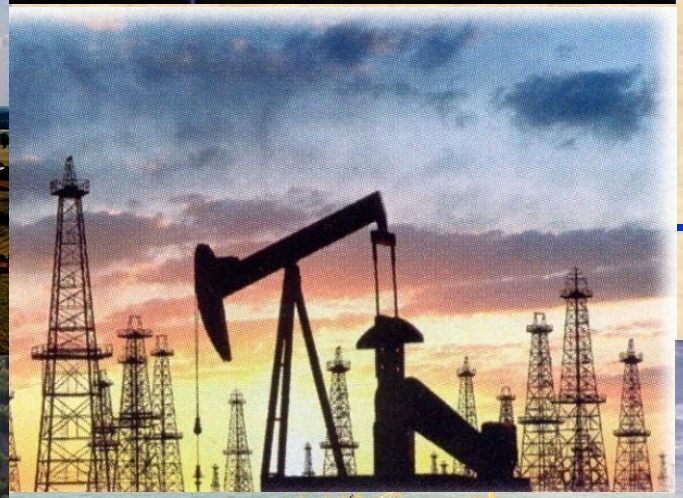
Geostrategy of Energy

Budapest October 2013



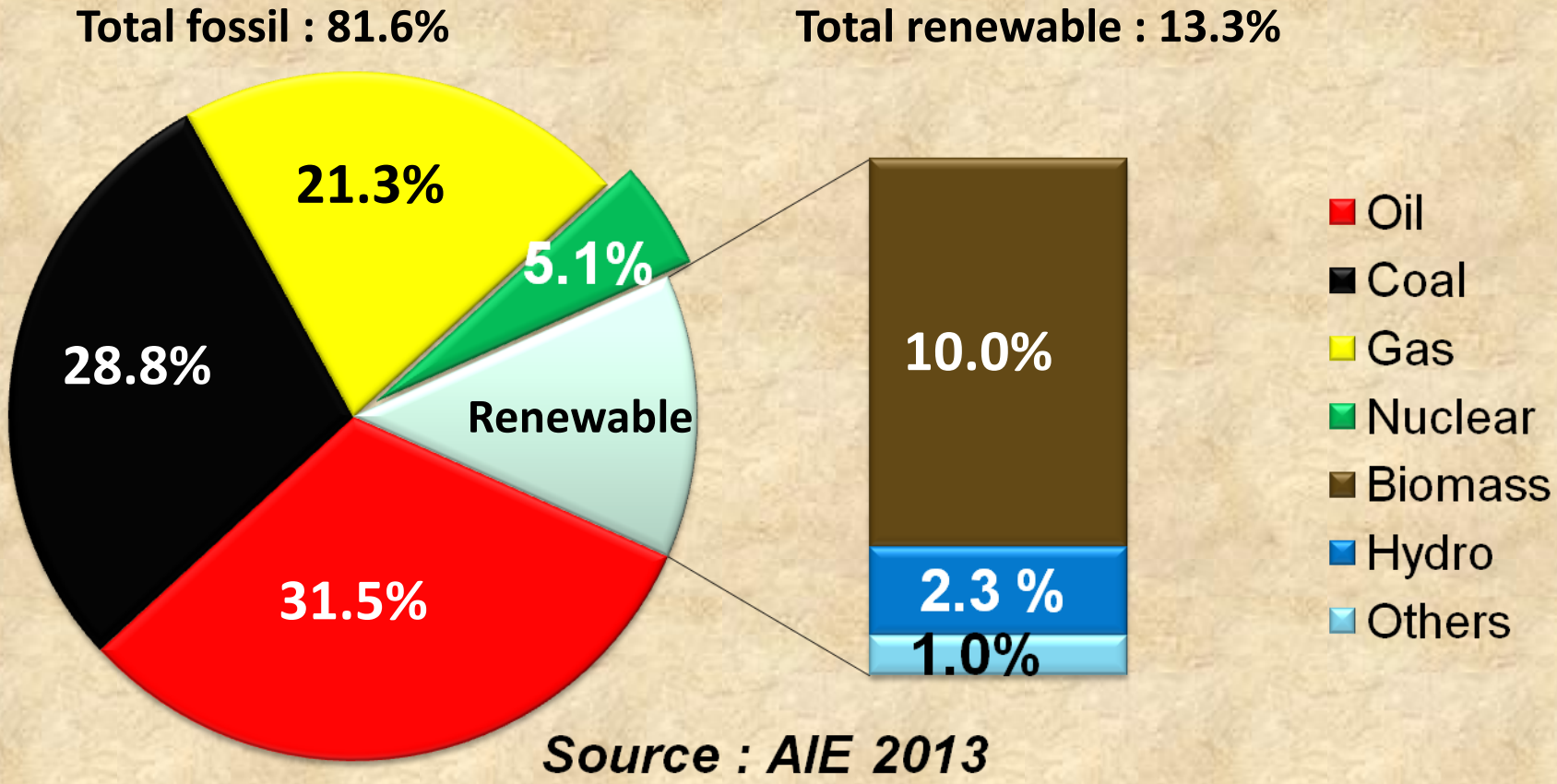
Bertrand BARRÉ

bertrandbarre.com

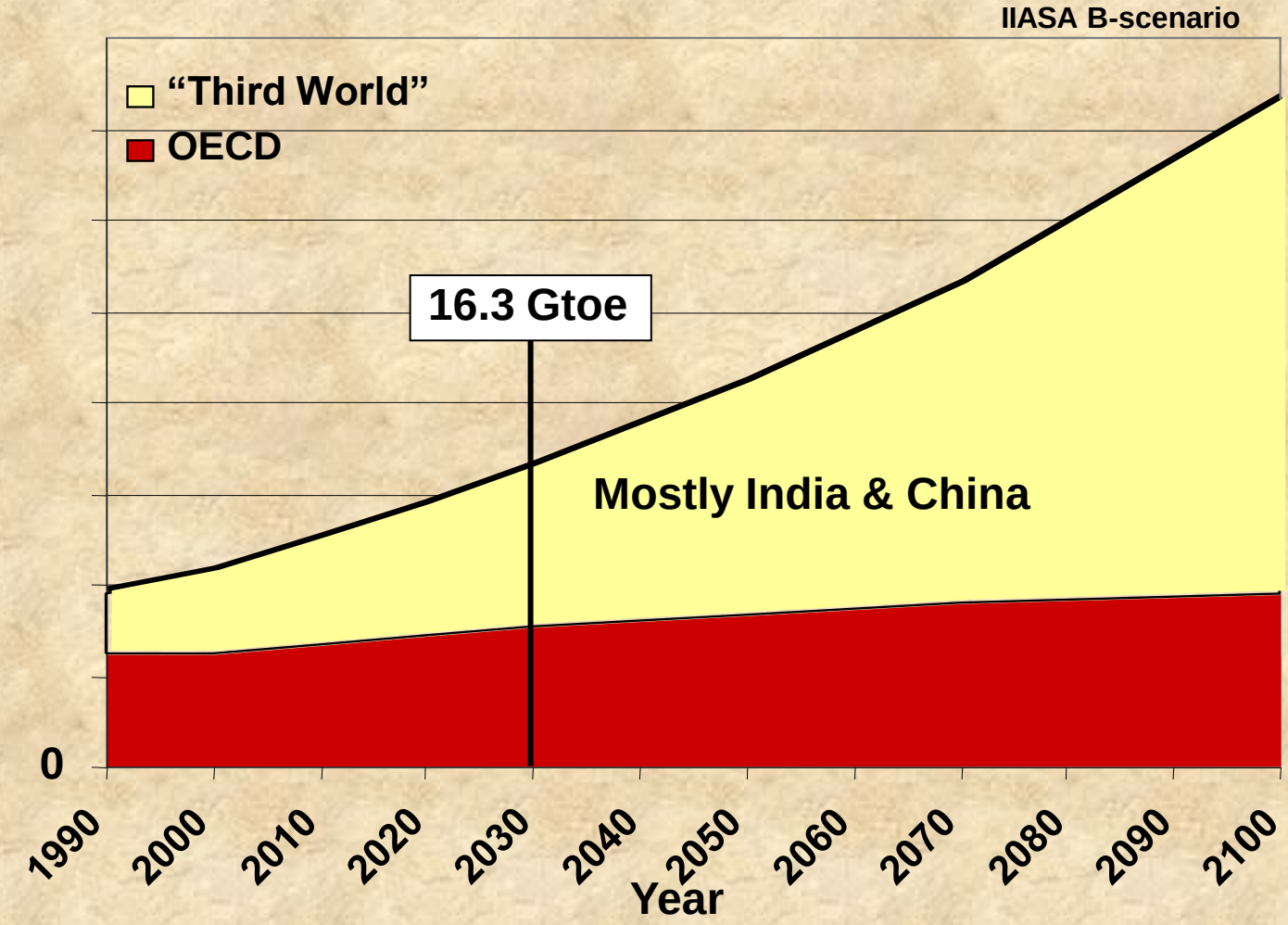
No Development without minimum Access to Energy

But the way we produce & consume energy is not sustainable

2000 : 6 billion Human beings, 10 billion toe
2011 : 7 billion Human beings, 13.1 billion toe



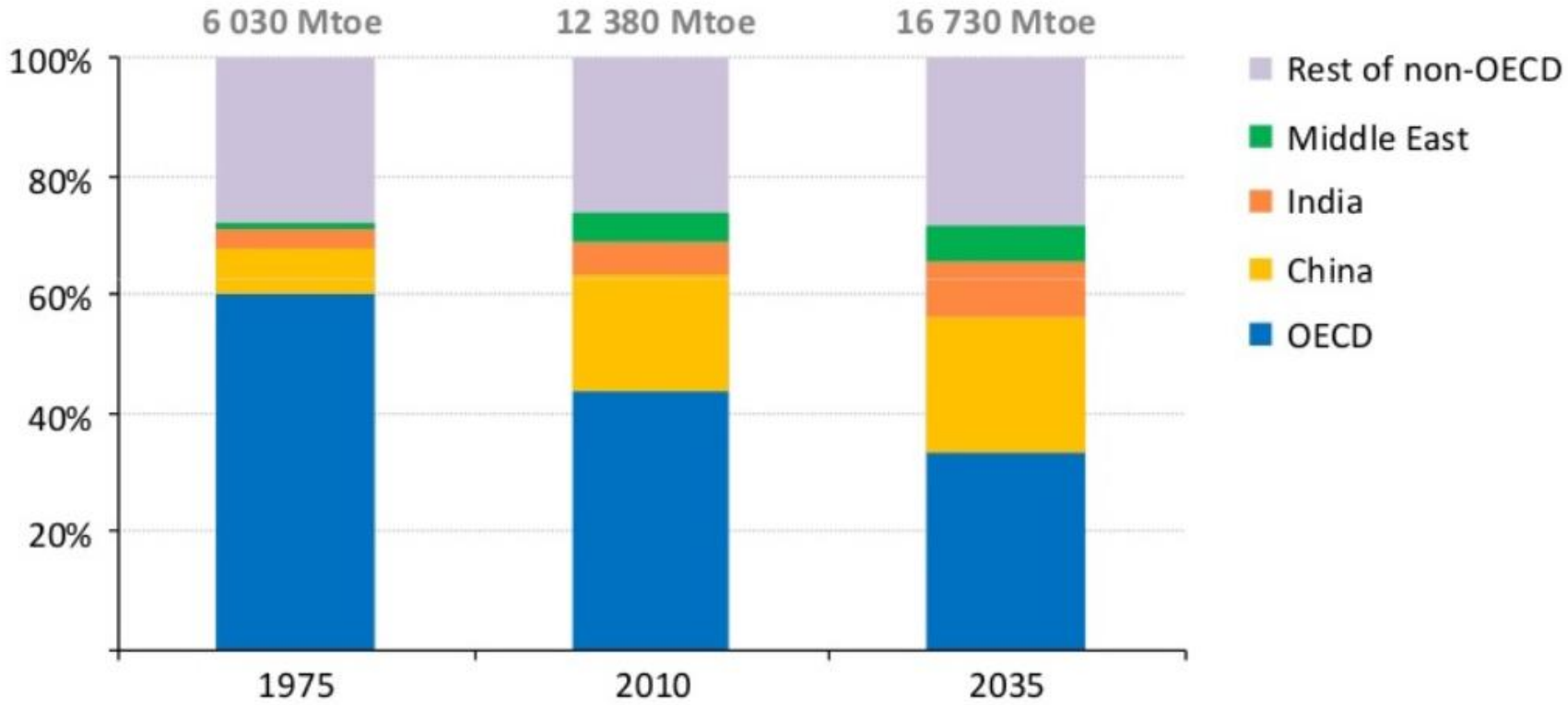
Source : AIE 2013


IIASA B-scenario
"Third World"
OECD
16.3 Gtoe
Mostly India & China
0
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Year

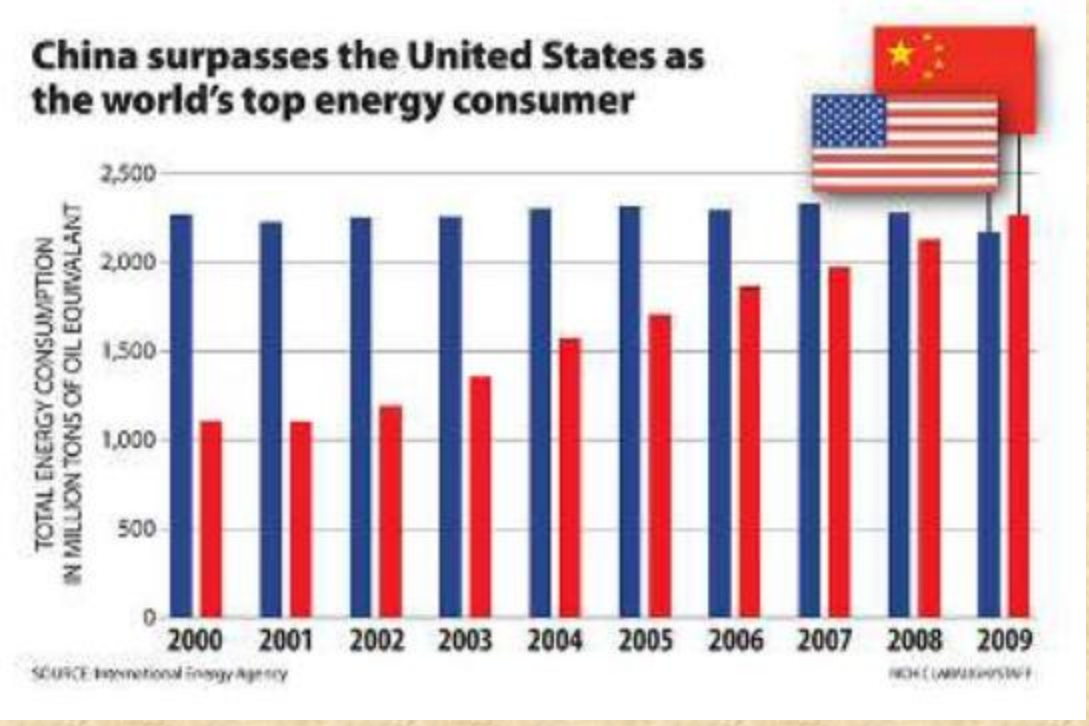
Emerging economies steer energy markets

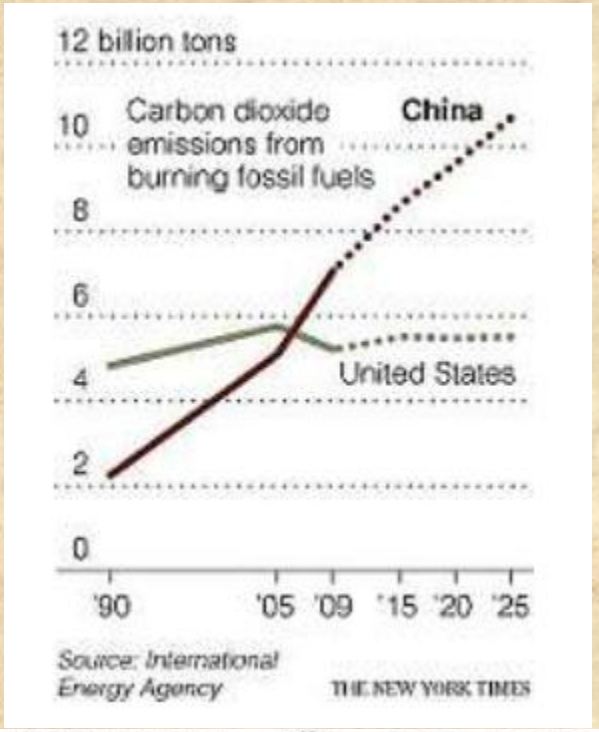
WORLD ENERGY OUTLOOK

Share of global energy demand



Global energy demand rises by over one-third in the period to 2035, underpinned by rising living standards in China, India & the Middle East

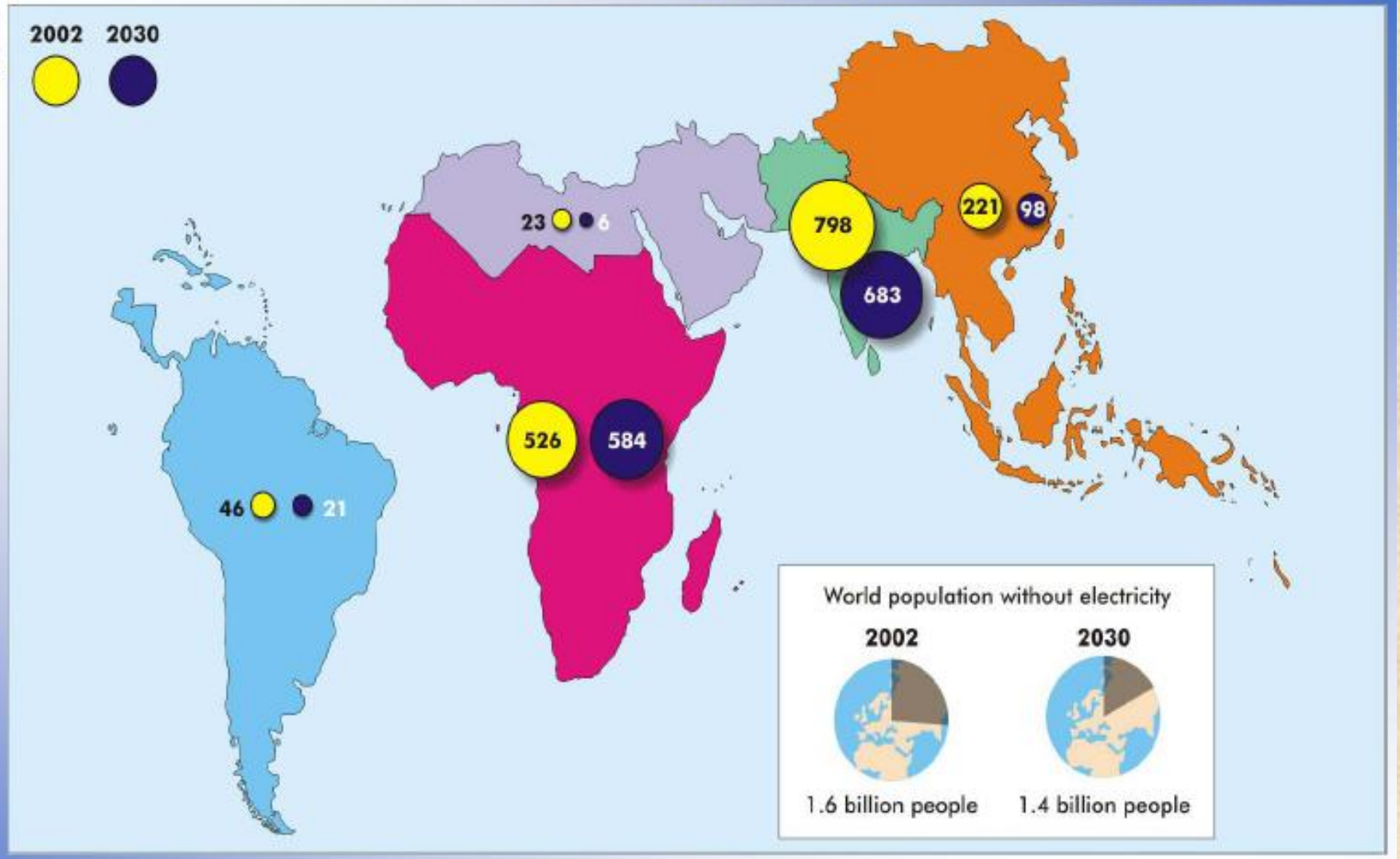




» *Car Sales (millions)*

	2005	2010
USA	**17**	**11**
China	**4**	**13**

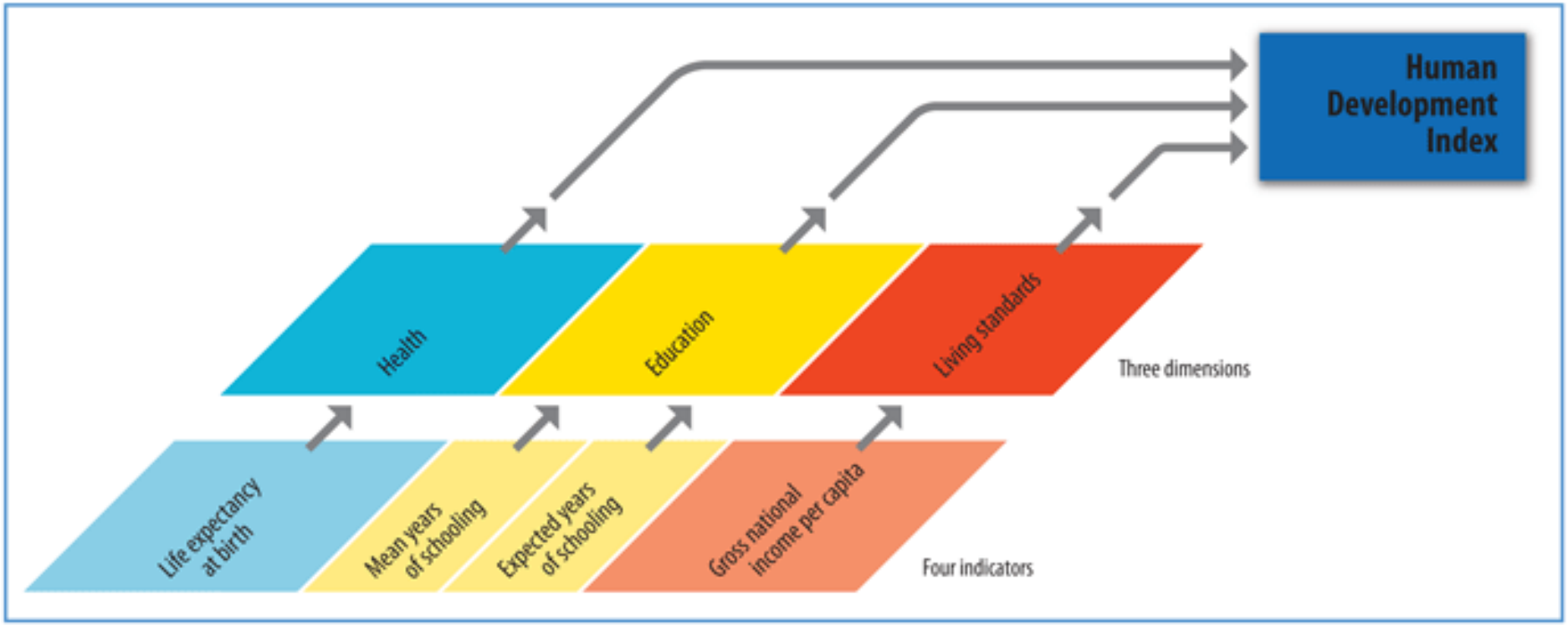
Electricity Deprivation



In 2030, if no new policies are implemented, there will still be 1.4 billion people without electricity

Components of the Human Development Index

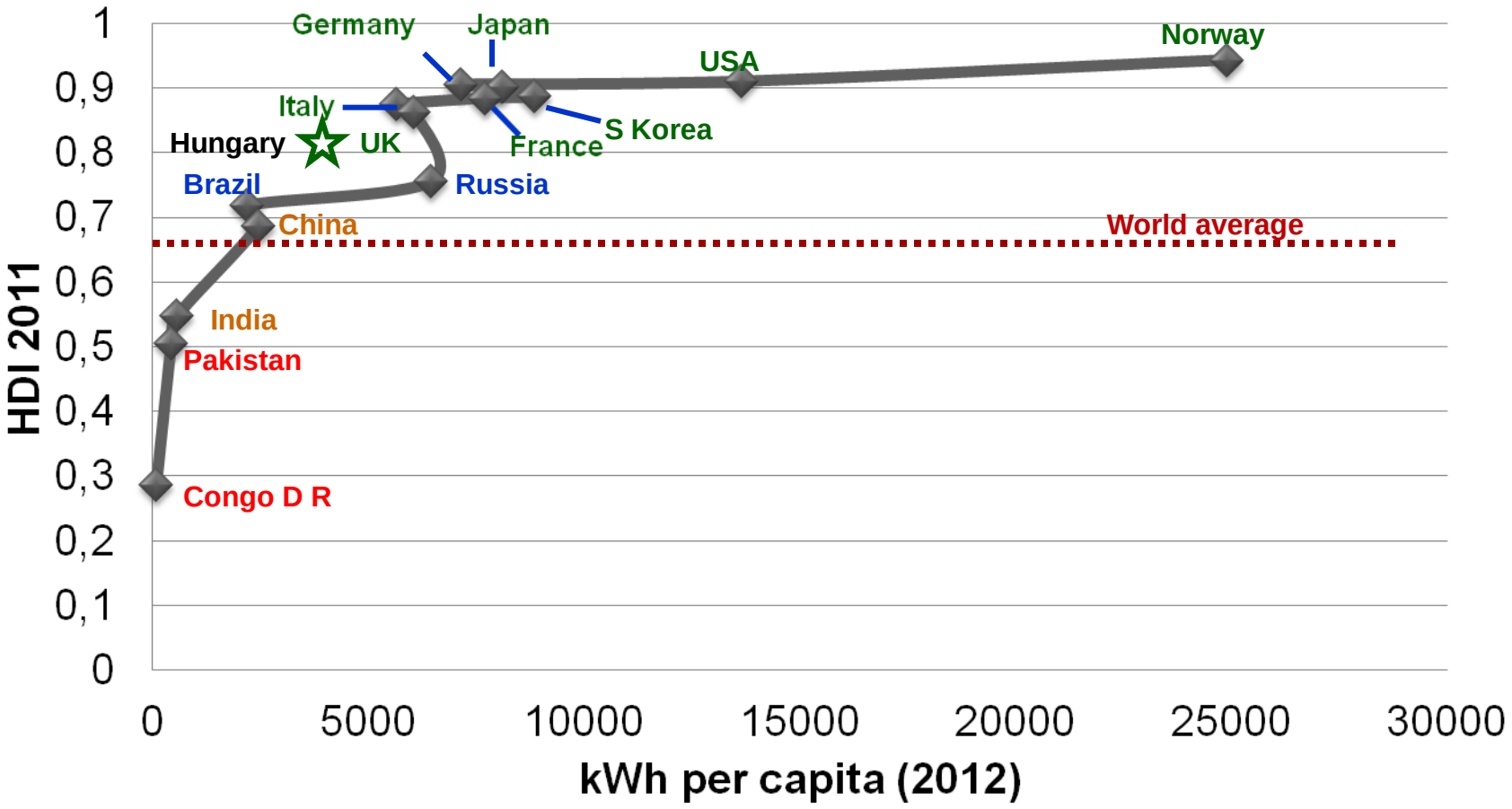
The HDI—three dimensions and four indicators



Note: The indicators presented in this figure follow the new methodology, as defined in box 1.2.

