Energy Technologies and Sustainability

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CIEMAT

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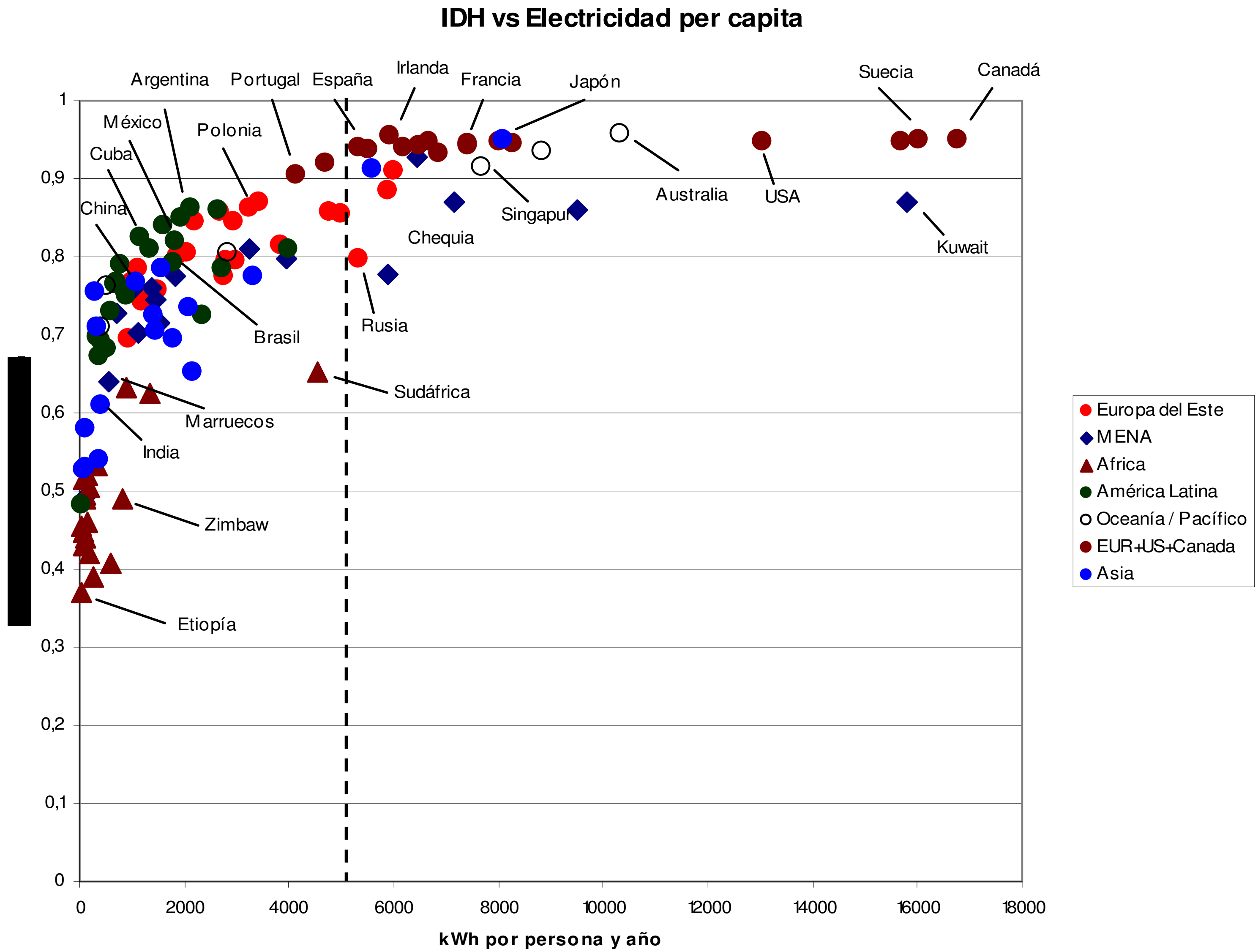
MINISTERIO DE EDUCACIÓN Y CIENCIA

Ciemat Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

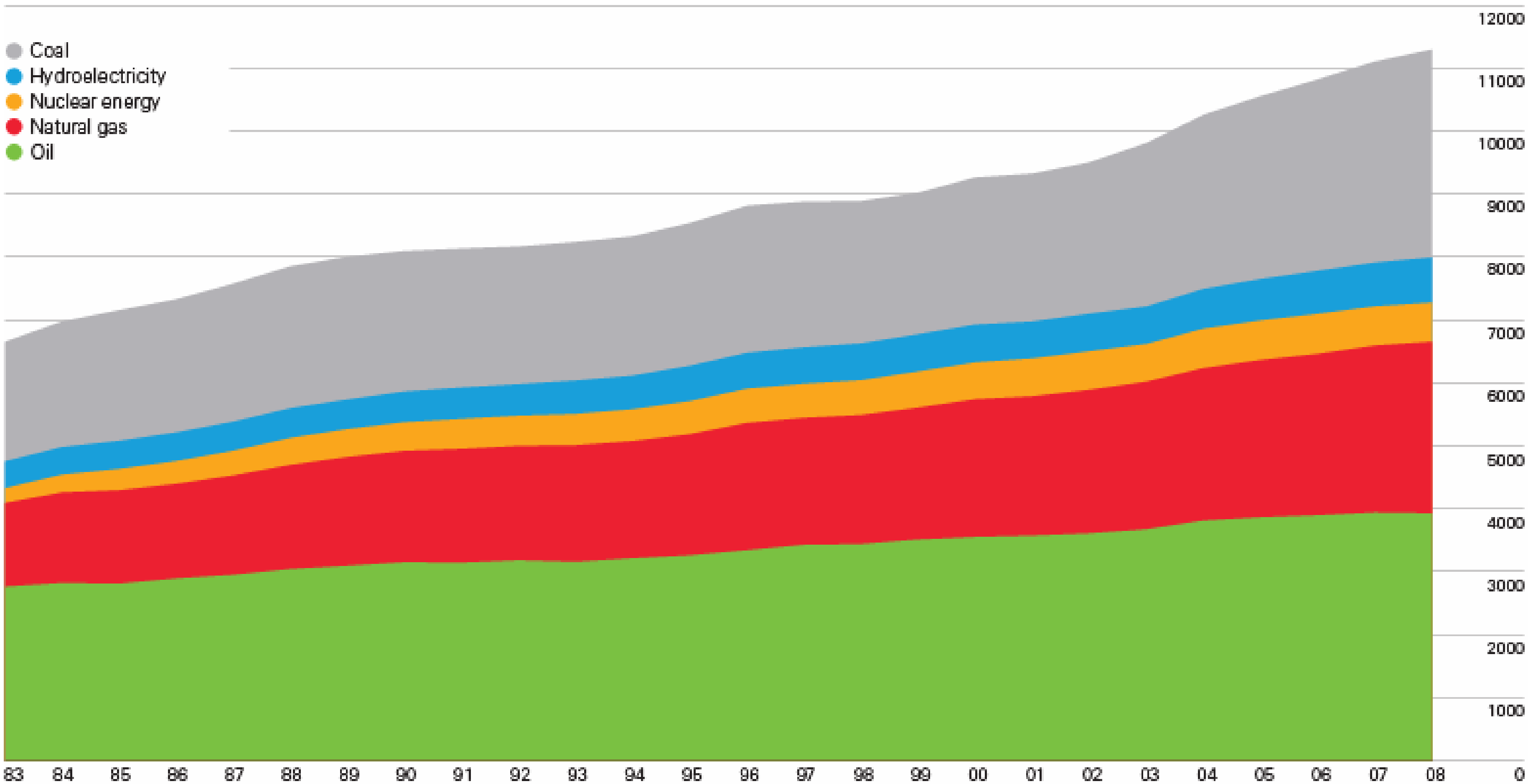
Energy consumption and welfare



Data from the UN Human Development Report 2006 and IEA 2004

The primary energy in the world

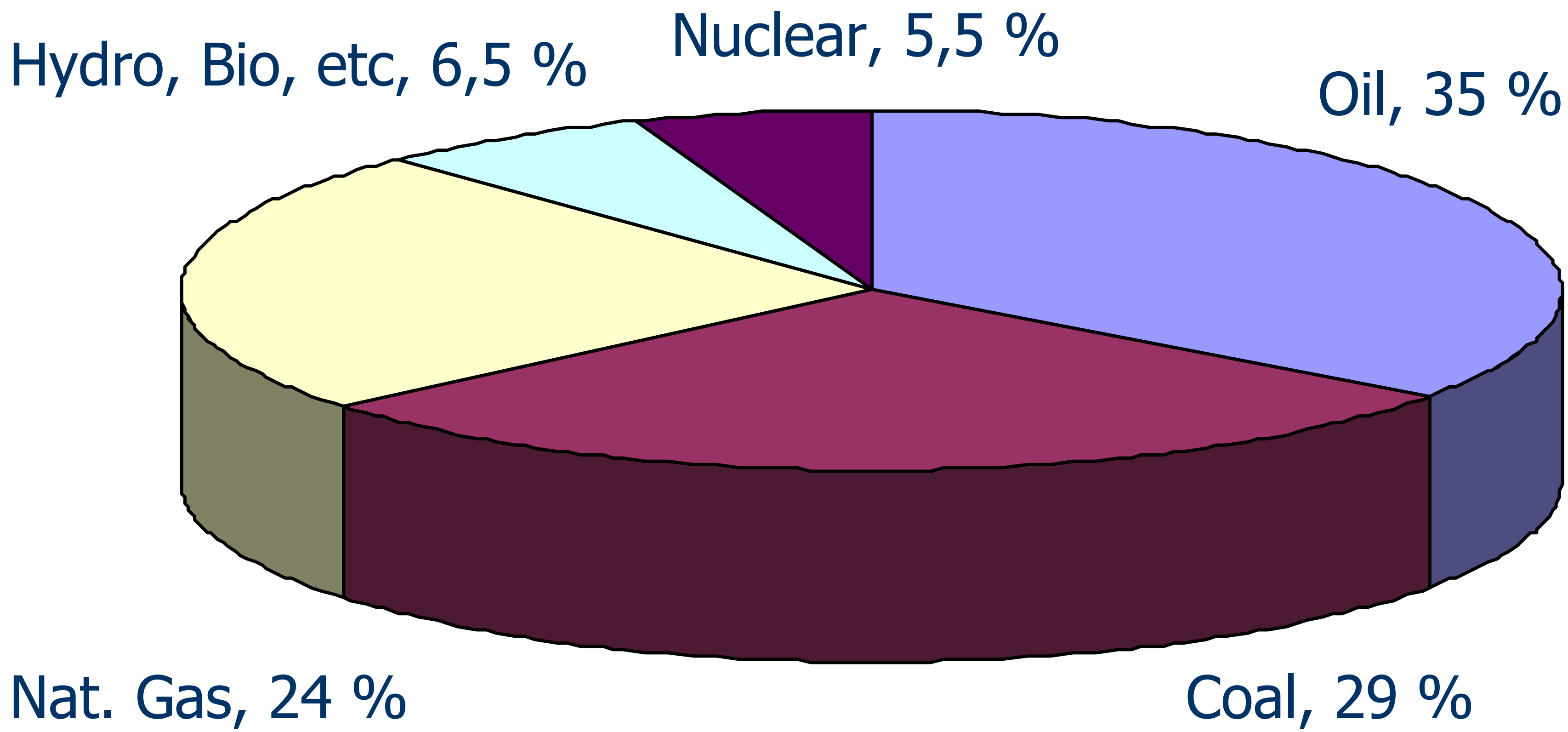
1980-2008: + 66 %, equivalent to 1,9 % per year



World primary energy consumption grew by 1.4% in 2008, below the 10-year average. It was the weakest year since 2001. Oil remains the world's dominant fuel, though it has steadily lost market share to coal and natural gas in recent years. Oil's share of the world total has fallen from 38.7% to 34.8% over the past decade. Oil consumption and nuclear power generation declined last year, while natural gas and coal consumption, as well as hydroelectric generation, increased.

BP Statistical Review 2009

World primary energy consumption by source, 2008

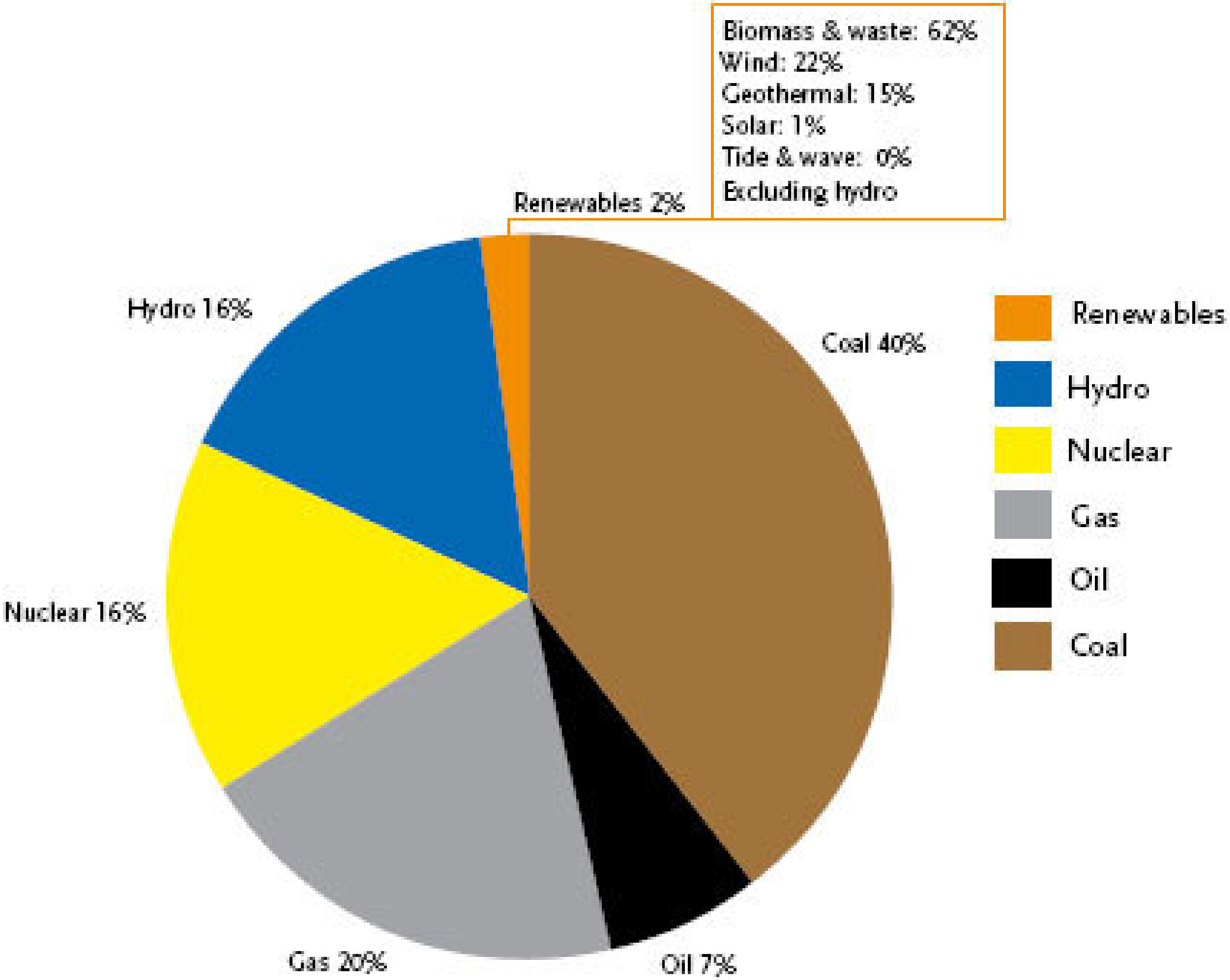


Complete dependency on fossil fuels.

