Prospects & Prerequisites for the « Renaissance » of Nuclear Power

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55 Years of Nuclear Power

436 reactors in 30 countries*

> 2600 billion kWh/year

~ Hydro-power

> Saudi Oil

15% Electricity

(*+ Taiwan)

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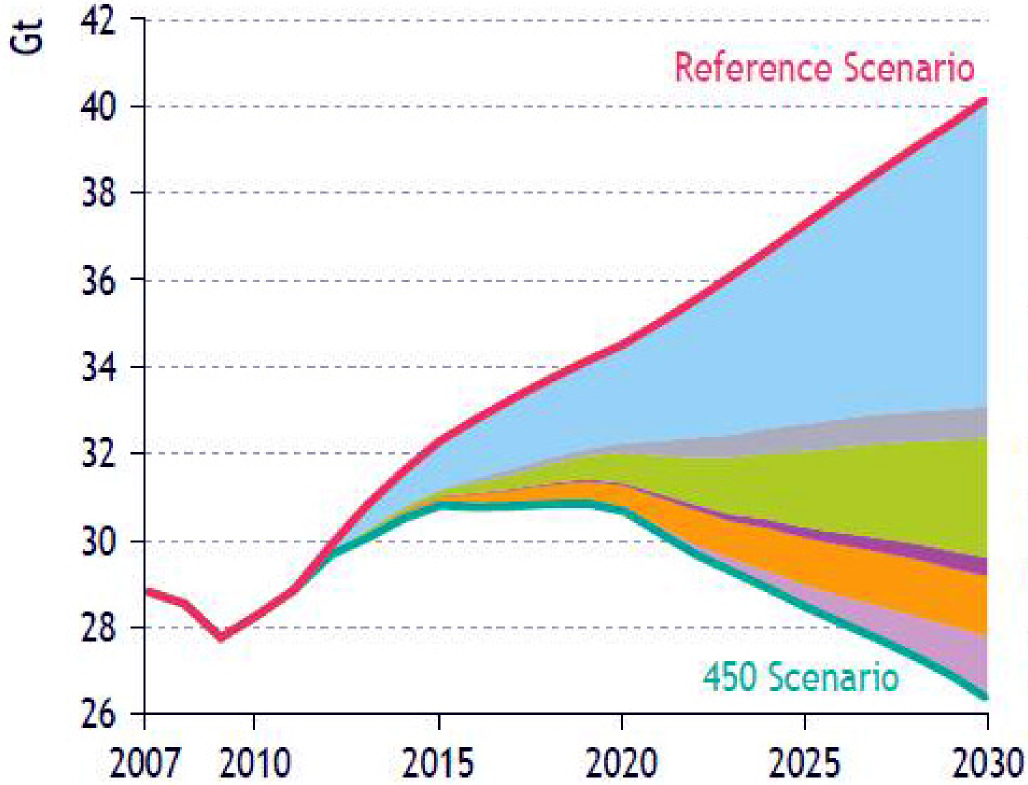
World Energy-related CO_2 Abatement for 450ppm scenario

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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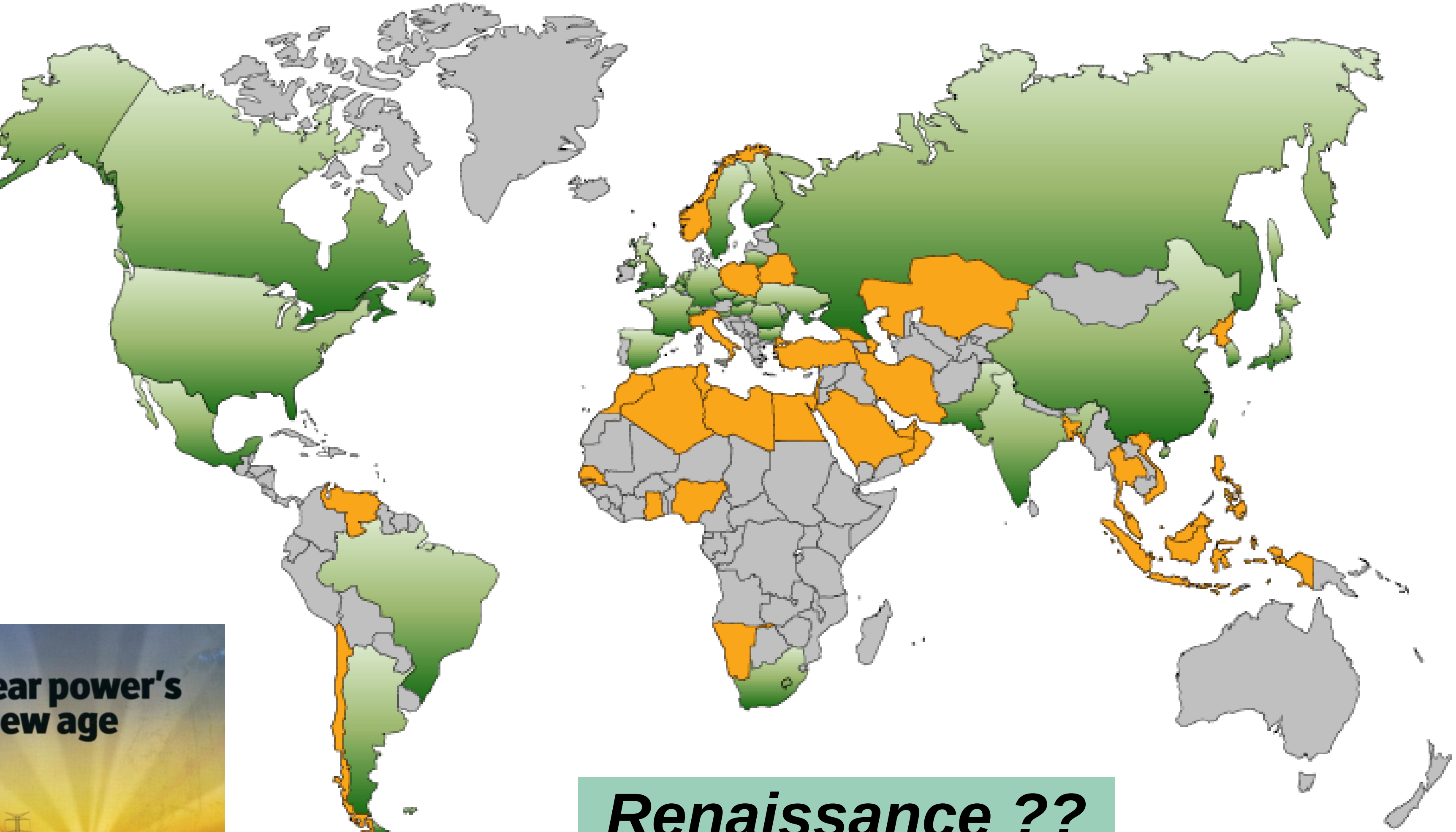
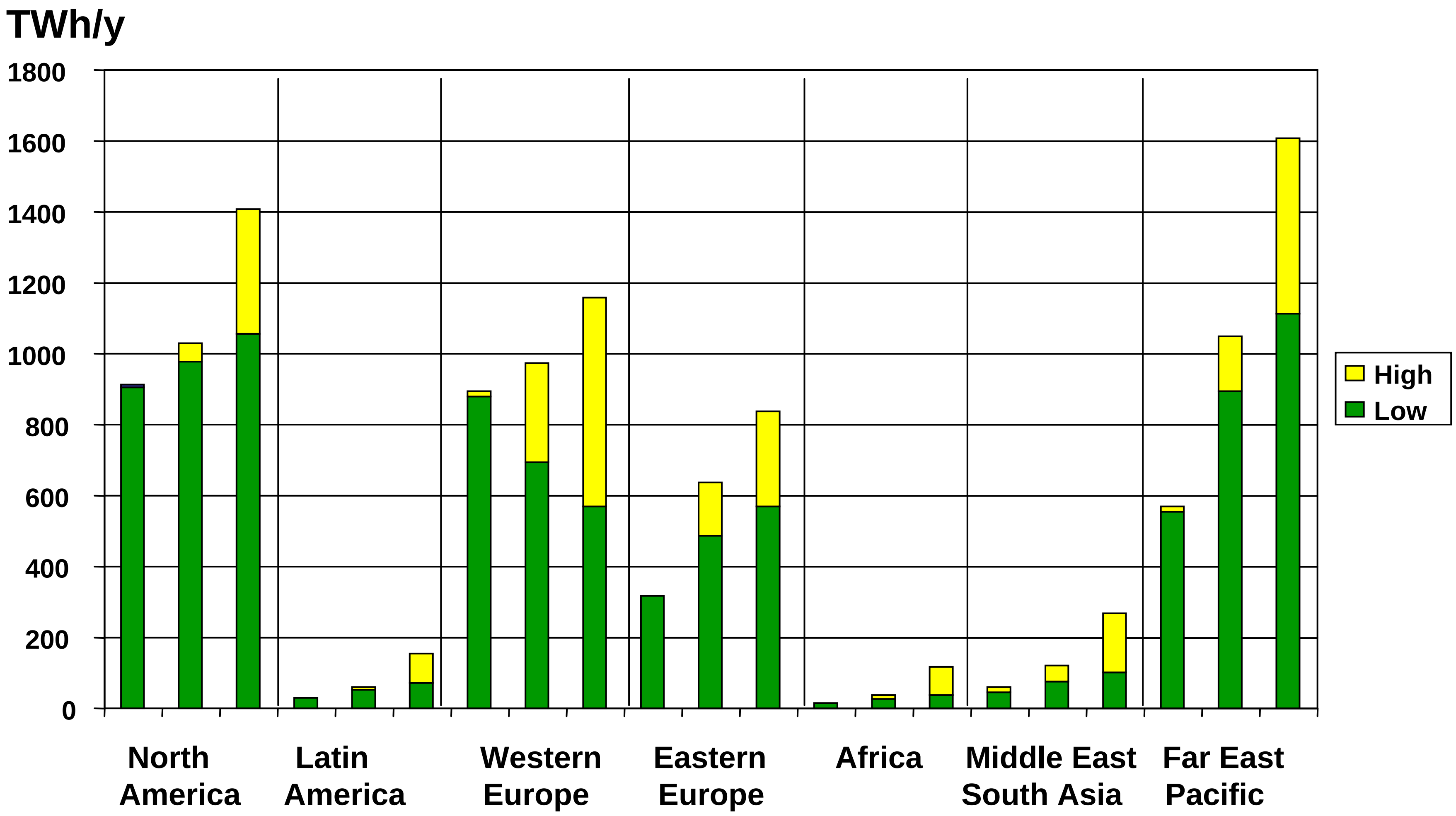
2008: 30 countries, 439 reactors, 370 GWe



Renaissance ??

