Nuclear Power: Status & Prospects

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Scientific Advisor AREVA
Pr. Emeritus INSTN

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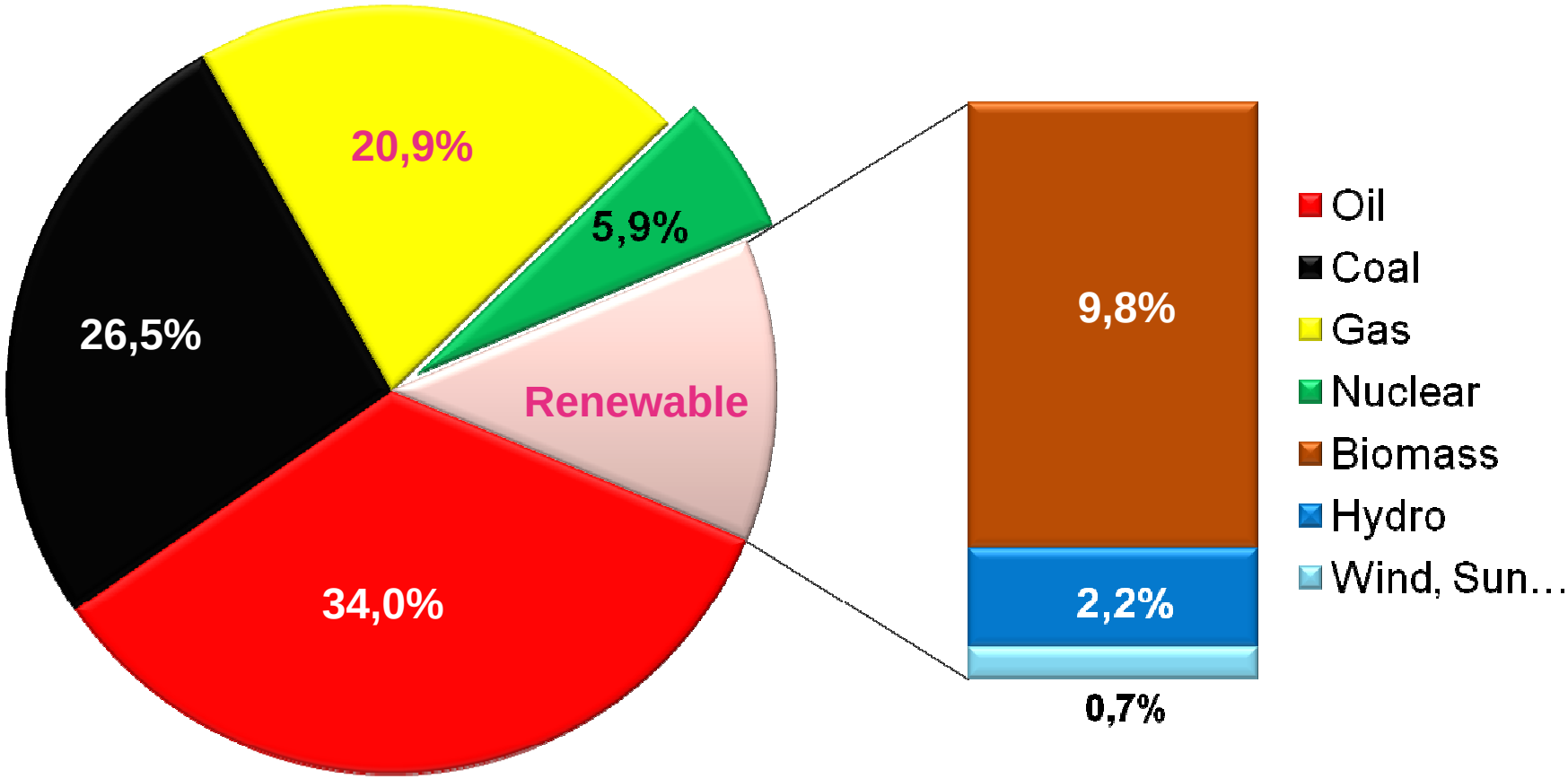
World Primary Energy Consumption 2007 (12 Gtoe)



Source:IEA 2009

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Nuclear Power 2008

Country	*GWe*	TWh	Reactors
USA	*101*	809	104
France	*63*	418	59
Japan	*46*	241	53
Russia	*22*	152	31
S Korea	*18*	144	20
Germany	*20*	141	17
Canada	*13*	89	18
Ukraine	*13*	84	15
China	*9*	65	11
Sweden	*9*	61	10
India	*4*	13	17
WORLD	*372*	2 601	436

WNA website
May 2009

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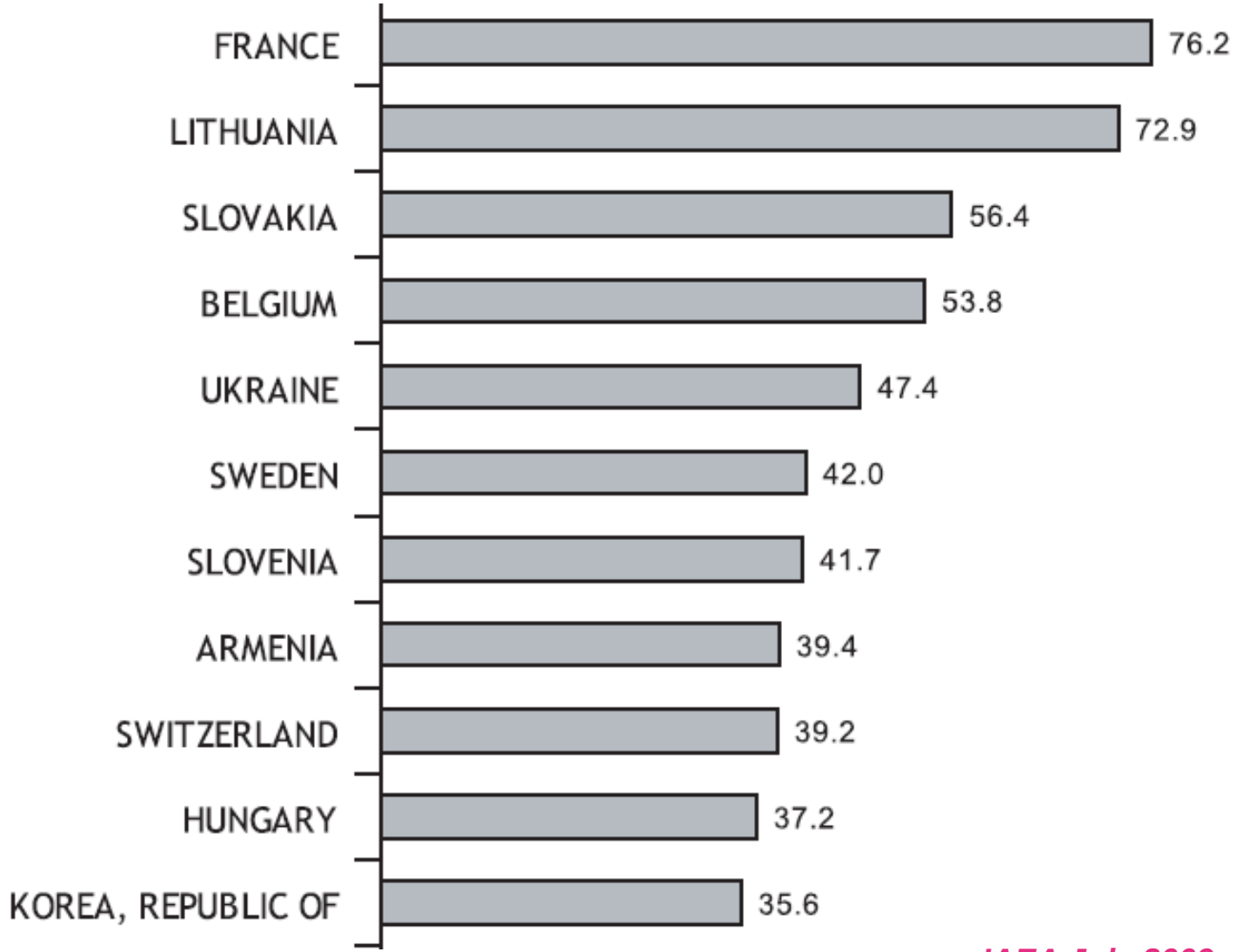
Countries with more than 1/3 electricity from nuclear power