Source: HDRO.

Human Development Index vs Electricity/cap



Hungary : HDI = 0,816 3895 kWh/cap

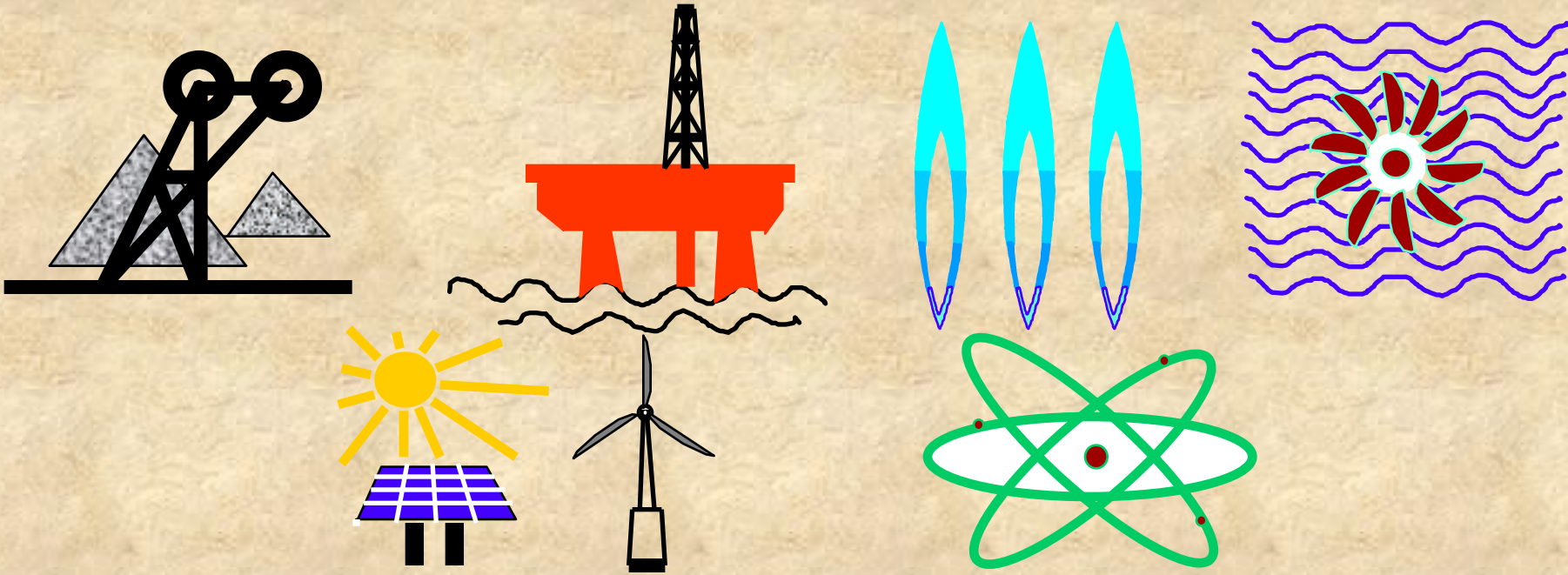
Sources : PNUD, IEA

During this Half-Century

~ 9.10^9 human beings

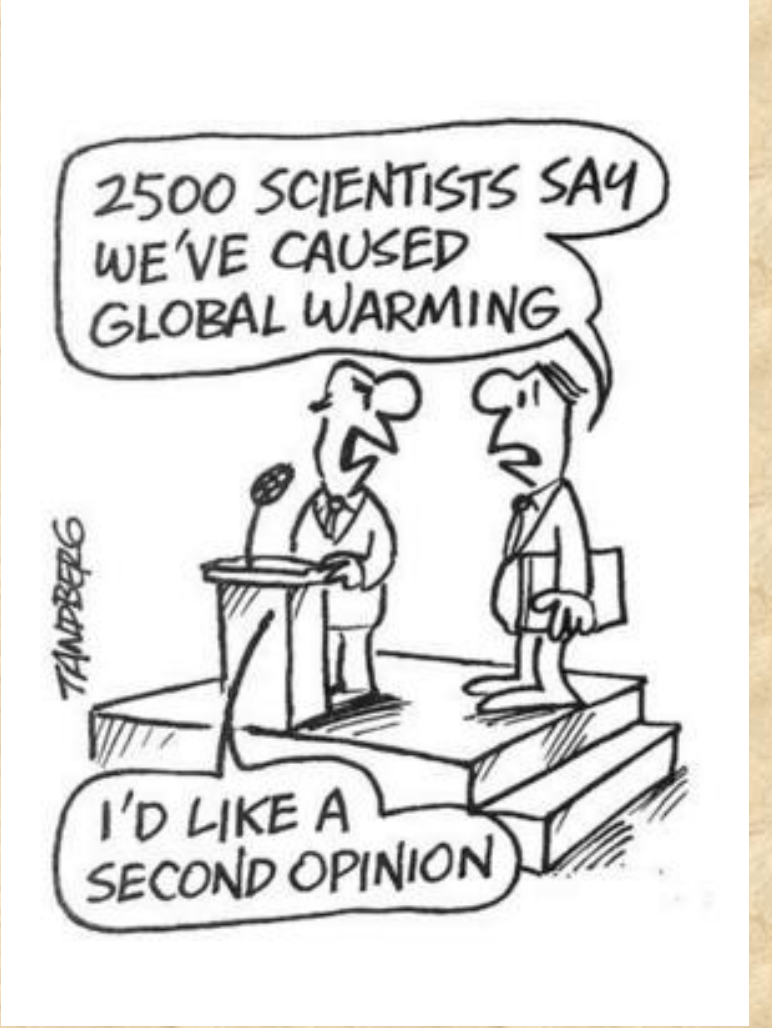
> 15 Gtoe/y

We shall need EVERY Source !

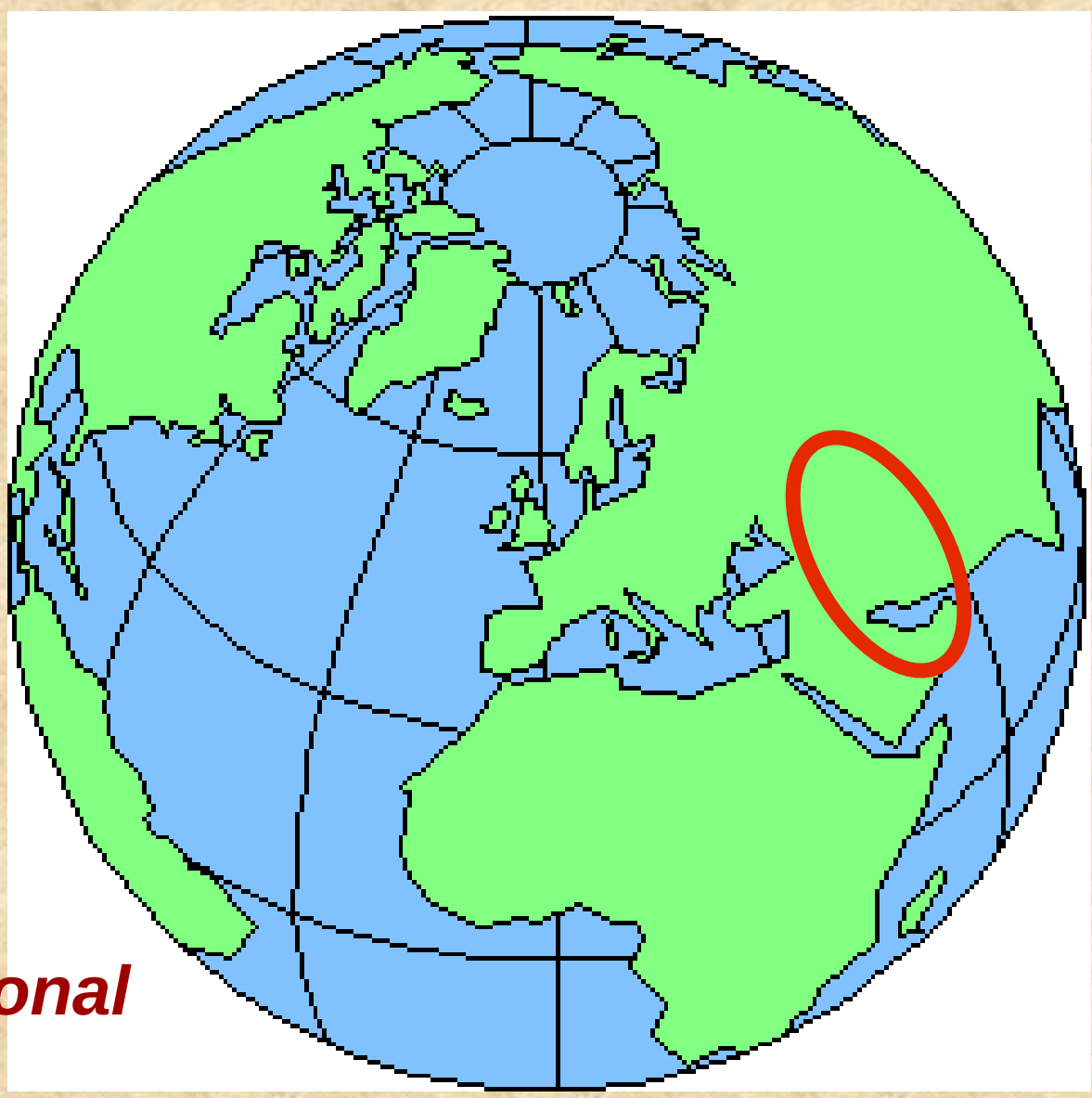


Main Features of the New Energy Context

- *China overtakes USA*
- *Fear of Peak Oil*
- *Unconventional Gas*
- *Coal is back*
- *Climate Change*

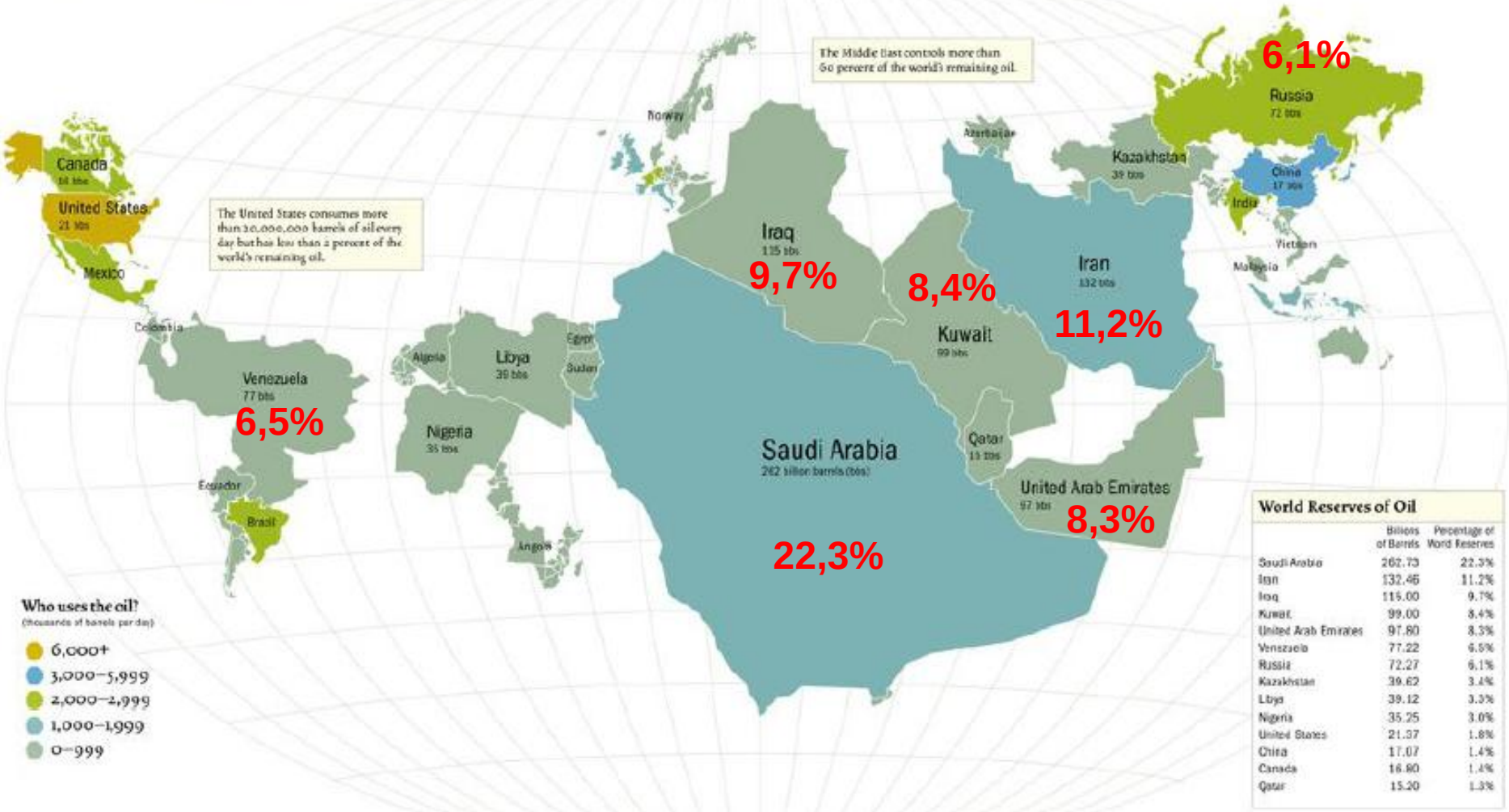


70% Oil* & 40% Gas* Reserves

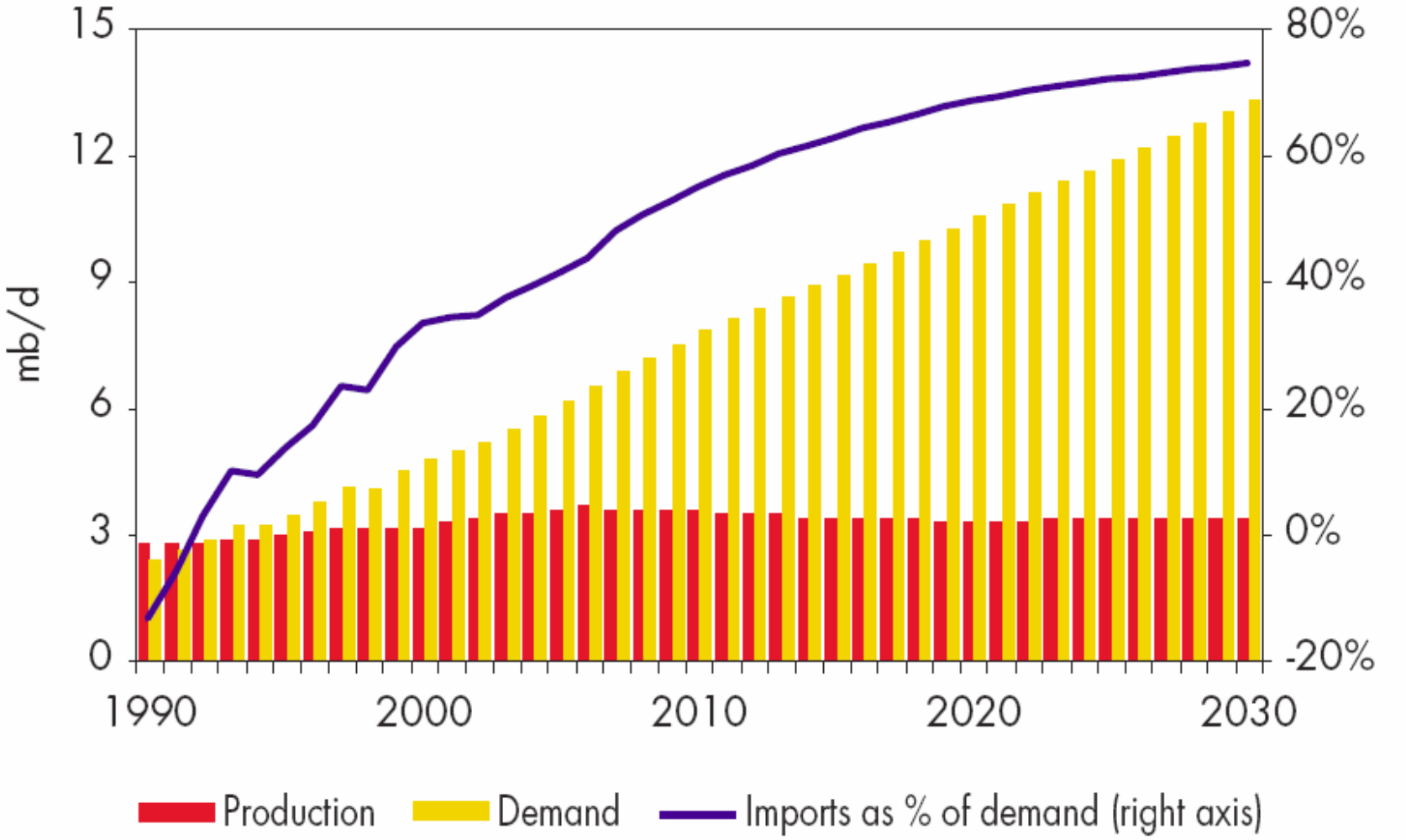


* Conventional

The World… according to conventional Oil

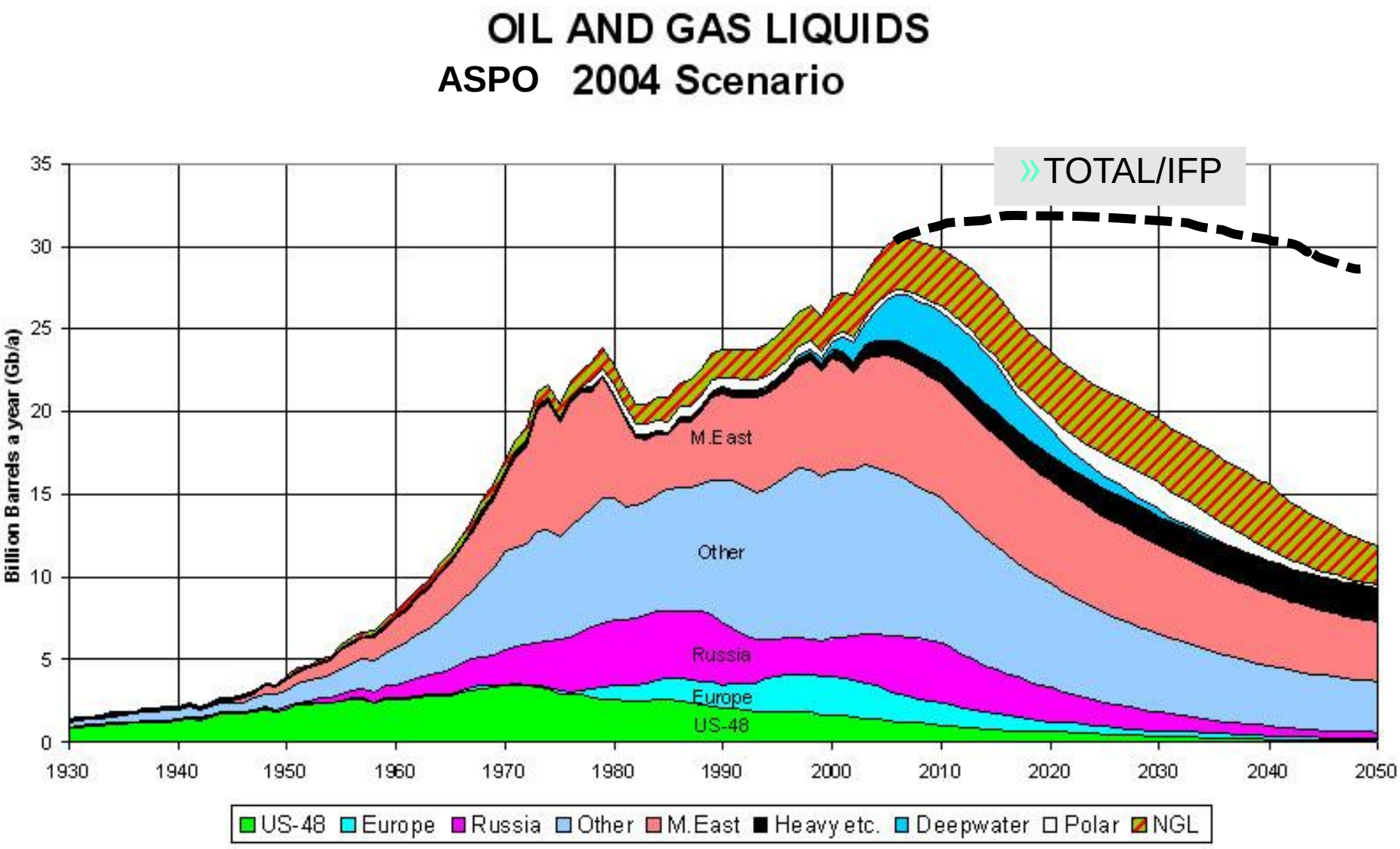


Oil Balance in China



source IEA 2004 outlook

Will there be a « peak oil » or an « oil plateau »?



