Curbing the addiction to fossil fuels: the great transformation

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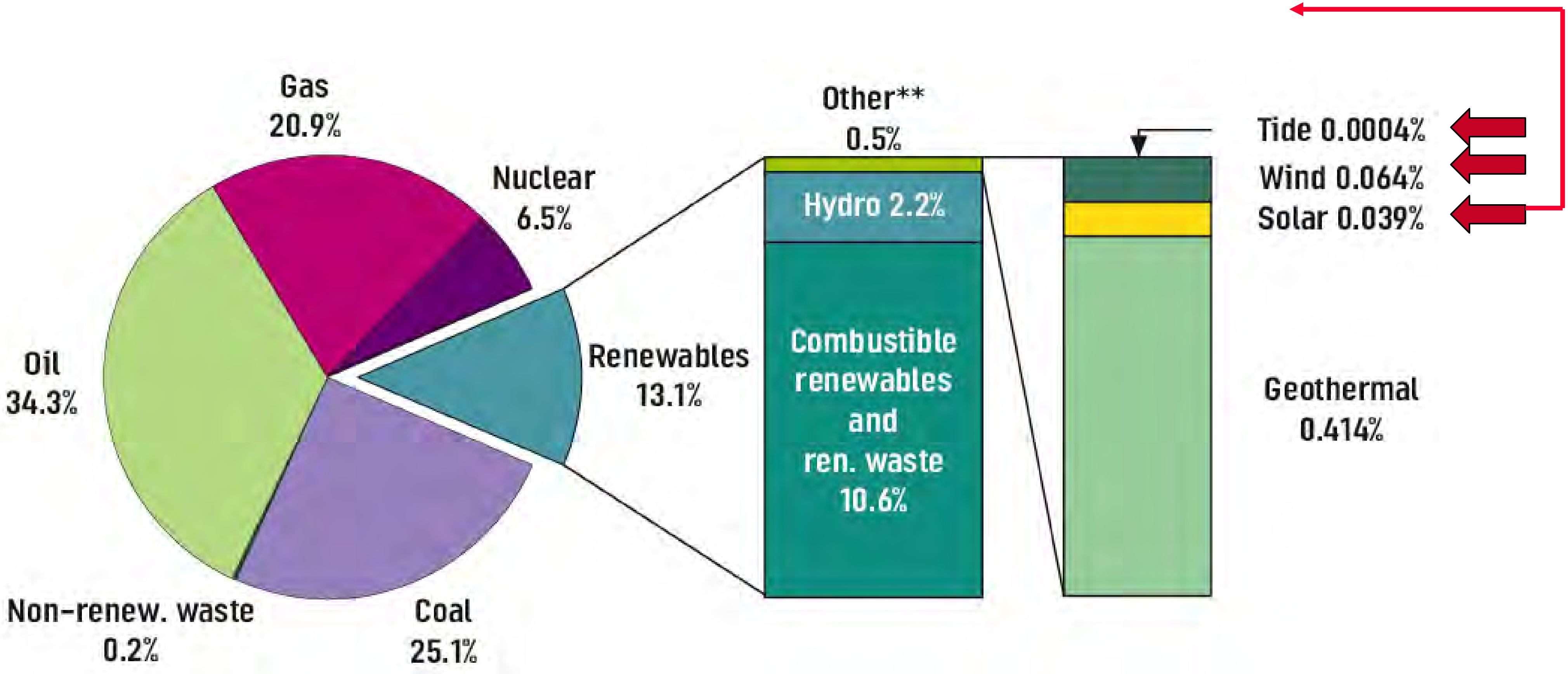
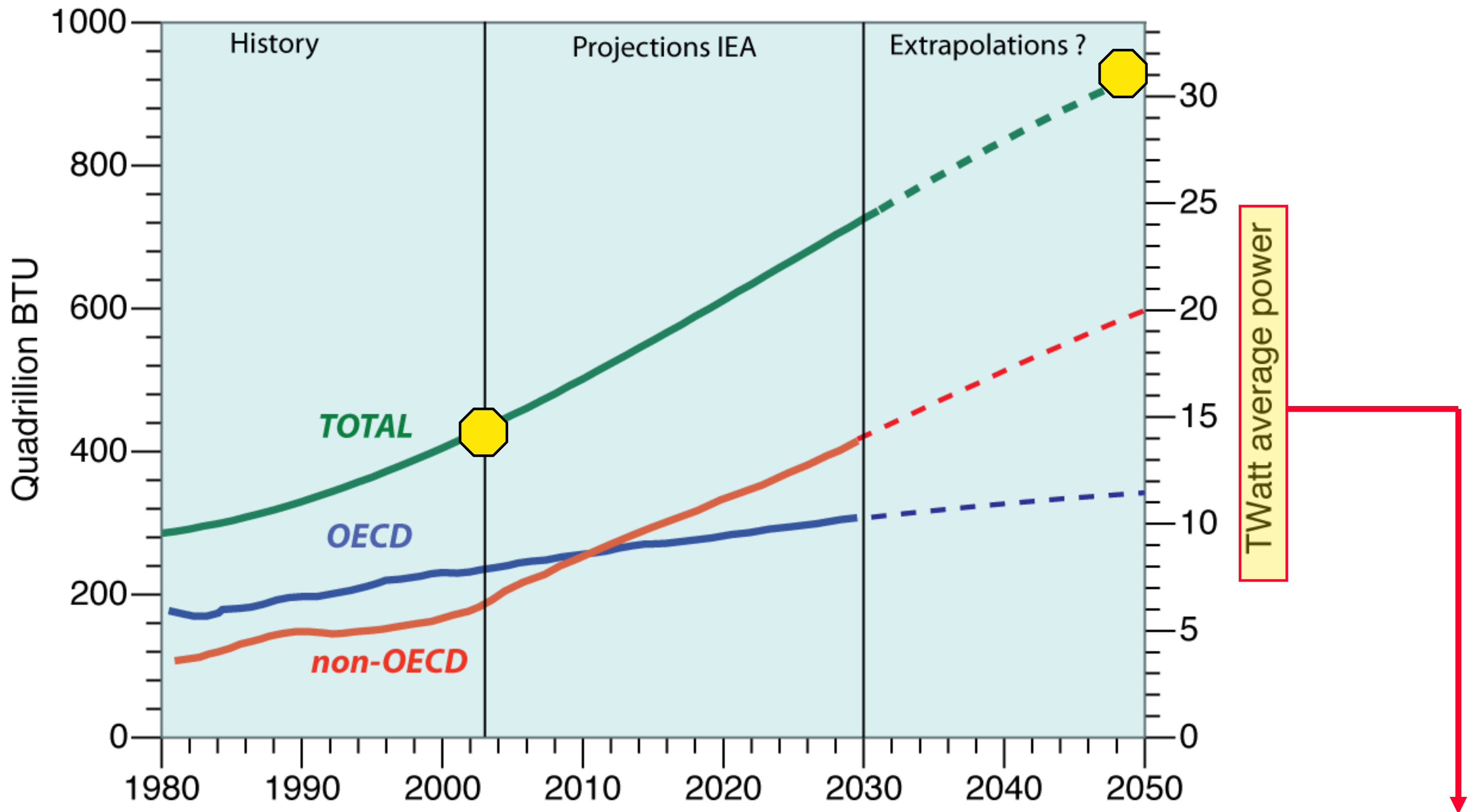
The future of energy

- The forecasts over the next several decades of leading Agencies, like for instance the International Energy Agency, foresee agreement with a continued increase of energy at the rate of 2%/year, for a population increment of 1%/year.
- The dominance of fossils is expected to continue, with the corresponding enhanced greenhouse emissions, a stable nuclear energy production and a rather small increase of renewables.
- In 2005 the fossil fuel dependence was 81% for the world, 82% for China and 88% for the United States.
- No doubt our appetite for power grows with time, even if 1% per year decline in energy intensity may be assumed, based on the historic trend.

