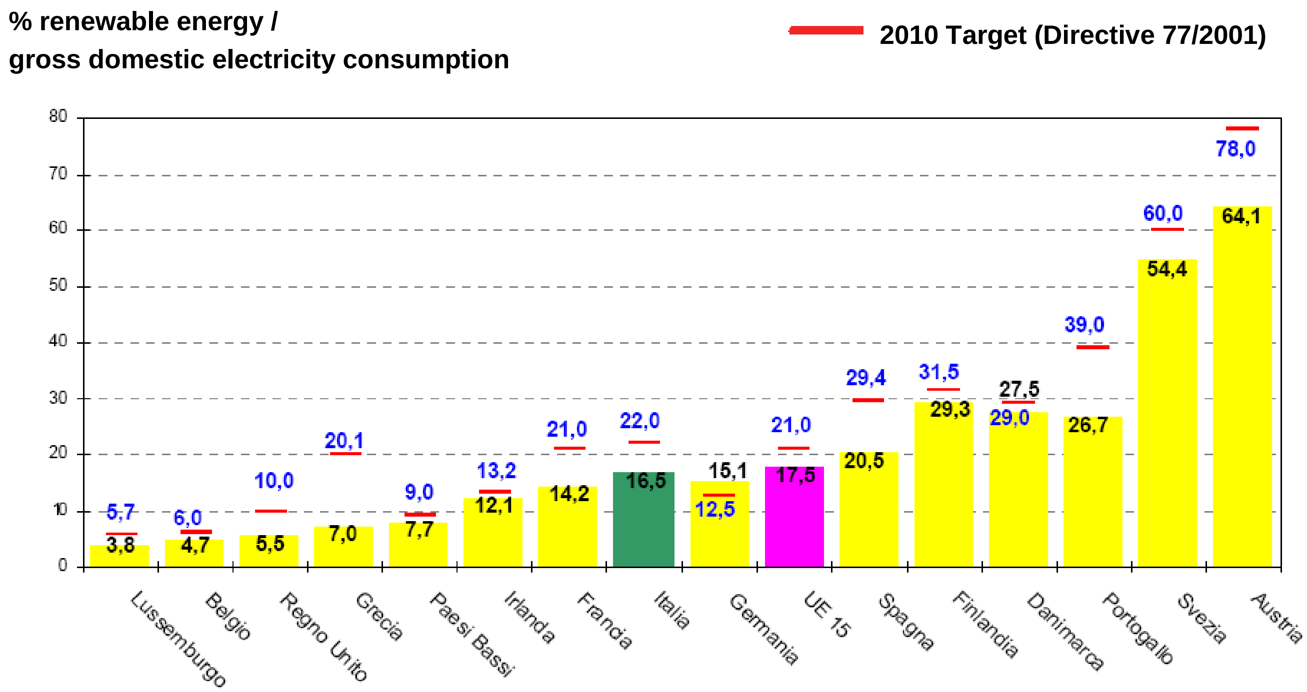

*Source: IEA Energy Statistics*

# Renewable energy production the EU



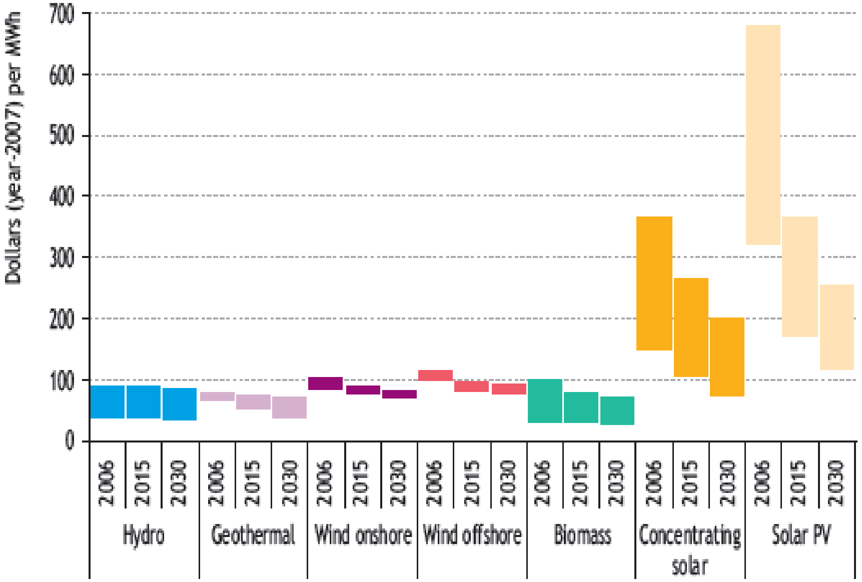

Source: GSE 2009

# Renewable share on gross domestic electricity consumption in Europe




Source: GSE 2009

# Outlook on electricity generation costs from renewable sources




*WEO, 2008*

- **Generation costs are expected  to decrease given the decrease in investment costs due to technological progress and scale economies**
- **Mature technologies' costs (geothermal and wind) will decrease less**
- **In reality costs vary substantially due to the expected life of the technology, the proximity of demand, the local availability of the renewable energy source.**
- **Output characteristics of various technologies also matter. Large hydro storage capabilities increase the value of this technology and hence its competitiveness**

# Grazie!

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