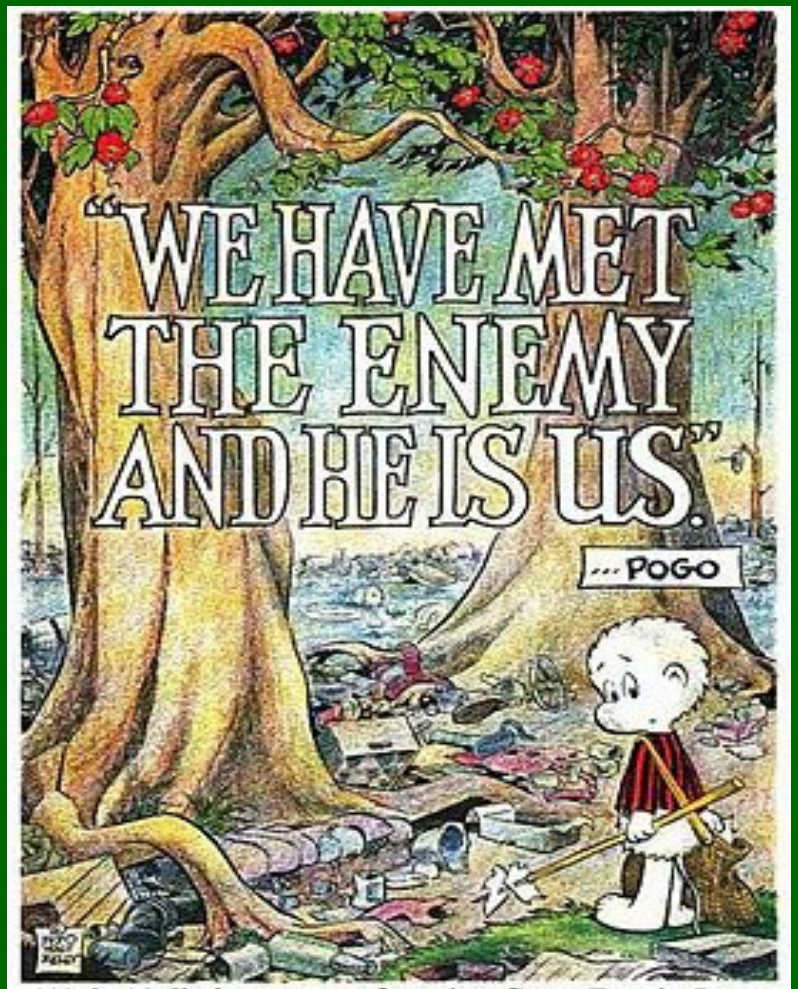
SAVING THE EARTH WITH CLEAN ENERGY

- A NEW POLITICAL PARADIGM FOR PROSPERITY



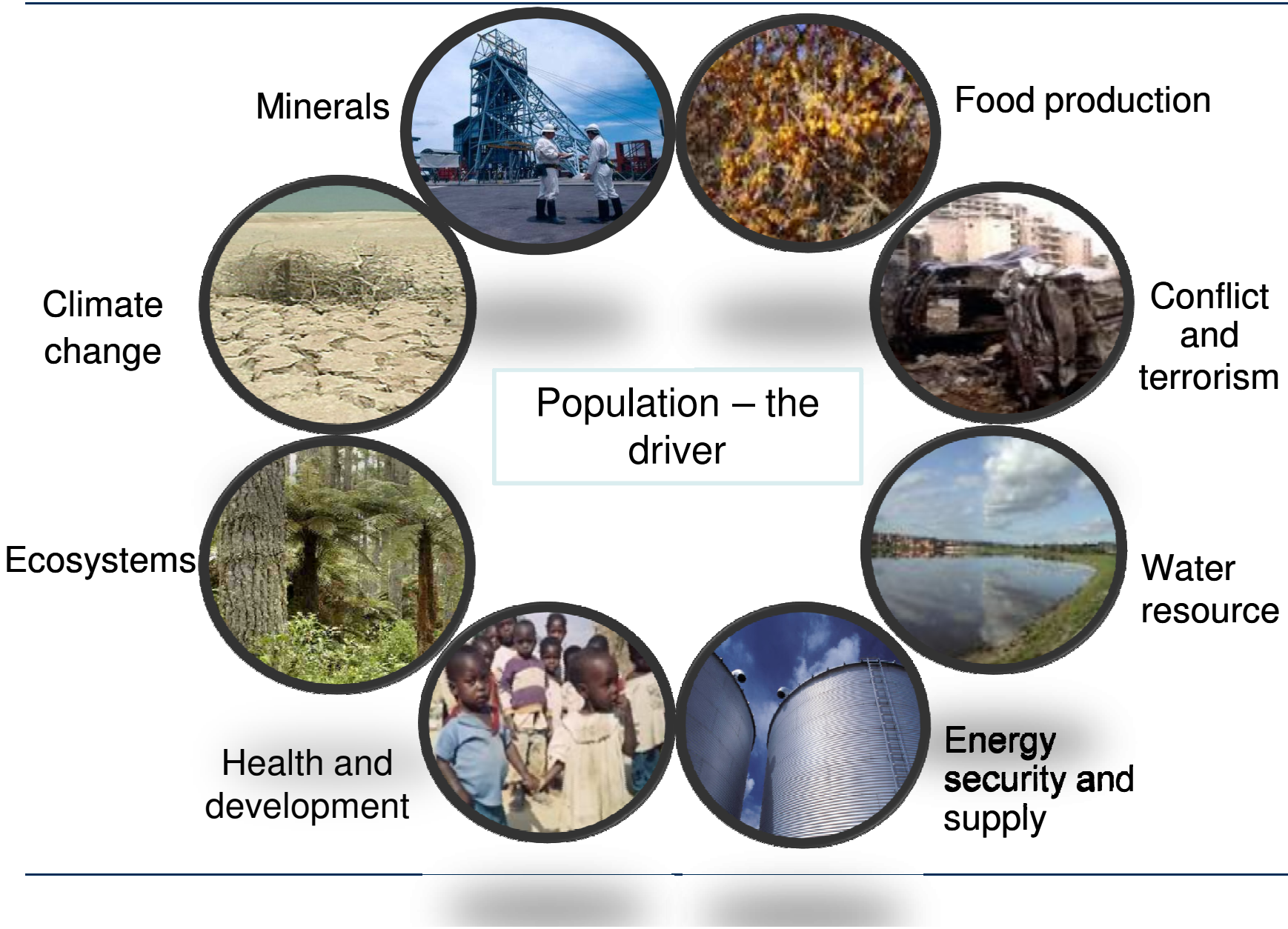
Walt Kelly's poster for the first Earth Day

Bikash Sinha

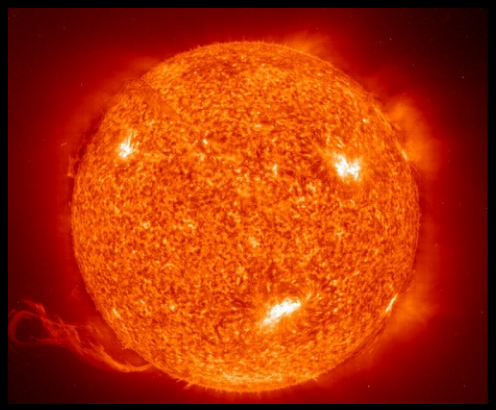
Homi Bhabha Professor
Department of Atomic Energy
Government of India
Variable Energy Cyclotron Centre
1/AF Bidhannagar, Kolkata - 700 064

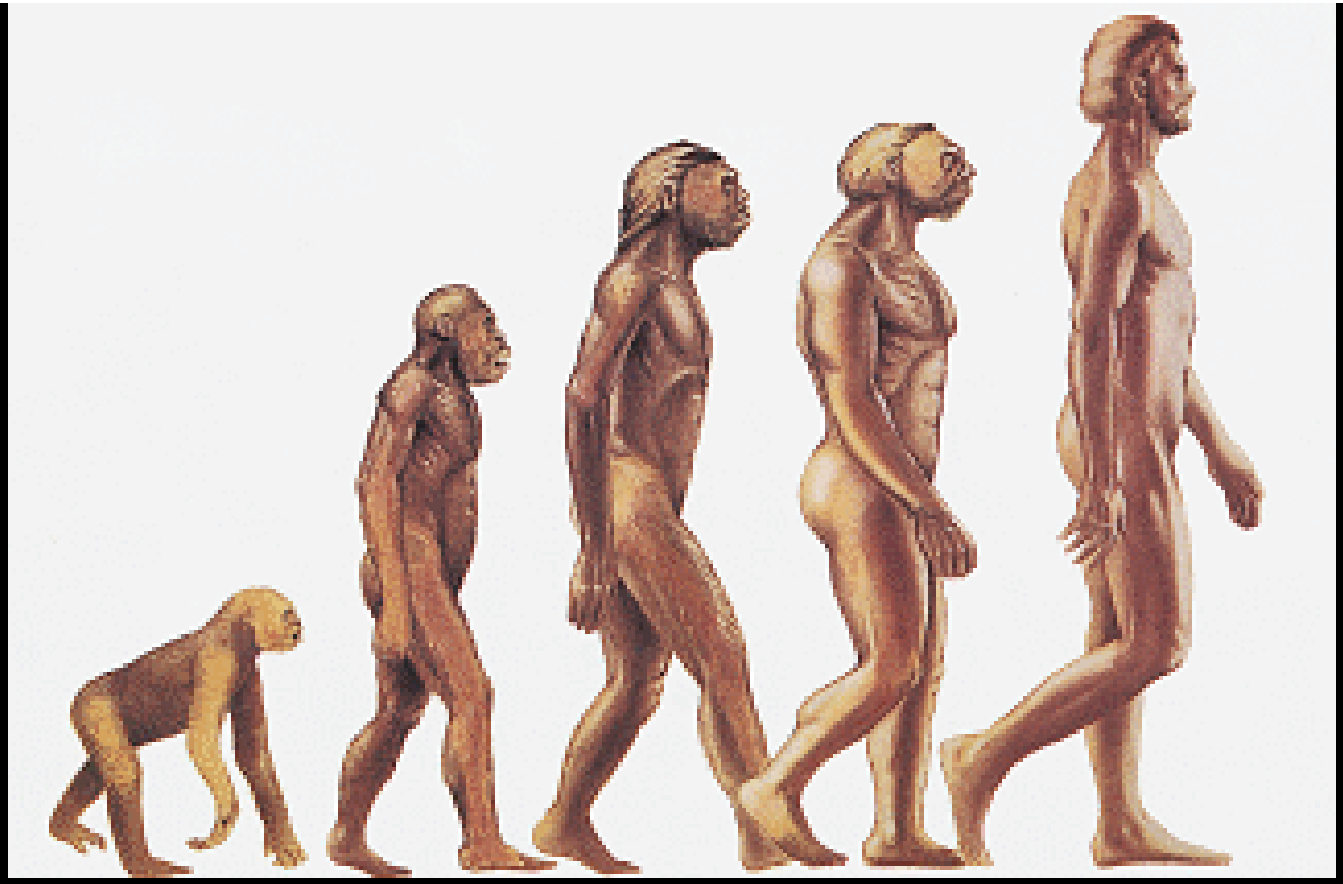
Bengal Chamber of Commerce,
August 31, 2013

21st Century Challenges



During the billions of years of our planet's existence, its climate has varied a lot. At times the entire planet may have been wholly or mostly enveloped by snow and ice ("Snowball Earth" or at least "Slushball Earth"), whilst at other times tropical animals inhabited the polar regions.





Even in the roughly hundred-thousand years of *Homo sapiens*' tenancy, ice ages have come and gone. The most recent 8,000 years or so, since the beginnings of agriculture and the first cities, however, have been unusually steady.

Energy Facts

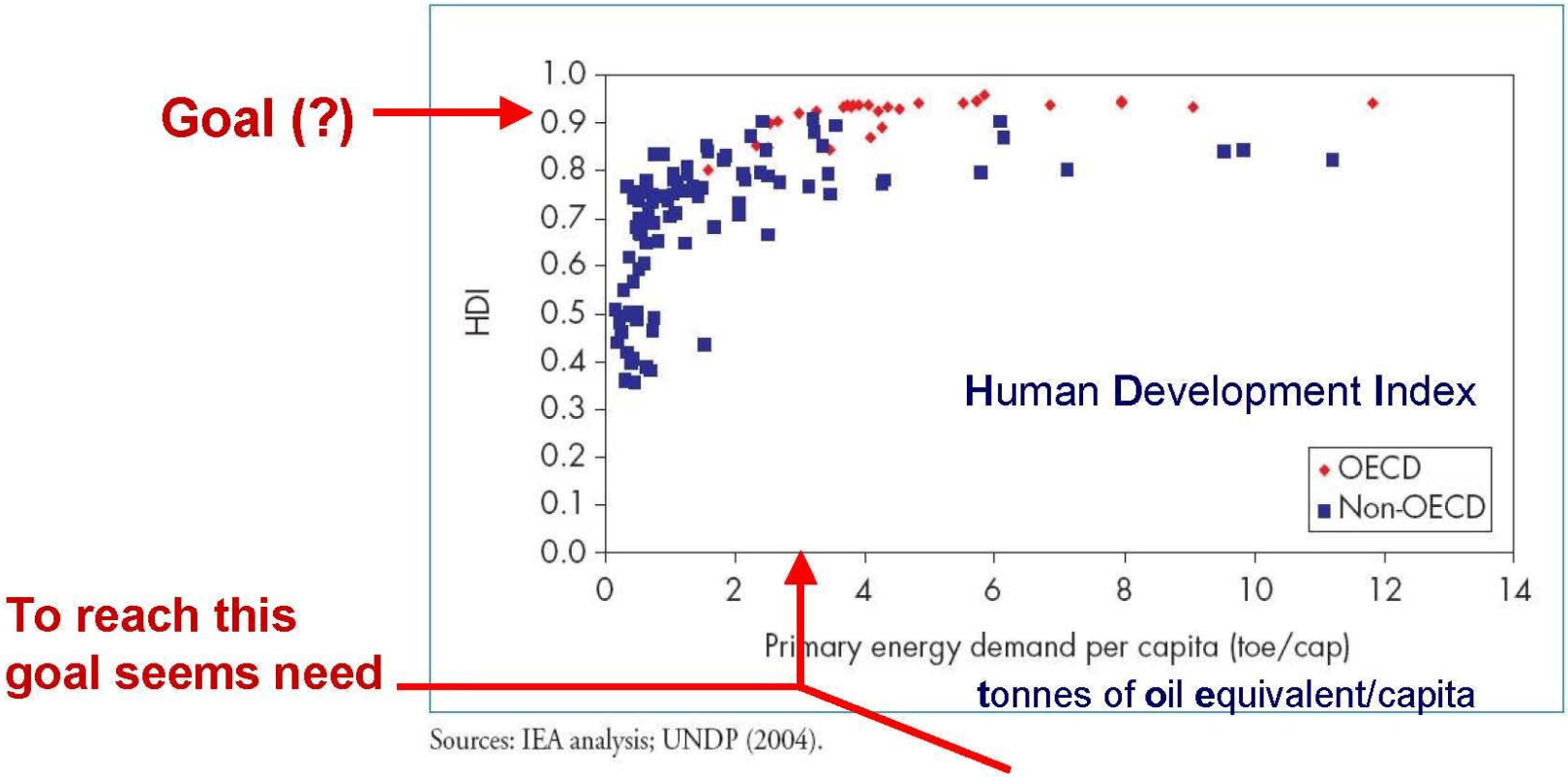
1) **The world uses a lot of energy** – *at a rate of 15.7 TW*
average 2.4 kW per person continuously [UK – 5.1 kW]
- **very unevenly** (use per person in USA = 2.1xUK
= 48x Bangladesh)

2) **World energy use is expected to grow 50% by 2030**
- growth necessary to lift billions of people out of poverty

3) **80% is generated by burning fossil fuels**
→ *climate change & debilitating pollution*
- *which won't last for ever*

Need more efficient use of energy (and probably a change of life style) and major new/expanded sources of clean energy - this will require fiscal measures and new technology

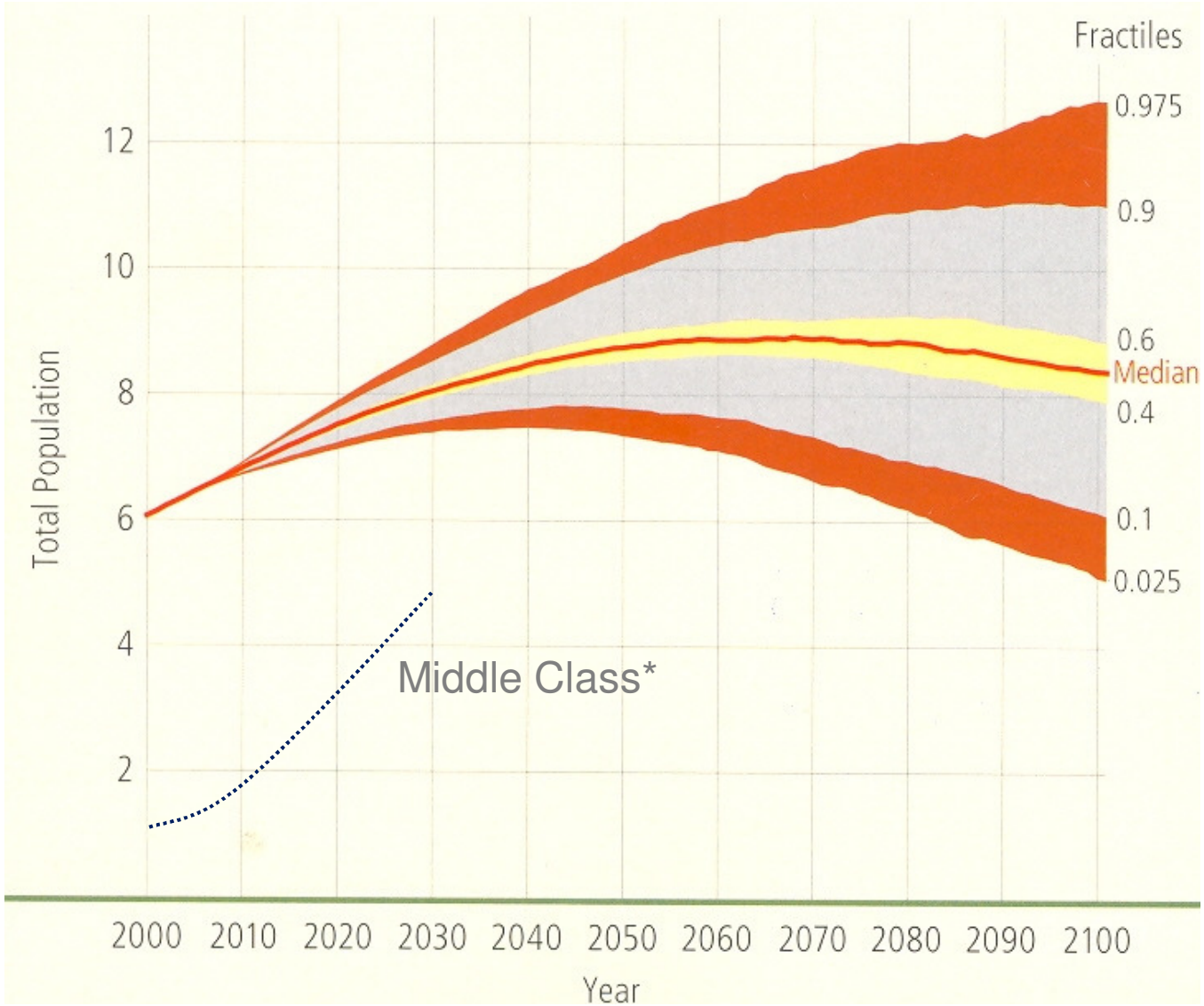
HDI (~ life expectancy at birth + adult literacy & school enrolment + GNP per person at PPP + Human happiness factor) and Primary Energy Demand per person, 2002