2004 fuel shares



Primary total world's Energy



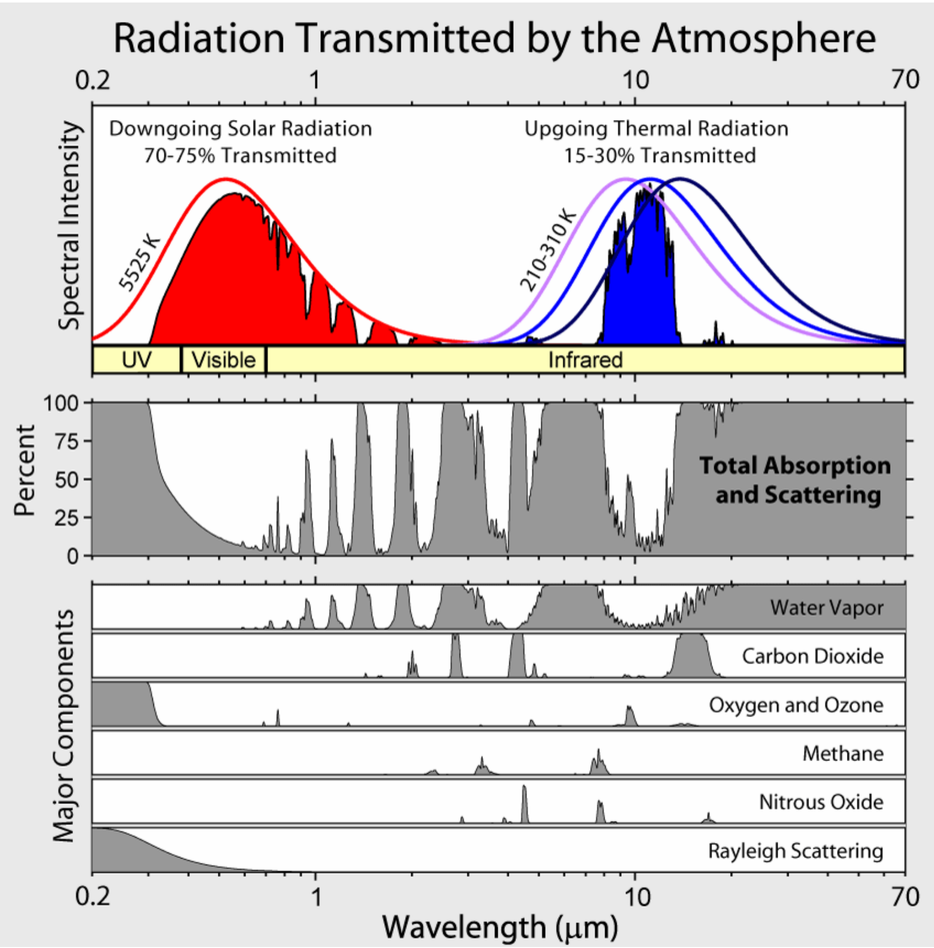
- Today the energy consumption is equivalent to the one of an "engine" with an average power of 15 TWatt
- Predictions of "business as usual" indicate that energy may increase to as much as 30-35 TWatt by 2050

Fossil reserves are huge and readily available

- Oil and Natural gas are expected to reach their limits sooner or later, due to an increase of consumption and the progressive reduction of easily available resources.
- *However there is plenty of cheap and readily available Coal*. The known reserves are about 5000 Gton and it could be up to 20'000 Gton if also less noble forms of supply are used.
- Coal or Shales can for instance be easily converted into liquids (Methanol, Ethanol and so on) to replace Oil and into a gas (Syngas and so on) to replace Natural Gas.
- *There are sufficient amounts of Carbon in its various forms to produce cheap and abundant energy for many centuries at several times the present level of energy consumption*.
- There is no *technical* reason why, once reduced the local pollutions, this huge amounts of Coal may not be eventually fully burnt………

A new term in the balance: climatic forcing

- It is therefore because of our conviction in the antropogenic gas emissions and of their expected, dramatic effects on the climate of earth that our reason may justify curbing an otherwise smoothly growing combustion of fossils.



- The whole Industrial Revolution has been driven by cheap and abundant fossil energies .
- Any major change of such a magnitude requires an immense innovation in the habits of us all.
- Even if very serious and compelling, is very difficult to implement a "carbon free" option without major oppositions.

An Example

Photos taken of Riggs Glacier in Alaska's Glacier Bay National Park in 1941 and in 2004 show that most of the 610 meter thick glacier has disappeared.