Problems of geographical distribution, resource scarcity and environment damages.

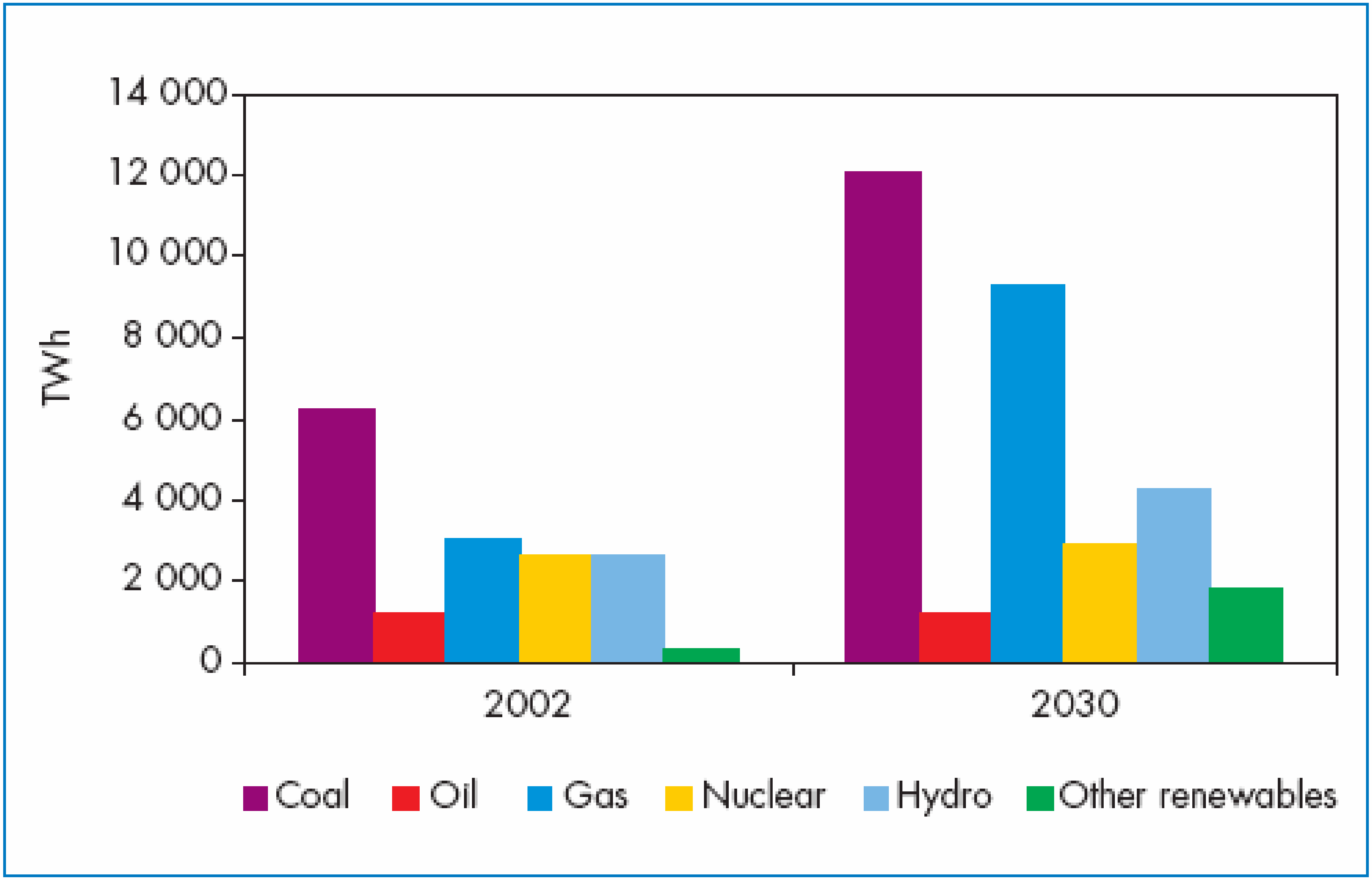
This scheme is not sustainable

World electricity generation by source



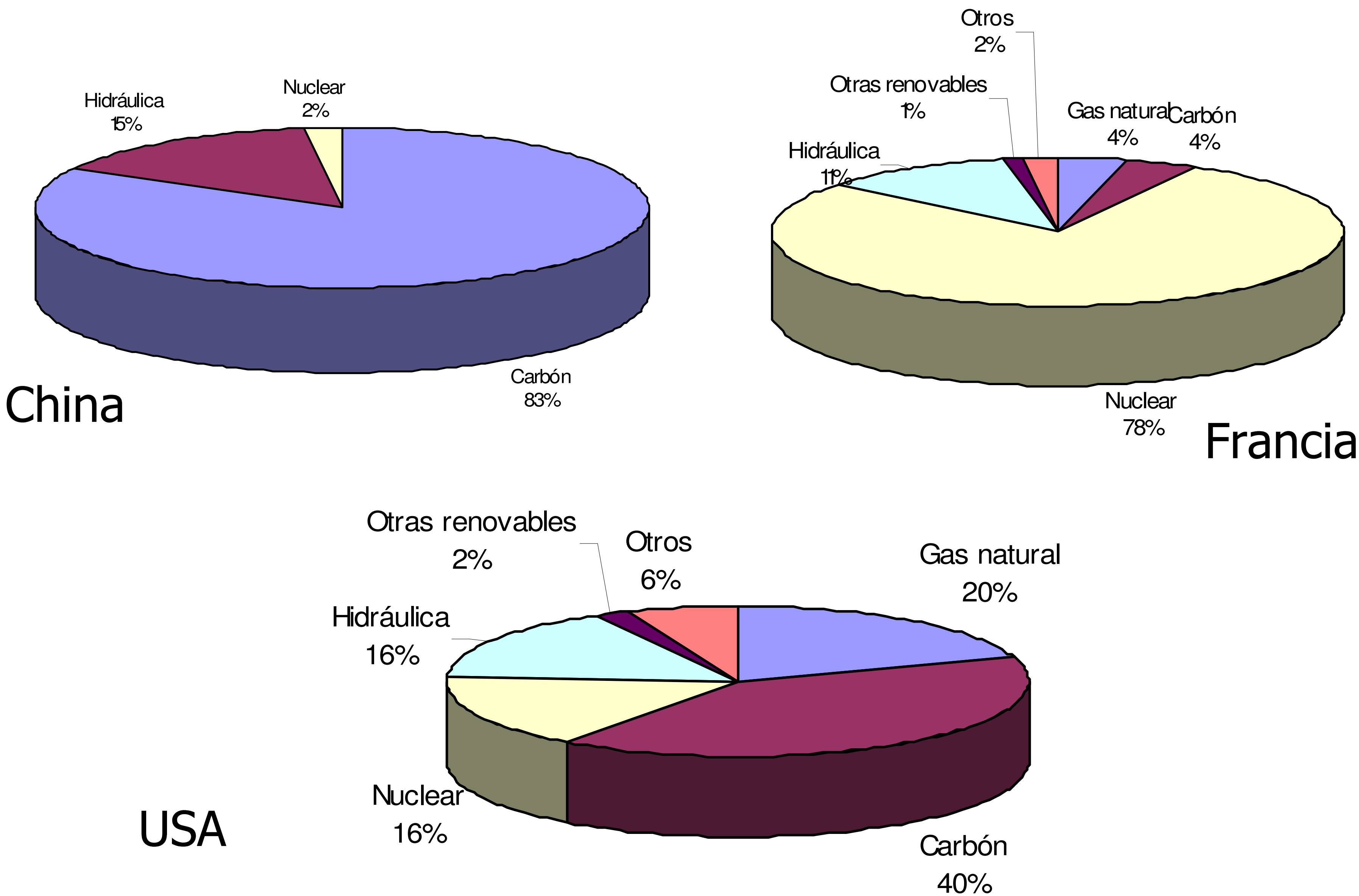
And the situation will not improve

Figure 6.5: **World Electricity Generation, 2002 and 2030**

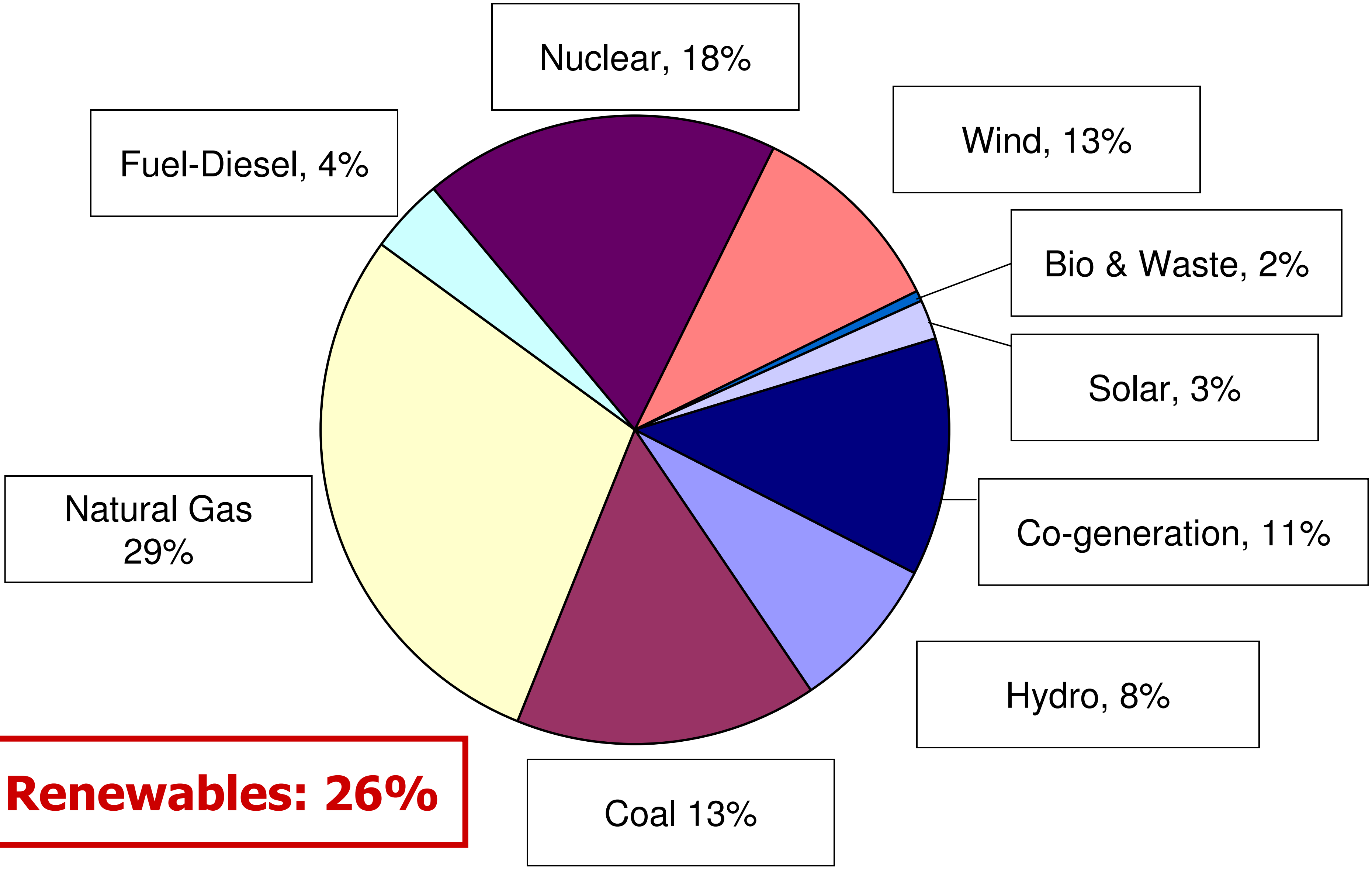


World Energy Outlook 2004

Electricity generation by source

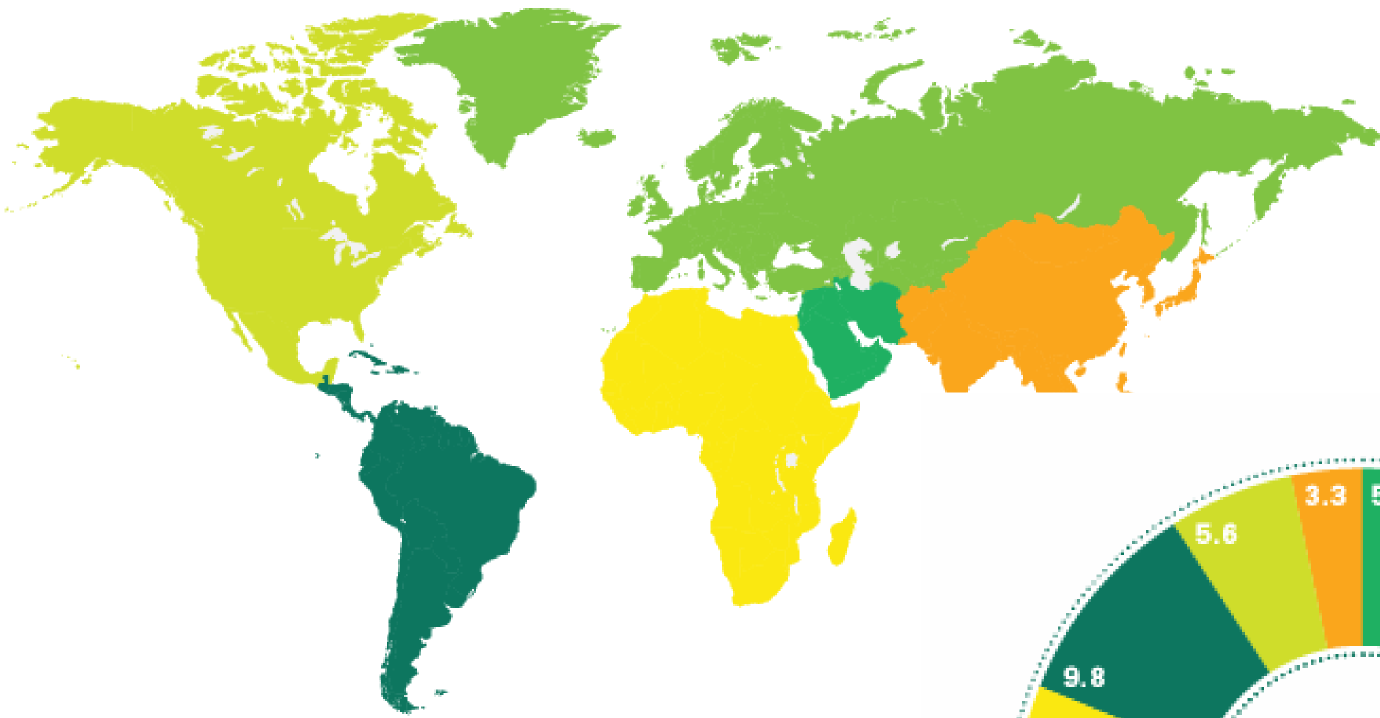


Electricity in Spain, 2009

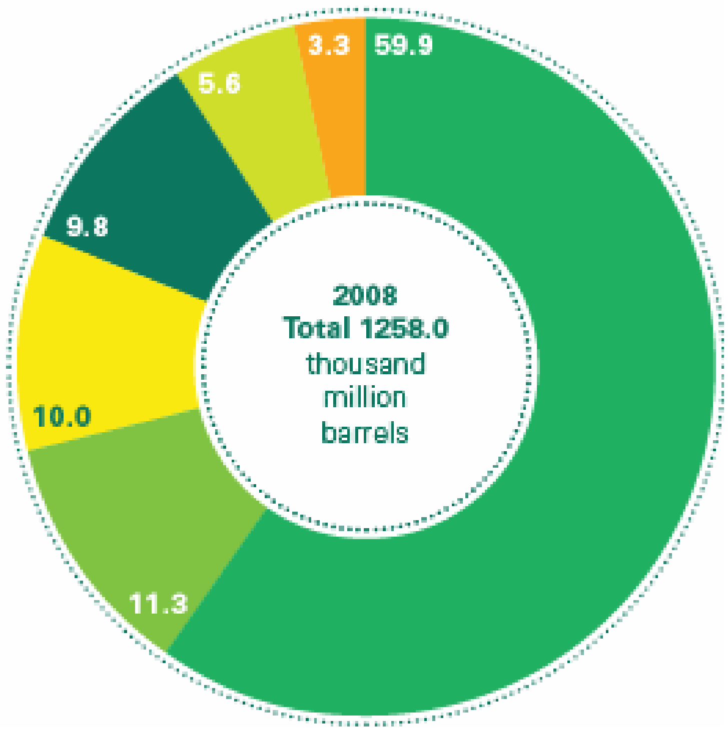


Renewables: 26%

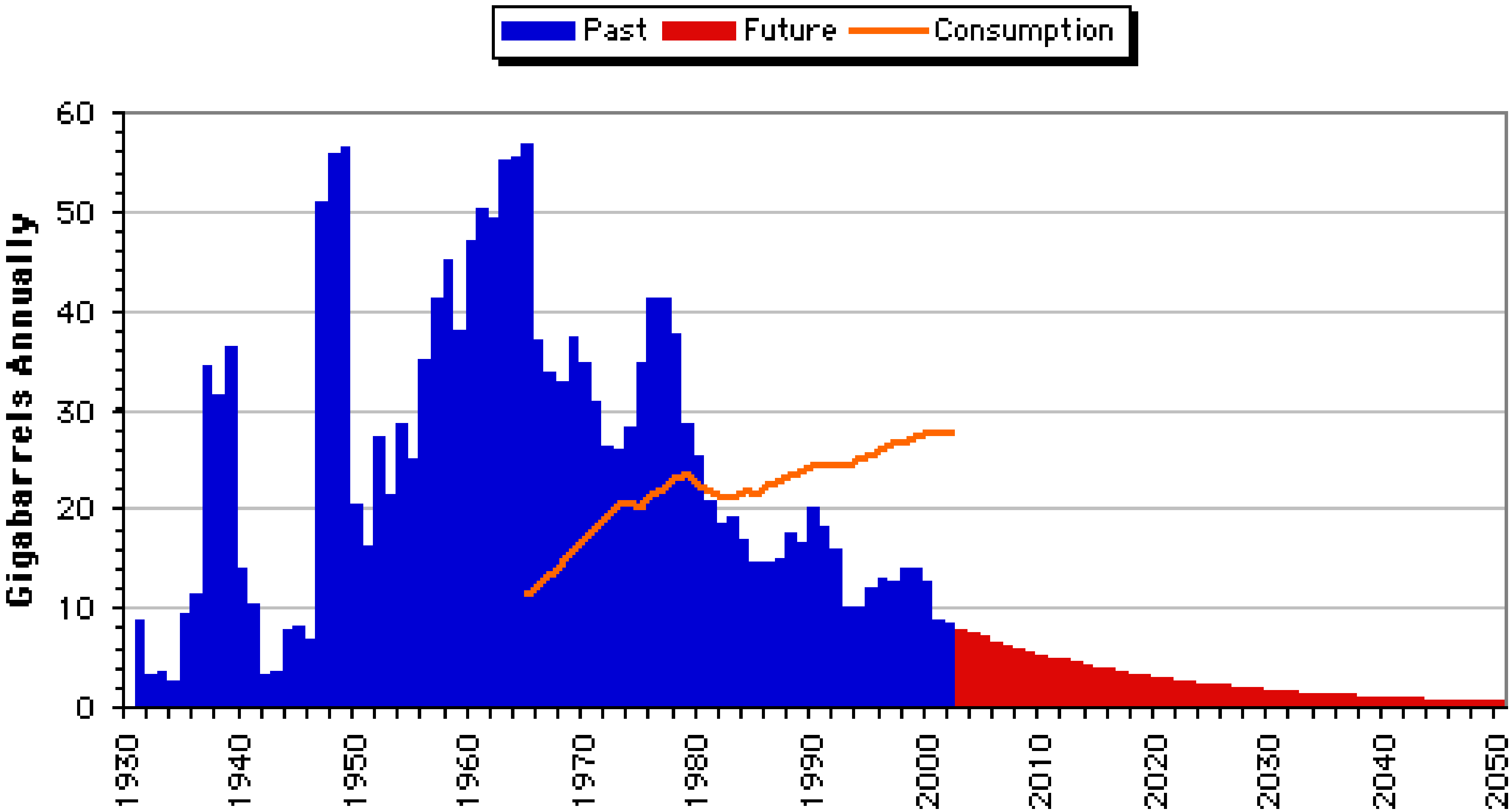
La distribución territorial del petróleo



Proved reserves at end 2008
Thousand million barrels

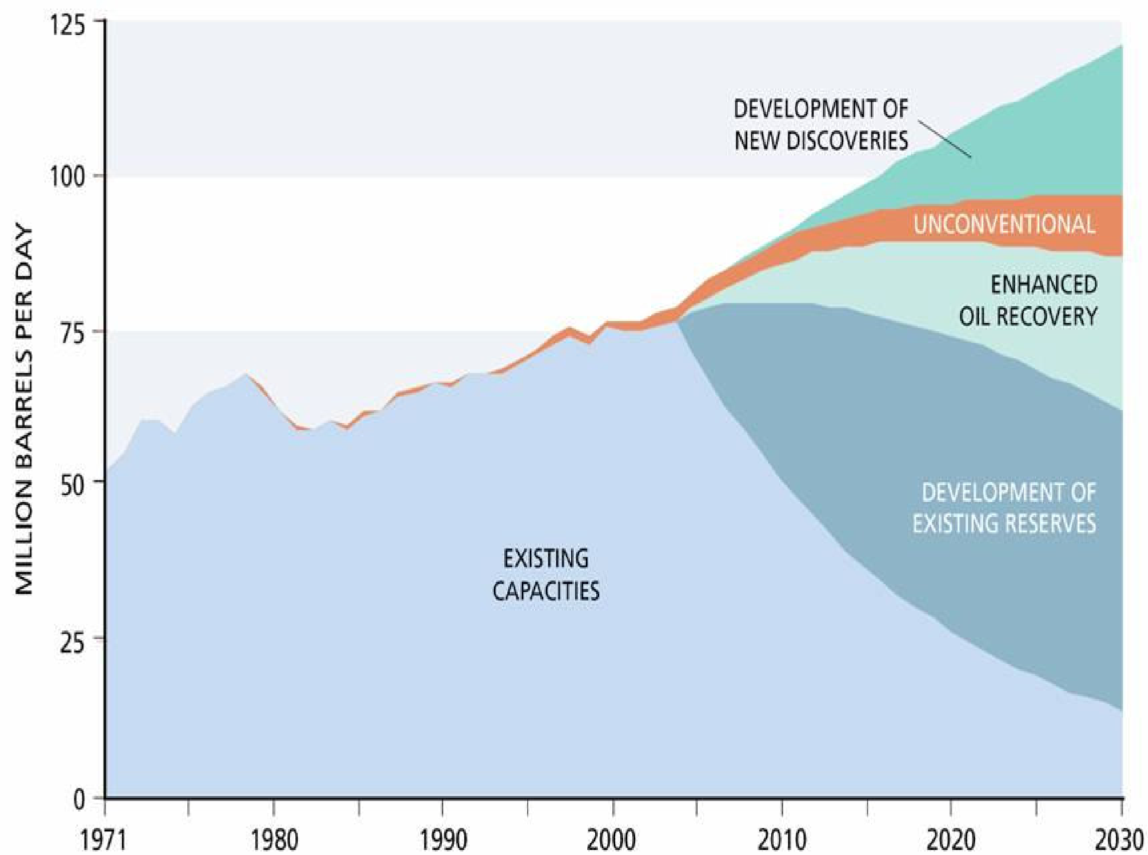


A worrying situation



Can we be optimistic?

The International Energy Agency says in a report that the 800 biggest fields around the world that comprise three-quarters of all reserves have already hit peak. Moreover, the pace of the decline in production is about twice that of what it was in 2007. That means that the so-called peak oil theory whereby global oil demand meets declining production is 10 years away, all according to the agency's chief economist Fatih Birol.



IEA, World Energy Outlook 2004

The elements of change

The serious drawbacks of the existing energy supply scheme

