



Nuclear power - basis, challenges and global status

Lauritzen, Bent

Publication date:
2009

[Link back to DTU Orbit](#)

Citation (APA):

Lauritzen, B. (2009). Nuclear power - basis, challenges and global status [Sound/Visual production (digital)]. Kollokvium at University of Århus, Department of Physics and Astronomy, Århus (DK), 17 March, 01/01/2009

DTU Library

Technical Information Center of Denmark

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

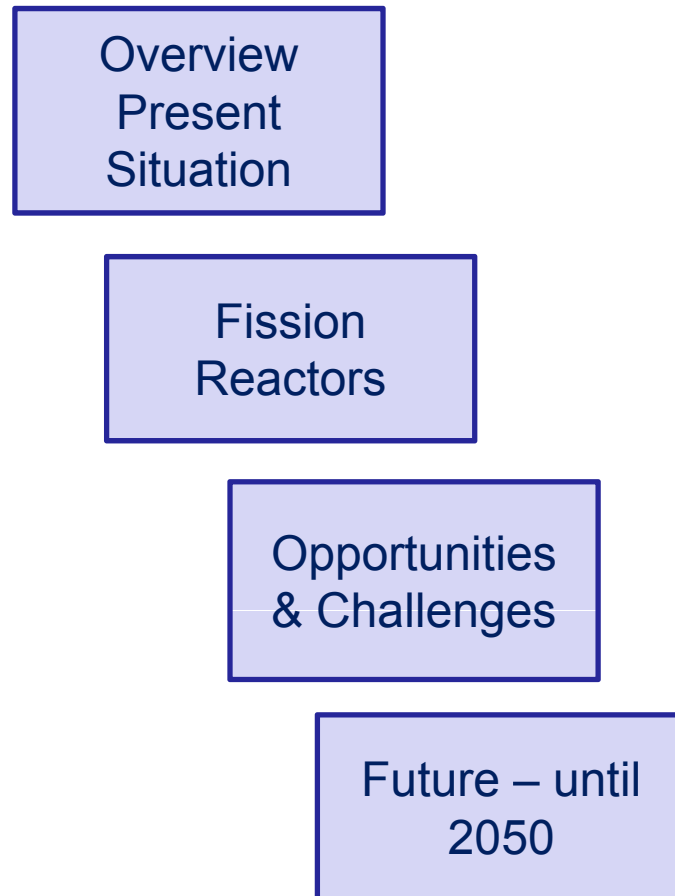
- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Nuclear Power: Basis, Challenges and Global Status

Bent Lauritzen
Risø DTU

Overview



Overview

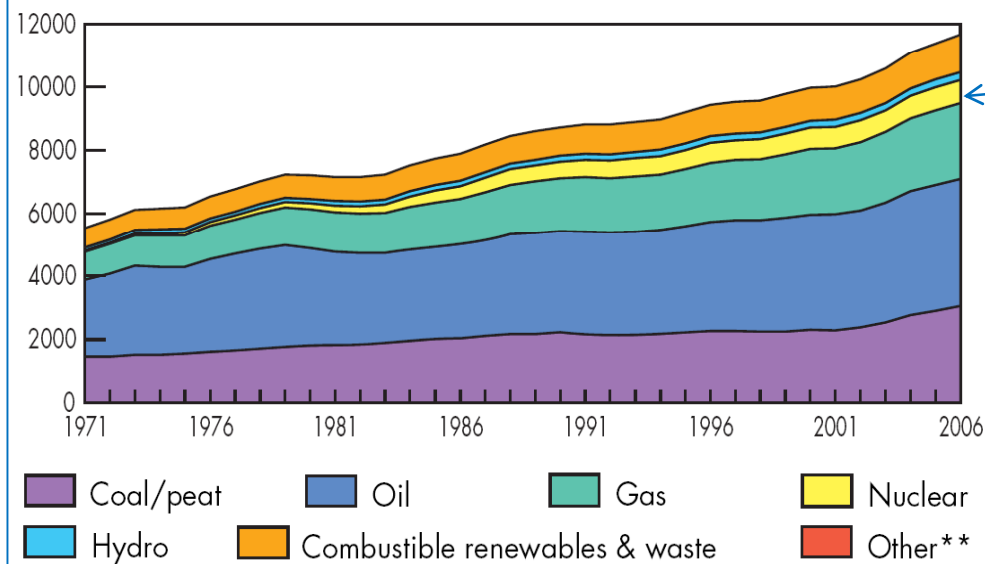
Present Situation

Nuclear power in brief

- 1918 Rutherford: Energy production from nuclear
- 1938 Fission
- 1942 Fermi's Reactor (natural uranium, graphite moderated thermal reactor)
- 1945 Atomic bomb
- ca. 1950 Generation I reactors: Magnox (Calder Hall)
- 1953 Atoms for peace (Dwight Eisenhower)
- ca. 1965 Generation II: PWR, BWR
- 1979 Three Mile Island
- 1985 DK: No nuclear power
- 1986 Chernobyl accident
- 1999 Barsebäck-1 closes
- 2002 Finnish newbuild
- Today Renaissance for nuclear power?

Nuclear Power in the World Today

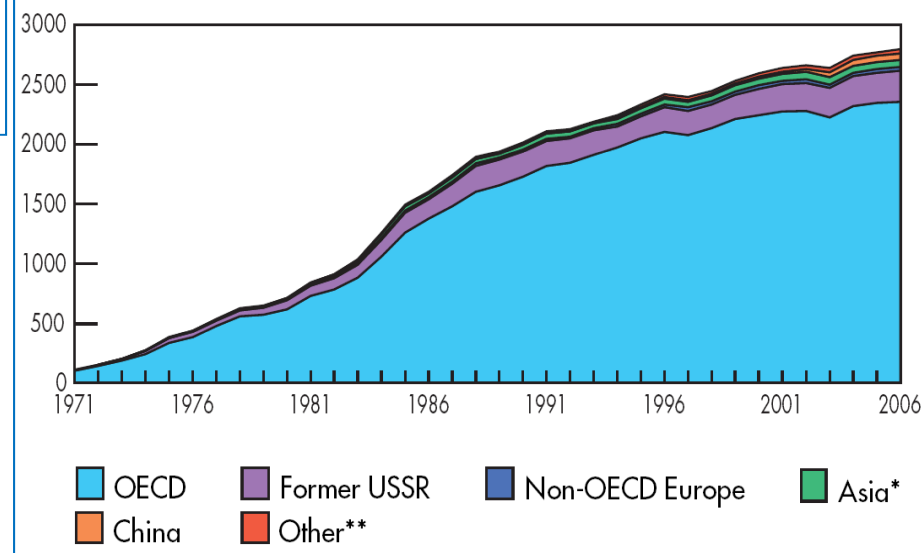
Evolution from 1971 to 2006 of world total primary energy supply* by fuel (Mtoe)



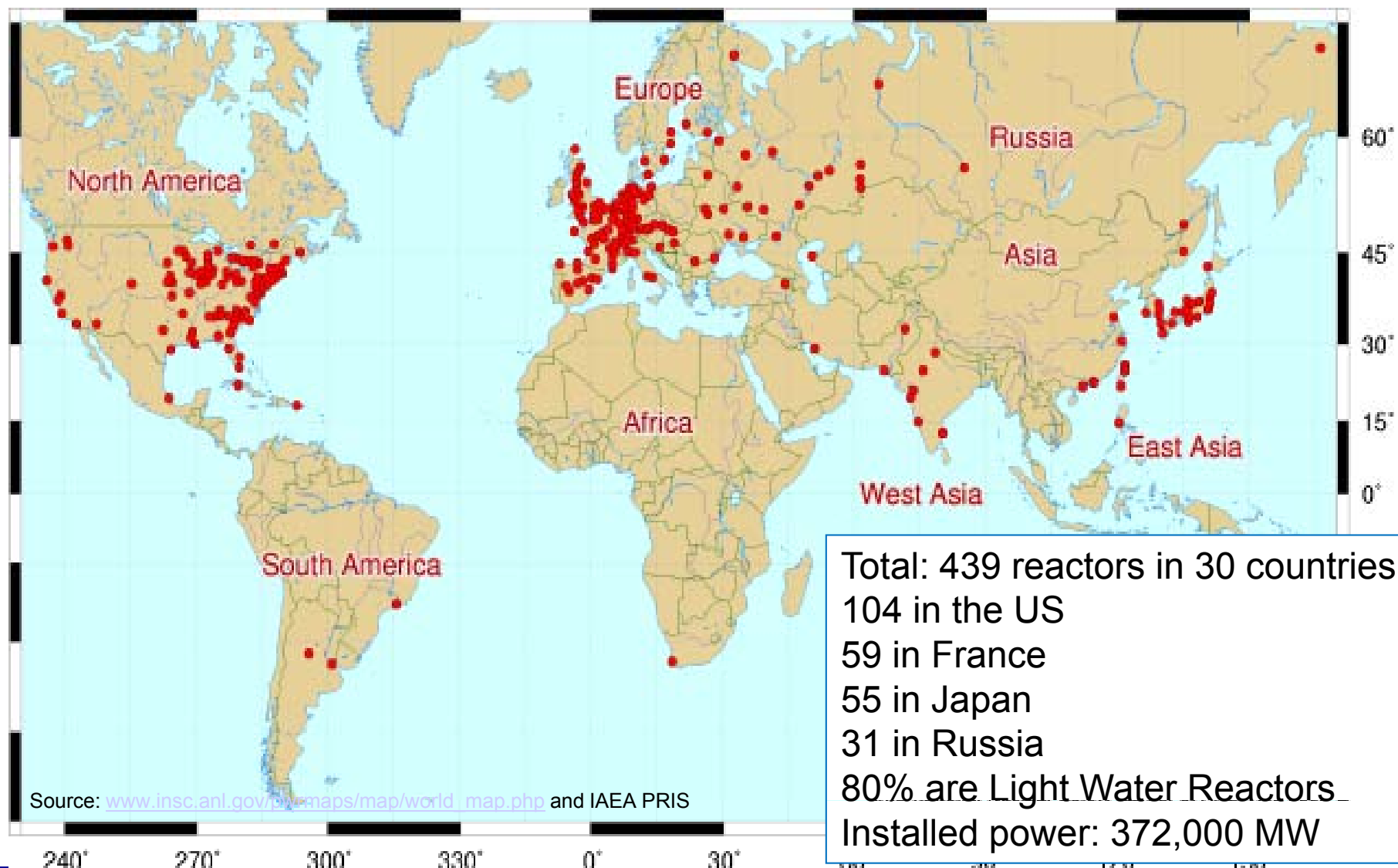
Nuclear power provides approximately 6 % of world total primary energy supply

Most of the nuclear power production has been added during the last 35 years. Nuclear provides about 2 610 TWh per year, which is 14.2% of all electric energy production (2007).

Evolution from 1971 to 2006 of nuclear production by region (TWh)