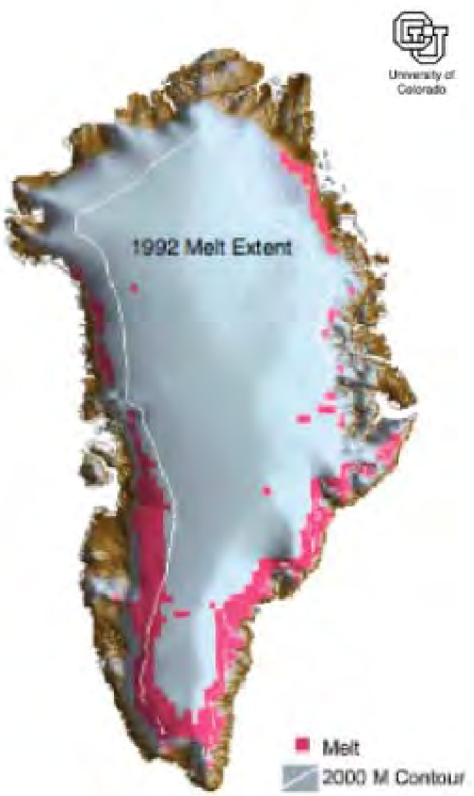
Upsala Glacier, Patagonia

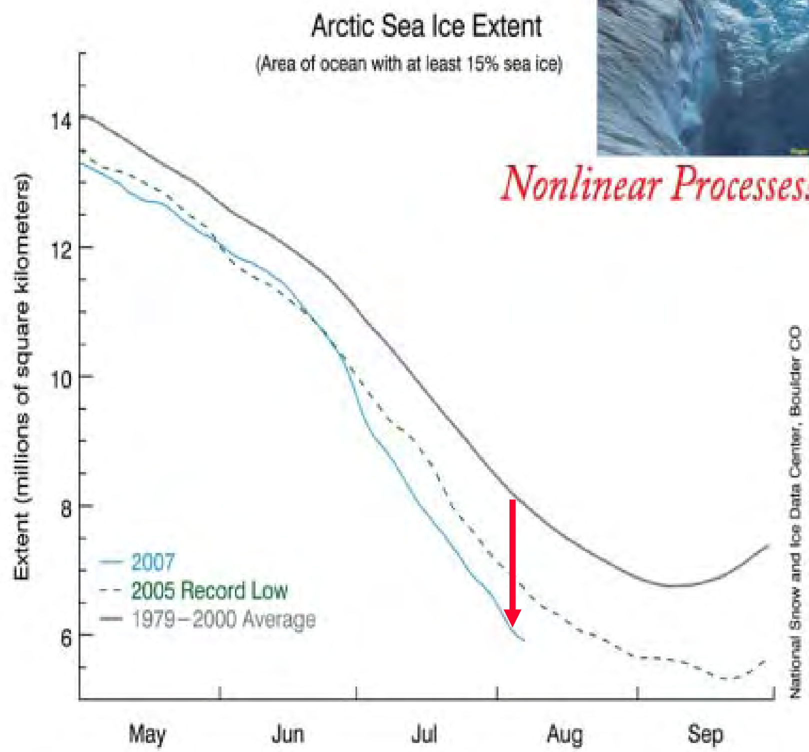
1928

Upsala Glacier, Patagonia

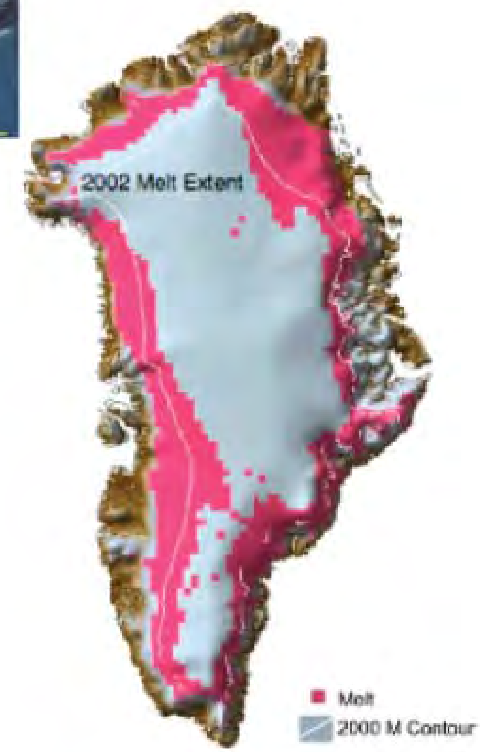
2004

Response of Greenland Ice Sheet to climatic forcing





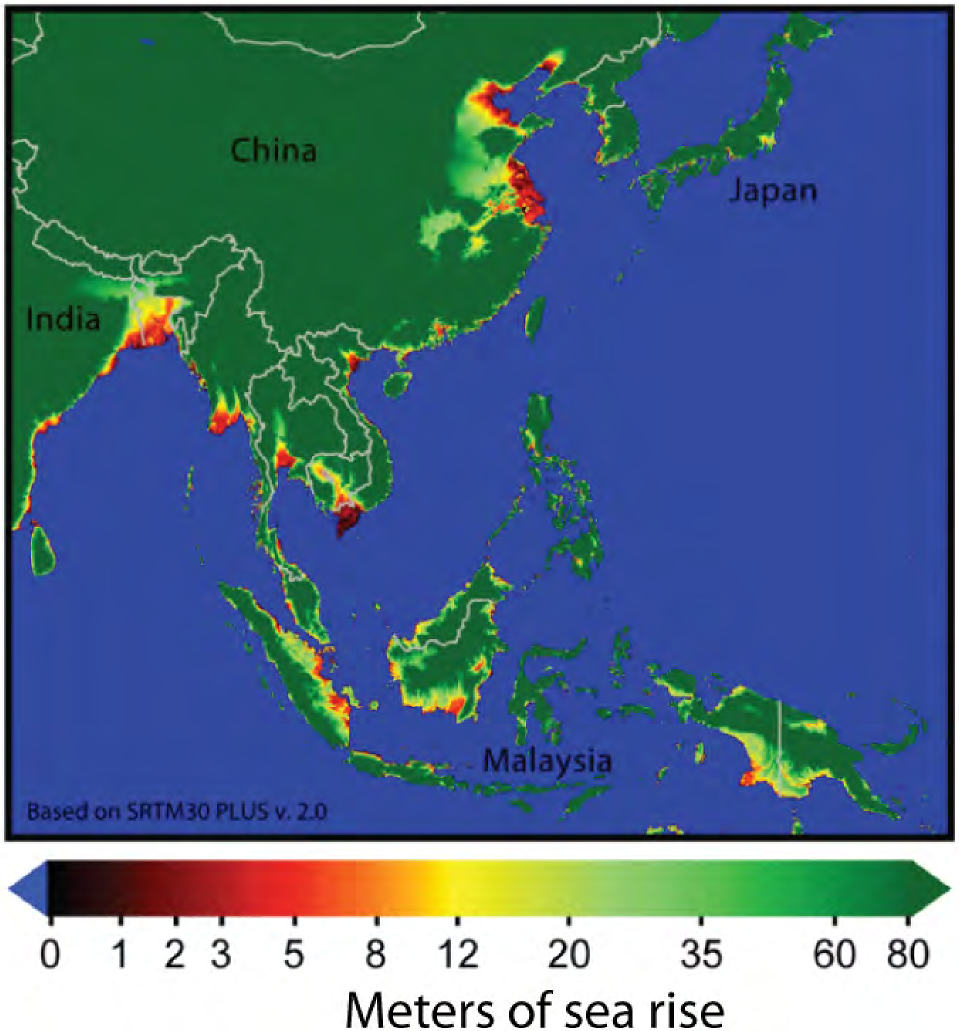
Nonlinear Processes!



Greenland ice sheet melt area has increased on average by 16% from 1979 to 2002, at a rate of about 0.7%/year.

Rise of oceans: how large ?

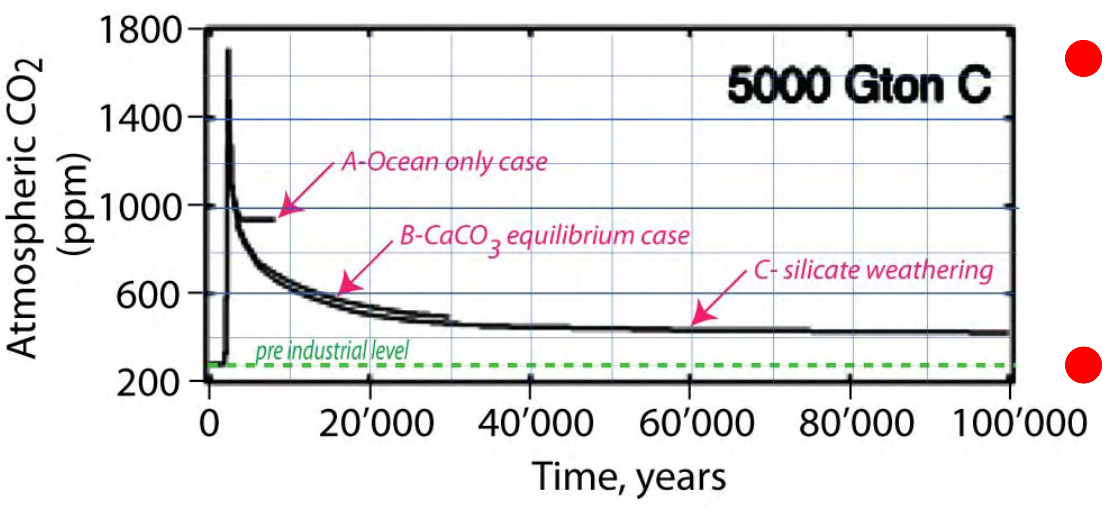
- The speed of reduction of the sea ice is growing much more rapidly than the worst predictions ! Such an ultimate ice caps ice meltdown may indeed cause increases of the sea level between 7 and 15 meters.



7 metres sea rise over Shanghay-Hangzhou-Nannjing region

How long will CO2 last in the biosphere ?

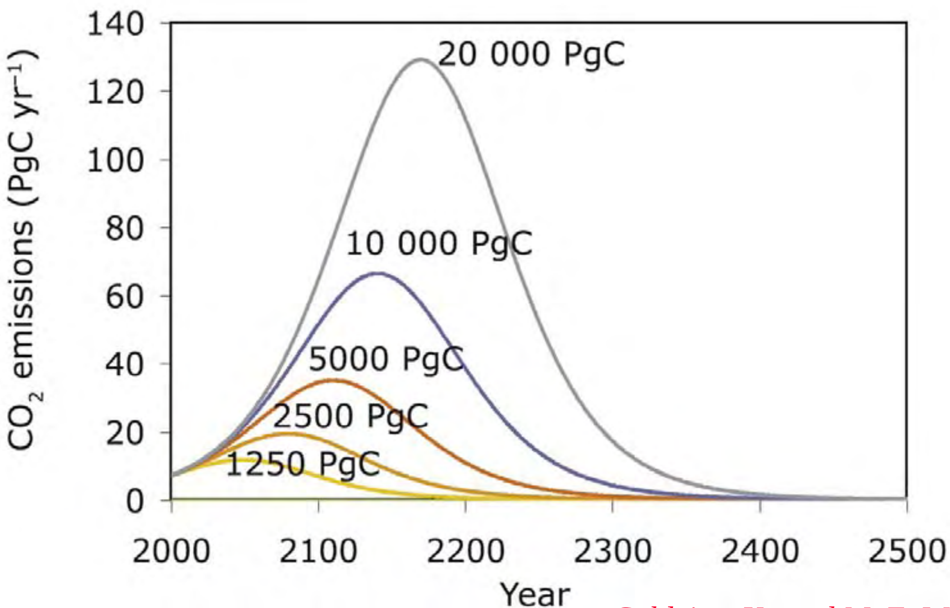
- The idea that anthropogenic CO2 release affects the climate of the earth for hundreds of thousands of years has not reached general public awareness.
- This misconception is still widespread also in the scientific community. The long-term consequences of fossil fuel CO2 release have not yet reached the same level of public awareness and concern as the production of long-lived nuclear waste, for example Plutonium lifetime is 26 kyr.