IAEA forecasts 2008 on nuclear generation 2010-2020-2030



IAEA July 2008

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 ?*

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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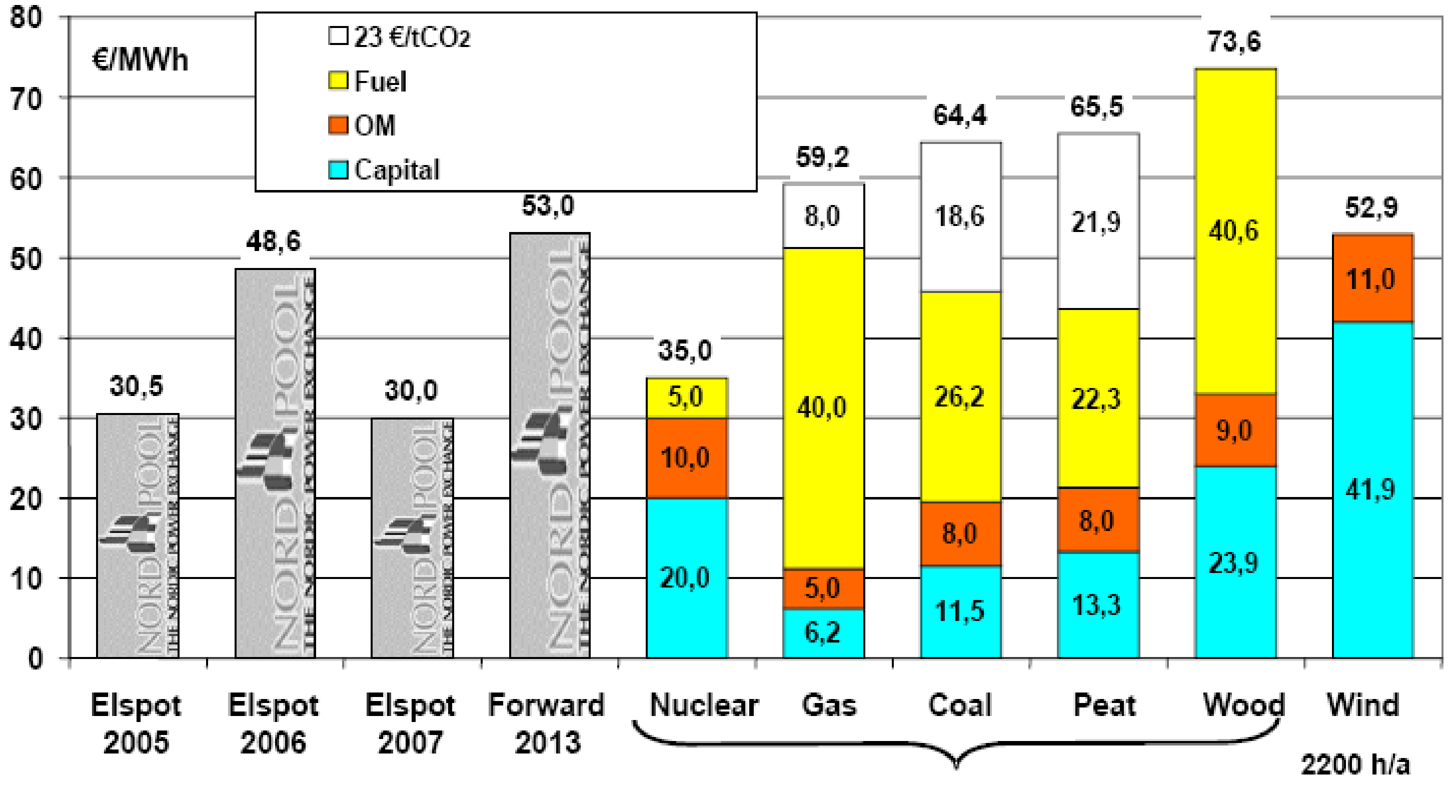
Recent Assessments
(1) The Finnish case, February 2008

Electricity production costs, 23 €/tCO_2



Real Rate 5,0 %

Price Level 1/2008

R.Tarjanne 11.02.2008

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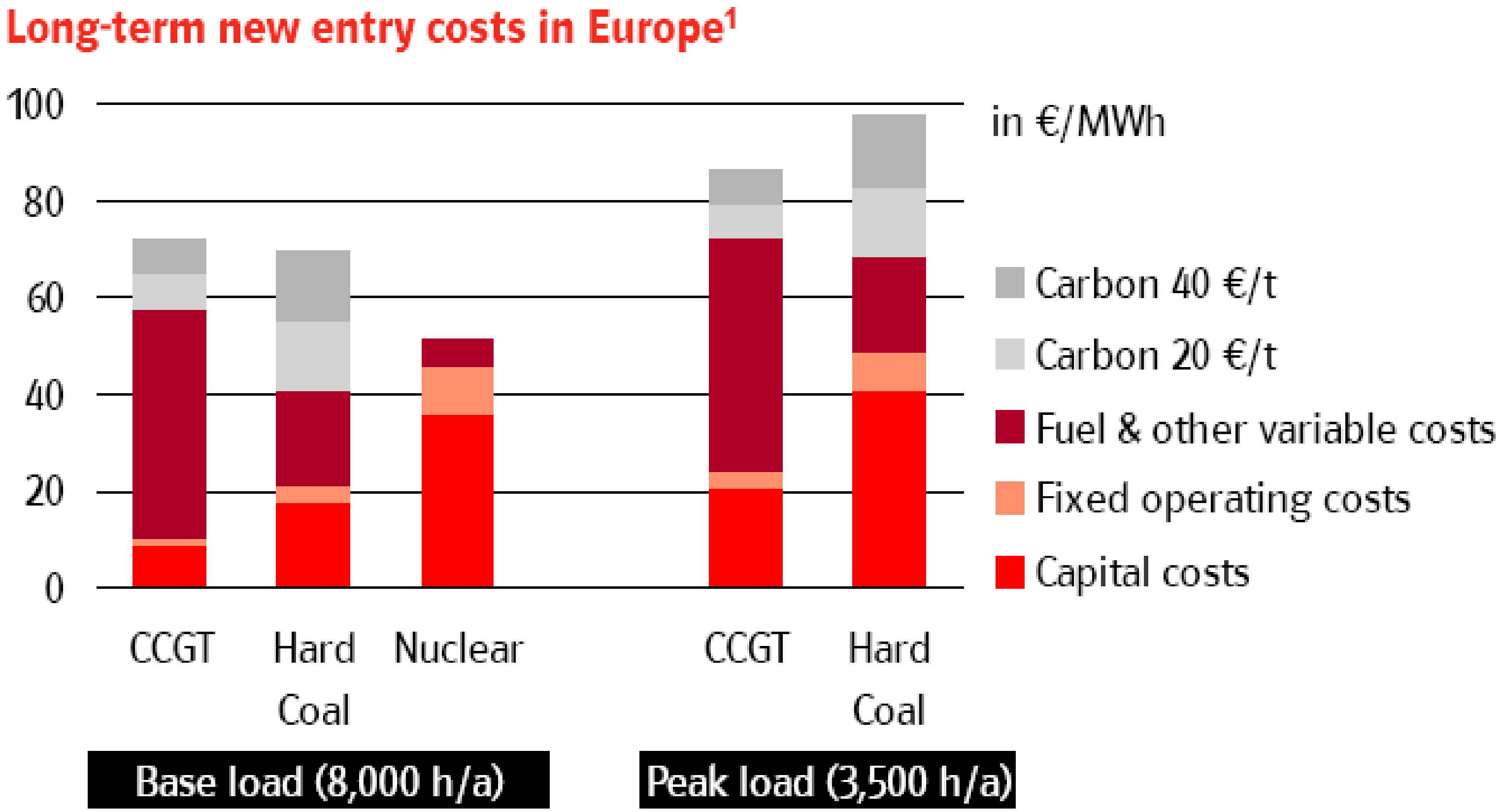
TVO 5.3.2008 Lauri Piekkari

Recent Assessments
(2) Communication by E-ON (March 2008)

Different load ranges require different technologies - nuclear economically most attractive for base load



1. Investment costs and commodity prices based on E.ON assumptions

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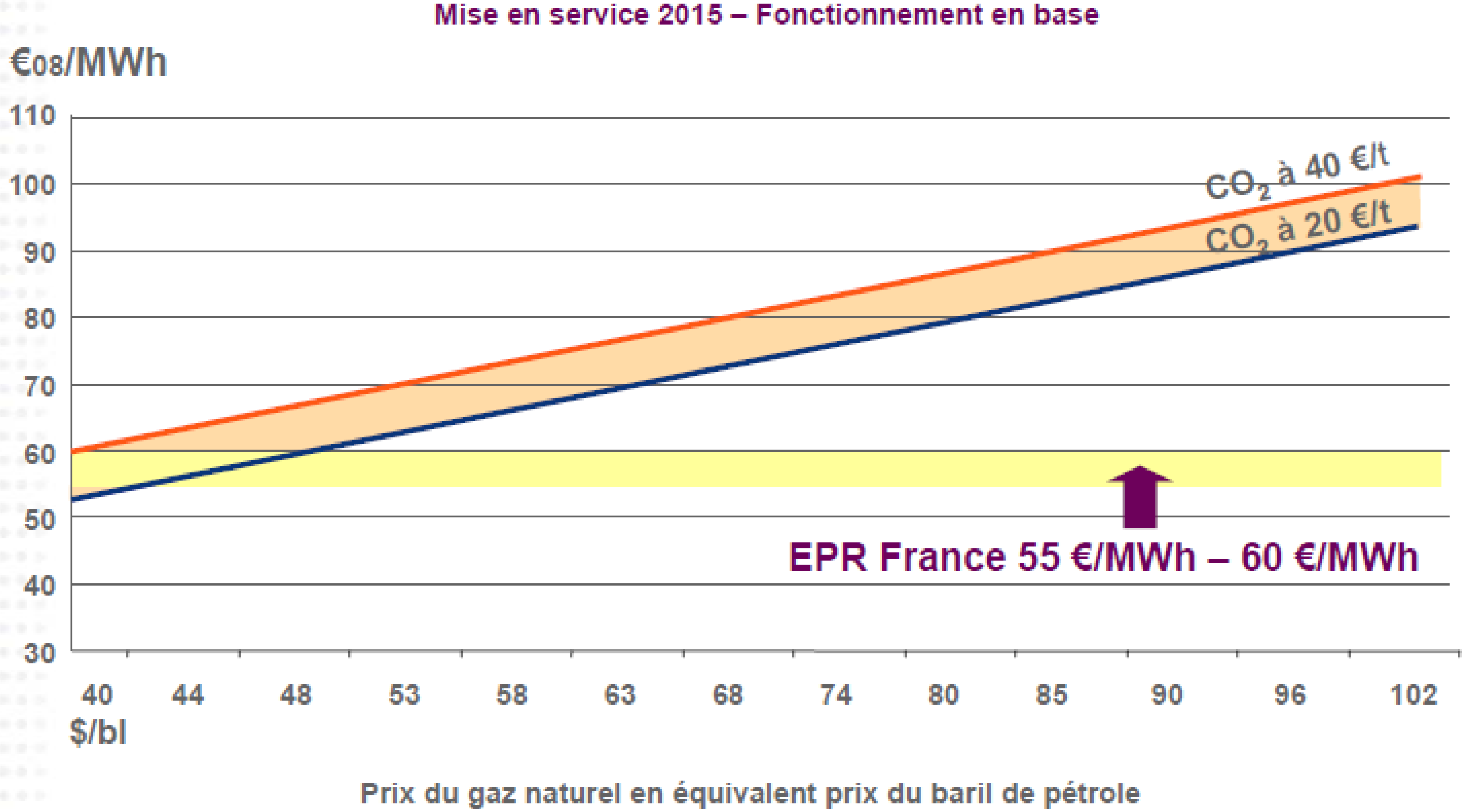
Nuclear Power is durably competitive in France