IAEA July 2009

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55 Years of Nuclear Power

436 reactors in 30 countries*

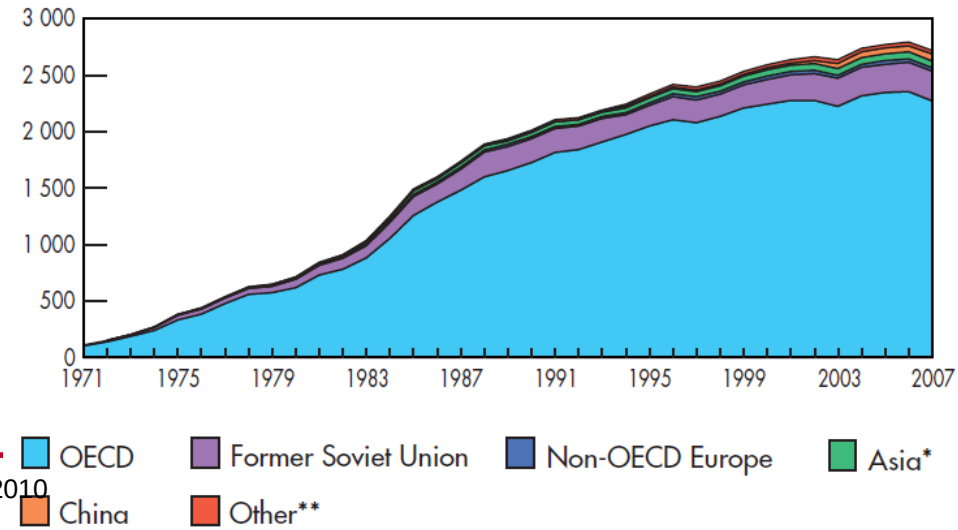
> 2600 billion kWh/year

~ Hydro-power

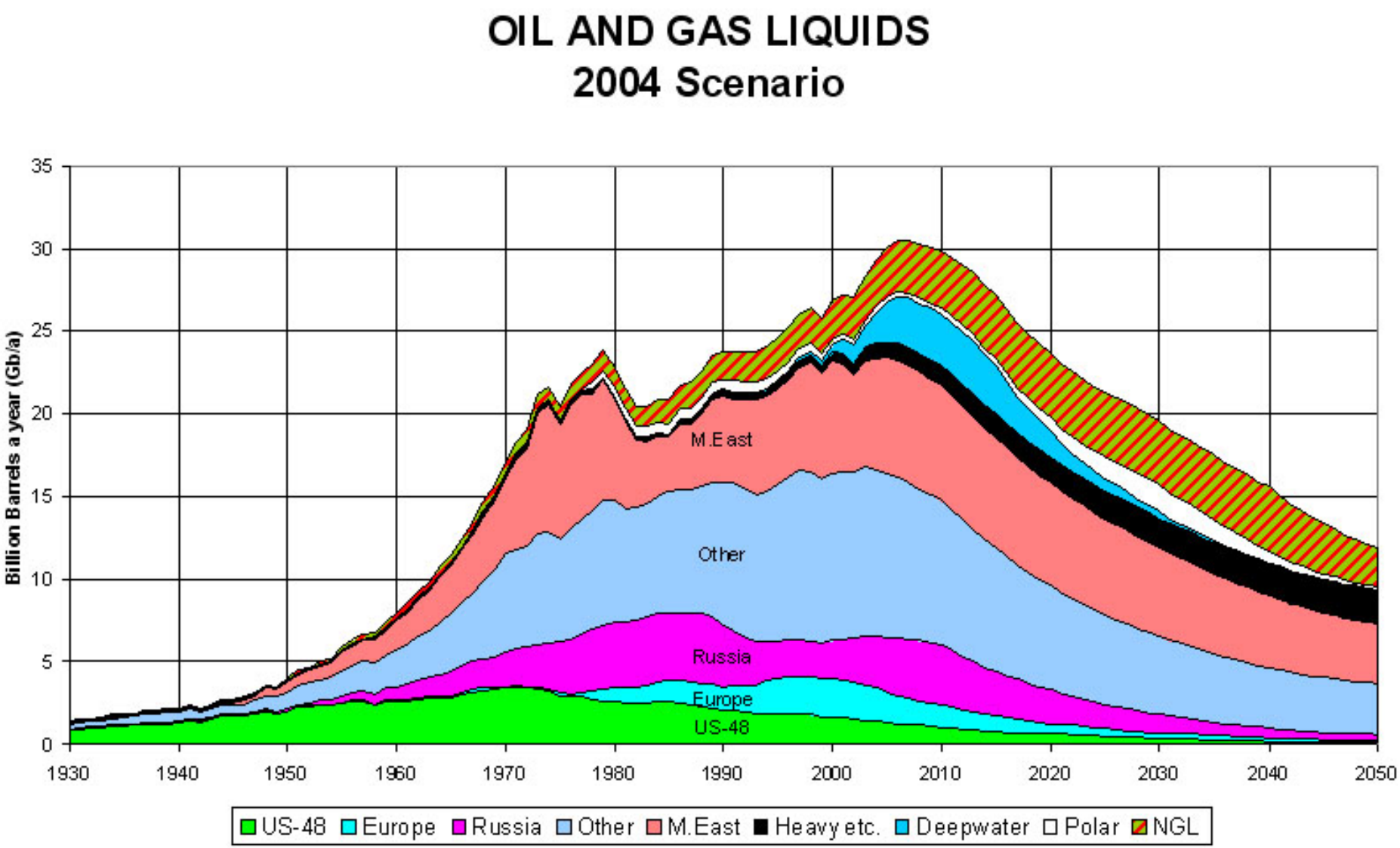
> Saudi Oil

15% Electricity

Evolution from 1971 to 2007 of nuclear production by region (TWh)



« Peak Oil » not far away ?



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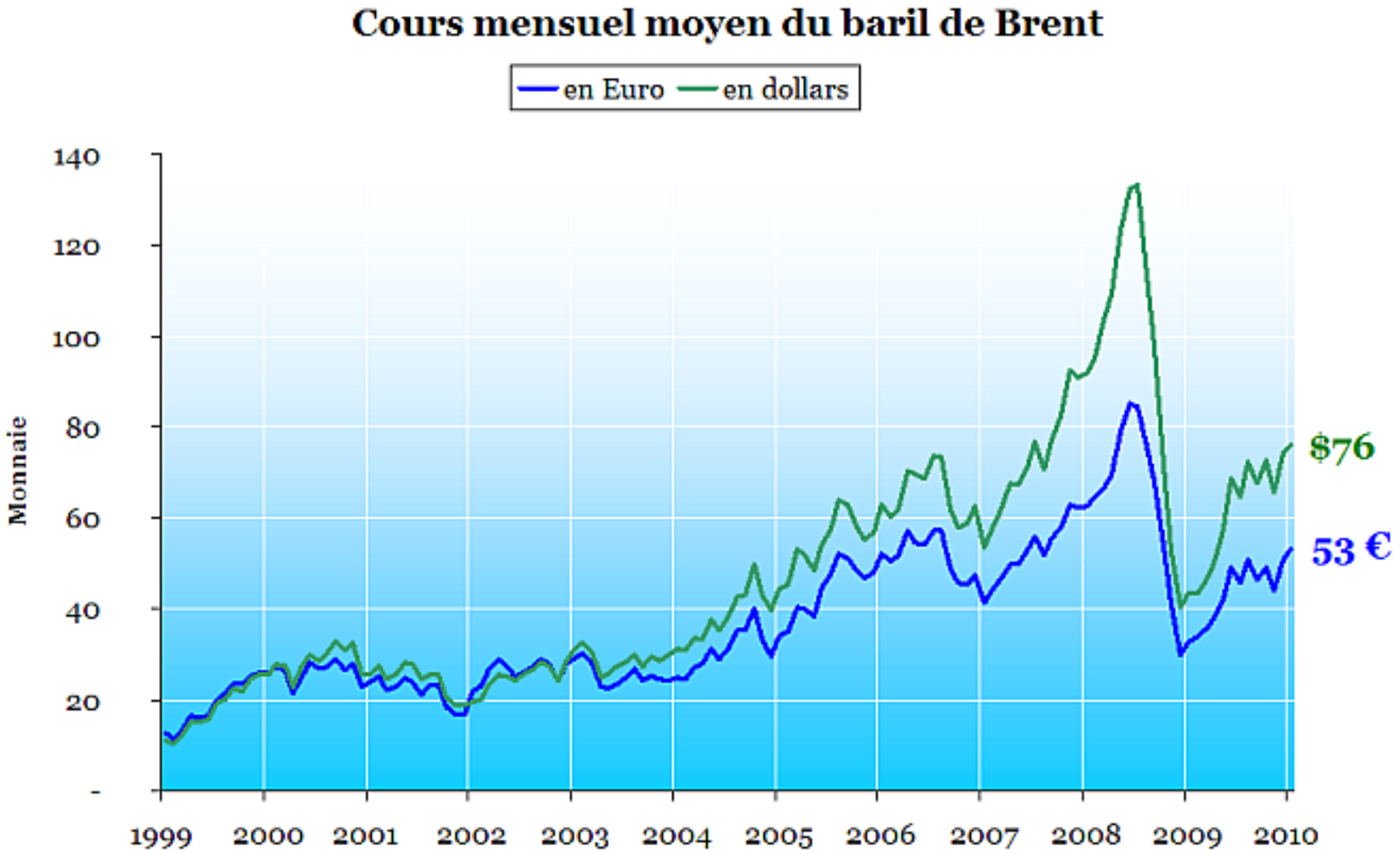
Average monthly cost of the Brent Barrel



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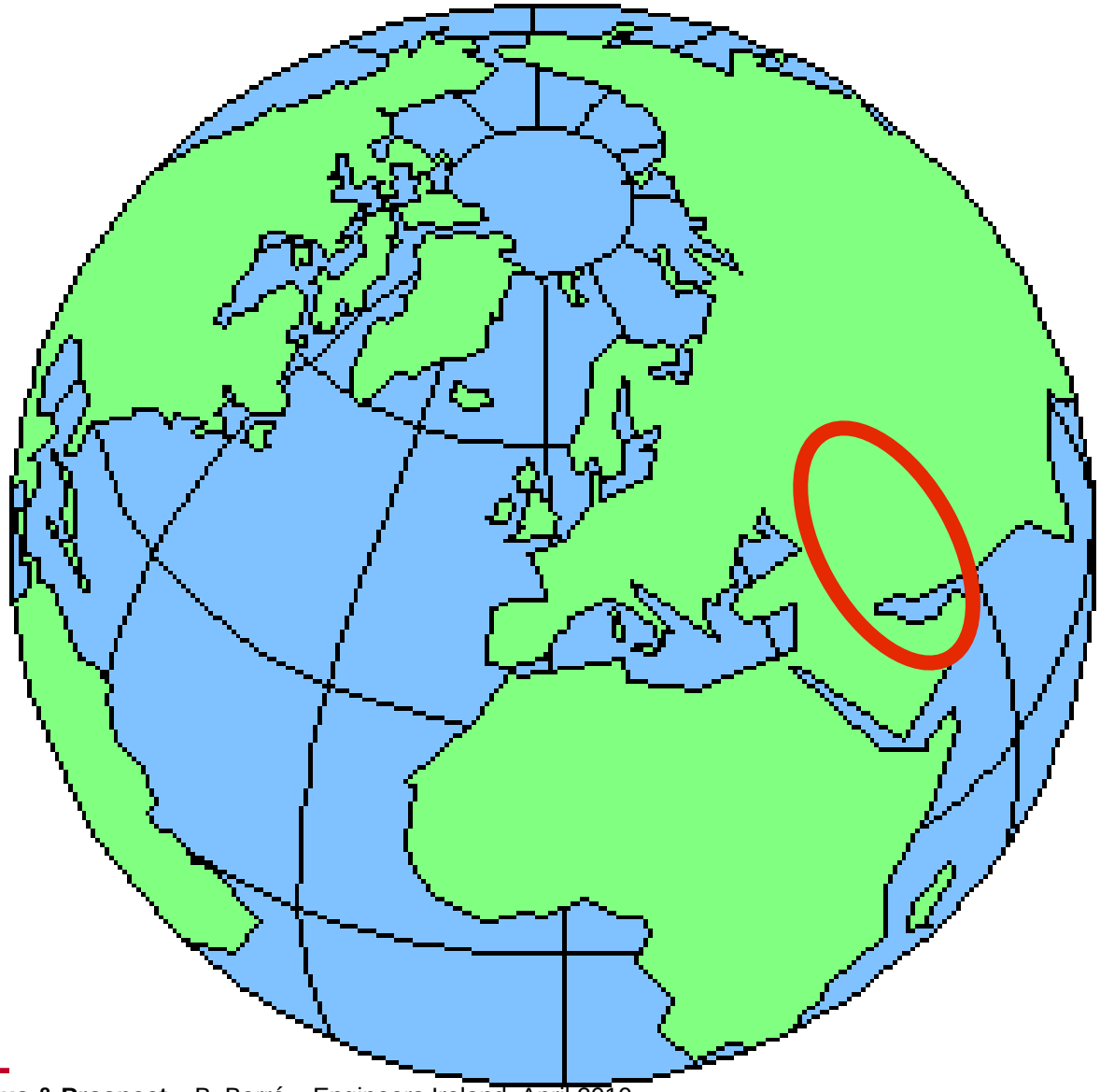
70% Oil & 40% Gas Reserves