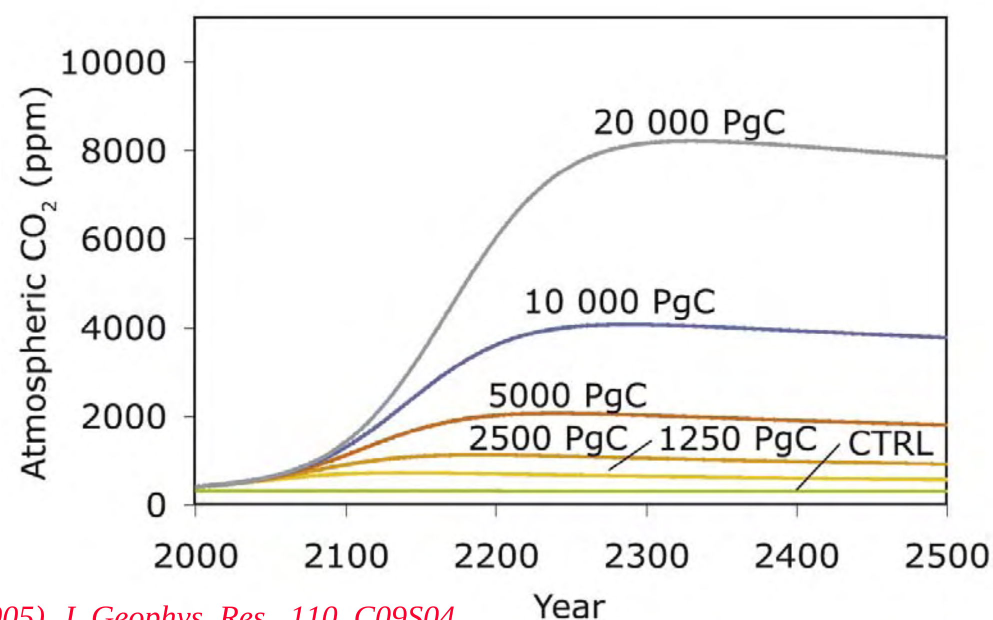


- *Fossil carbon survival :*
  - *After 1'000 years 17-33%*
  - *At 10'000 years 10–15%*
  - *At 100'000 years 7%*
- *The mean lifetime of fossil CO2 is about 30–35 kyr.*

Therefore…

- A mean atmospheric lifetime of order 10^4 years is in start contrast with the "popular" perception of several hundred year lifetime for atmospheric CO2.
- The 300 year simplification misses the immense longevity of the tail on the CO2 lifetime, an hence its interaction with major ice sheets, ocean methane clathrate deposits, and future glacial/interglacial cycles.



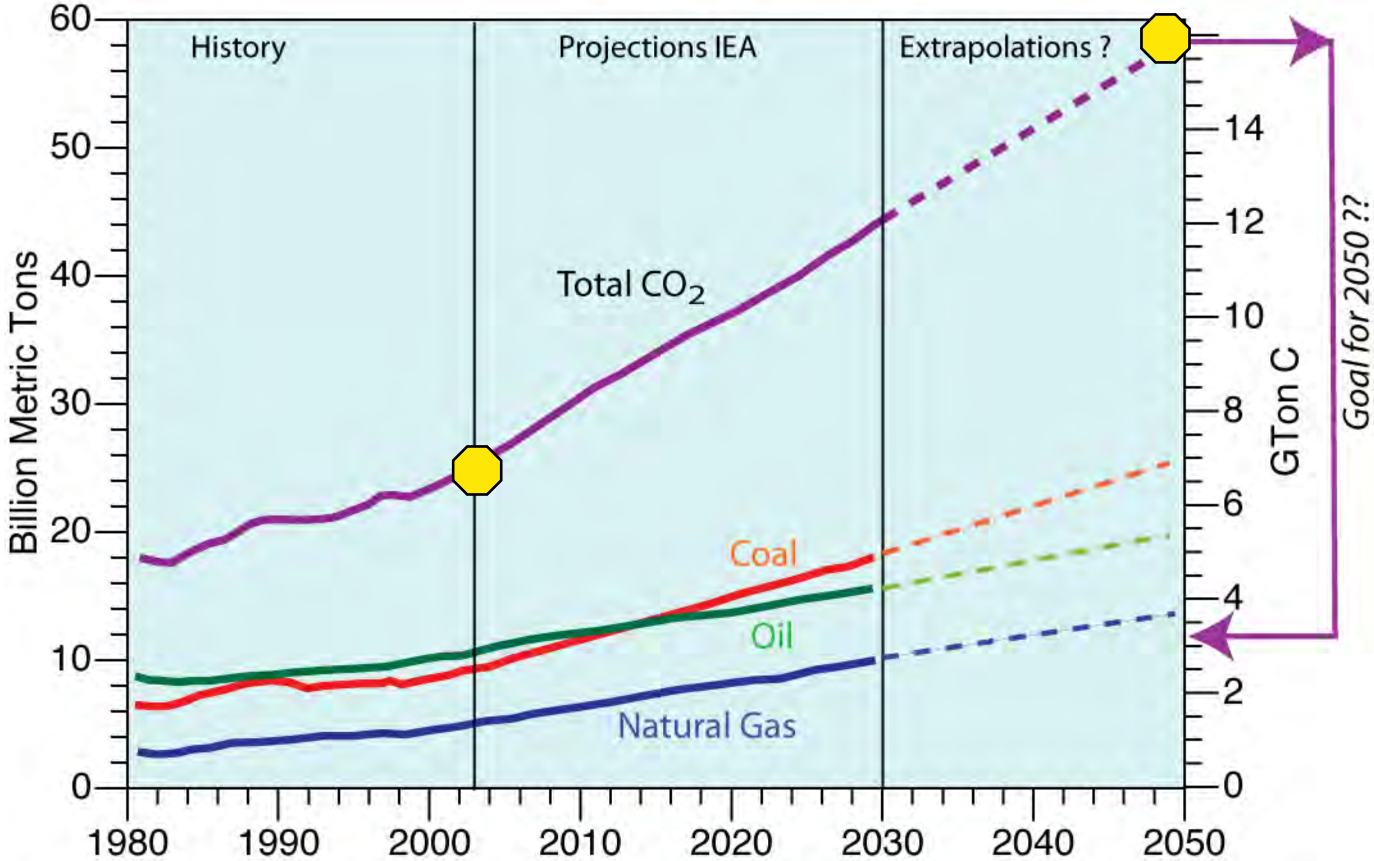


Caldeira, K., and M. E. Wickett (2005), J. Geophys. Res., 110, C09S04.
Archer, D. (2005), J. Geophys. Res., 110, C09S05

A new "political" determination…

- The realization of the risks related to Climate Change has generated especially in the in the EU -but also elsewhere- the political determination (based on well founded scientific considerations) for a quick and dramatic reduction of the present emissions from fossils.
- Global warming and pollution are inevitable consequences of our growing population and economies. Investing in devices which conserve energy is worthwhile, but also **new alternatives** must be vigorously pursued with an appropriate level of investment.
- It is generally believed that by 2050, or even earlier, a progressive reduction to at least 1/2 the present CO2 emissions from fossils is needed, namely to 6 TWatt, leading to 24-29 TWatt of "carbon free" supplies, or if possible, of more.
- *WARNING: Reversing an **un-interrupted fossil dominance** lasted for over three centuries may not be accomplished **without fierce oppositions**.*