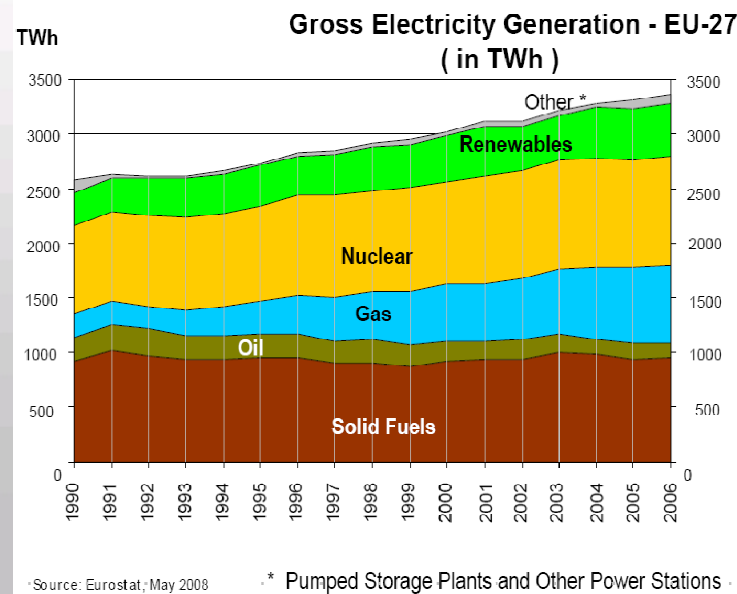
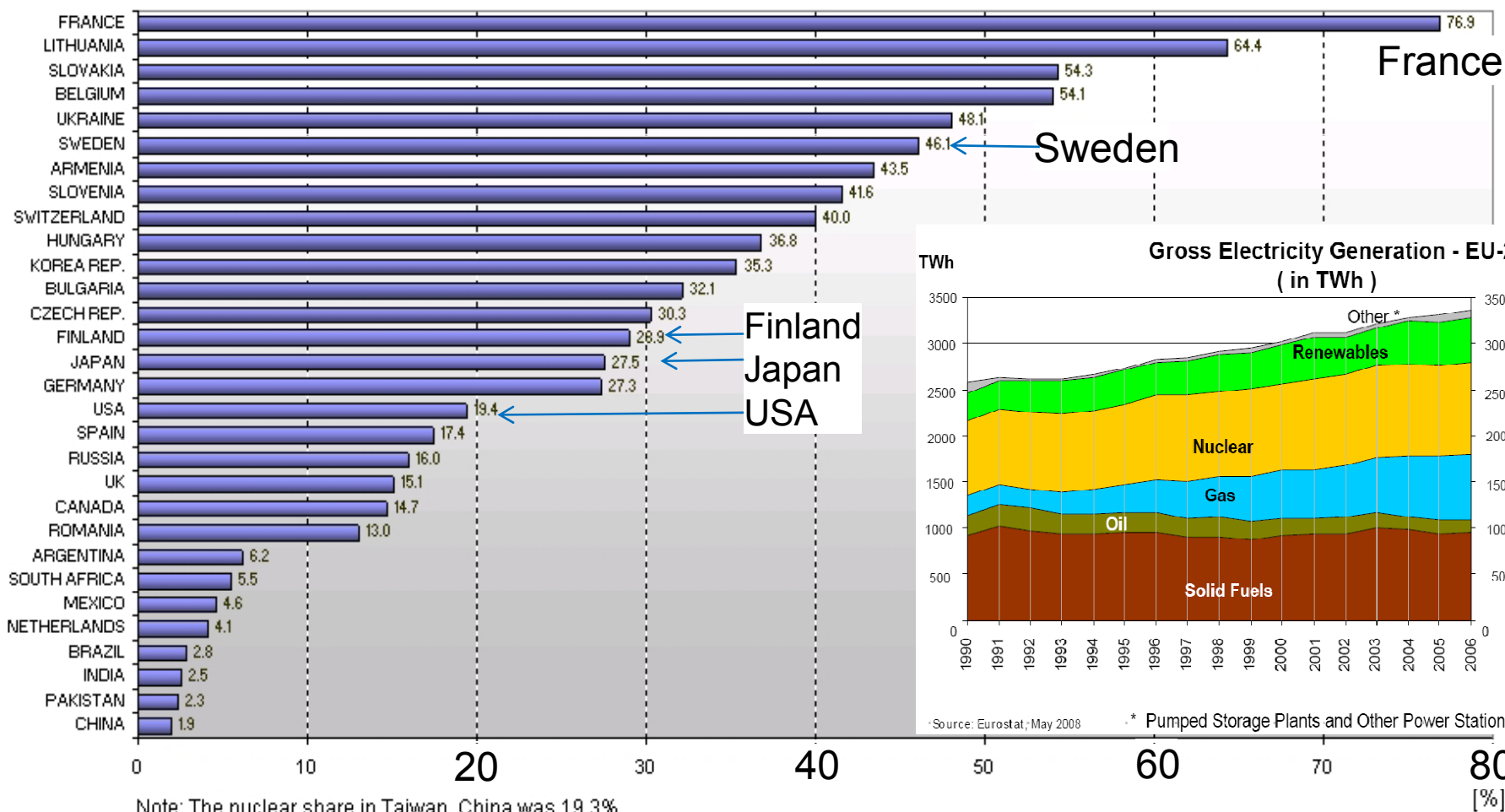


Nuclear Power Plants in the World



Nuclear Share of Electricity Generation

Nuclear Share in Electricity Generation in 2007



Nuclear Power Plants in Europe

- ❑ Most of the world NPPs are in Europe (198 out of 439)
- ❑ Europe has the largest installed power in NPPs (172 GW out of 372 GW in total)
- ❑ Europe produces most electric energy from NPPs (1200 TWh out of 2610 TWh in total)
- ❑ 30% of EU's electric energy is from NPPs

För att ersätta en reaktor i Forsmark...



- Forsmark 1 och Forsmark 2 har en nettoeffekt på nära 980 megawatt vardera – det motsvarar drygt 1,3 miljoner hästkrafter.
- Forsmark 3 har en nettoeffekt på 1 170 megawatt – det motsvarar nära 1,6 miljoner hästkrafter.

Under ett års drift gör varje reaktor av med 20 ton uranbränsle, det är cirka en femtedel av den totala mängden bränsle i reaktorn. Skulle en reaktor ersättas med något alternativ krävs något av följande per år:

För att ersätta en reaktor i Forsmark krävs



Vindkraft

I snitt lämnar ett vindkraftverk full effekt 2 000 timmar per år, då krävs ett par tusen vindkraftverk.



Biobränsle (träflis)

16,5 miljoner m³. Det är runt 15 procent av den totala skogs-avverkningen i Sverige.

Stenkol

Tre miljoner ton. Det är lika mycket som Sveriges årliga import.



Vattenkraft



Det skulle kräva utbyggnad av Torne älv och Kalix älv.

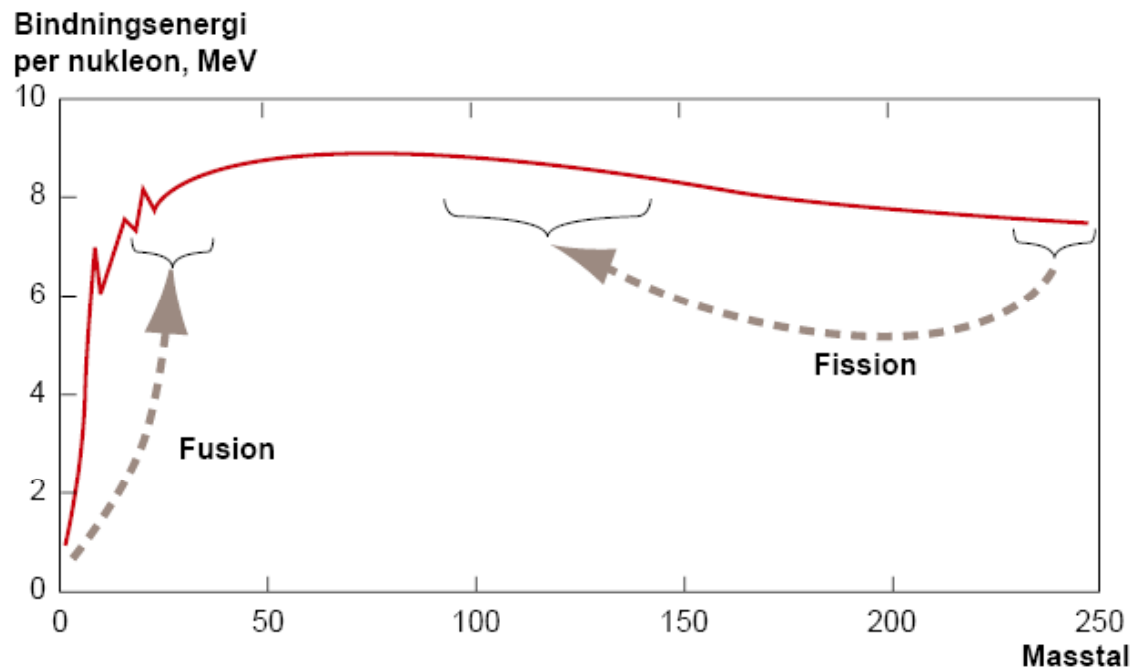
Naturgas eller olja



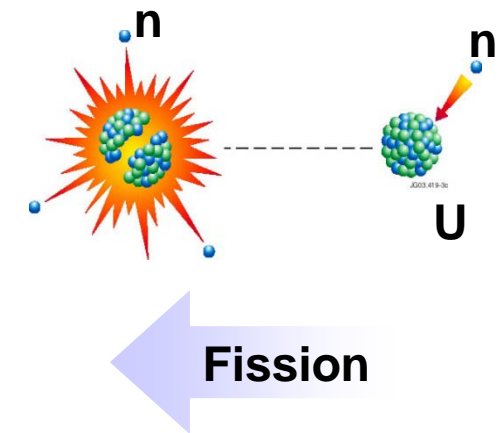
- Naturgas: 2,1 miljarder m³. Det är mer än dubbelt så mycket som Sverige importerar idag.
- Olja: 2,1 miljoner m³. Det är en tredjedel av allt bränsle som bilarna i Sverige förbrukar.

Fission reactors

Nuclear binding energy

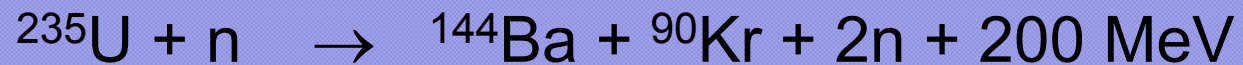


Figur 1 Atomkärornas bindningsenergi



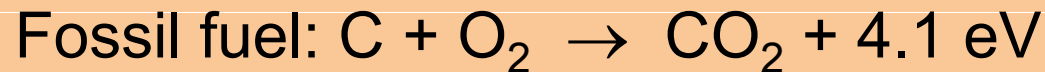
$$\text{Binding energy: } E = \Delta m \cdot c^2 = (Z \cdot m_p + N \cdot m_n - m_a) \cdot c^2$$

Energy released in fission of U-235



Fission energy:

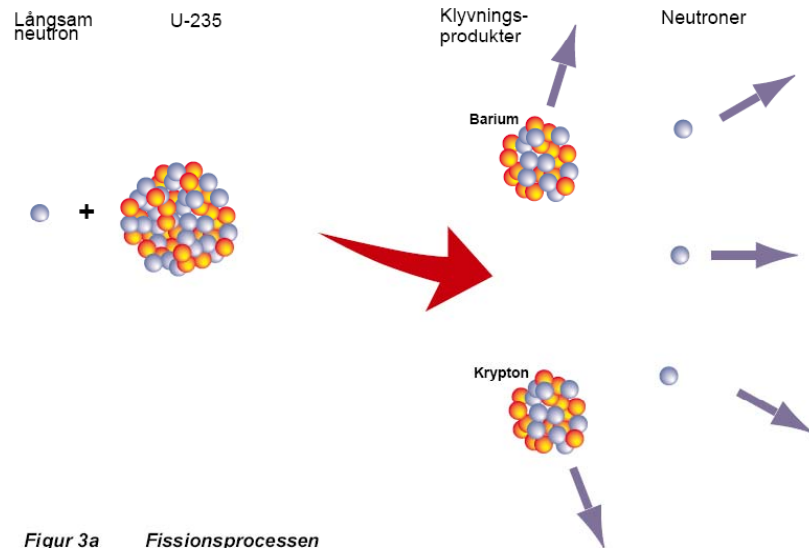
$$\begin{aligned}\Delta E &= E_B({}^{144}\text{Ba}) + E_B({}^{90}\text{Kr}) - E_B({}^{235}\text{U}) \\ &\approx 144 \cdot 8.4 \text{ MeV} + 90 \cdot 8.6 \text{ MeV} - 235 \cdot 7.6 \text{ MeV} \\ &\approx 200 \text{ MeV}\end{aligned}$$



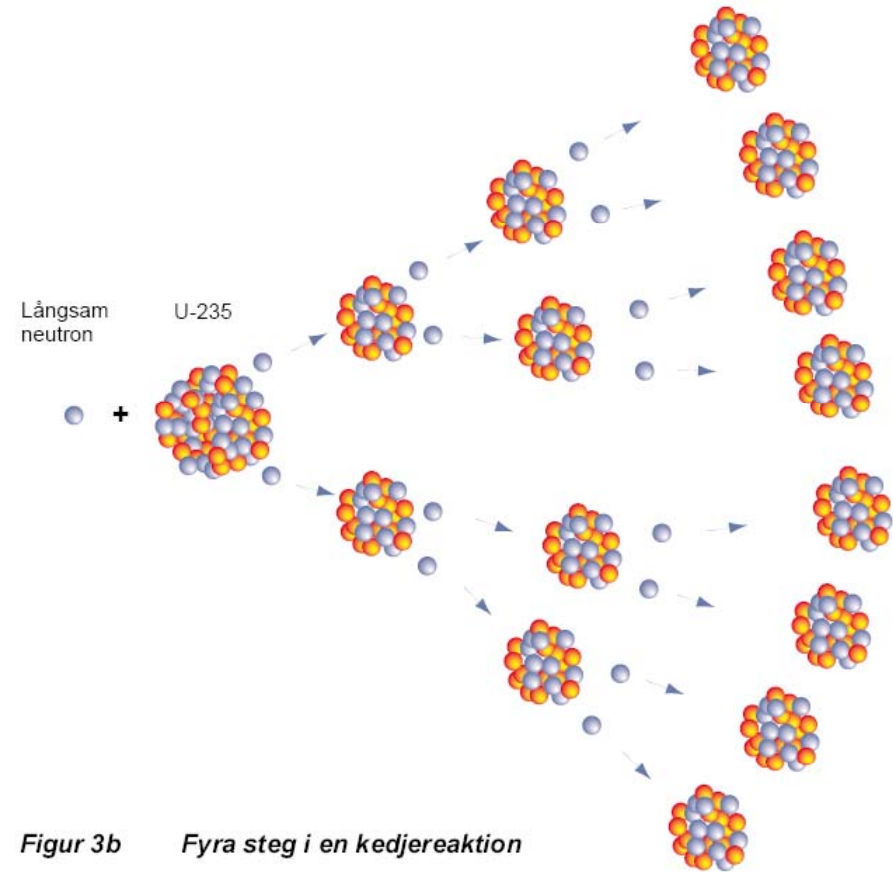
Energy released in fission

Energy	MeV
Kinetic energy of fission fragments	168
Prompt gamma radiation	5
Kinetic energy of fission neutrons	5
Beta decay of fission products	7
Gamma decay of fission products	6
Neutrinos	11
Total	202