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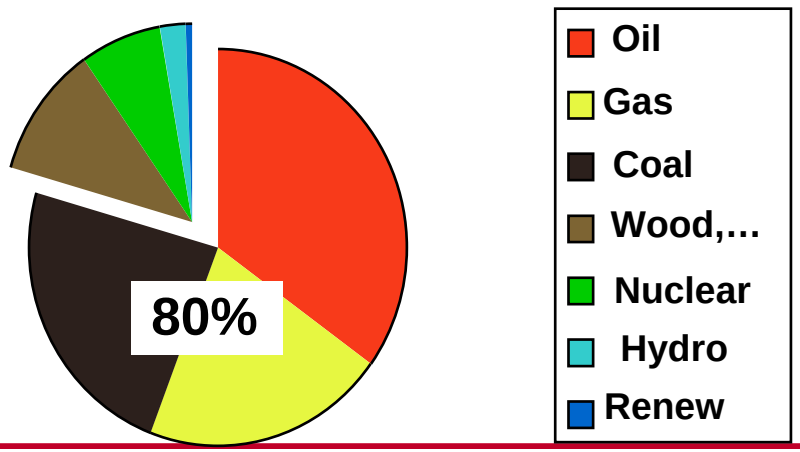
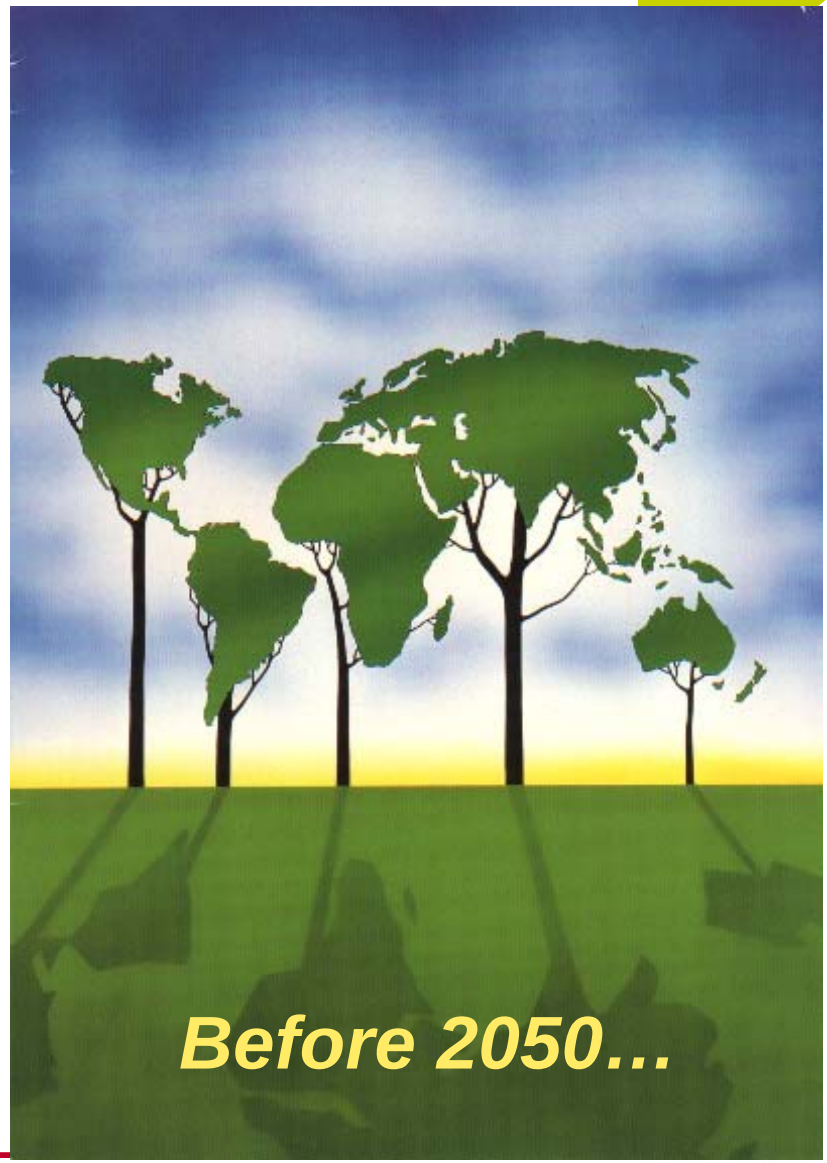
The Challenge of Global Change :

Divide by 2 world CO_2 Emissions

while

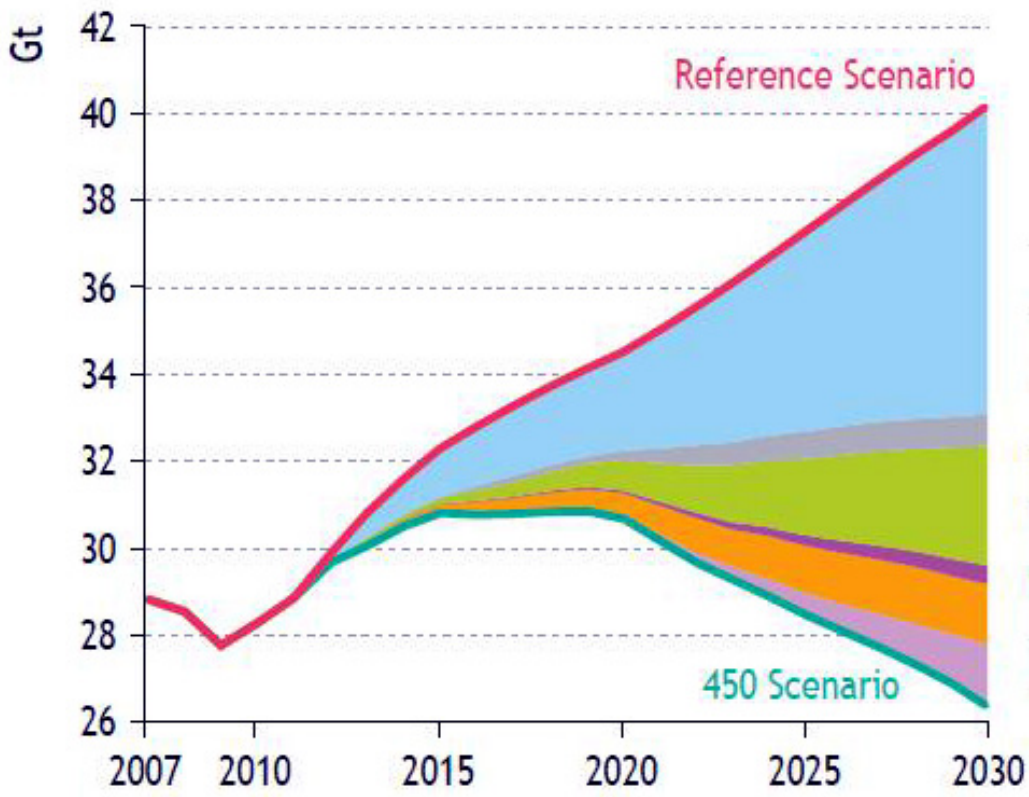
Doubling Energy Production





World Energy-related CO_2 Abatement for 450ppm scenario

IEA - WEO 2009



	Abatement ($Mt CO_2$)		Investment ($2008 billion)	
	2020	2030	2010-2020	2021-2030
Efficiency	2 517	7 880	1 999	5 586
End-use	2 284	7 145	1 933	5 551
Power plants	233	735	66	35
Renewables	680	2 741	527	2 260
Biofuels	57	429	27	378
Nuclear	493	1 380	125	491
CCS	102	1 410	56	646

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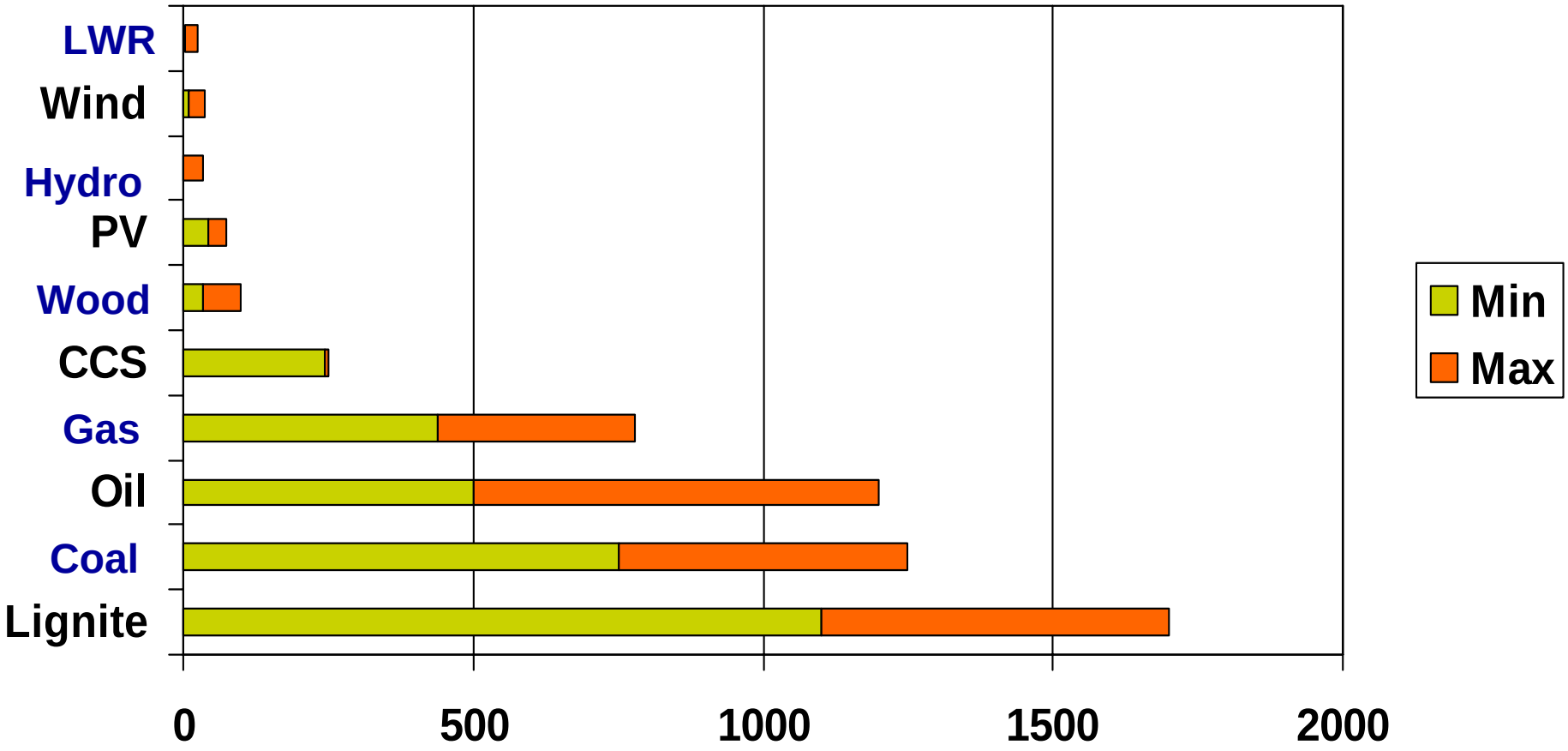
Life Cycle GHG Emissions, g CO_2eq per kWh_e