For all developing countries to reach this point, would need world energy use to double with today's population, or increase 2.6 fold with the 8.1 billion expected in 2030

If also all developed countries came down to this point the factors would be 1.8 today, 2.4 in 2030

Total Population of the World in Billions



*Middle class here defined as daily per capita spending of between $10 and $100 in PPP terms

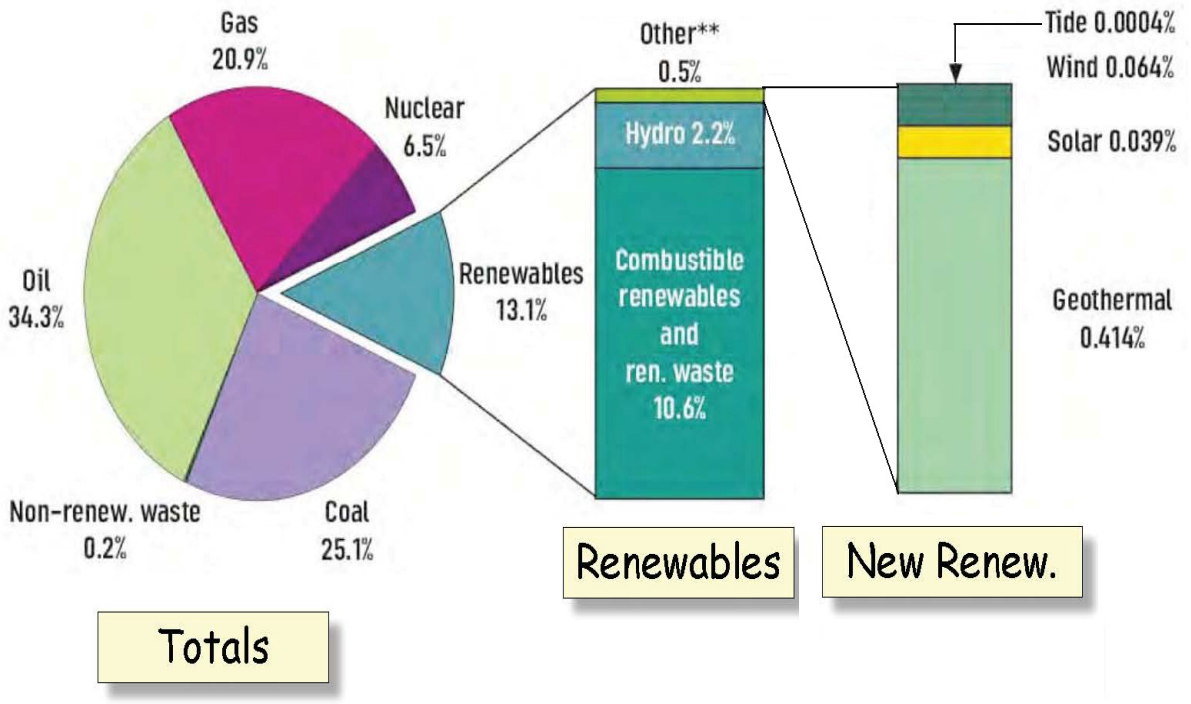
Source: IIASA

Rising Middle Class

- 1.8 billion middle-class consumers today
- 3 billion more middle-class consumers expected by 2030
- 90% of that growth coming from the Asia-Pacific region

Source: McKinsey Global Institute 2011

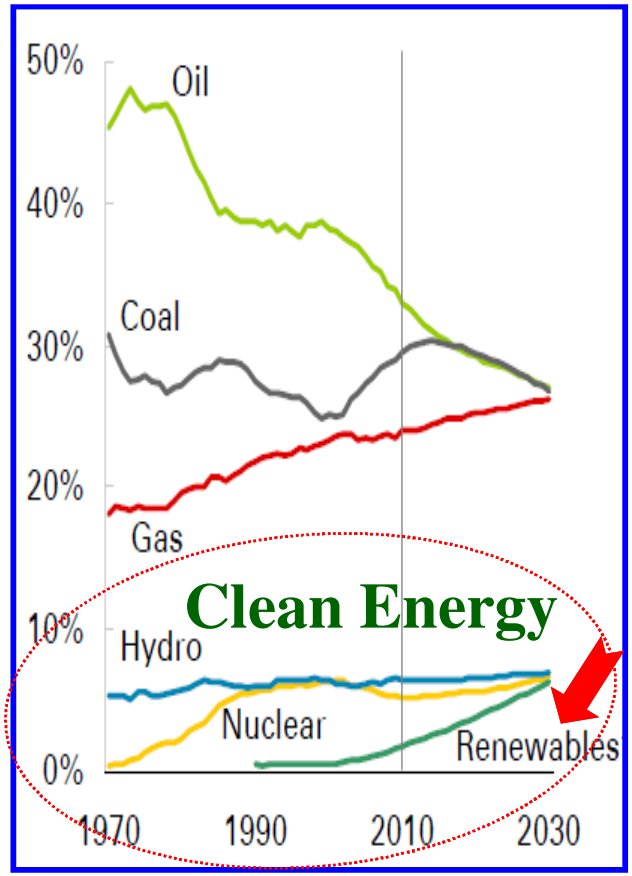
World's Primary Energy Supply



80 % is generated by burning fossil fuels

Source: IEA 2006

Shares of world primary energy



Source: BP Energy Outlook 2030, London, 2011

Sources of Energy

- **World's primary energy supply (rounded)**:

  80 % - burning fossil fuels (43% oil, 32% coal, 25% natural gas)

  10% - burning combustible renewables and waste

  5% - nuclear

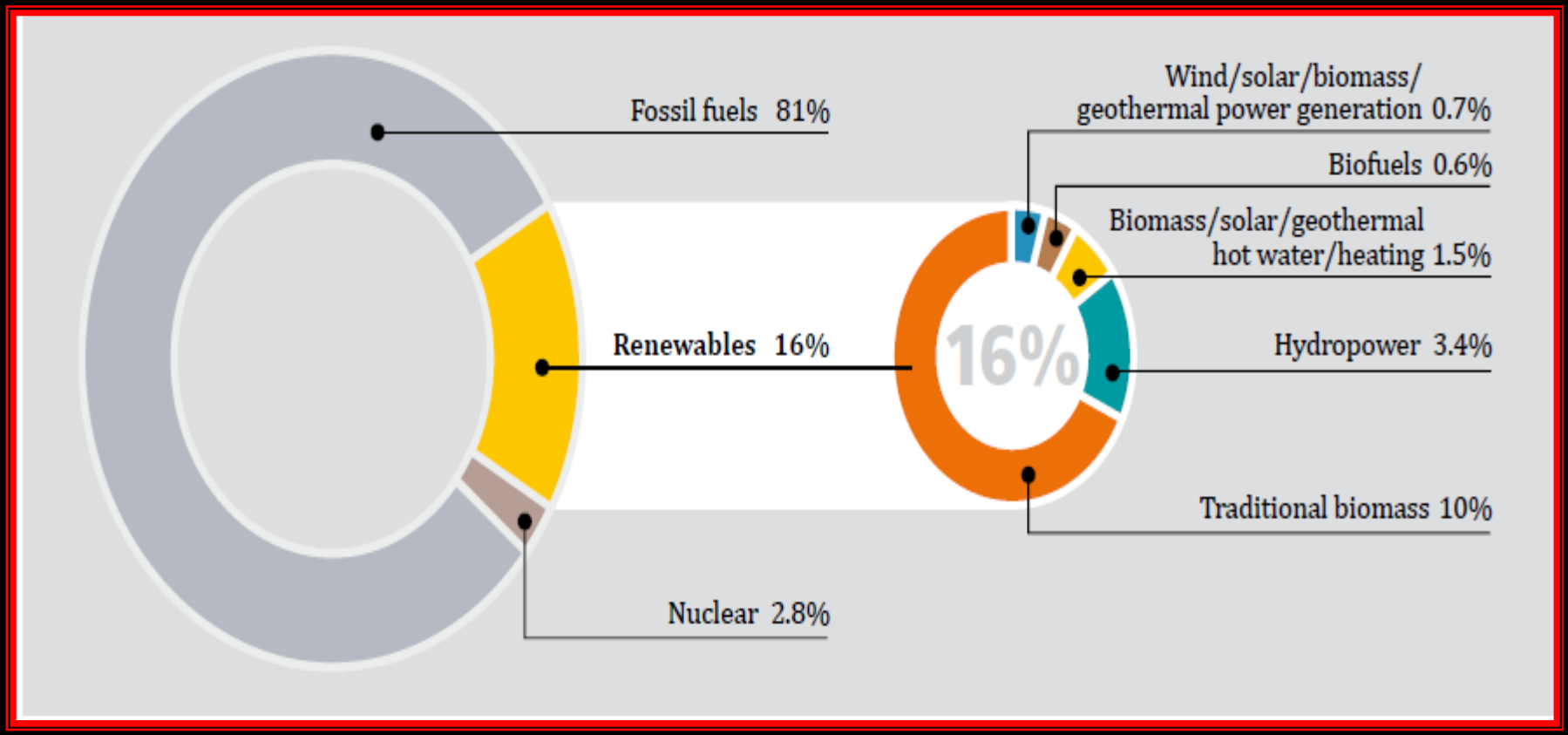
  5% - hydro

  0.5% - geothermal, solar, wind, . . .

NB Primary energy defined here for hydro, solar and wind as equivalent primary thermal energy

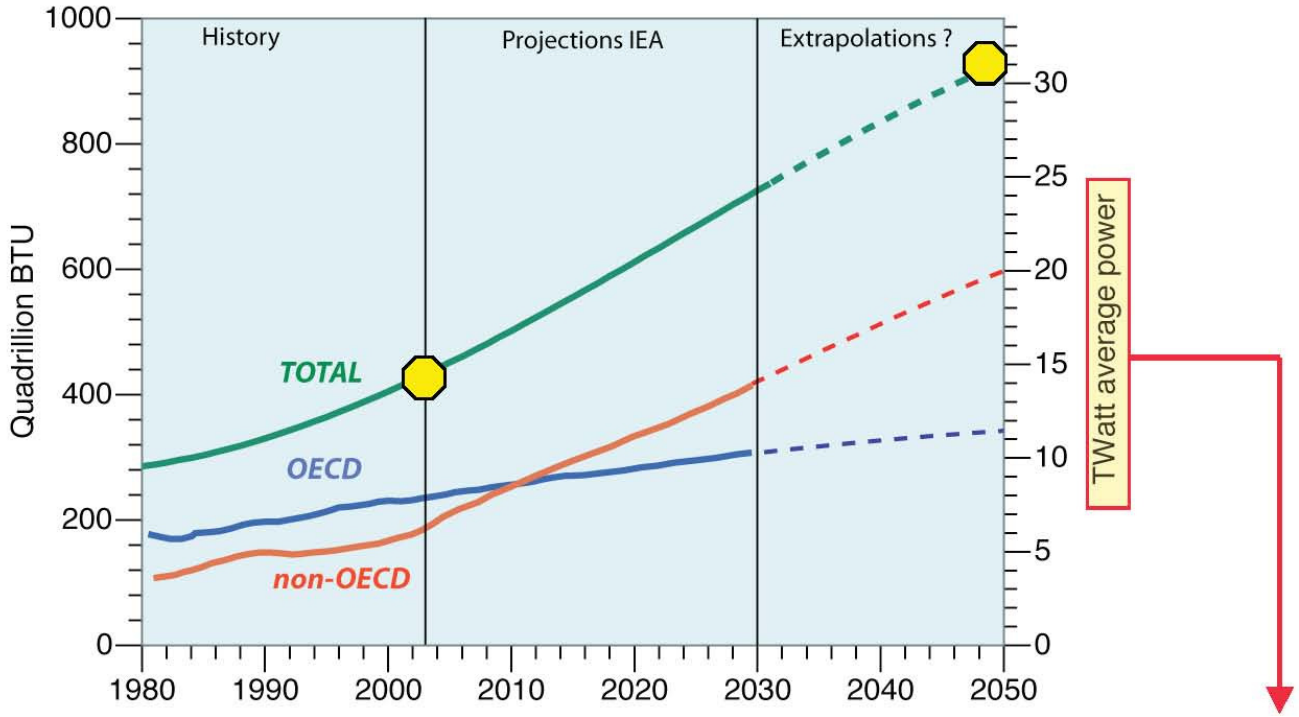
electrical energy output for hydro etc is also often used, e.g. hydro ~ 2.2%

Renewable energy Share of Global final energy Consumption, 2009



Source: Renewable, GLOBAL STATUS REPORT, 2011

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

Environmental Impact of Fossil Fuel based Power Plants

- **Generating debilitating pollution**
- **Driving potential catastrophic climate change**
  - **CO_2 emission**
  - **Rise in global mean temperature**
  - **Rise in sea level**
- **Limited resource of fossil fuels**
  – won't last for ever

Saudi saying “My father rode a camel. I drive a car. My son flies a plane.

"His son will ride a ca

Is this true? Perhaps

August, 1941 (photo by Willim Field)

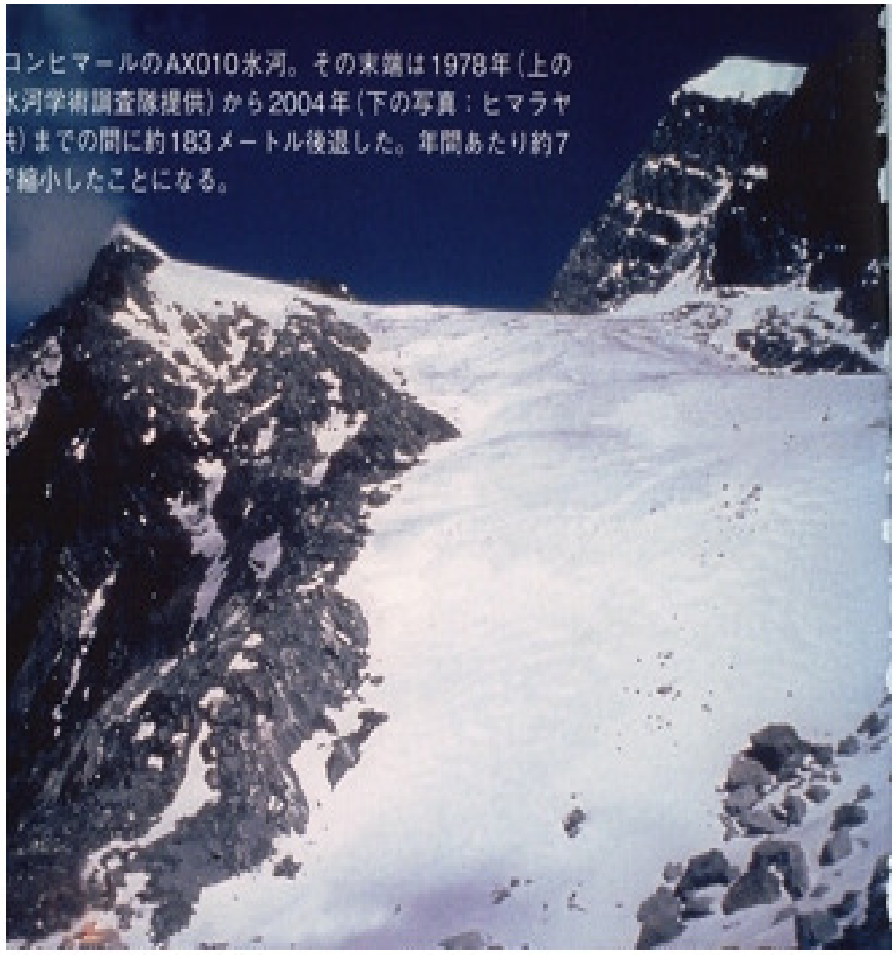
August, 2004 (photo by Bruce Moinia)

Muir Glacier, SE Alaska

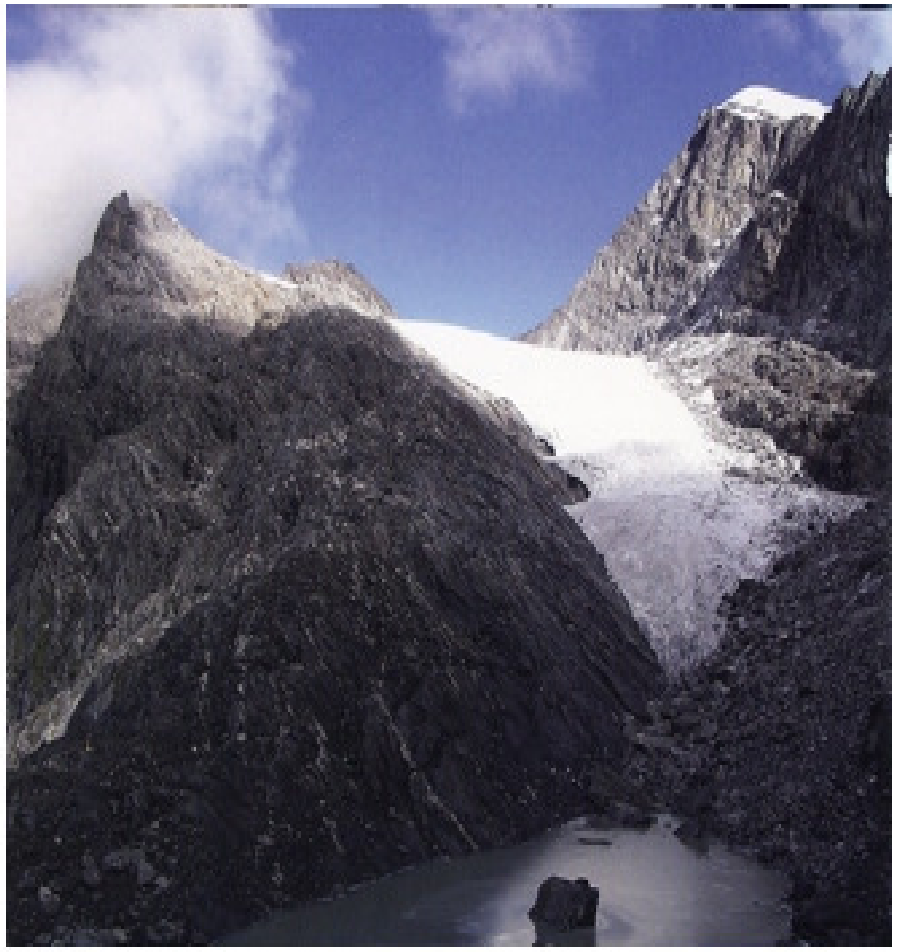
Environmental Impact of Global Warming

Source: http://www.whiteearth.org/WhiteEarthScience.html

Himalayan Glacier, South Asia



Himalayan Glacier, 1978



Himalayan Glacier, 2004

Source: http://www.whitearth.org/WhiteEarthScience.html

Many people find it hard to grasp the significance of such seemingly small temperature changes, given that temperatures can differ from one day to the next by 10^0C. But there is a huge difference between daily fluctuations, and global averages sustained year-on-year. The difference in average global temperature between today and the depth of the last ice age is only around 5^0C.