Nuclear chain reaction



Figur 3a Fissionsprocessen

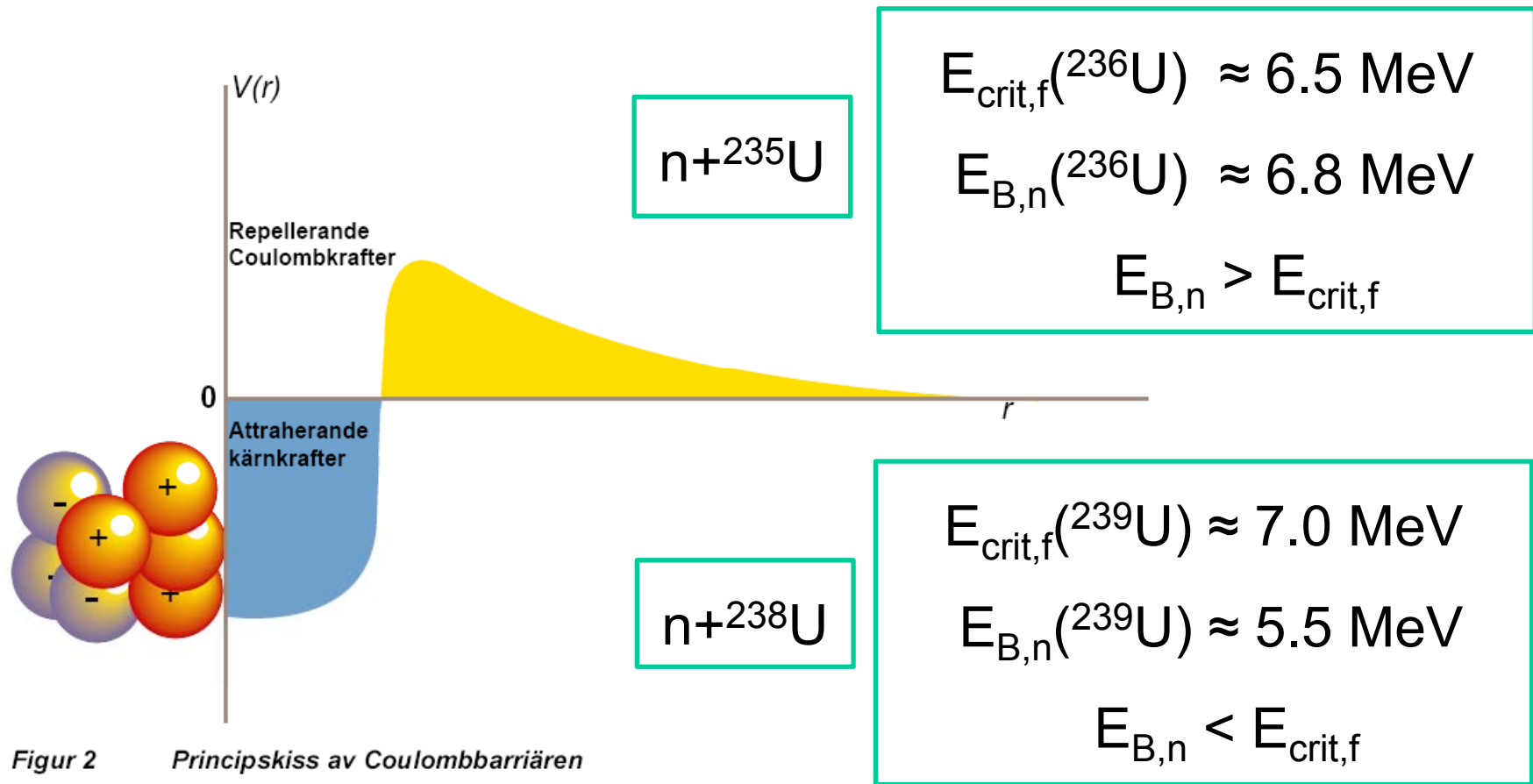


Nuclear chain reaction

- Effective multiplication factor (k_{eff}): No. fission neutrons in one generation / neutrons in previous generation
 - $k_{\text{eff}} < 1$ subcritical
 - $k_{\text{eff}} = 1$ critical
 - $k_{\text{eff}} > 1$ supercritical
- Neutron economy:
 - neutron leakage
 - non-fission cross section

Safe reactor operation: $k_{\text{eff}} < 1.001$

Nuclear and Coulomb forces



Figur 2 Principskiss av Coulombbarriären

Fission cross section – ^{235}U

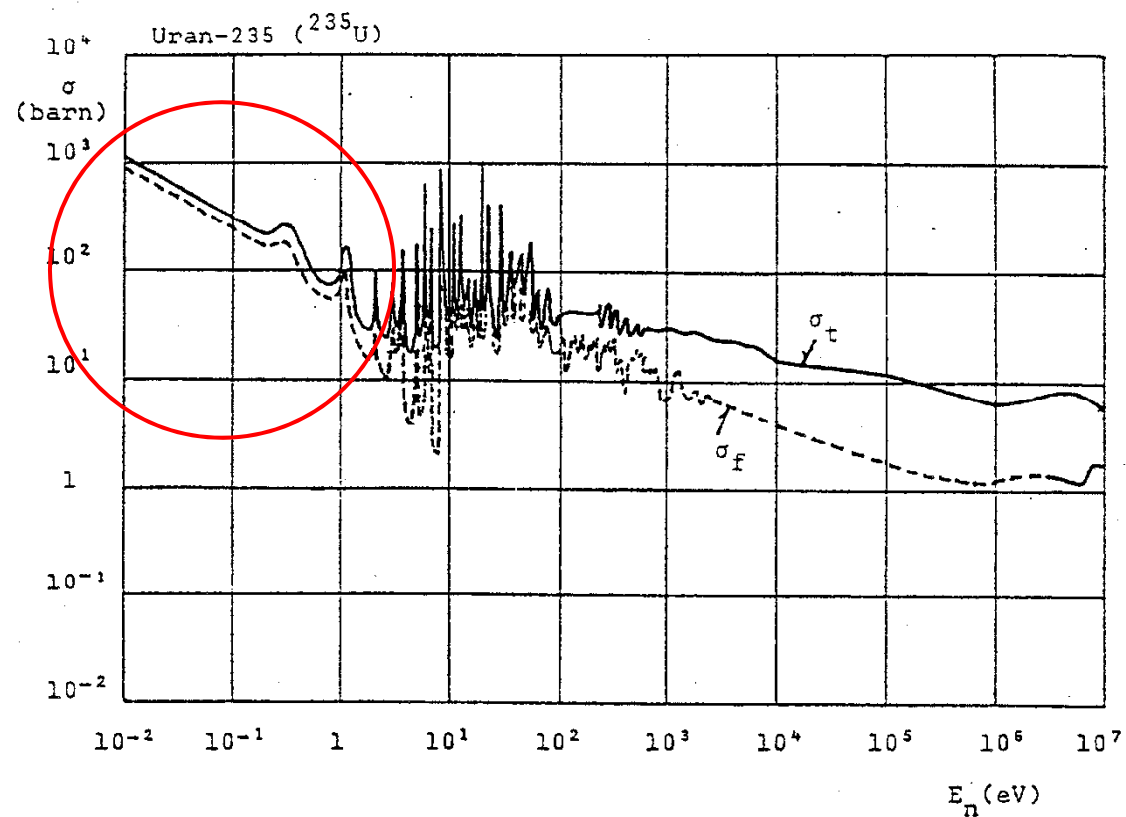


Fig.23. Uran-235's total- og fissionstværsnit versus neutronenergien.

Fission cross section – ^{238}U

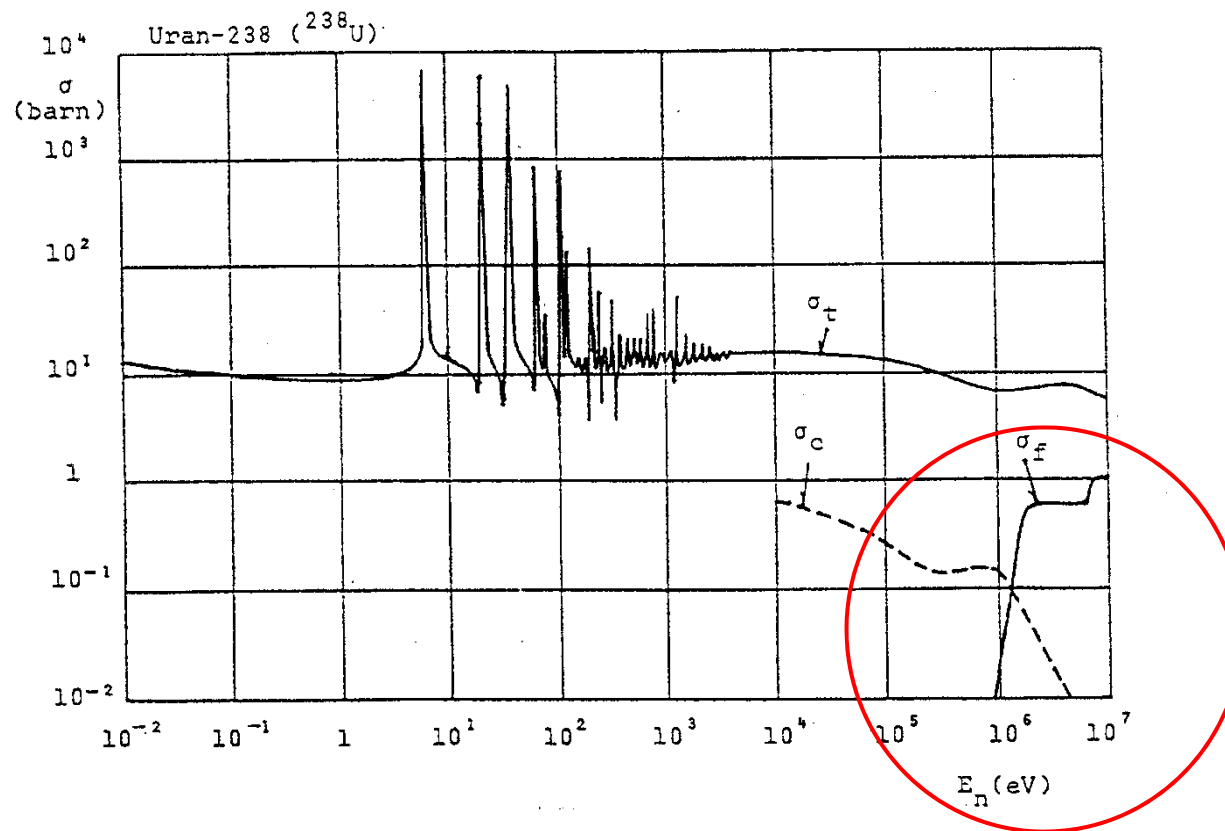


Fig.22. Uran-238's total-, fissions- og indfangningstværsnit uden fission versus neutronenergien.

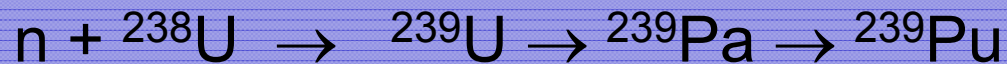
Nuclear chain reaction

A self-sustained chain reaction is not possible
in natural uranium (0.7% ^{235}U)

1. Fast neutrons, 10-20% enriched uranium fuel
2. Thermal neutrons, moderator: ^{12}C , H_2O , D_2O ,
and natural or 2-5% enriched uranium fuel

Nuclear chain reaction – thermal neutrons

- Fuel breeding:



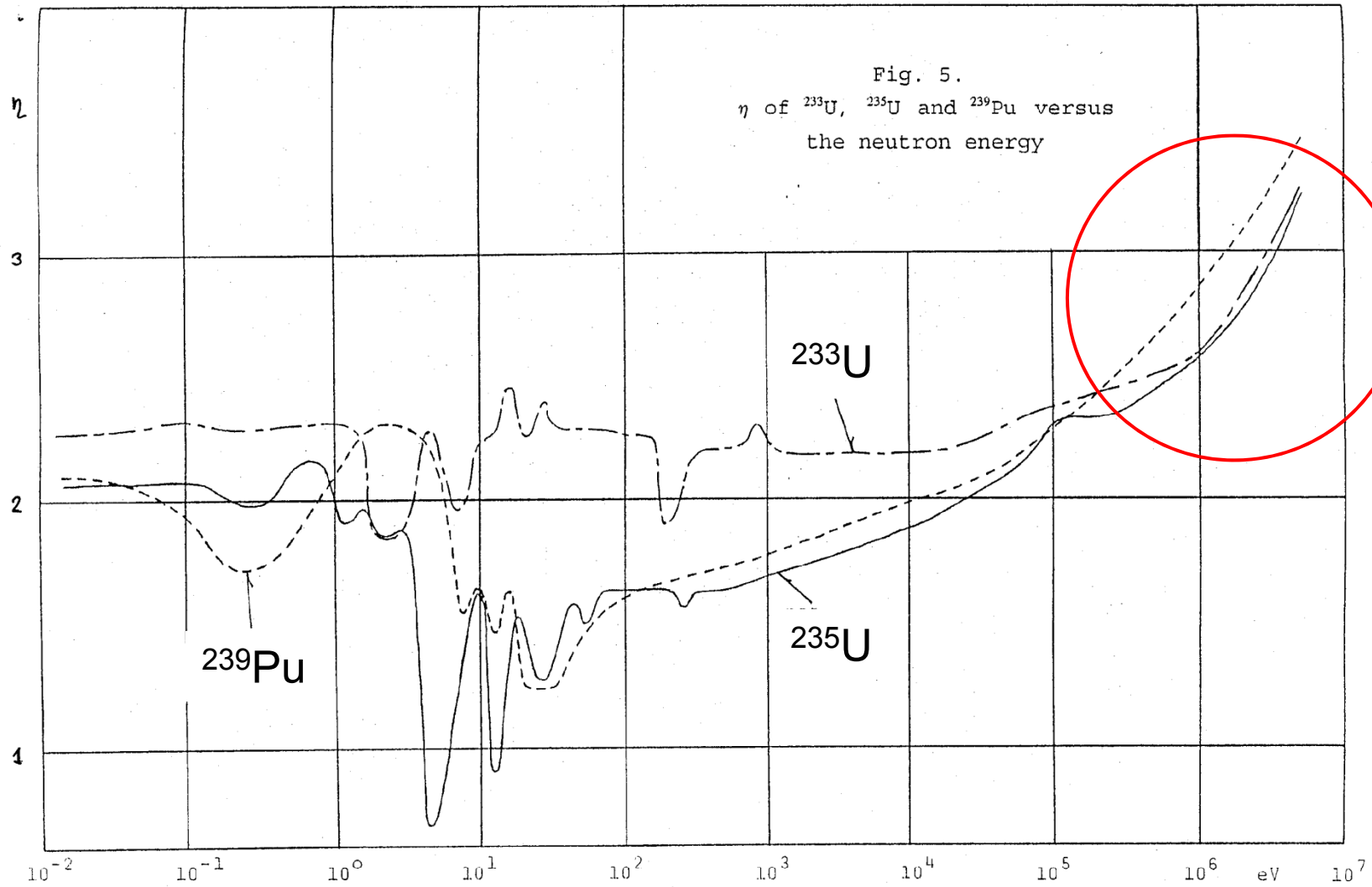
- Neutron yield (η):