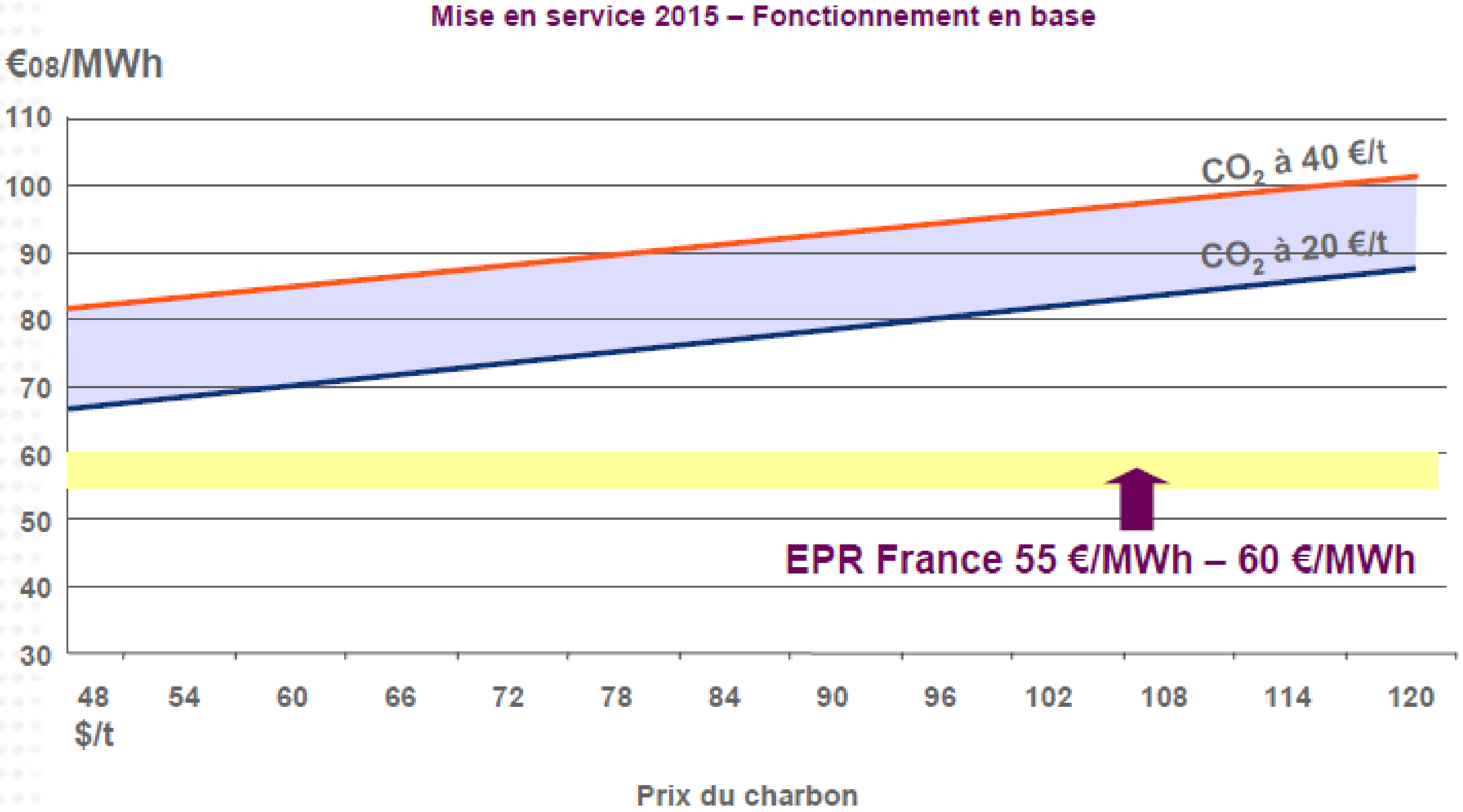
Versus CCGT



Source : EDF
Pour 1 taux de change long terme de 1 € = 1,22 $

Nuclear Power is durably competitive in France

Versus Supercritical Coal



Source : EDF
Pour 1 taux de change long terme de 1 € = 1,22 $

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
- Conversely, externalities are not (yet) 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.

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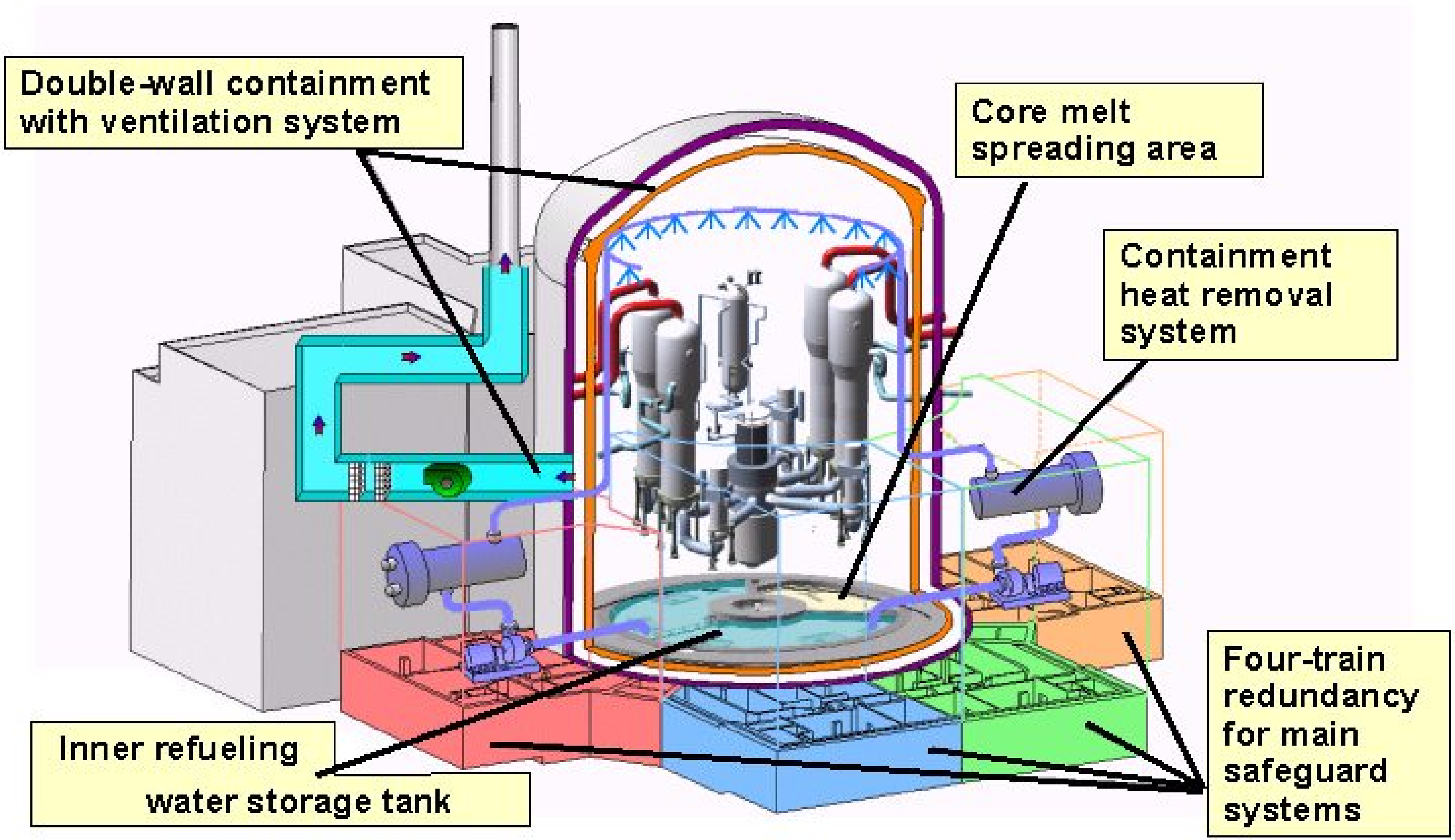
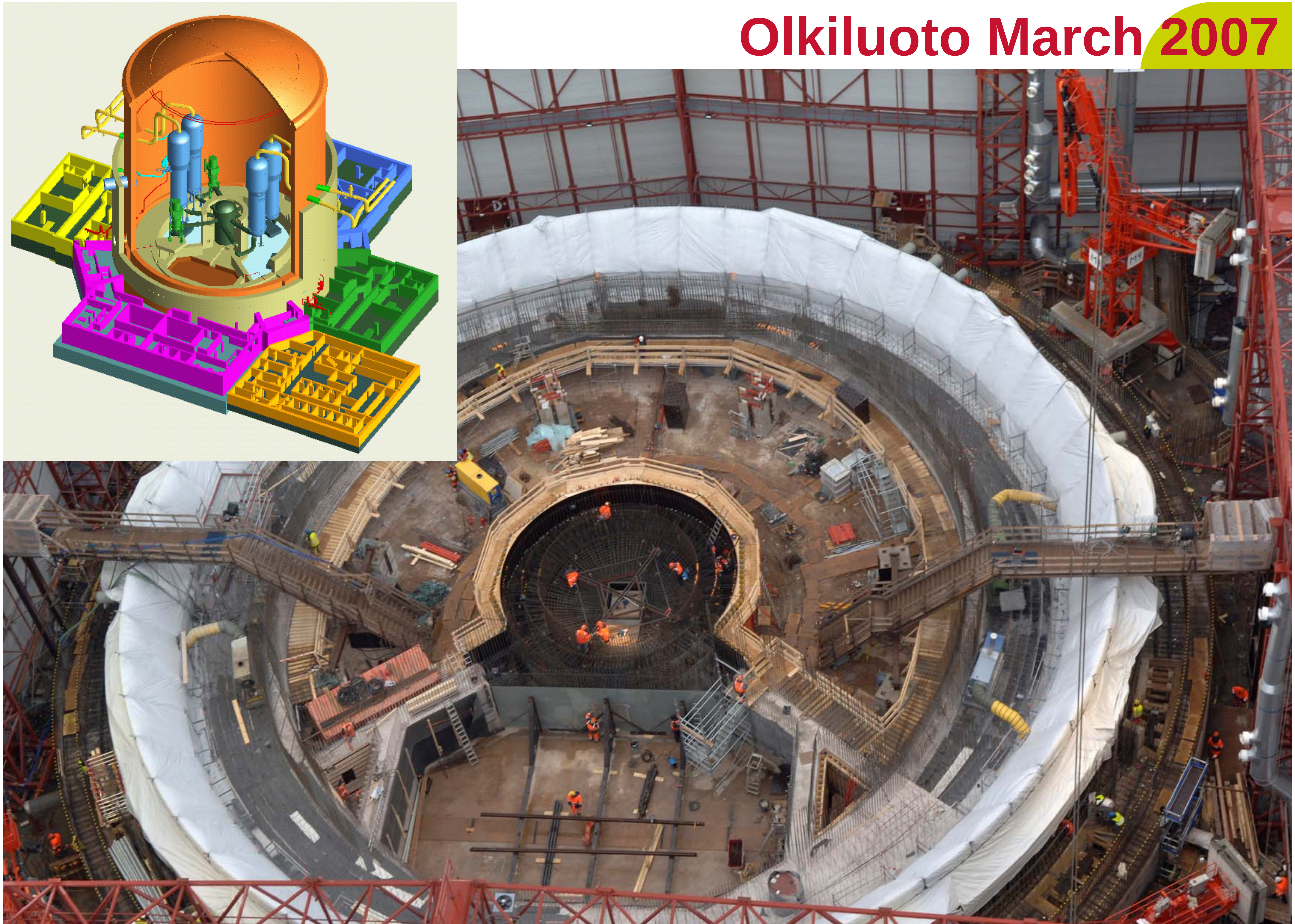
Since Tchernobyl, philosophy itself was changed

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

EPR Safety : Summary...