Tar Sands

As many Oil molecules in Athabasca as in Saudi Arabia…

…but huge needs in energy and water and significant environmental impact

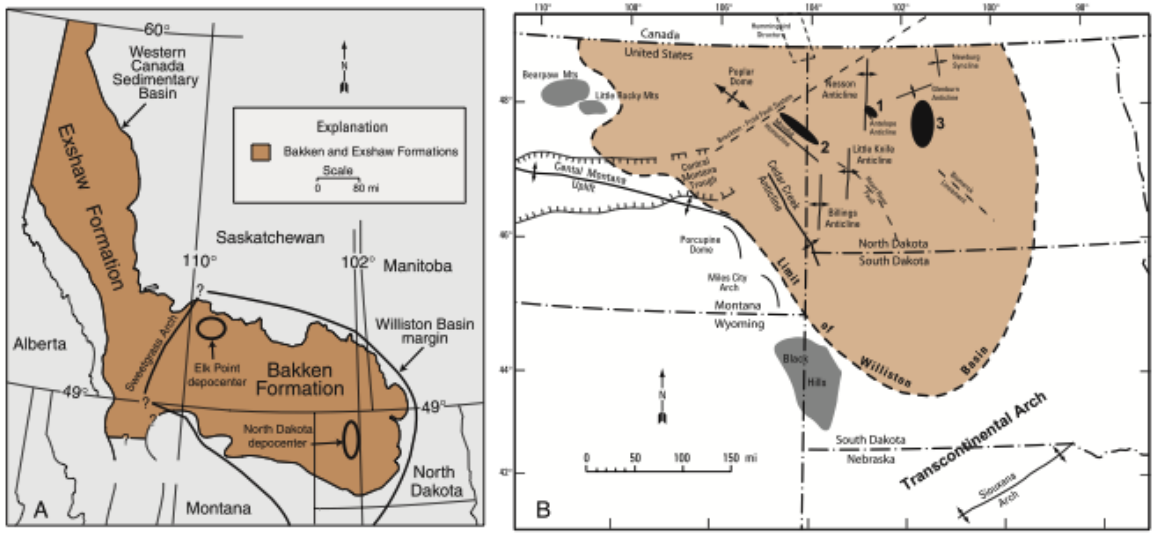
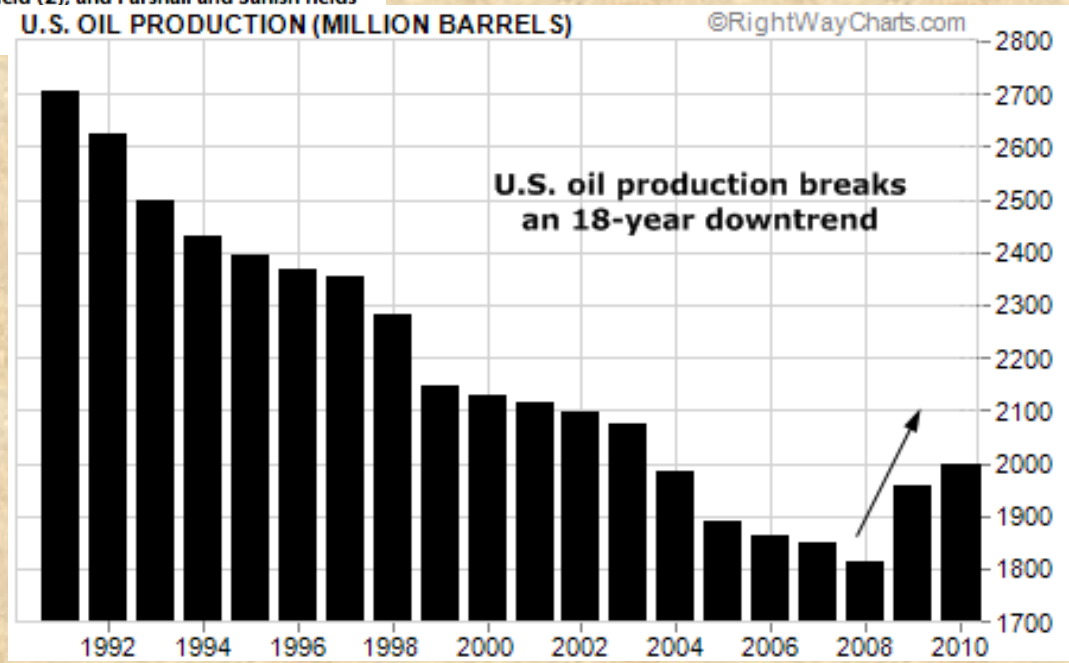
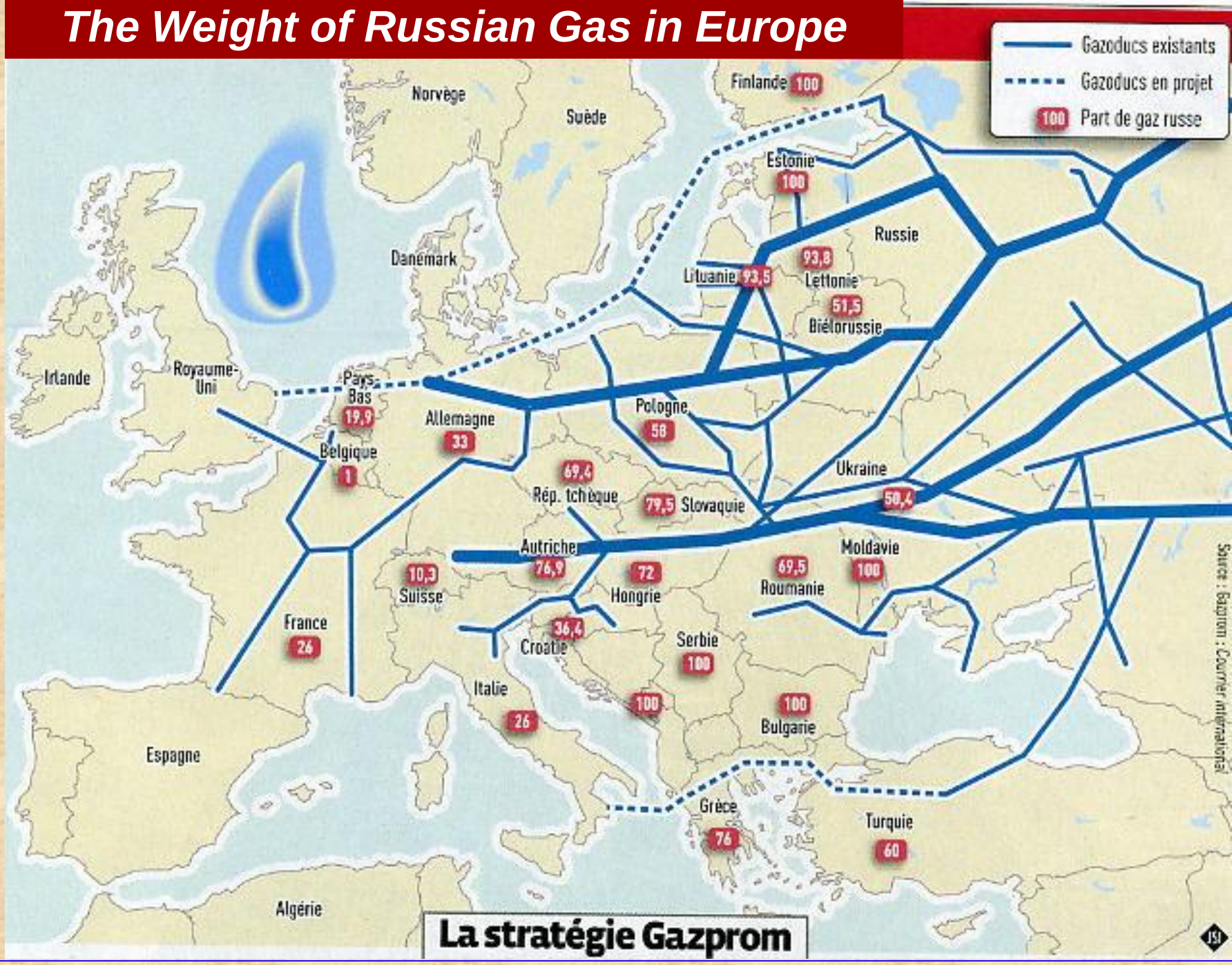


FIGURE 1. Maps of Bakken Formation and Williston Basin. (A) Distribution of Bakken Formation in the Williston Basin and Exshaw Formation in the Western Canada sedimentary basin. Modified from Smith and Bustin (2000). (B) Present-day major structural elements of the United States part of Williston Basin. Solid black ovals are locations of three major areas of oil production from the Bakken Formation: Antelope field (1), Elm Coulee field (2), and Parshall and Sanish fields (3). Modified from Gerhard et al. (1991).

Shale Oil



The Weight of Russian Gas in Europe



Natural Gas Glut… in the USA

- ***Unexpected recent increase in « unconventional » gas production in the USA : Shale Gas, Tight Sand Gas and Coal Bed Gas (might supply 60% US gas consumption by 2030)***
- ***Significant decrease of gas demand (notably for electricity & industry) due to the worst financial crisis since 1945***

USA will for a long time remain little (5%) dependent upon gas imports: LNG available to the rest of the world, coal to gas for power (coal exports to Germany…)

For how long ??

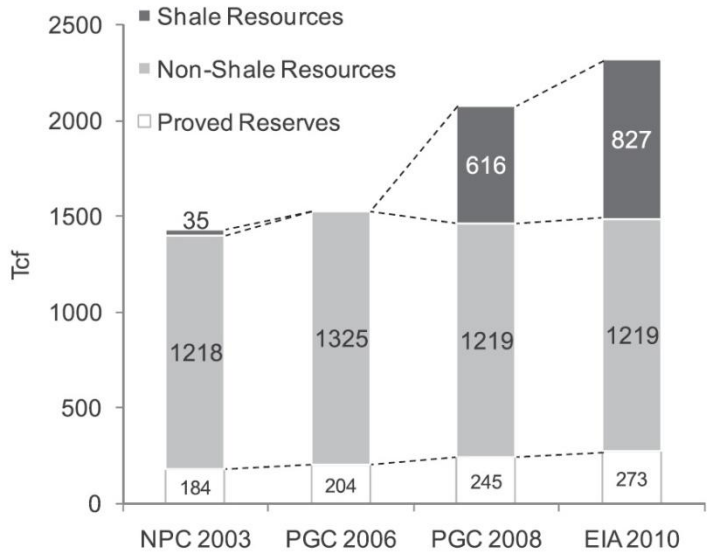


FIGURE 2
Impact of Shale Gas on Estimates of U.S. Resources and Proved Reserves

THE SHALE BOOM

The technology for pulling natural gas from deep shale, refined in the 1990s in Texas, has since spread to other "plays"—parts of a shale basin where large quantities of gas have been found. More than a third of U.S. gas now comes from shale.

Richest shale deposits

Recoverable gas, in trillion cubic feet (tcf)
Total for continental U.S. **542***

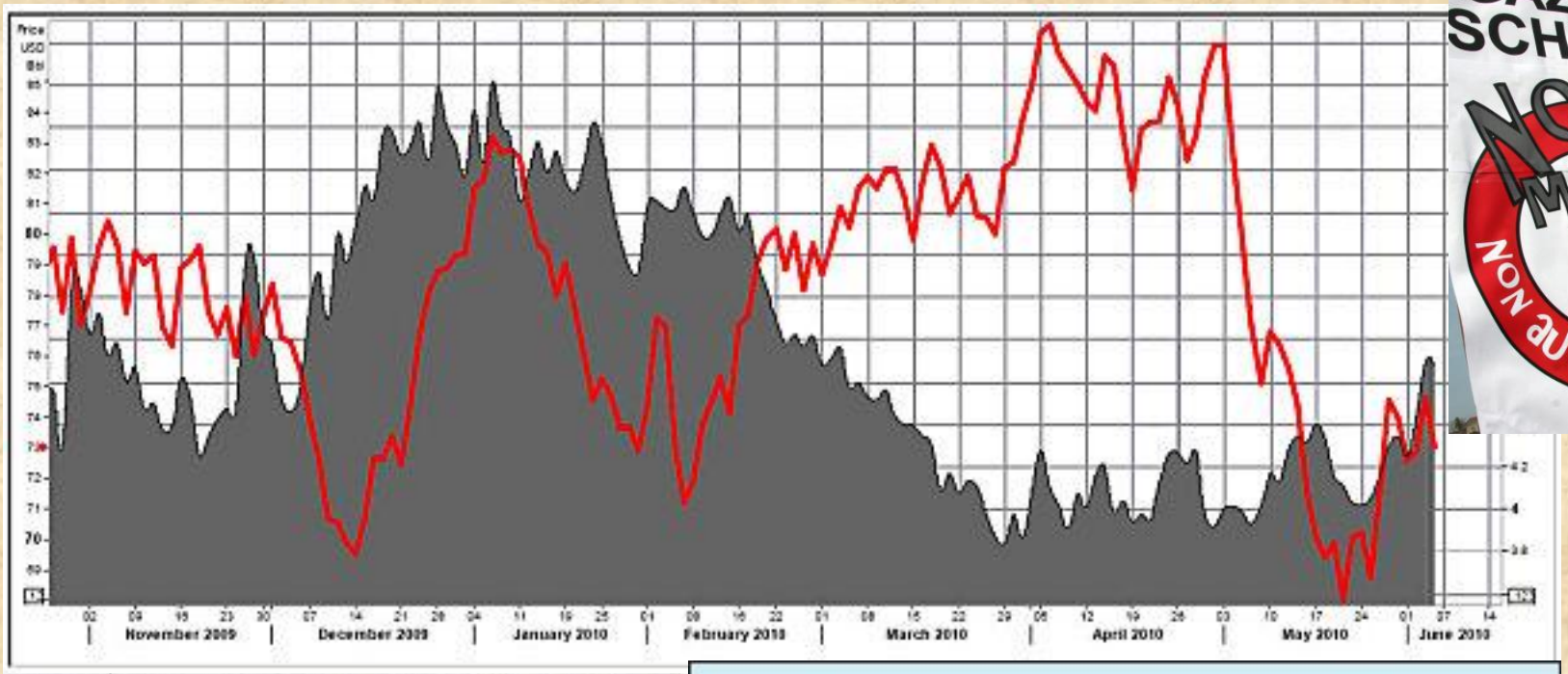
1. Marcellus	**141**
2. Haynesville	**66**
3. Eagle Ford	**50**
4. Barnett-Woodford	**27**
5. Woodford	**24**

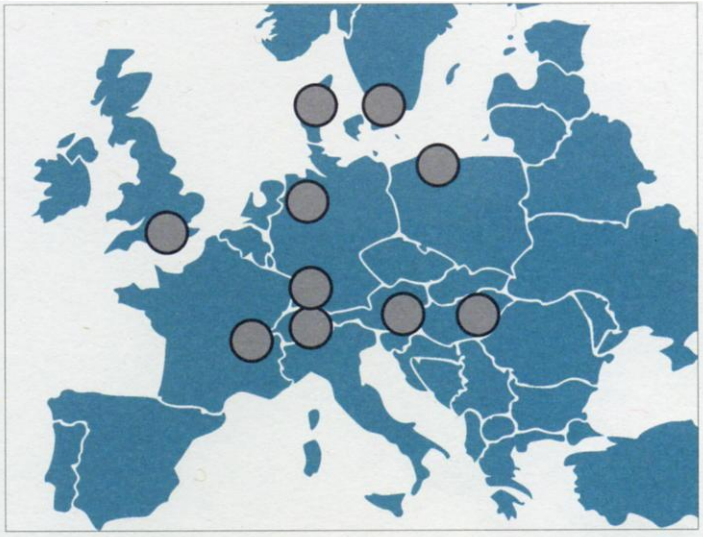
Shale play (active or expected drilling)

Shale basin (potential gas resource)

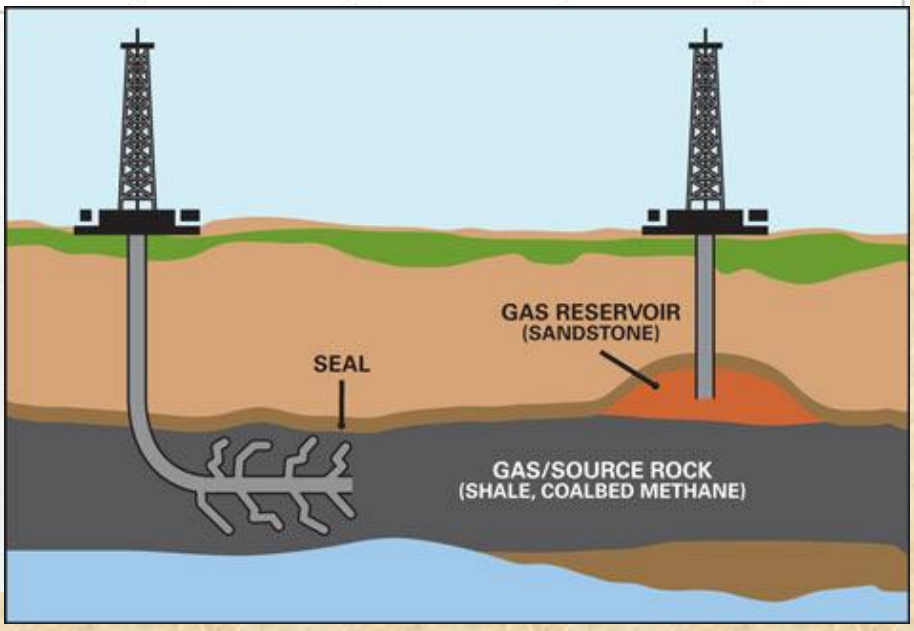
ONE TCF CAN HEAT 15 MILLION HOMES FOR A YEAR.
*TOTAL INCLUDES "PROVED RESERVES" AND "UNPROVED RESOURCES."

VIRGINIA W. MASON, NGM STAFF; ALEXANDER STEGMAIER, NG STAFF
SOURCES: U.S. EIA; FRACTRACKER; U.S. CENSUS BUREAU; STATISTICS CANADA

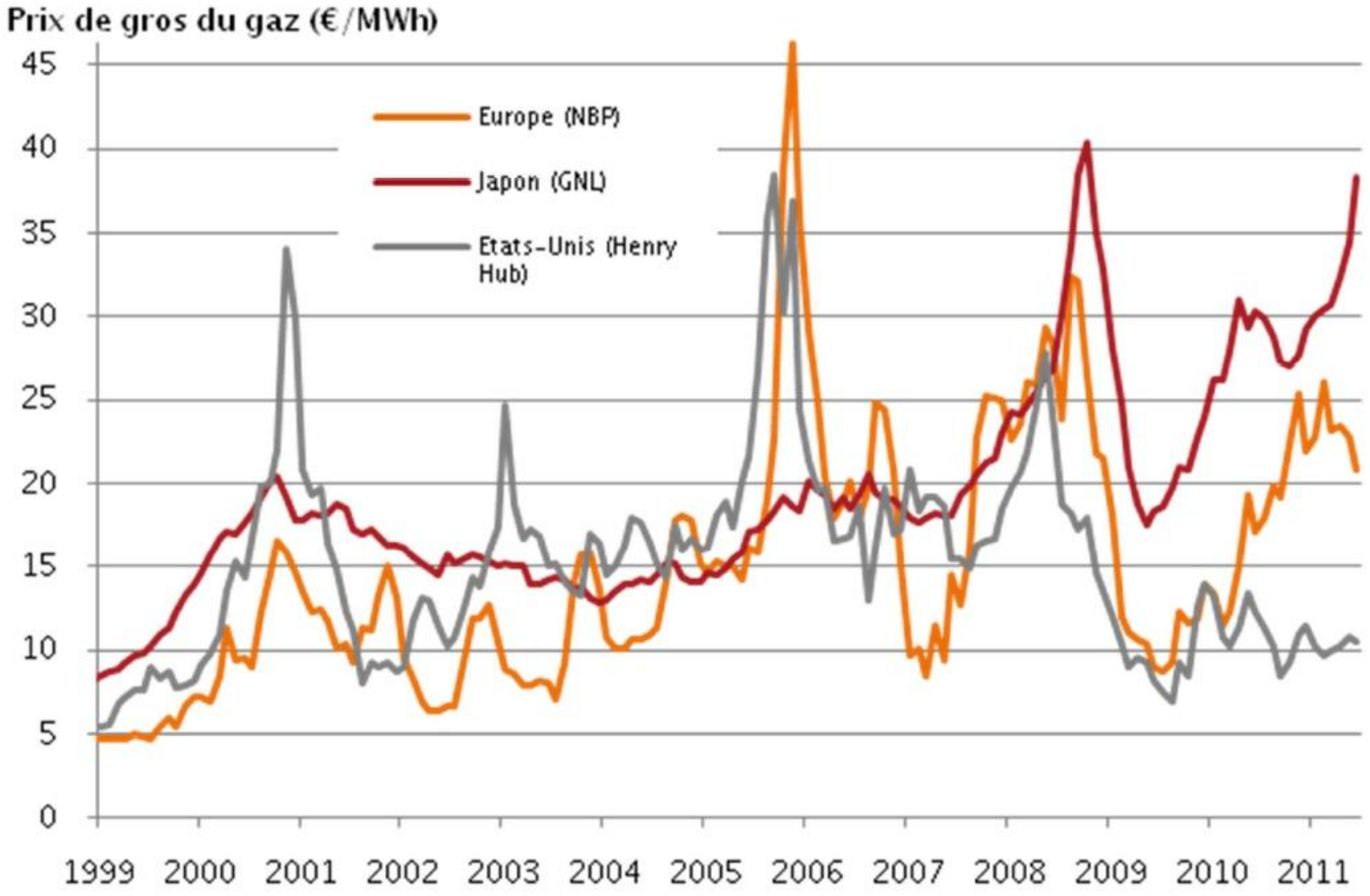




Shale Gas-Vorkommen in Europa



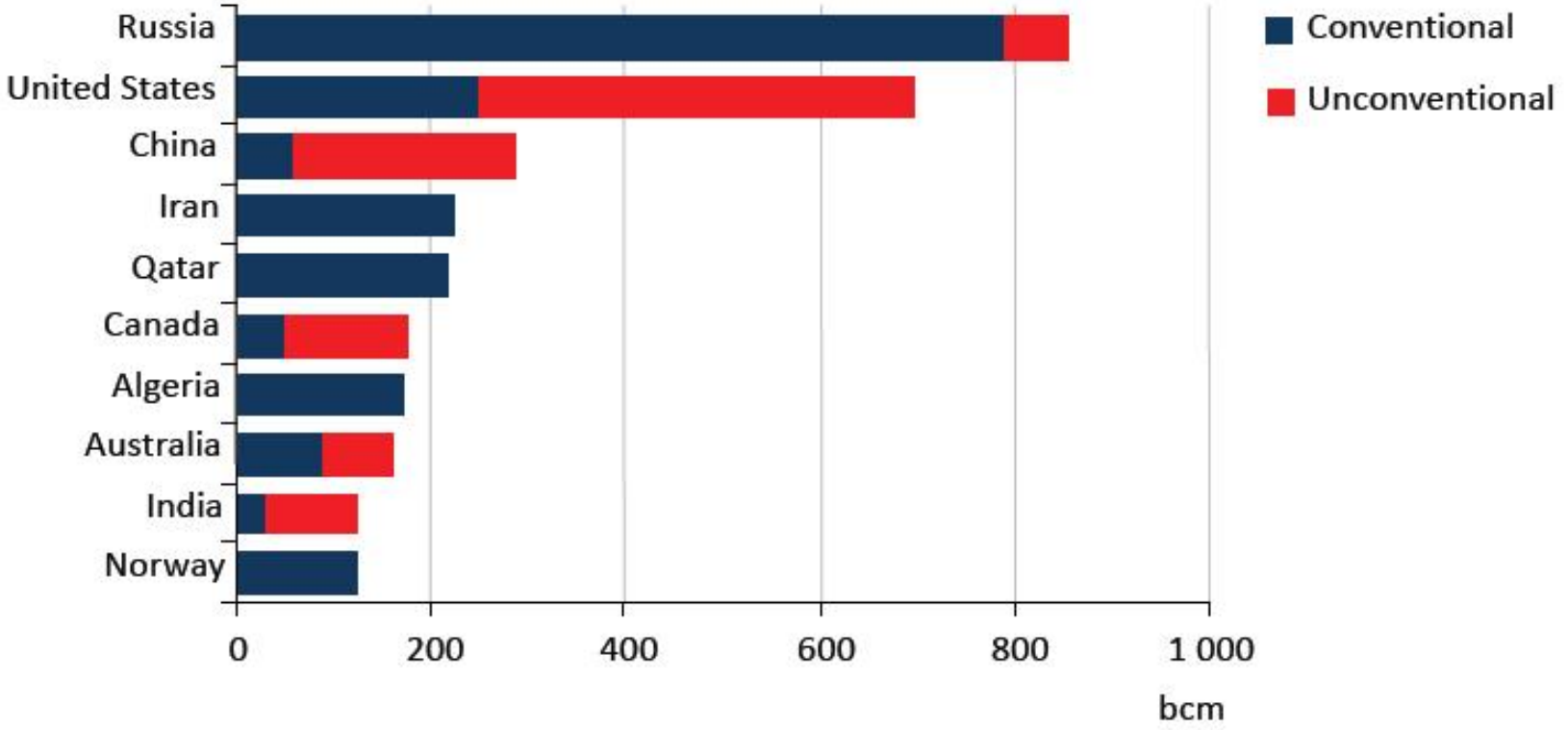
Prix du gaz sur les trois principales zones de consommation dans le monde