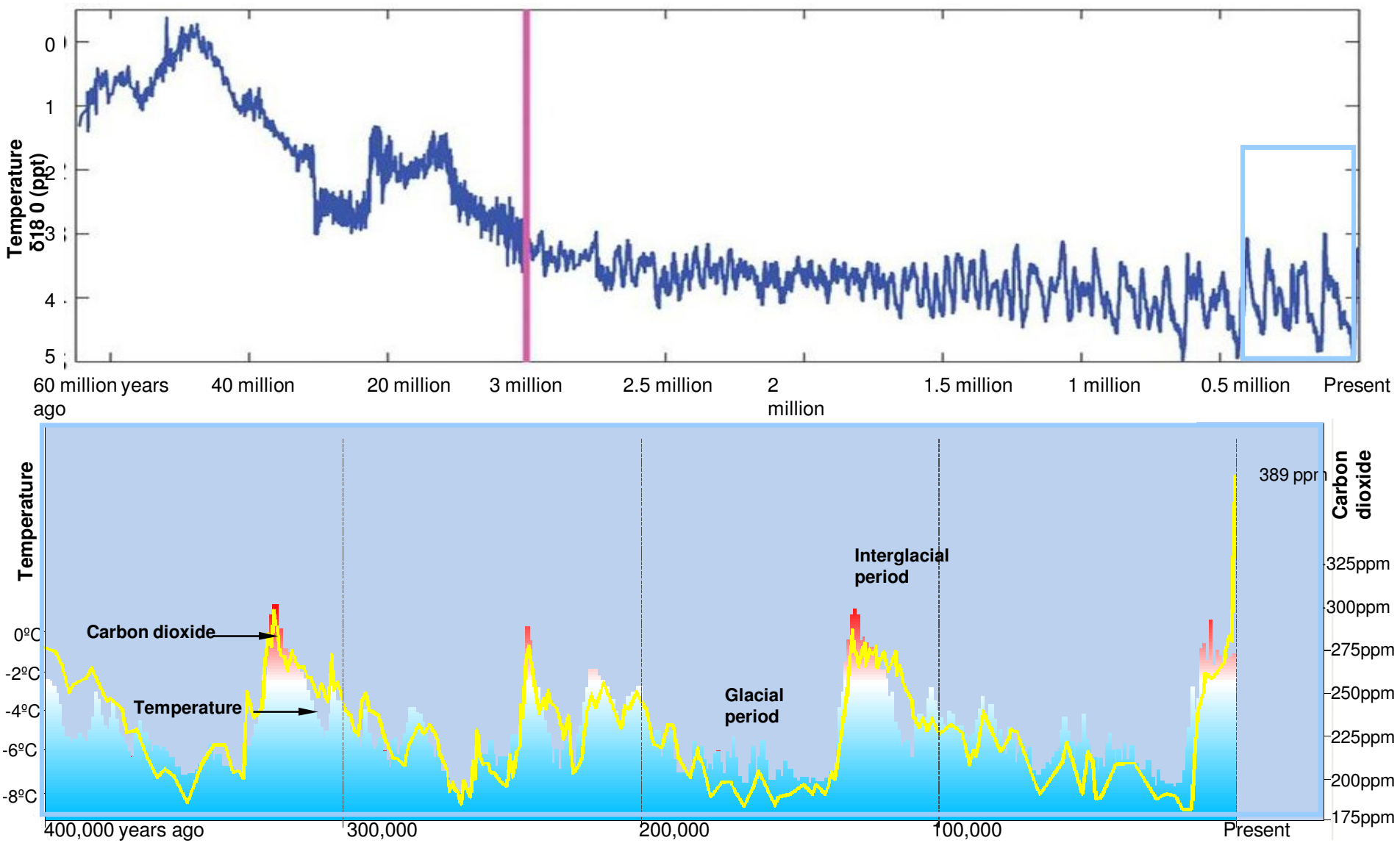
Upsala Glacier, Patagonia

1928

Upsala Glacier, Patagonia

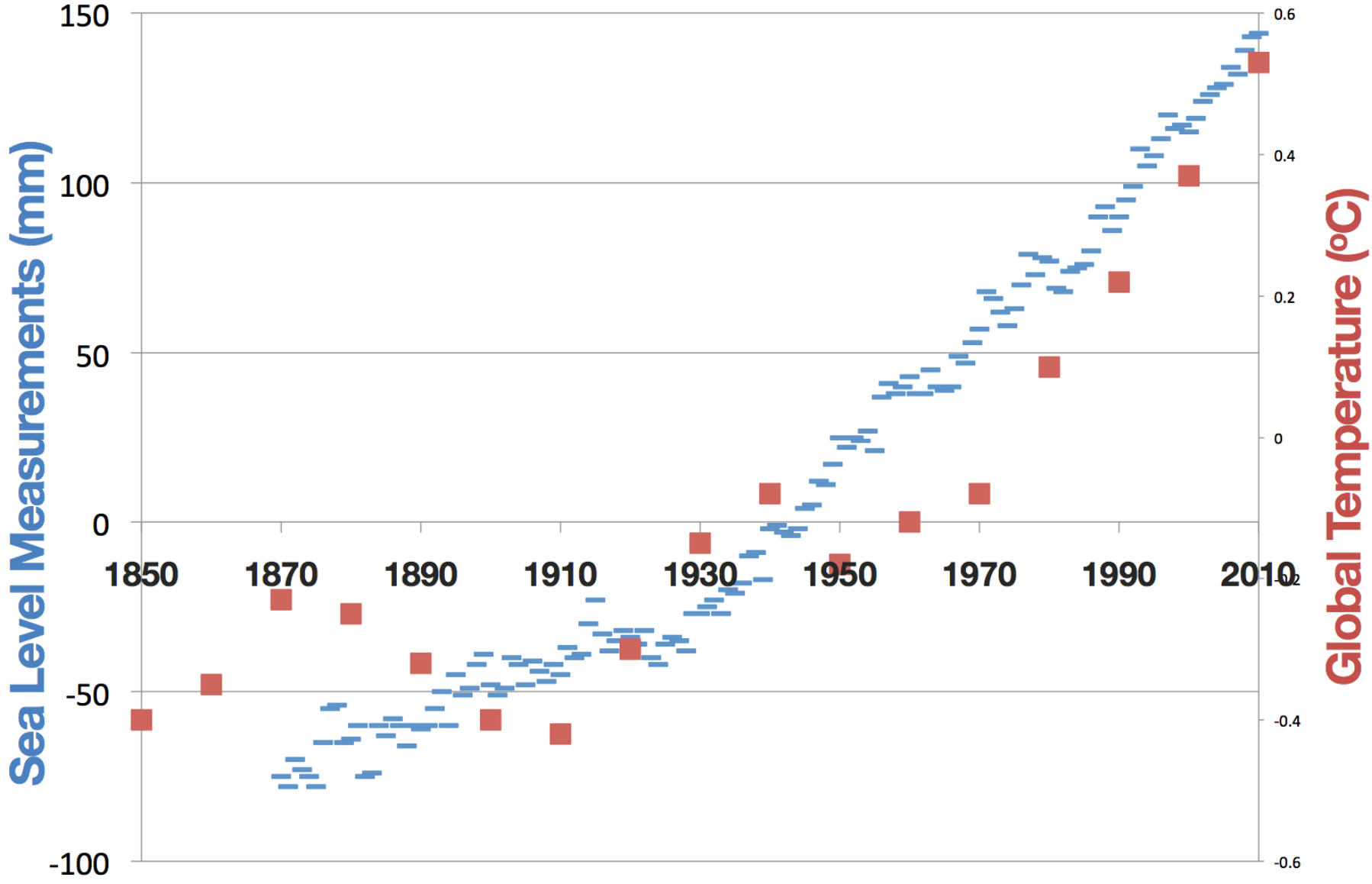
2004

Observed Global Temperatures



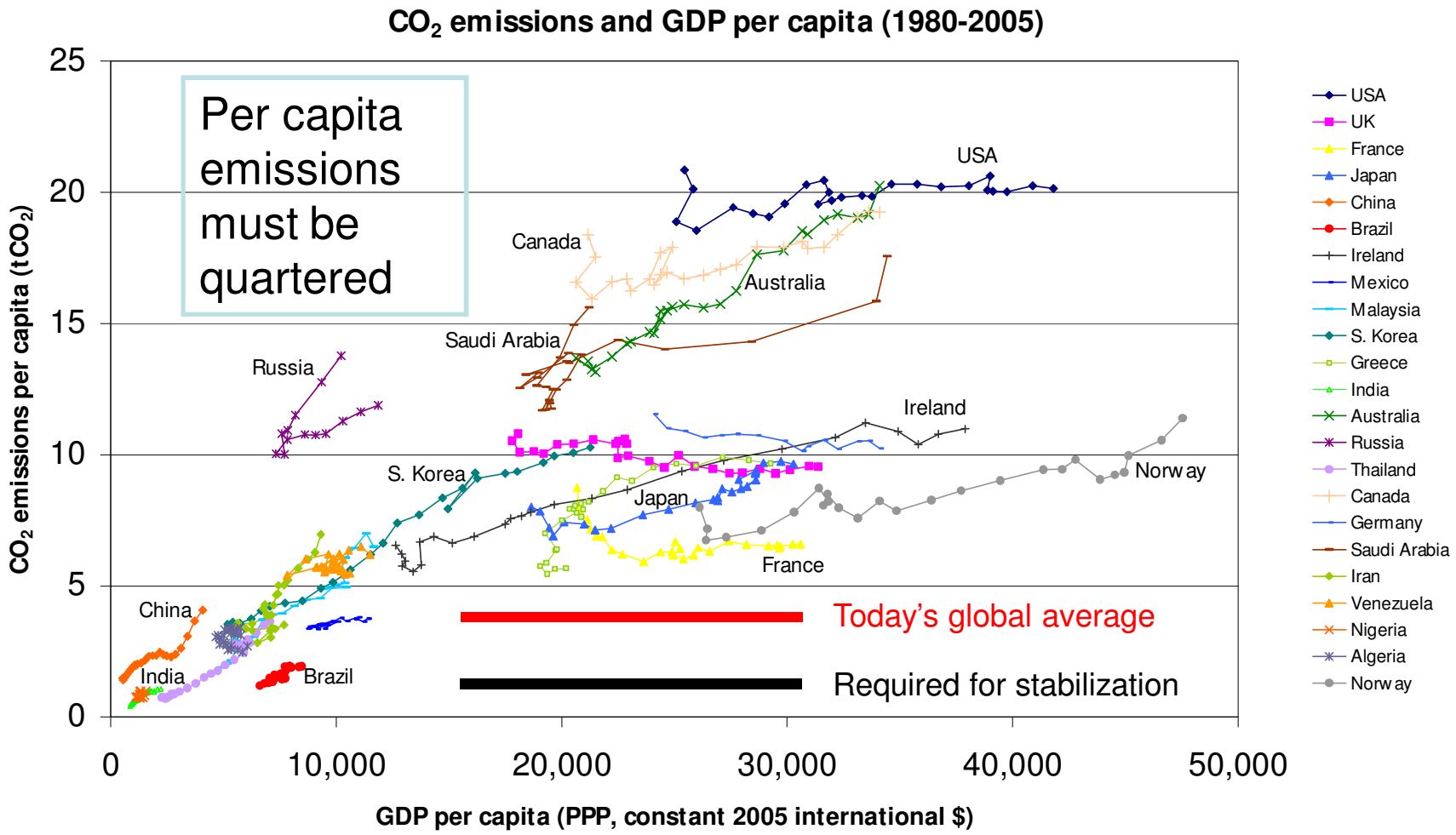
Source: Fedorov et al. Science 2006, 312, 1485
Source: ML Design. From "The Complete Ice Age: How Climate Change Shaped the World" edited by Brian Fagan, Thames & Hudson Ltd., London, 2009