Imply a change whose main vector is:

Reduce the carbon content of the primary energy sources

Less fossil fuels

More renewables

More nuclear

Possible clean use of coal (CO_2 capture and sequestration)

Fusion (not available in the short term)

Renewable Energy

Europe objective: 20% of renewables in 2020. At present, 6% (in Spain 8 -10 %). Much progress is needed, but

Problem 1: High Cost

Possible solutions:

Increasing size of the plants

Advances in R + D

Improvements in component manufacture

Series production (market expansion)

Experience in O & M

Problem 2: Intermitency

Possible solutions:

Hybridation

Energy storage (electricity, heat, H_2)

Wind energy, a story of success

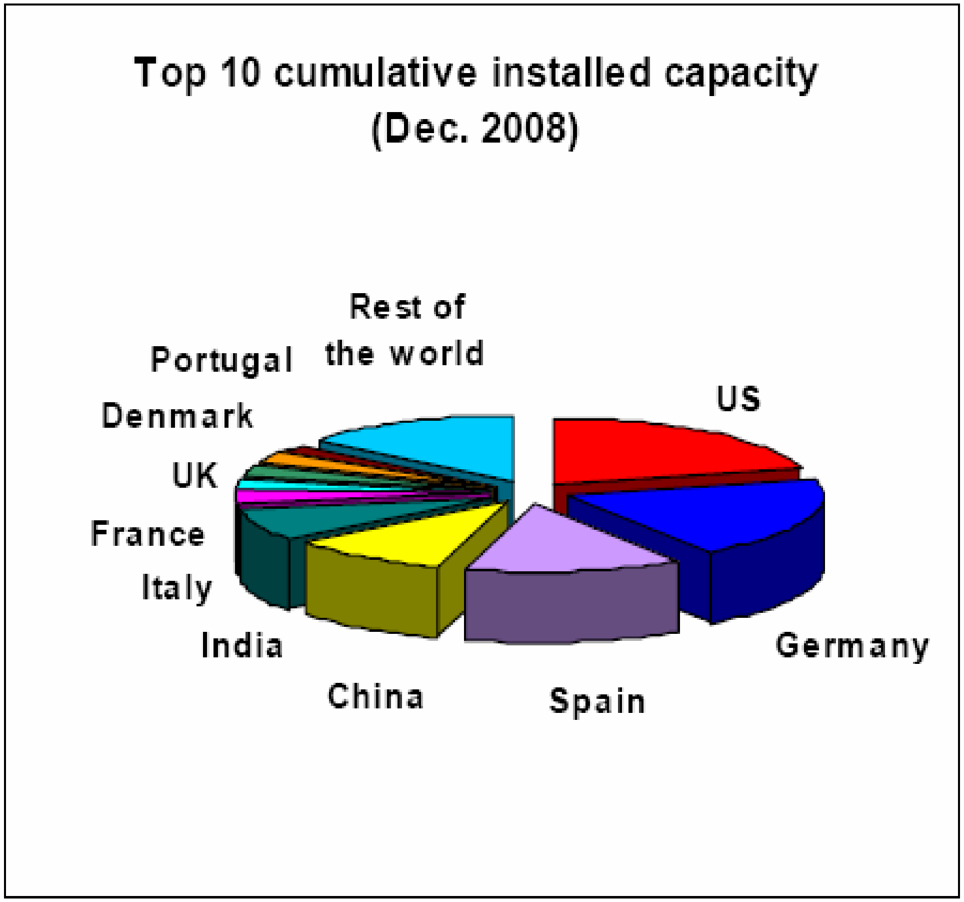
1979: 40 c€/kWh

- Increased Turbine Size
- R&D Advances
- Manufacturing Improvements
- Operating Experience

Wind park in Carnota (A Coruña)

2006:
4 - 7 c€/kWh

Market expansion, dec 2008



Source: GWEC

Top 10 total installed capacity

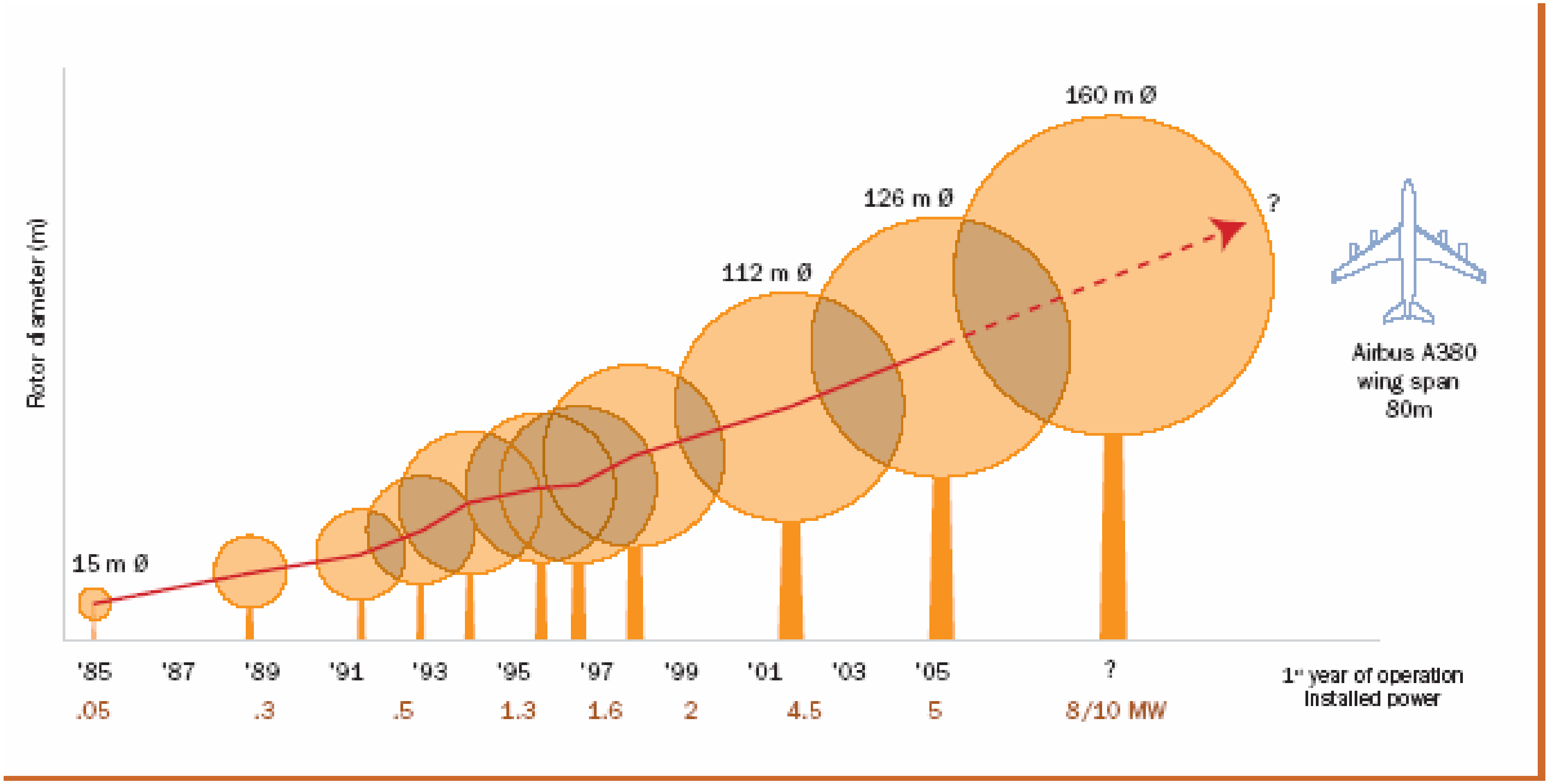
	MW	%
US	25,170	20.8
Germany	23,903	19.8
Spain	16,754	13.9
China	12,210	10.1
India	9,645	8.0
Italy	3,736	3.1
France	3,404	2.8
UK	3,241	2.7
Denmark	3,180	2.6
Portugal	2,862	2.4
Rest of the world	16,686	13.8
Total top 10	**104,104**	**86.2**
World total	**120,791**	**100.0**