Golden prospects for natural gas

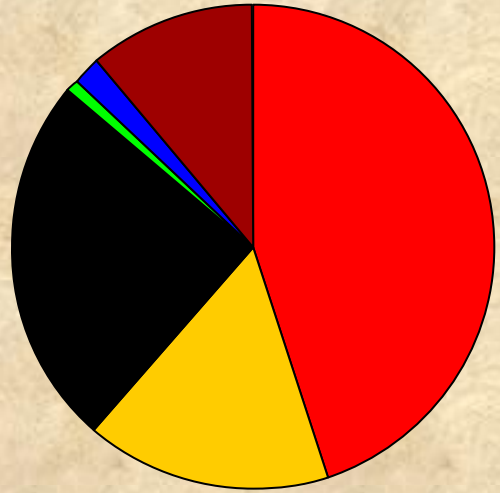
WORLD ENERGY OUTLOOK 2011

Largest natural gas producers in 2035

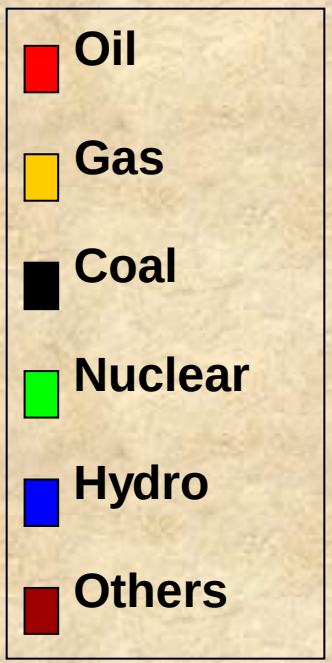


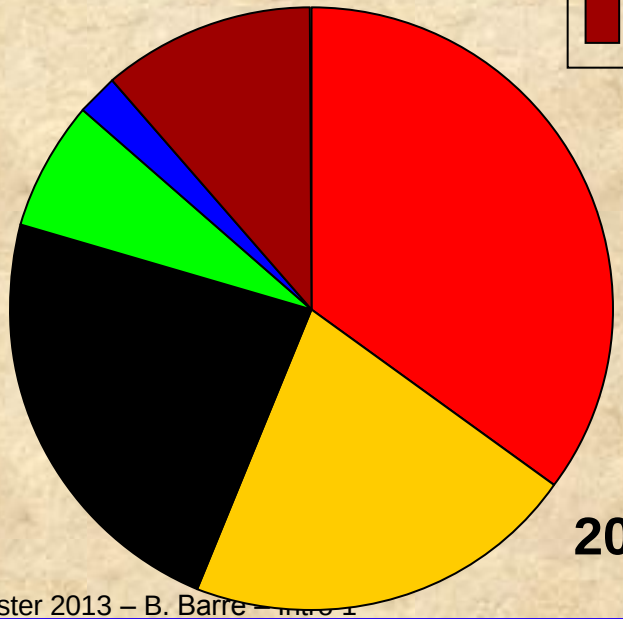
Unconventional natural gas supplies 40% of the 1.7 tcm increase in global supply, but best practices are essential to successfully address environmental challenges

Primary Energy 1973 – 2002 – 2030

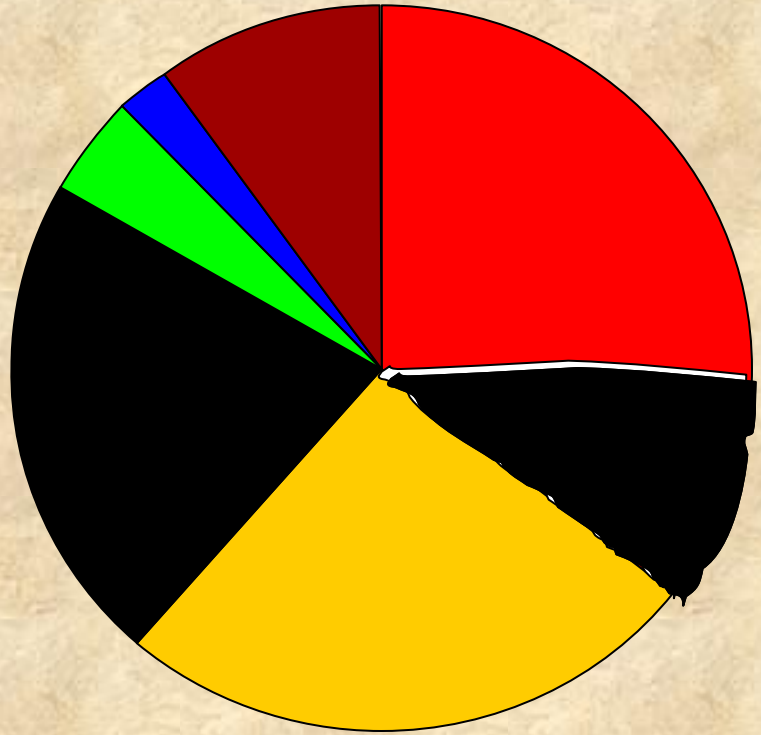


1973 : 6 Gtoe





2001 : 10 Gtoe

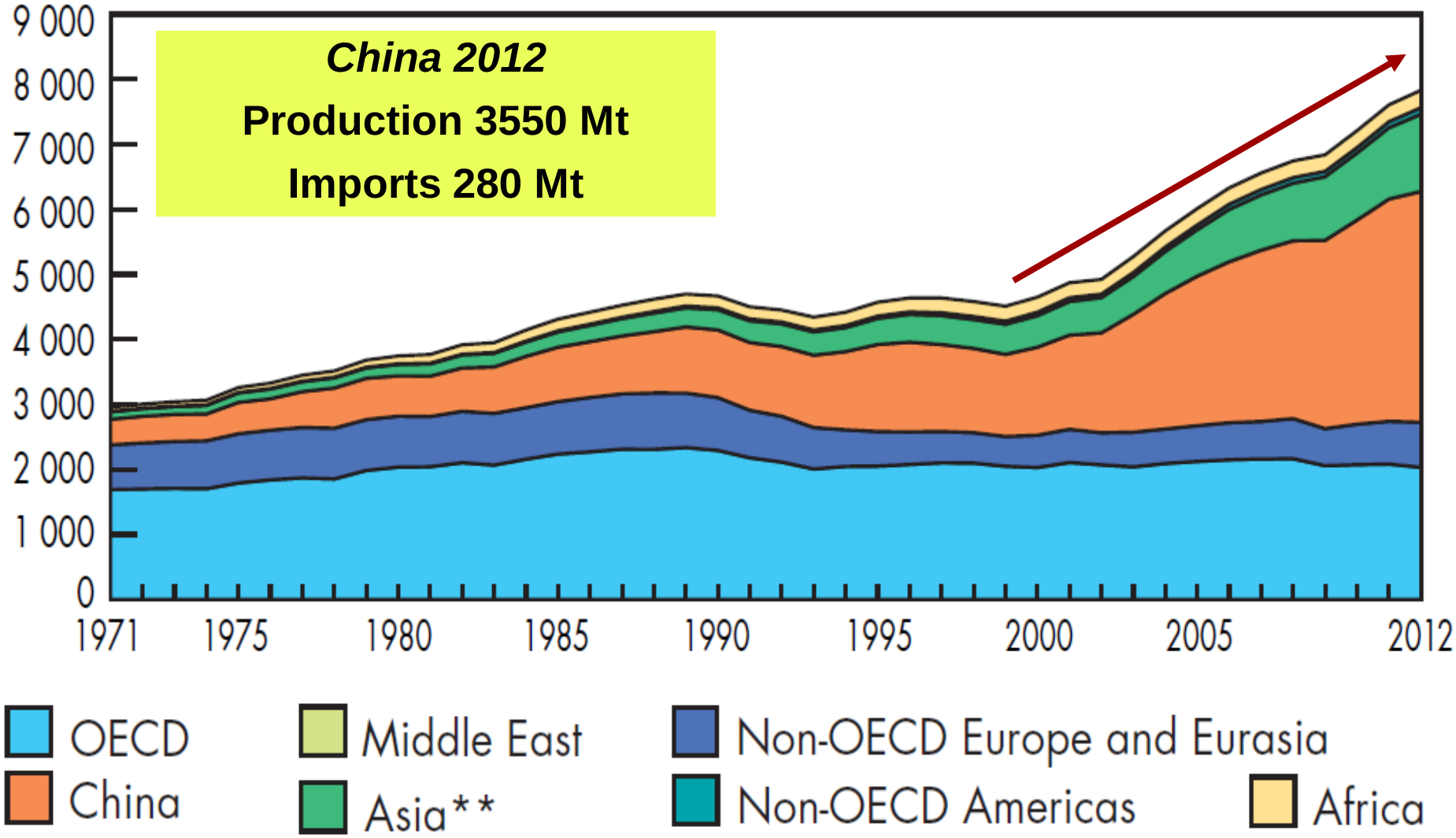


2030 : 16,3 Gtoe

Key World energy Statistics IEA 2003

World Hard Coal Production 1971-2012

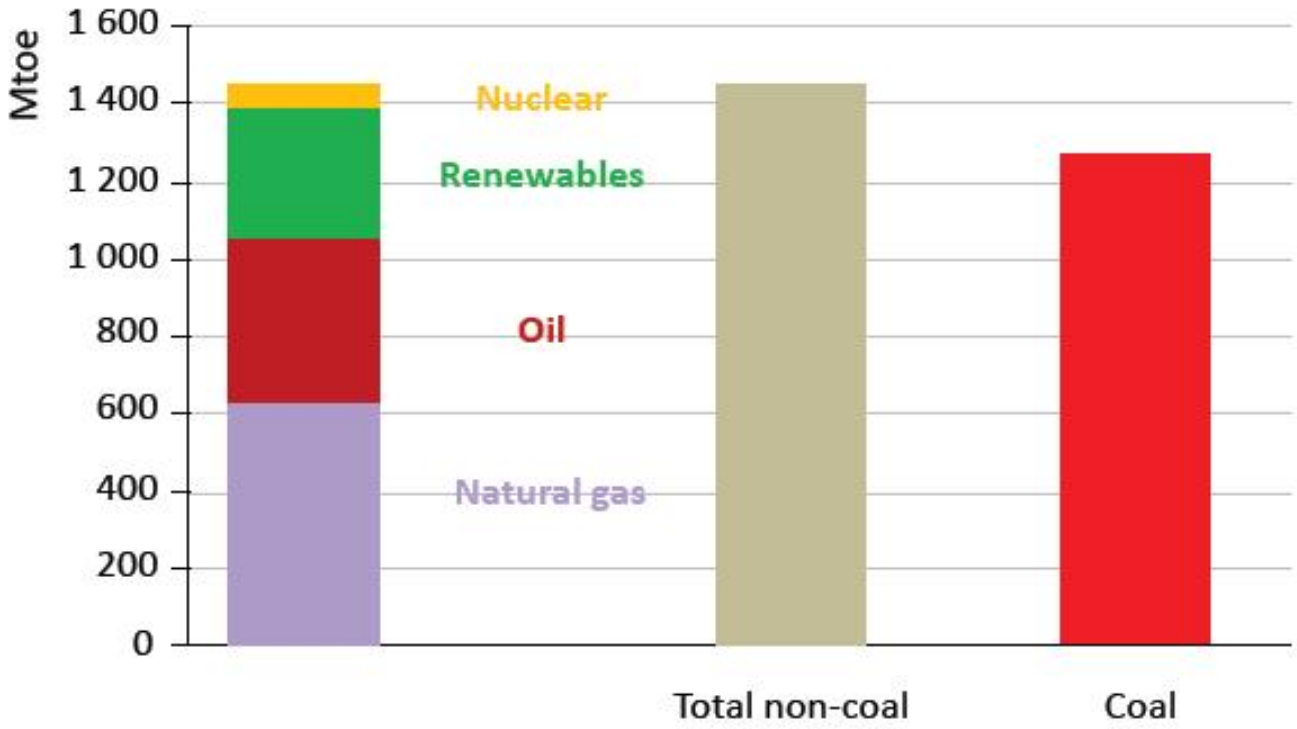
(add 900 Mt Lignite)



Coal won the energy race in the first decade of the 21st century

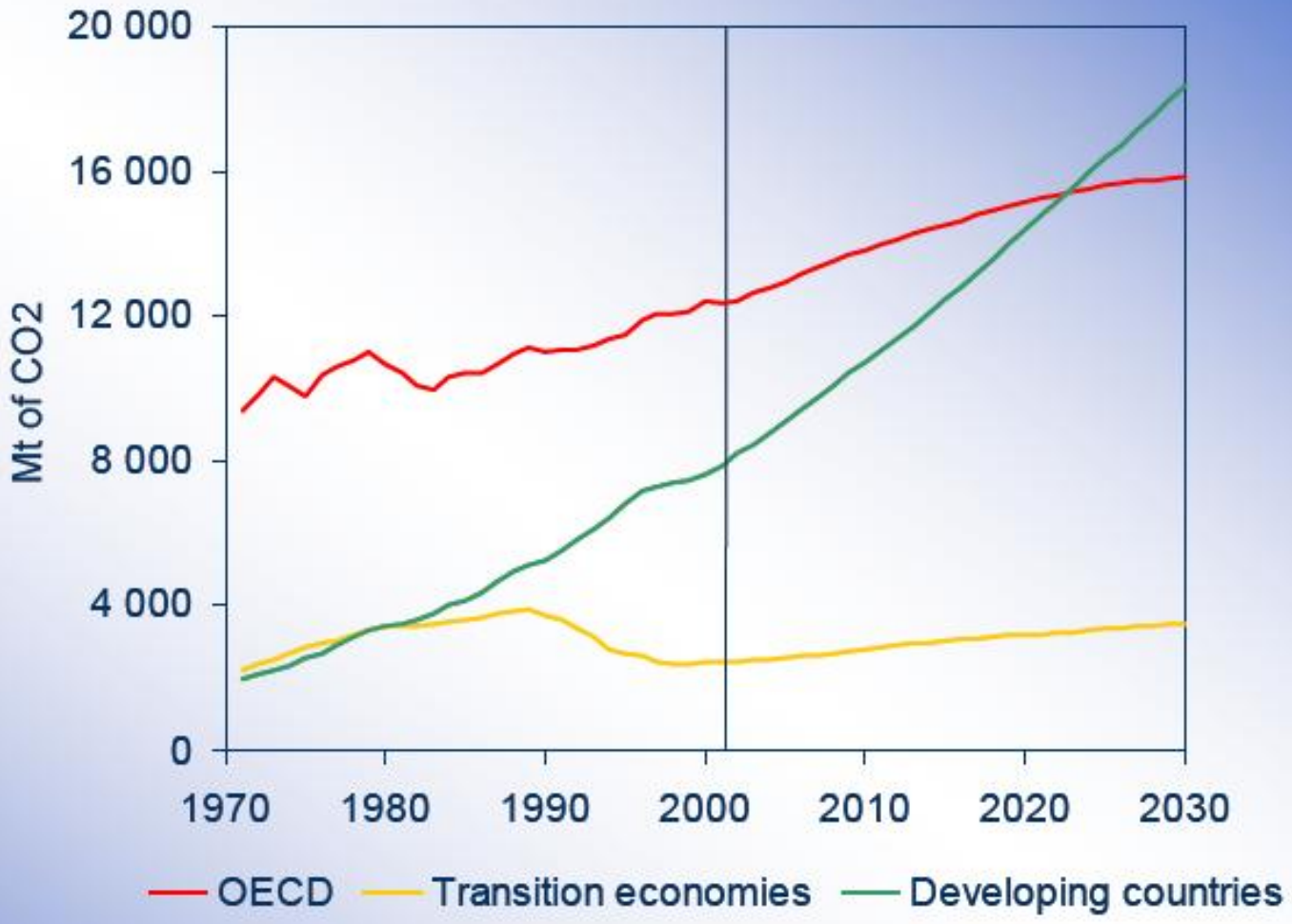
WORLD ENERGY OUTLOOK 2011

Growth in global energy demand, 2000-2010



Coal accounted for nearly half of the increase in global energy use over the past decade, with the bulk of the growth coming from the power sector in emerging economies

World Energy-Related CO2 Emissions



Global emissions grow 62% between now & 2030, with developing countries' emissions overtaking OECD's in the 2020s

www.undp.org

Human Development Report 2007/2008

Fighting climate change:
Human solidarity in a divided world

Climate change is the defining human development issue of our generation

Today, we are witnessing at first hand what could be the onset of **major human development reversal** in our lifetime.

Looking to the future, the danger is that it will stall and then reverse progress built-up over generations not just in cutting extreme poverty, but in health, nutrition,education and other areas.

IPCC established in 1988

WMO UNEP

Anthropogenic interference with the climate system ?

IPCC 1990 : Maybe, Maybe not

IPCC 1995 : Maybe

IPCC 2001 : Likely *(66% confidence)*

IPCC 2007 : Very Likely ! *(90%)*

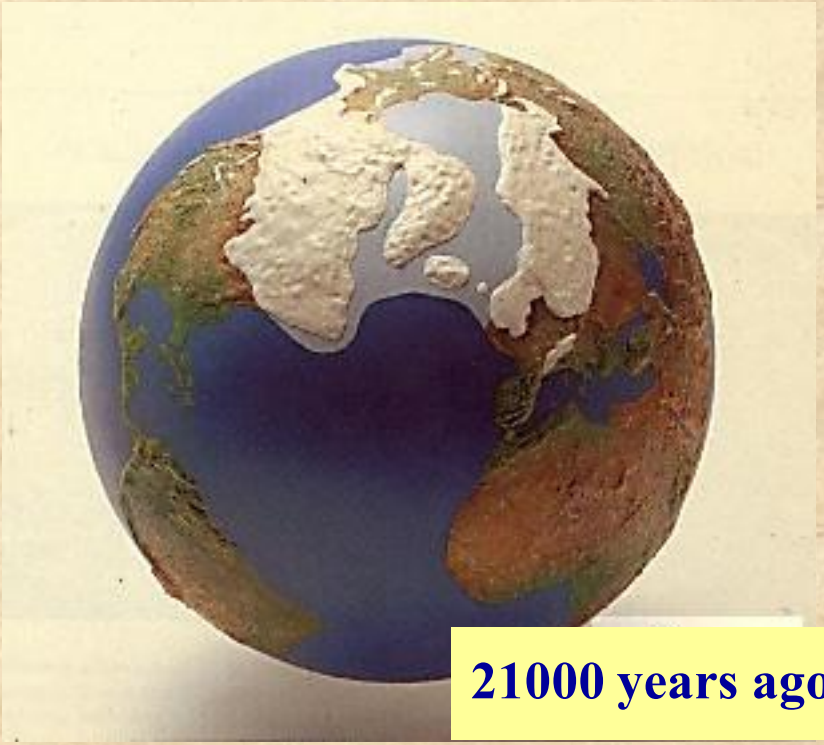
IPCC 2013 : Extremely likely *(95%)*

There have always been climate changes, so why worry ?

Today

CO_2 Pre-industrial = 280 ppmv

CO_2 2000 AD = 370 ppmv



21000 years ago

ΔT=-5°C

Δ sea level = –130m

Δ ice volume = +52 $10^6 km^3$

CO_2 = 200 ppmv

(Joussaume, 1993)

Dilemma : More Energy AND less CO_2

No Magic Bullet

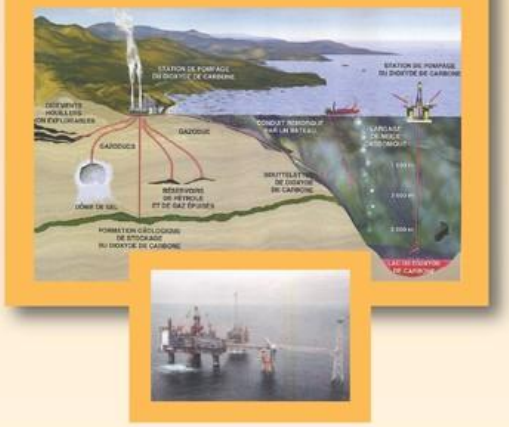
Energy Efficiency + Conservation

CO_2 – free Energy Sources

> l'énergie nucléaire

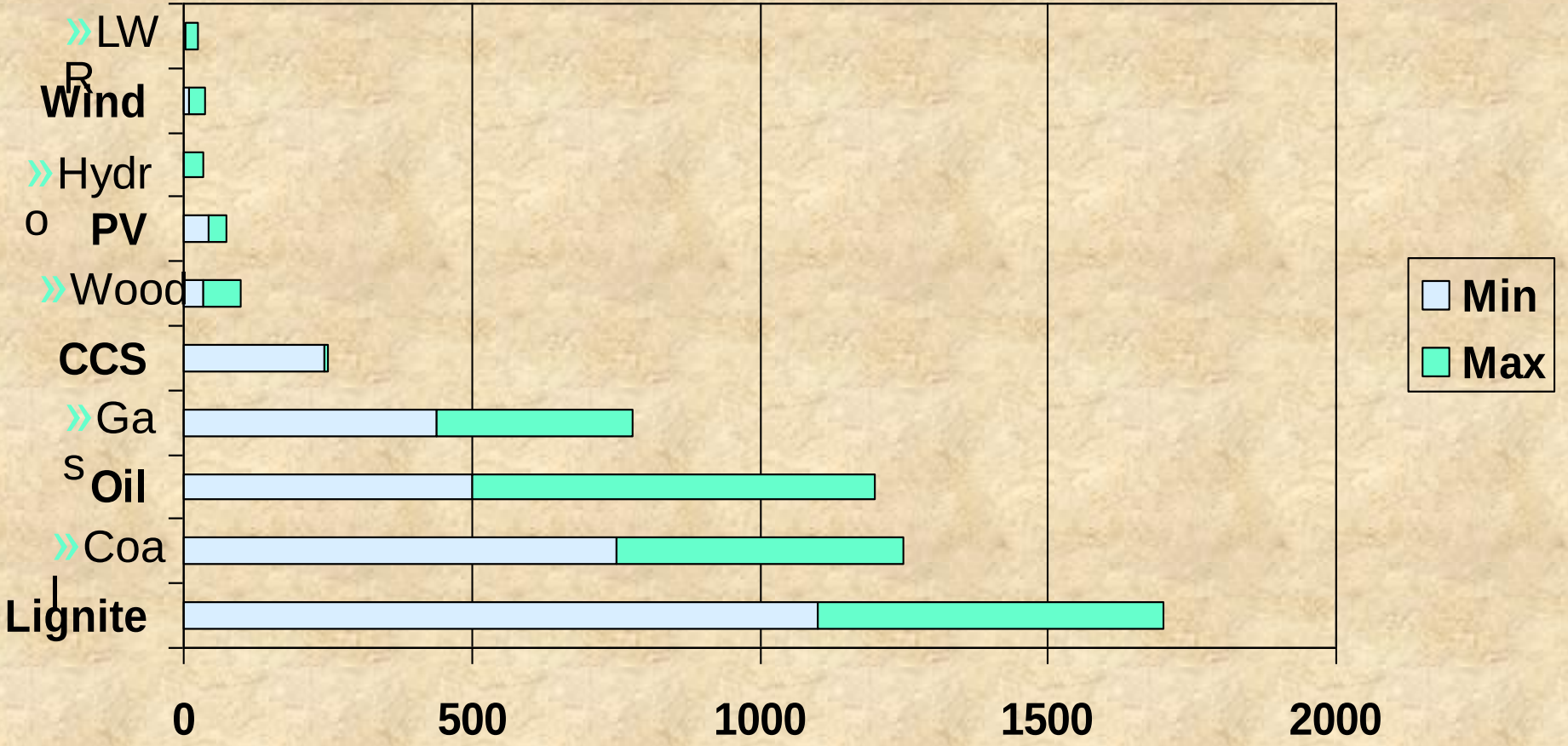
> les énergies renouvelables

CO2 Capture & Storage *or Recycle*



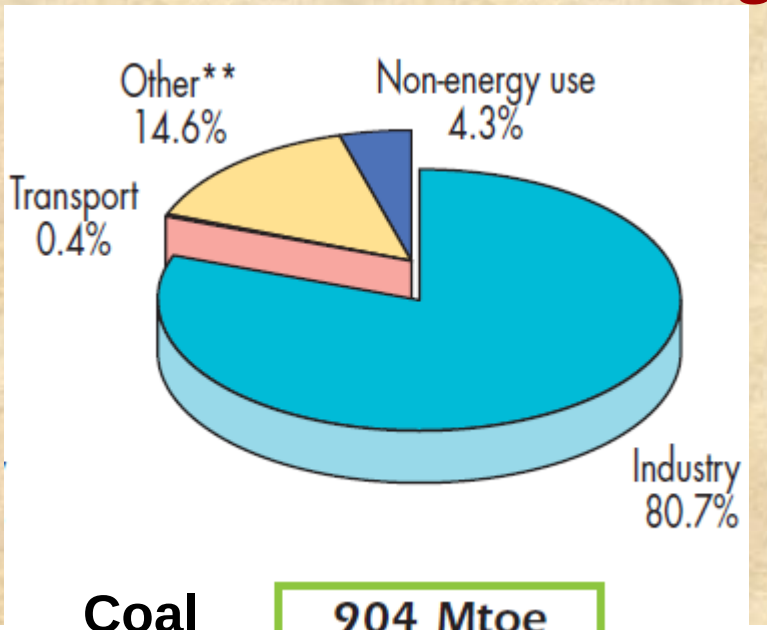
Life Cycle GHG Emissions, g CO_2eq per kWh_e

D. Weisser IAEA May 2006

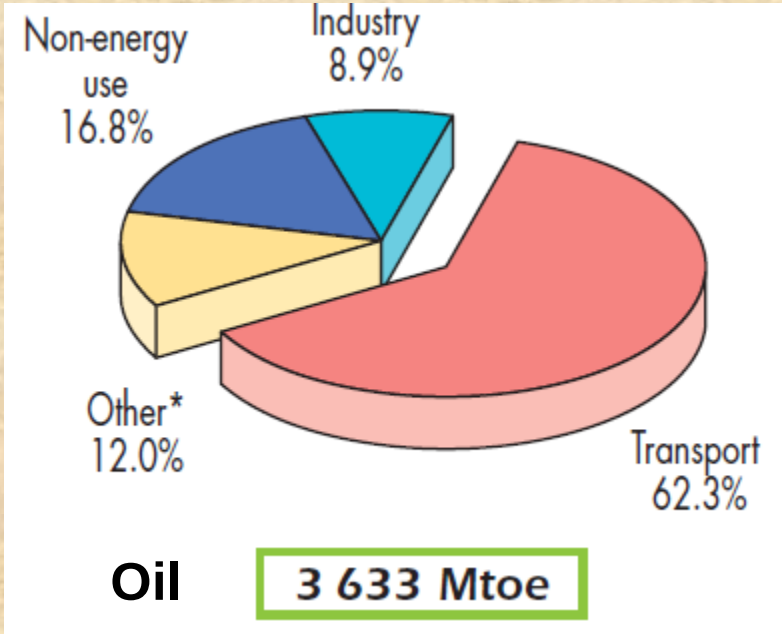


Ranges reflect differences in assessment technology, conversion efficiency, assessment boundary, etc.