No. produced neutrons per captured **thermal** neutron

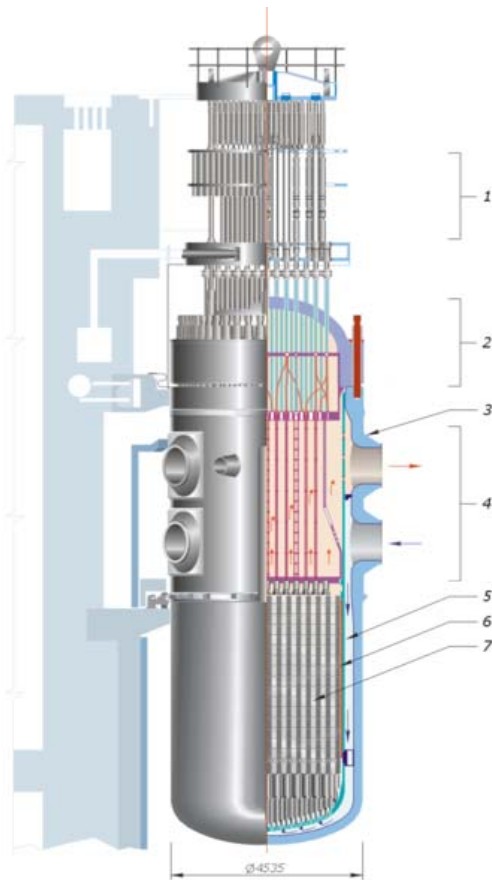
Nuclide	${}^{233}\text{U}$	${}^{235}\text{U}$	${}^{239}\text{Pu}$	Nat. uran.
η	2.28	2.05	2.09	1.3

→ Fast neutrons needed for breeder reactors

η for ^{233}U , ^{235}U og ^{239}Pu

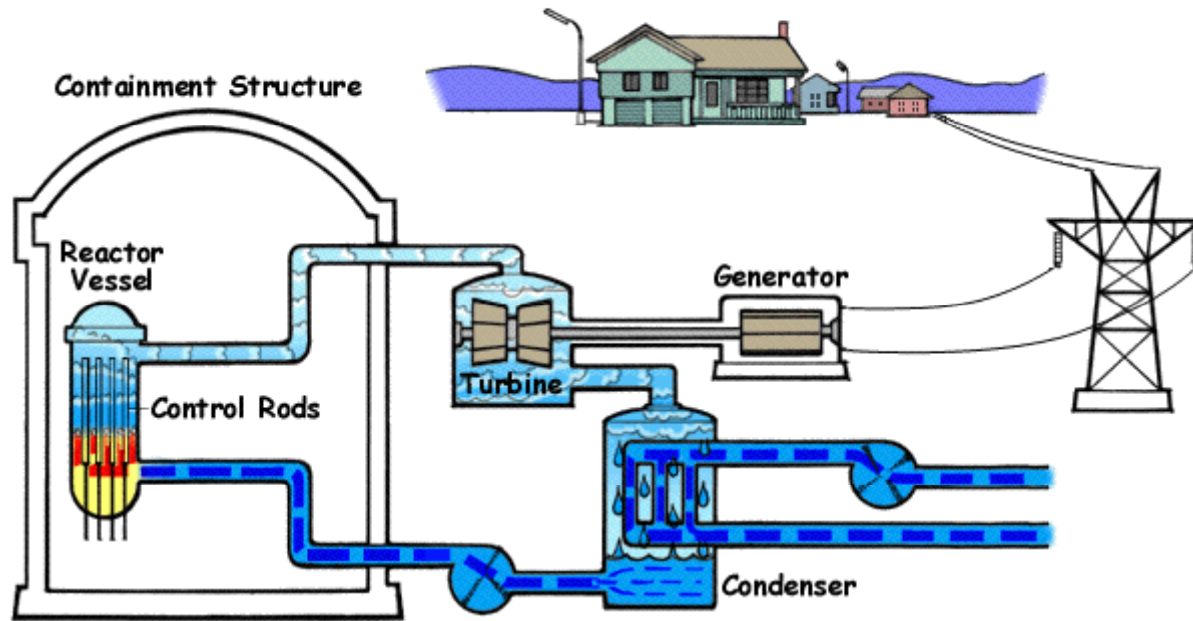


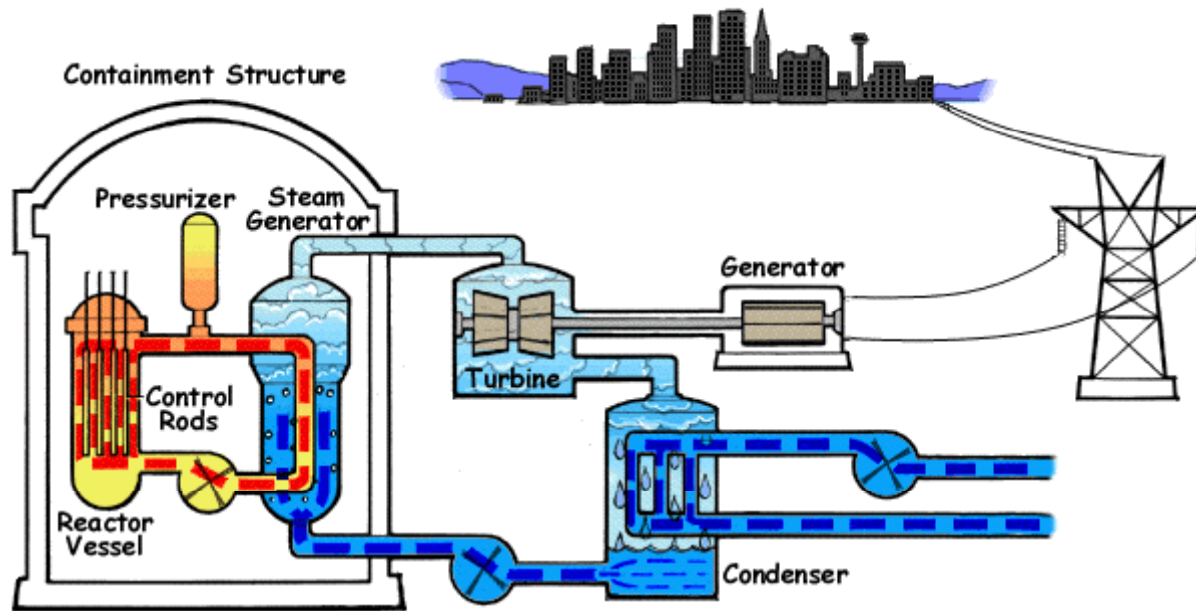
Nuclear reactors by type



	Thermal (LWR, HWR, GCR)	Fast (FBR, LMFBR)
Fuel	3-5% U-235 Pu-239	10-20% U-235 Pu-239 Th-232 + U-233
Moderator	H ₂ O, D ₂ O Graphite	—
Coolant	H ₂ O, D ₂ O CO ₂ , He	Liquid metals, metal alloys

Boiling Water Reactor - BWRc





Opportunities and Challenges

Nuclear renaissance?

Opportunities

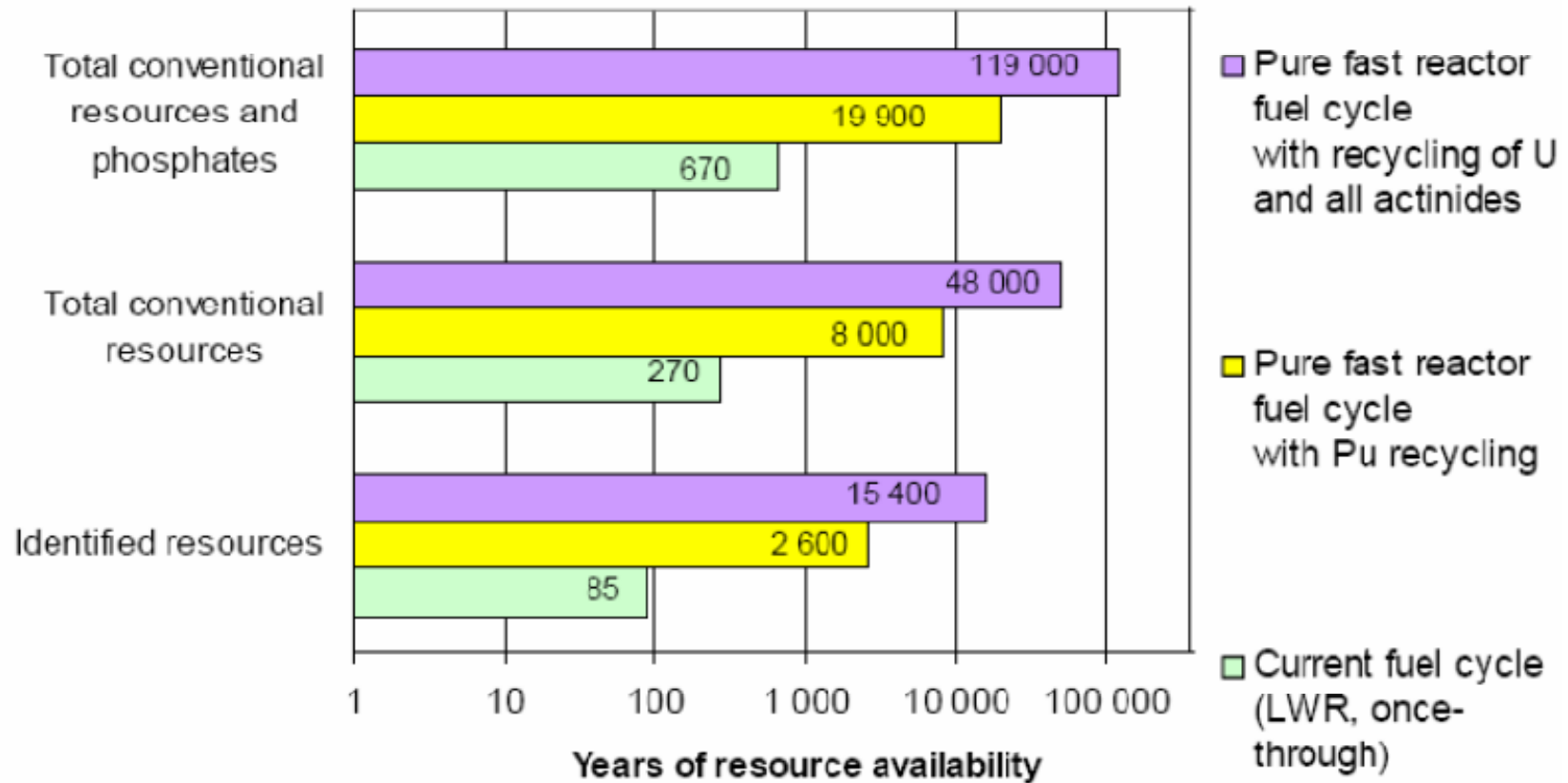
- Security of supply
- Environmental issues
- Economy