Source: GWEC

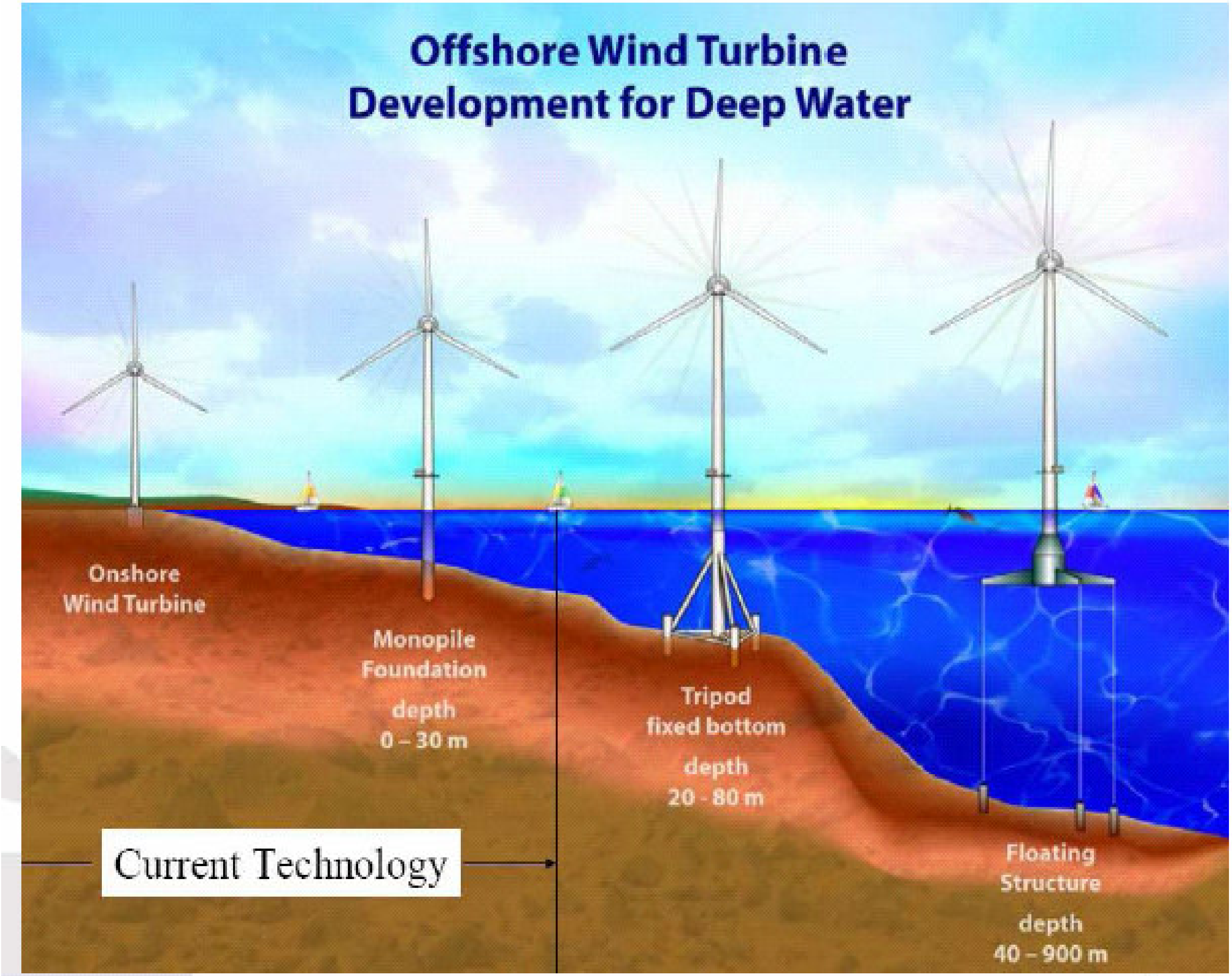
In Spain, wind amounts to 13% of the electricity generated in 2009, REE

Increasing size of the turbines

¿Is there a limit in turbine power?



New developments: Off-Shore technology



Solar energy is plentiful but disperse

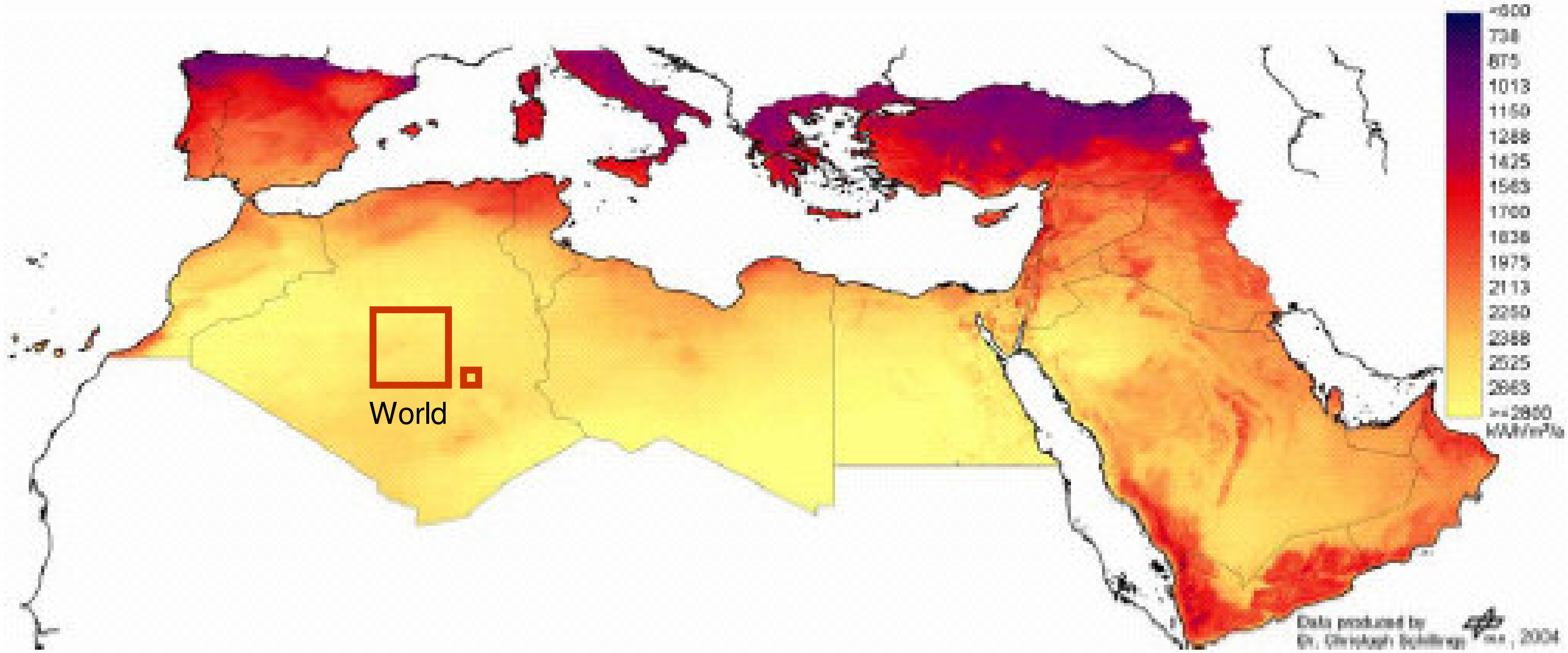
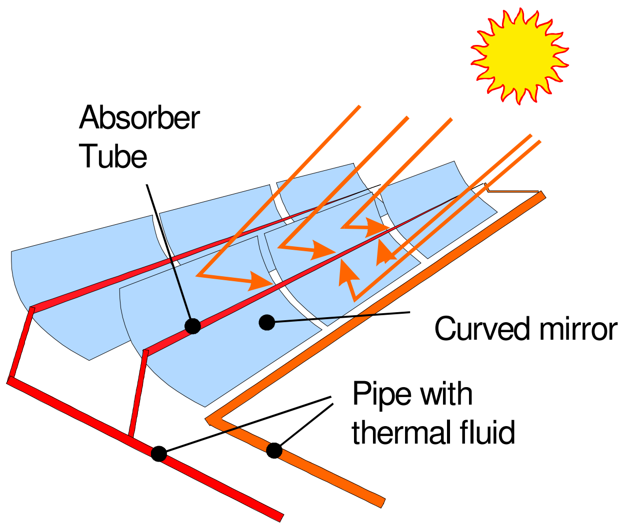
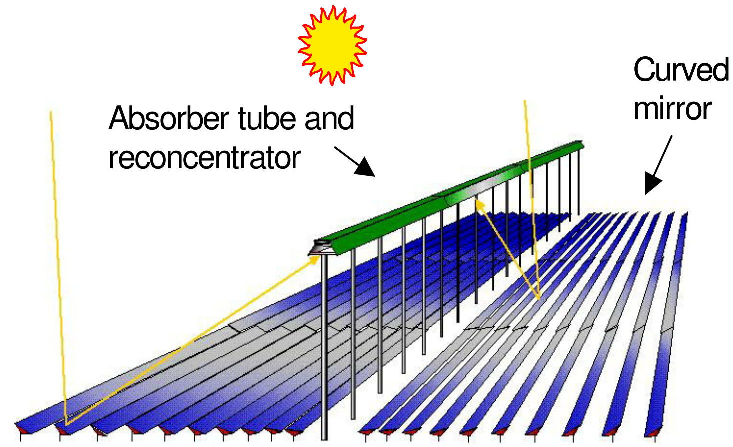


Figure 2-20: Annual direct normal irradiance in kWh/m²/y. In terms of primary energy, the direct solar irradiance in North Africa equals a layer of crude oil of 0.25 meters thickness on the total land surface every year. This gigantic resource is several orders of magnitude larger than the global energy demand. A small part could be harvested by concentrating solar thermal power stations and exported to Europe via High Voltage Direct Current interconnections /MED-CSP 2005/

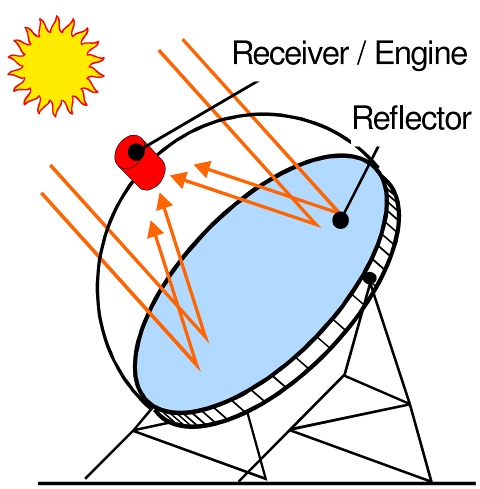
Concentration technologies



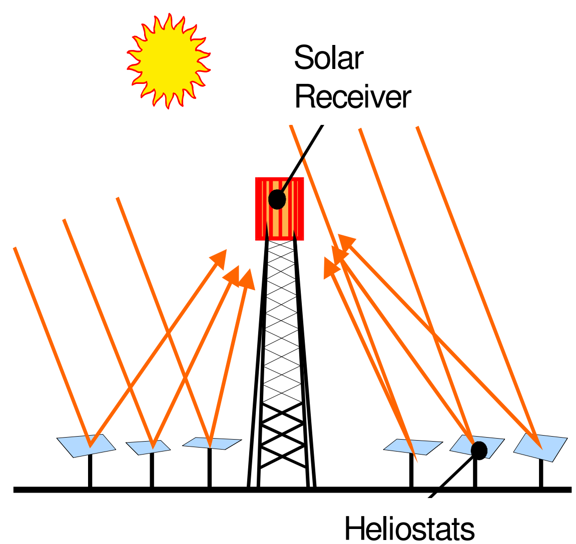
Parabolic Trough



Linear Fresnel



Dish/Engine



Central Receiver

Experimental installations at PSA

The Plataforma Solar de Almería is the world most complete experimental installation in concentration solar energy