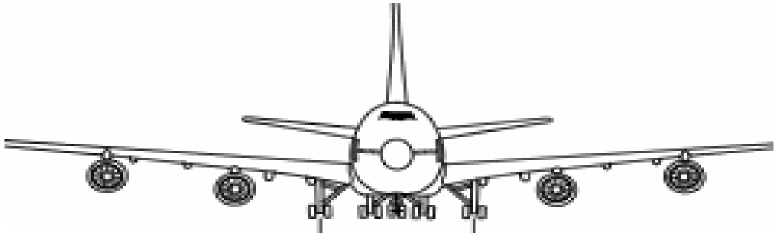
Olkiluoto March 2007



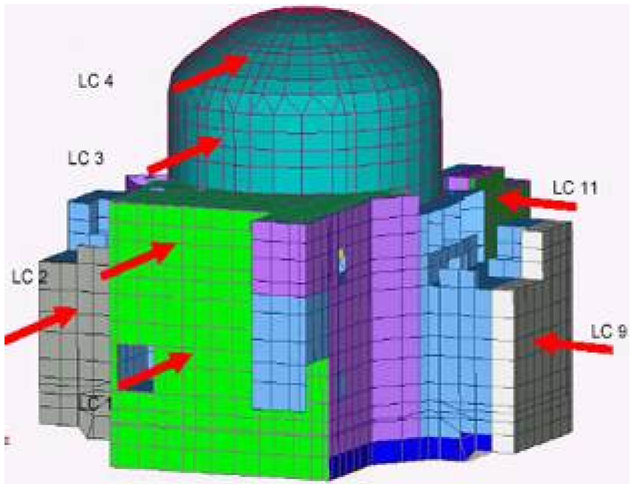
EPR aircraft hazard protection in the post 9-11 World

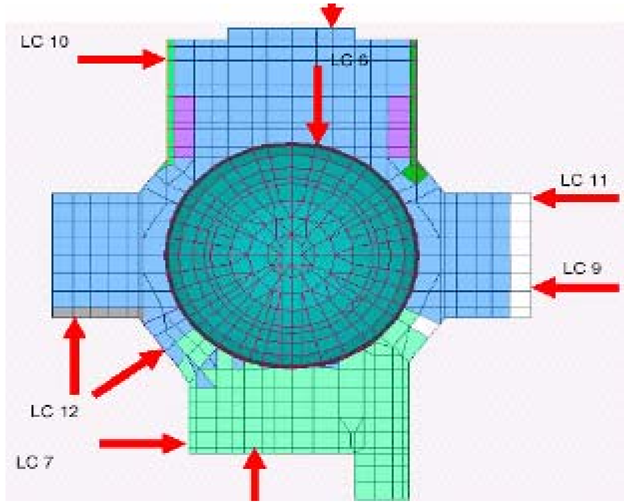
- EPR Designed to withstand impact of:

	Large Commercial Jet	&	Military Aircraft



At various Elevations	&	From different Sides





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

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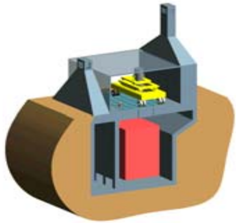
Spent Fuel Management

Spent fuel.

Reversible direct disposal

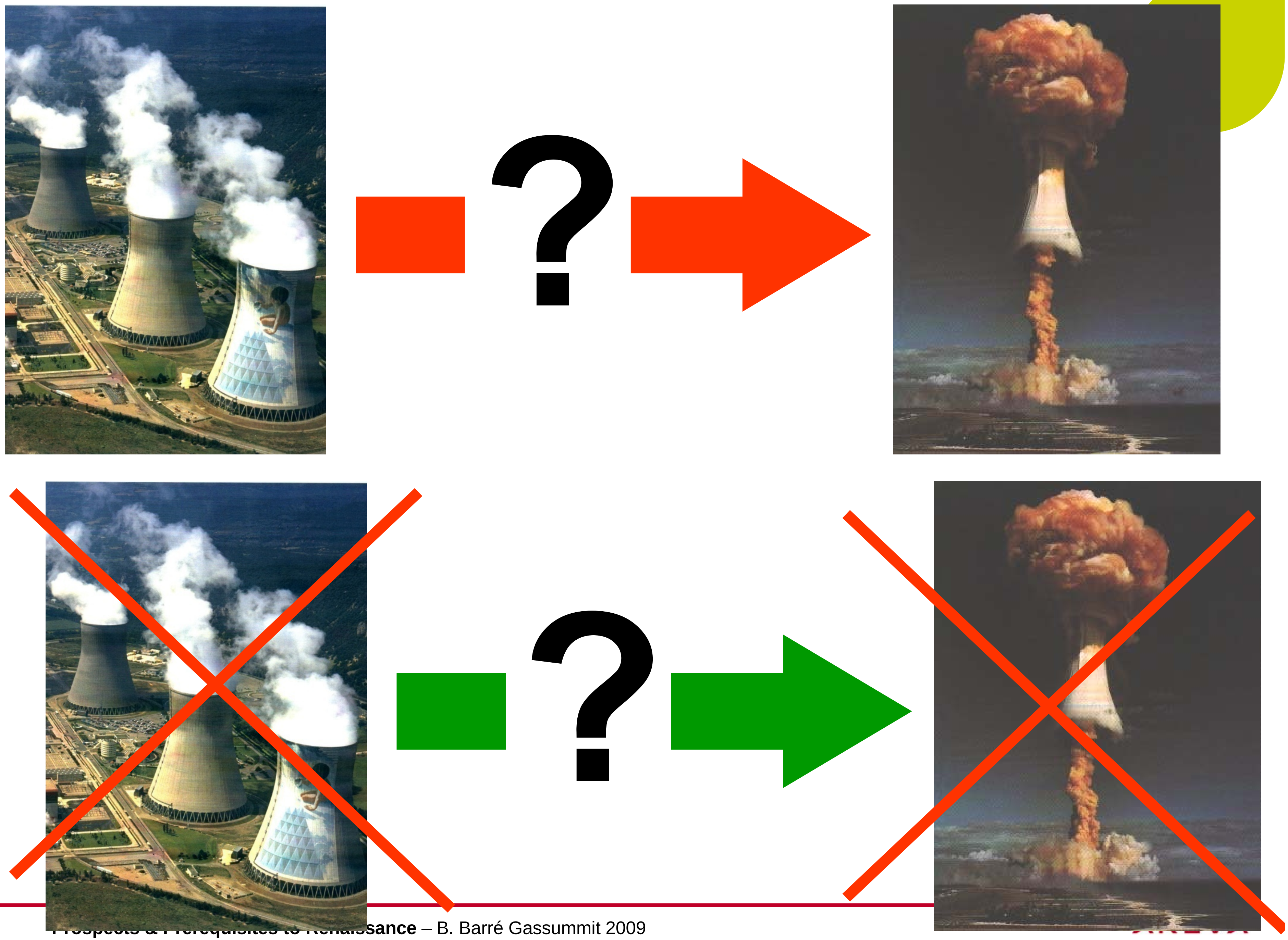
Storage, then decision



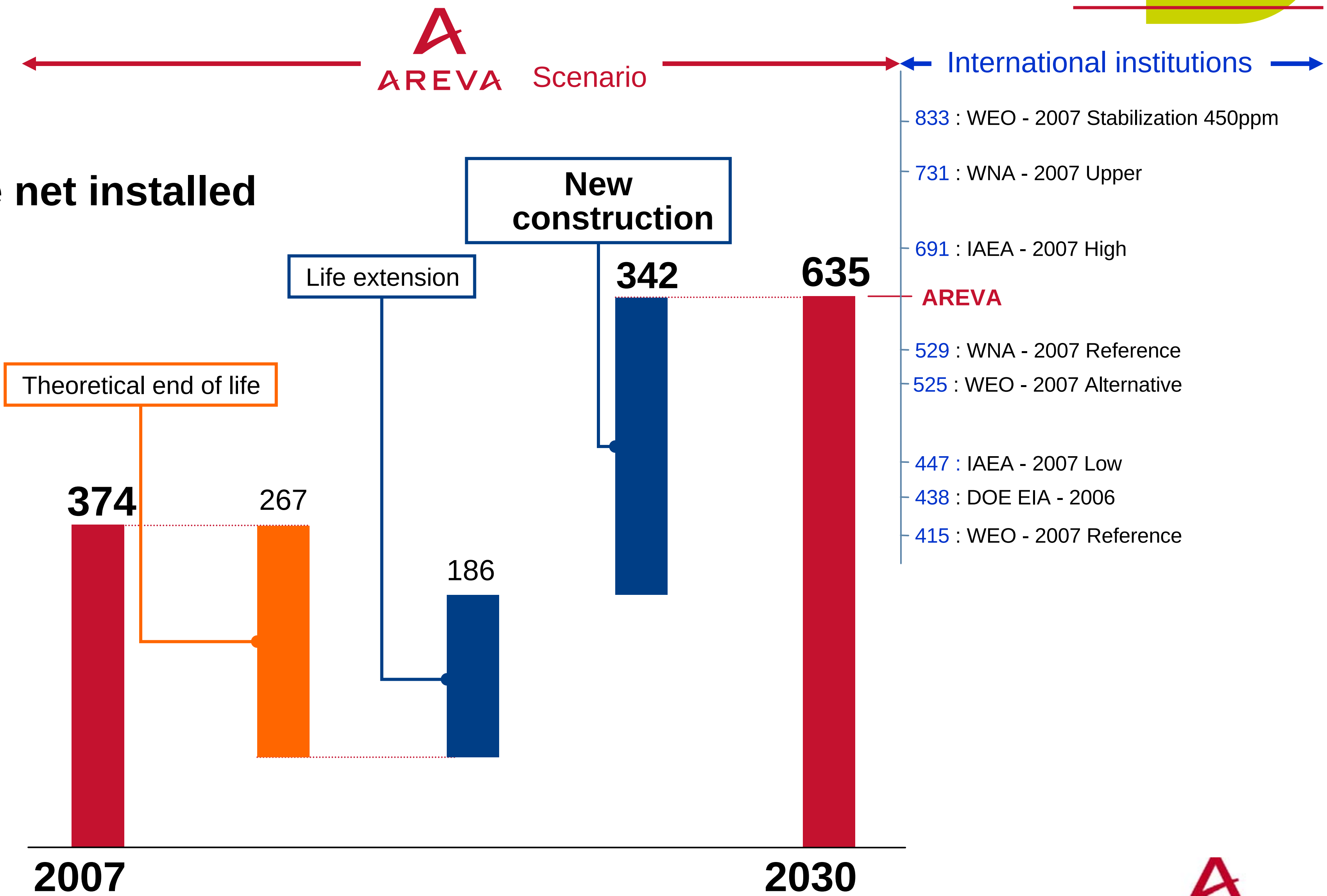
Reprocessing & Recycle + HLW reversible disposal

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**



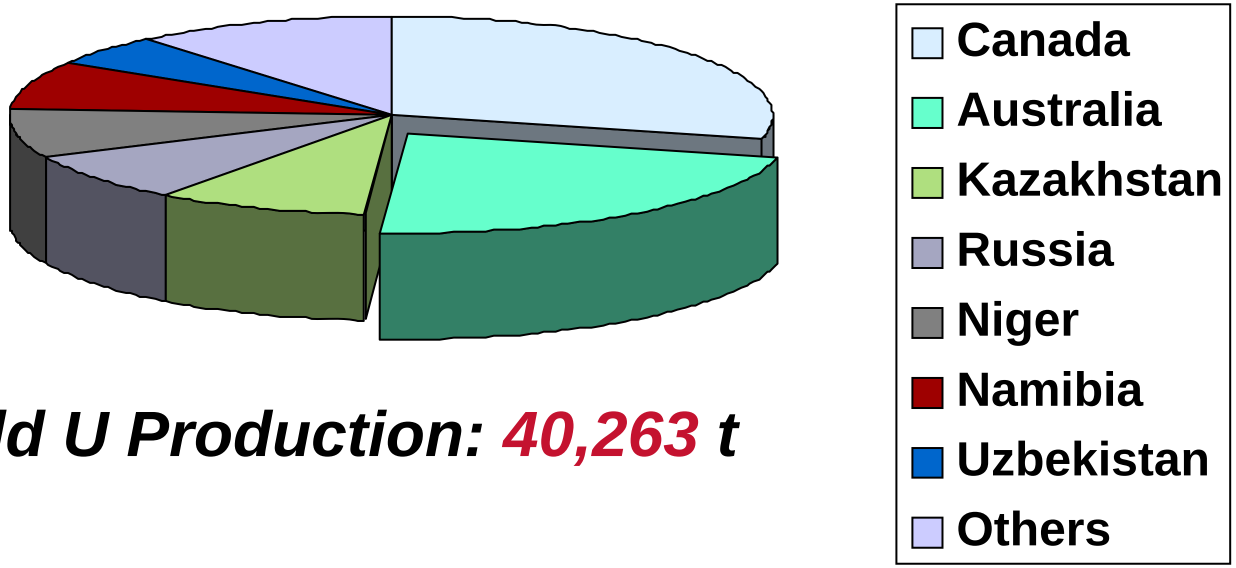
AREVA's 2030 scenario: construction of more than 340 GWe of nuclear power