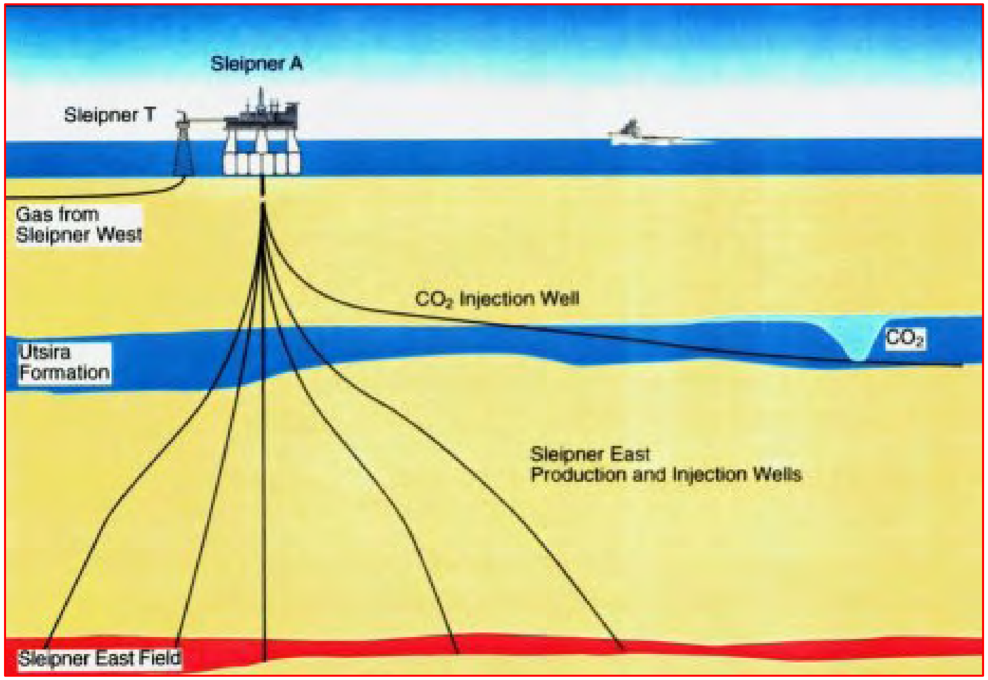
Curbing the CO2 emissions: the magnitude of the problem



- Today about 80% of the energy produced is due to fossils, with about 6.5 GTonC emitted every year.
- Predictions of "business as usual" indicate that that it may continue to increase to as much as 15 GTonC/year by 2050.

“Have the cake and eat it”: CO2 sequestration ?

- Already used by the oil industry, at the level of few million tons/y (Sleipner Field, Statoil,NO)
- Considerable room is apparently available, especially in deep saline acquifers (sufficient for many decades of coal consumption)
- It requires a distributed pipeline network for CO_2 disposal, roughly doubling the cost of electricity.



- Several drawbacks, which may imply considerable R & D, with huge investments if they were to have a sizeable effect:
  - Volumes of CO_2 to be sequestrated are huge. For instance a single 1 GWe power station produces every year 11 million tons of CO_2
  - Sequestration does not mean elimination and eventually most of such a gas may have eventually to be re-emitted in the atmosphere
  - Safety due to accidental leaks of such a large amounts of CO_2, is critical. *At concentrations >10% CO_2 is lethal and produces death in less than 4 minutes*

A few numbers on nuclear power ….

- In order to produce with *ordinary reactors* 12 TWatt i.e. 1/3 of the "carbon free" primary energy, we would need to build for instance about 5000 nuclear reactors each of 1 Gwatt(e), ≈ 80% efficiency and a nominal lifetime of 30 years, slightly less than one new 1 GWatt reactor every two days.

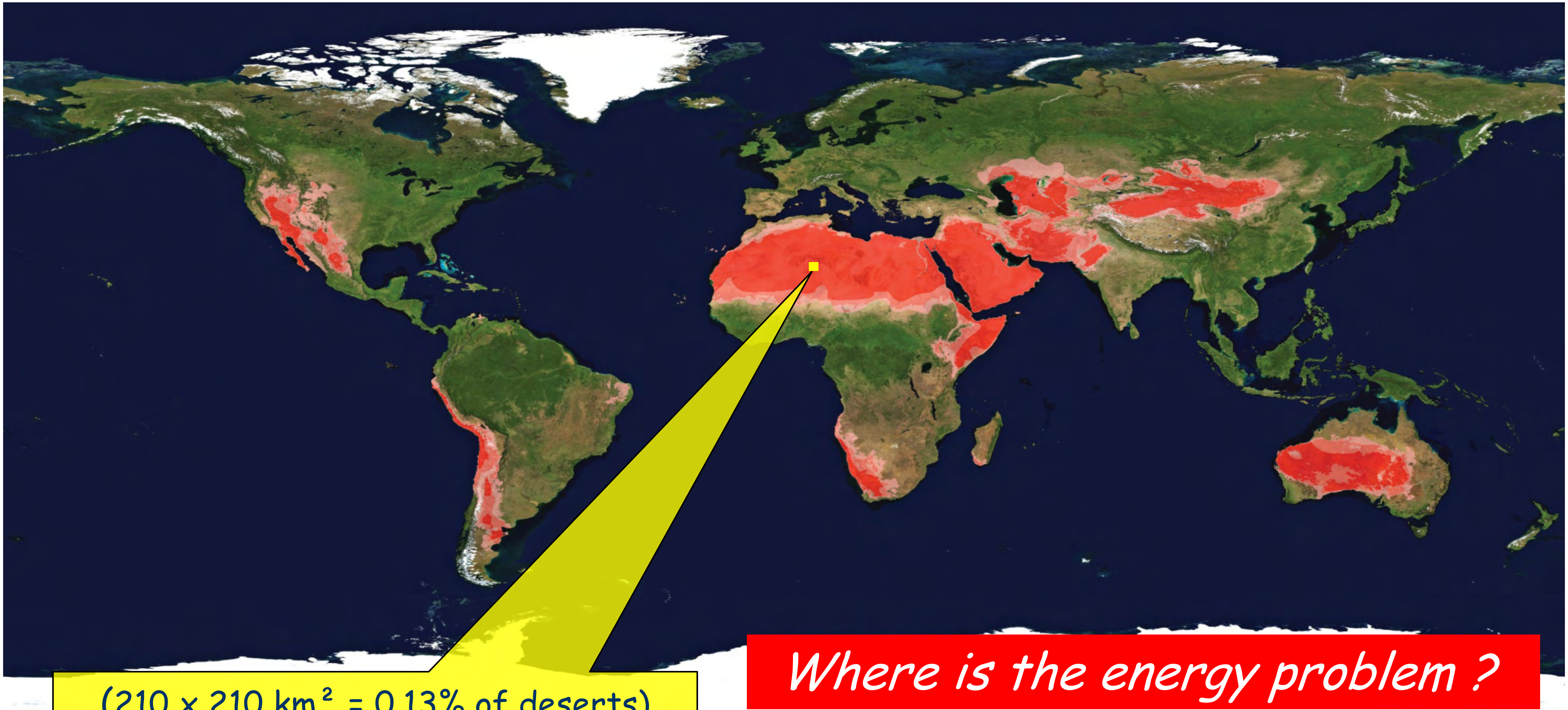
- A serious evaluation of the costs and critical issues related to proliferation especially in the developing countries and the security of long-term waste disposal should be carried out when facing these numbers in a long-time perspective.

- *A New Nuclear*, but on a longer timetable and with due consideration for its problems will necessarily require different fuel, "breeding", incineration of the long lived waste and a new reprocessing with a "closed" fuel cycle.

Energy from renewables ?

- If we want to produce the remaining 12 TWatt with the *traditional* renewables, wind, geothermal, biomass and PV, we are confronted with similarly unrealistic numbers.
- The image is clear: the energy needs of our planet by 2050 are much too large to be achieved by a generalised mix of the presently indicated sources.
- There is, however, a new Solar option *which is ready* and that it can provide the required energetic deficit of 10 to 20 TWatt, enough to limit the dreaded risks related to climate change.
- The yearly energetic yield of solar energy in the sun-belt is equivalent to a thickness of 25 cm of oil.
- A 15 TWatt of planetary energy supplied by the Sun, corresponds to only about 0.1 percent of the surface of all sunny, desertic areas, namely about 200 x 200 km^2!