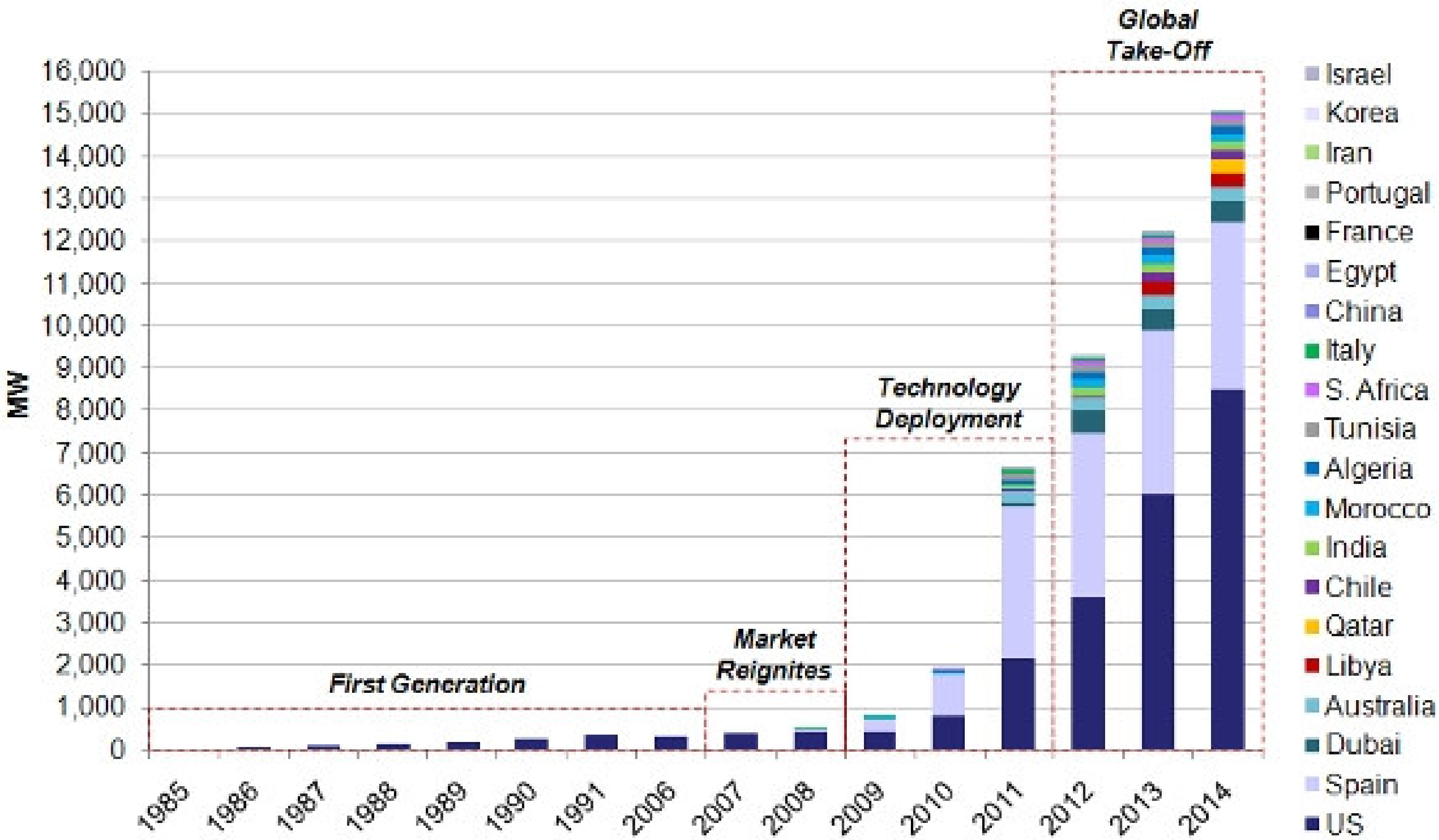
Prospects for CSP

With Spain at the Epicenter, Global Concentrated Solar Power Industry to Reach 25 GW by 2020

Cambridge, Massachusetts, 28 April 2009 - Led by development in Spain and potential in the US, concentrated solar power markets are entering a new growth phase, amidst a tumultuous global economic landscape. The CSP industry is scaling rapidly with 1.2 GW under construction as of April 2009 and another 13.9 GW announced globally through 2014, according to a new study from Emerging Energy Research analyzing global CSP markets and strategies.

Spain is the epicenter of CSP development with 22 projects for 1,037 MW under construction, all of which are projected to come online by the end of 2010. Despite only 75 MW of CSP under construction, the US continues to offer significant opportunity for CSP, with 8.5 GW in the pipeline and scheduled for installation by 2014. Attracted to promised lower costs, US utilities have turned to CSP -- through both Power Purchase Agreements and direct ownership -- to meet their Renewable Portfolio Standard mandates.

The four development steps



Source: Emerging Energy Research, Global Concentrated Solar Power Markets & Strategies, 2009-2020

64 MWe Acciona-Solargenix: Boulder City, NV

Solúcar PS-10, PS-20

PS-10

PS-20

Heliostats:

624 x 121 m2

1255 x 121 "

Tower Height:

120 m

160 m

Power:

11 MWe

20 MWe

Andasol, 2 x 50MWe

Andasol 1: Power Block

2 tanks: Ø = 36 m; h = 14 m

28.500 tm of molten salts

7,5 h storage at 50 MW

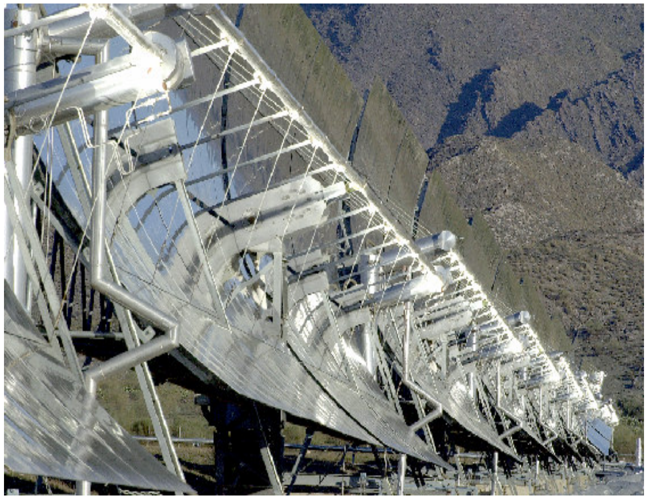
A technological breakthrough: Direct Steam Generation

Environment friendly

Cost reduction (20 %)

Máx. temperature and pressure: 400 ºC and 120 bar.

11 troughs. Opening: 5.76 m; total length: 550 m; Power: 1.8 MW_t

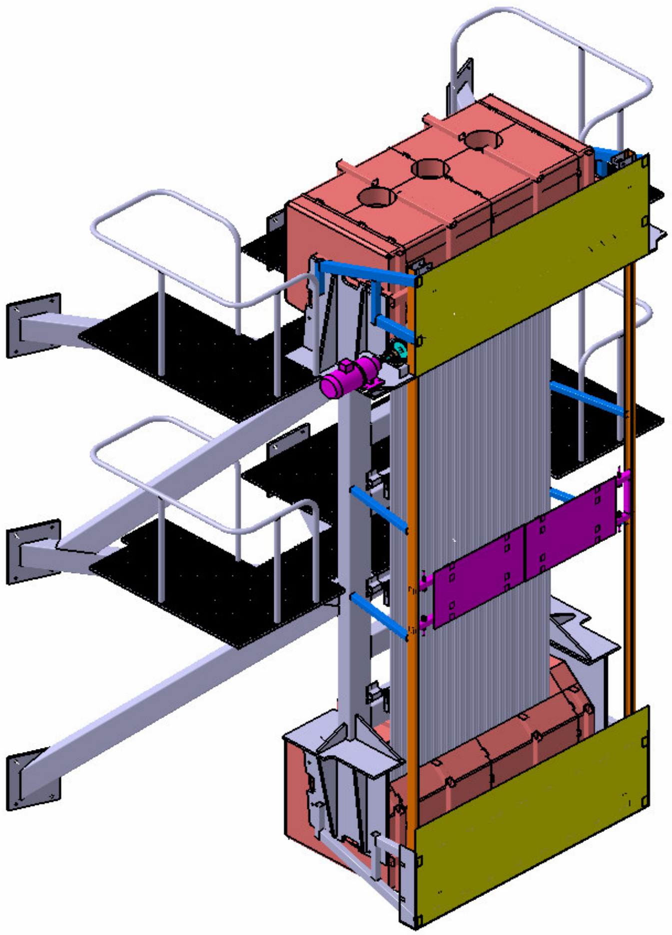


3 Mwe prototype in order to check this technology at PSA.

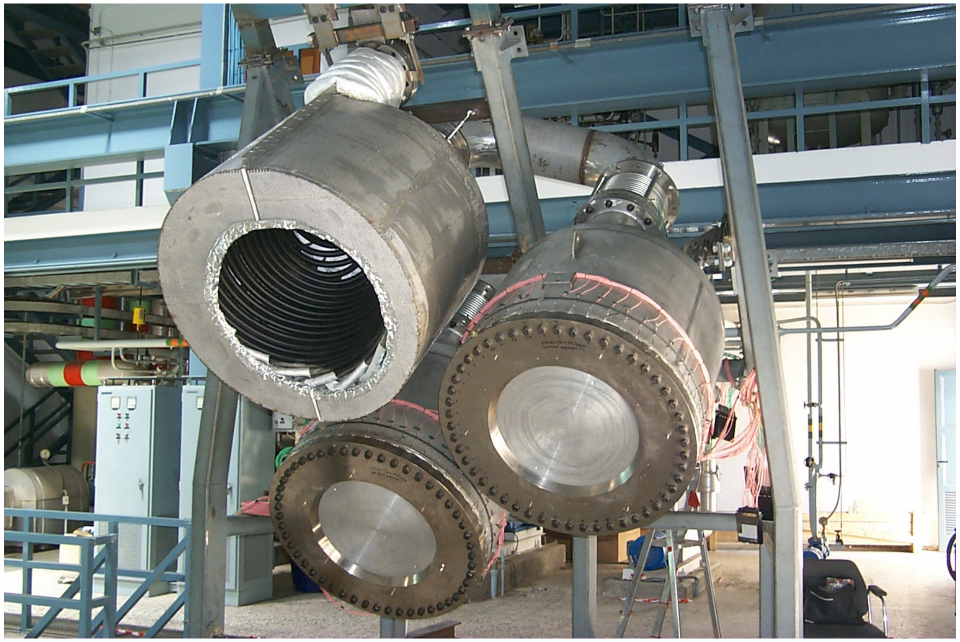
Hopefully completed in 2011

VI FP Project: DISTOR (Heat Storage)

Receptor central



Receptor de sales fundidas instalado en el nivel 70 de la torre CESA-1 (Gemasol)



Receptor con aire a presión (SOLGATE) instalado en la torre CESA 1

Solar electricity from North Africa to Europe

A visionary project:

6.000 MW in 2020

Desertec Project

Ain Beni Mathar

Hassi R'mel

Mediterranean H.V. Networks

Source: M. Geyer (SolarPACES)

Photovoltaics

Distributed

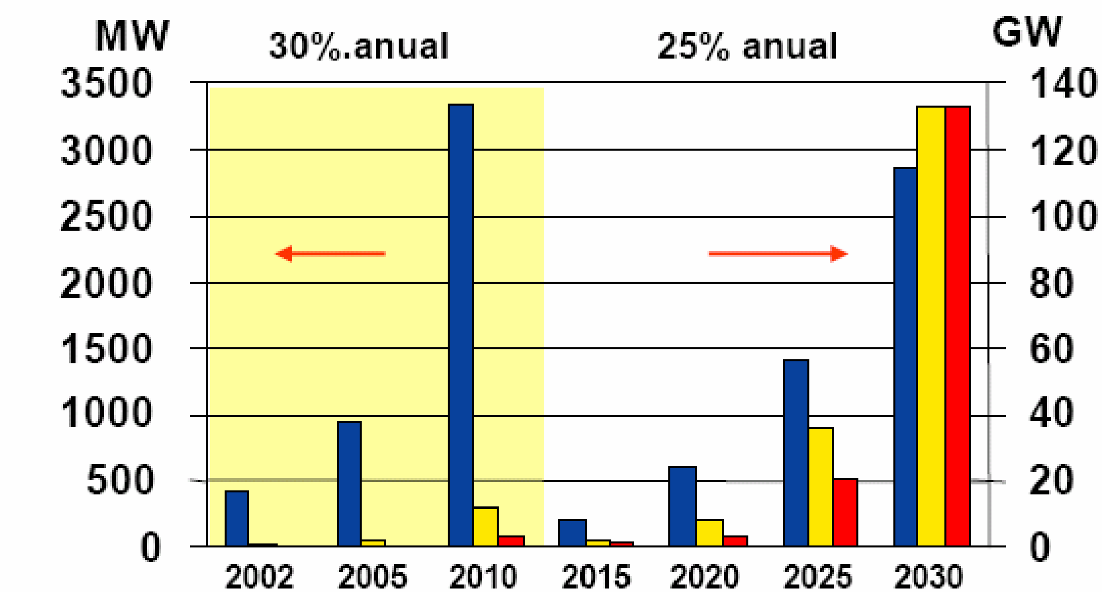
Sustainable

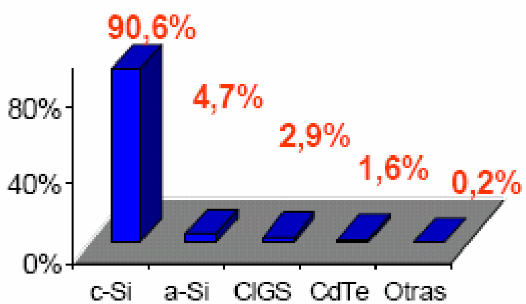
Modular

Expensive

Technology (foreseen) evolution

Producción de módulos fotovoltaicos usando diferentes tecnologías





- ***La industria fotovoltaica hoy en día está basada en la tecnología del silicio. ¿En el futuro?***