Sea Level and Temperature Measurements

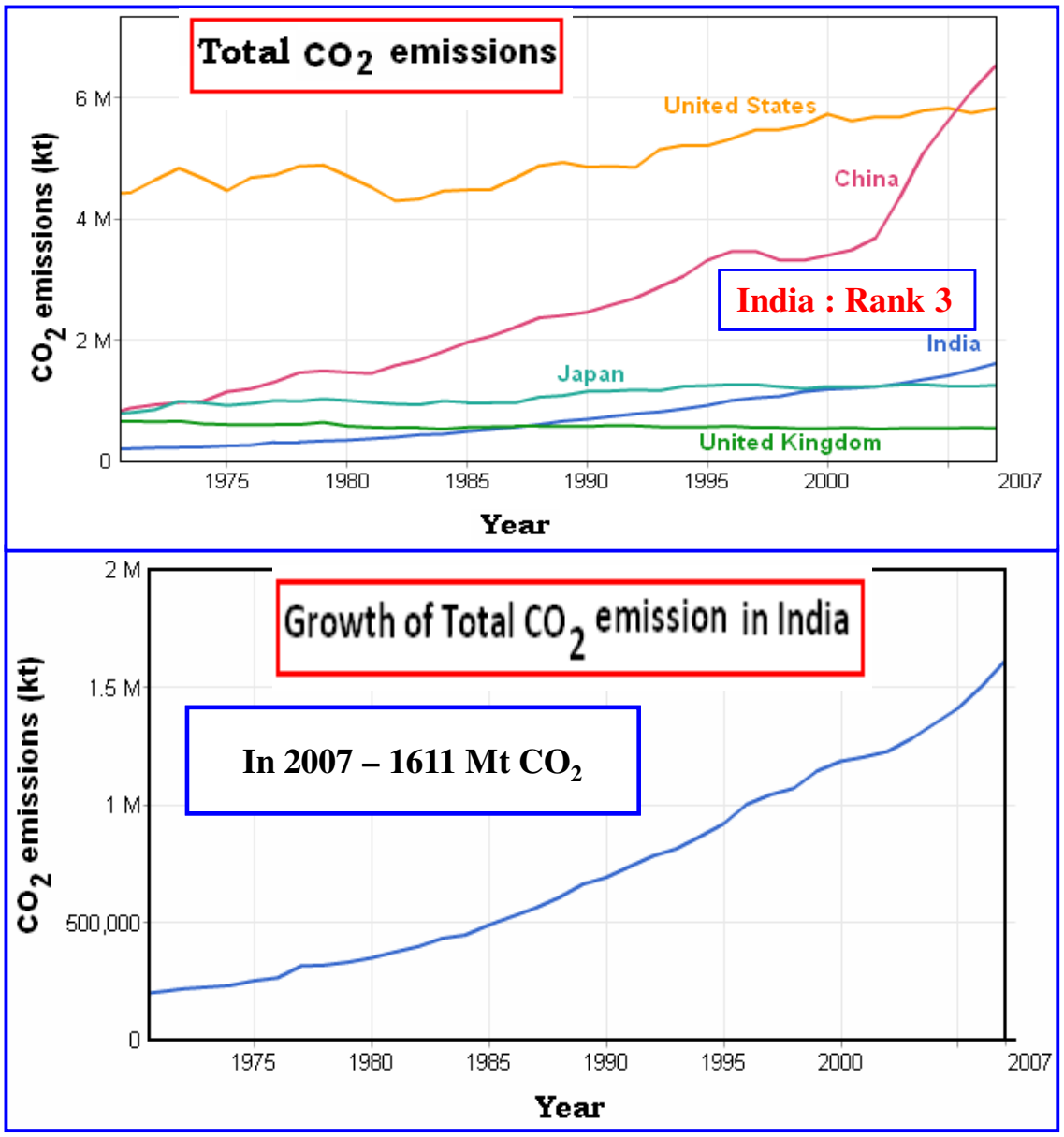


Source: Met Office & Proudman Oceanographic Laboratory Liverpool

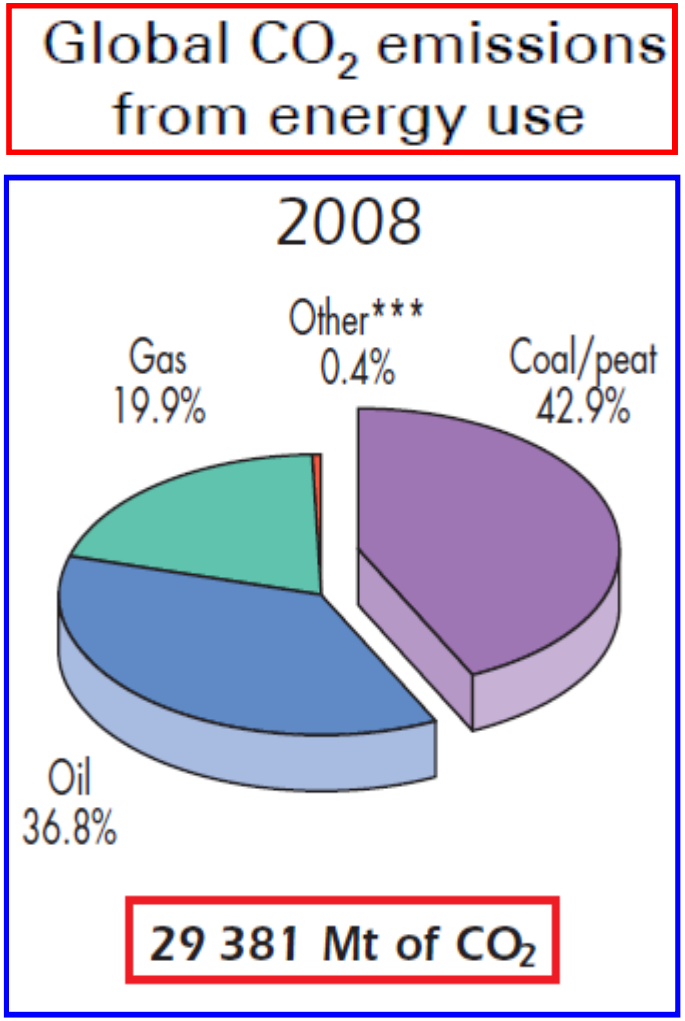
CO_2 emissions and GDP per capita



Source: DOE EIA database (2008)
Russia data 1992-2005, Germany data 1991-2005

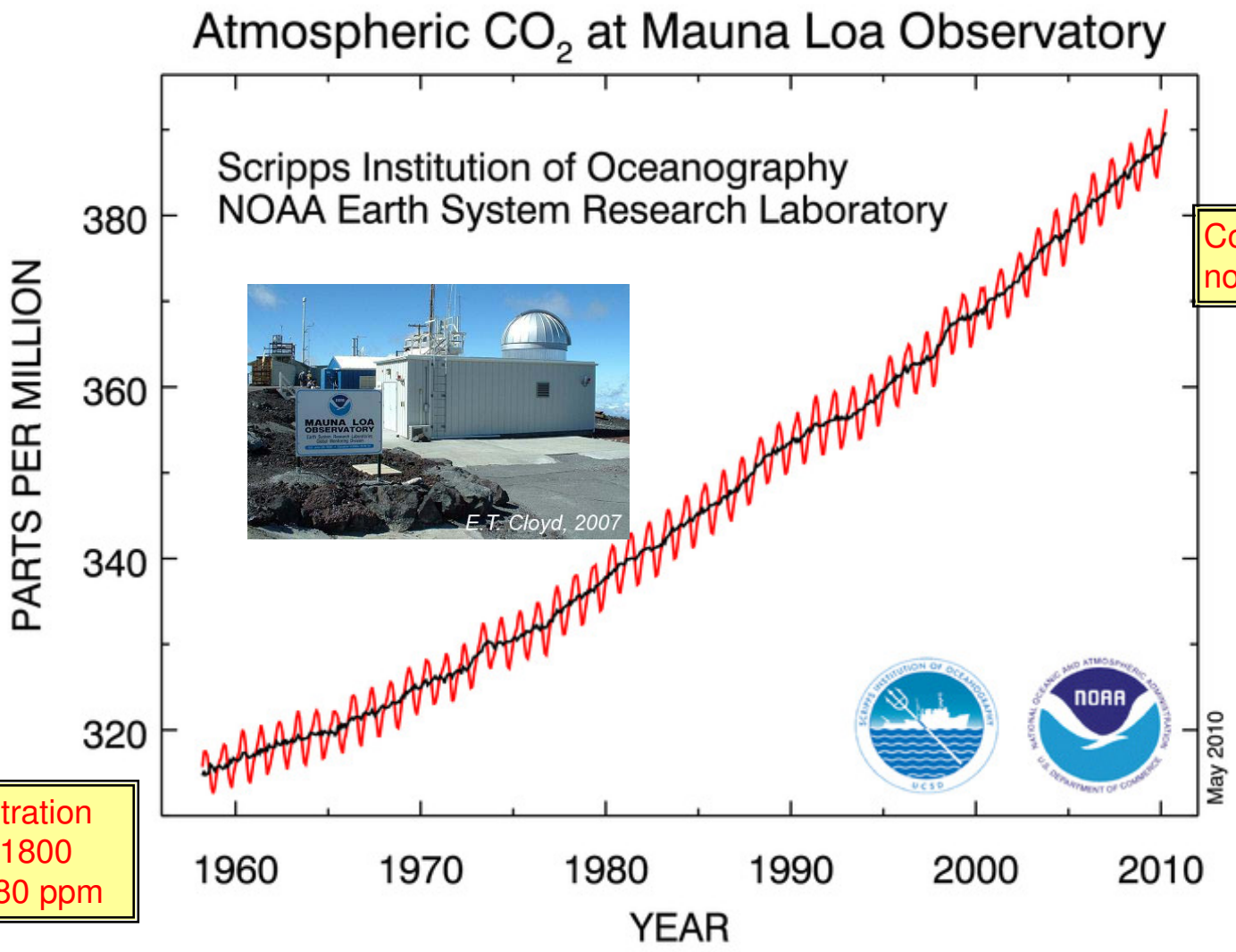


Source: World Bank, World Development Indicators, 2010



Source: Key World Energy Statistics, 2010, IEA

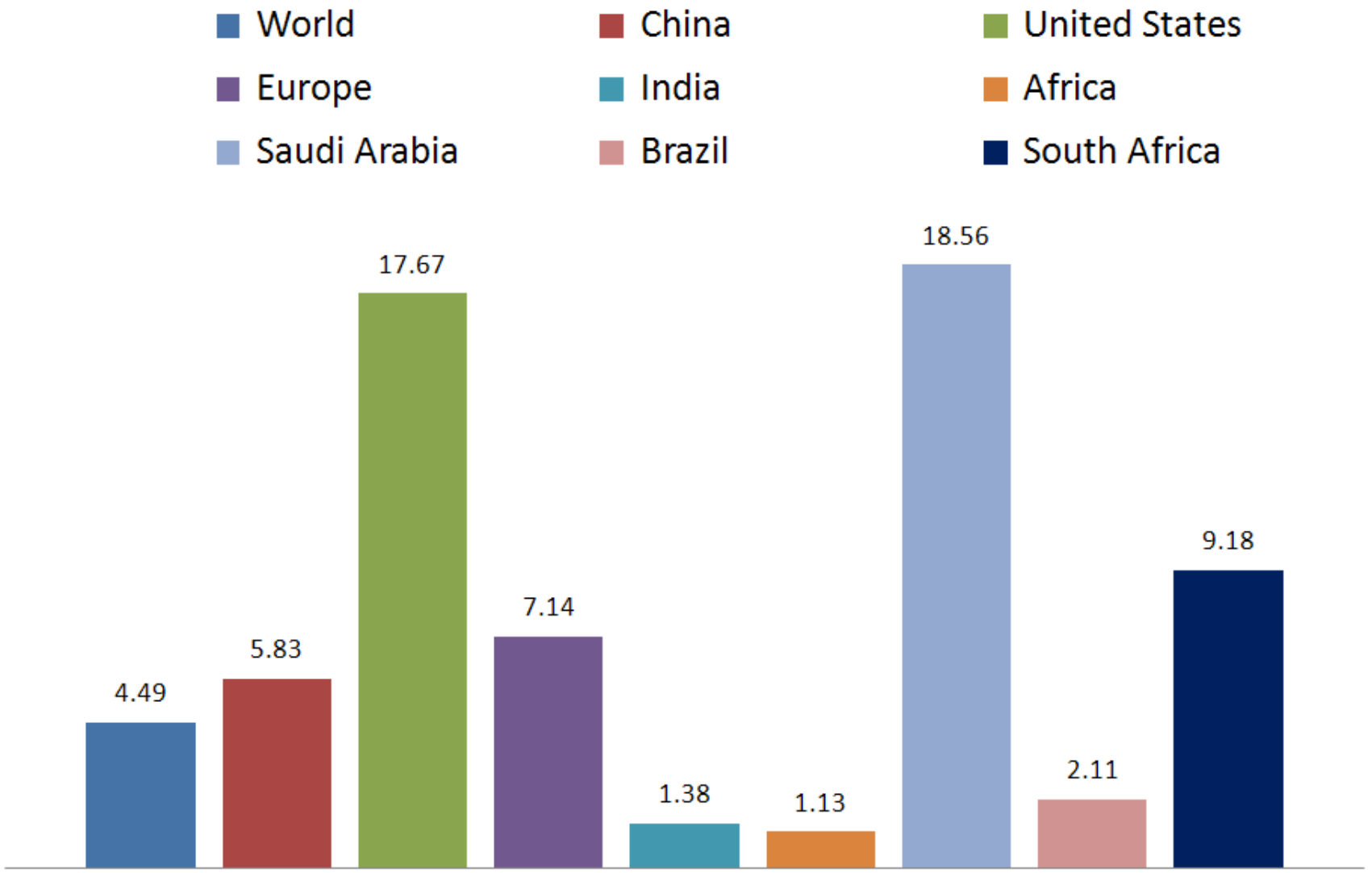
Observed CO_2 concentrations



Concentration now ~390 ppm

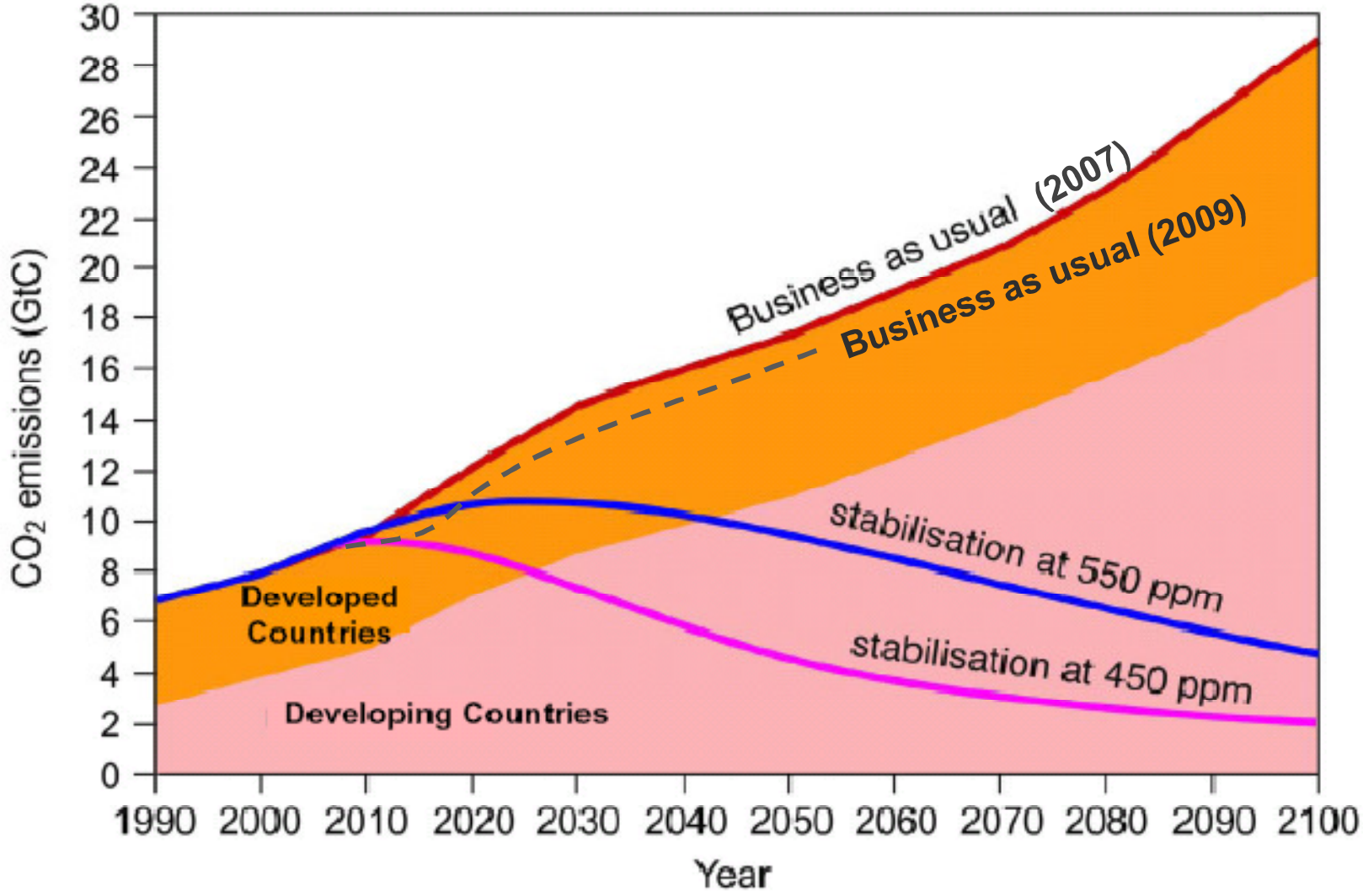
Concentration prior to 1800 was ~280 ppm

Per Capita Carbon Dioxide Emissions 2009 (Tonnes)



Source: International Energy Statistics

The Rise in Emissions to 2100

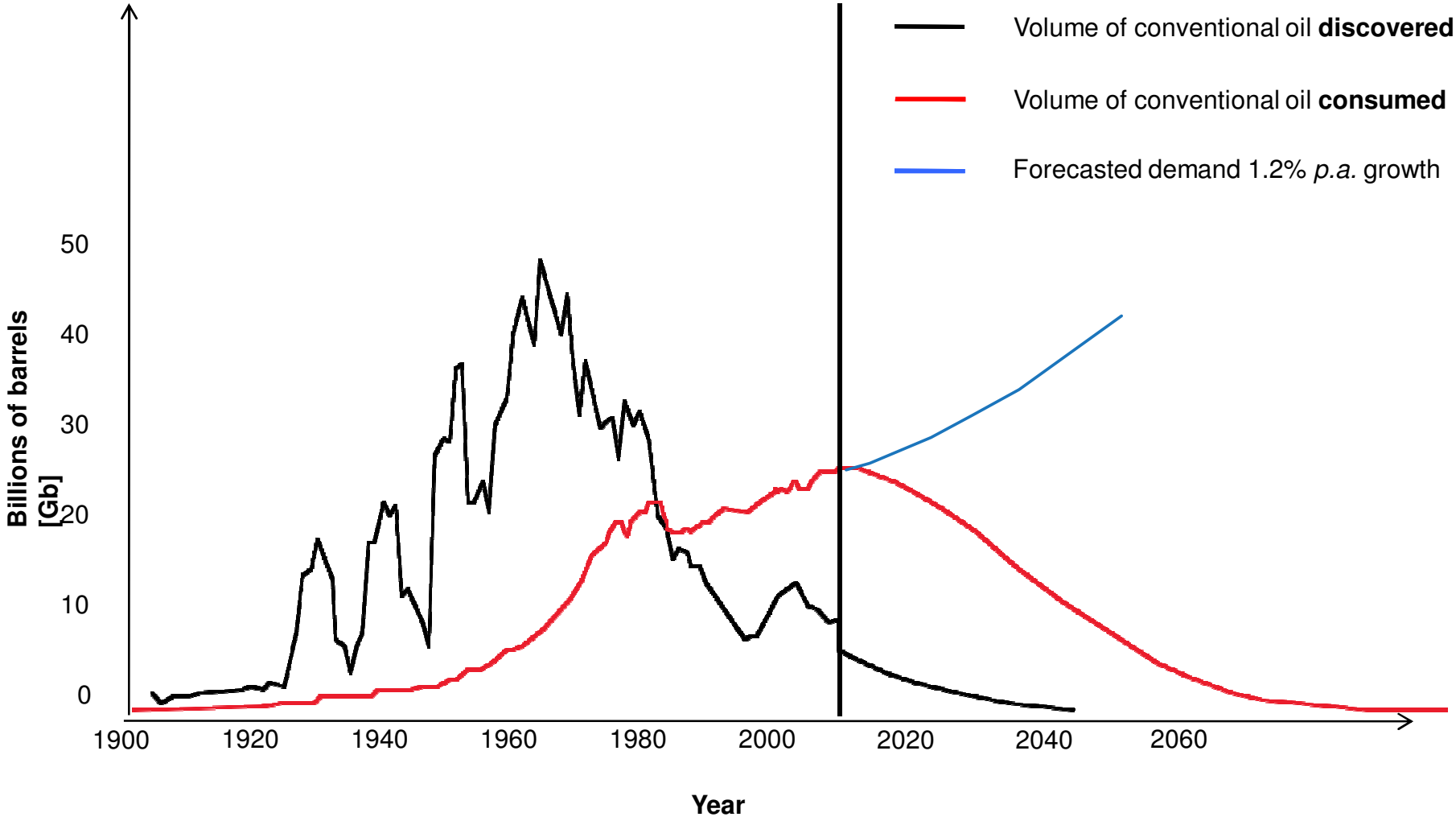


Source: Adapted from Defra

Oil Production:
Has Oil Passed its Tipping Point?

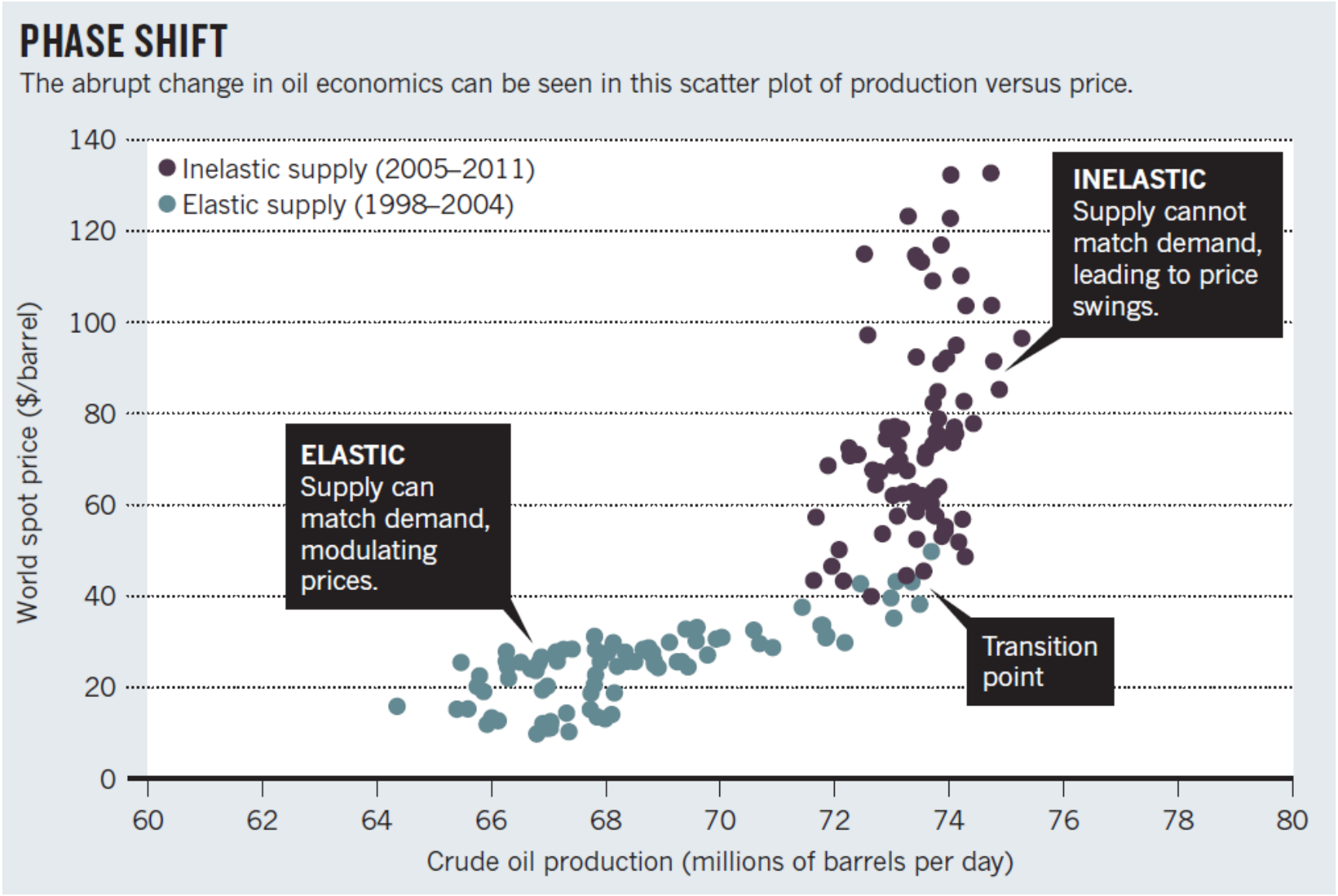
Source: K. James/Bloomberg/Getty

Conventional Oil Supply and Demand



Source: N.A. Owen, O.R. Inderwildi and D.A King, 'The status of conventional world oil reserves - Hype or cause for concern?' (2010) Energy Policy, doi:10.1016/j.enpol.2010.02.026

Crude Oil Price versus Crude Oil Production from 1998 to present



Source: Murray, J. and King, D. (2012) Oil's Tipping Point has Passed, Nature, Volume 481, 433-435

A few disturbing facts from Greenland last summer

- 552 billion tons of ice melted from the ice sheet (NASA), +15% than the average summer melt, beating 2005's record.

- The surface ice loss was +12% more than in 2005, nearly quadruple the amount that melted just 15 years ago.

Contd.....

A few disturbing facts from Greenland last summer

- **We are not aware of this amount of loss of ice in the last 300 years**

- **The surface area of summer sea ice floating in the Arctic was nearly 23% below the previous record. The Northwest Passage was open to navigation.**

Contd……..

A few disturbing facts from Greenland last summer

- Surface temperatures in the Arctic Ocean this summer were the highest in 77 years of record-keeping, in some places 5^0C above normal, twice as fast as the rest of the planet.

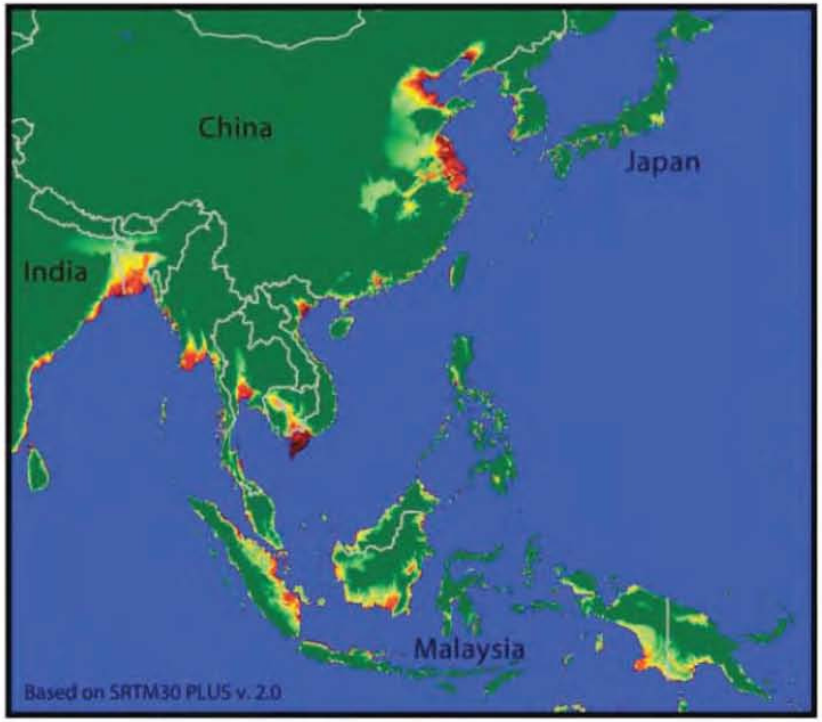
- By 2020/40 the summer sea ice may be gone. The induced warming up may lead to the subsequent melt of the ice sheet.