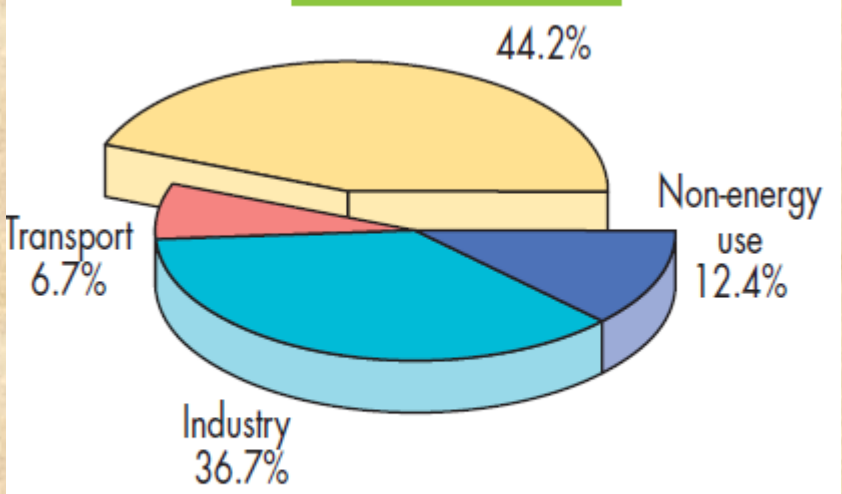
Final Energy Consumption by Sectors



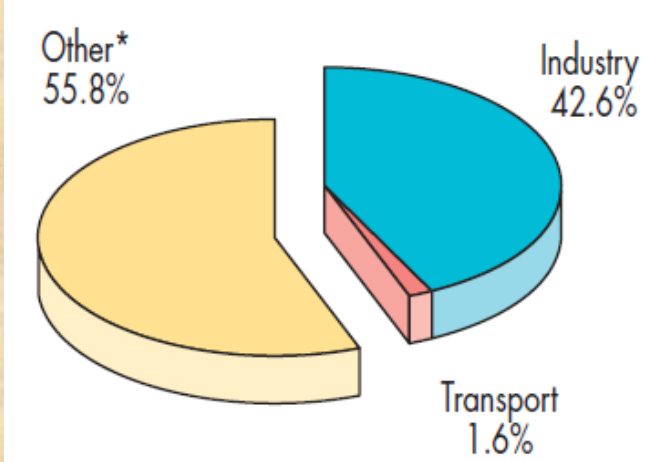
Coal 904 Mtoe



Oil 3 633 Mtoe

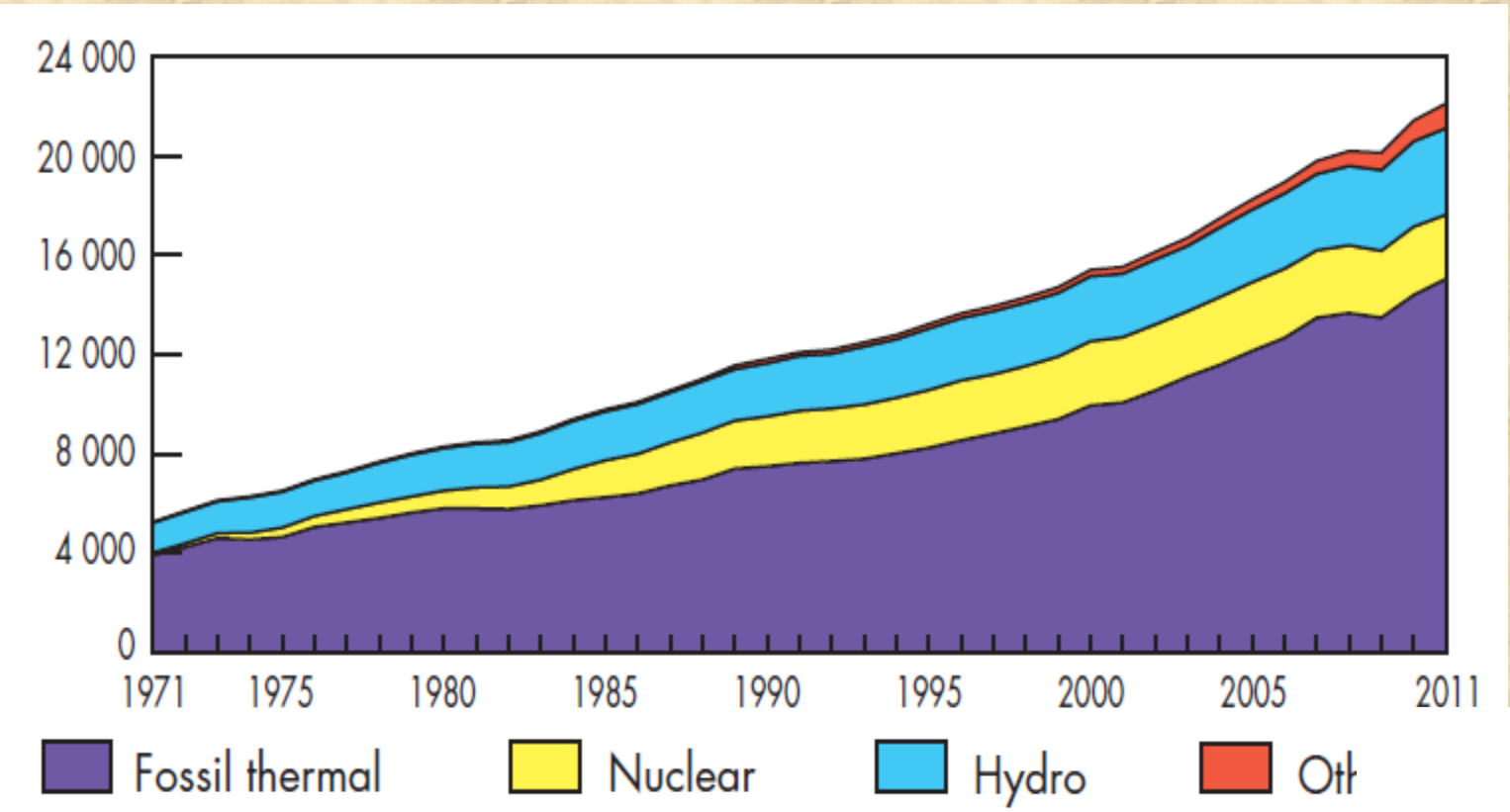


Natural Gas 1 380 Mtoe



Electricity 1 582 Mtoe

World Electricity Generation, TWh



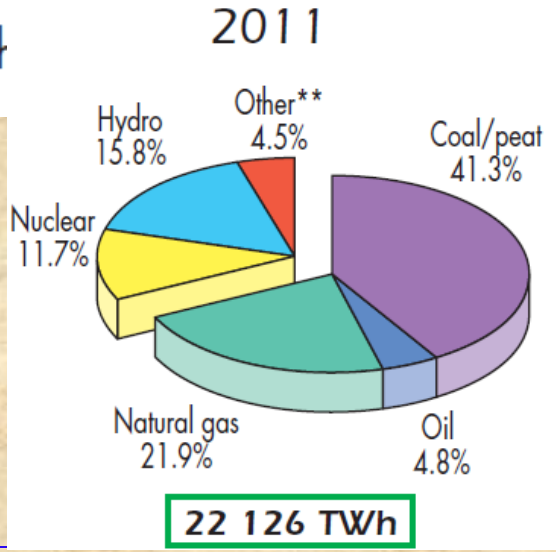
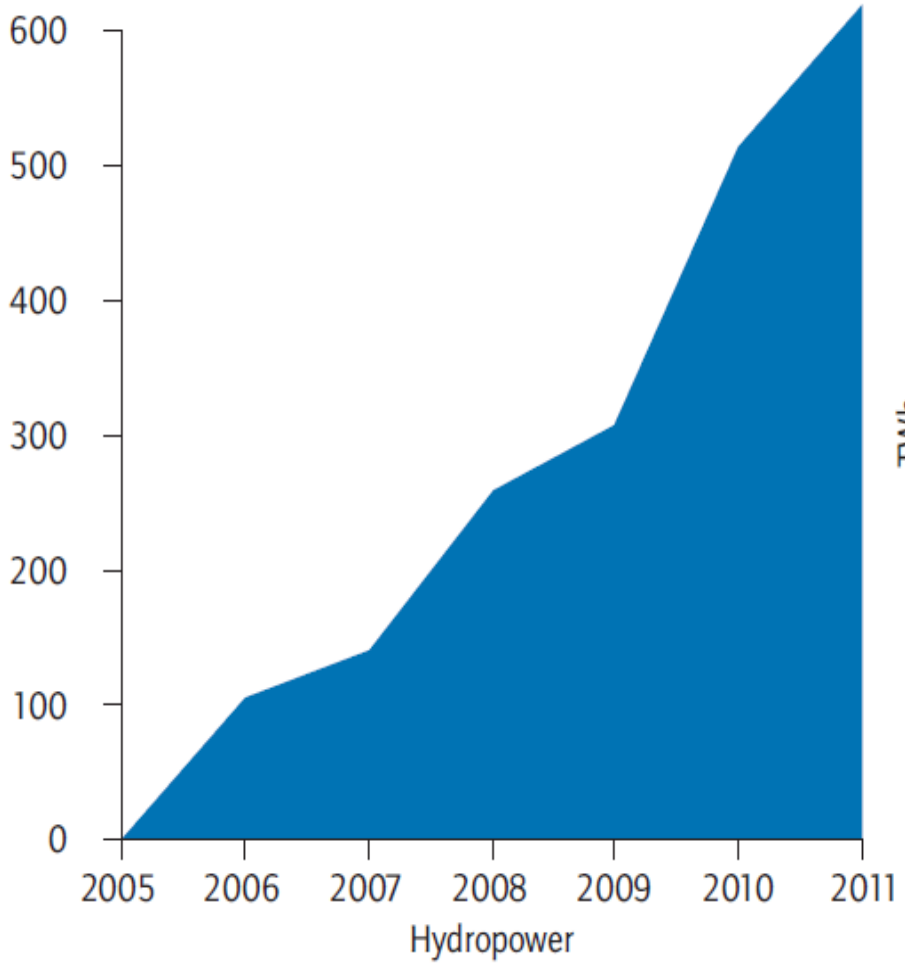
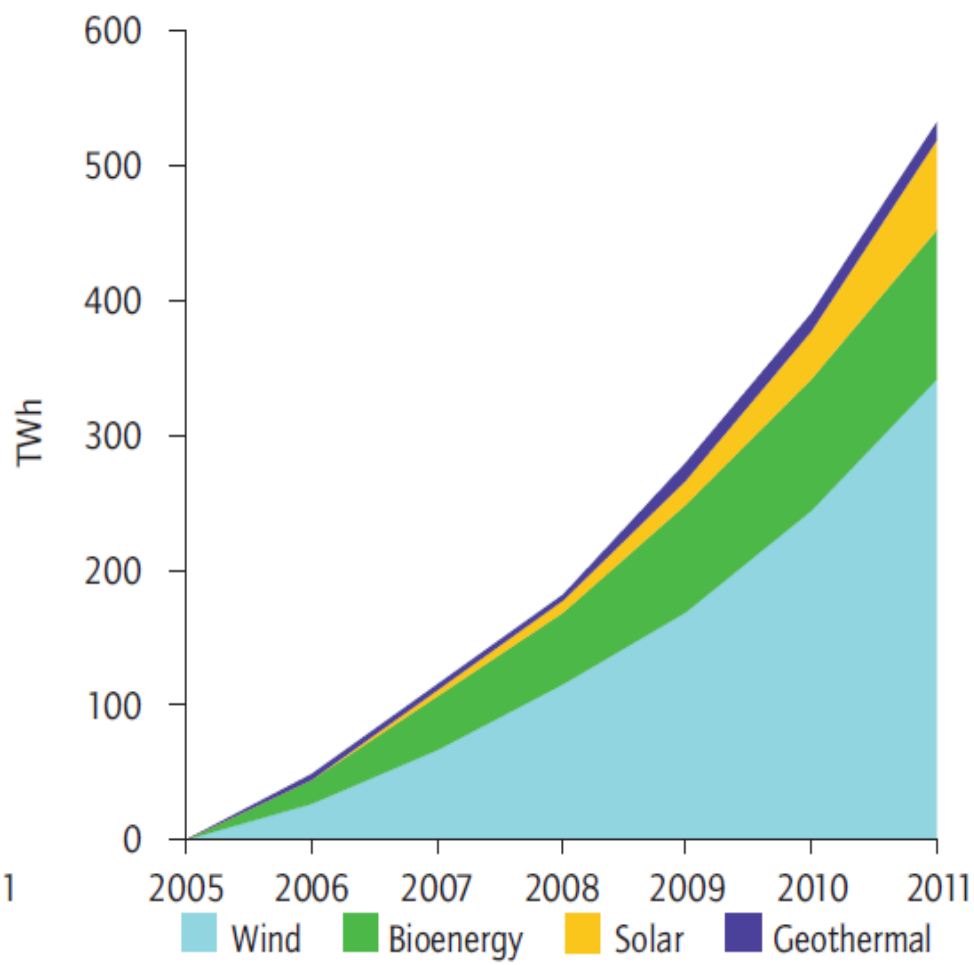


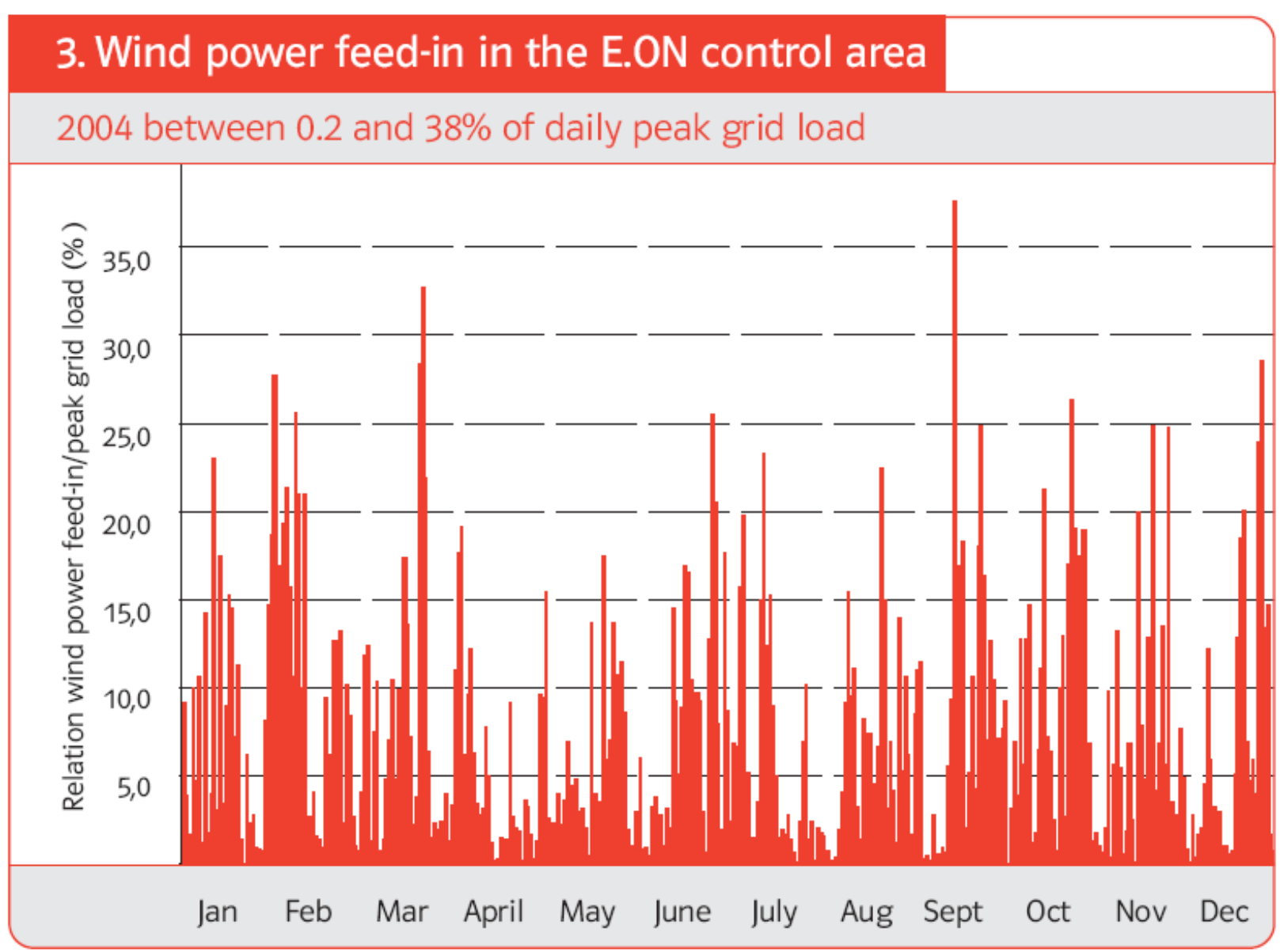
Figure 3: Electricity generation from recent additions to hydropower (left) and other renewables (right)





Source: IEA, 2012b.

Intermittency : Achilles's Heel of Windpower

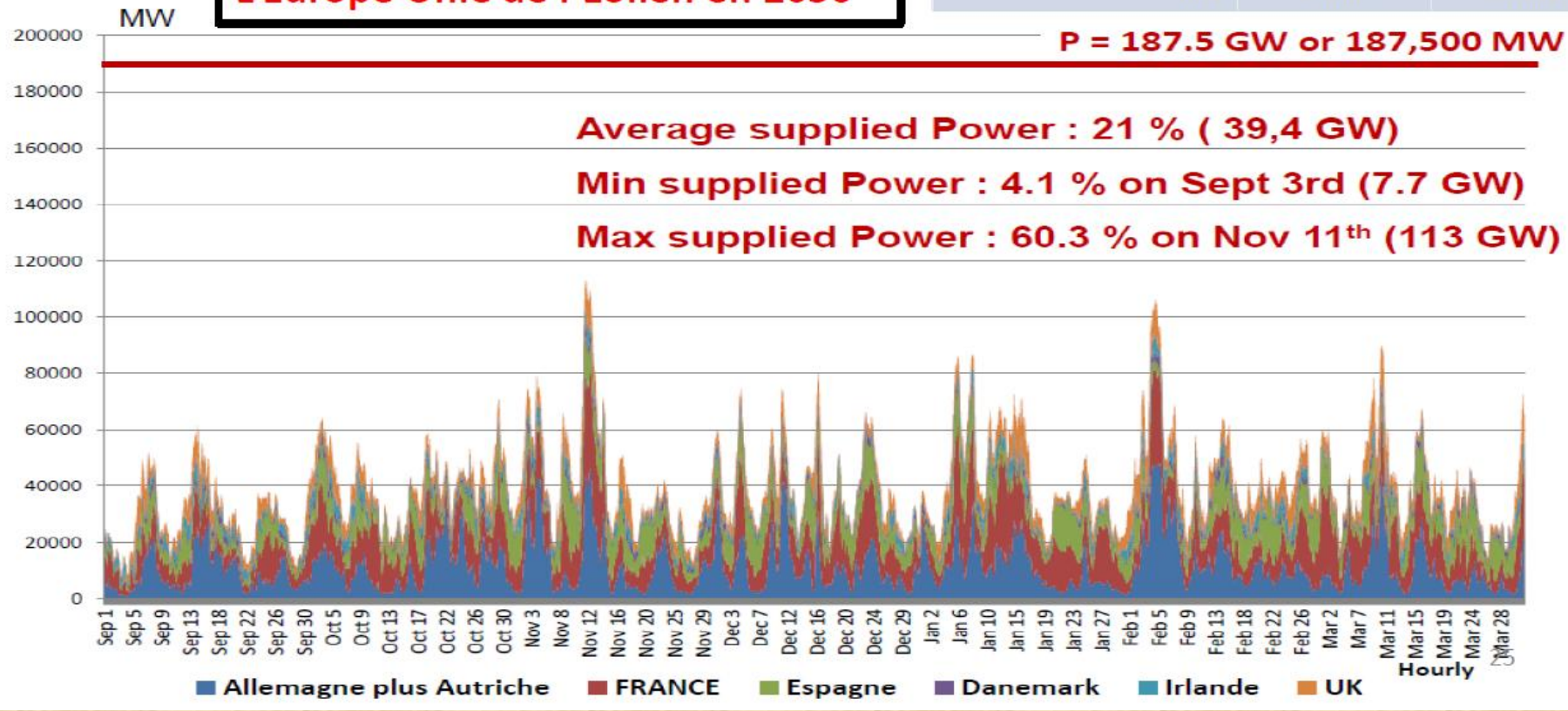


Windpower : even total transmission accross EU won't solve intermittency

- Collecte des données horaires éoliennes du 1er Sept. 2010 au 31 Mars 2011 dans 7 pays
- Puissance éolienne installée totale 65GW
- Renormalisation aux ambitions éoliennes annoncées par chaque pays pour 2030 : 187,5GW

MW	2010	2030 est.
France	5660	53000
Germany/Austria	28200	60000
Spain	20700	30000
Denmark	3800	4500
Ireland	1430	10000
Great Britain	5200	30000
Total	65000	187500

L'Europe Unie de l'Eolien en 2030



Nuclear Power 2012-13

Country	*GWe*	TWh	Units	%Elec
USA	*102*	771	102 + 3	19
France	*63*	407	58 + 1	75
Russia	*24*	166	33 + 10	18
S Korea	*21*	144	23 + 4	30
Germany	*20*	94	9	16
China	*14*	93	17 + 28	2
Canada	*14*	89	19	15
Ukraine	*13*	85	15	46
U Kingdom	*11*	64	16	18
Sweden	9	62	10	38
Spain	*7*	59	7	14
WORLD	*374*	2 346	434 + 67	12