Source: AREVA's estimates

U Resources = 220 times 2005 demand

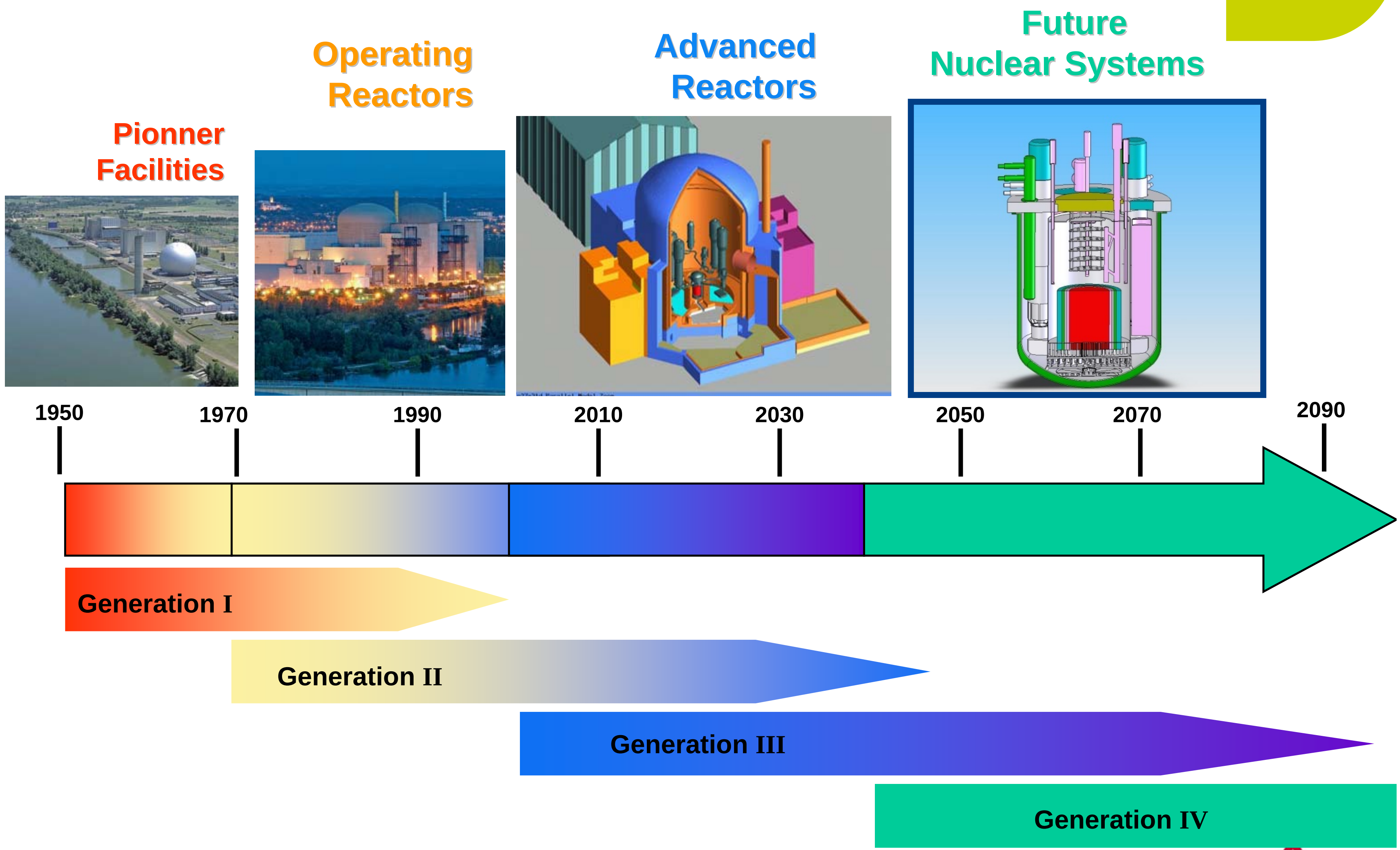
General total of conventional U resources:	***16,000,000 t***
World demand in 2005:	***67,000 t***



2004 World U Production: 40,263 t

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

Nuclear reactors « Generations »



For more, please visit my website :

www.bertrandbarre.com

	2002 indicative values	2007 indicative	Variation	Cost Impact (US$/MWh)
Uranium US$/lb U3O8	12.5	100	**Factor 8**	
Resulting fuel cost(*) (US$/MWh)	4.3	10.1		**+5.8**
Gas (US$/MMBtu)	3.5	9.5	**Factor 3**	
Resulting fuel cost (US$/MWh)	23.1	62.6		**+39.5**
Coal (US$/t)	30	90	**Factor 3**	
Resulting fuel cost (US$/MWh)	10.5	31.5		**+21**

(*) including uranium + conversion + enrichment + fuel fabrication

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

Two complementary cost assessments

- **The private point of view (as measured by the producer):**
  - **Total cost = Generation cost = Capital cost + O&M + Fuel procurement**
  - **Taxes to be included**
  - **Interest rate = private financing rate depending on project risk assessment**
- **The social point of view (as measured by public authority):**
  - **Total cost = social cost = generation cost + external costs**
  - **No tax to be included in the generation cost (the net cash expenditure is zero for the State)**
  - **Interest rate = long term, low risk (= public bonds)**

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Public versus Private Point of View
(example based on French case, DGEMP Reference Costs, 2003)

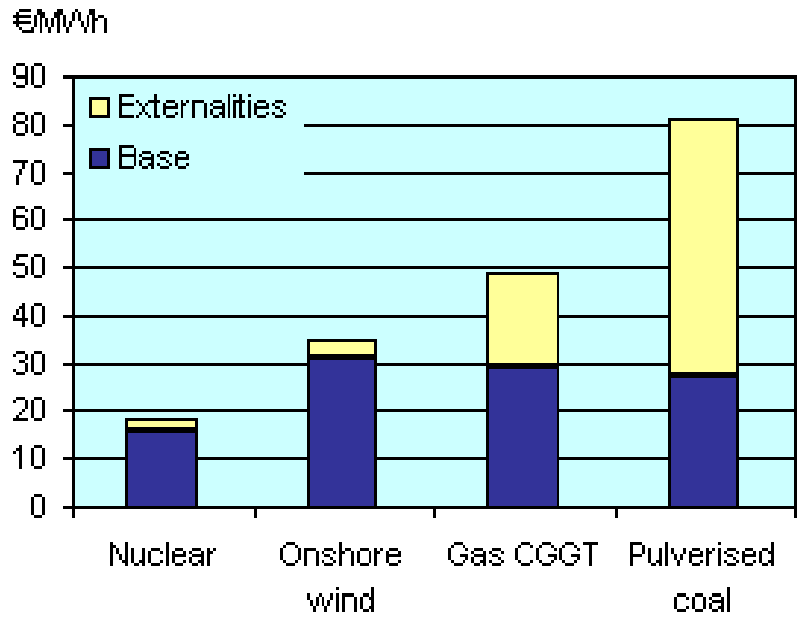

Figure 1.

Generation Cost for a public authority

(baseload supply,
no tax, 3% real discount)

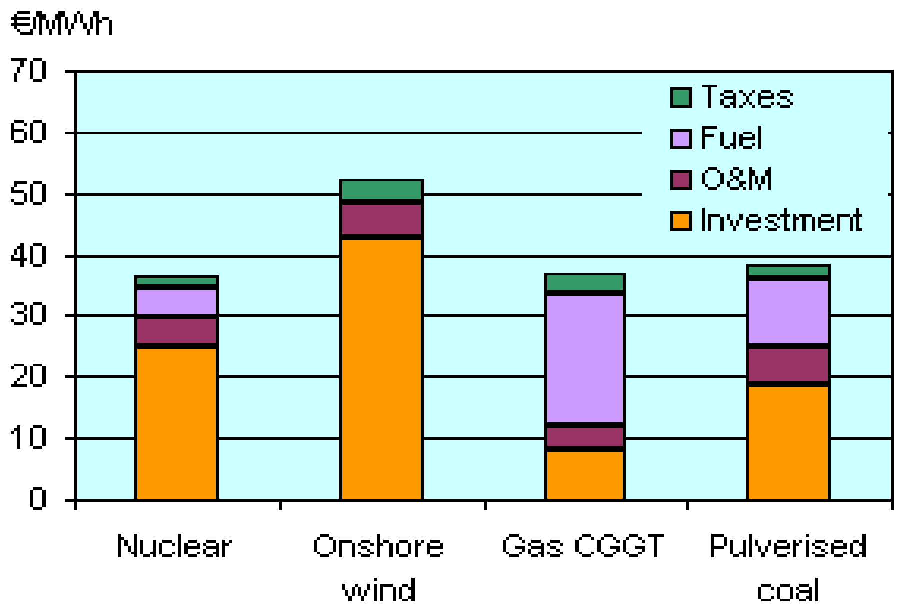

Figure 2.

Generating cost for a private utility

(baseload supply,
11% real discount = WACC, real before tax)