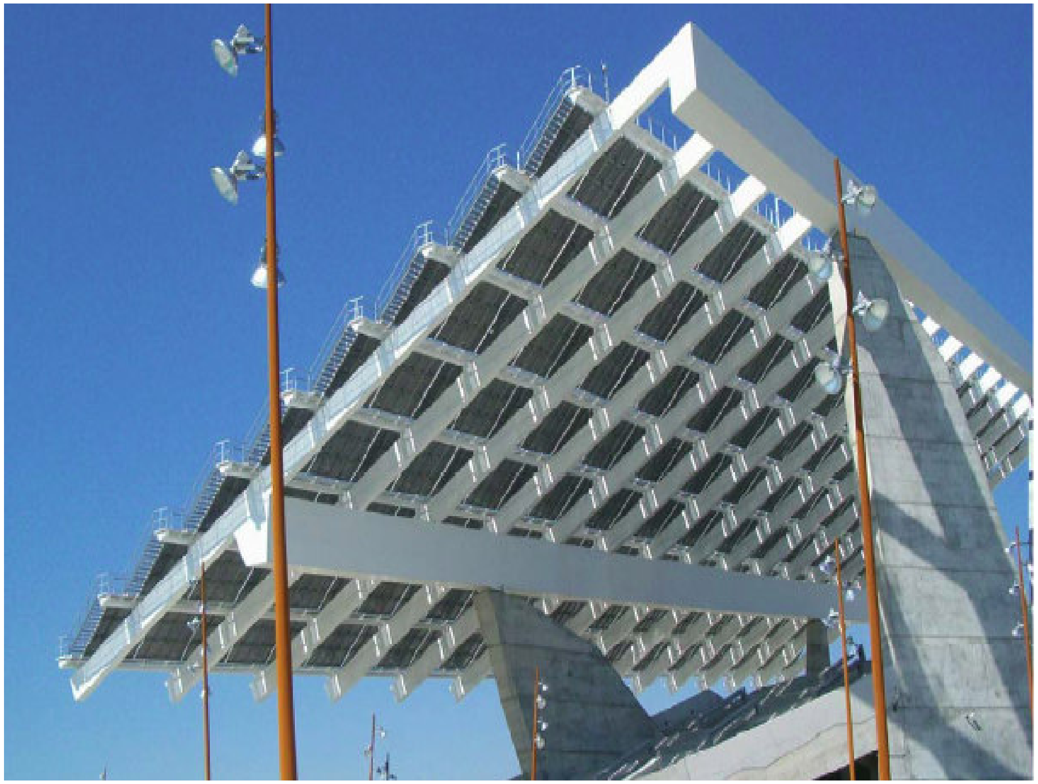
PV: Trends in R + D

✓Concentration

✓Cost reduction in the manufacture of silicon cells

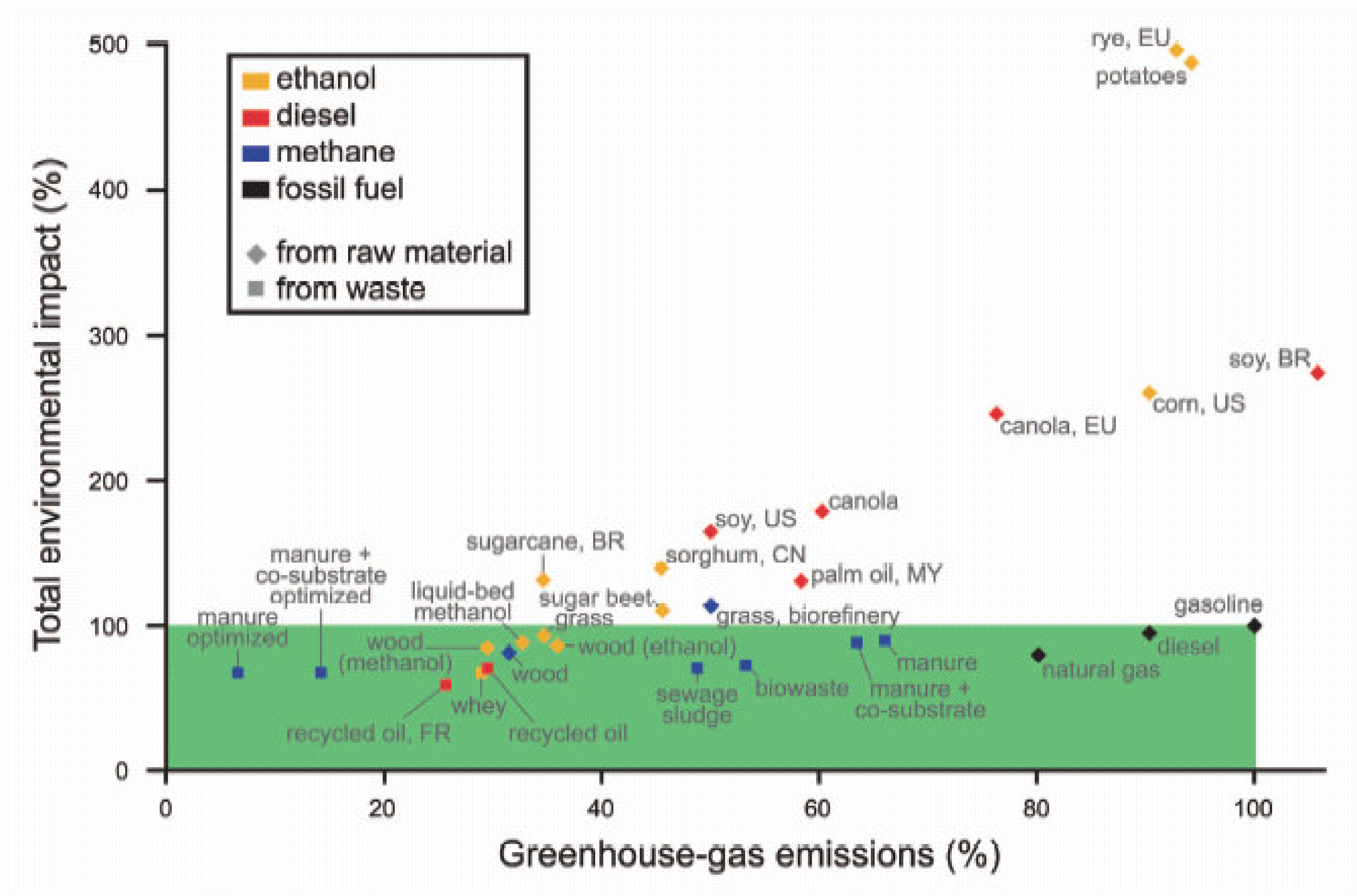
✓Introduction of the thin film technology and hetero-union devices

✓New concepts: polymeric materials or III-V systems , e. g. As-Ga (not without important drawbacks).



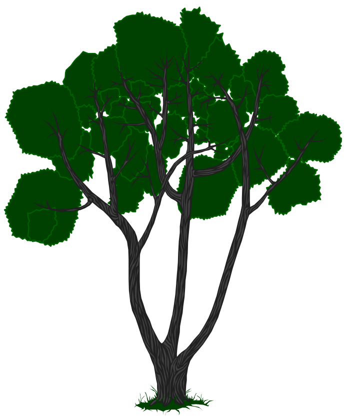
PV in Spain, an unsustainable growth

Biocombustibles vs. Combustibles fósiles



R. Zah *et al.*, *Ökobilanz von Energieprodukten: Ökologische Bewertung von Biotreibstoffen* (Empa, St. Gallen, Switzerland, 2007).

Ethanol from cellulosic biomass



- A more plentiful resource than seeds
- Not related to the food market
- The raw material can be organic waste
- Lower prices

BUT

The biochemical conversion from lignocellulose to ethanol is difficult

At present, there are no commercial plants in operation
(One demonstration plant CIEMAT-IMECAL at Valencia)

The technology is not standard (several possibilities to be explored)

CO_2 capture from coal combustion

PRE-COMBUSTION

Coal gasification and separation of CO_2 before the combustion of syngas (ElCOGAS plant at Puertollano)

POST- COMBUSTION

CO_2 separation after burning the coal (10% to 15%)

OXI-COMBUSTION

Combustion in Oxygen that produces an almost pure CO_2 gas (> 70%)

Carbon capture and sequestration (CCS)

CCS is (nearly) impossible in diffuse sectors (transportation …)

Storage structures:

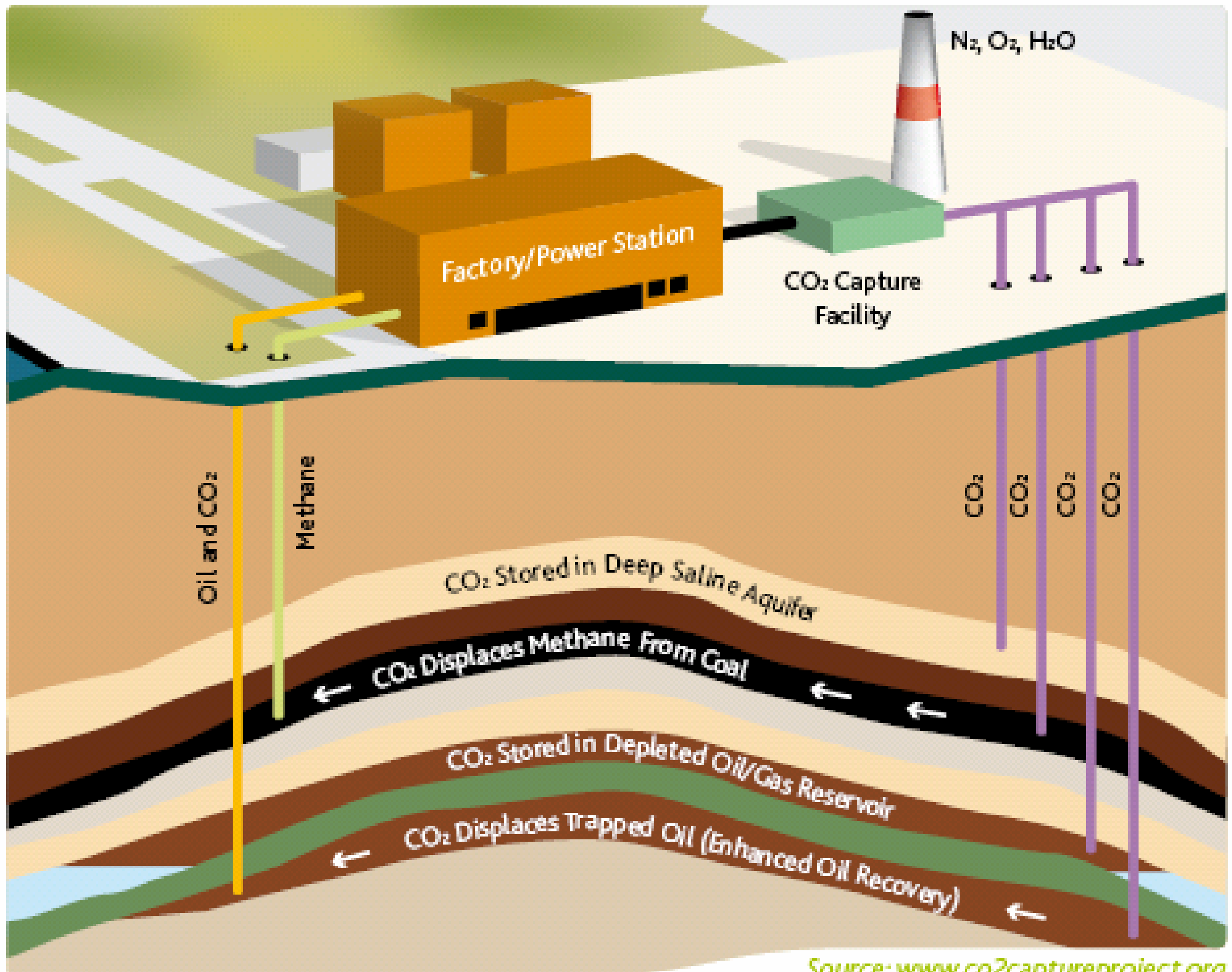
Deep saline aquifers

Depleted Oil/gas fields

Deep unmineable coal beds

Mineral sequestration

CCS always increases the price of electricity



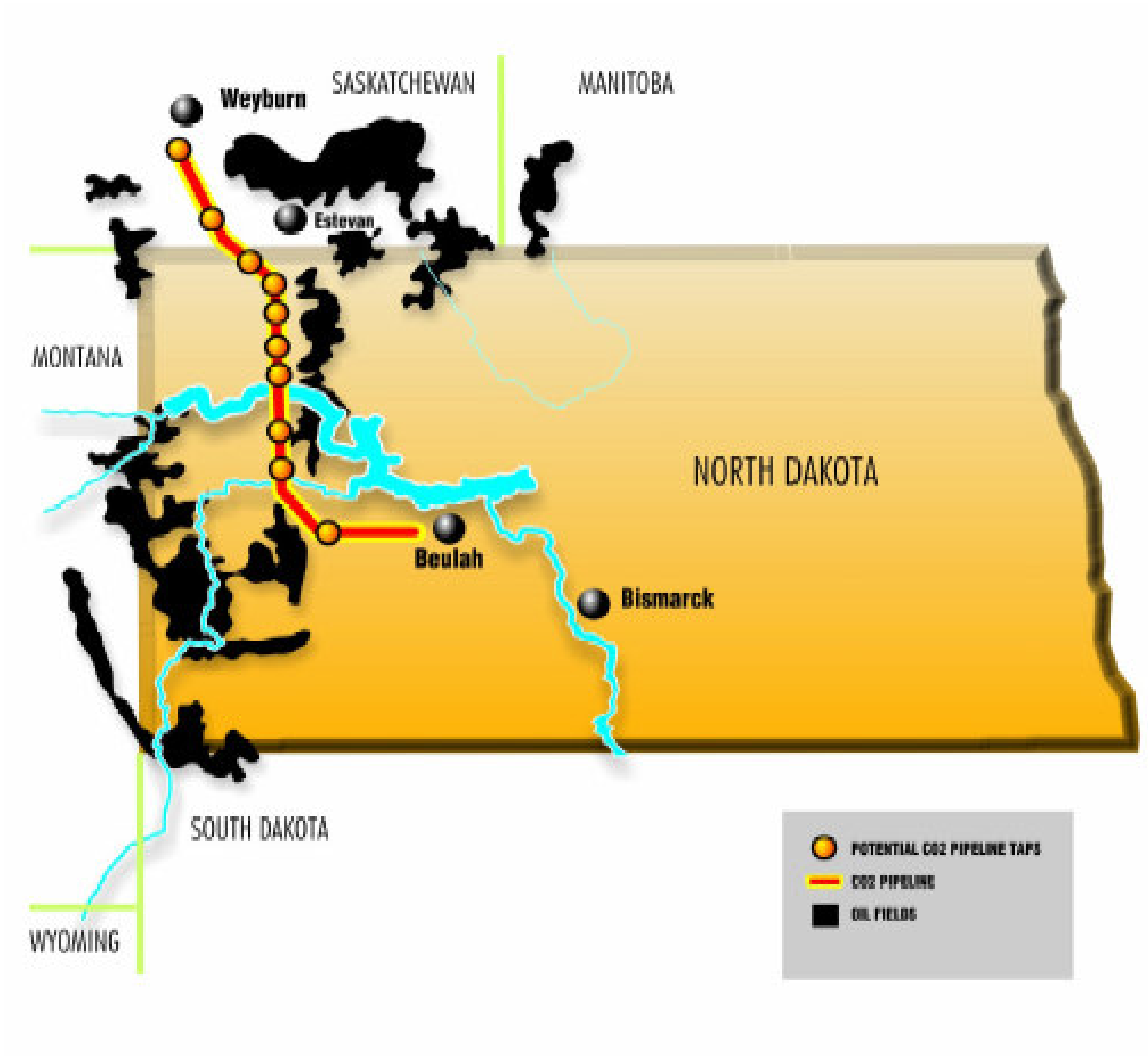
Source: www.co2captureproject.org

There is a wide variety of options for CO_2 underground storage available

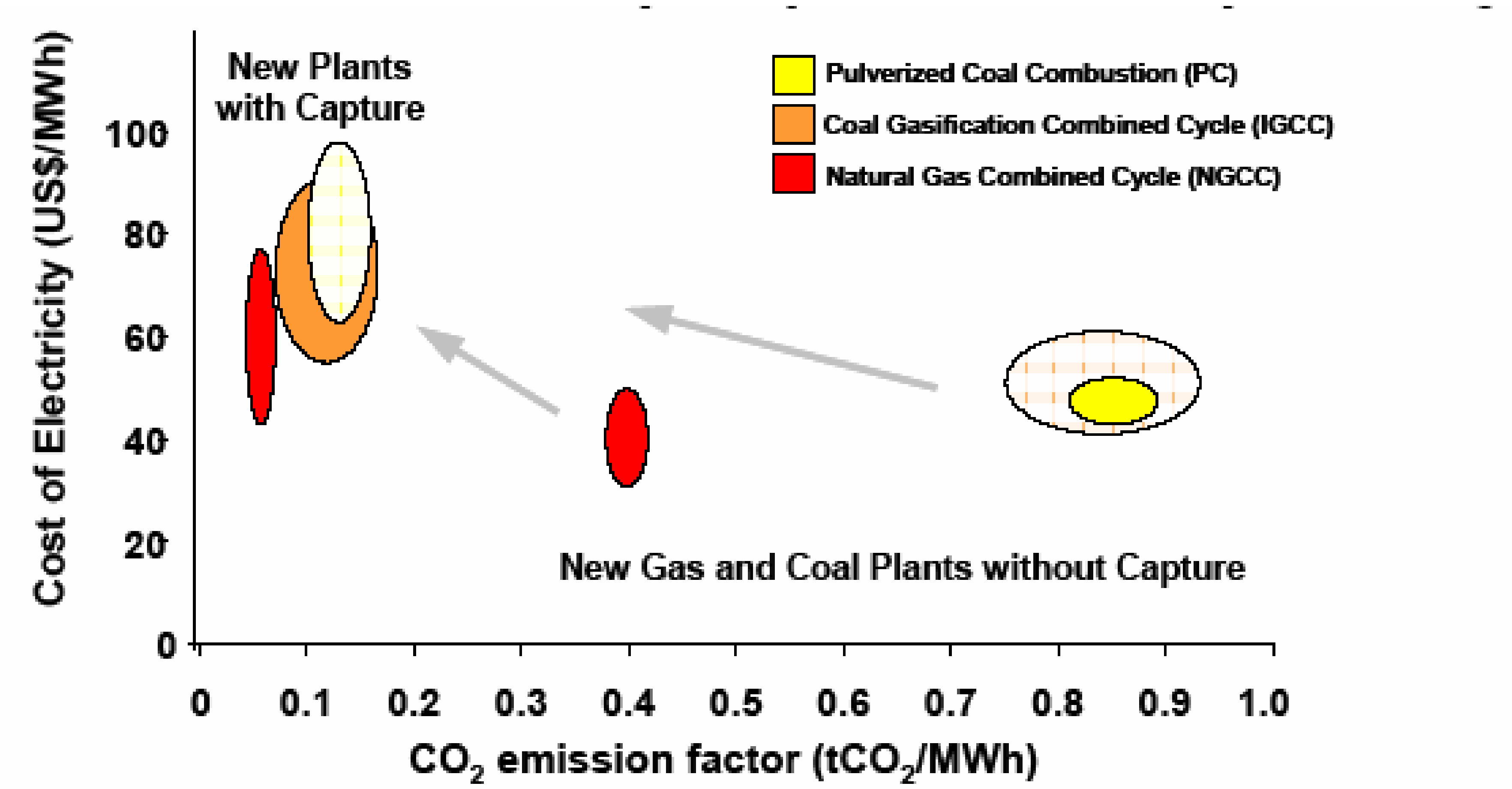
Carbon sequestration and EOR

The Weyburn oil field, in Canada.