% Nuclear Power 2012

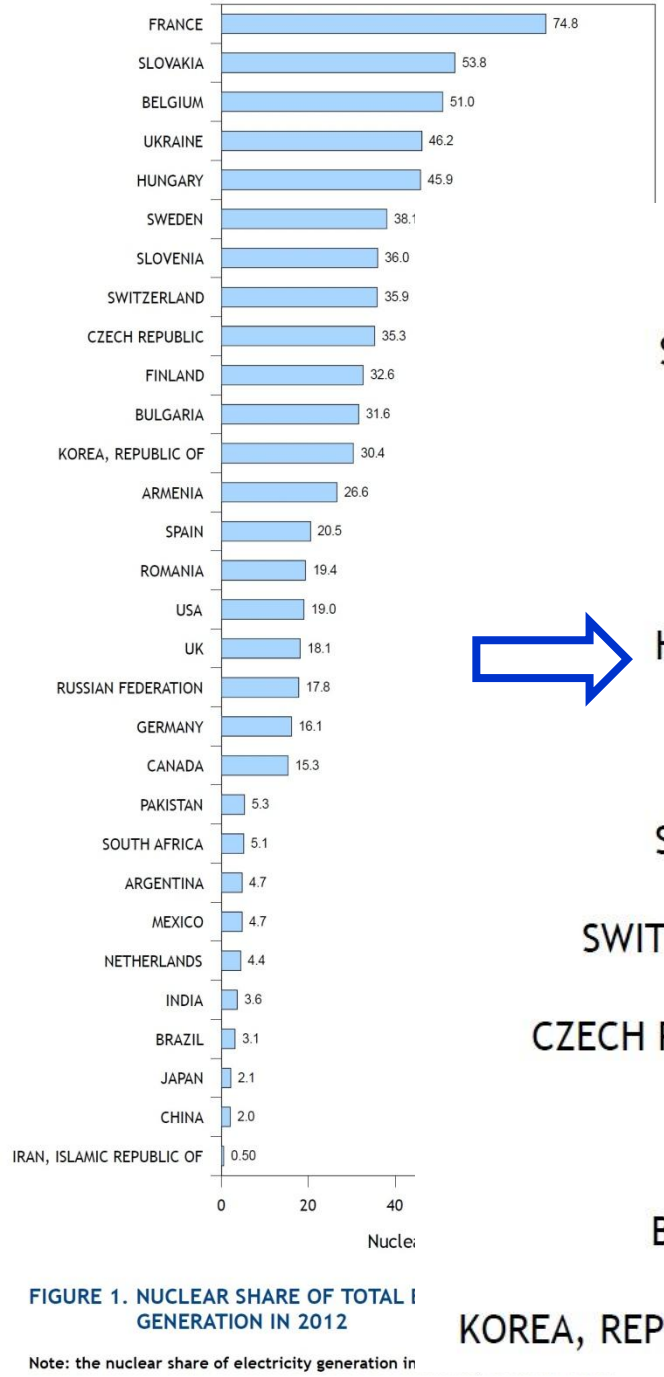
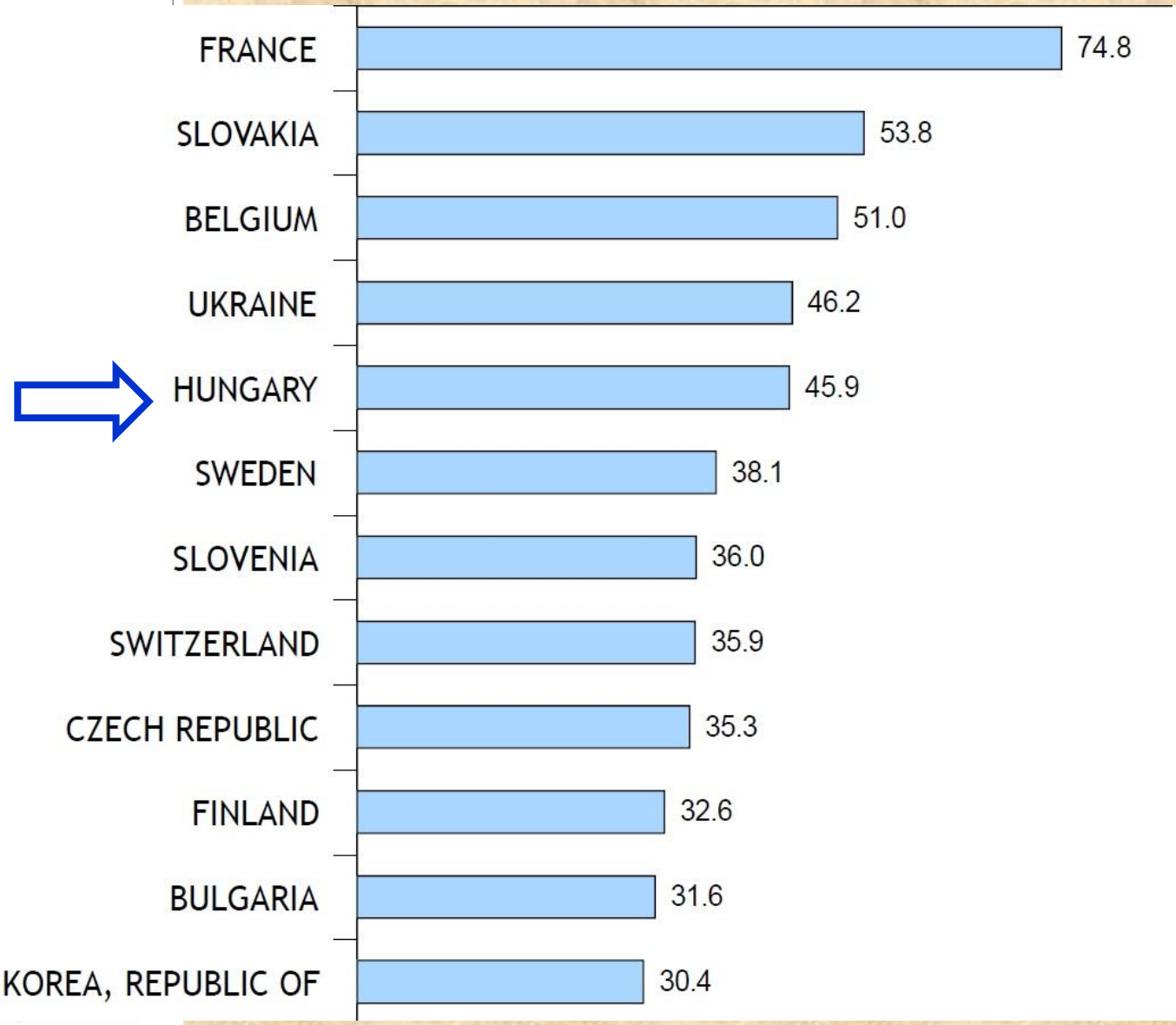
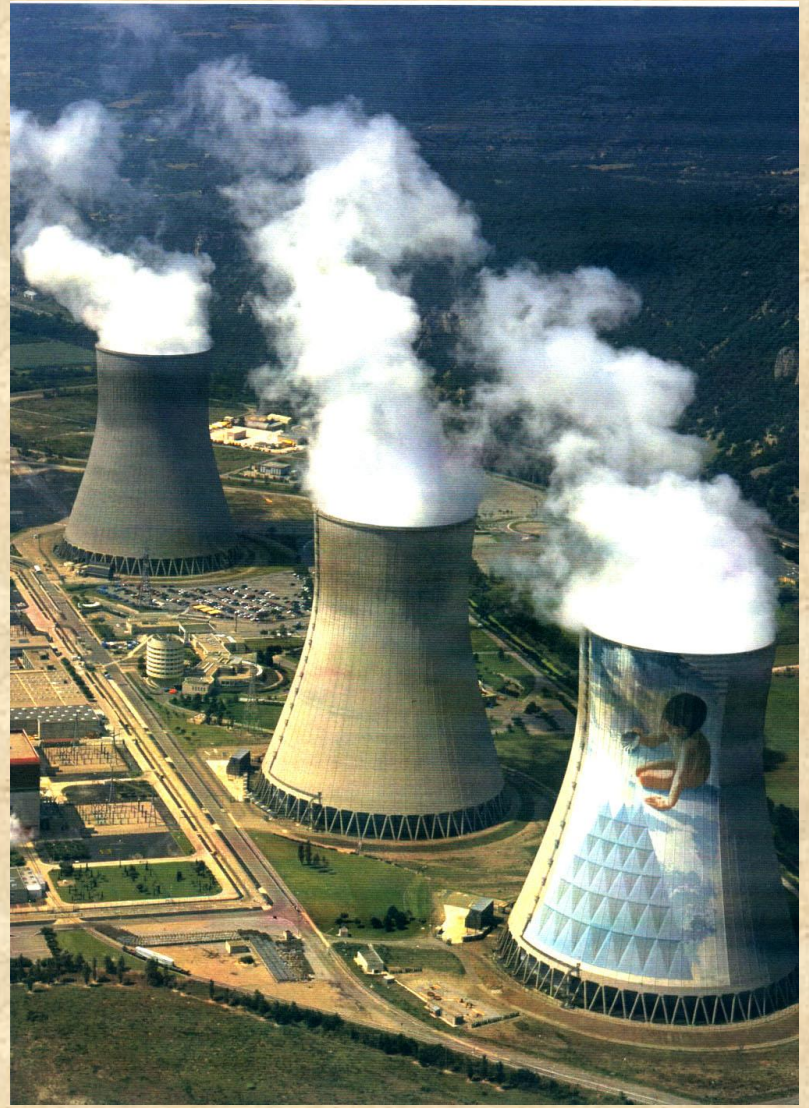


FIGURE 1. NUCLEAR SHARE OF TOTAL E
GENERATION IN 2012

Note: the nuclear share of electricity generation in



58 Years of Nuclear Power



434 reactors in 30 countries*

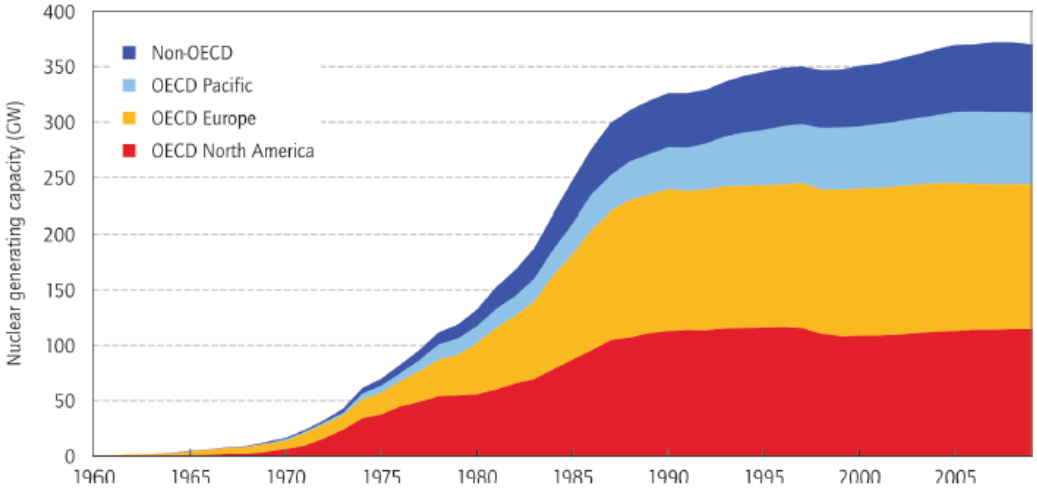
2350 billion kWh/year

~< Hydro-power

> Saudi Oil

12% Electricity

Figure 2. World nuclear generating capacity, 1960 to 2009



Source: IAEA PRIS.

KEY POINT: Nuclear capacity grew rapidly in the 1970s and 1980s, but much more slowly after 1990.

«Renaissance» of Reactor Build

Date	Operating Units	GWe	Construction Units	GWe
31-12-2004	440	366	26	21
31-12-2005	443	370	27	22
31-12-2006	435	370	29	27
31-12-2007	439	372	33	27
31-12-2008	438	371	44	39
31-12-2009	437	370	55	51
31-12-2012	437	372	64	62
04/10/2013	434	371	70	68

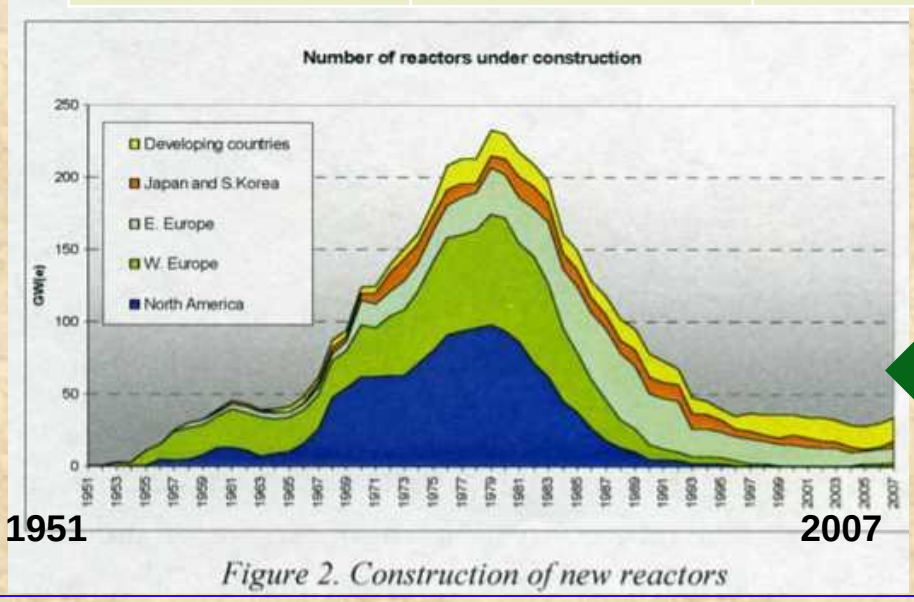
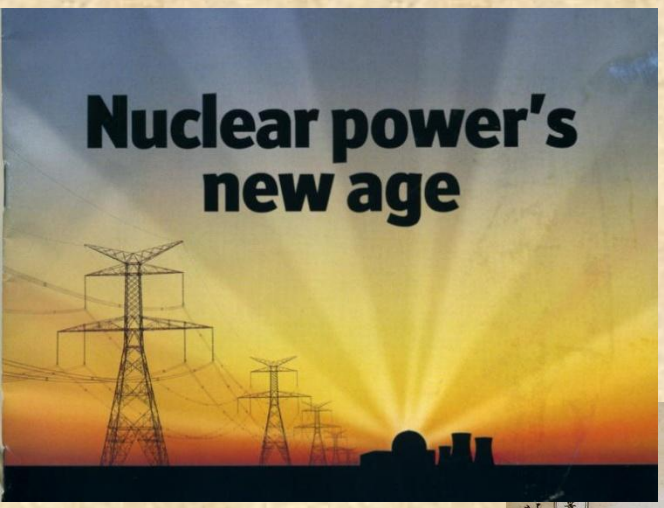


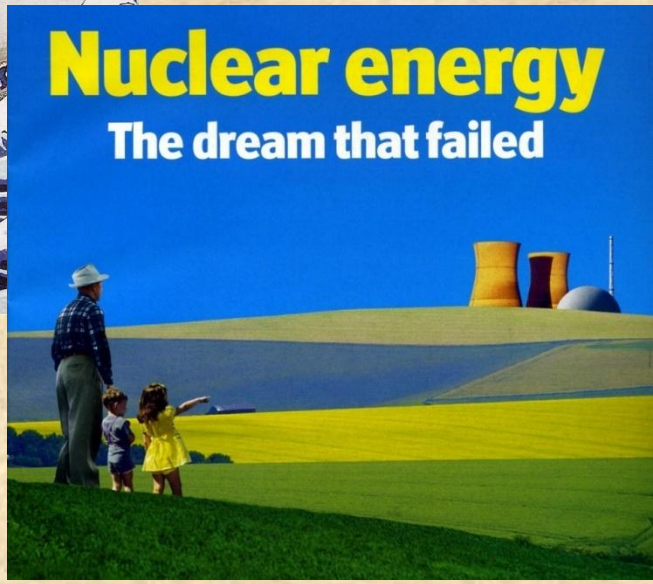
Figure 2. Construction of new reactors

2013

China:	29
Asia total:	45



What will be the consequences of Fukushima ?



International Reactions

- **Shut down operating NPPs:**
  - **Germany**
- **Cancel firm Projects:**
  - **Japan, Italy, Taiwan, Switzerland ?**
- **Proceed with Nuclear Power:**
  - **USA, Russia, China, India, UK, Finland, France, Hungary, Czech Republic, Slovakia, Brazil, South Africa, South Korea, Argentina, UAE, Ukraine, Belarus…**
- **Intend to start Nuclear:**
  - **Poland, Turkey, Saudi Arabia, Jordan, Vietnam,…**

ALL : Additional Safety Analysis (Stress Tests)

Main Actions from Stess Tests (in France)

- *Reinforce NPP protection against external aggressions (seism, flood,…)*
- *Reinforce electricity and water supply sources*
- *Limit releases in case of severe accidents (no significant and longlasting contamination of outside lands)*
- *Reinforce local and national Crisis Management*

- *« Hard Kernel » of water and emergency power supply reinforced beyond intial dimensionning. Plug & Play inlets. Reinforced crisis building.*
- *Rapid Nuclear Action Force (FARN), able to help the operators anywhere in France within 24 hours : ~300 trained specialists with materials & airlift capability.*
- *~10 billion Euros for 58 French units.*

Current Status of the Nuclear Power Plants in Japan

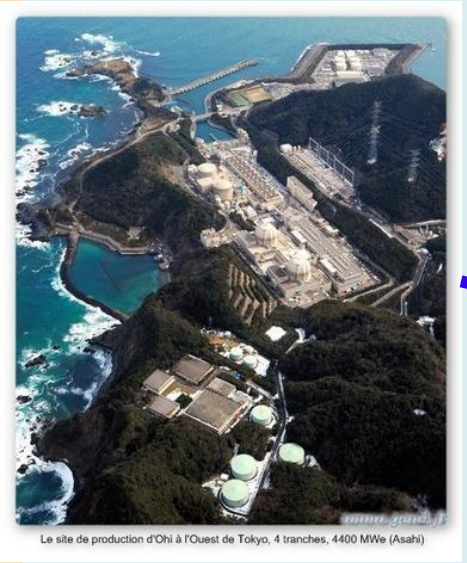
(as of May 28, 2012)

: **In operation**
(0 unit, 0GWe)

: **Outage for the periodic inspection and others**
(37 units, 32.97GWe)

: **Shutdown due to tsunami and the government request**
(13 units, 13.18 GWe)

TOTAL : 50 units, 46.15 GWe

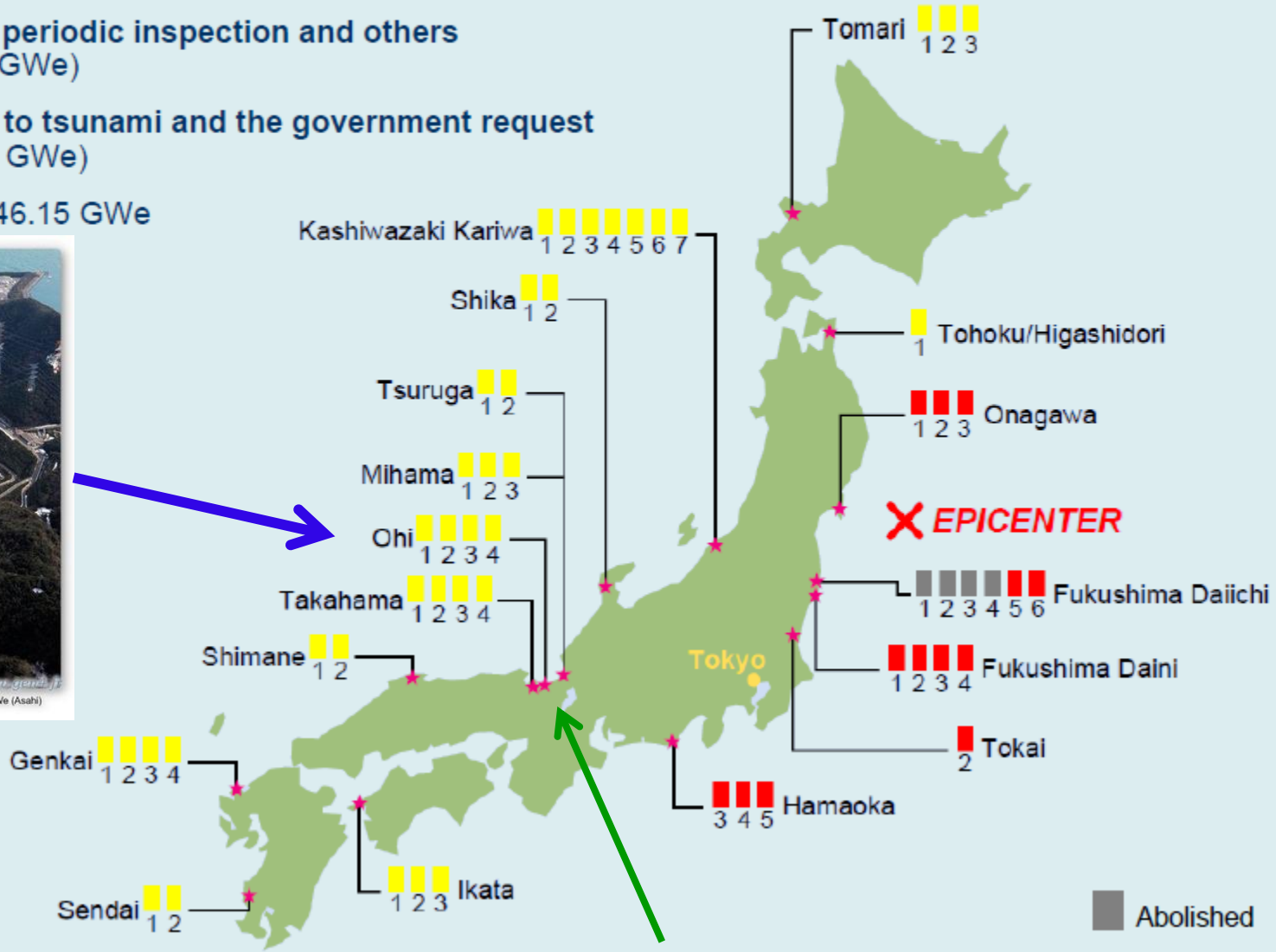


Le site de production d'Ohi à l'Ouest de Tokyo, 4 tranches, 4400 MWe (Asahi)

Restart Ohi 3&4
June 2012

Shutdown Ohi 3+4

September 2013



General Elections in Japan December 16, 2012

- *Noda Government : Position on Energy and Environment (September 2012):*

"Realization of a society not dependent on nuclear in earliest possible future"

Abe Government (Decembre 31):

- *« New Reactors will differ from those built 40 years ago, from those of Fukushima Daiichi which created the crisis", « We shall build them and explain to the public to which extent they are different, in order to gain its acceptance".*

Pdt Hollande's Campaign Proposal 41

- ***I will engage a reduction from 75% to 50% of the nuclear share of electricity generation around 2025***
- ***I will close down Fessenheim***
- ***I will complete the EPR in Flamanville***

2 Public Debates in 2013 :

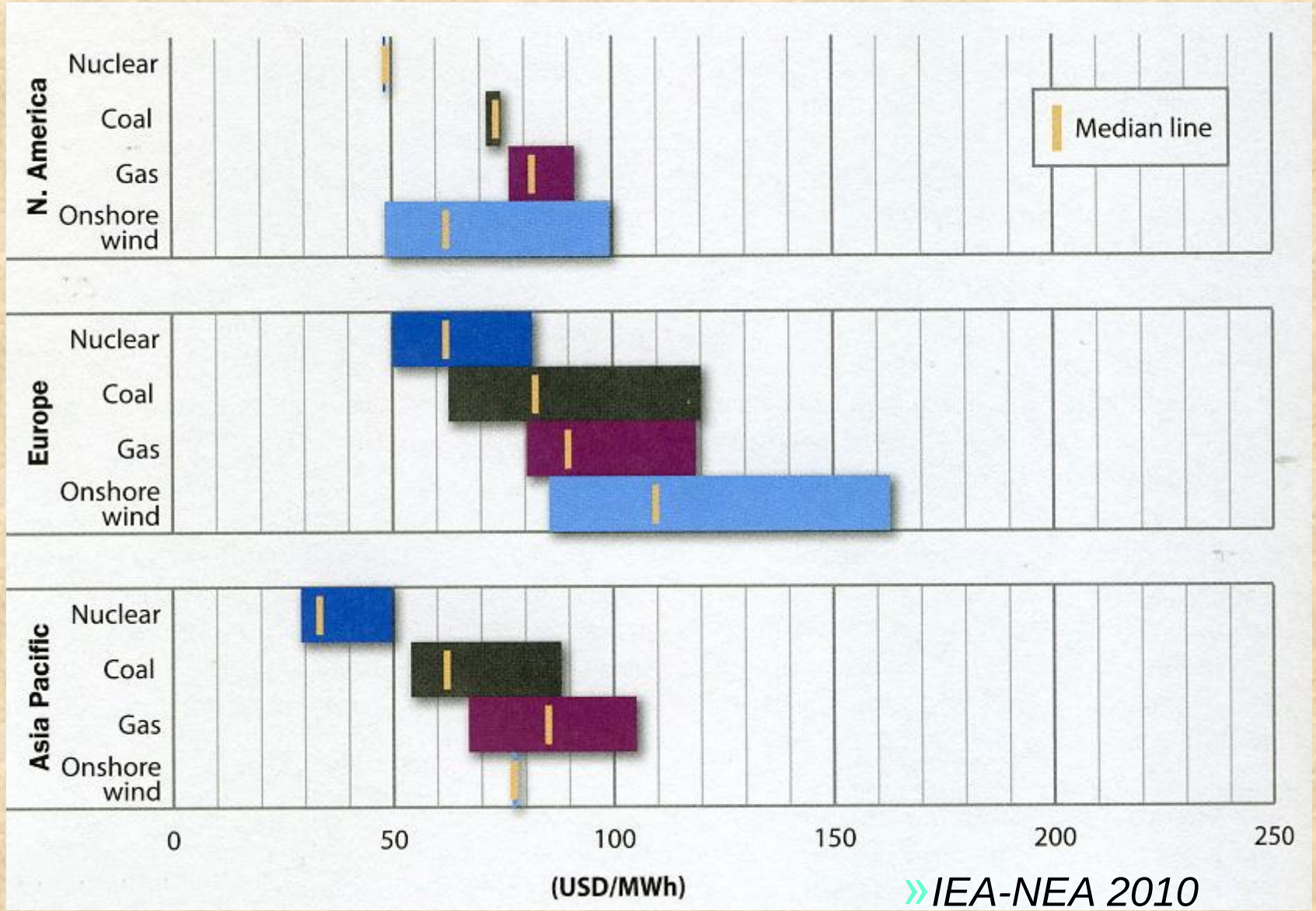
« Energy Transition »

CIGEO geological Repository for long-lived radwaste

Issues

- ***Economy***
- ***Public Acceptance***
  - ***Severe Accidents***
  - ***Waste Disposal***
  - ***Proliferation***
- ***Uranium Resources***

Future costs of Electricity $/MWh (DR=5%)



» *IEA-NEA 2010*

What about post-Fukushima ?