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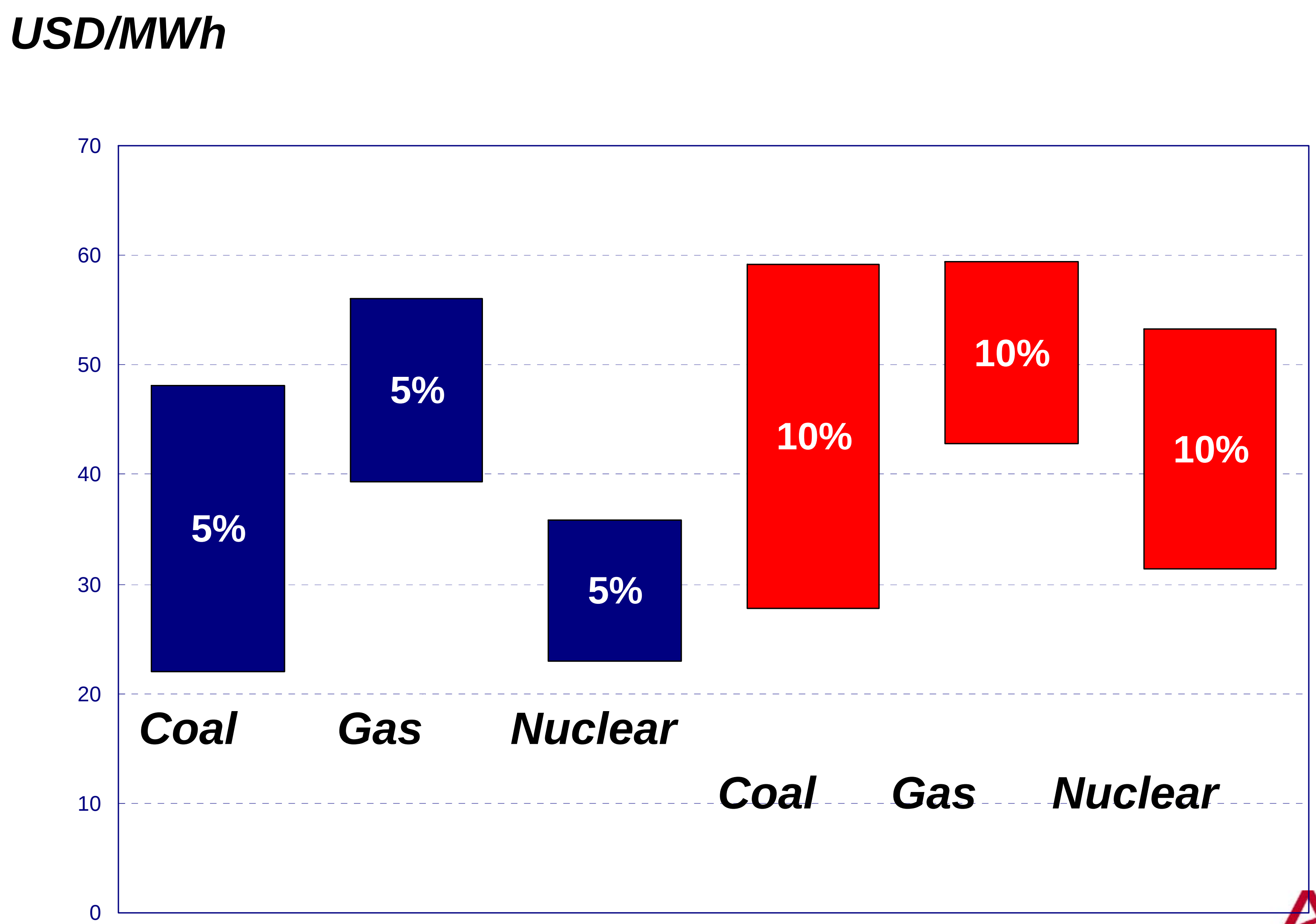
Assumed Prices in OECD 2005 Projected Costs (2003 economic conditions, 21 countries)

- Projected OVN construction costs
  - Coal = 900 – 1300 €/kW
  - CCGT = 350 – 600 €/kW
  - Nuclear = 1400 – 1800 €/kW
- Projected Fuel prices
  - Coal = 40 – 75 $/t
  - Gas = 3.5 – 6.5 $/GJ
  - Nuclear = 3 – 7 €/MWh (total fuel cycle)
- 1 Euro = 1.14 $

OECD/NEA 2005 Projected Cost Ranges (19 countries, load factor = 85%, D.R. = 5% and 10%)



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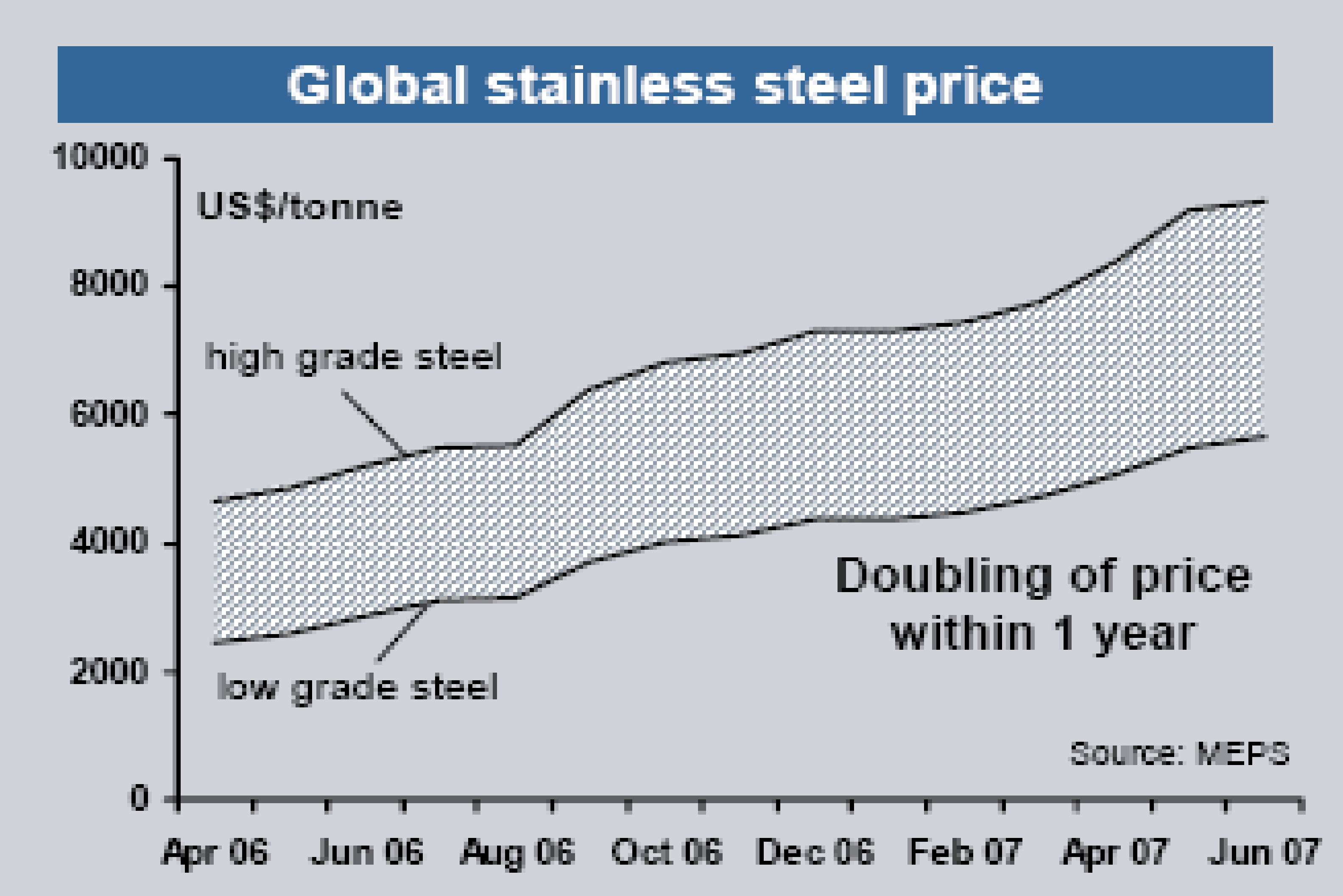
BUT…

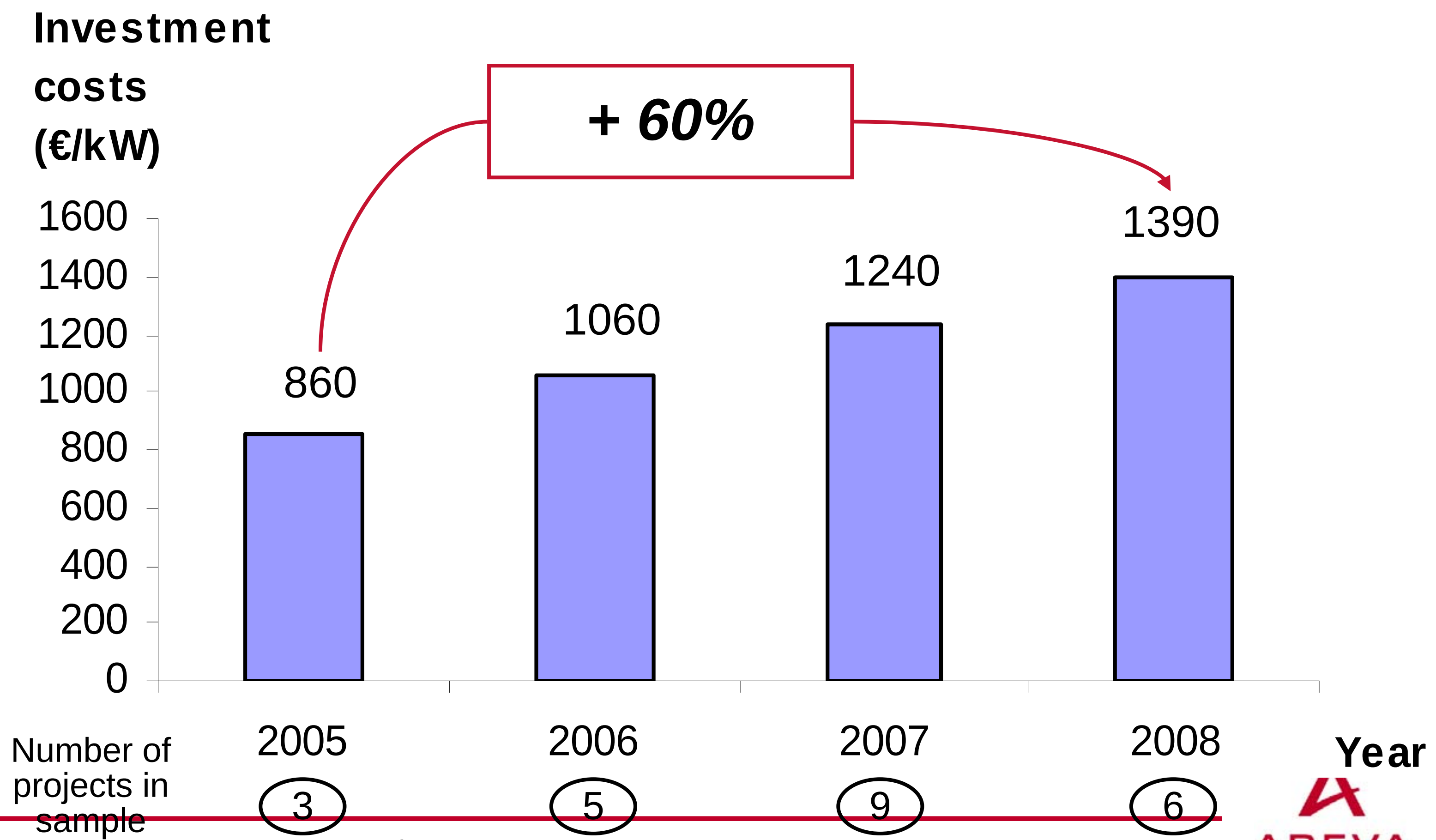
The context has changed since 2005

Material prices have soared: the case of stainless steel



Construction Costs have soared whatever the technology and the country

- **Evolution of investment costs for coal-fired plants in Europe** ***(annual average, source DEEP/ Platts Tracker)***
  - **Thermal efficiency = 43% on Low Heating Value (LHV)**