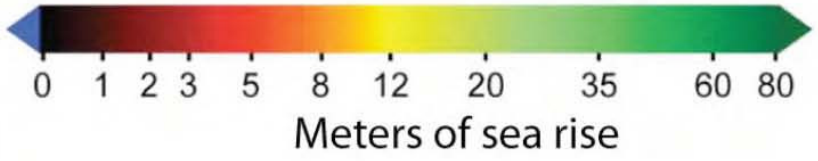
The impacts of a rise of around 2-3^{0}C in global average temperatures are many and serious. And they fall disproportionately on the inhabitants, human and non-human, of developing countries.

Sea-level rise derives both from warmer water expanding, and also from ice melting at the poles. This threatens not only low-lying islands and countries (such as Bangladesh), but also – at the higher levels of estimated temperature increase – major cities such as London, Shanghai, New York, and Tokyo.

Rise of oceans: how large ?

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



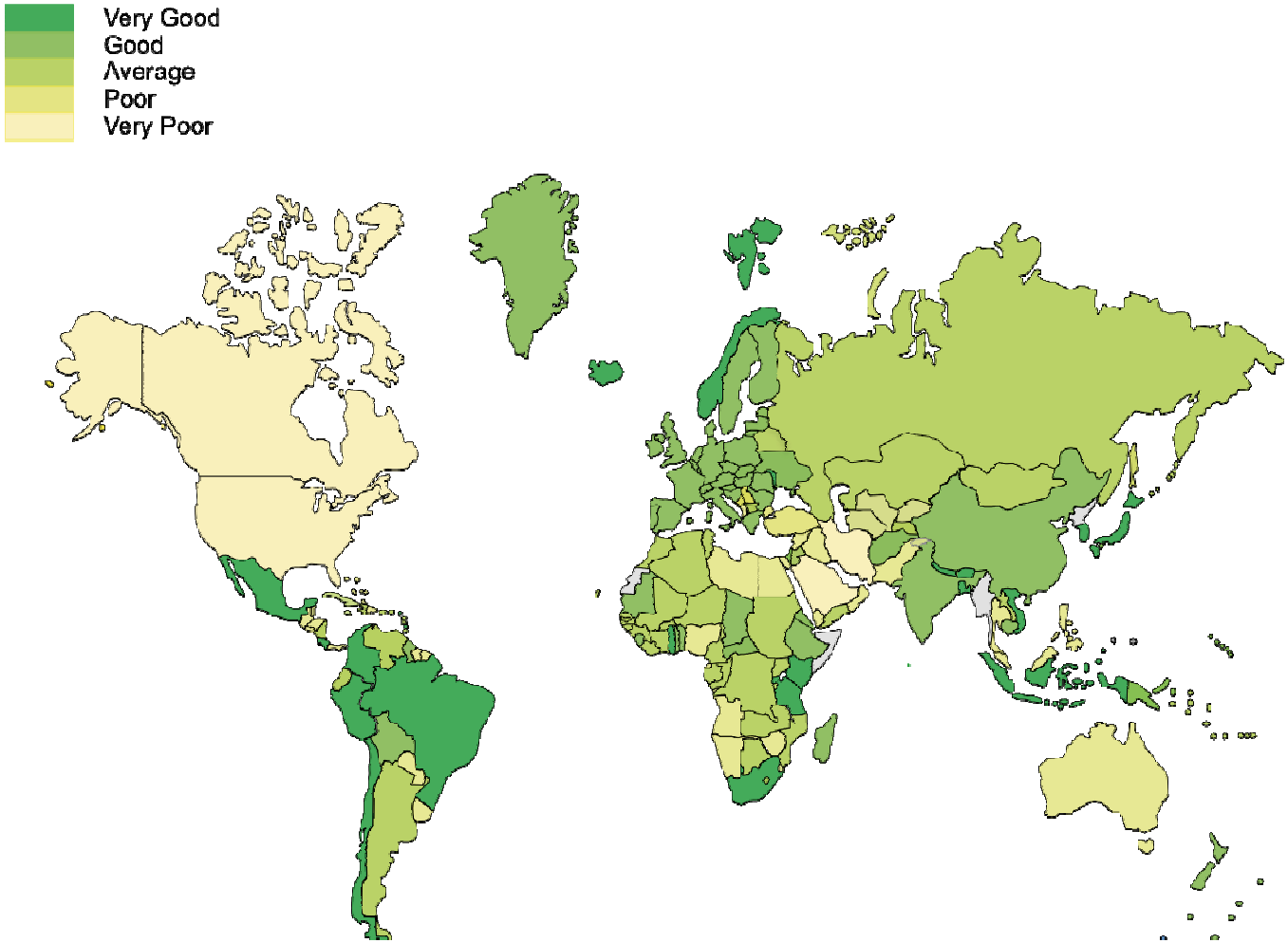


7 metres sea rise over
Shanghay-Hangzhou-Nannjing region

During the last one and half years, the average rate of the earthquakes increased and this trend continues

The increase in average rate of Earthquakes may well be due to climate change

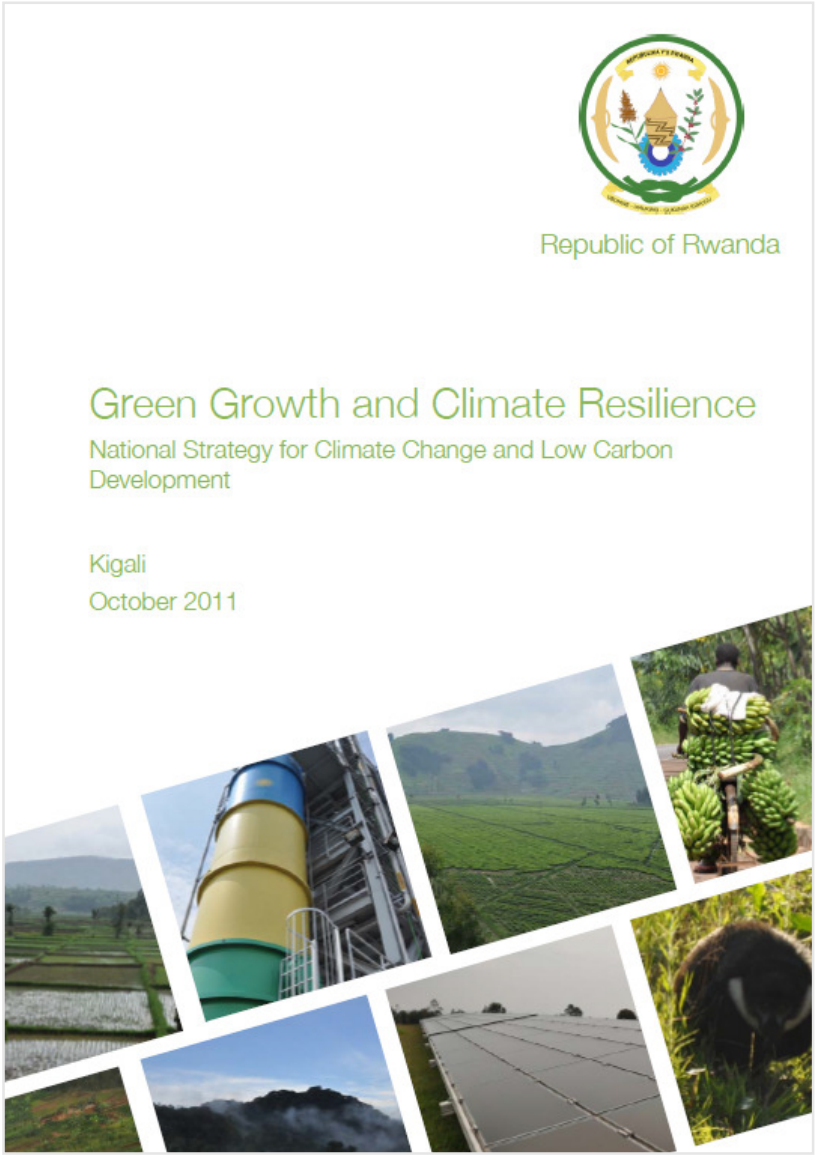
National Actions on Climate Change



Annex I countries are rated based on submissions pertinent to the Cancun Agreements.
'Very good': meet IPCC recommendations, Annex I: 25 - 40% reduction by 2020, Non-Annex I: submitted NAMA, 15-30% below BAU by 2020, or vocal in pressing for action.

Source: King, Richards and Tyldesley (2011) International Climate Change Negotiations: Key Lessons and Next Steps

National Action: Rwanda



So, what are the sources of clean energy – Saving the earth !!!

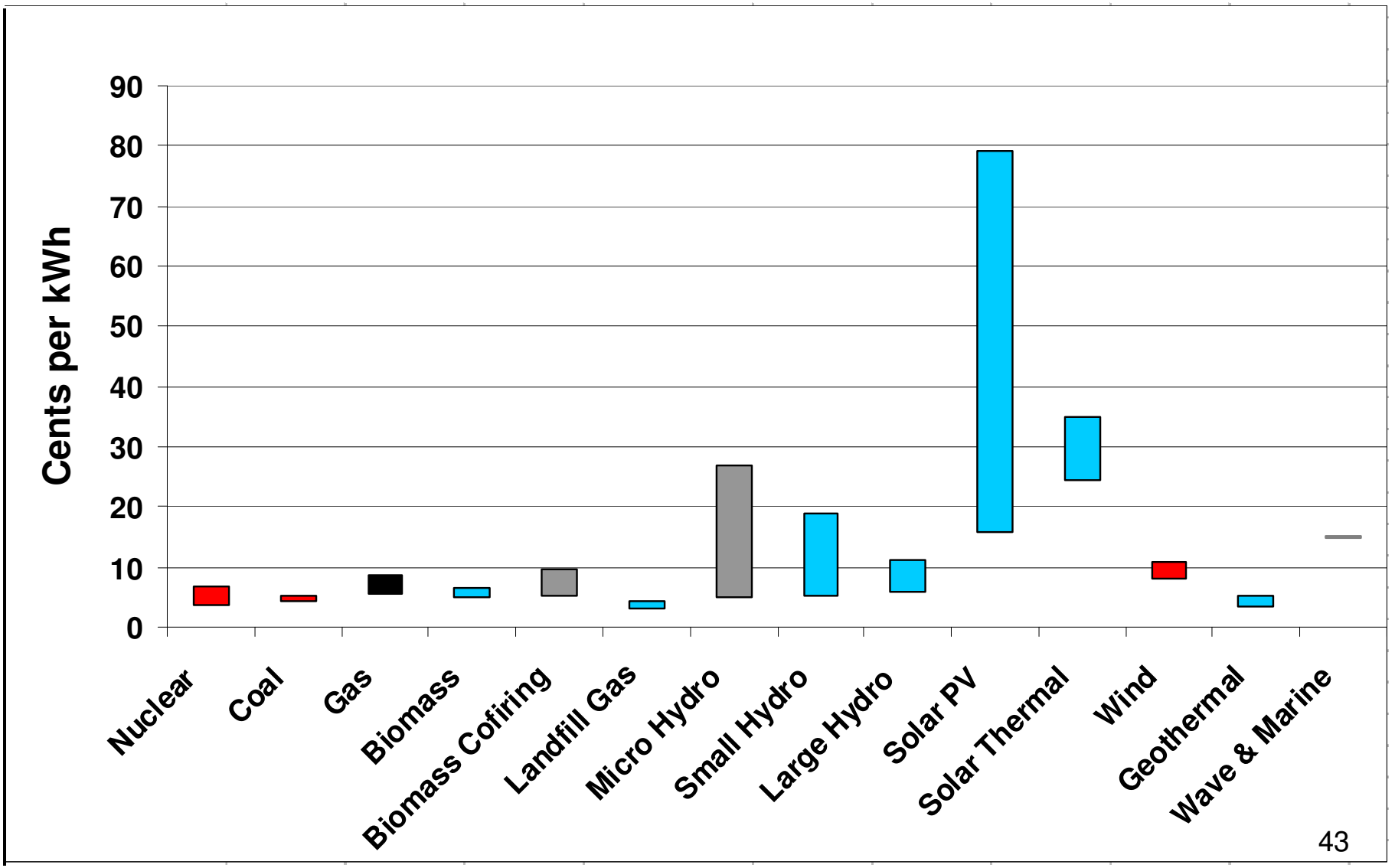
Options:

- **Nuclear energy**
- **Hydro power**
- **Renewable energy – Geothermal, Wind, Biomass, Solar etc.**

Energy Options

- No single source of energy can meet the growing demand for electricity even in India.
- Fossil fuel will continue to be the major contributor. Hydro will get more attention
- Nuclear at locations away from coal mines and near to the load centres.
- Known Indian uranium reserves are very moderate, but thorium reserves are amongst the largest in the world.

Costs of Different Energy Sources



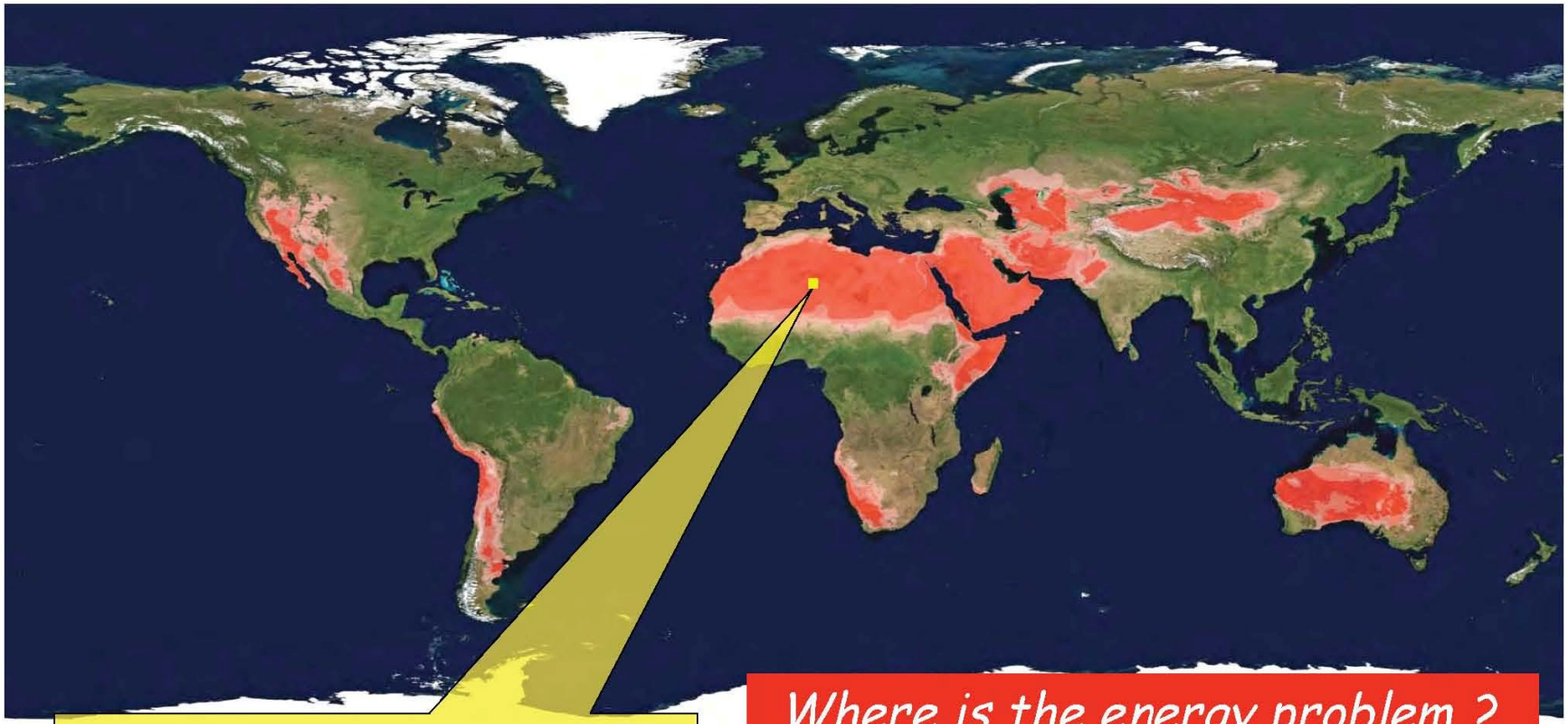
Energy from renewables ?

- 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.
- 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.
- A 15 TWatt of primary 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!

Table 1. Emission reduction targets announced by selected countries

	Countries	Emission reduction targets	Base year
Developed countreis	EU	20-30%	1990
	USA	In the range of 17% (30% reduction in 2025 and a 42% reduction in 2030, in line with the goal to reduce emissions 83% by 2050)	2005
	Australia	5% up to 15% or 25%	2000
	Japan	25%	1990
	Canada	17%	2005
Developing countries	India	20-25% by 2020 (emission intensity of GDP)	2005
	China	40-45% per unit of GDP by 2020	2005
	Brazil	36-39% by 2020	Reduction in projected emissions
	South Africa	42% by 2025	Business as usual

Solar energy in the “sunbelt”



(210 x 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 ?

High efficiency conversion of CSP solar into high temperature heat (450-650 °C)
The "great transformation" from fossils to solar

Gerhard Knies, ISES-Rome CSP WS 2007

CSP ≡ Concentrating Solar Power

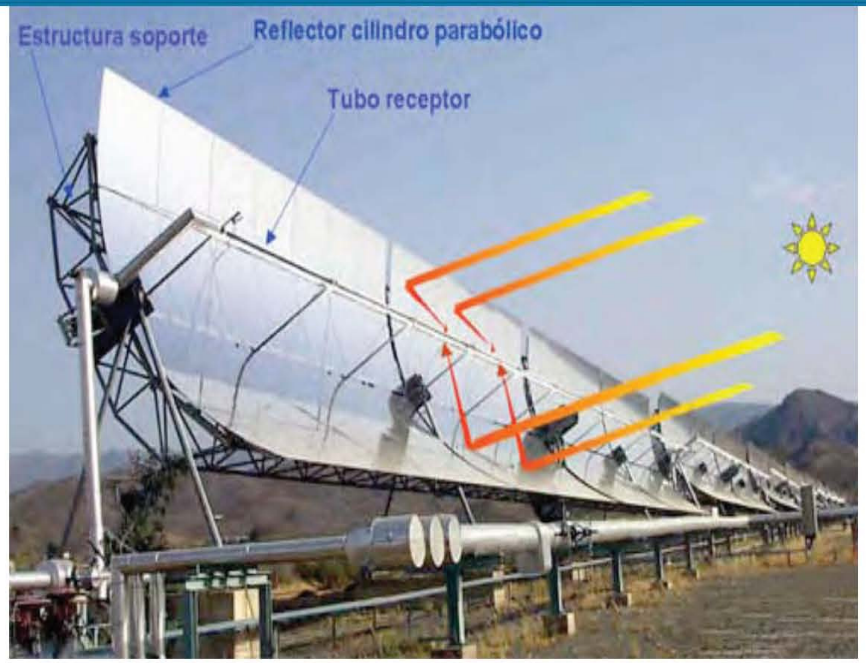
Concentrating solar energy: The earliest ideas

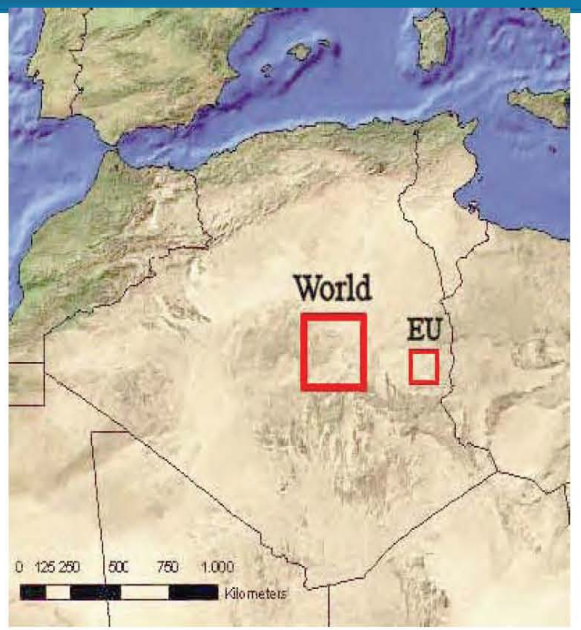
Painting Title : Burning Mirrors, Stanzio della Mattematica, 1587-1609
Artisit: Parigi, Giulio (1571-1635)

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.