- ***58 French nuclear reactors did cost ~150 billion Euros for 40 years of electricity each***
- ***Additional investments, post Stress-tests, will cost ~10 billion Euros…***
- ***…to be added to 40 billion* anticipated by EDF to generate electricity during 20 years more***

⇨

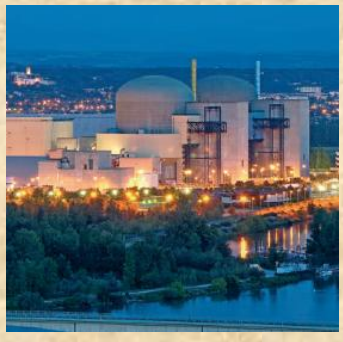
- ***Total Generation Cost : 46-50 €/MWh***

(to be spent over 30 years)*

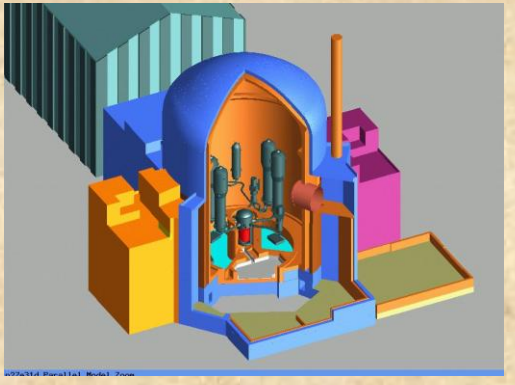
Nuclear reactors « Generations »

Pionner Facilities

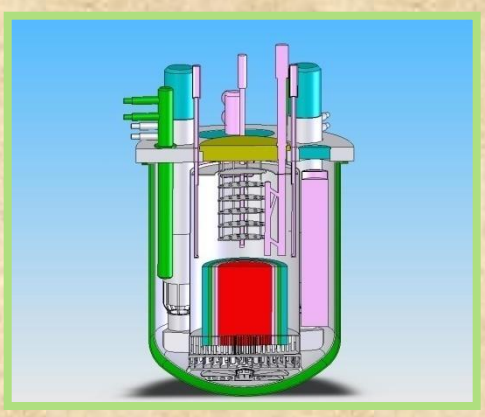
Operating Reactors



Advanced Reactors



Future Nuclear Systems



1950 1970 1990 2010 2030 2050 2070 2090

Generation I

Generation II

Generation III

Generation IV

Generation 3 : Post-Chernobyl

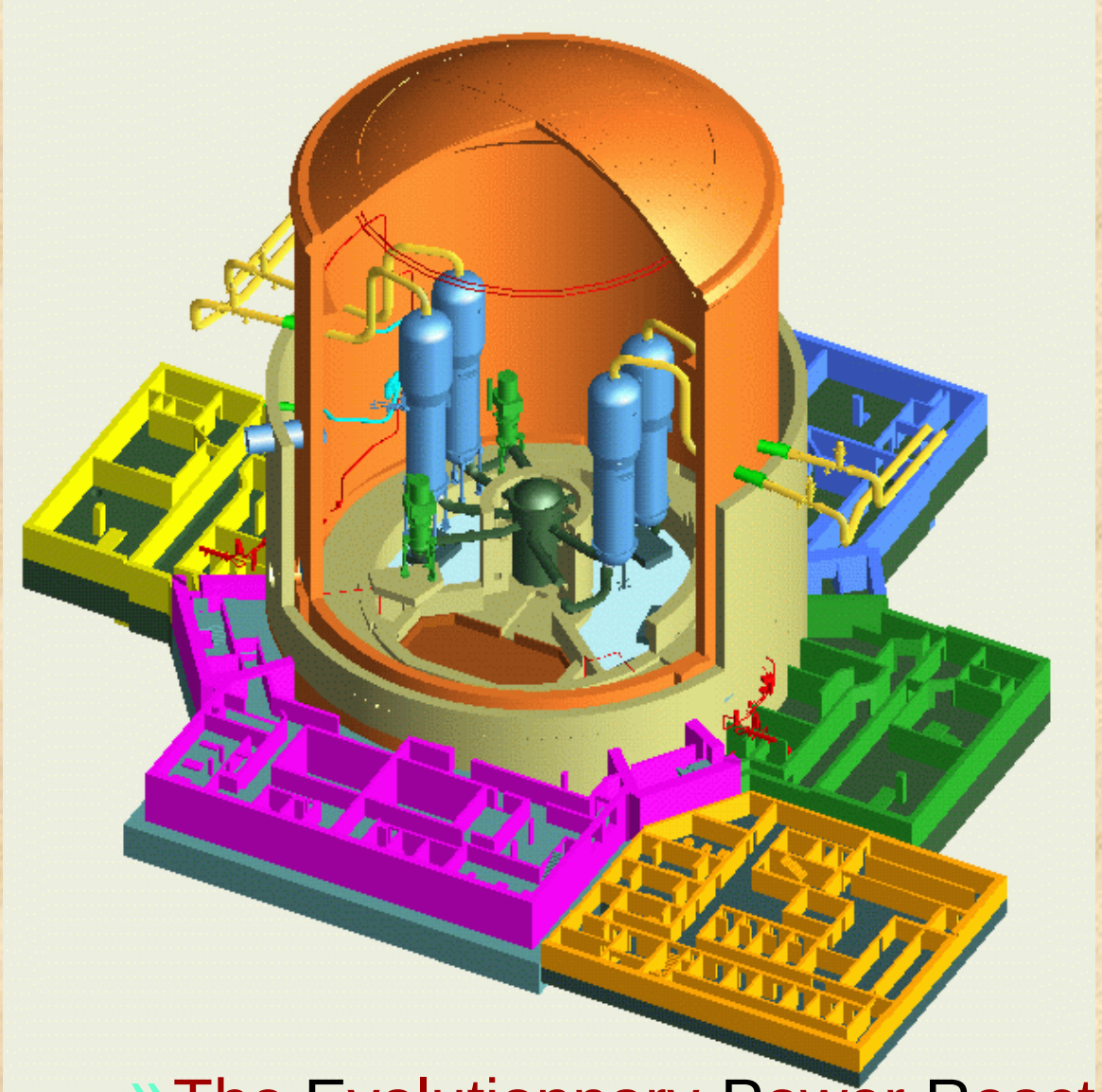
Increased Safety (prevention & mitigation)

Simplification

Reliability & Operational Flexibility

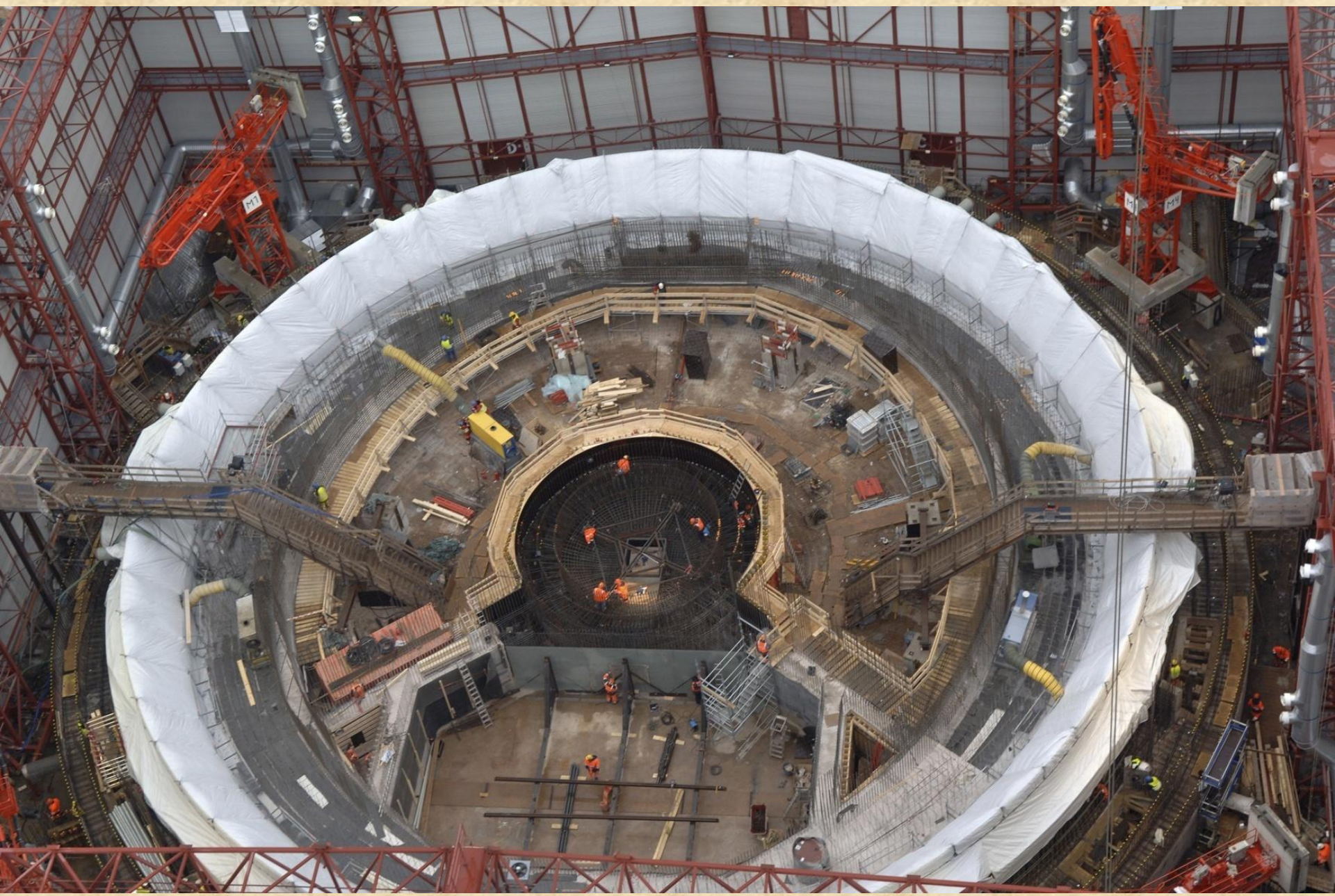
Economy (vs best Fossil)

Generation III : Severe Accident Mitigation



» The Evolutionnary Power Reactor

Olkiluoto March 2007



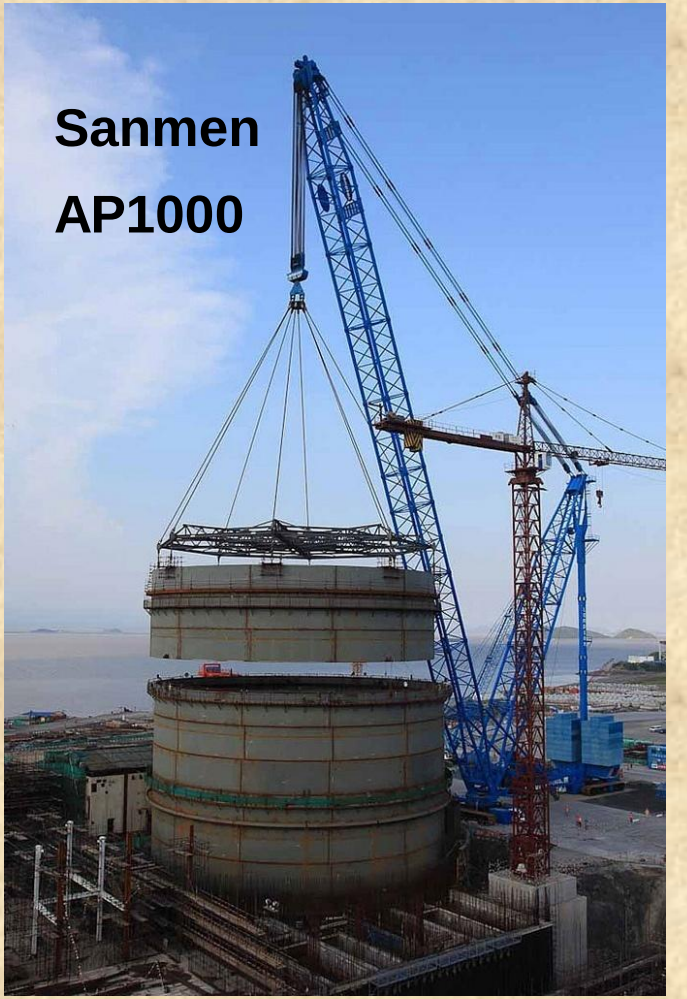
- **Les principes de sûreté de l'EPR sont confortés après Fukushima :**
  - robustesse aux agressions externes
  - défense en profondeur accrue
  - prise en compte des accidents graves dès la conception
- **Des ajustements sont apportés :**
  - étanchéité renforcée
  - autonomie allongée
  - possibilité de connecter des moyens mobiles
- **La démarche d'analyse et de retour d'expérience sera poursuivie**

EDF

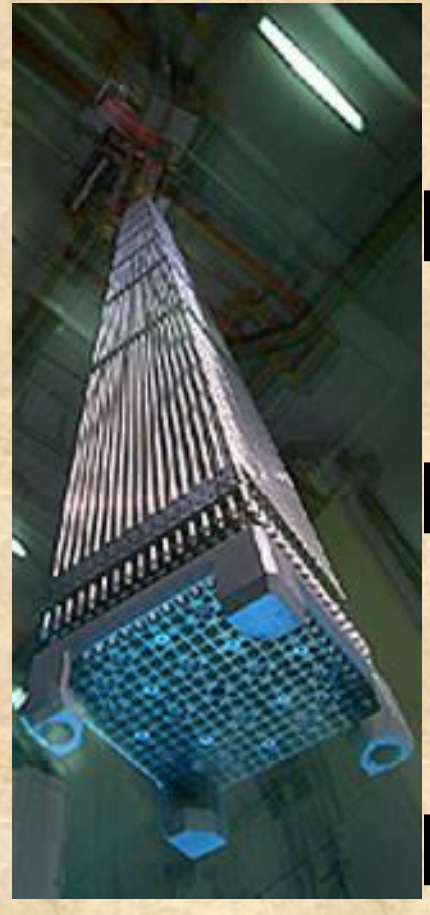
AREVA

October 2012 : China decides all new NPP Projects shall be « Generation 3 »

Taishan 1&2 EPR



Spent Fuel Management



Spent fuel.

Reversible direct disposal

Storage, then decision *later…*

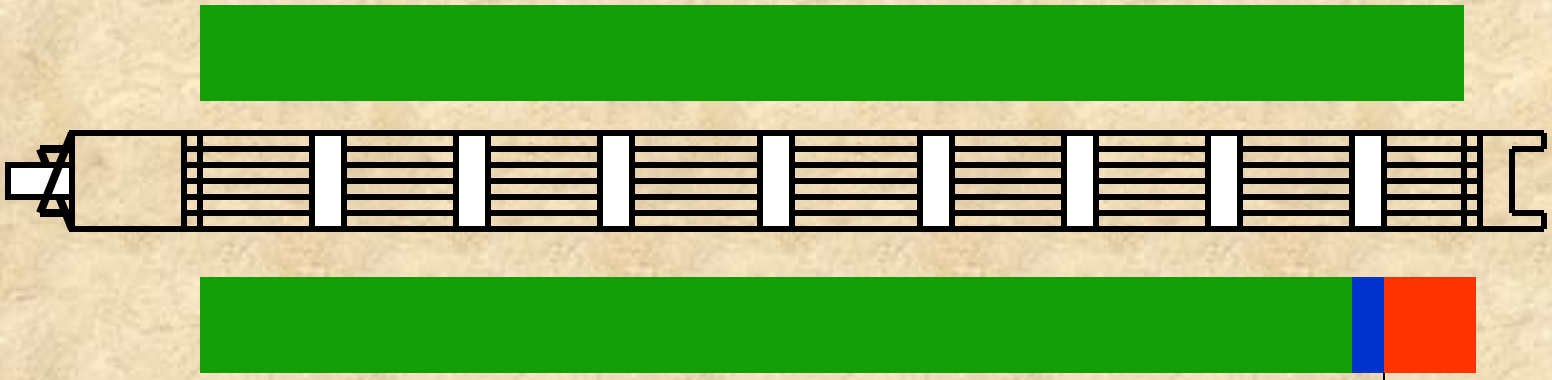
Reprocessing & Recycle + HLW reversible disposal

Progress in HLW Management

PWR Spent Fuel Composition

Fresh Assembly

Uranium (4% ^{235}U) : 500 kg



Uranium (0,9% ^{235}U) : 475 kg Pu : 5kg FP* : 20 kg

recyclables

Spent Assembly

*(and a few Minor Actinides)

Natural Uranium Resources

Millions t U naturel	Red Book 2009	Red Book 2011
Ressources identifiées <260$/kgU	6,3	7,1
Ressources à découvrir	10,4	10,4
Consommation	59000 t/an	64000 t/an
Dont production des mines	75%	85%

- *Identified Uranium "conventional" Resources exceed 100 times 2011 world Consumption*
- With Breeders, Resources are practically limitless

New energy systems for the future

GENERATION IV : development of nuclear energy systems

Deployable by 2040

With significant advances in :

- Sustainability
- Safety and reliability
- Proliferation and physical protection
- Economics

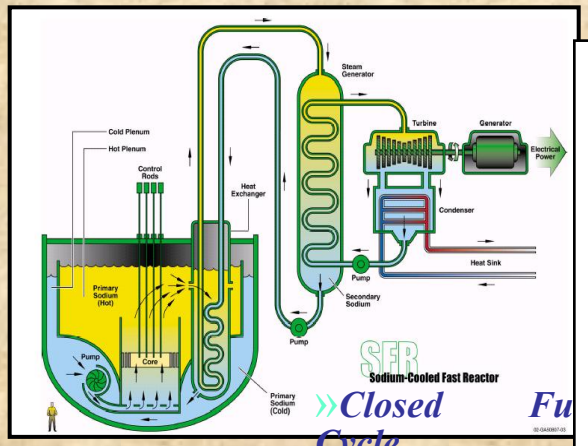
Competitive in various markets

Designed for different applications :

Electricity, Hydrogen,
Clean water, Process Heat

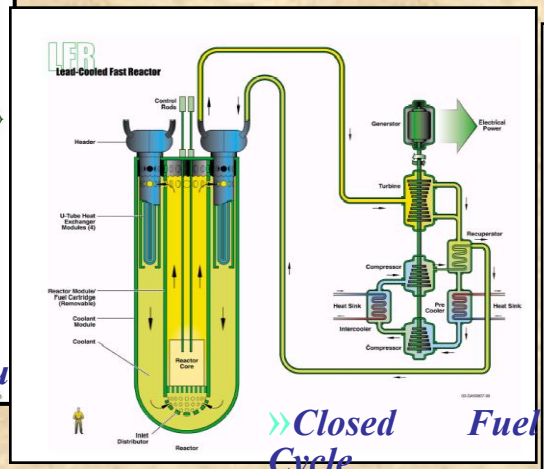
Framework Agreement signed Feb 2005

6 Innovative concepts with technological breakthroughs



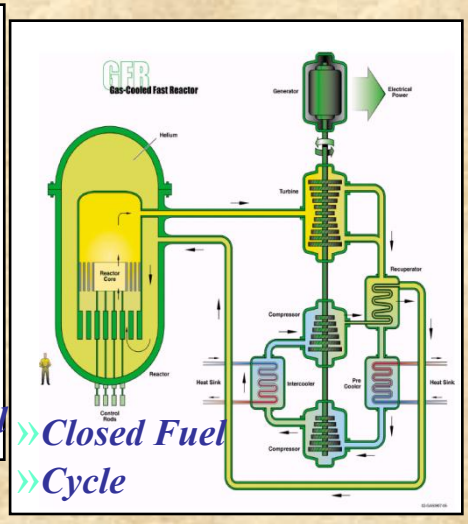
»Closed Cycle Fu

»Sodium Fast reactor



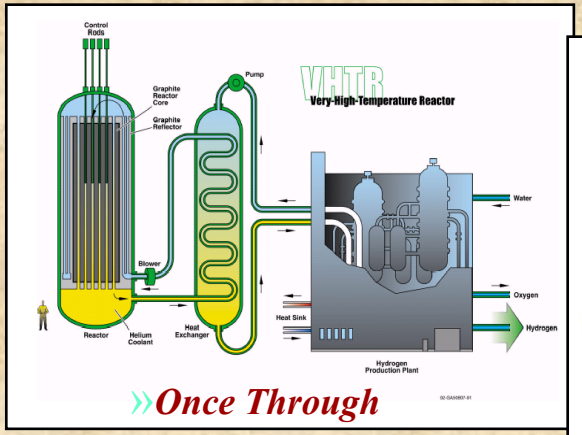
»Closed Cycle Fuel

»Lead Fast Reactor



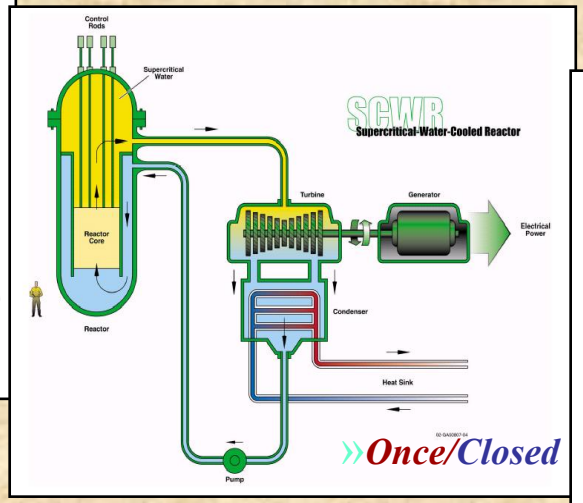
»Closed Fuel Cycle

»Gas Fast Reactor



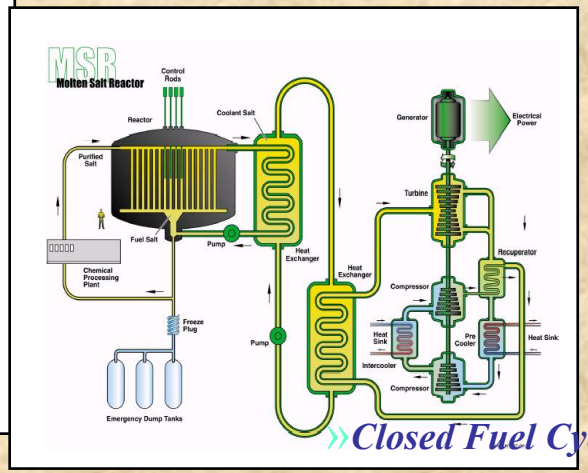
»Once Through

»Very High Temperature Reactor



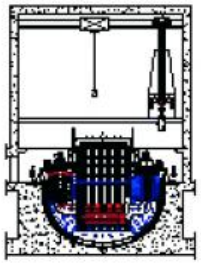
»Once/Closed

»Supercritical Water Reactor



»Closed Fuel Cycle

»Molten Salt Reactor



2008 2012 2020

SFR ASTRID Reference technology

SFR Prototype (250-600MWe)

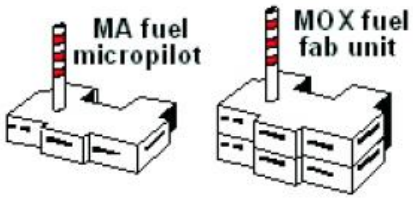
LFR

LFR Demo 50 -100MWth

Alternative technology

GFR ALLEGRO

GFR Demo 50 -100MWth



Supporting infrastructures, research facilities
Irradiation facilities
and fuel manufacturing facilities

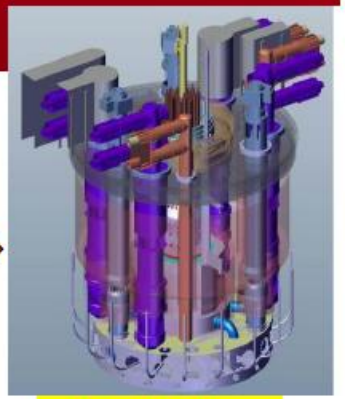
Fig. 13: European Industrial Initiative of the SET Plan, dedicated to the demonstration of GenIV (sustainable fission) technologies

Les réacteurs à neutrons rapides au sodium

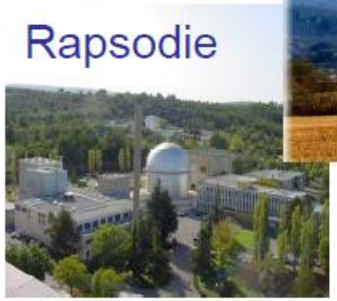
Une expérience unique au service d'un projet