Solar energy in the “sunbelt”



($210 \times 210 \ km^2$ = 0.13% of deserts)
is receiving yearly averaged solar energy equal to global energy consumption (15 TW x year)

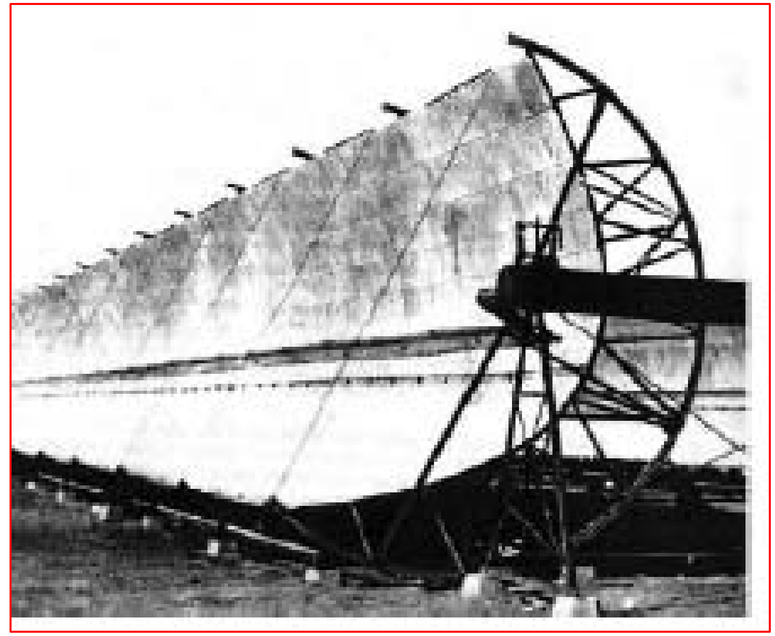
Where is the energy problem ?

Gerhard Knies, ISES-Rome CSP WS 2007

Concentrating solar energy: The earliest ideas

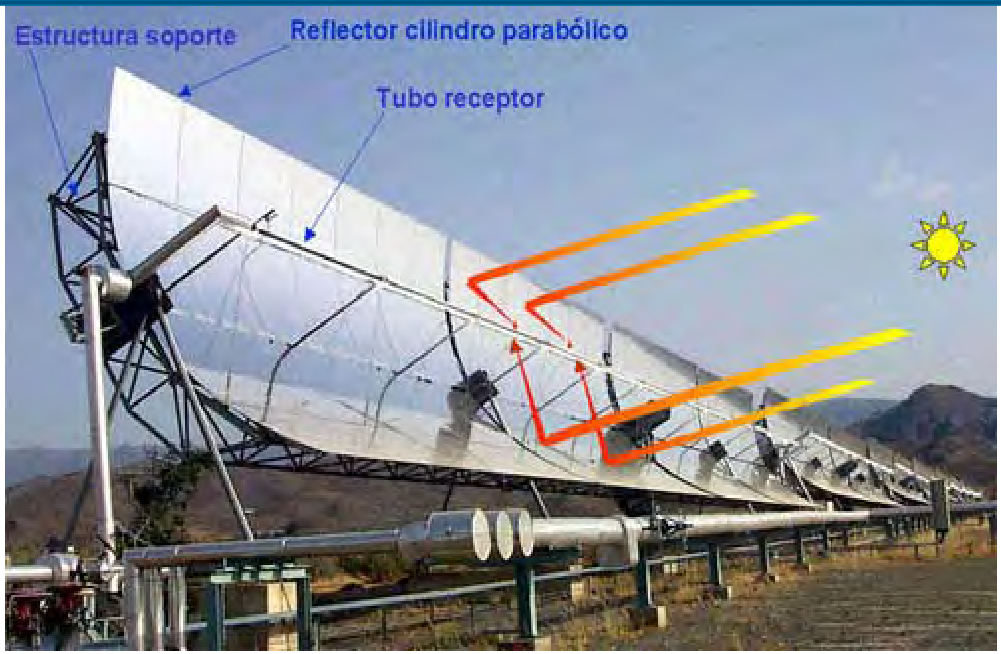
Painting Title : Burning Mirrors, Stanzio della Mattematica, 1587-1609
Artisit: Parigi, Giulio (1571-1635)

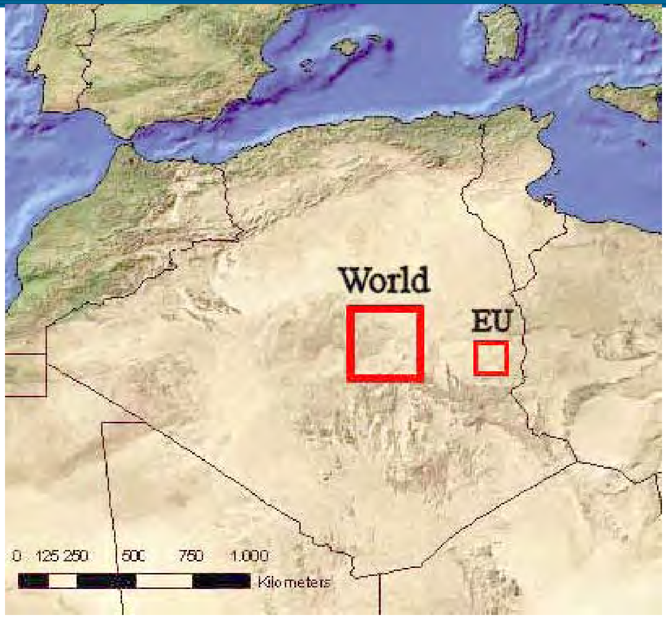
According to the tradition, Archimedes destroyed the Roman fleet at the siege of Syracuse in 213 BC by the application of directed solar radiant heat concentrating sufficient energy to ignite wood at 50 m.



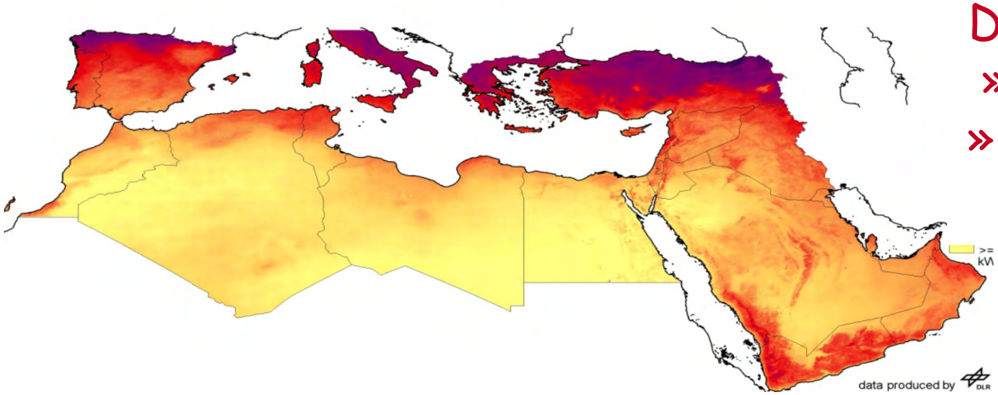
The first solar facility to produce electricity was installed in 1912 by Shuman in Maady, Egypt.
The parabolic mirror trough concentrates sunrays on a line focus in which a tube was situated containing water that was brought to evaporation.
It produced 55 kWatt of electric power.

Principle of modern CSP





Typical yield CSP, PV≈250 $GWh_{el}/km^2/y$



Demand of electric power:

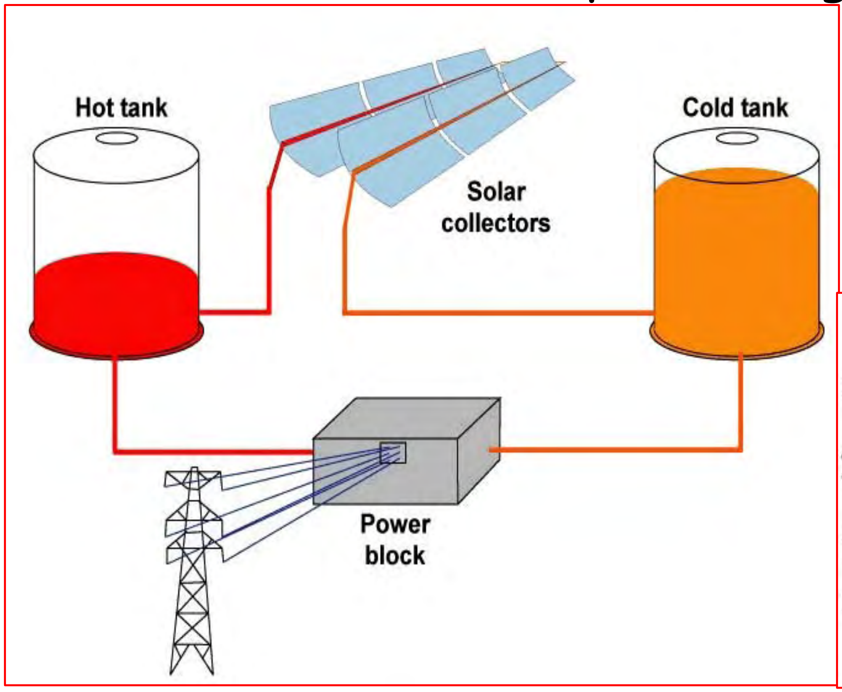
» 7 500 TWh/y Europe + Desert 2050

» 35 000 TWh/y world-wide 2050

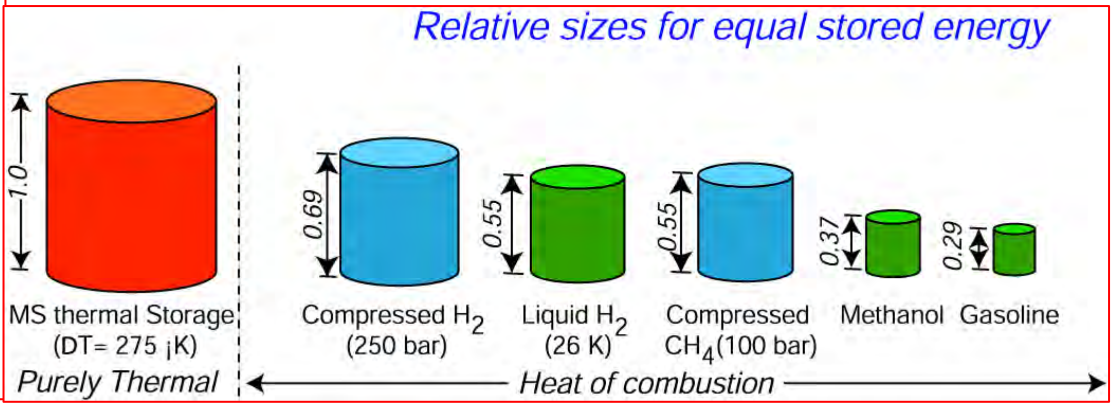
Economic potentials > 600 000 TWh_{el}/y

The storage of energy

- Indeed any primary main form of energy, in order to be realistically capable to counteract fossils and their emissions must be available *whenever it is needed by the user and not according to the variability of the source*.
- It is possible to insure the continuity of utilisation of CSP plant with the addition of a thermal liquid storage, in the form of a cheap molten salt.



Dual container of molten salt



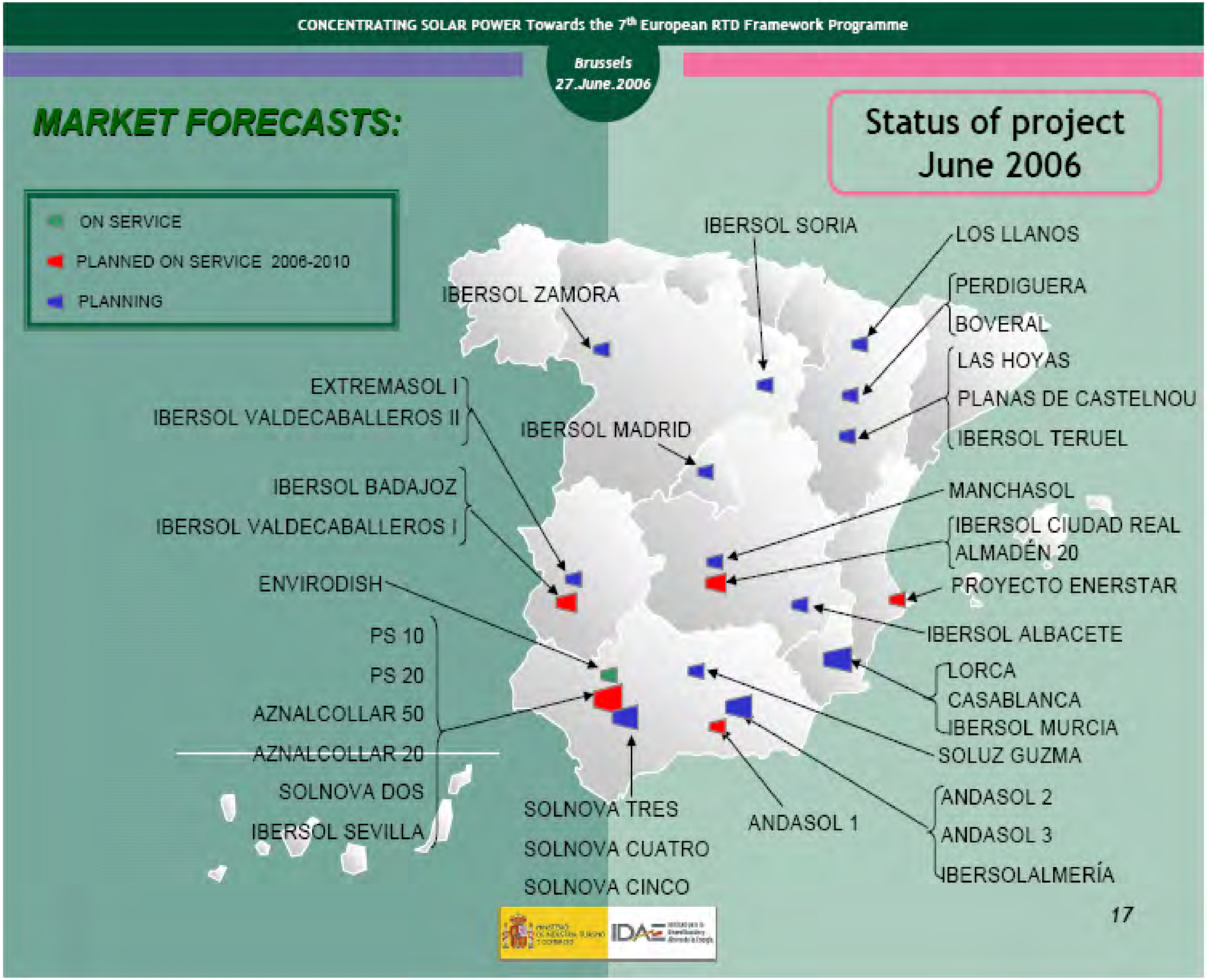
- Thermal storage process is very efficient (less than 1% loss per day).

Financial considerations in favour of CSP

- Far from today's PV, CSP is the cheapest source of renewable solar power. The levelized energy cost (LEC) for the current plants in California is 10-12 US¢/kWh.
- The Spanish law setting the energy to the grid for CSP at 18 ¢/kWh plus market price is an important incentive, since, at this rate, CSP , unlike today's PV can be operated profitably on purely private funding.
- Experts agree that costs can be reduced to 4-6 ¢/kWh if the peak power capacity is expanded in the next 10/15 years to 5-20 GWatt. Likewise the
  - (a)World Bank,
  - (b)the US-DOE and
  - (c) the International Energy Agency (IEA)

  all predict CSP's will drop below 6 ¢/kWh by 2020. They all agree that CSP is the most economical way to generate electricity from solar energy.
- On the contrary of fossils and Uranium, costs for CSP electricity production in the future are well predictable. Once the plant has been paid off, like with hydro, the operating costs remain very small, of the order of ≤ 3 US¢/kWh.