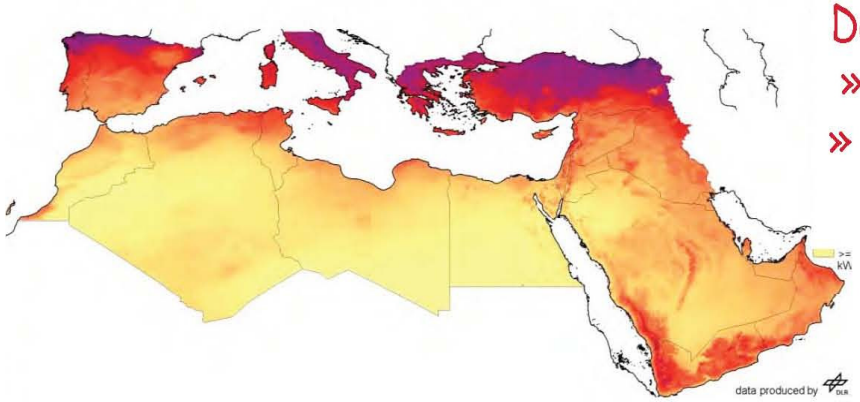
The first solar facility to produce electricity was installed in 1912 by Shuman in Maady, Egypt.
The parabolic mirror trough concentrates sunrays on a line focus in which a tube was situated containing water that was brought to evaporation.
It produced 55 kWatt of electric power.

Principle of modern CSP





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

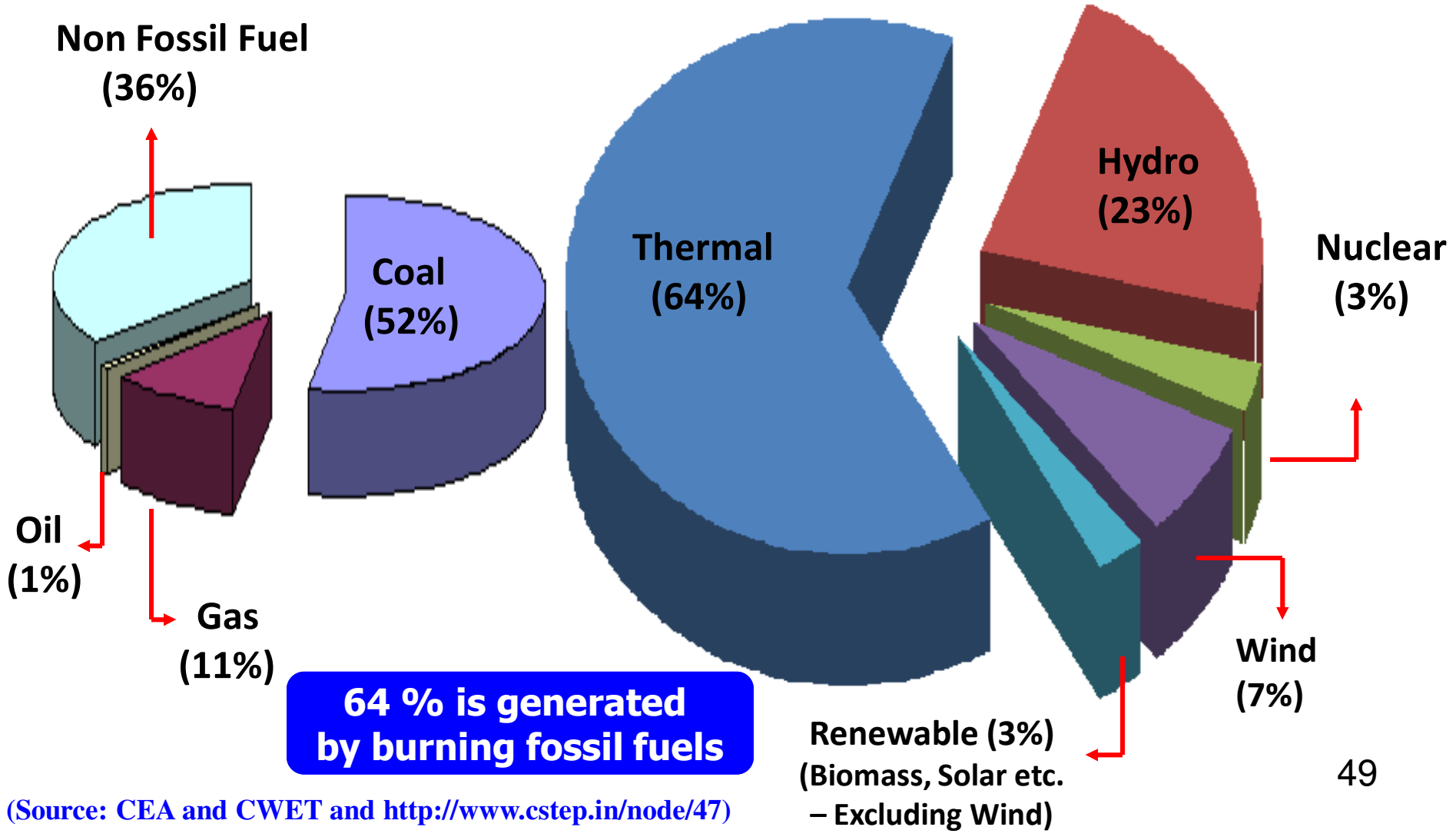


Demand of electric power:
» 7 500 TWh/y Europe + Desert 2050
» 35 000 TWh/y world-wide 2050

Economic potentials > 600 000 TWh_{el}/y

INDIA'S PRESENT ENERGY MIX

As on June, 2010

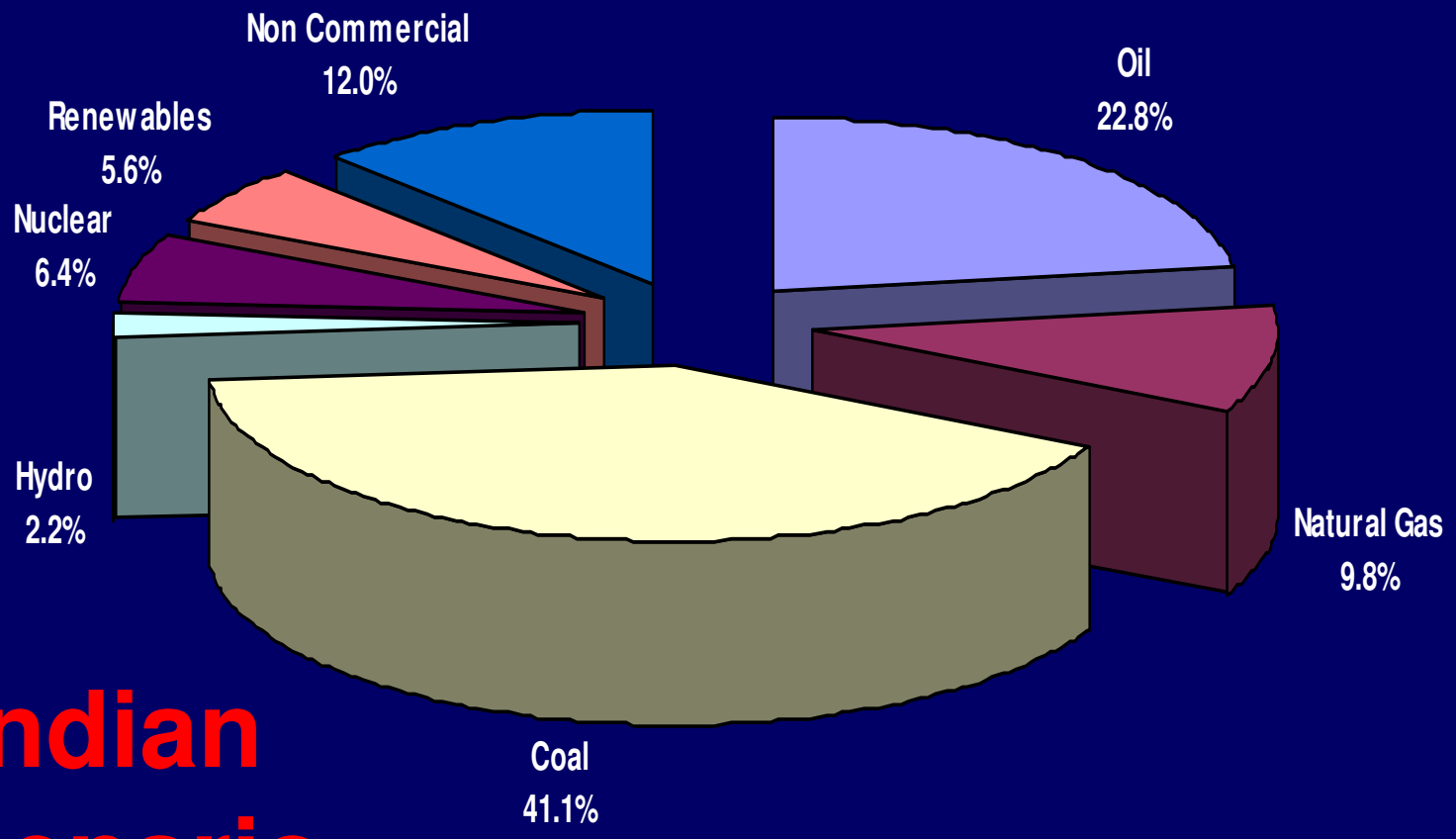


64 % is generated by burning fossil fuels

(Source: CEA and CWET and http://www.cstep.in/node/47)

Energy Mix in 2031-32 for 8% GDP growth

(Max. Nuclear, Hydro, Gas & renewables scenario)



Indian scenario

Estimates of Energy Sources in India

- Coal can last for

  140 years at current levels of use.

  45 years at 5% increased use

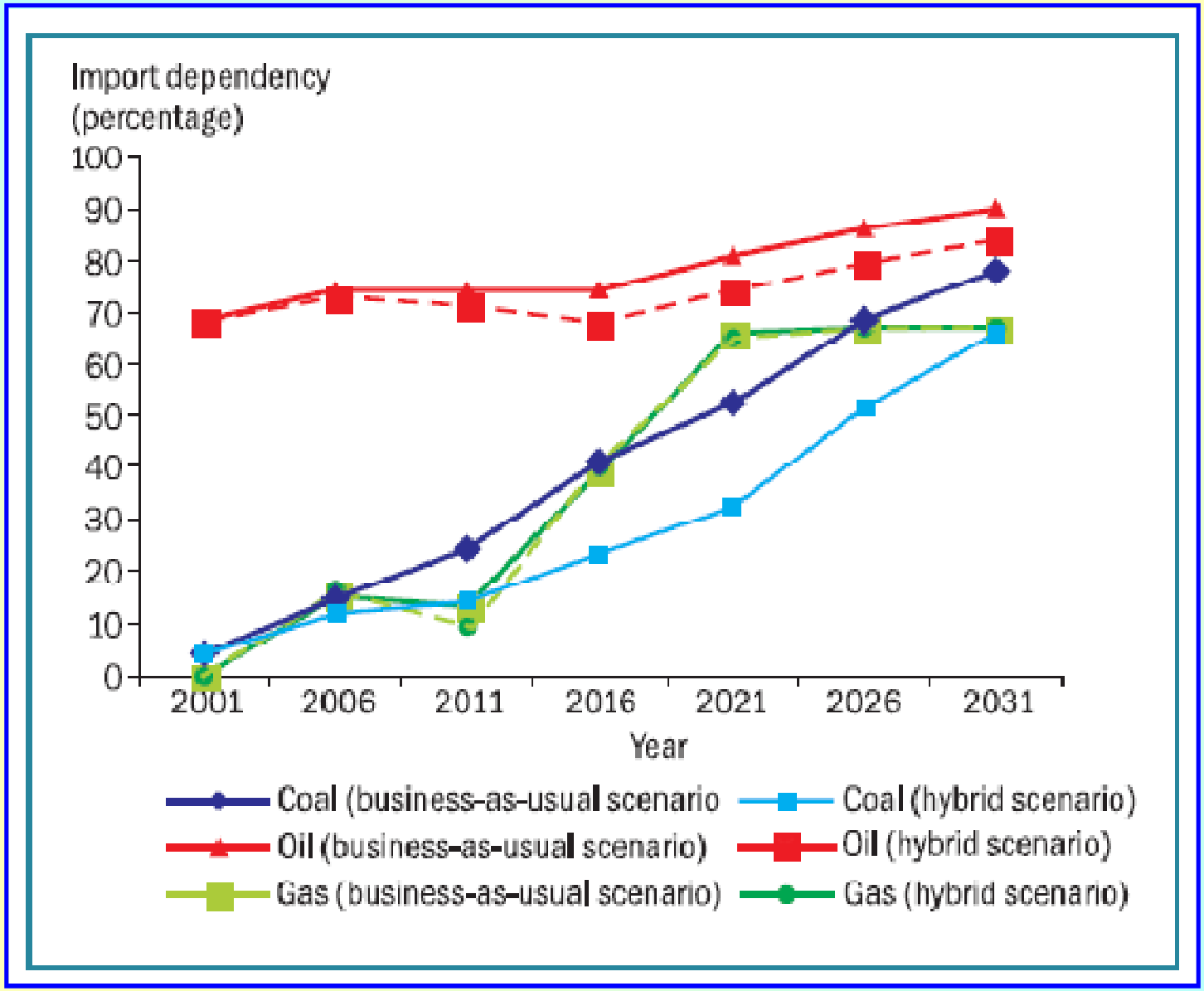
- Crude oil at current levels of use will last

  23 years.

- Gas is enough only for

  30 years.

Import rate of Indian fossil fuel



Source: National Energy Map for India: Technology Vision 2030

Journey towards the Clean Energy in India

India's limited resources of coal and fossil fuel, its nonviable resources for harnessing solar energy and its inability to use other sources such as wind power, biomass etc. make nuclear power rectors an important option for this country.

India's nuclear power programme

In recent times, nuclear power experienced a renaissance, since nuclear power reactors do not cause pollution. India, of course, is on a fast track to increase its nuclear capacity, By 2020 India may reach a production level of 20,000 MW, subject to the Nuclear Suppliers Group commitment of exporting uranium and other necessary advanced equipment to India.

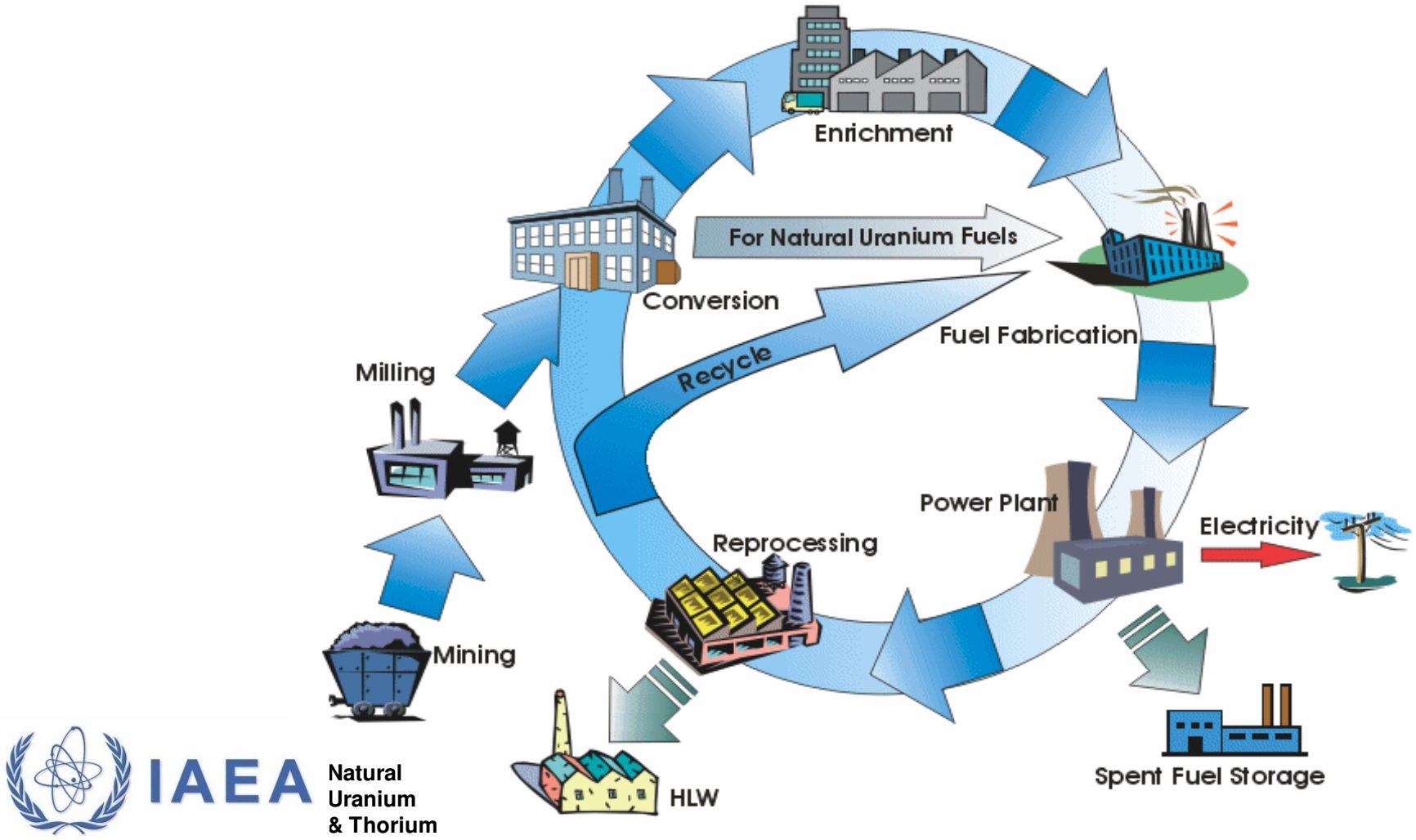
INDO – US

123

NSG GO!