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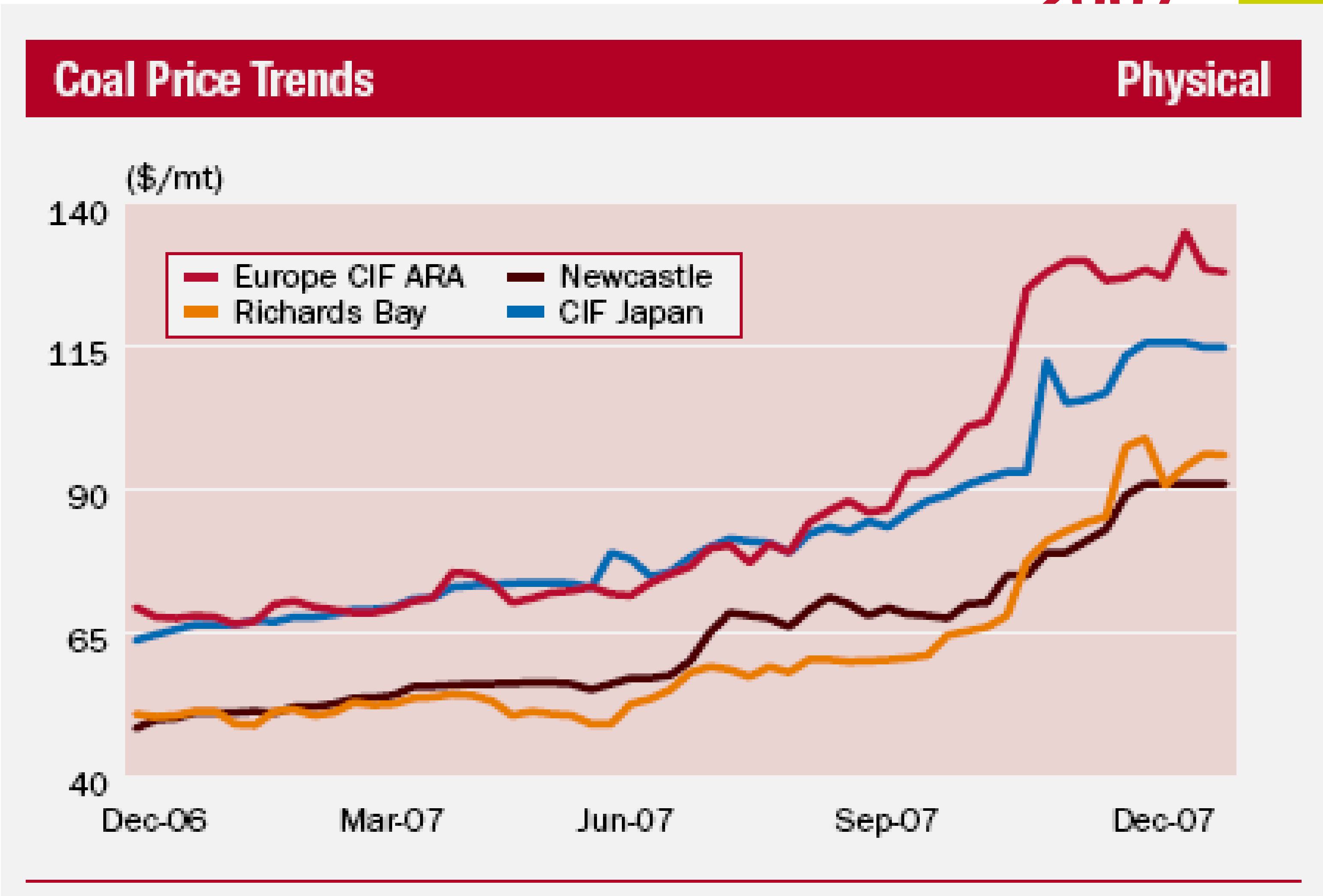
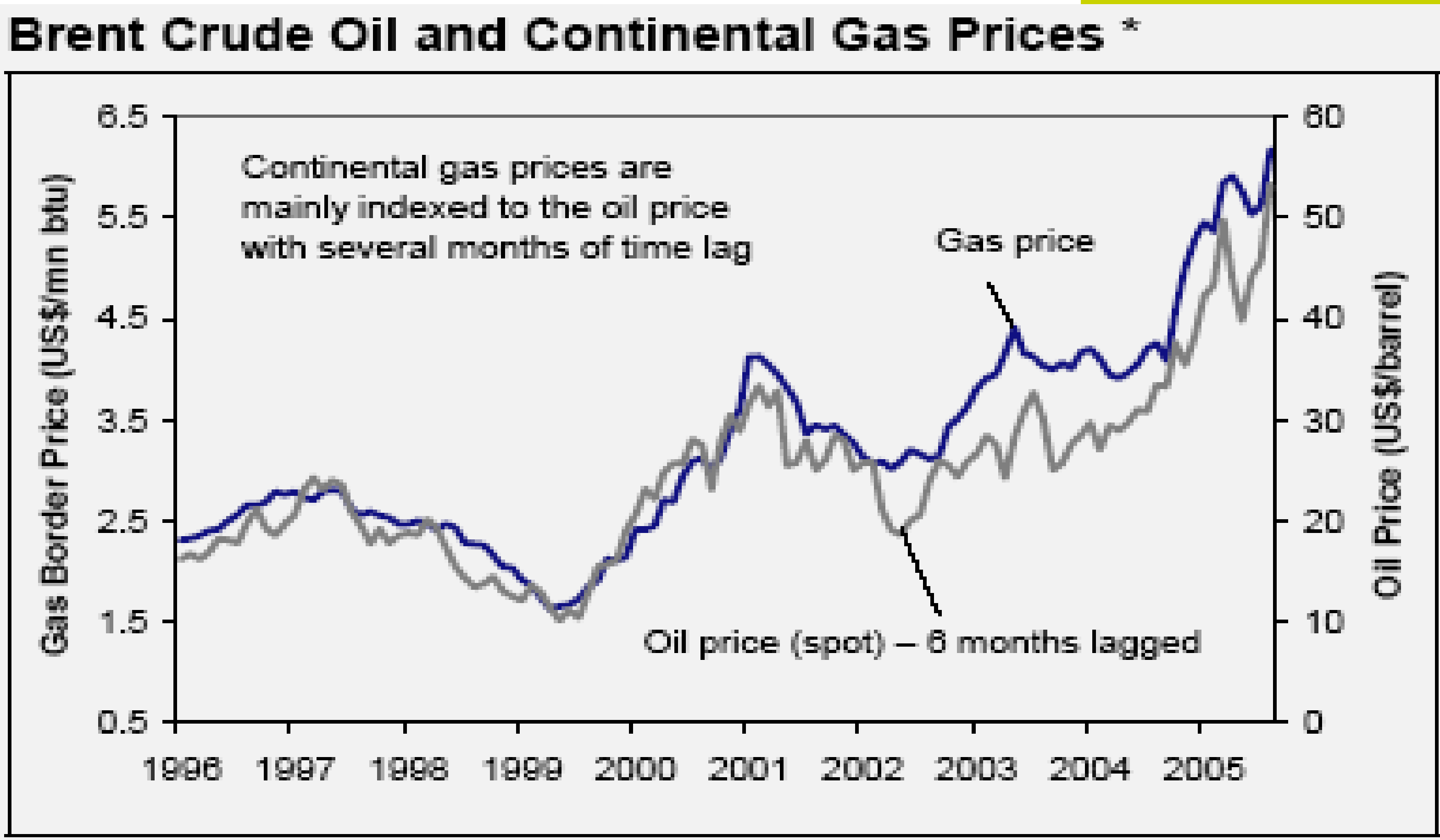
Coal: spot prices doubled over 2007



Reference Platts ICT, 2008/01/04

Gas price : bound to oil for ever?



** German gas border prices*

Source: Bloomberg, Morgan Stanley Research

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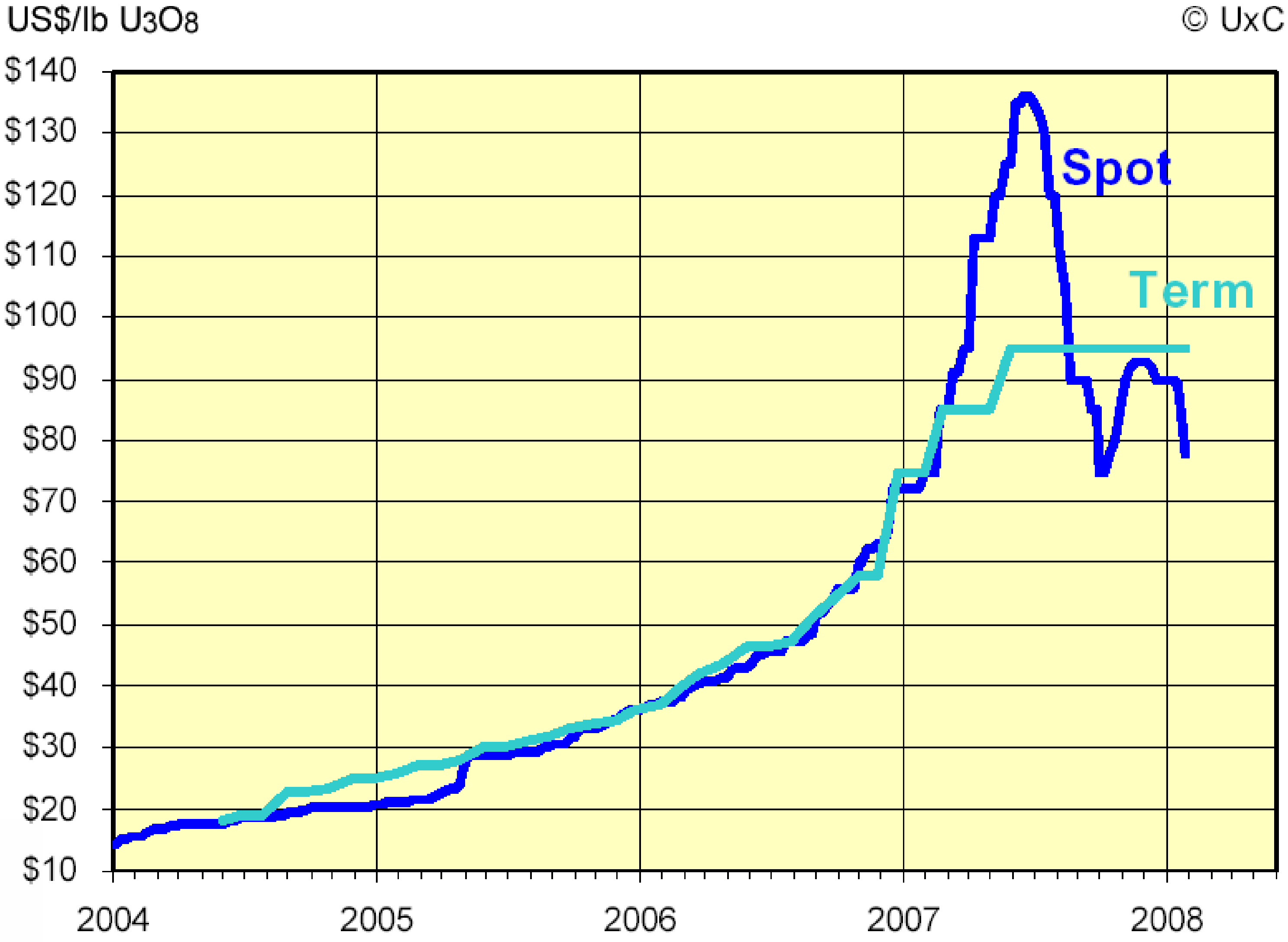
Uranium price also has become volatile



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Cost Impact of Fuel Price Variations over the past 5 years

	2002 indicative values	2007 indicative (**)	Variation	Cost Impact (USD/MWh)
Uranium Volatility USD/lb U_3O_8	12.5	100	**Factor 8**	
Resulting fuel cost(*) (USD/MWh)	4.3	10.1		**+5.8**
Gas volatility (USD/MMBtu)	3.5	9.5	**Factor 3**	
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(*) including uranium + conversion + enrichment + fuel fabrication