D. Weisser IAEA May 2006

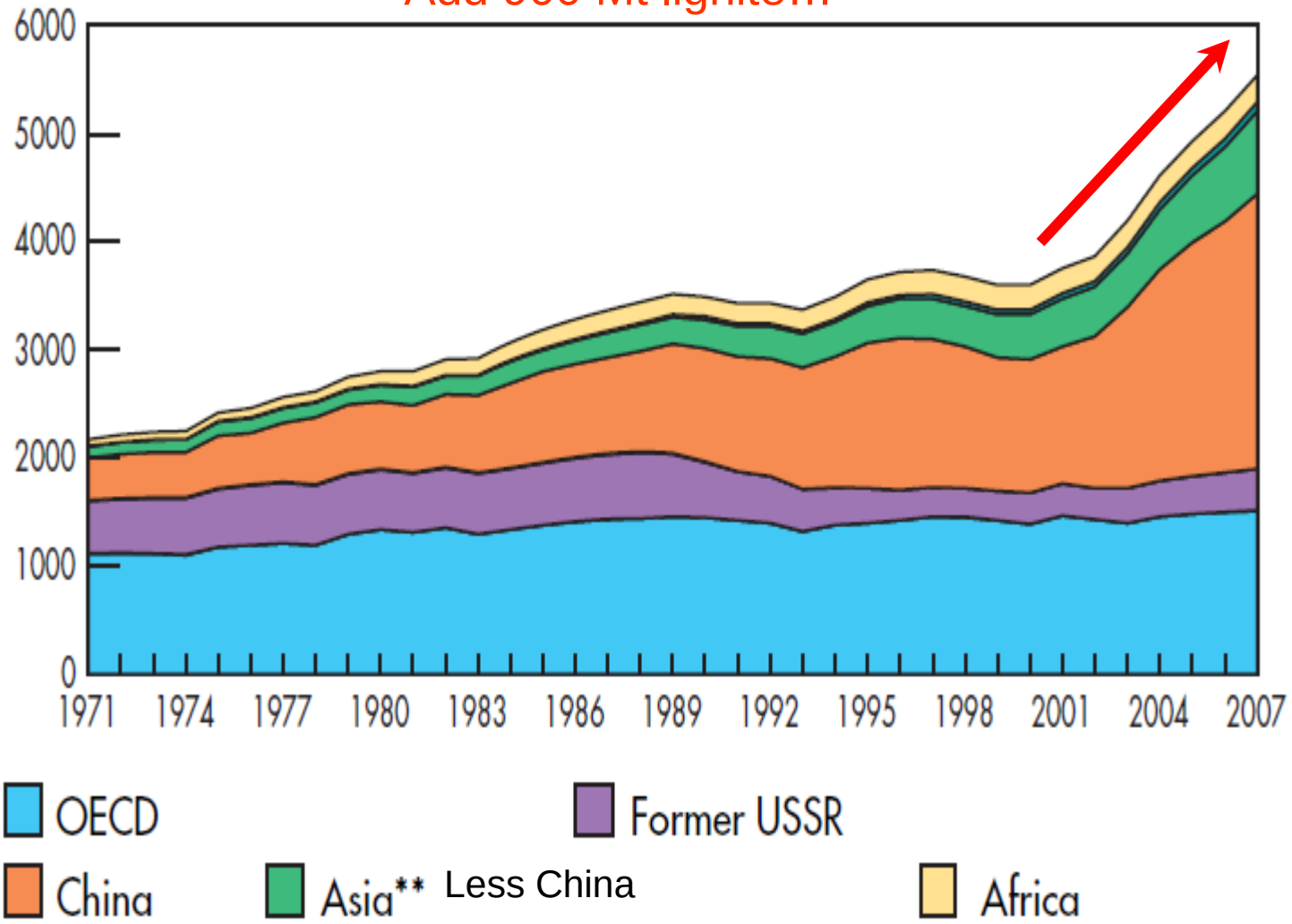


Ranges reflect differences in assessment technology, conversion efficiency, assessment boundary, etc.

Coal is back !

Evolution from 1971 to 2007 of hard coal* production by region (Mt)

Add 900 Mt lignite…



2008: 30 countries, 439 reactors, 370 GWe

Renaissance ??

Reactors under construction end 2008

Country	Types	GWe
China	11 PWR	10.2
Russian Federation	6 PWR, 1 RBMK, 1 FBR	5.8
South Korea	5 PWR	5.2
India	2 PWR, 3 PHWR, 1 FBR	2.9
Japan	1 PWR, 1 BWR	2.2
Bulgaria	2 PWR	1.9
Ukraine	2 PWR	1.9
Finland	1 PWR	1.6
France	1 PWR	1.6
United States	1 PWR	1.2
Iran	1 PWR	0.9
Argentina	1 PHWR	0.7
Total	44* (36 PWR)	39

***54 in 2010**

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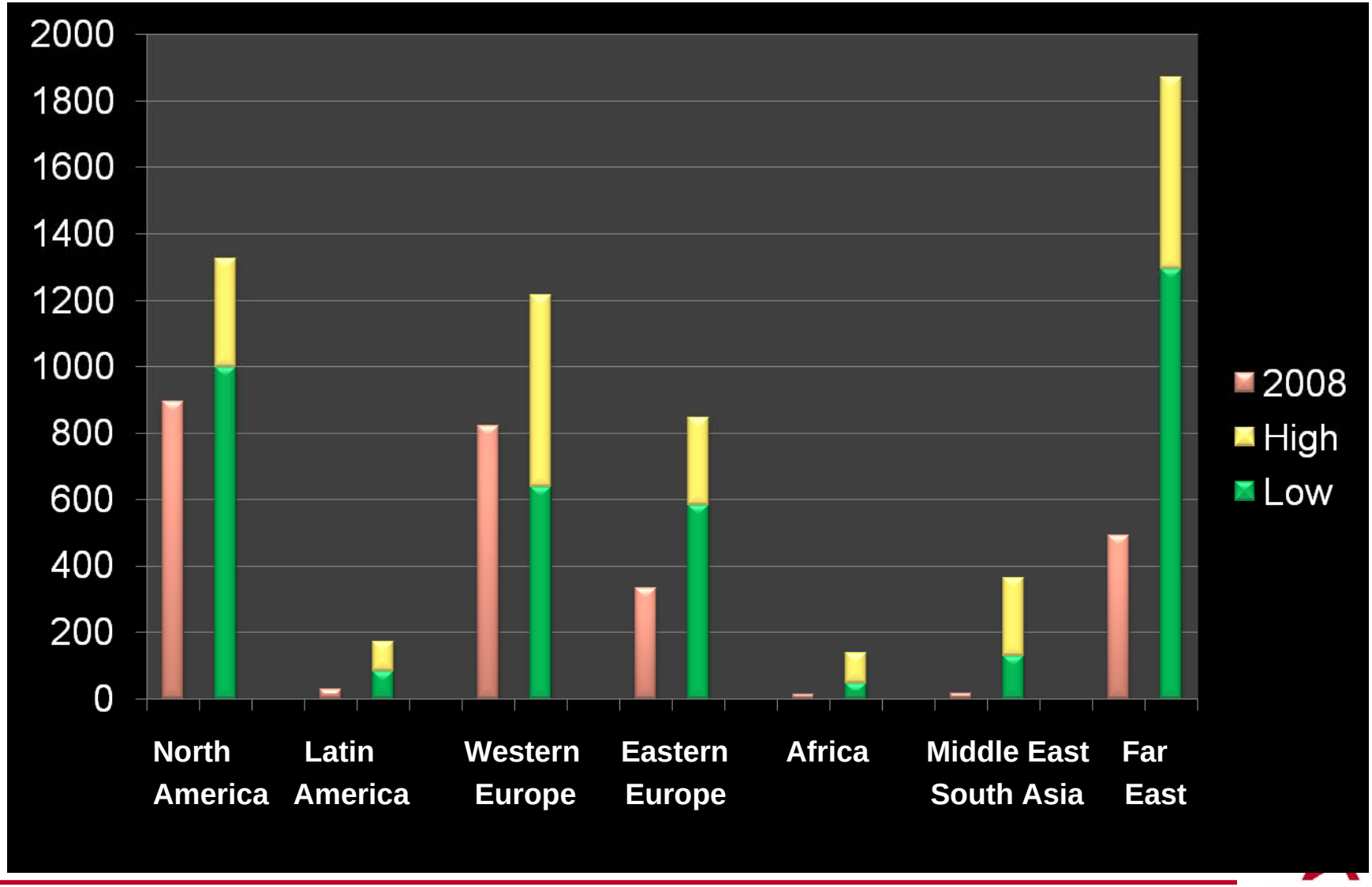
IAEA 2009 forecasts on 2008-2030 nuclear generation



In Europe, the pendulum is swinging back

- *Finland and France are building 2 EPR, +Romania, Bulgaria*
- *New UE27 Member States more pro-nuclear – change of mood in the European Parliament*
- *2003 British White Paper to the dustbin*
- *Sweden cancels 1980 ban, February 2009*
- *French-Italian Agreement, April 2009*
- *German General Elections September 2009*
- *Belgium plants get 10 more years*
- *Next Switzerland ?*