Challenges

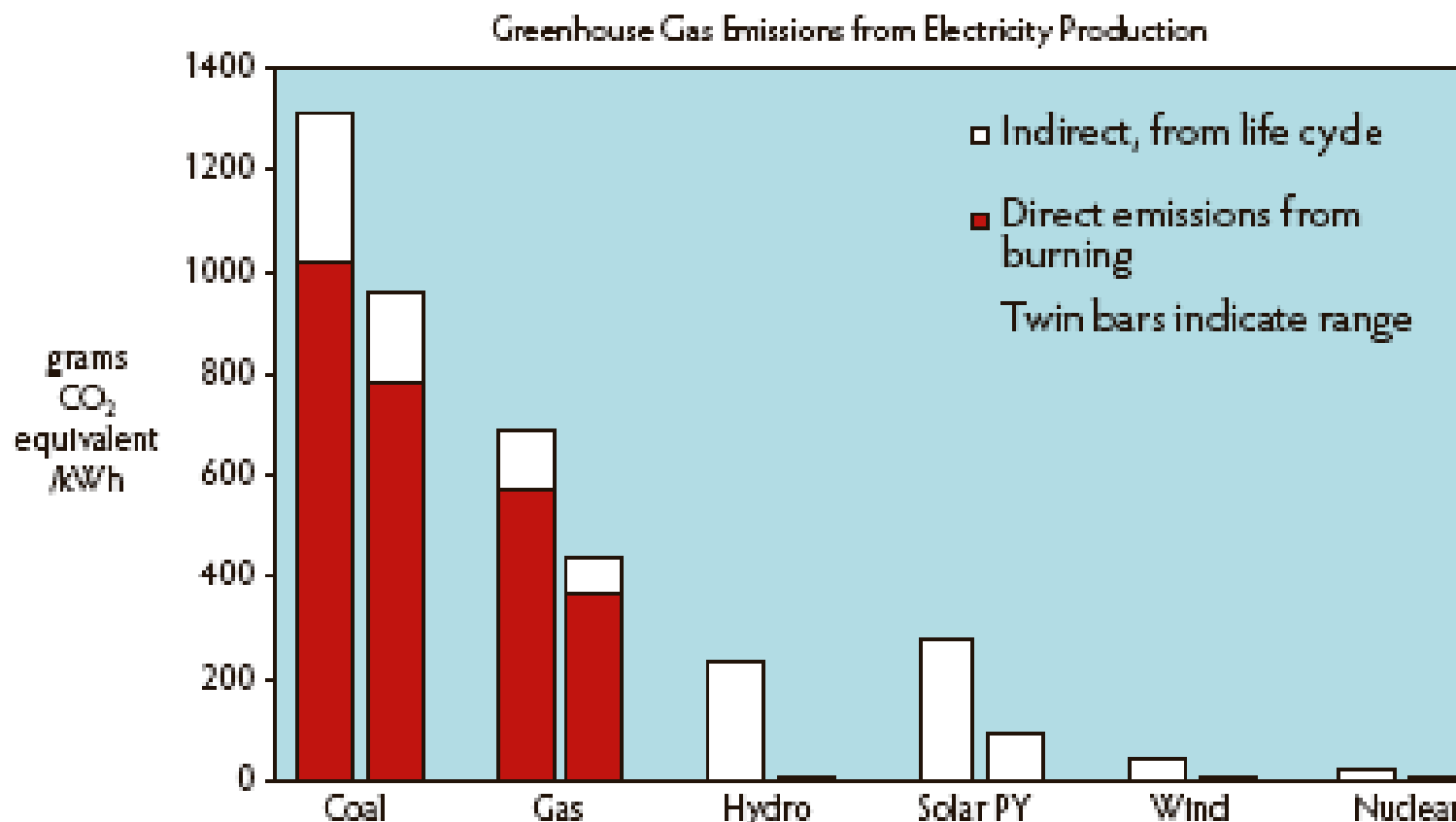
- Aging fleet of reactors
- Waste management
- Proliferation issues
- Public acceptance

- Uranium will last 100-200 years depending on the scenario for new builds
- Uranium will last thousands of years if reprocessing and recycling is applied
- Thorium is another reserve that can be used

Back

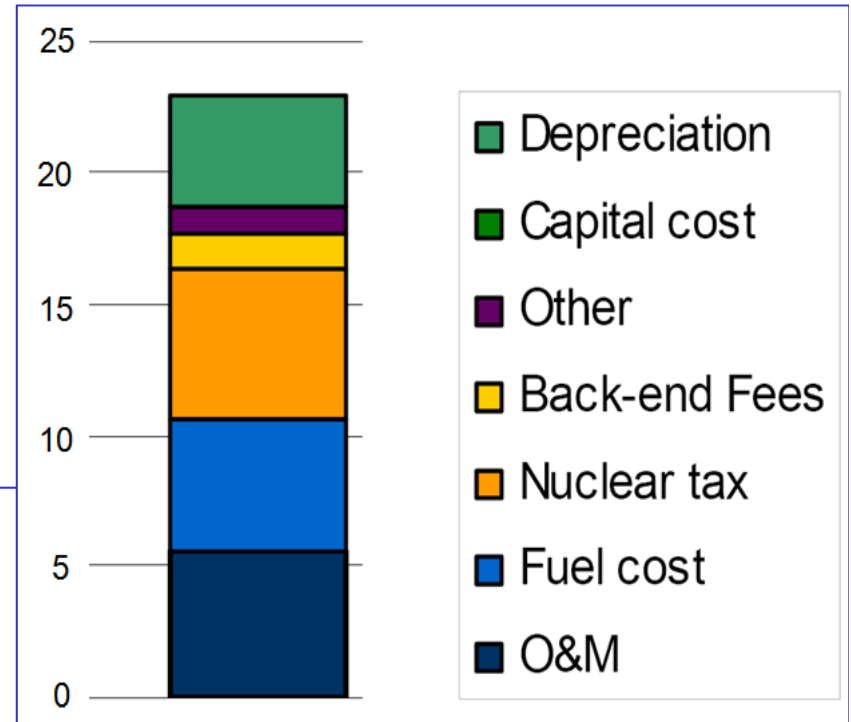


Source: *Uranium 2005 – Resources, Production and demand, Joint Report by the OECD NEA and IAEA.*

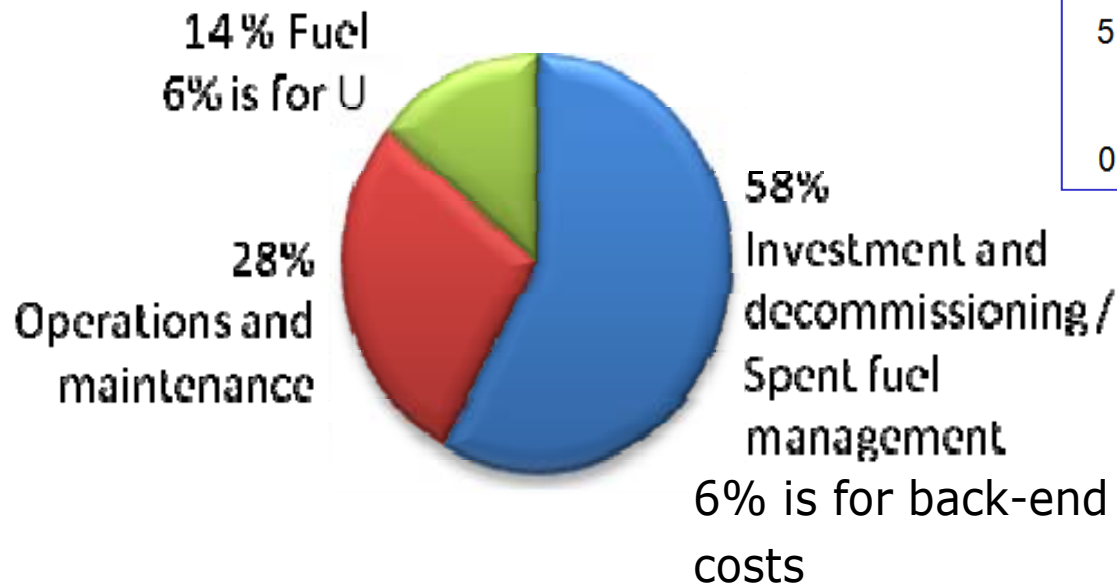


Source: IAEA 2000

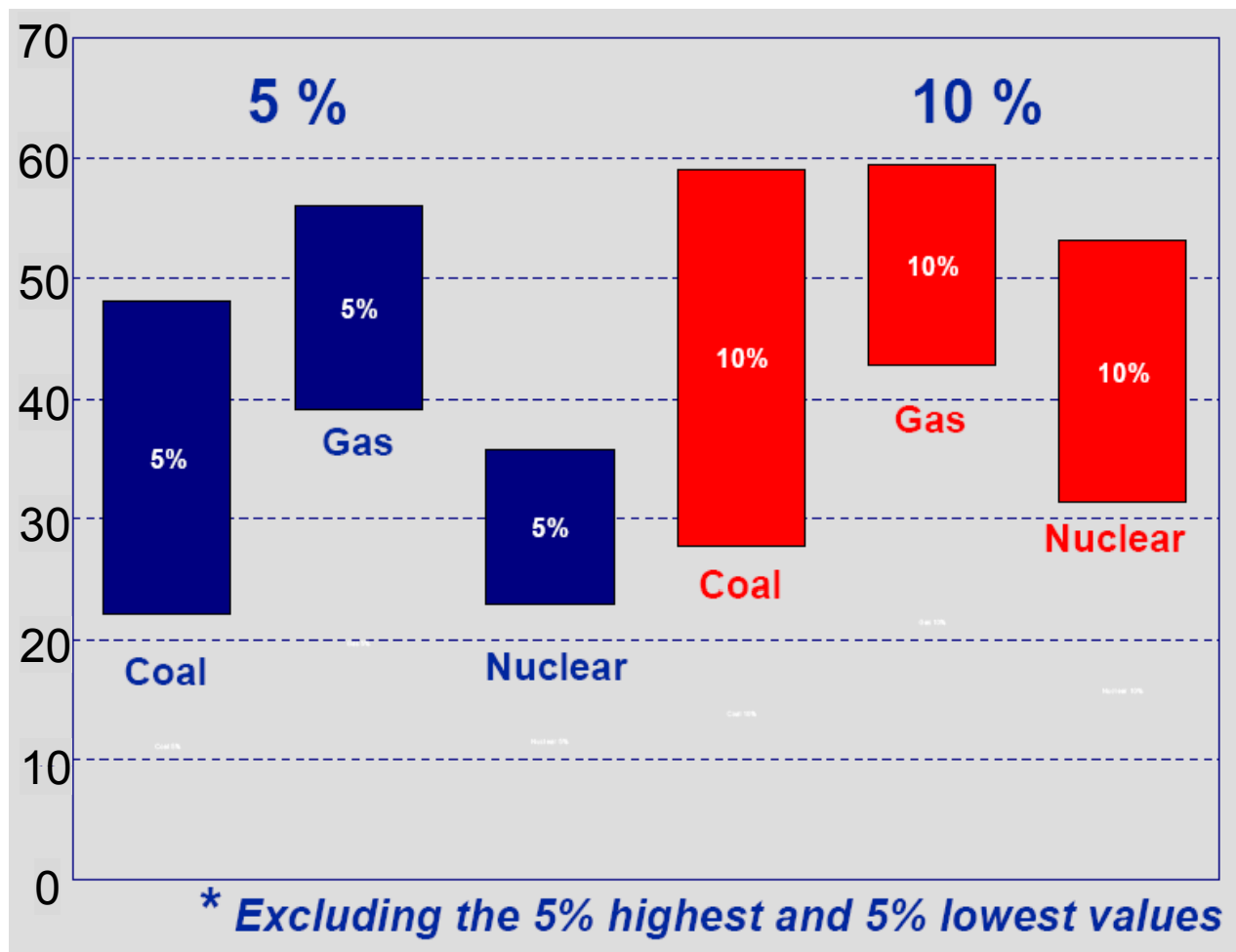
*Typical Swedish Cost Distribution
(öre/kWh)*



Typical International Cost Distribution



Levelised Cost (USD/MWh)