The source of CO_2 is a coal gasification plant in North Dakota.



Electricity price increase from CO2 capture



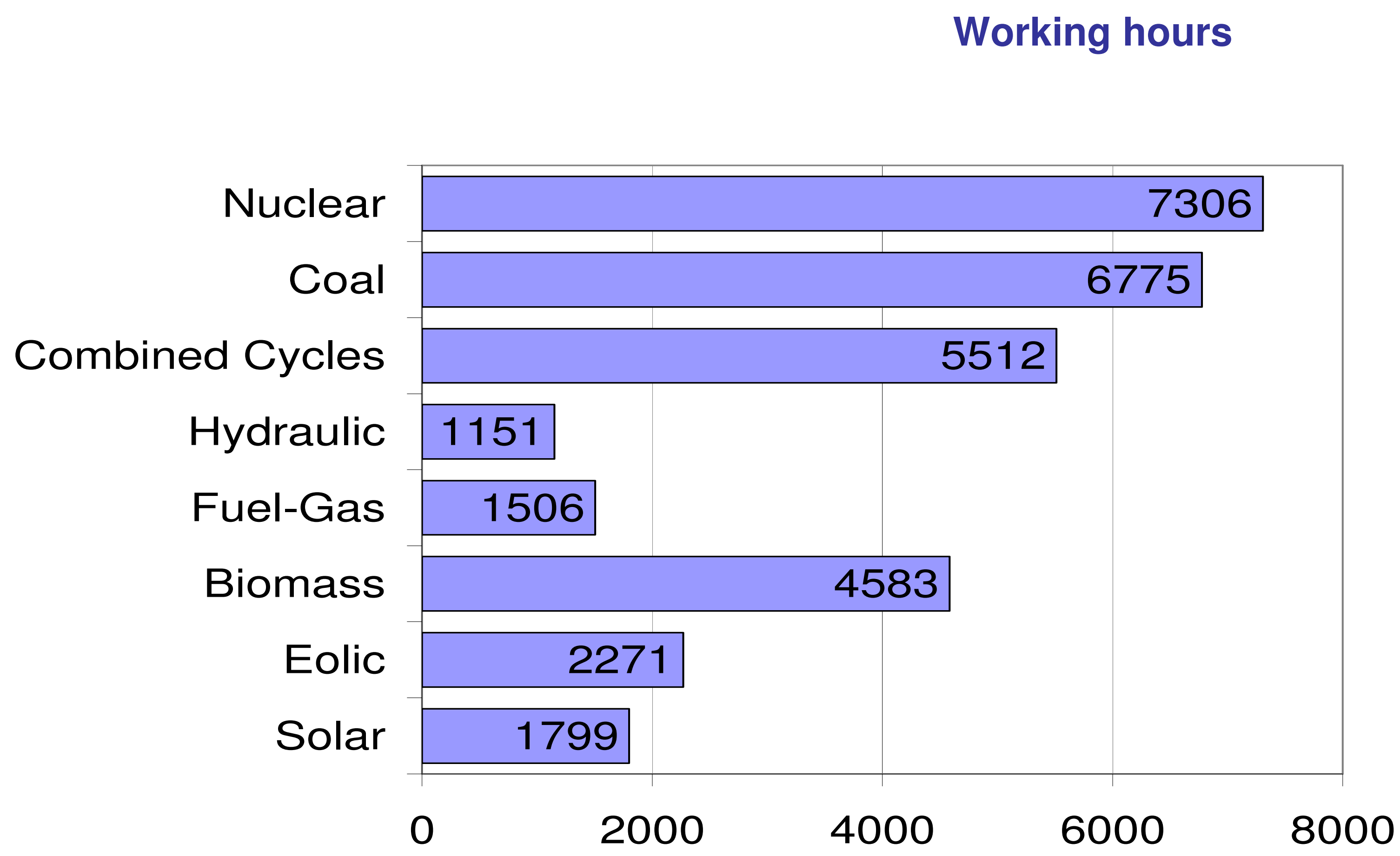
Fuente: IPCC Special Report on Carbon Dioxide Capture and Storage

The cost increase from transport and storage is around 1 / 3 the cost increase from to capture

Nuclear energy: positive features

- Safe (nuclear technology is at the origine of quality control, the pollutant emissions are easy to detect; it is the most controlled and regulated industry sector)
- It does neither emit greenhouse gases (CO2 in particular) nor produces acid rain
- It does not affect the landscape (very compact installations)
- Predictable electricity generation
- It has a positive impact on the high technology industrial sector
- The fluctuations in the fuel price have a small impact on the final electricity price

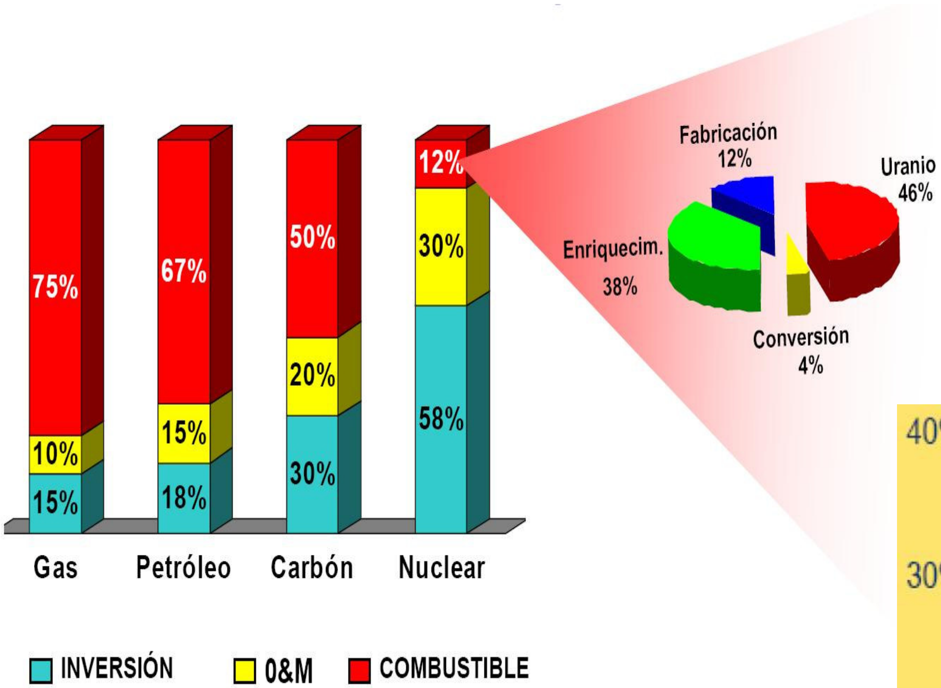
Load factor

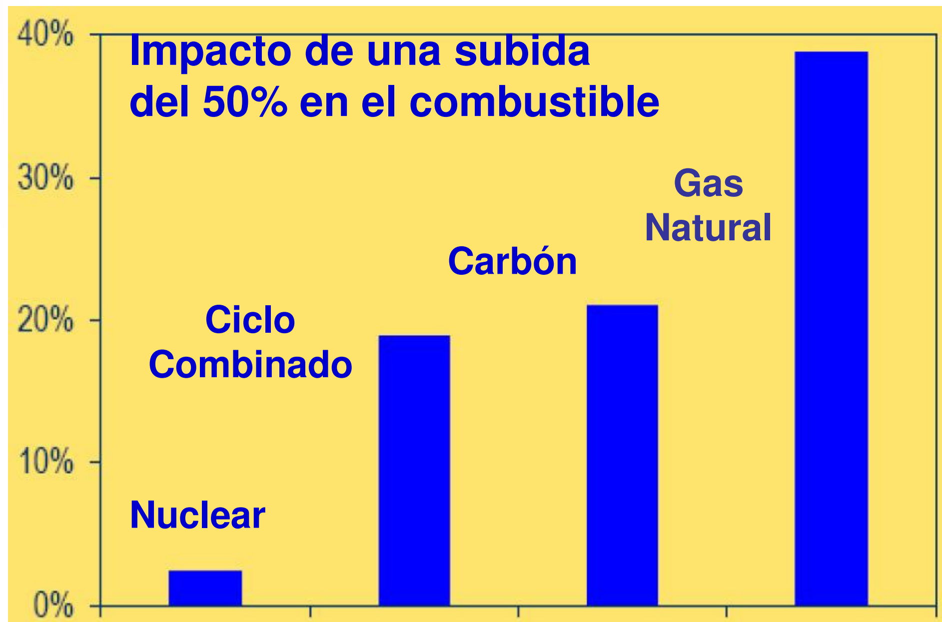


Spain, 2007

The impact of the fuel price

- The cost of Uranium represents between 4% and 6% of the electricity cost
- But it depends a lot on the financial conditions of the initial investment





World Energy Outlook 2006

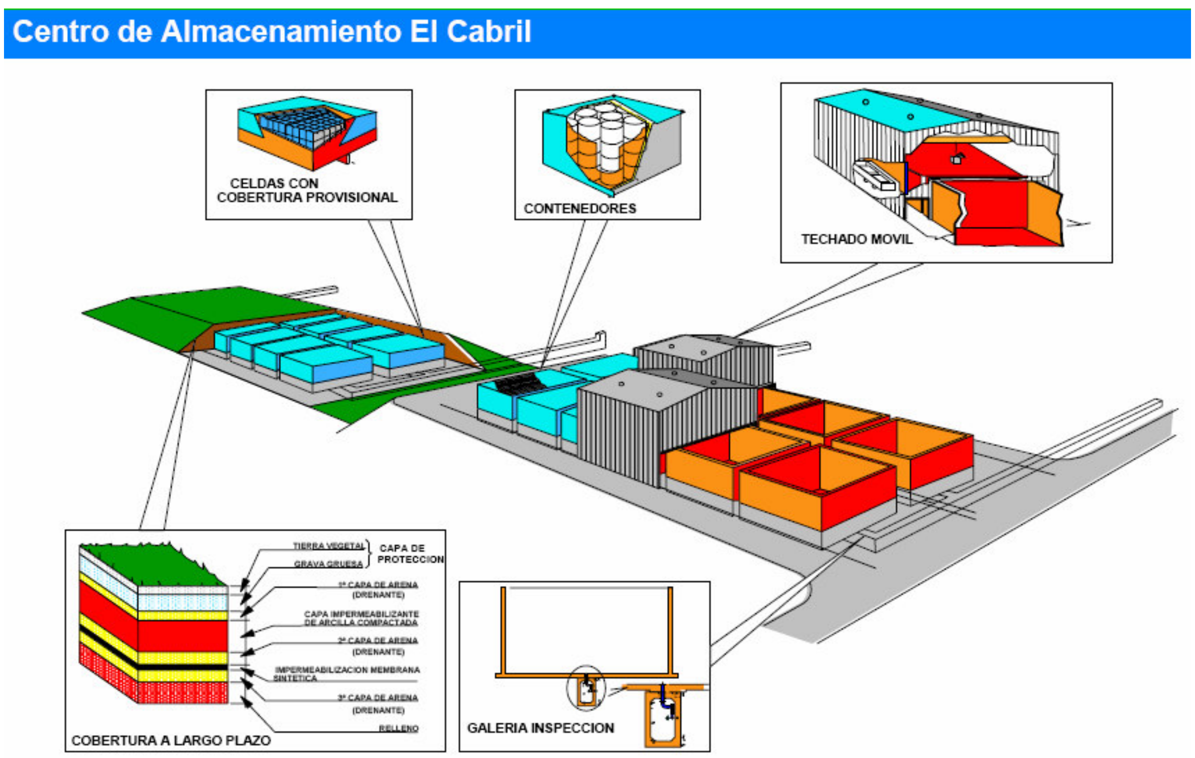
Negative features

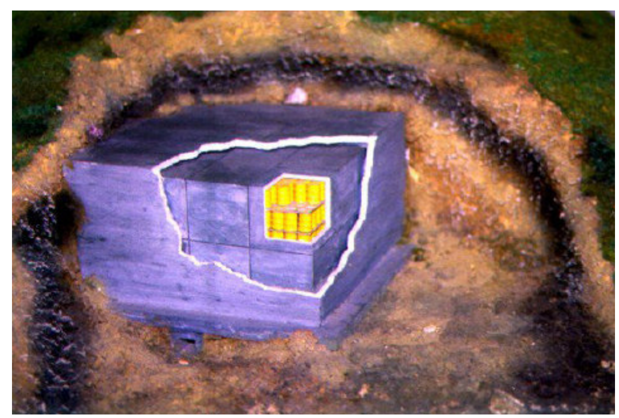
- Needs cooling and produces radioactive waste (in Spain, they amount to 0.1% of all toxic and dangerous effluents)
- Radioactive waste: fission fragment (half-life < 30 years) + very highly radioactive and long half-life actinides
- Risk of accidents (whose public perception is very acute)
- In the long term, and for the thermal reactors (Generations I, II and III), the reserves of Uranium. This will not be the case for fast reactors
- Huge initial investment (Obama initiative)
- Proliferation risk in countries that have a nuclear weapon program
- A certain level of technological development is required to build and operate nuclear installations

Intermediate an low level radioactive waste

In Spain, the nuclear plants generate every year 2.000 tons of ILRW and 160 tons of spent fuel (high level radioactive waste)

The ILRW are sent to El Cabril where they are analysed, compactified and stored for the time they continue to be radioactive (half life < 30 years). EL Cabril is the kind of definitive solution for this kind of waste





High level radioactive waste

It comes mainly from the spent fuel:

- high density in radioactivity,
- very long half life of some of their components (actinides)
- they can be used to build nuclear weapons
- they emit heat that can harm themselves or the environment.