(**) in the higher range

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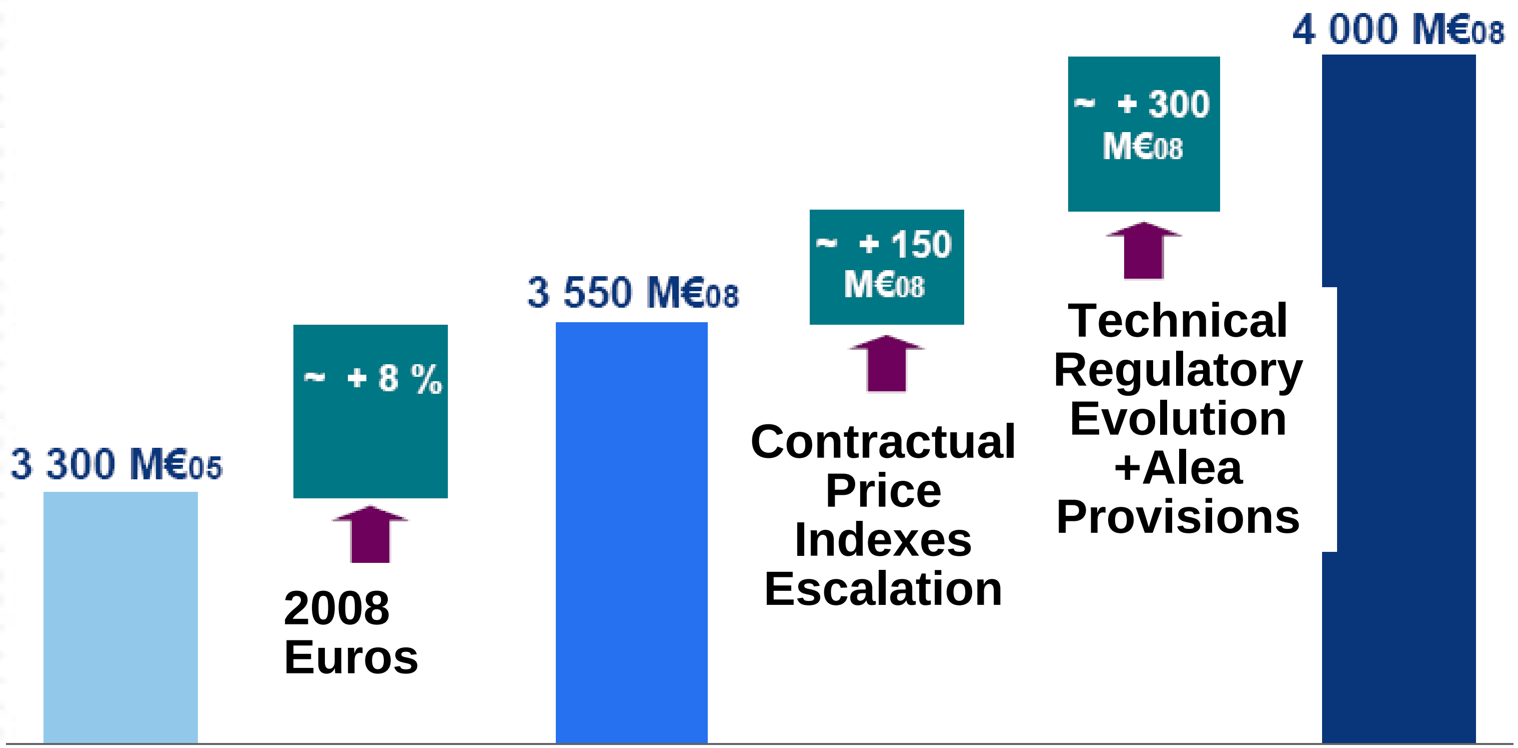
The carbon cost by 2008-2012 and in the long term

- 3 ways of estimating the carbon cost in Europe.

CO_2 cost	Short term by 2008-2012	Long term
Macro-economical models	20 €/t (POLES + developing countries)	Depending on Global policies and objectives
Technical avoidance cost	Shift from coal to gas: about 30€/t Depending on fuel relative prices	Carbon Capture & Storage: around 50 €/t?
Emissions trading price	▶~20 €/t for 2008-2012 ▶~40 €/t by 2020?	Market price fixed by CCS credits

Flamanville 3 Construction Cost

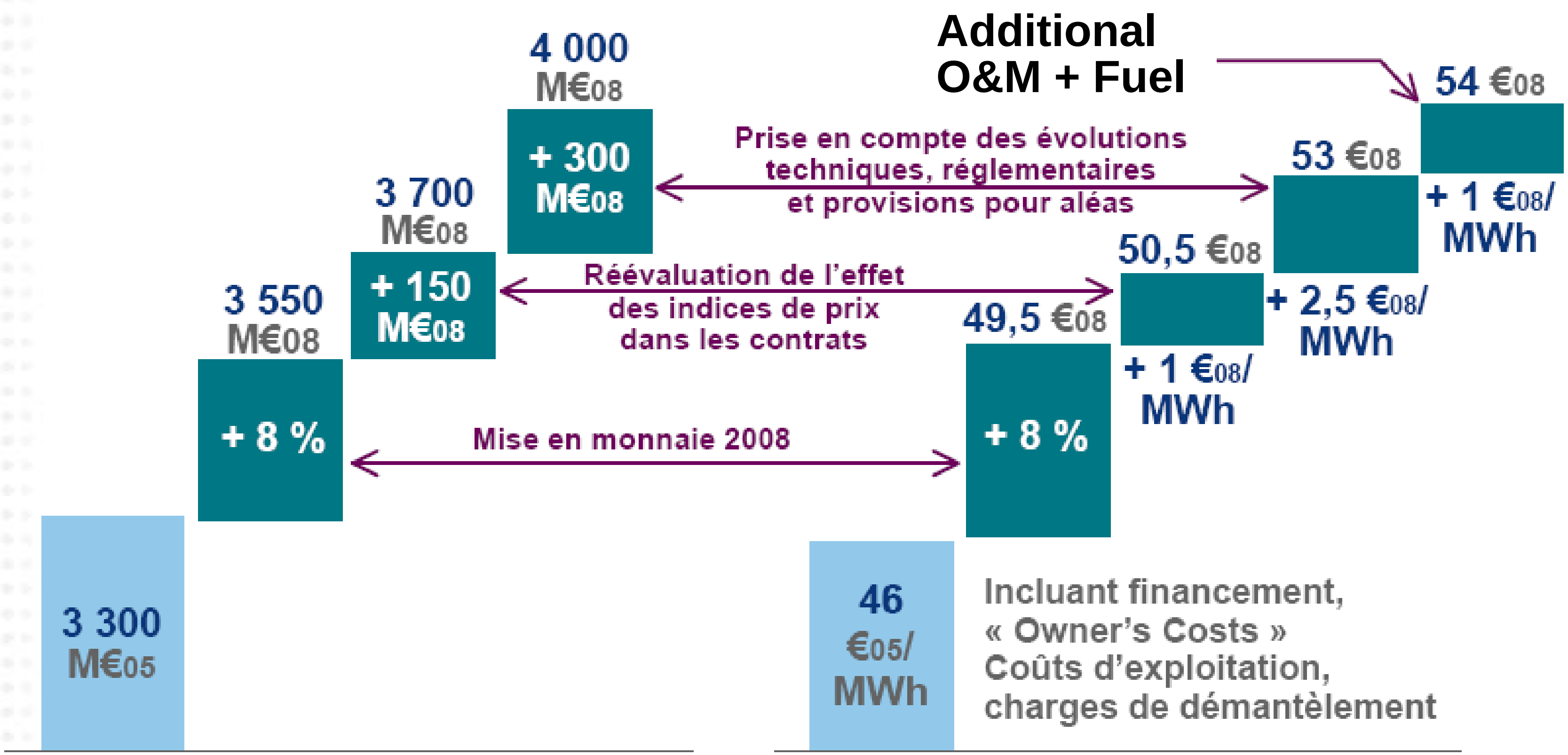
2005 - 2008



Flamanville 3 Complete kWh Cost 2005 - 2008

Engineering & Construction Cost
en millions d'€

Complete Busbar Cost
en €/MWh



Nuclear energy is not fraught with other kinds of risks

- The low marginal cost of production warrants priority for injection to the grid, which means high load factor
- Fuel supply security (sources, storage, recycling)
- Fuel contribution to the total cost is small, allowing long-term price stability
- No risk of CO_2 emissions related extra cost from emerging climate change policies
- The external costs of nuclear power are among the lowest of all electricity generating options – but no credit is applied yet

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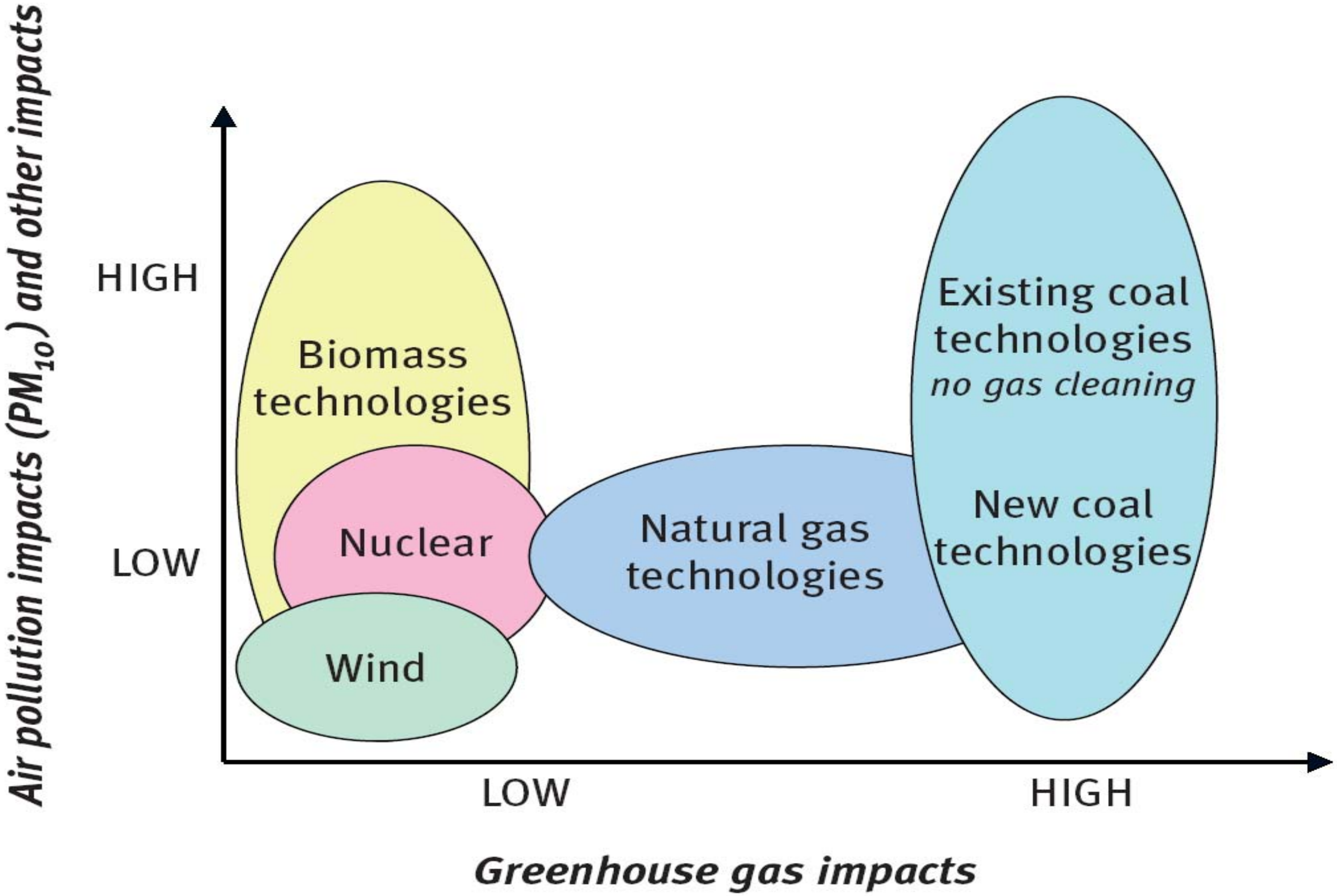
Externalities of Electricity Generating Technologies



Source: EU-EUR 20198, 2003