Source: OECD/NEA, IEA study 2005

Challenges for nuclear power production

Main challenges

Aging fleet of reactors

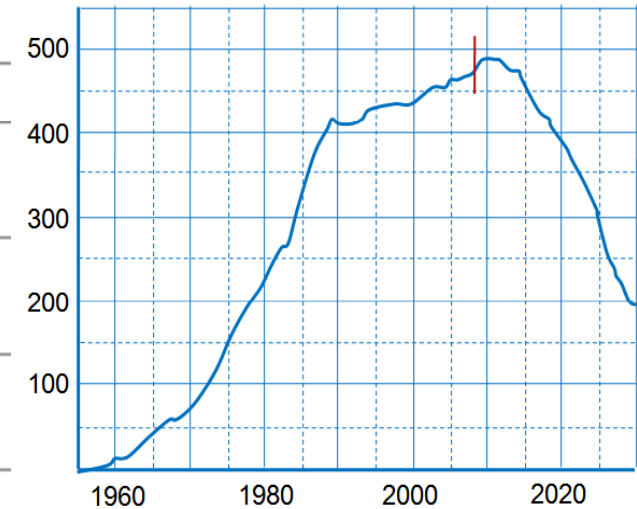
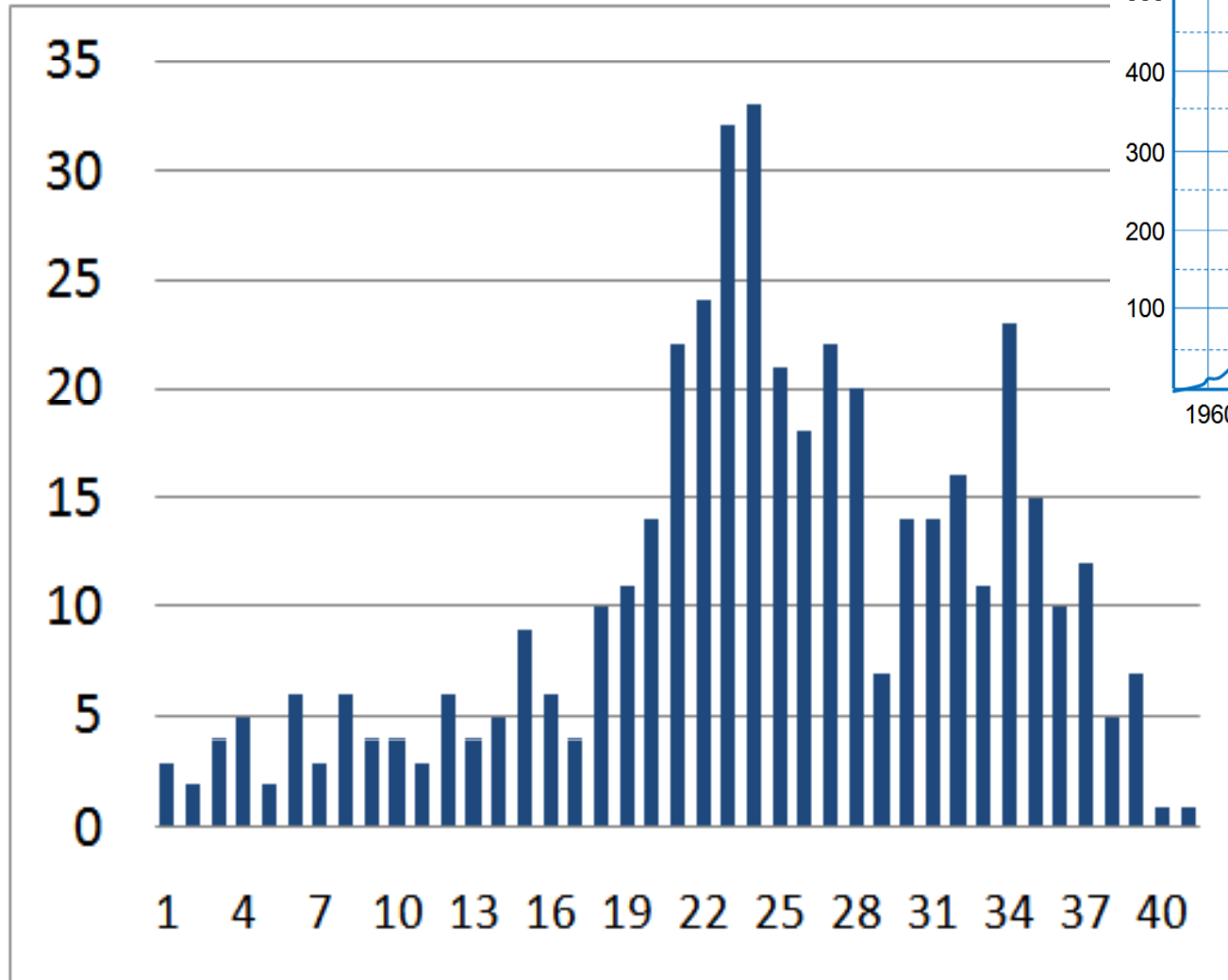
Waste management

Proliferation issues

Public acceptance

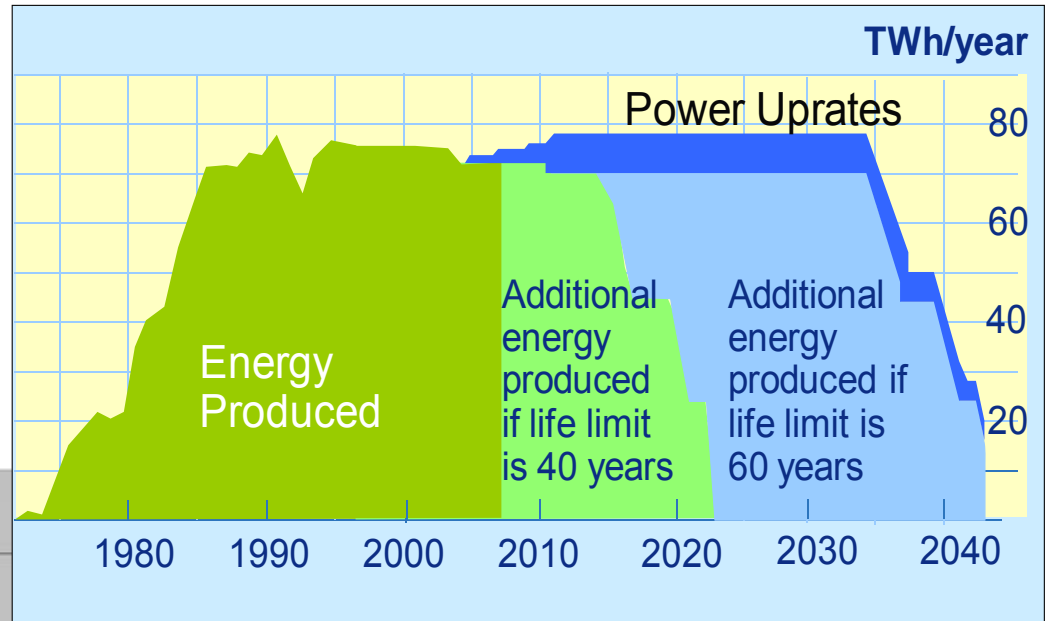
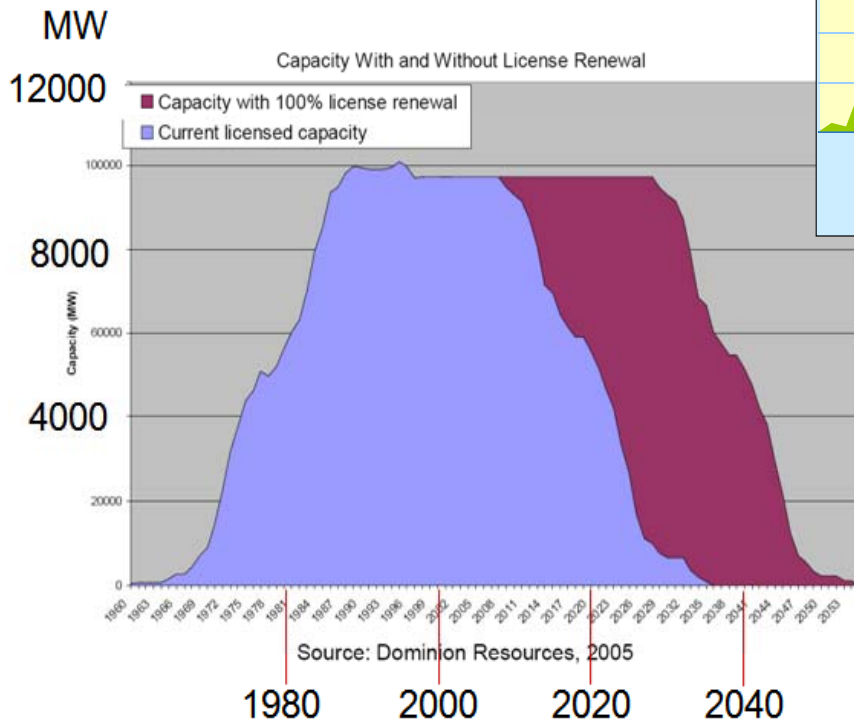
An Aging Fleet of Reactors

Number



Age

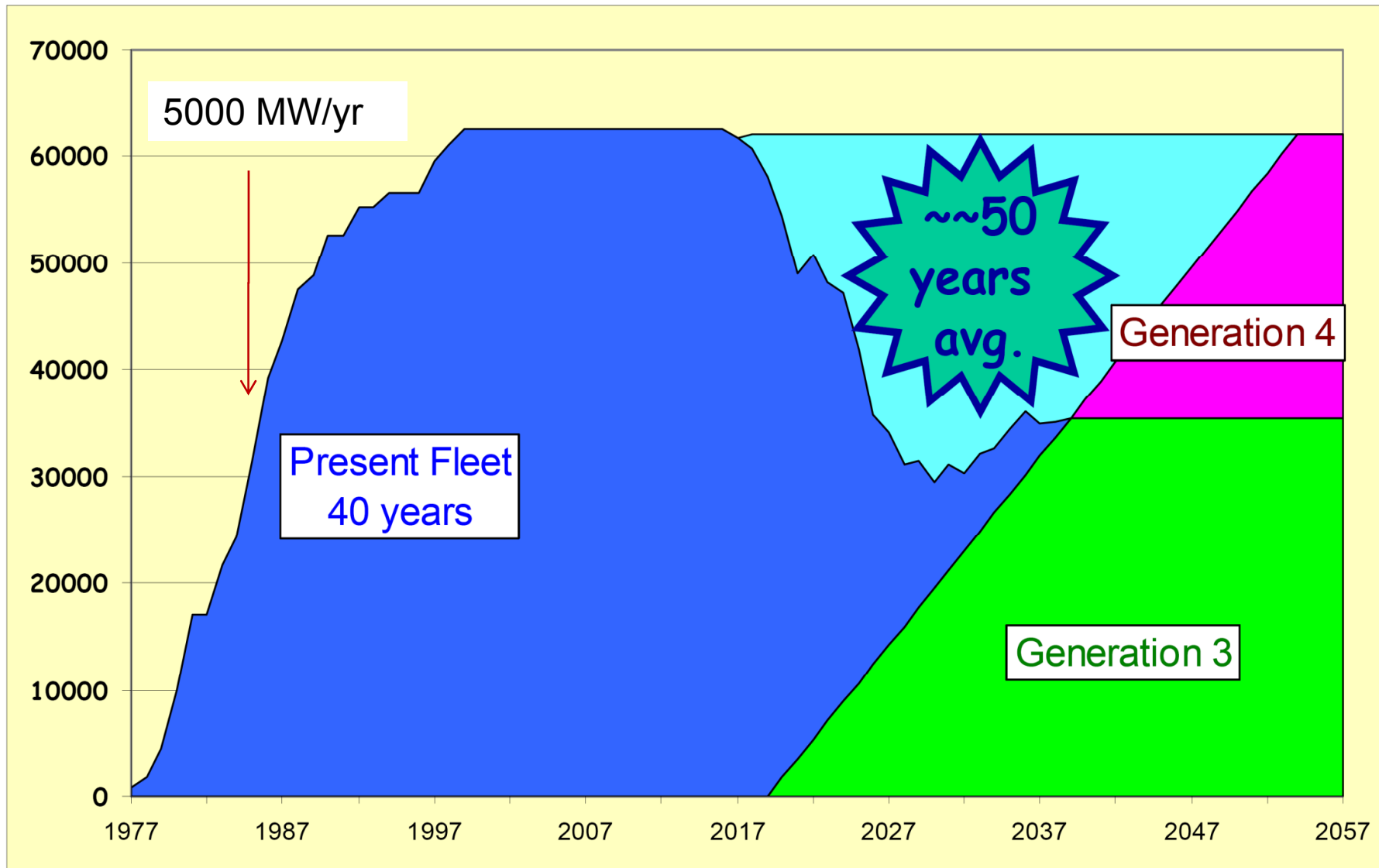
Original design life-time typically 40 years.
Most owners aim for an extension to 60 years.