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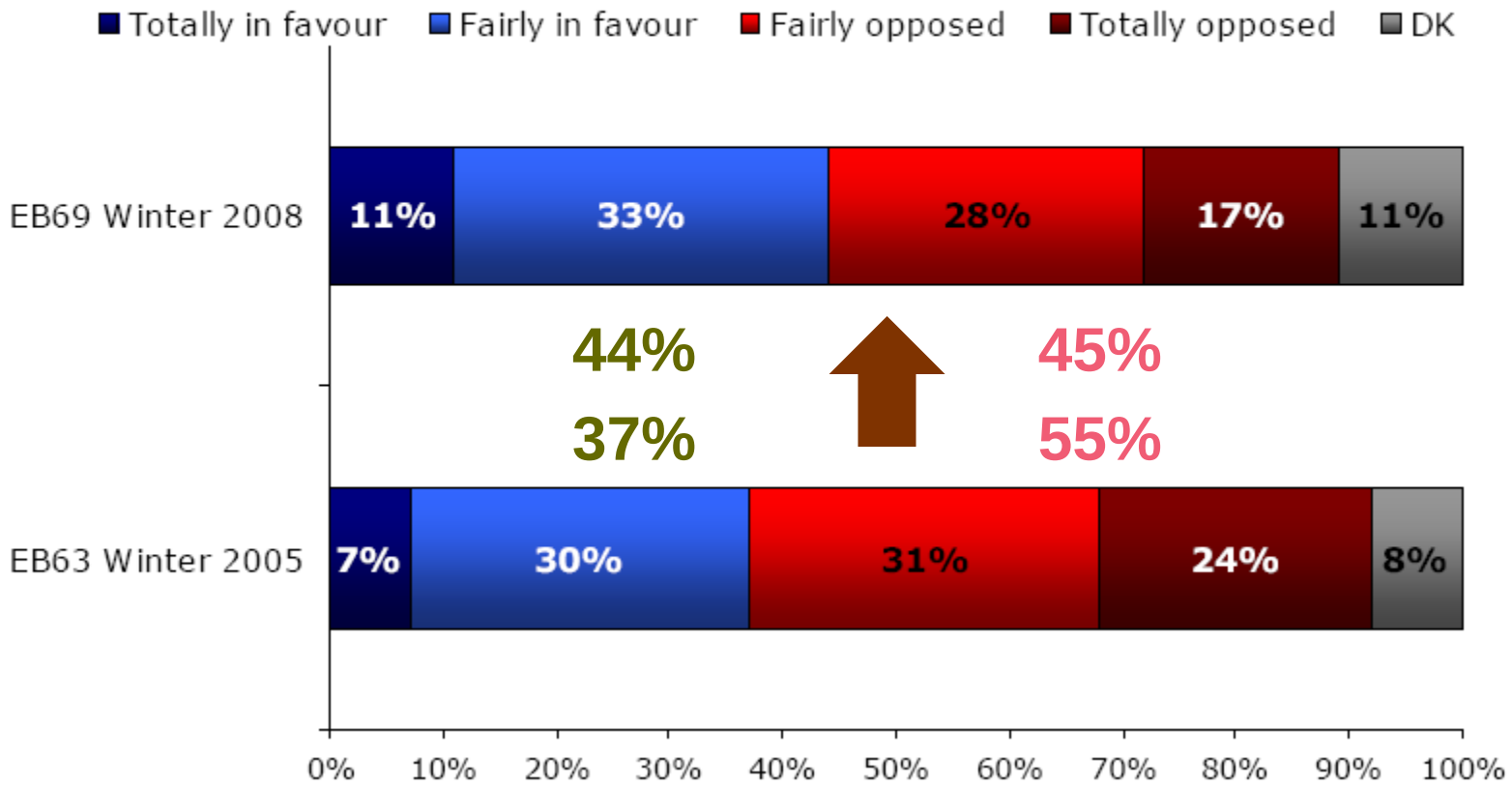
QB2 Are you totally in favour, fairly in favour, fairly opposed or totally opposed to energy production by nuclear power stations?
%EU



Issues about Nuclear Power

Prerequisites to Renaissance :

- **Economic Competitiveness**
- **Public Acceptance**
  - **No severe Accident**
  - **Long-lived Waste Disposal**
  - **No rampant Proliferation**

For a sustainable Renaissance :

- **Enough Fissile Resources ?**

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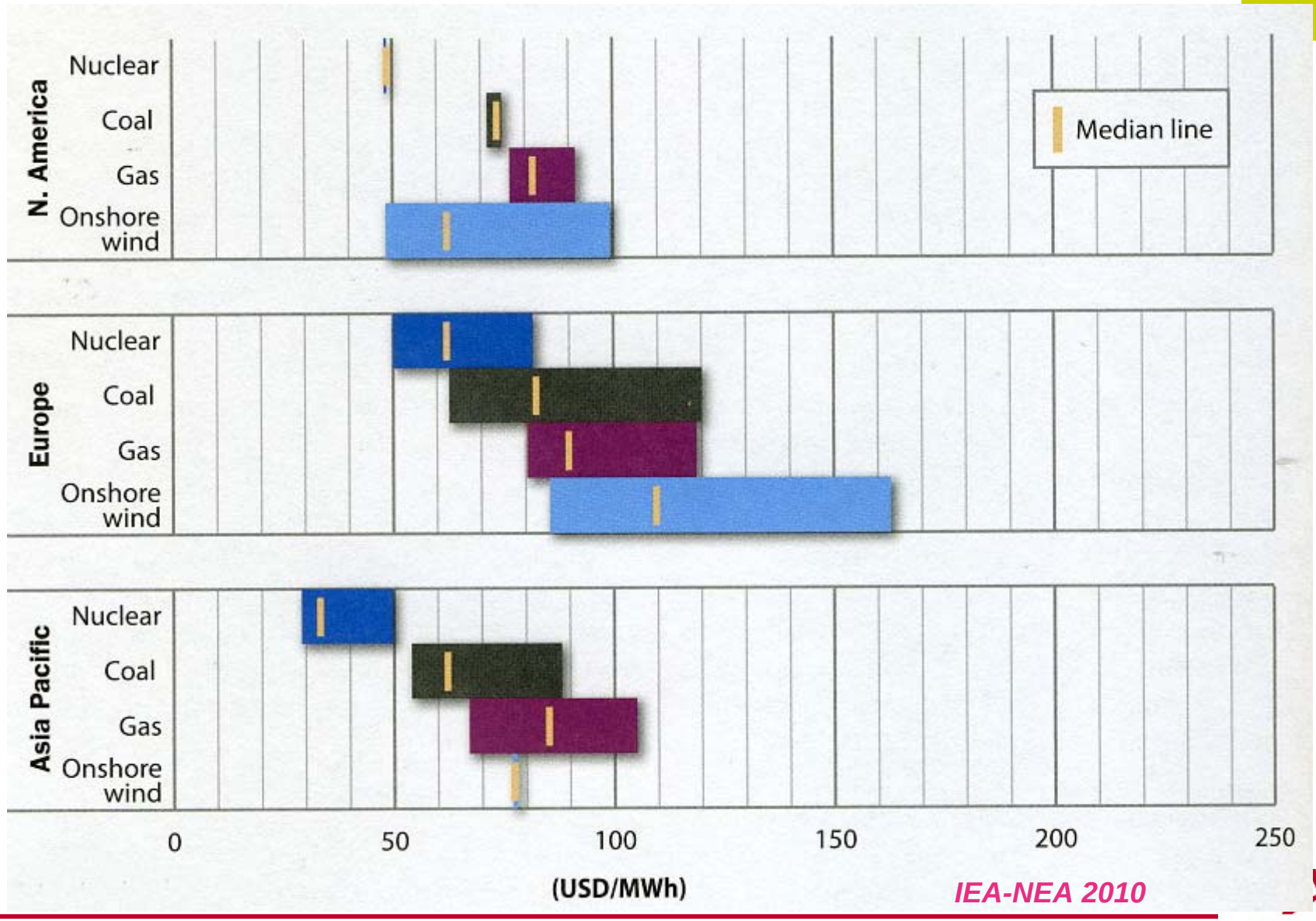
Future costs of Electricity $/MWh (DR=5%)



IEA-NEA 2010

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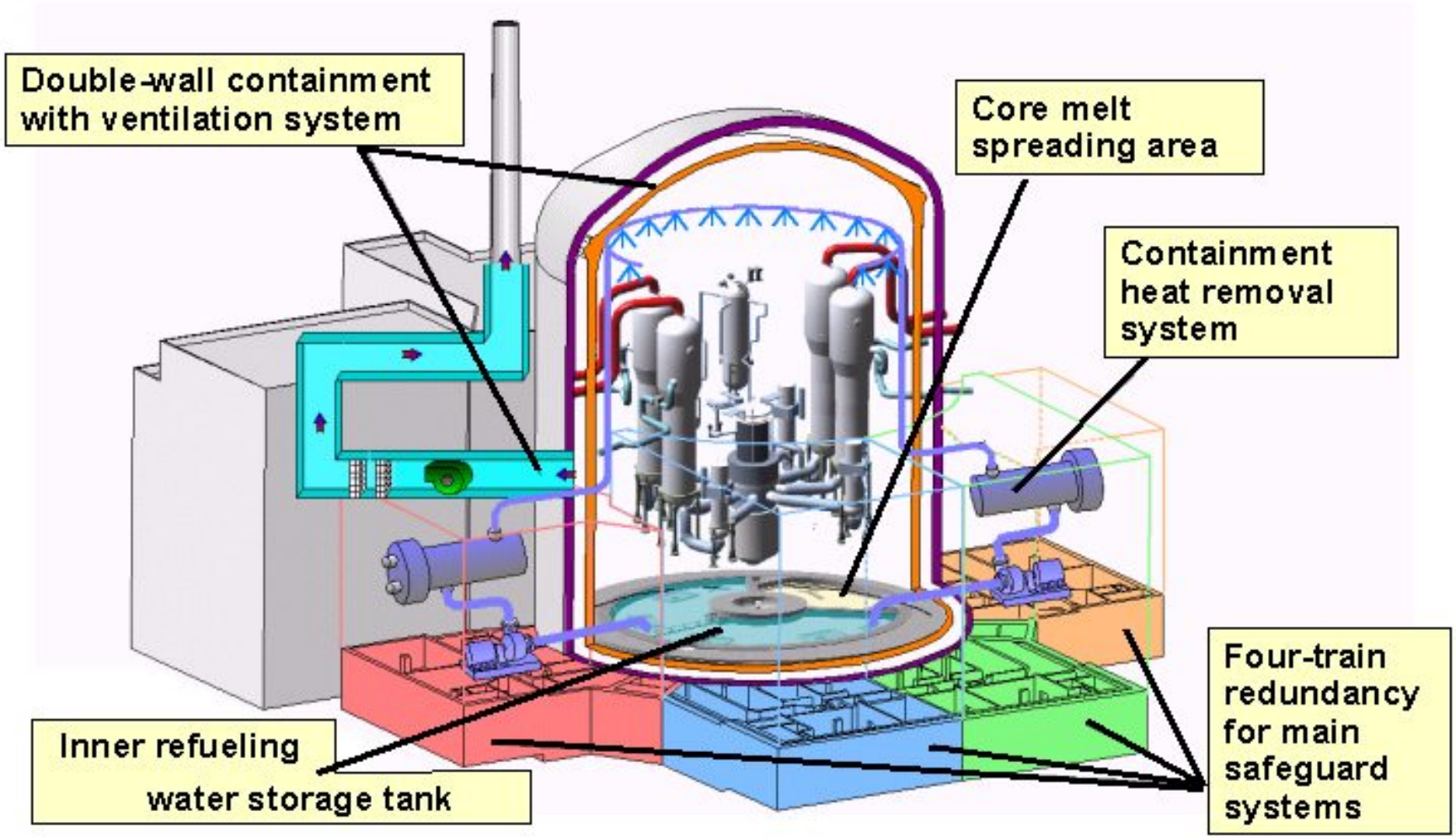
Issues about nuclear competitiveness

- **<u>Everything is included</u>: decommissioning & dismantling, HLW disposal are provisionned, and R&D is accounted for**
- **EDF did not receive any subvention or capital dotation since 1982… but it is profitable and pays taxes far in excess of the public contribution to CEA's nuclear R&D**
- **30 $ penalty per ton CO_2 included in fossil kWh costs**
- **Discounted costs cover 70 years or so : nuclear, being capital inyensive, is very sensitive to discount rates while fossil fuels are very sensitive to projected fuel costs.**
- **Uranium prices vary a lot, but their impact on kWh costs is small.**

Since Tchernobyl, philosophy itself was changed

- Preventing is not enough
- One must « mitigate » consequences
- Hence the EPR

EPR Safety : Summary...