ASSAINISSEMENT DEMANTELEMENT

EFR



ASTRID

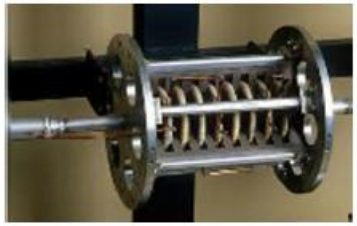


DEVELOPPEMENT TECHNOLOGIQUE

inspection en service

ENSEIGNEMENT

ECOLE SODIUM



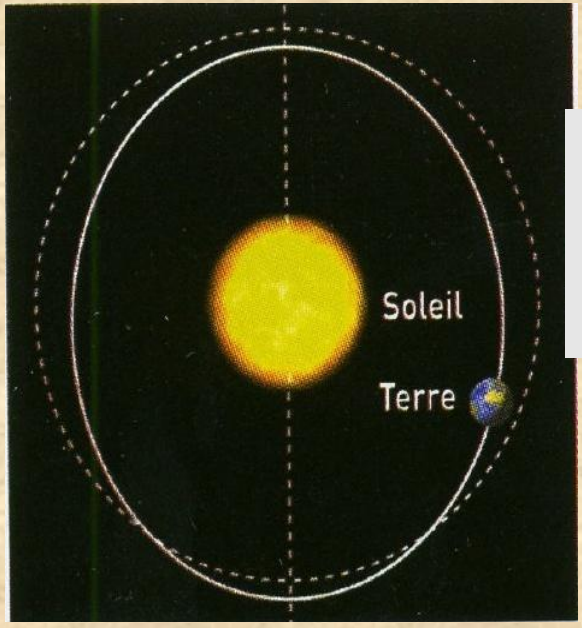
pompes électromagnétiques

Purification

Projet ASTRID – conférence SFEN PACA Corse – Aix en Provence le 22 novembre 2012 - P. LE COZ 5

Additional Slides for Q&A

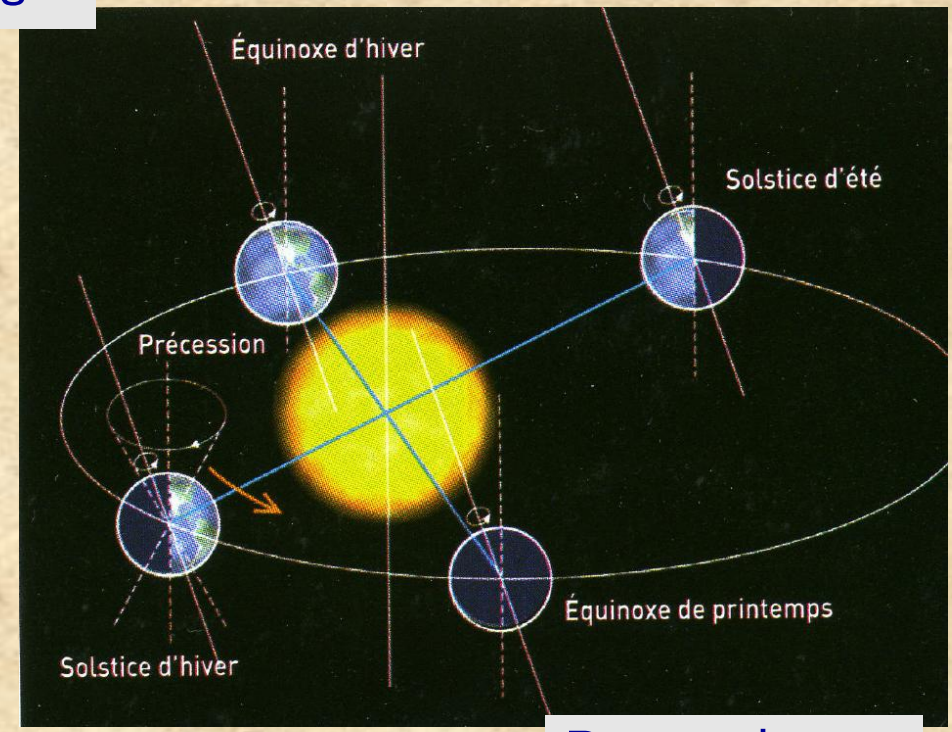
It's all about Astronomy

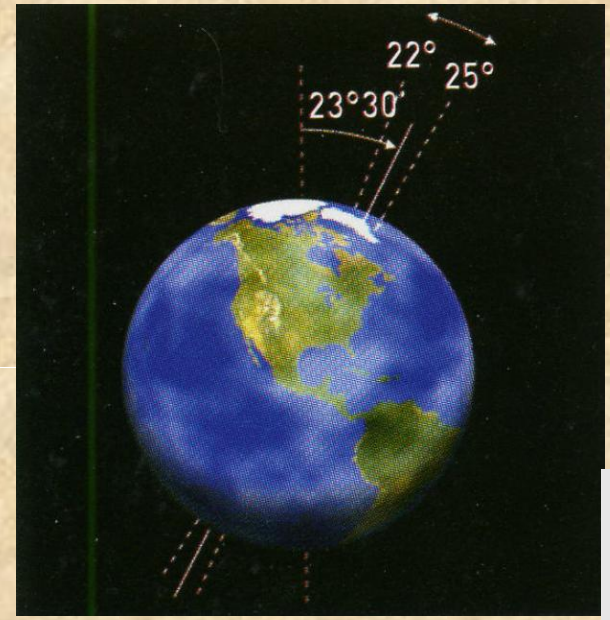


Ellipsity:

100 000 years

413 000 years





Inclination :

41 000 years

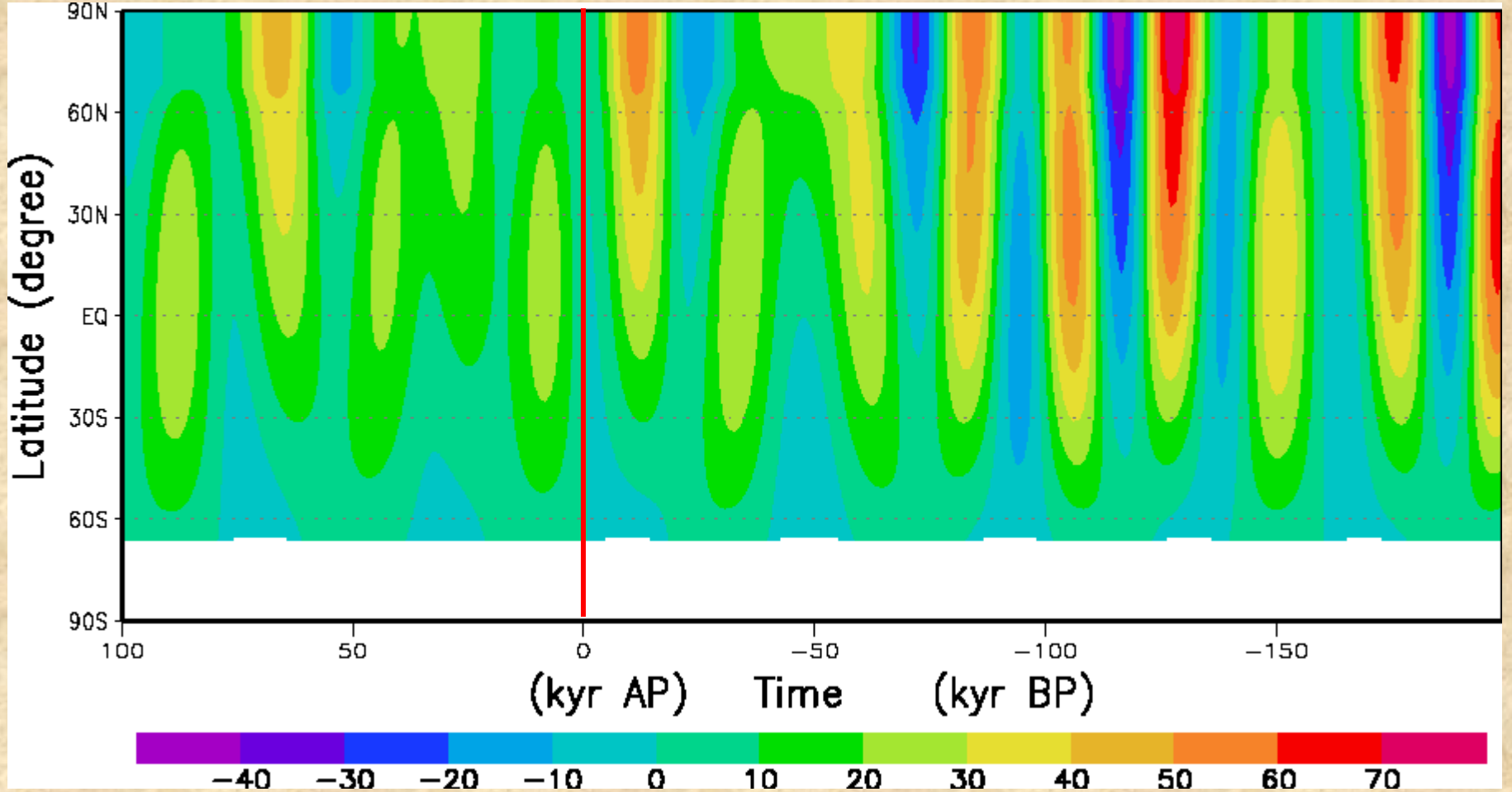
Precession :

19 000 years

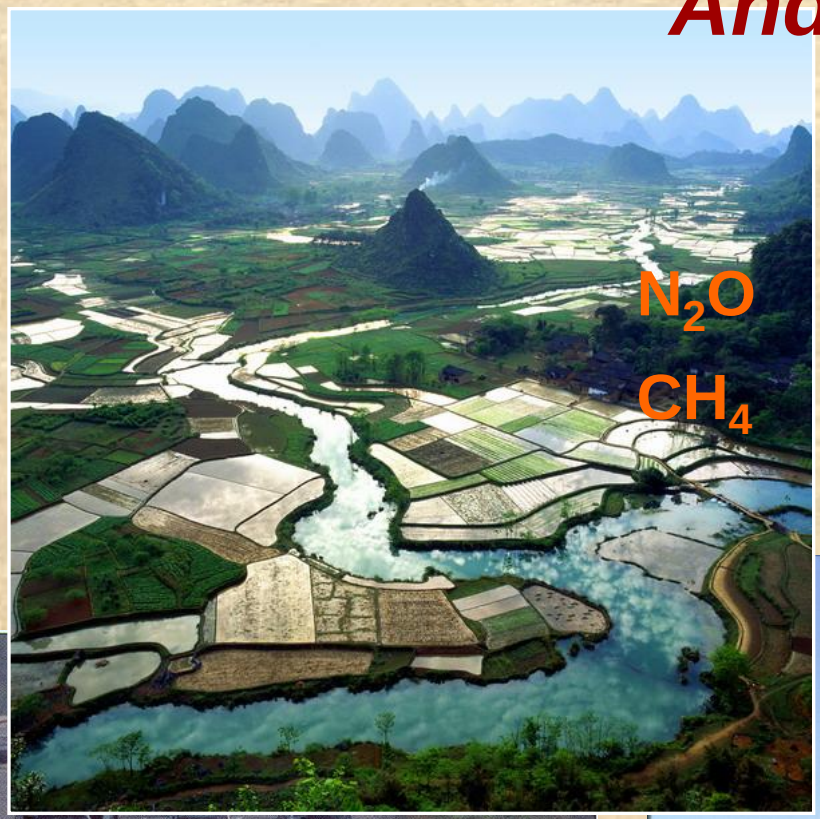
23 000 years

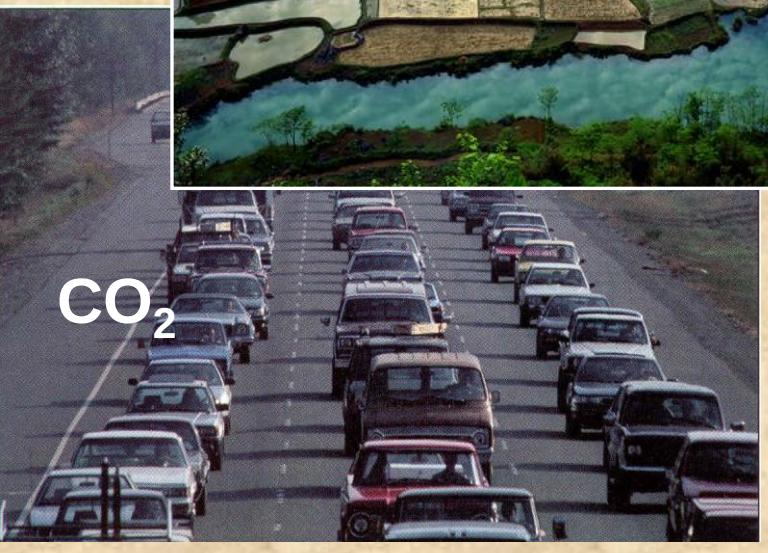
Average Daily Insolation (Wm^{-2})

mid-June



And what about Mankind ?

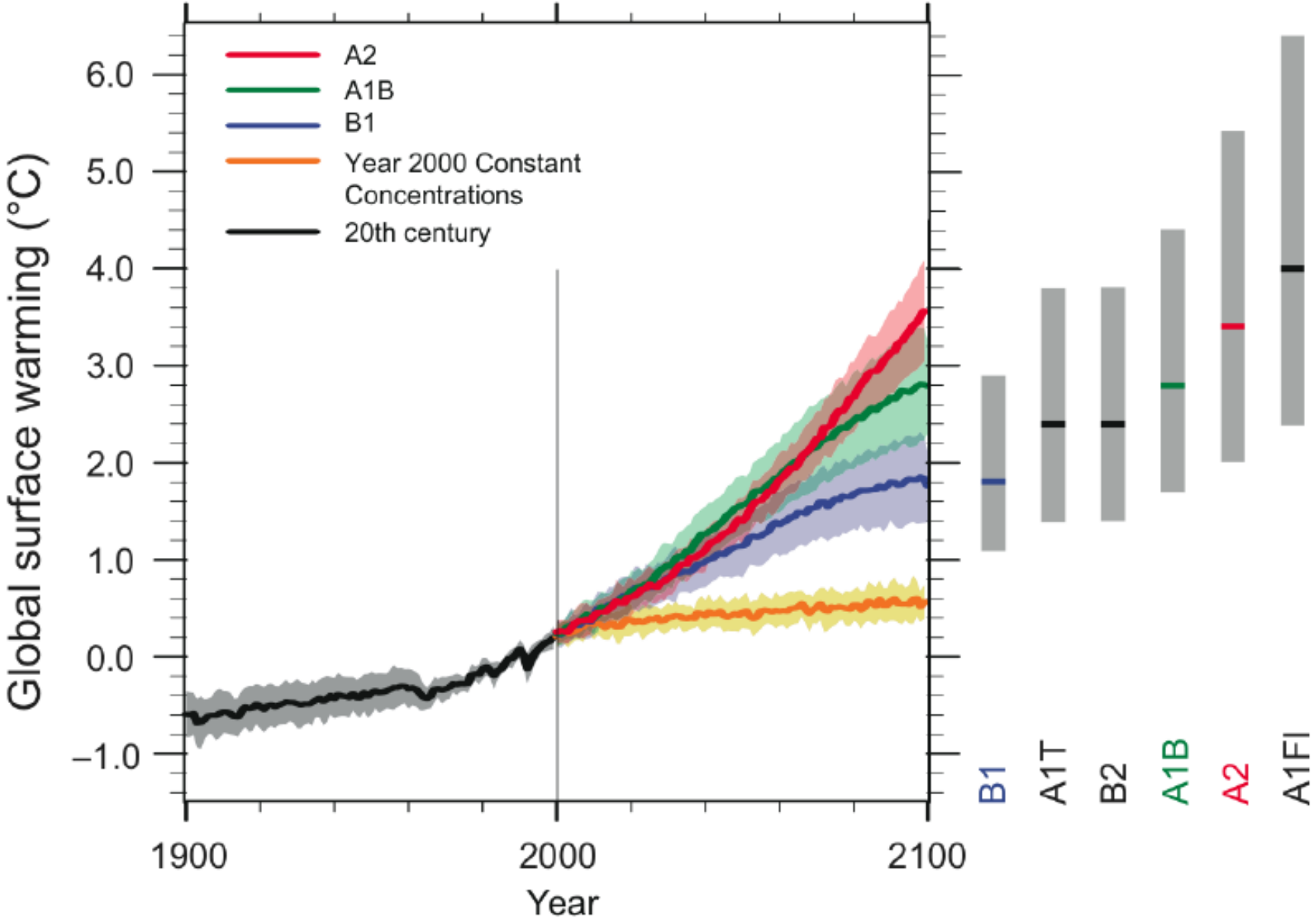




IPCC 2007 Findings

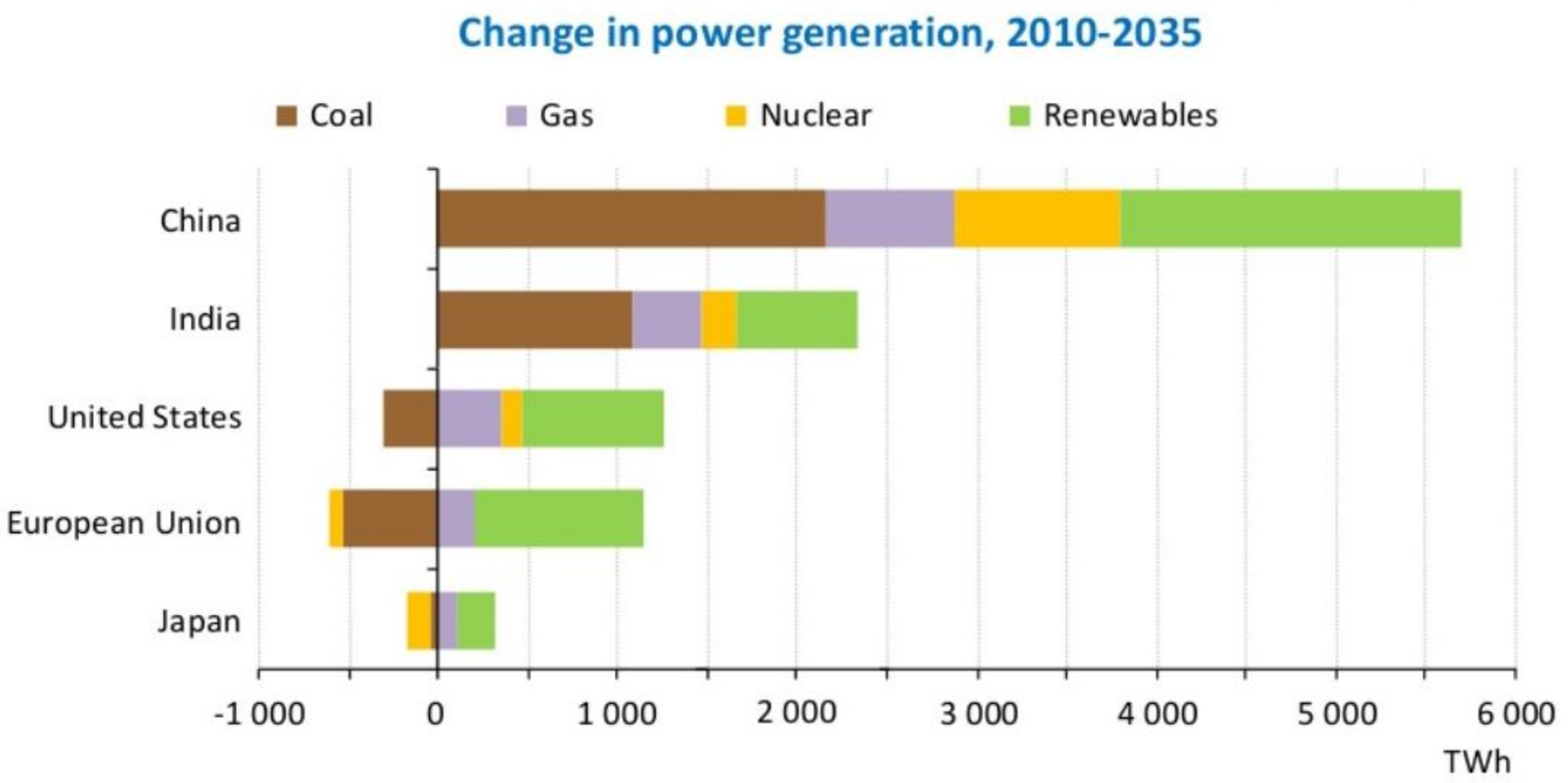
»Global atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values determined from ice cores spanning many thousands of years. The global increases in carbon dioxide concentration are due primarily to fossil fuel use and land-use change, while those of methane and nitrous oxide are primarily due to agriculture.

Multi-model Averages and Assessed Ranges for Surface Warming



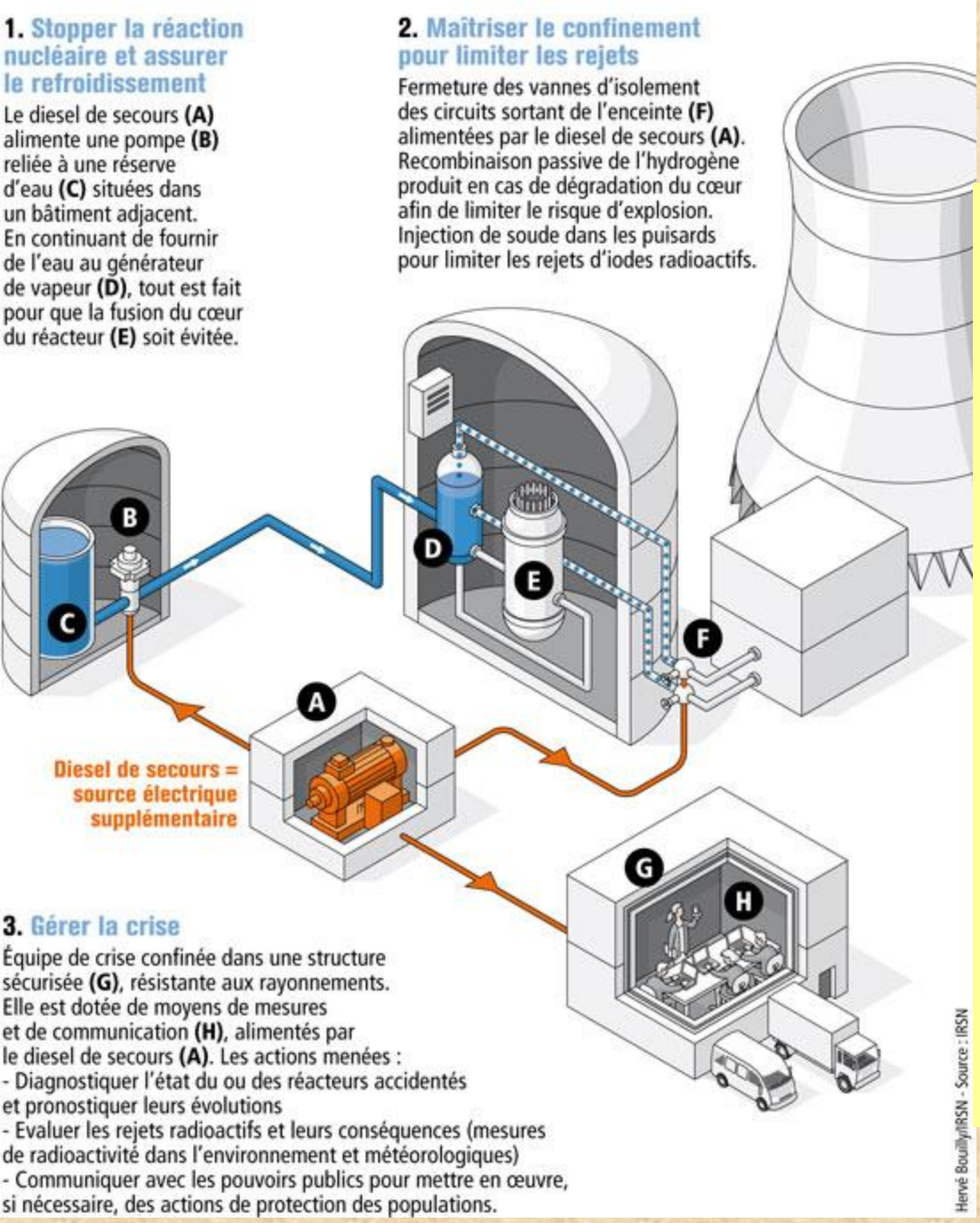
A power shift to emerging economies

WORLD ENERGY OUTLOOK



Need for electricity in emerging economies drives a 70% increase in global demand, with renewables accounting for half of new global capacity

« Hard Kernel »



1. Shutdown & Cooling :

A : Emergency Diesel Generator

B: Safeguard Pump

C : Emergency Feedwater Tank

D : team Generator

E Pressure Vessel with Core

2. Contain & Limit Releases

F : Isolation Valves (powered by A)

+ Passive H_2 Recombiners

3. Manage the Crisis

G : « Bunkerized » Crisis Building (powered by A)

H : Secured Communications

CONSEQUENCES OF THE FUKUSHIMA ACCIDENT IN CHINA

- *15 reactors operating on 3 sites + 26 under construction (18 CPR1000, 2 EPR, 4 AP1000, 2 CPY650)*
- *Strong program acceleration in 2008 (10 new per year)*
- *16 march 2011-october 2012 : freeze of 41 projects but constructions proceed*
- *October 2012 : Nuclear Safety Plan + Nuclear Power Mid- and Long-term Plan : slowdown, cancellation of riverside sites and standard Gen III*

- *Operating Reactors : Buildings Tightness, Mobile on-site Equipments, Seismic Surveillance, Flood Protection, Recombiners, Emergency Planning…*
- *Existing Sites validated*
- *8 reinforcements on reactors under construction before fuel loading*
- *« New » Crisis Organization*

- *Acceptance : Fukushima for the Chinese public = Chernobyl for the Europeans…*