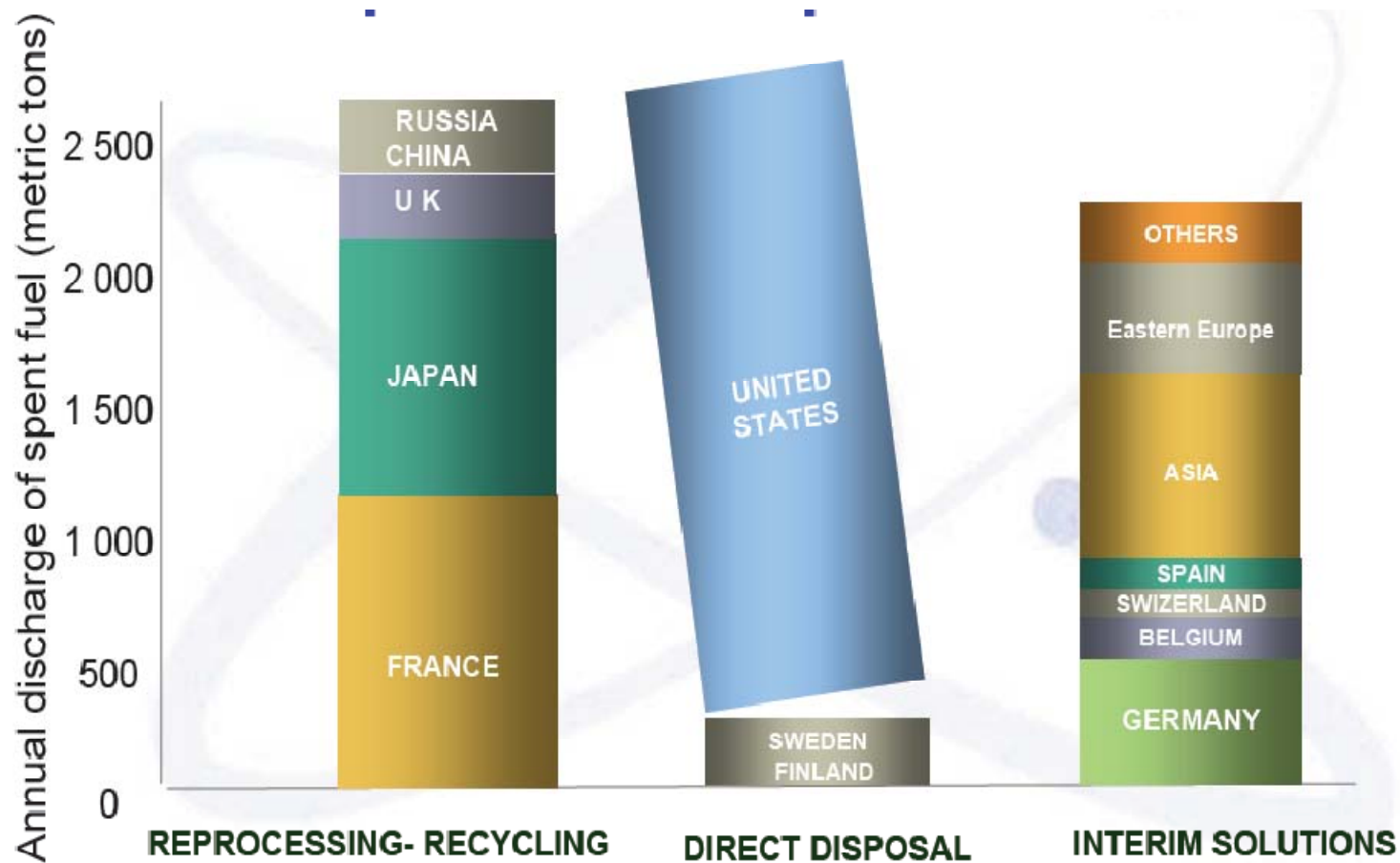
SWEDEN

USA

Life-Extension and New Technology are Required, France

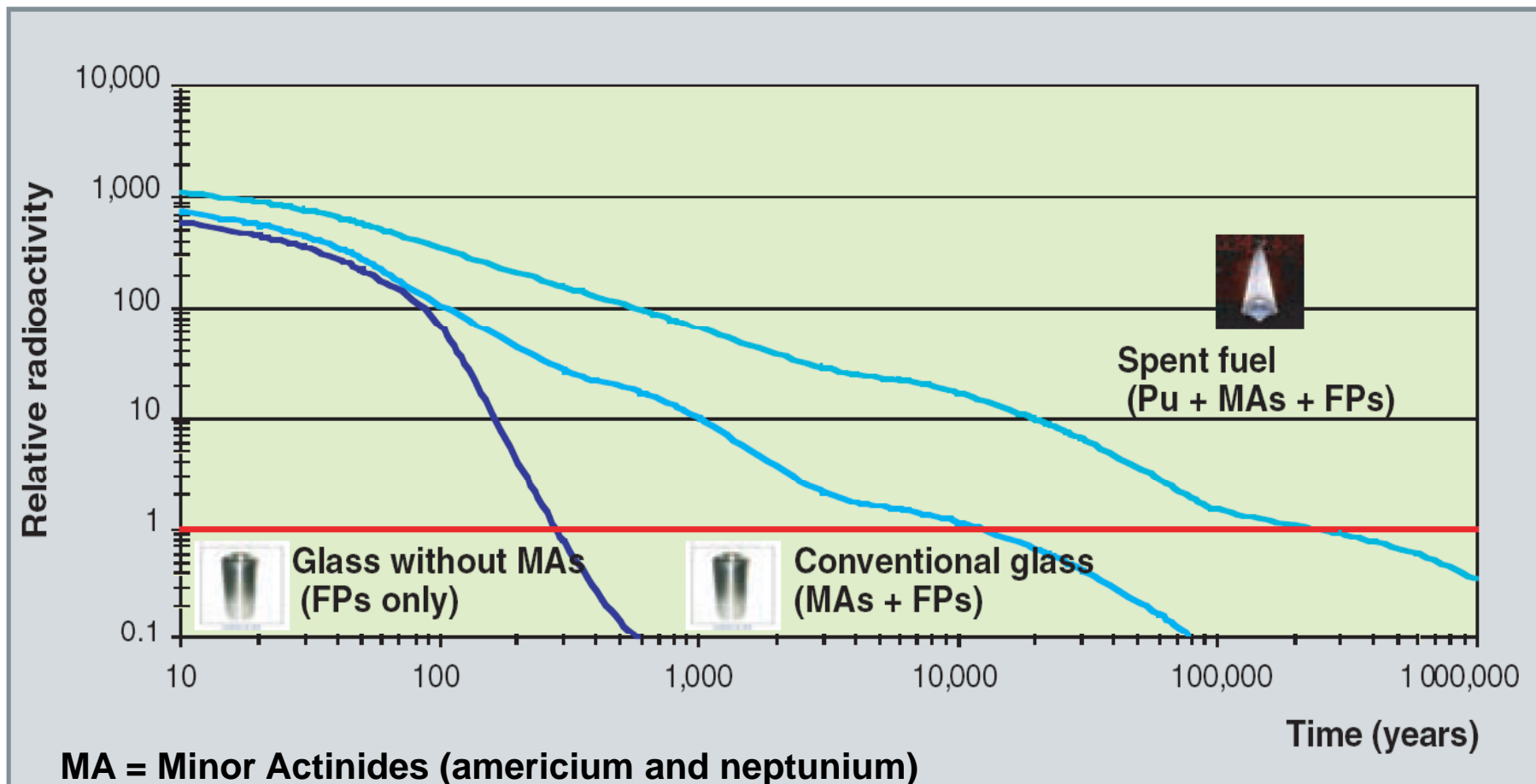


- Waste handling approach varies between countries – reprocessing requires large scale investments



- Radiotoxicity – relative to natural uranium

Back



MA = Minor Actinides (americium and neptunium)

FP = Fission Products

Public & Political Acceptance

Eurobarometer QA1 (2007)

When you think about nuclear power, what comes first to mind:

- A The advantages of nuclear power as an energy source outweigh the risks it poses
- B The risks of nuclear power as an energy source outweigh its advantages

Eurobarometer QA1

When you think about nuclear power, what comes first to mind:

- A The advantages of nuclear power as an energy source outweigh the risks it poses
- B The risks of nuclear power as an energy source outweigh its advantages

DK: A: 28%, B: 66%, neither: 6%

EU: A: 33%, B: 53%, neither: 14%

Eurobarometer QA5 (2007)

How well informed do you think you are about the safety of nuclear power plants?

- Very well informed
- Fairly well informed
- Not very well informed
- Not at all informed

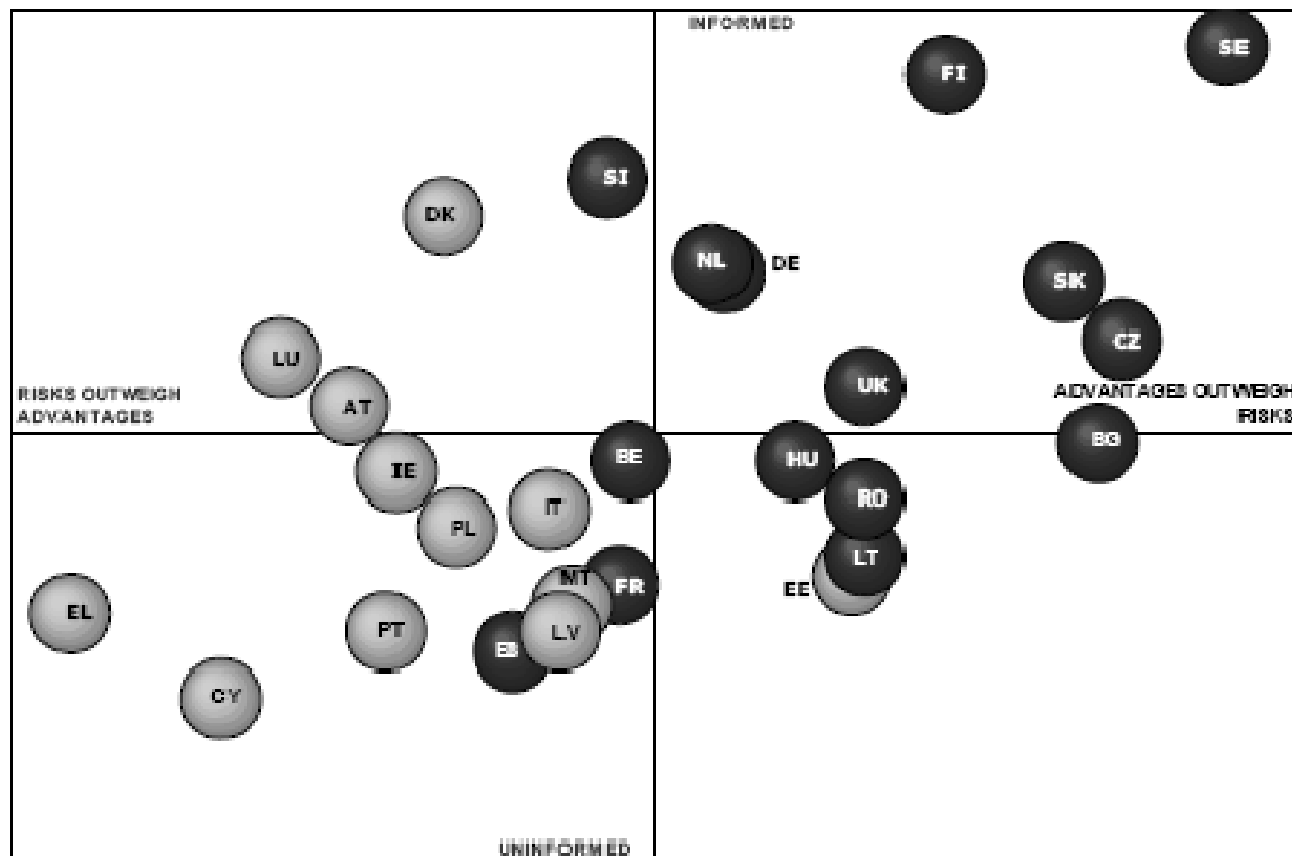
Eurobarometer QA5

How well informed do you think you are about the safety of nuclear power plants?

- Very well informed
- Fairly well informed
- Not very well informed
- Not at all informed

	DK	EU
• Very well or well informed	34%	23%
• Not very well or not at all informed	64%	76%
• Neither	2%	1%

POSITION OF EUROPEAN COUNTRIES ACCORDING TO RISK PERCEPTION AND THE FEELING OF BEING INFORMED

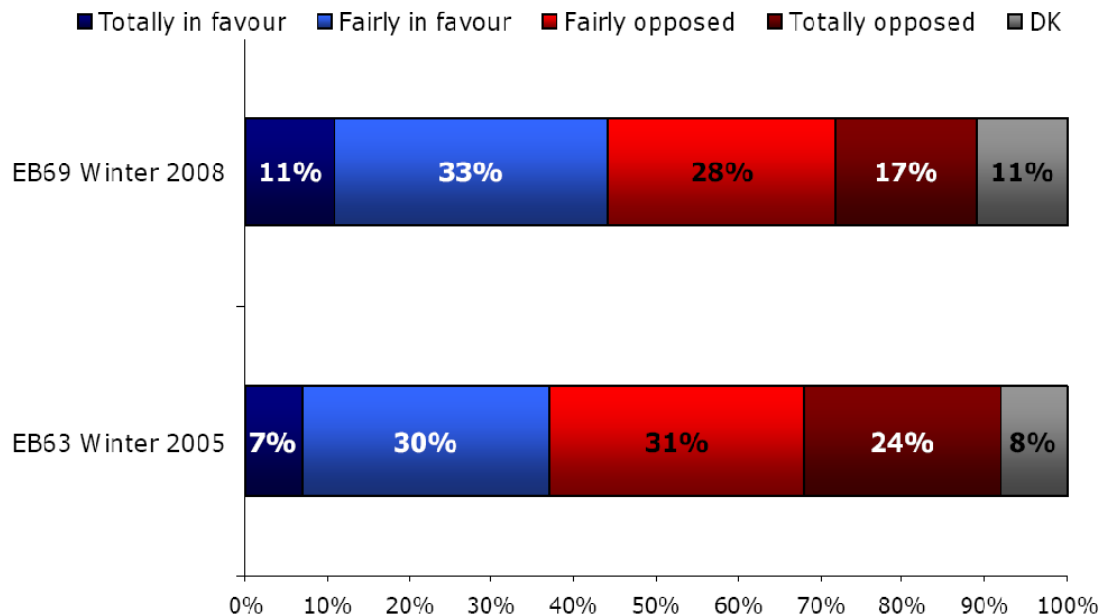


Feeling of being informed vs. risk perception

Public Acceptance and Political Decisions

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

%EU



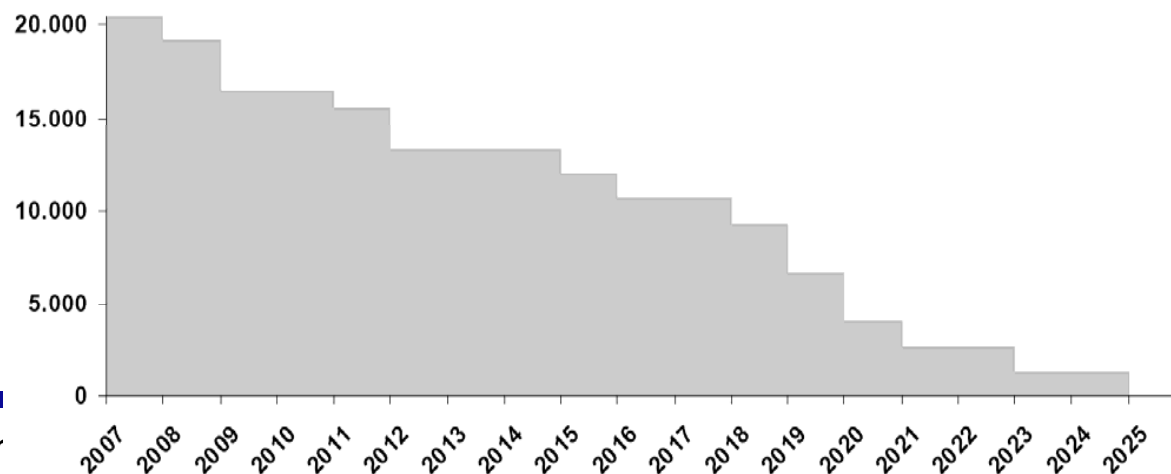
Public Opinion Development

Political Decision to build 10-15 GW New Nuclear Power in the UK confirmed January 2008