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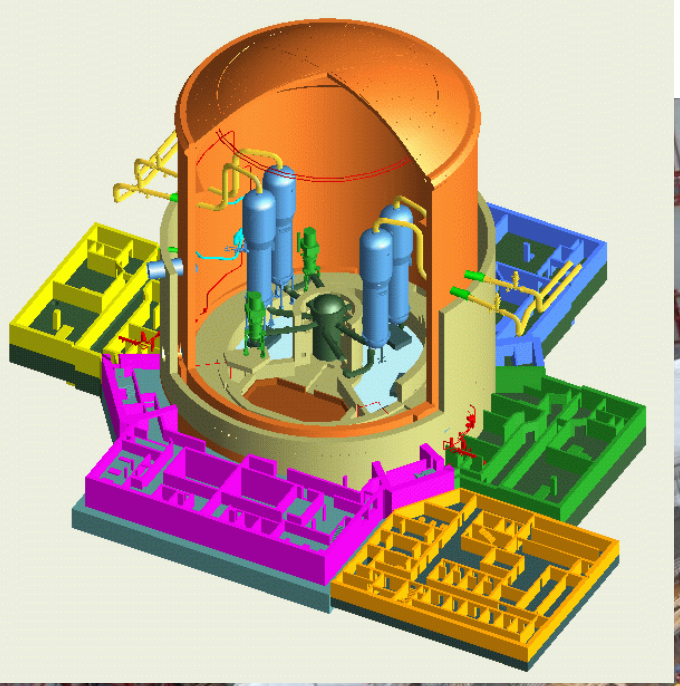
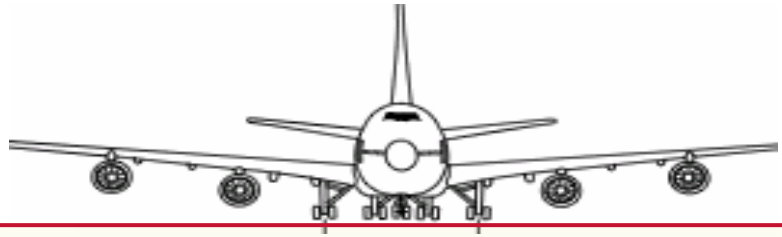
Olkiluoto March 2007



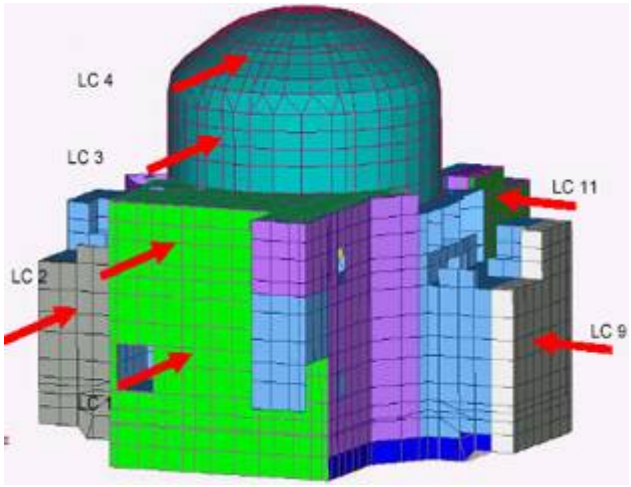
EPR aircraft hazard protection in the post 9-11 World

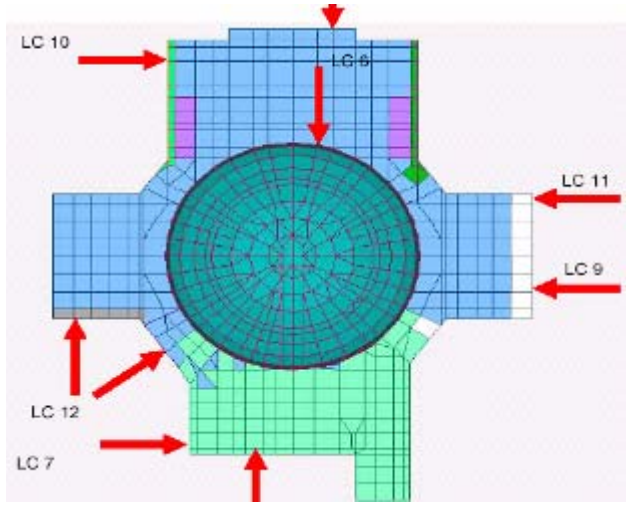
- EPR Designed to withstand impact of:

Large Commercial Jet	&	Military Aircraft



At various Elevations	&	From different Sides





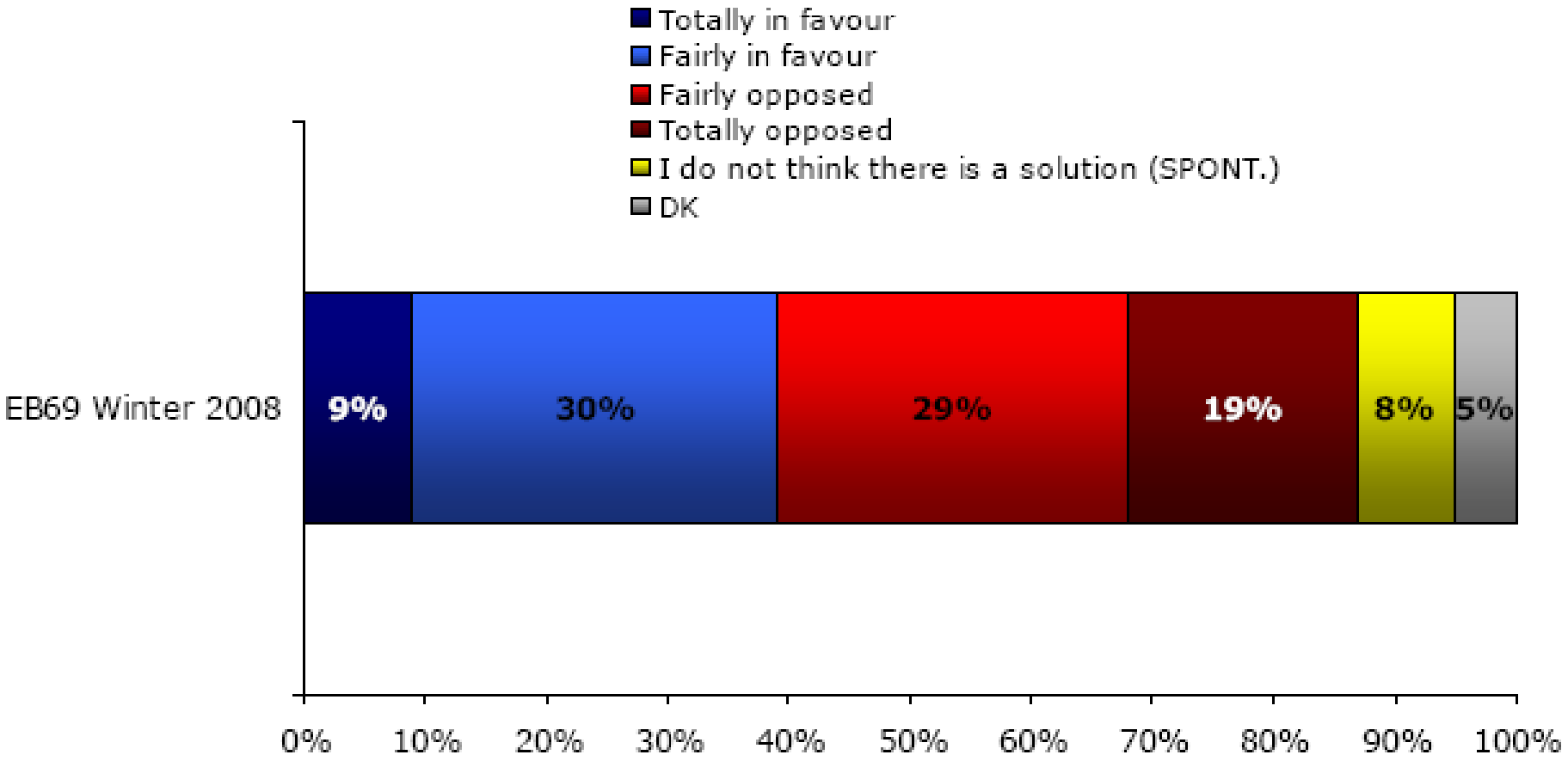
Simply, yes, the EPR resists to commercial and military aircraft crashes

Nuclear Waste: N°1 Concern

QB3 And if there was a permanent and safe solution for the management of radioactive waste, would you then be [...] in favour or [...] opposed to energy production by nuclear power stations?

%EU

Base: Those that are opposed to nuclear energy production



Spent Fuel Management

Spent fuel.

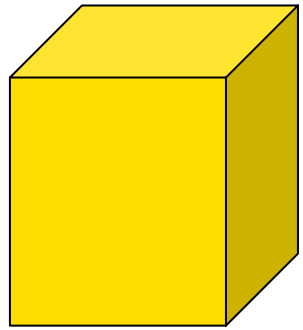
Reversible direct disposal

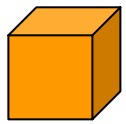
Storage, then decision

Reprocessing & Recycle + HLW reversible disposal

Categories of radioactive Waste

- « A Waste » : packages of low to medium activity containing only nuclides with $T^{1/2}$ < 31 years. Ater ~300 years, their residual radioactivity is close to natural background. (Gloves, boots, syringes, sources…).
- « B Waste » : packages of medium activity containing long-lived radionuclides. (resins, hulls and endpieces).
- « C Waste» : High activity packages : spent fuel assemblies or vitrified FP.