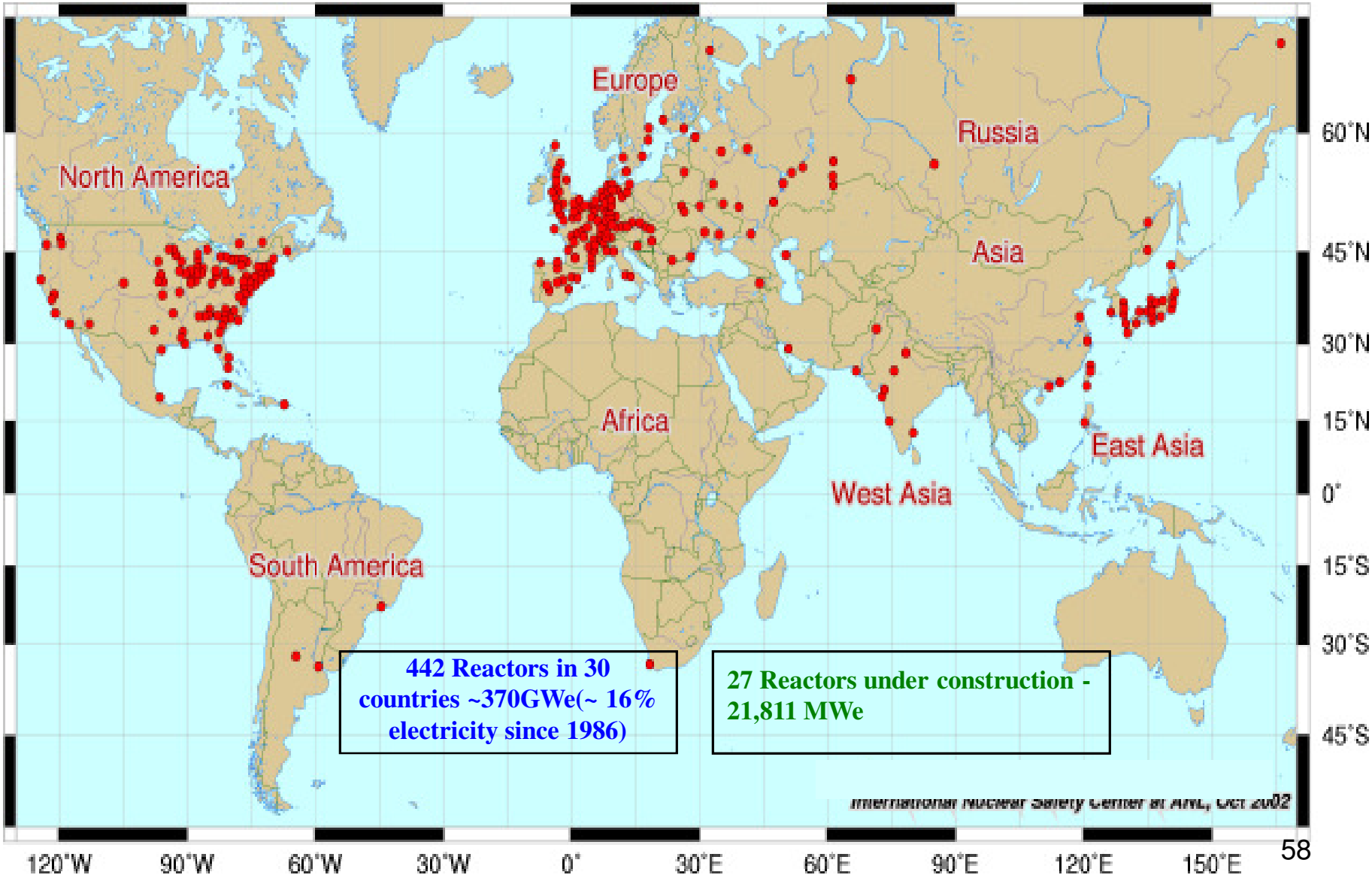
Nuclear Renaissance

NUCLEAR FUEL CYCLE



For nuclear energy to be sustainable as a global source of emission – free energy, the reactor fuel cycle must also remain sustainable (DG-IAEA Scientific Forum 2004)

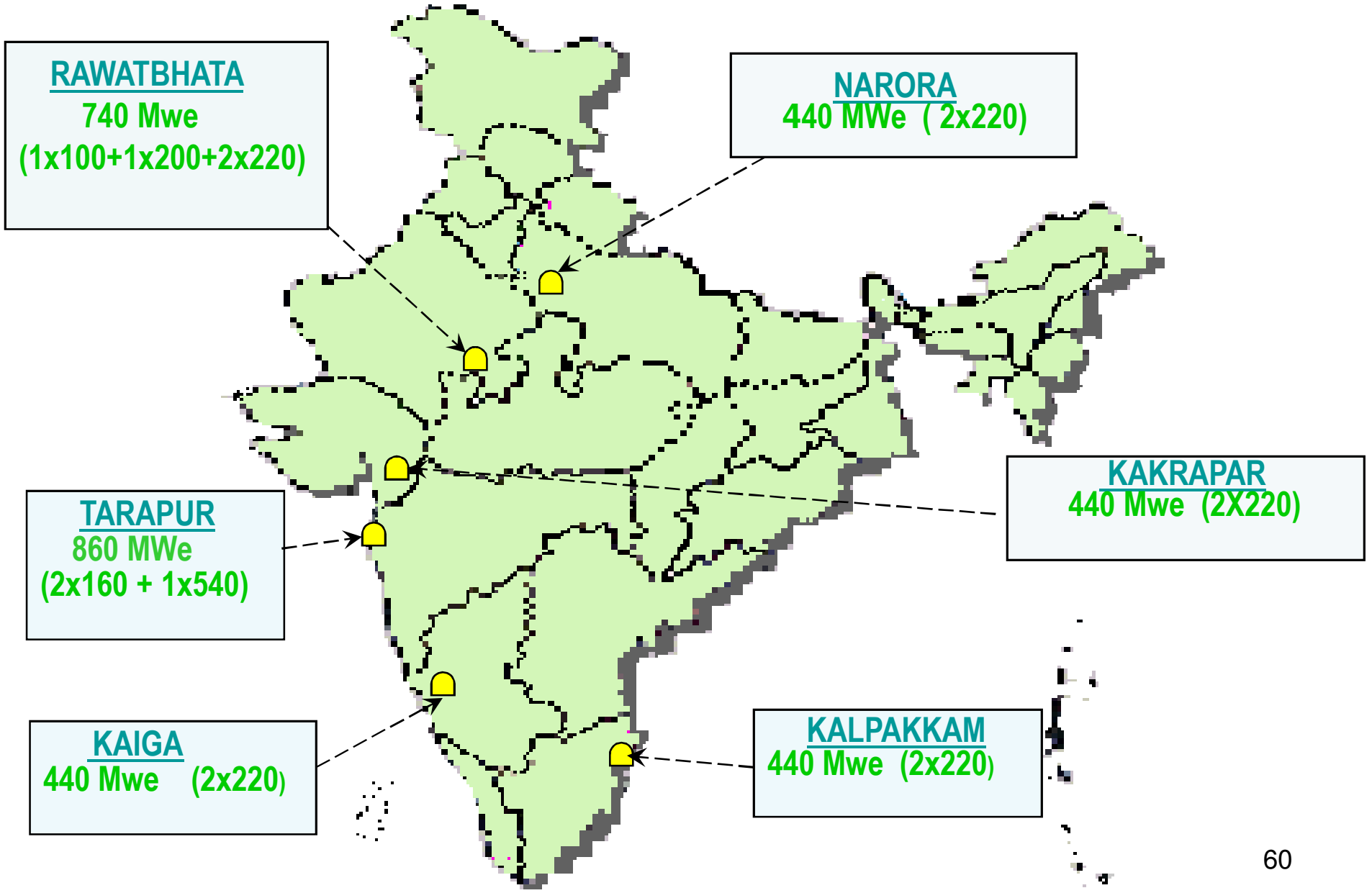
NUCLEAR POWER REACTORS (Nov. 2006)



Country wise share of nuclear Power

France	82.5
Belgium	55.6
South Korea	44.7
Germany	31.0
Japan	29.3
UK	19.9
USA	19.3
Russia	15.8
India	3.1
China	2.0

NUCLEAR POWER PLANTS IN OPERATION

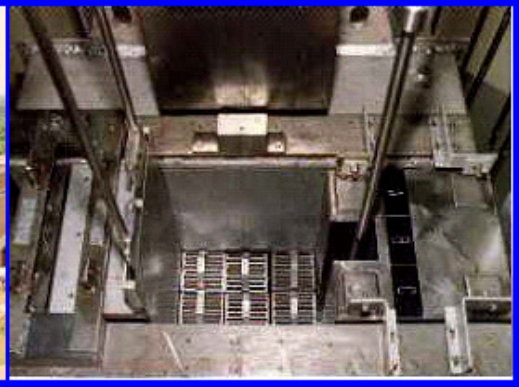


Future Plans

- Eight units (4 x 700 MWe PHWRs + 4 x 1000 MWe LWRs) are sanctioned.
- India envisages a total nuclear capacity of about 20000 MWe by the year 2020.
- With global access capacity of 40,000 MWe by 2020 can be achieved.

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.



Stage – I
PHWRs

- 14- Operating
- 4 - Under construction
- Several others planned
- Scaling to 700 MWe
- Gestation period being reduced
- Power potential ≅ 10,000 MWe
- Presently in industrial Domain

Stage - II
Fast Breeder Reactors

- 40 MWth FBTR – Operating, Technology objectives realised
- 500 MWe PFBR- Construction commenced
- Power potential ≅ 530,000 Mwe
- Industrial domain by 2020 (5 FBRs of 500 MWe in operation with closed fuel cycle)

Stage - III
Thorium Based Reactors

- 30 kWth KAMINI- Operating
- 300 MWe AHWR- under Regulatory Examination
- Power potential ≅ 155,000 Gwe-yr.
- Thorium-U233 Thermal or Fast Reactor
- Industrial domain by 2035
- Development of Accelerator Driven System for U-233 production and incineration of long lived actinides and fission products

Three Stage Nuclear Power Programme

Kalpakkam has the unique distinction of being the only place in the world, where all the three fissile isotopes (Uranium 235, Plutonium 239 and Uranium 233) are used in the nuclear reactors.

Fukushima Nuclear Disaster

- **<u>Fukushima Nuclear Disaster</u> immediately followedby Germany capping Nuclear Programme**

World wide controversy and debate

Contd..

Fukushima Nuclear Disaster…….

Solar Energy at per with Grid ≡ 2022 ≅ 2030

it will be short sighted if not down right foolish

to abandon "Nuclear energy although, "Whoever

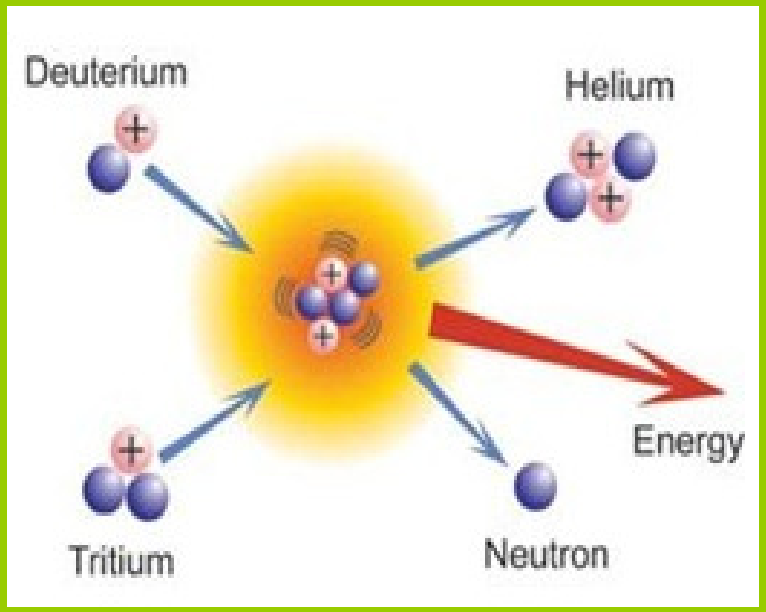
invented the term 'fool-proof' underestimated

the ingenuity of fools"

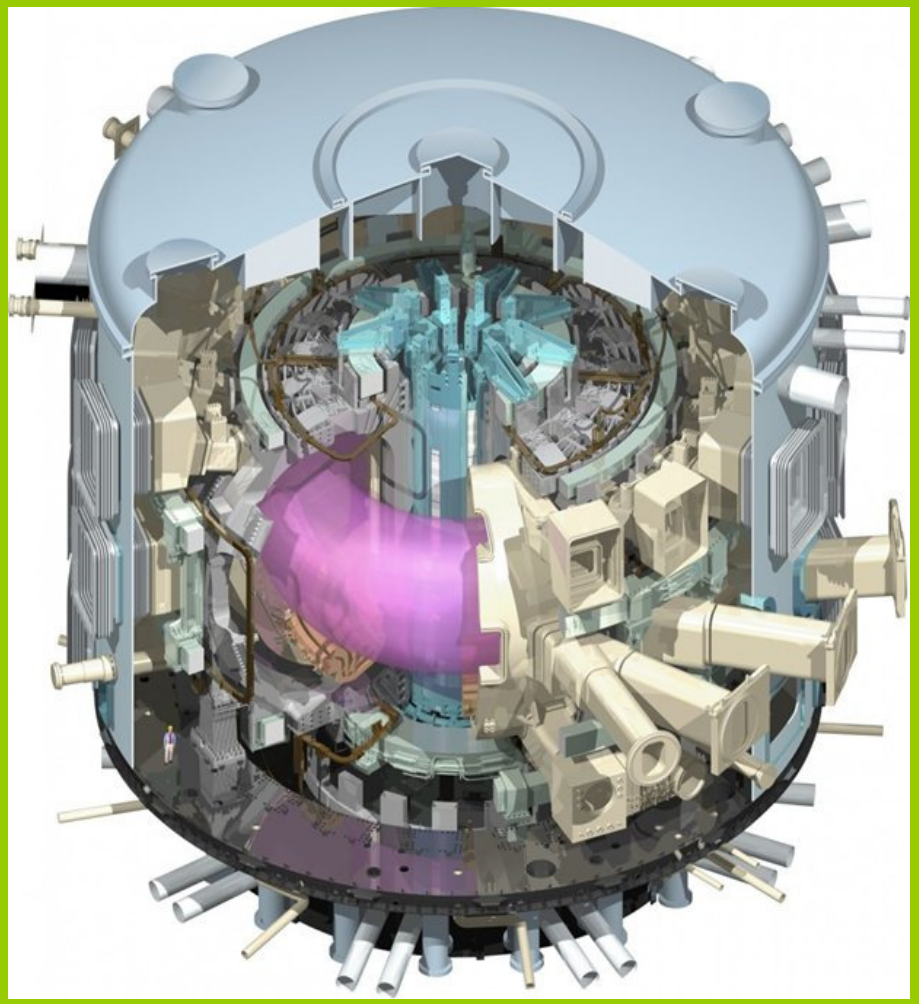
Contd..

Impact of Fukushima Nuclear Disaster (March, 2011) on the Indian NPPs

- **Fukushima Nuclear Disaster immediately followed by Germany capping Nuclear Programme.**
- **World wide controversy and debate.**
- **With Germany capping its nuclear programme , the anti nuclear lobby in India has turned more vociferous in the issue of banning of nuclear power reactors in the country.**
- **Land acquiring process also become a crucial political issue in recent time in India.**



Fusion in the core of the Sun and Stars



Fusion on the Earth – ITER: the world's largest Tokamak


ITER, currently under construction
in the South of France, aims to
demonstrate that fusion is an energy
source of the future


A global collaboration
has been formed to
test the feasibility of
fusion

Total budget of the ITER Project

~ 5 billion Euro

India's contribution → 10 % of the cost

Geothermal Energy –

An alternative energy source for future power

(i) Environment impact is almost negligible. Greenhouse gas emission is negligible.

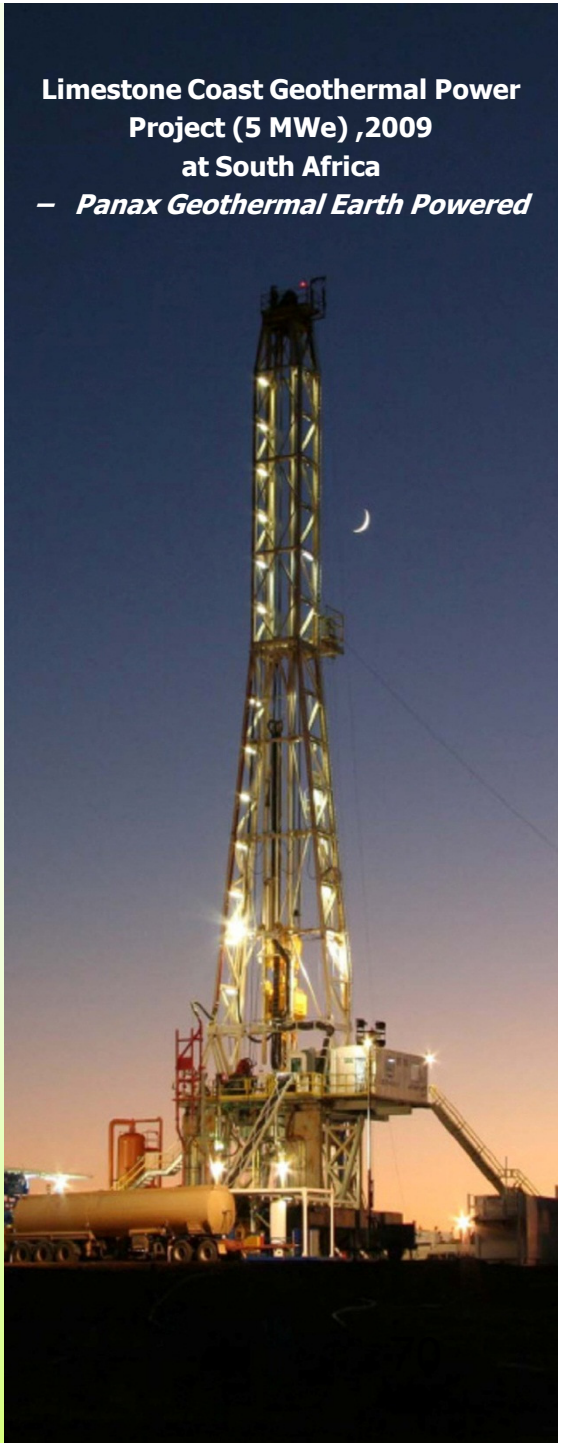
(ii) No consumption of any type of fossil fuels.

(iii) Maintenance cost is low.

(iv) In terms of energy consumption, a geothermal power plant is self-sufficient.

(v) It is a globally sustainable energy source.

(vi) Deep drilling well of the power plant (2-4 km) could also be used in experimental study related to the Earth Sciences and Earthquake Precursor Study as well.