The leading role of CSP in Spain: June 2006



Puertollano Panoramic Photo

Number of collectors (150 m)	352
Total area of captation	287.760 m2
Number of mirrors	118.272
Power output:	50MWe
Production:	114,2GWh/year

Plataforma Solar Sanlucar la Mayor (PSSM)

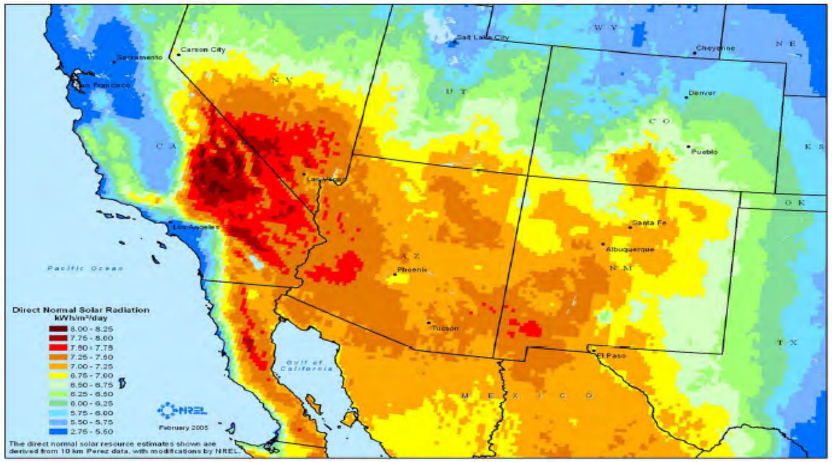
- 300 MW
- 1200 Mio Investment
- 800 hectar
- 180.000 homes
- Avoids annually 600.000t of CO_2

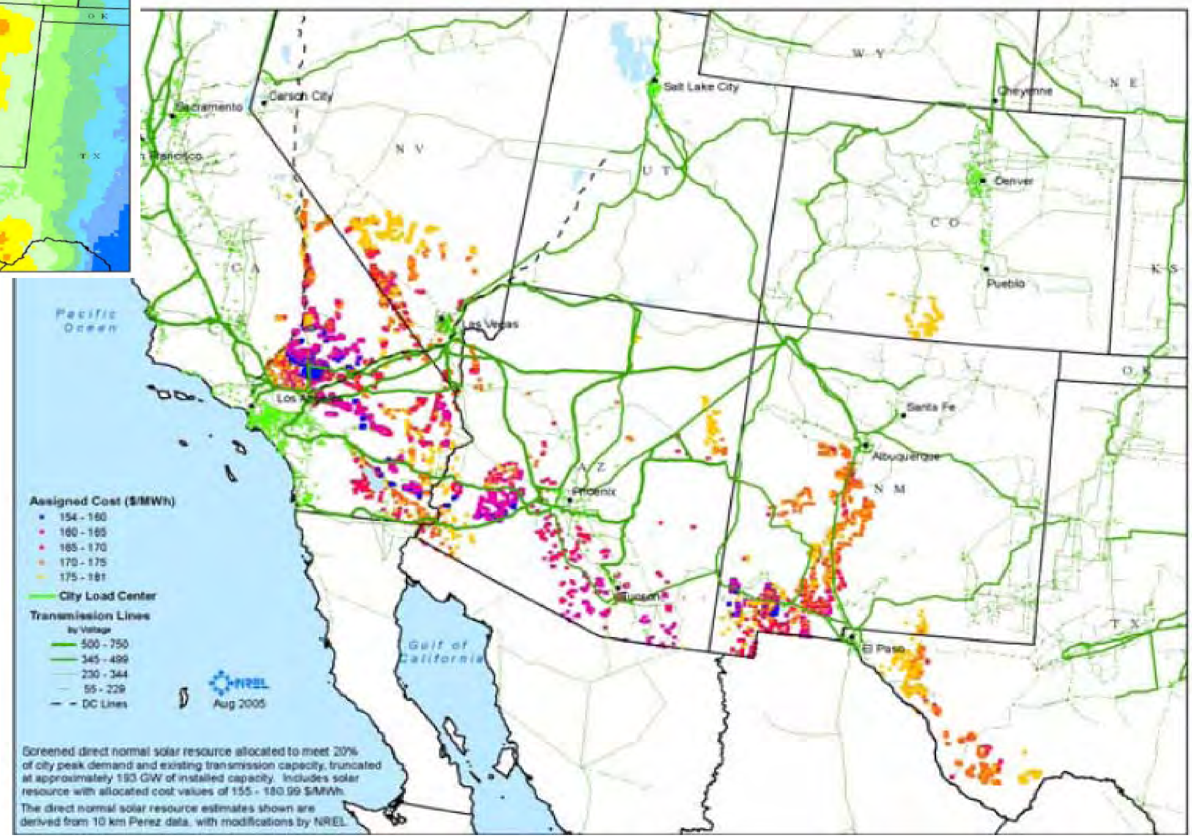
	MW
Sevilla PV	1,2
Sanlúcar Solar	10
Copero PV H1 - H8	1
PS20	20
AZ20	20
Solnova 1	50
Solnova2	50
Solnova3	50
Solnova 4	50
Solnova 5	50
Sevilla PV2	2
Total	303,9

2004				2005				2006				2007				2008				2009				2010				2011				2012				2013			
1T	2T	3T	4T	1T	2T	3T	4T	1T	2T	3T	4T	1T	2T	3T	4T	1T	2T	3T	4T	1T	2T	3T	4T	1T	2T	3T	4T	1T	2T	3T	4T	1T	2T	3T	4T	1T	2T	3T	4T

High Potential for CSP in the South West of USA

Huge power demand meets excellent solar resource





Potential of identifiable areas:

200 GW generation capacity

470 TWh electricity per year

(» 17% of U.S consumption)

(Source: NREL)

Nevada Solar 1 (2007)

- Generating Capacity 64 MW (Nominal)
- 357,200 m2 of Solar Field
- Annual Production > 130,000 MWh
- Construction in Less than 18 months,
- 1.6 million man-hours
- *Capital investment : ≈ 250 Millions USD*

CSP Pan European Forecast for 2020-50

- The planned EURO-MED electricity interconnection permits to produce from the Sahara large amounts of solar electricity toward the Pan-European network.
- Transport of electricity from far regions to central Europe is both economically and technically feasible.

Year		2020	2030	2040	2050
Transfer Capacity GW		2 x 5	8 x 5	14 x 5	20 x 5
Electricity Transfer TWh/y		60	230	470	700
Capacity Factor					
Turnover Billion €/y		3.8	12.5	24	35
Land Area	CSP	15 x 15	30 x 30	40 x 40	50 x 50
km x km	HVDC	3100 x 0.1	3600 x 0.4	3600 x 0.7	3600 x 1.0
Investment	CSP	42	143	245	350
Billion €	HVDC	5	20	31	45
Elec. Cost	CSP	0.050	0.045	0.040	0.040
€/kWh	HVDC	0.014	0.010	0.010	0.010

Solar power costs are not the problem !

generation

transmissio

The need for a great transformation: the Potsdam Memo

- *On 8-10 October 2007 a Nobel Symposium on Climate Change was hosted in Potsdam by Chancellor Angela Merkel. It took careful account of interactions between climate policies and the challenges of development in the short, medium and long-term.*
- *A range of actions in the areas of climate stabilization, energy security and sustainable development are considered necessary, in particular, these could include:*
  - *A global target such as the 2° C-limit relative to pre-industrial levels or the (largely equivalent) halving of worldwide greenhouse gas emissions by 2050.*
  - *Leadership role of industrialized countries both in regards to drastic emissions reductions and development of low/no-carbon technologies in order to give poor developing countries room for urgently needed economic growth within the boundaries of a global carbon contract*

Potsdam Memorandum, cont.

- *Carbon justice. Striving for a long-term convergence to equal-per-capita emissions rights accomplished through a medium-term multi-stage approach accounting for differentiated national capacities.*
- *The generation of a carbon price, for instance, through an international cap-and-trade system (of systems) based on auctioning permits.*
- *The establishment of a powerful worldwide process supporting climate-friendly innovation, international cooperation of R&D institutions, combined with increased RD&D funding, integrating basic research as well, to facilitate technology transfer and cooperation.*
- *Major contributions to a multinational funding system for enhancing adaptive capacities.*
- *Scaled-up efforts to both reduce emissions from deforestation and accelerate ecologically appropriate reforestation by creating new incentives for communities and countries to preserve and increase their forests.*
- *Ensure reductions of non-CO_2 greenhouse gases.*

Potsdam: a global contract between Science and Society

- There is overwhelming evidence that we need to tap all sources of ingenuity and cooperation to meet the environment & development challenges of the 21st century and beyond.
- This implies, in particular, that the scientific community engages in a strategic alliance with the leaders, institutions and movements representing the worldwide civil society. In turn, governments, industries and private donors should commit to additional investments in the knowledge enterprise that is searching for sustainable solutions.
- This new contract between science and society would embrace:
  - A multi-national innovation program on the basic needs of human beings (energy, air, water, food, health etc.) that surpasses, in many respects, the national crash programs of the past (Manhattan, Sputnik, Apollo, Green Revolution etc.).
  - Removal of the persisting cognitive divides and barriers through a global communication system
  - A global initiative on the advancement of sustainability in science, education and training. The best young minds need to be motivated to engage in interdisciplinary problem-solving, based on ever enhanced disciplinary excellence.

Thank you !