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Waste per capita in France

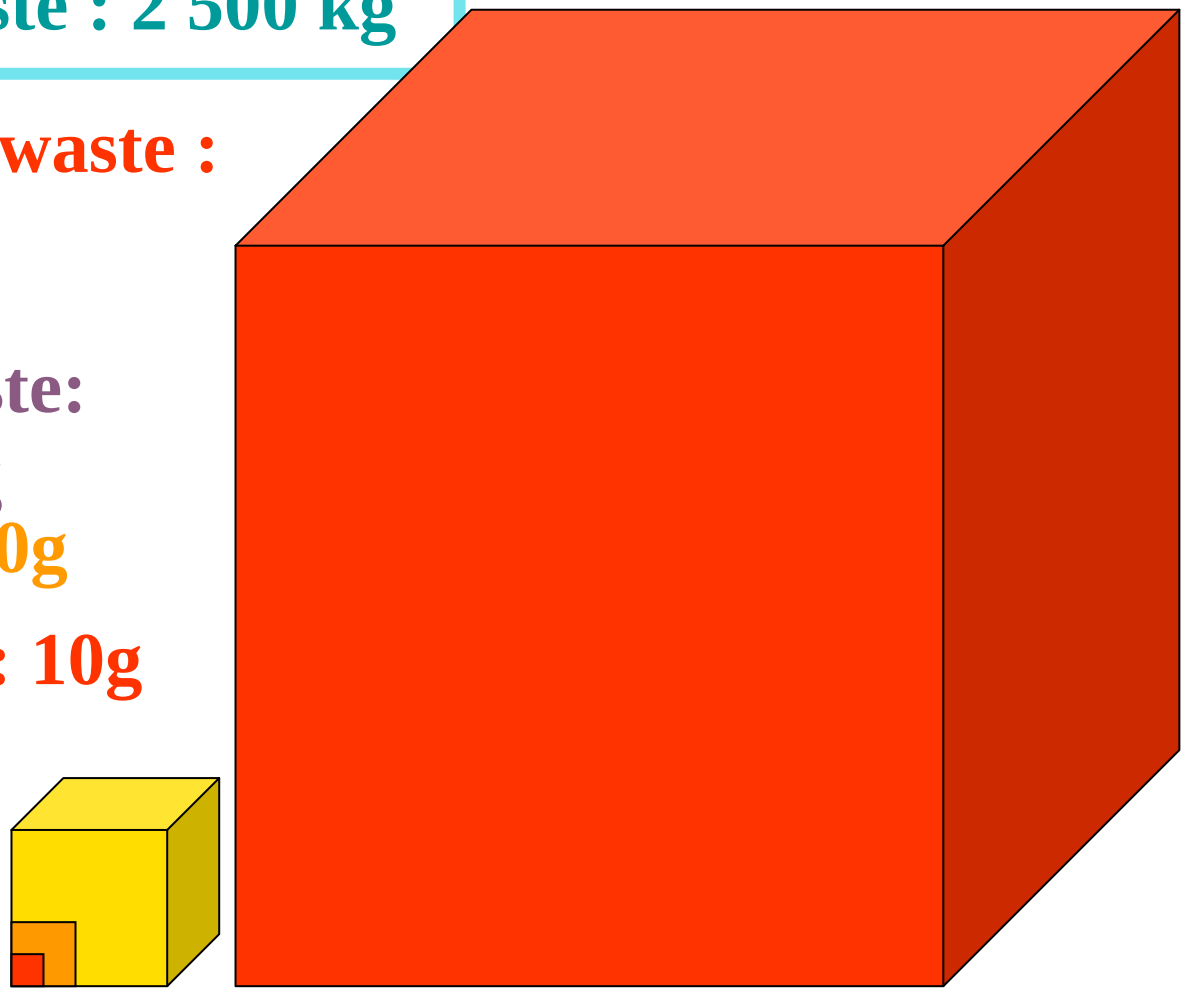
Industrial Waste : 2 500 kg

Including toxic waste : 100 kg

Radioactive waste: less than 1 kg

Of wich LL : 100g

Of which HA : 10g



The amount is small enough to allow for complete management

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Nuclear Waste : We care !

They are neither orphans nor released freely

LLW are diposed of

HLW and LL-MLW are concentrated, contained, stored under surveillance.

Where they are, they create no hazard to anybody,

But it is a interim solution:

The 28 june 2006 French Law defines a roadmap

Law for the Sustainable Management of Radioactive Materials & Waste. June 28, 2006

- **Spent Fuel Reprocessing + Recycle**
- **Interim Storage of HLW and LL-MLW …**
- **… followed by their reversible disposal in deep geological stratum**
- **Opening of the Disposal Site before 2025, after local and national consultation.**
- **Continue R&D on P&T within the « Generation 4 » frame**
- **Demonstrator in 2020 (CEA)**
- **Waste producers pay for everything.**
- **No « foreign » waste disposal in France**

A Waste disposal site in Soulaines (CSA)

Bure, France

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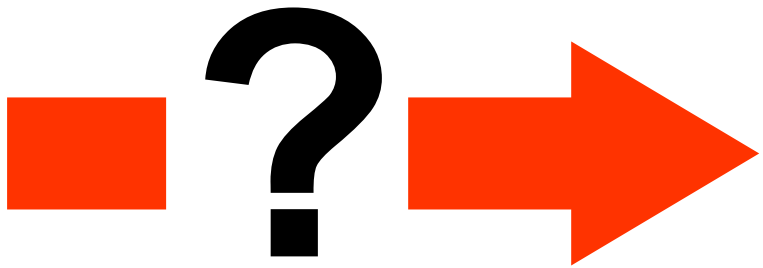
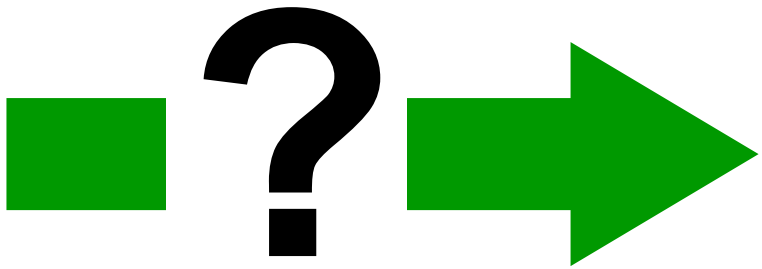
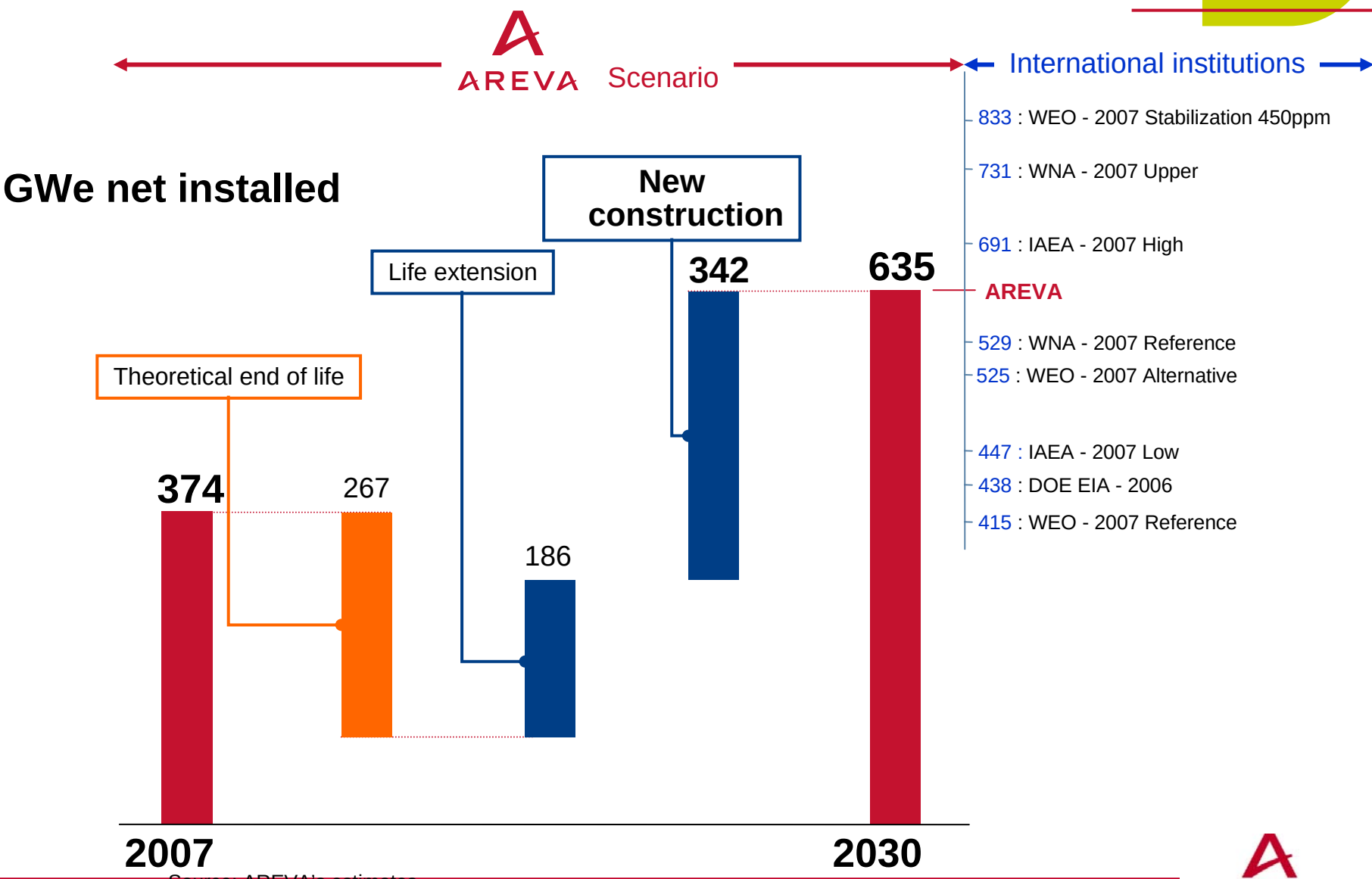
Oklo, Gabon





AREVA's 2030 scenario: construction of more than 340 GWe of nuclear power



Source: AREVA's estimates

Mission Impossible ?