Limestone Coast Geothermal Power Project (5 MWe) ,2009 at South Africa – *Panax Geothermal Earth Powered*

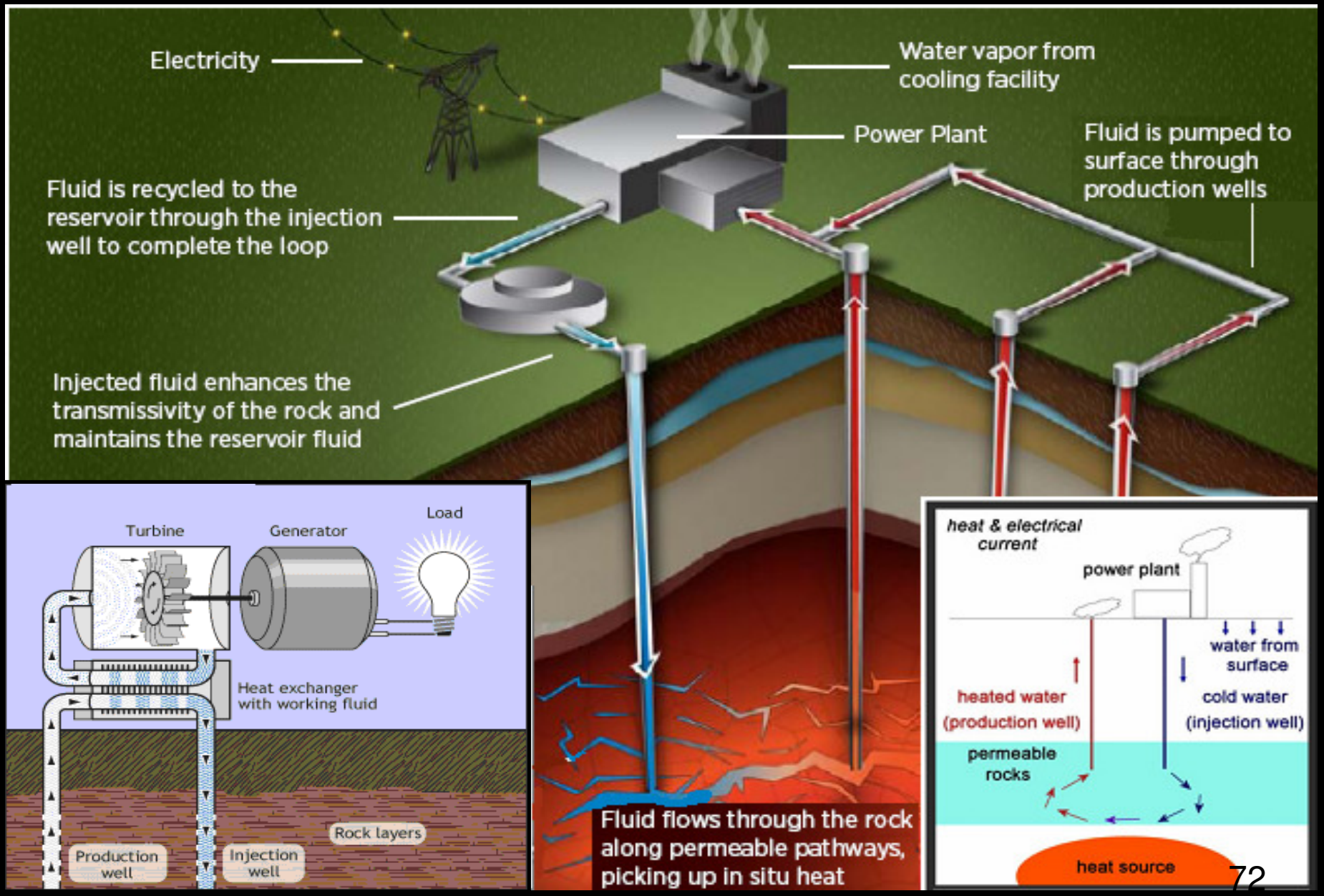
Worldwide Geothermal Electricity Production (2010)

Sr No	Country	Installed Capacity (MW)	%
1	United Sates	3,086.00	28.800
2	Philippines	1,904.00	17.770
3	Indonesia	1,197.00	11.170
4	Mexico	958.00	8.940
5	Italy	843.00	7.870
6	New Zeland	628.00	5.860
7	Iceland	575.00	5.370
8	Japan	536.00	5.000
9	El Salvador	204.00	1.900
10	Kenya	167.00	1.560
11	Costa Rica	166.00	1.550
12	Nicaragua	88.00	0.820
13	Russia	82.00	0.770
14	Turkey	82.00	0.770
15	Papua new Guinea	56.00	0.520
16	Guatemala	52.00	0.490
17	Portugal	29.00	0.270
18	China	24.00	0.220
19	France	16.00	0.150
20	Ethiopia	7.30	0.070
21	Germany	6.60	0.060
22	Austria	1.40	0.013
23	Australia	1.10	0.010
24	Thailand	0.30	0.003
Total			10,716.700

India is not in the list till the date

Source: Geothermal Energy: International Market Update Geothermal Energy Association, May, 2011 and International Geothermal Association (IGA)

Schematic diagram of Geothermal Power Plant



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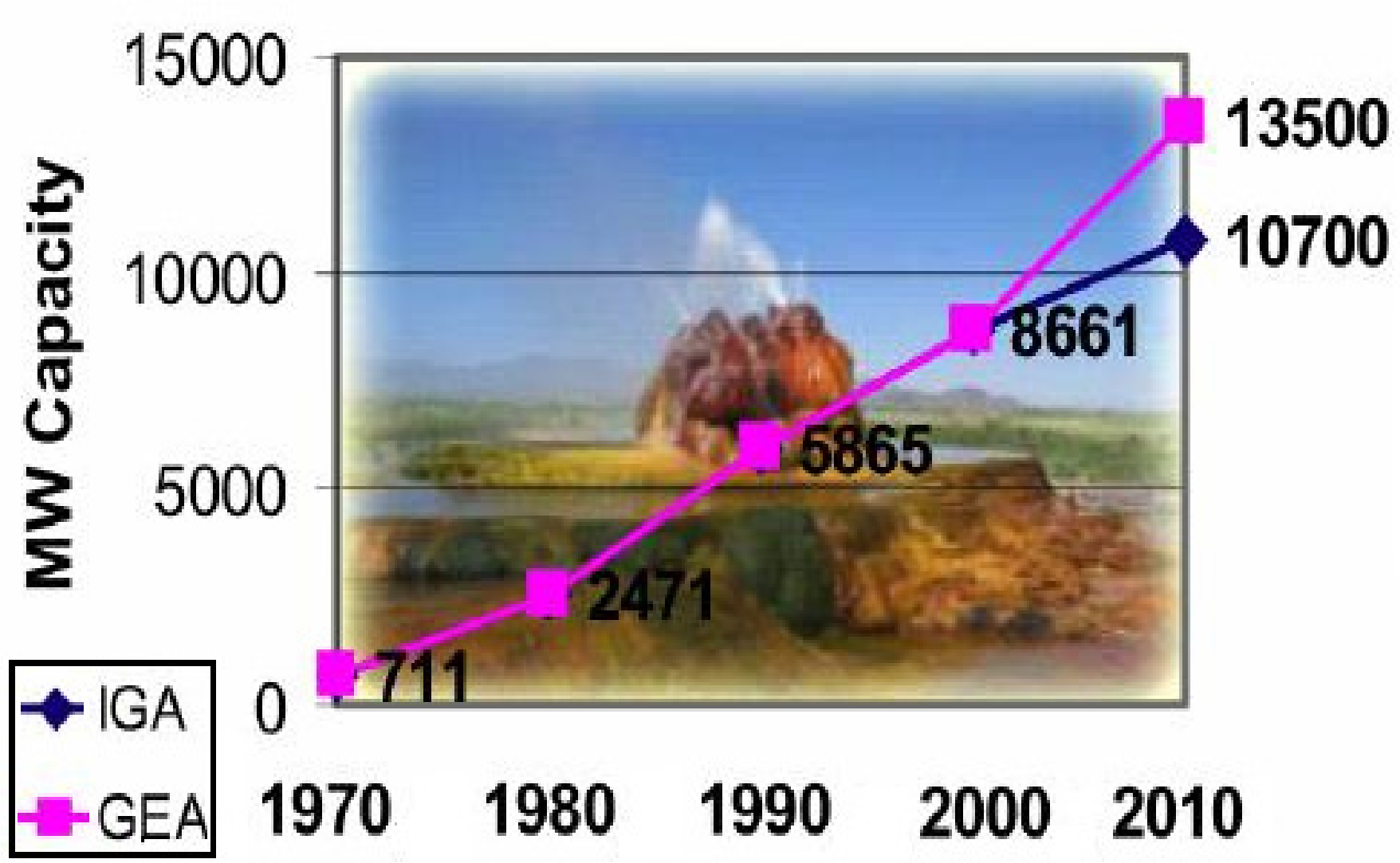
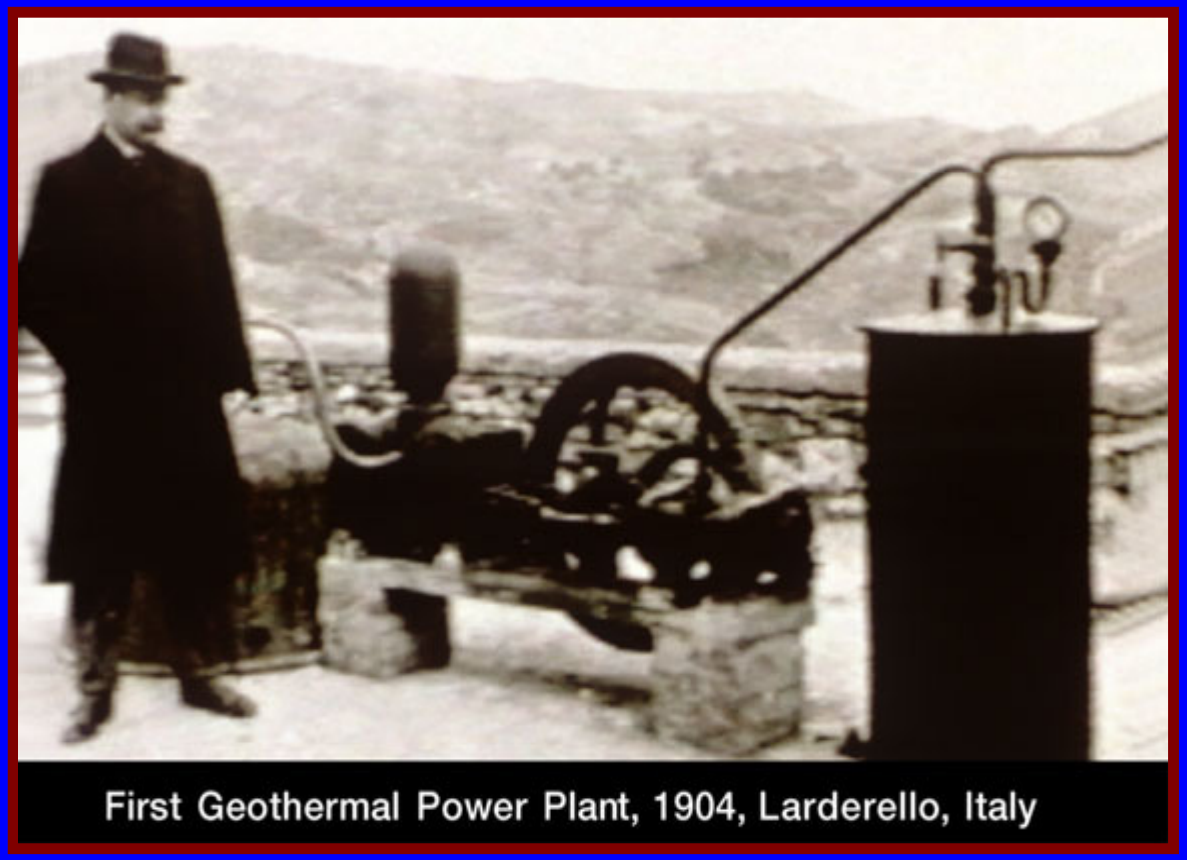
Geothermal Power Trends



IGA - International Geothermal Association
GEA - Geothermal Energy Association

World's First Geothermal Power Plant: Still Producing 2800 MW



First Geothermal Power Plant, 1904, Larderello, Italy

Geothermal Potential of India

- India has more than 300 hot springs (GSI Geothermal Atlas) and the estimated value of geothermal power potential ~ 10, 600 MW

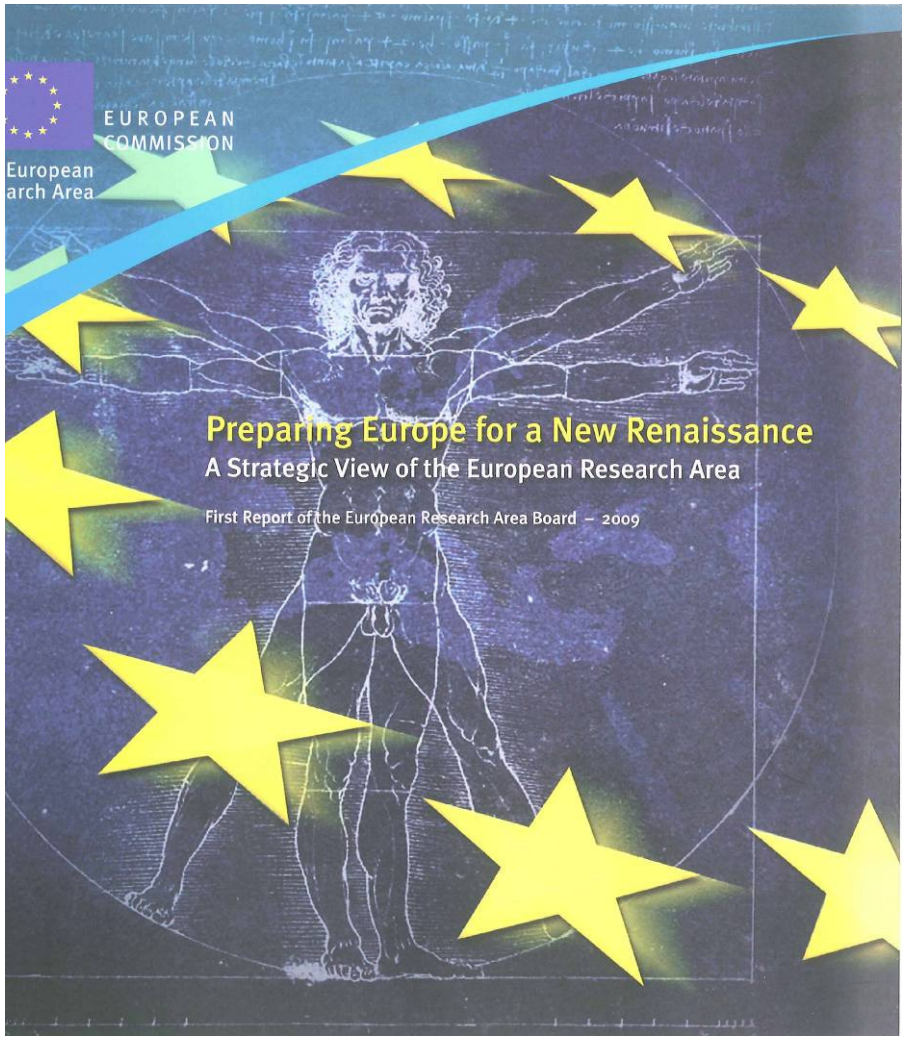
- In India the utilization of geothermal energy has so far been confined to pilot plants only.

No commercial geothermal power plant (larger scale) in India till the date

Source: Geothermal Energy:International Market UpdateGeothermal Energy Association, May, 2011

The Paradigm Shift

- Collective response
- Global governance
- Sustainable consumption
- The need to overcome INERTIA

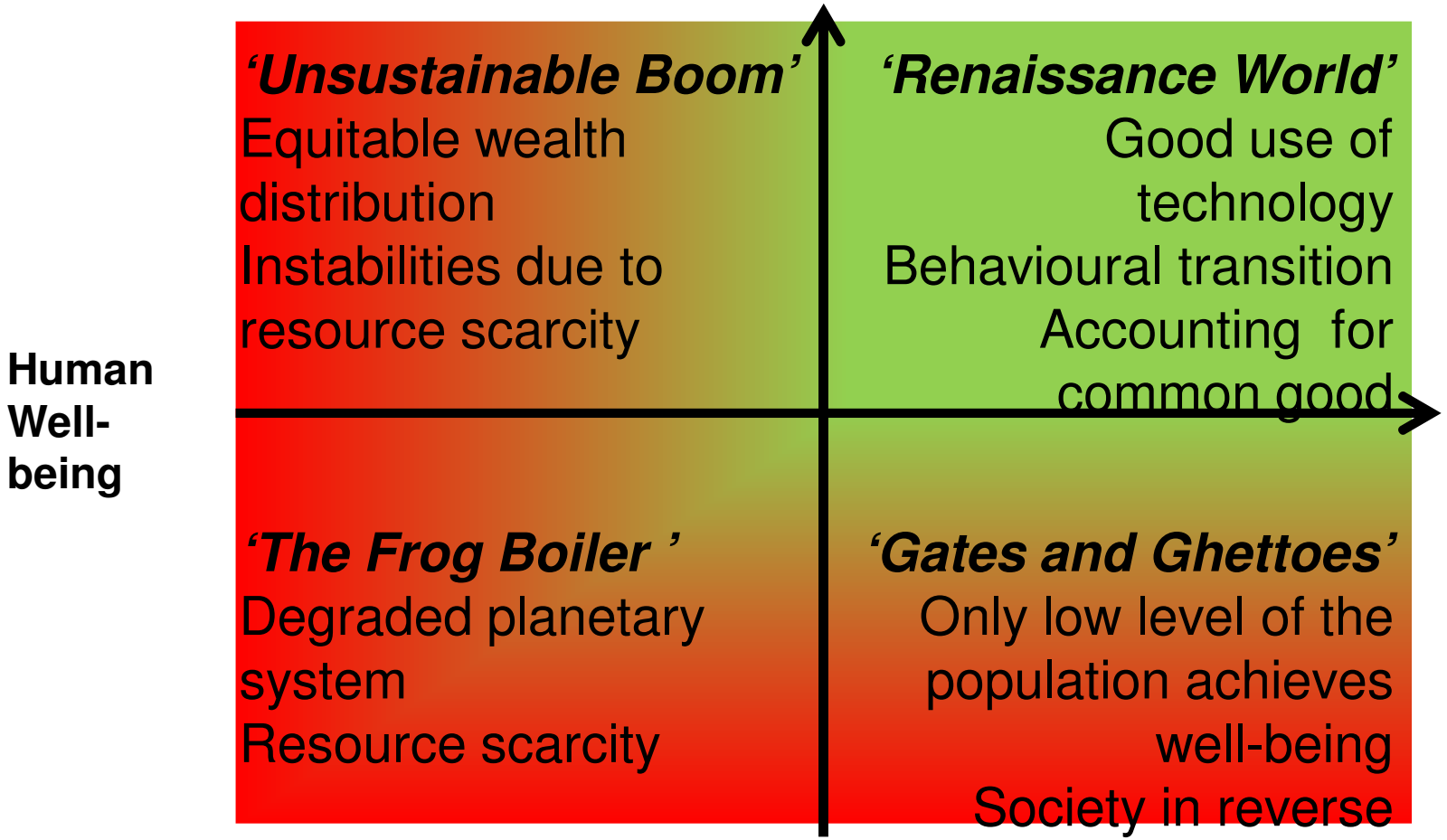


A Twenty First Century Renaissance

Energy Technologies Institute

- Public-Private partnership between Indian Government and industry
- for example BP, Shell, CSIR, DAE, IITs, ONGC etc.
- Looking to develop links with other countries

Ecosystems and Human Well-Being Scenarios



Ecosystem Rehabilitation: China's Loess Plateau

1997 2005

Source: EARTH'S HOPE The Lessons of the Loess Plateau - John D. Liu, EEMP www.eemp.org

Conclusions on Energy Challenge

- Large increase in energy use expected, and needed to lift billions out of poverty
- Seems (IEA World Energy Outlook) that it will require an increased use of fossil fuels
  - which is driving potentially catastrophic climate change*
  - will run out sooner or later

There is therefore an urgent need to reduce energy use (or at least curb growth), and seek cleaner ways of producing energy on a large scale

IEA: "Achieving a truly sustainable energy system will call for radical breakthroughs that alter how we produce and use energy"

***Ambitious goal for 2050 - limit CO_2 to twice pre-industrial level. To do this while meeting expected growth in power consumption would need 50% more CO_2-free power than today's *total* power**

US DoE "The technology to generate this amount of emission-free power does not exist"

EPILOGUE

As we stand in the beginning of the twenty first century, we see man relentlessly pursuing one single dominant goal – and – that is prosperity and prosperity sometime at any cost. There has never been in human history one singular objective that has dominated so many so much. This has been possible by mindless industrialization and the unprecedented growth of technology. We want more and more is not enough because we want even more.

In the process we have managed to destroy the essential equilibrium of our ecology.

Thus, technology owes an apology to the ecology.

EPILOGUE (contd…..)

The final epitaph is : we have to live, generations after generations after us have to live, and, to live they have to breathe and we have but have to embark on "a new paradigm for conserving the ecological balance".

Man has gone through many revolutions throughout history. The revolution that daunts us and stare at us just now is not a social or political revolution but a revolution of our basic perception, perception of how we should live and a revolution in our perception of the future and beyond, a revolution to usher in a quantum shift of our mind set. This is just the beginning.

“ *The Triumph of Death*” by Pieter Bruegel the Elder (c. 1562)

"The earth, the air, the land and the water are not an inheritance from our fore fathers but on loan from our children. So we have to handover to them atleast as it was handed over to us"

Mahatma Gandhi