A difficult solution to a complex problem:

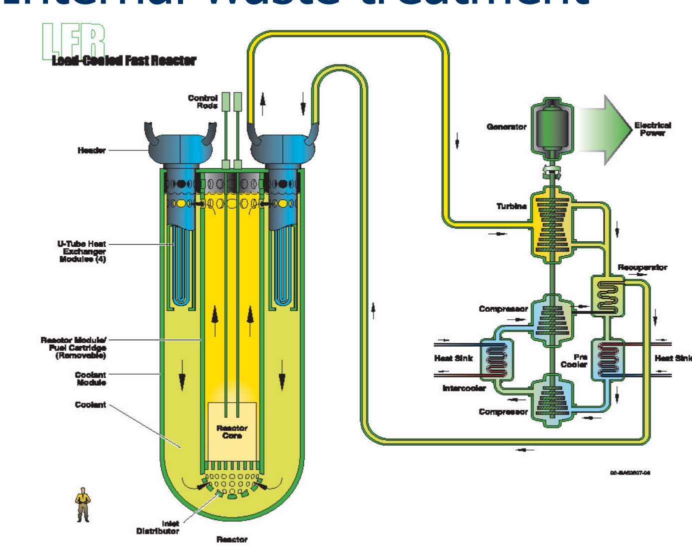
1) Storage in pools in situ (Trillo excepted). Very provisional
2) Centralized Temporary Repositories, around 100 years
3) <u>Reduction by Partition and Transmutation (recycling)</u>
4) Deep Geological Repository (Finland)

The newest generations

Gen III:
High temperature (efic. 33 → 48 %)
Fuel containing Pu and a very high burning degree

The safety level is improved through passive response measurements (mainly physical phenomena independent of operators and devices).

Gen IV:
Fast neutron reactors
235U (0.7%) → 238U (99.3%)
Very high temperature reactors
Re-use of Pu
Possible re-use of minor actinides
Possibility of implementing the Thorium cycle
Intrinsic Safety
Internal waste treatment



Some conclusions

We have to face a (near) future of energetic and environmental diffciulties

The main goal has to be:

Decrease the dependency on carbon based energy sources

Increase renewables and nuclear

Trigger a drastic change in our energy use habits

In the short term, clean energy is more expensive. So, public support and public education are needed

Deal with the other side of unsustainability: the public attitude in energy matters

¡¡Muchas Gracias!!

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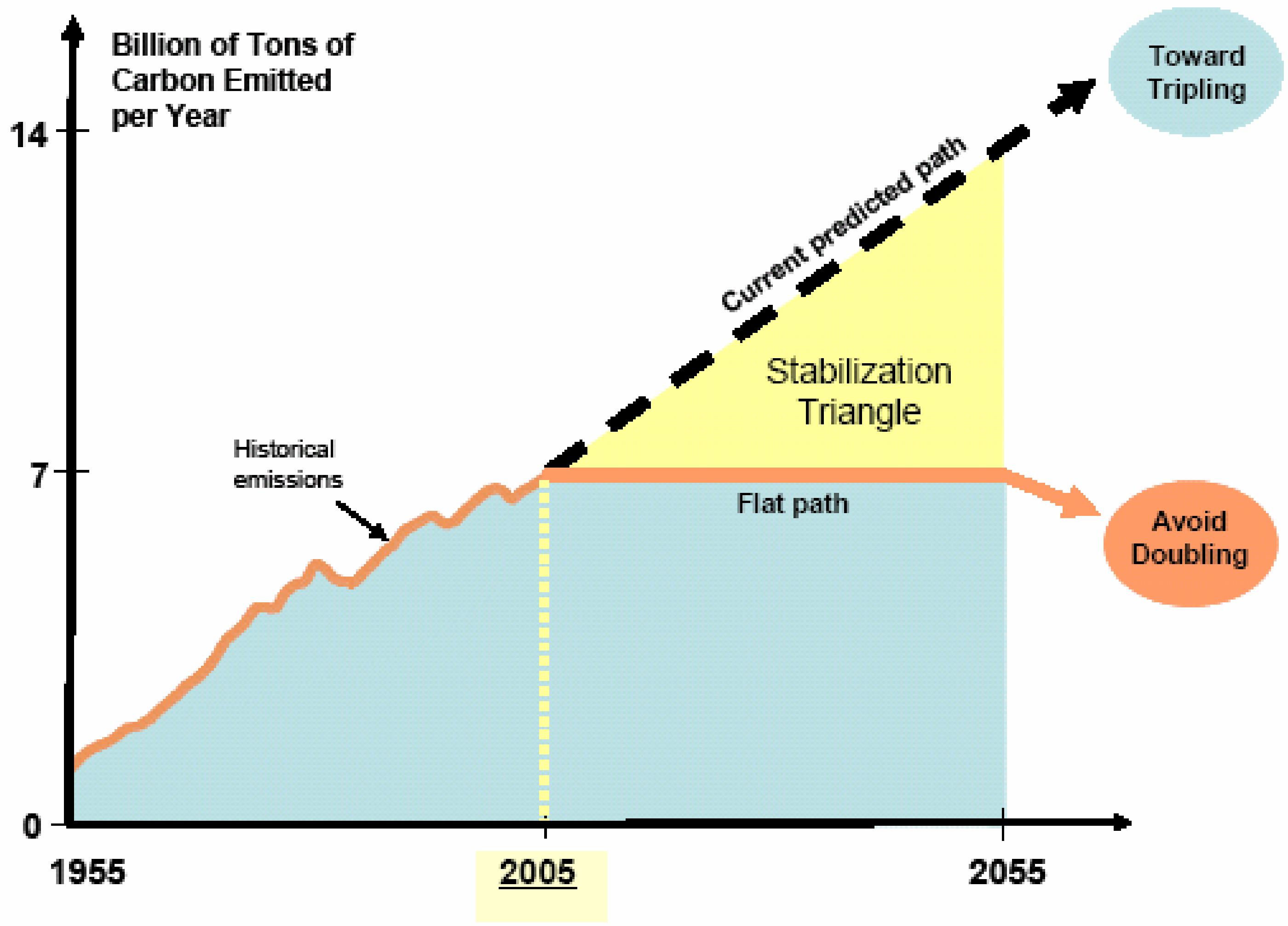
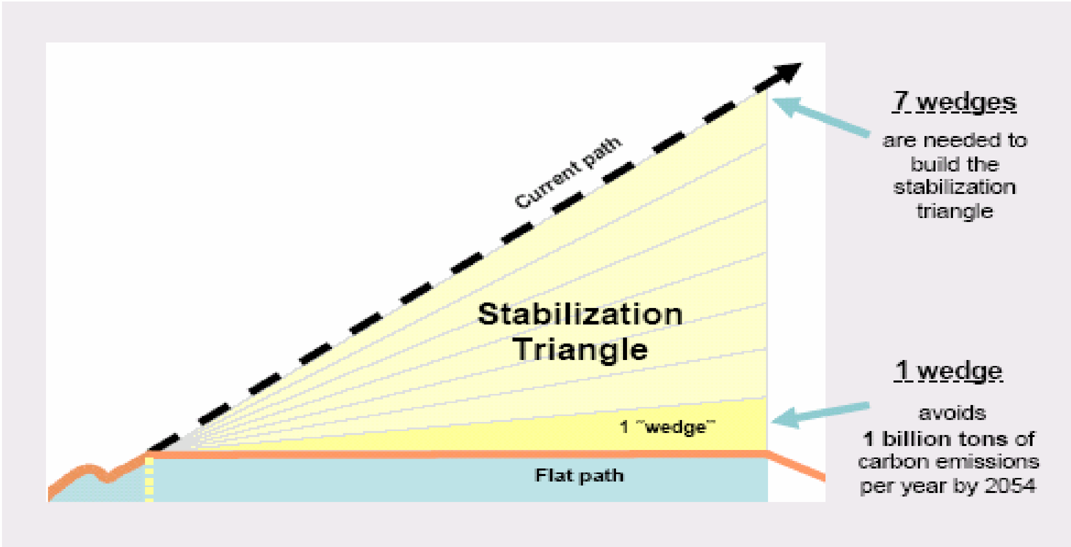
The task of stabilizing CO2 emissions



S. Pacala, R. Socolow, 2004

Is a huge task

Examples of 1 GtC per year “wedges”:



Increasing the efficiency of 2.000 Mill vehicles from 12 km/l to 24 km/l

Doubling the efficiency of all the coal plants (from 32 % to 60 %)

Introducing CCS in 800 coal GW (1060 GW in 1999): 3.500 Sleipners

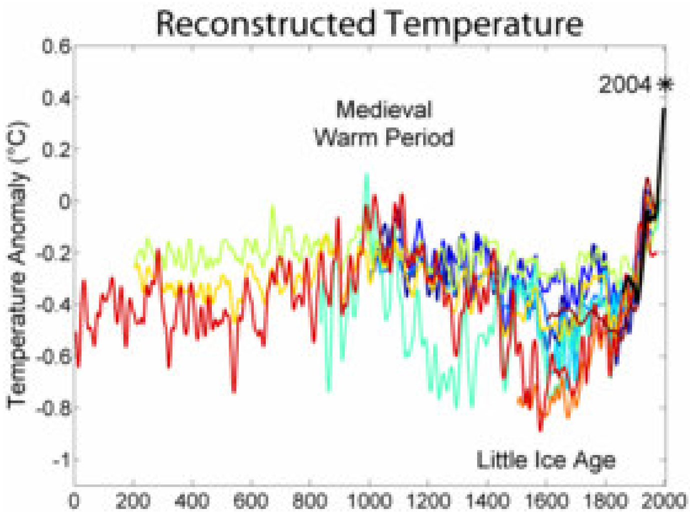
Adding 700 nuclear GW (doubling the present nuclear park)

Adding 2.000 wind GW (x 20 the present capacity, 30 MHa)

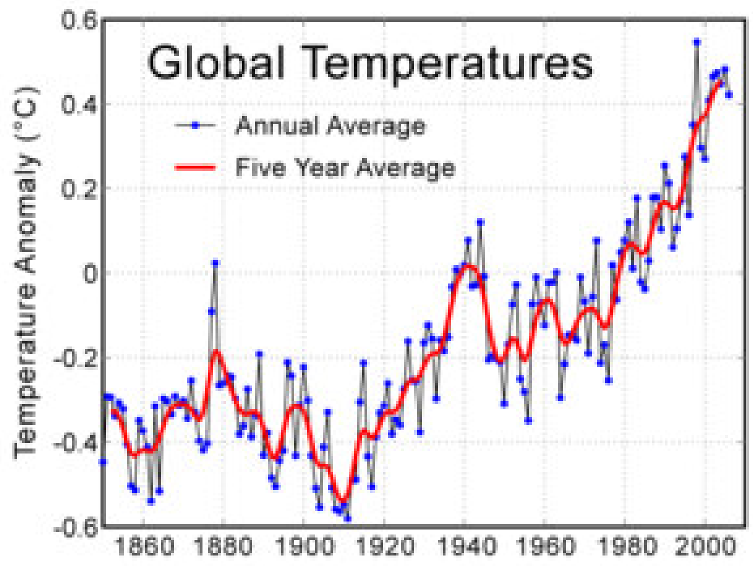
Adding 2.000 solar GW (x 400 the present capacity, 5 MHa)

Multiplying by 100 the ethanol Brasilian production (250 MHa, 1/6 world cropland)

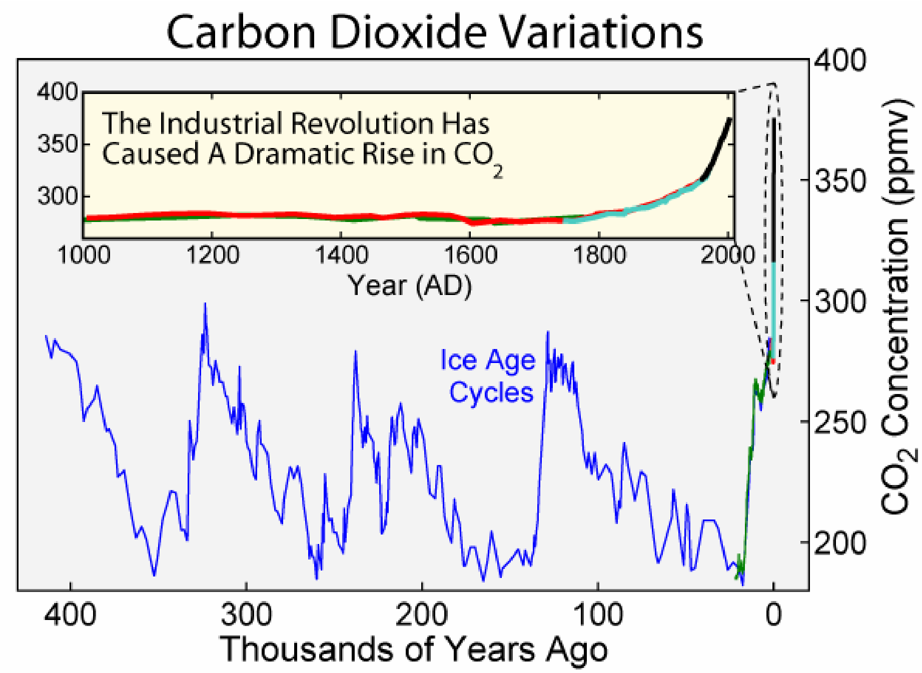
Clima y CO_2



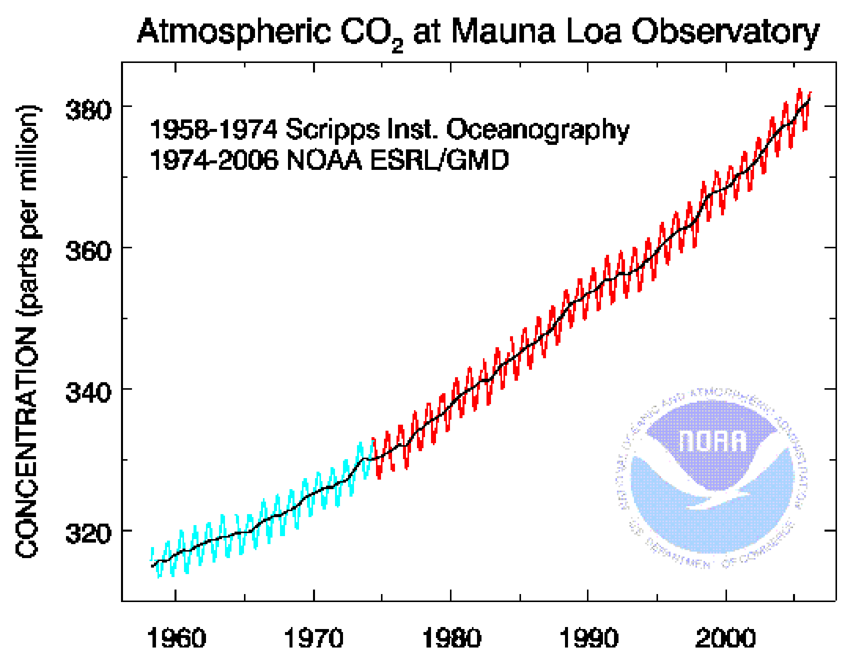
Reconstructed Temperature
Temperature Anomaly (°C)
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
2004
Medieval
Warm Period
Little Ice Age
0 200 400 600 800 1000 1200 1400 1600 1800 2000



Global Temperatures
Annual Average
Five Year Average
Temperature Anomaly (°C)
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
1860 1880 1900 1920 1940 1960 1980 2000



Carbon Dioxide Variations
The Industrial Revolution Has
Caused A Dramatic Rise in CO2
400
350
300
1000 1200 1400 1600 1800 2000
Year (AD)
Ice Age
Cycles
CO2 Concentration (ppmv)
400
350
300
250
200
400 300 200 100 0
Thousands of Years Ago



Atmospheric CO2 at Mauna Loa Observatory
1958-1974 Scripps Inst. Oceanography
1974-2006 NOAA ESRL/GMD
CONCENTRATION (parts per million)
380
360
340
320
1960 1970 1980 1990 2000