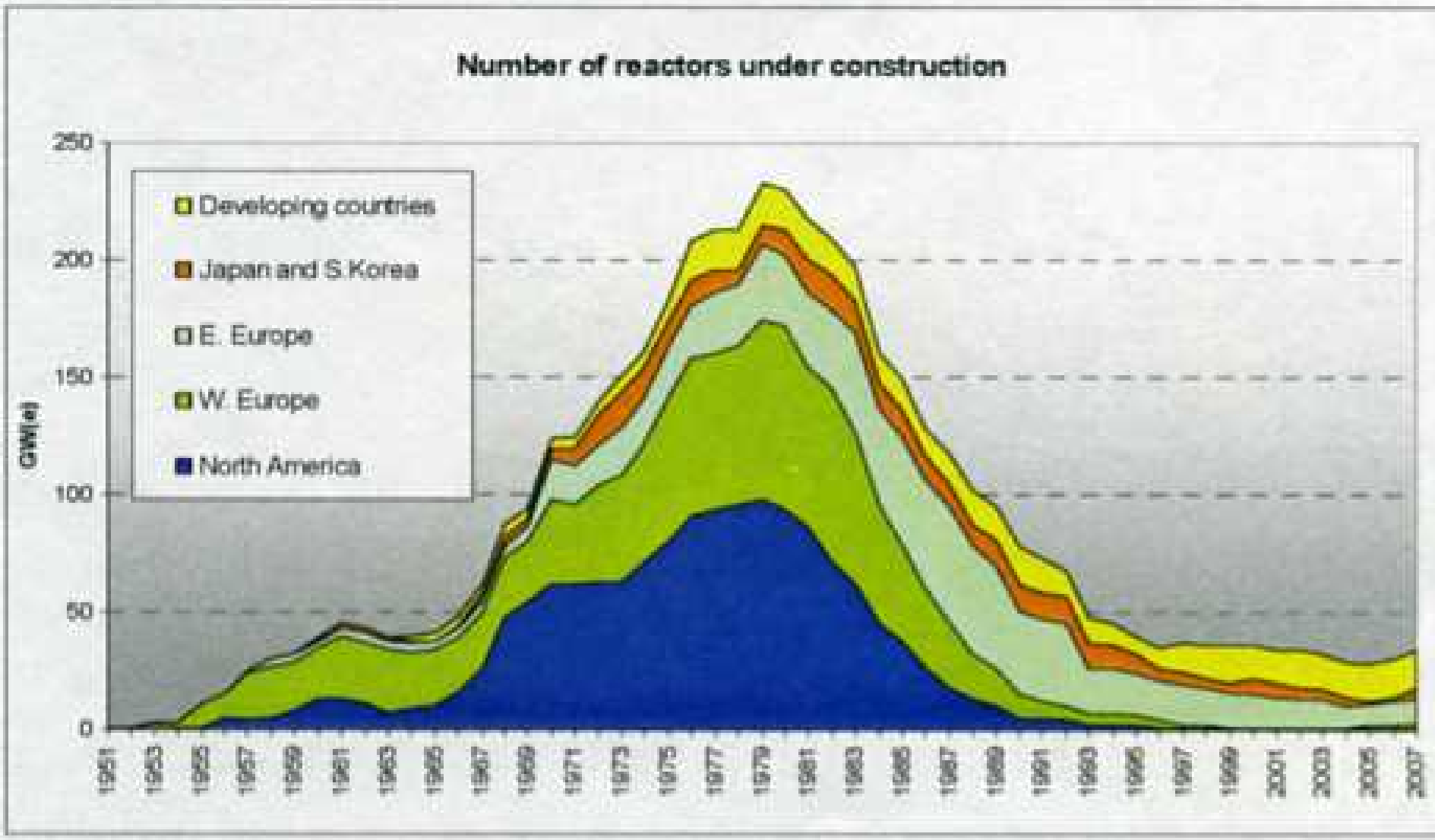


Figure 2. Construction of new reactors

Reported Uranium Resources; status at date* and speculations

**** Resources as of 1/01/2007***

- Source: Red Book OECD-NEA-IAEA; version 2008 (data 2007)

MtU	Conventional Resources				Un Conven-tional.
	identified		Undiscovered		
US$/kg U $/lbU308	RAR	Inferred	Prognosti-cated	Specula-tive	
< 40 <15	1,8	1,2	2,0	4,8	about 15 à 25 (cost limits unknown)
40 – 80 15 - 30	0,8	0,6			
80 – 130 30-50	0,7	0,3	0,8		
> 130 > 50	?	?	?	3,0	
	3,3	2,1	2,8	7,8	
TOTAL	5,5	16,0	10,5		15 – 25

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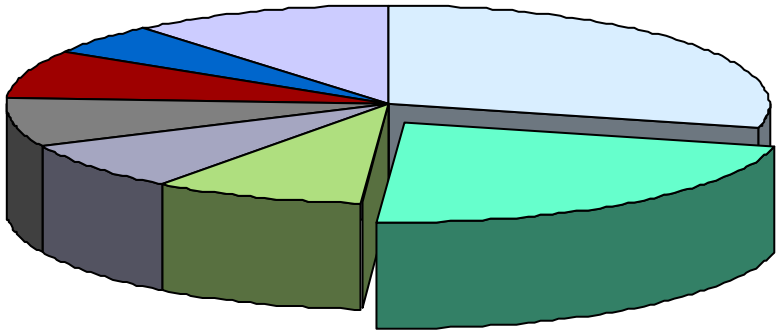
U Resources = 220 times 2005 demand

General total of conventional U resources: ***16,000,000 t***

World demand in 2005: ***67,000 t***



2004 World U Production: 40,263 t

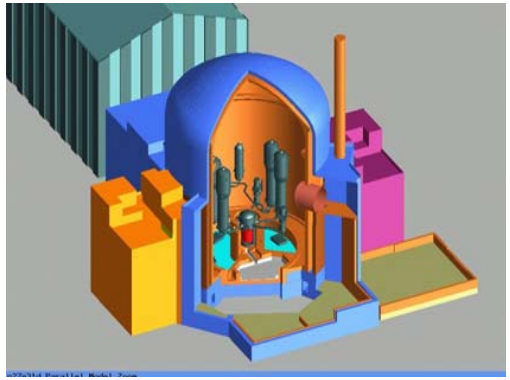
+ With Gen IV Fast Breeder Reactor, resources are virtually unlimited

Nuclear reactors « Generations »

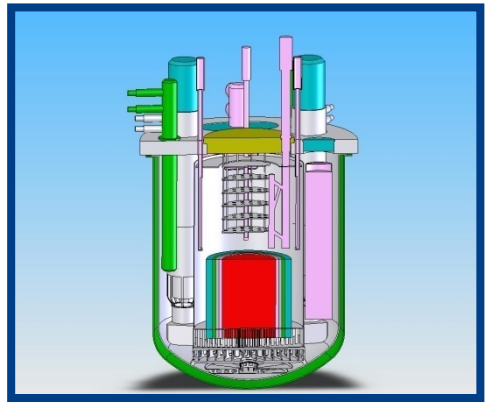
Pionner Facilities

Operating Reactors

Advanced Reactors



Future Nuclear Systems



1950 1970 1990 2010 2030 2050 2070 2090

Generation I

Generation II

Generation III

Generation IV

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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

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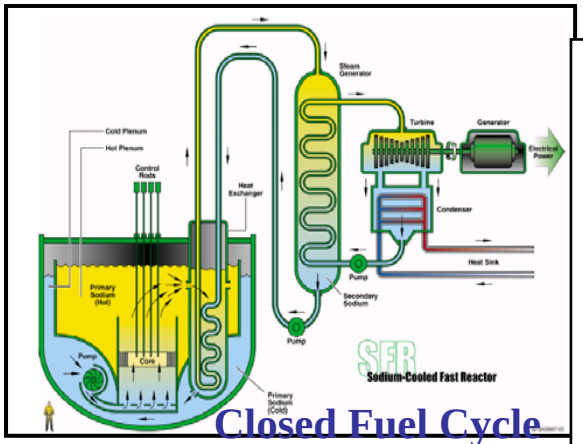
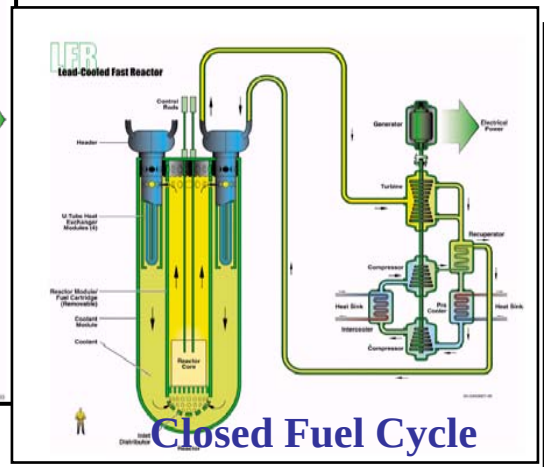
6 Innovative concepts with technological breakthroughs



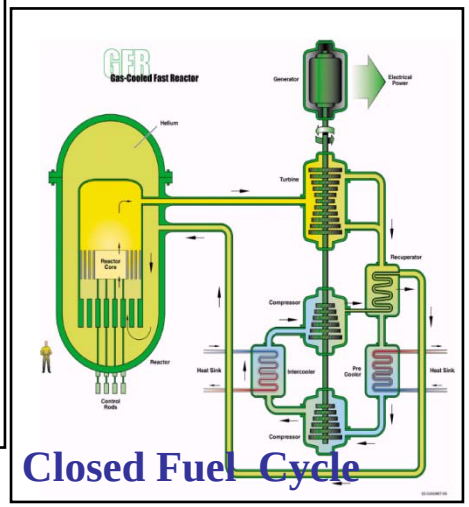
Closed Fuel Cycle

Sodium Fast reactor



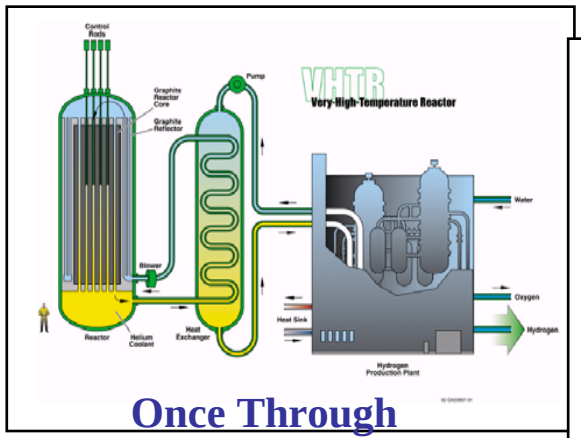
Closed Fuel Cycle

Lead Fast Reactor



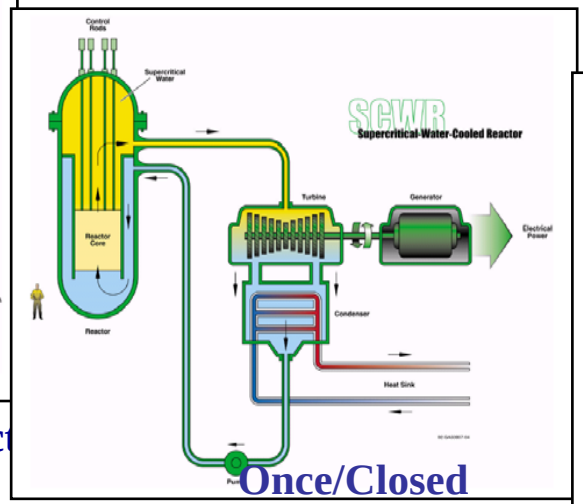
Closed Fuel Cycle

Gas Fast Reactor



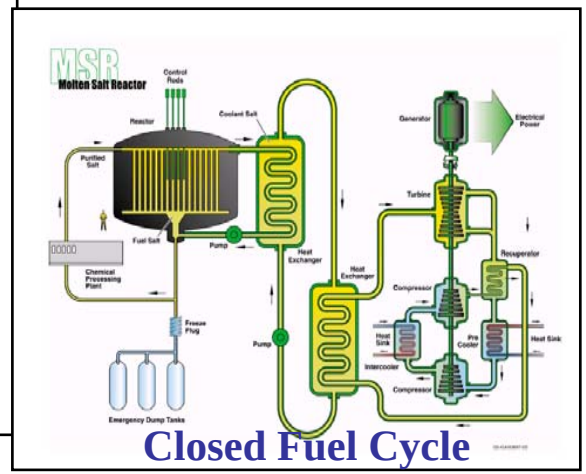
Once Through

Very High Temperature Reac



Once/Closed

Supercritical Water Reactor



Closed Fuel Cycle

Molten Salt Reactor

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For more, please visit my website :

www.bertrandbarre.com