Political Decision for Nuclear Phase-out in Germany

Source: Special Eurobarometer 297. "Attitudes towards Radioactive Waste", June 2008

Aart

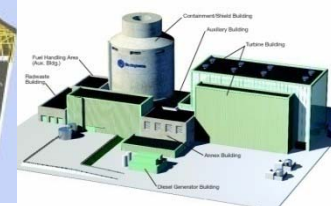
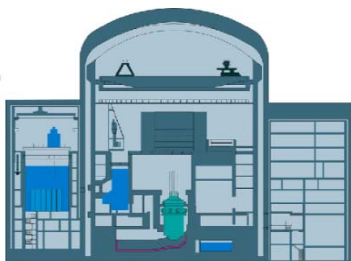
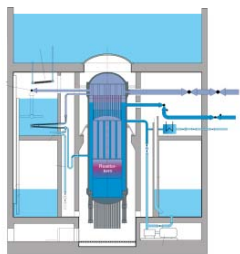


The Future

Until 2050 and beyond

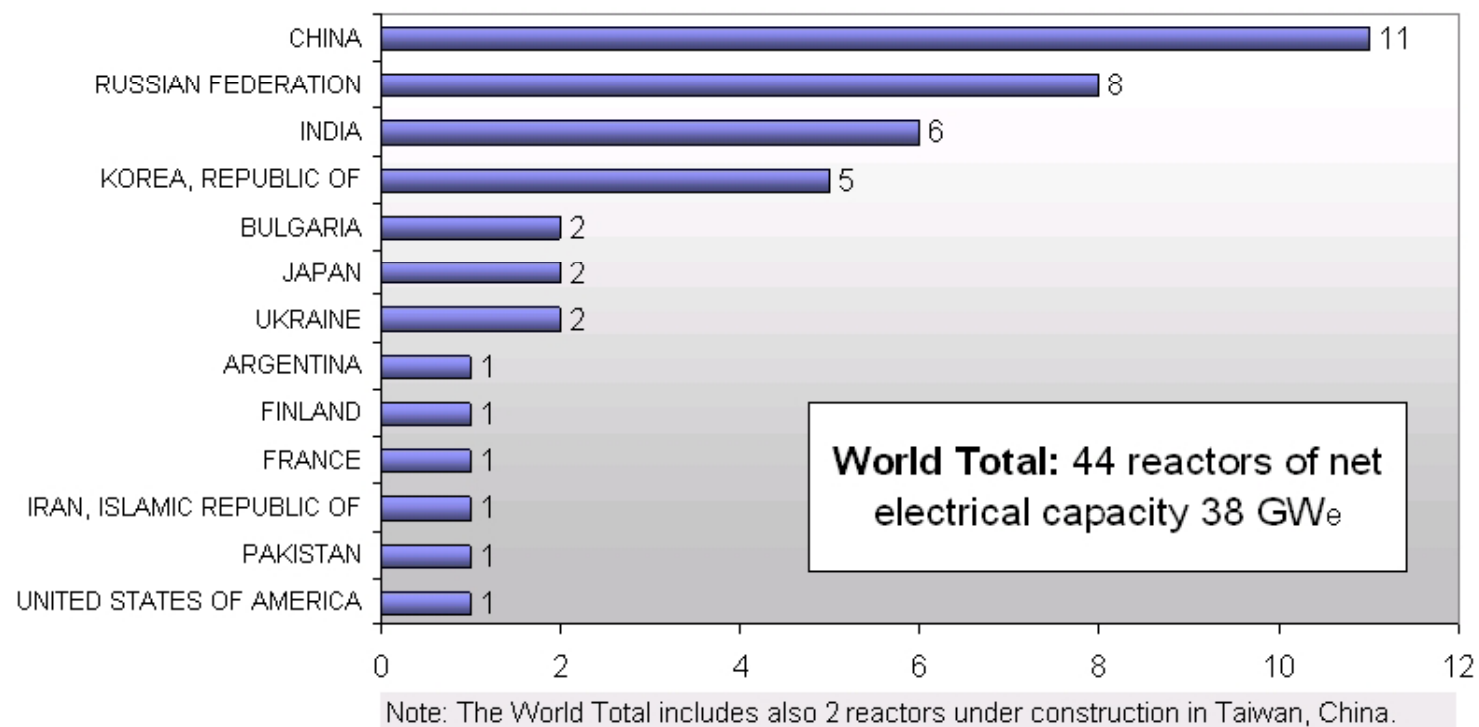
Generation 3 och 3+ Available on the market today

Type	Model	Electric power	Supplier	Country of origin
BWR	ABWR	1400 – 1600 MW	GE/Hitachi, Toshiba/W	USA Japan
	SWR1000	1250 MW	Areva	France
	ESBWR	1550 MW	GE/Hitachi	USA
PWR	EPR	1600 – 1750 MW	Areva	France / Germany
	AP1000	1150 MW	Westinghouse	USA
	APWR	1700 MW	Mitsubishi	Japan



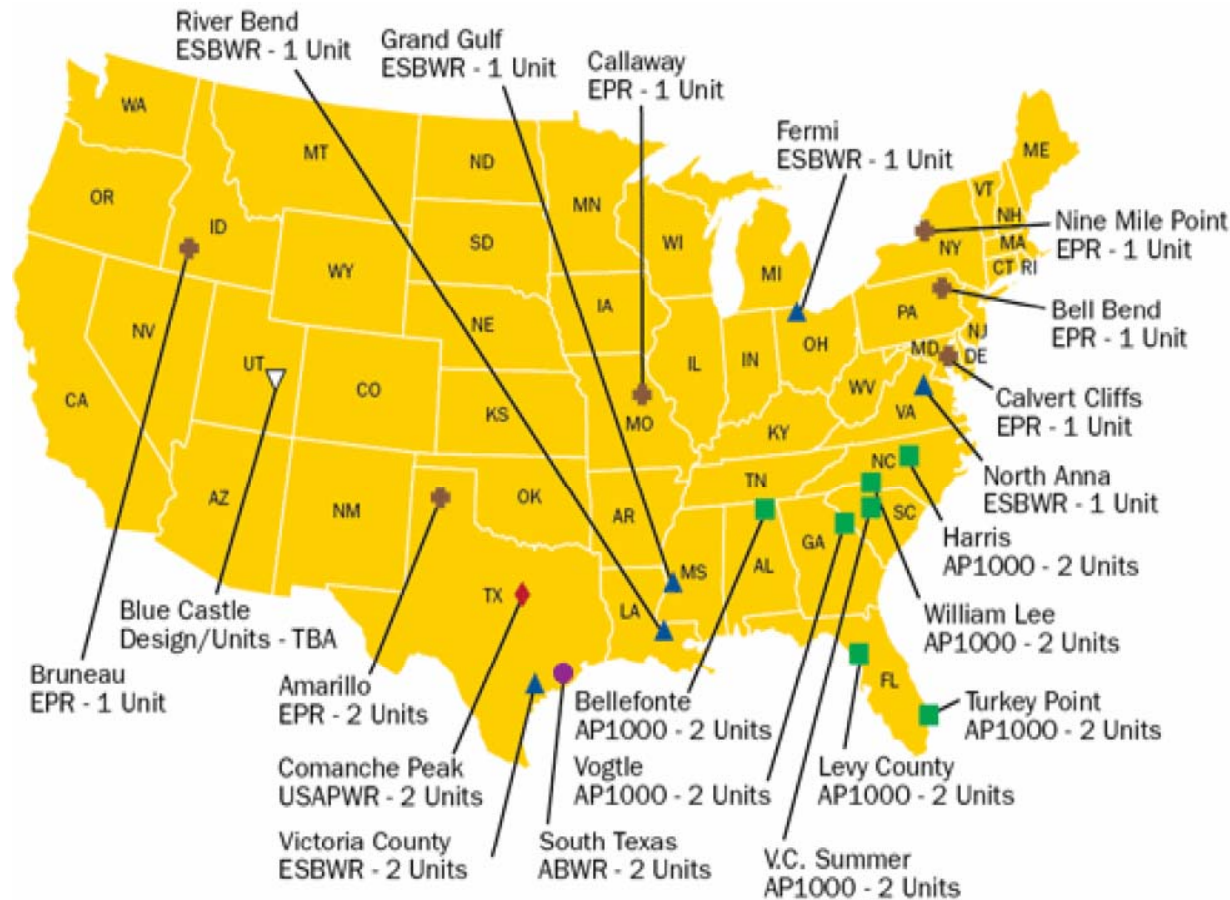
More than 40 New Nuclear Power Plant Builds in Progress and Another Close to 100 are Planned

Number of Reactors under Construction Worldwide



Source: © 2000 International Atomic Energy Agency.

New Plants Planned in the USA



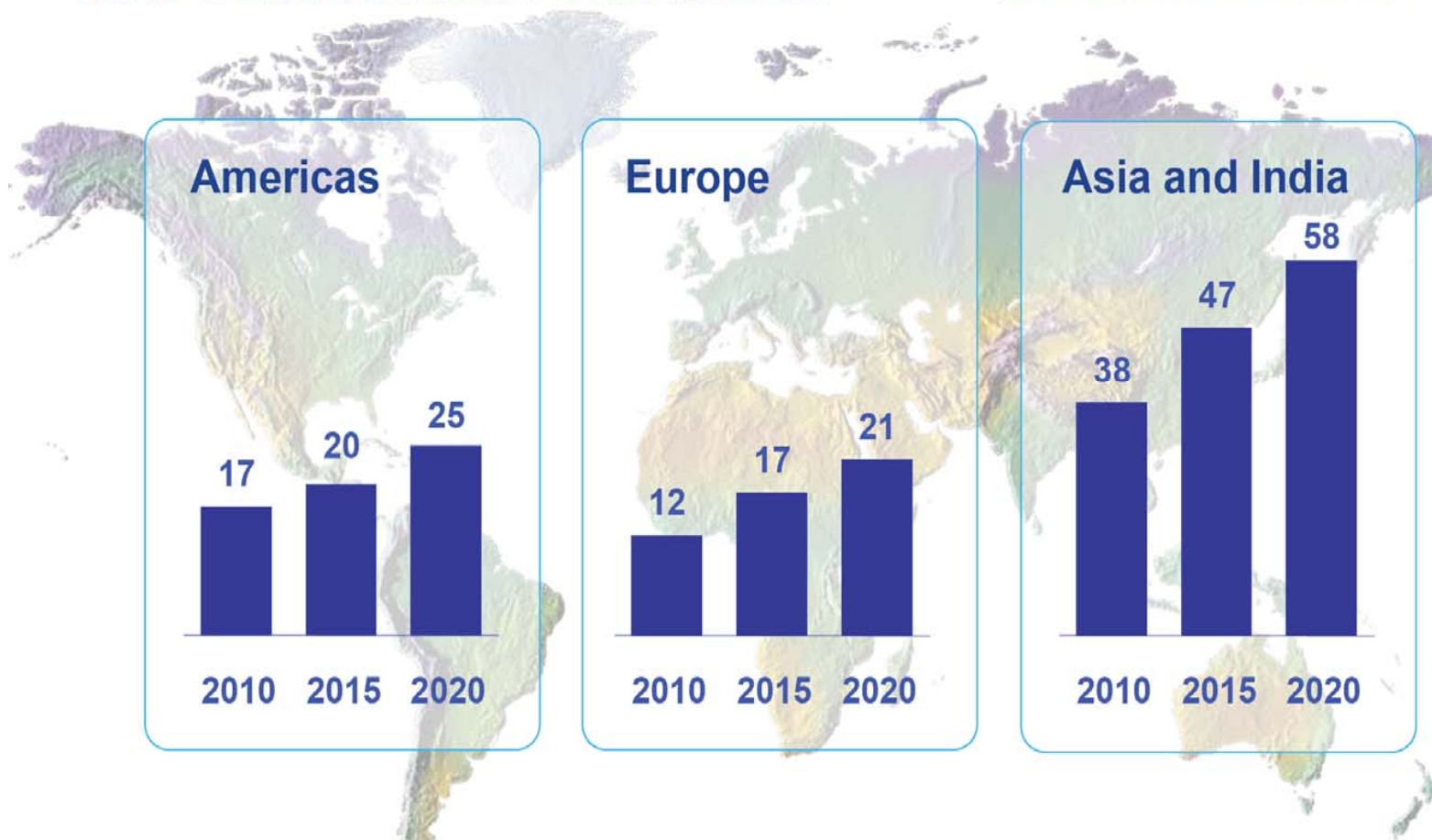
Planned New Builds in the USA
(32 units)

You may click on a design name to view the NRC's Web site for the specific design.

● ABWR
 ■ AP1000
 ⊕ EPR
 ▲ ESBWR
 ◆ USAPWR
 ▽ Design/Units - TBA

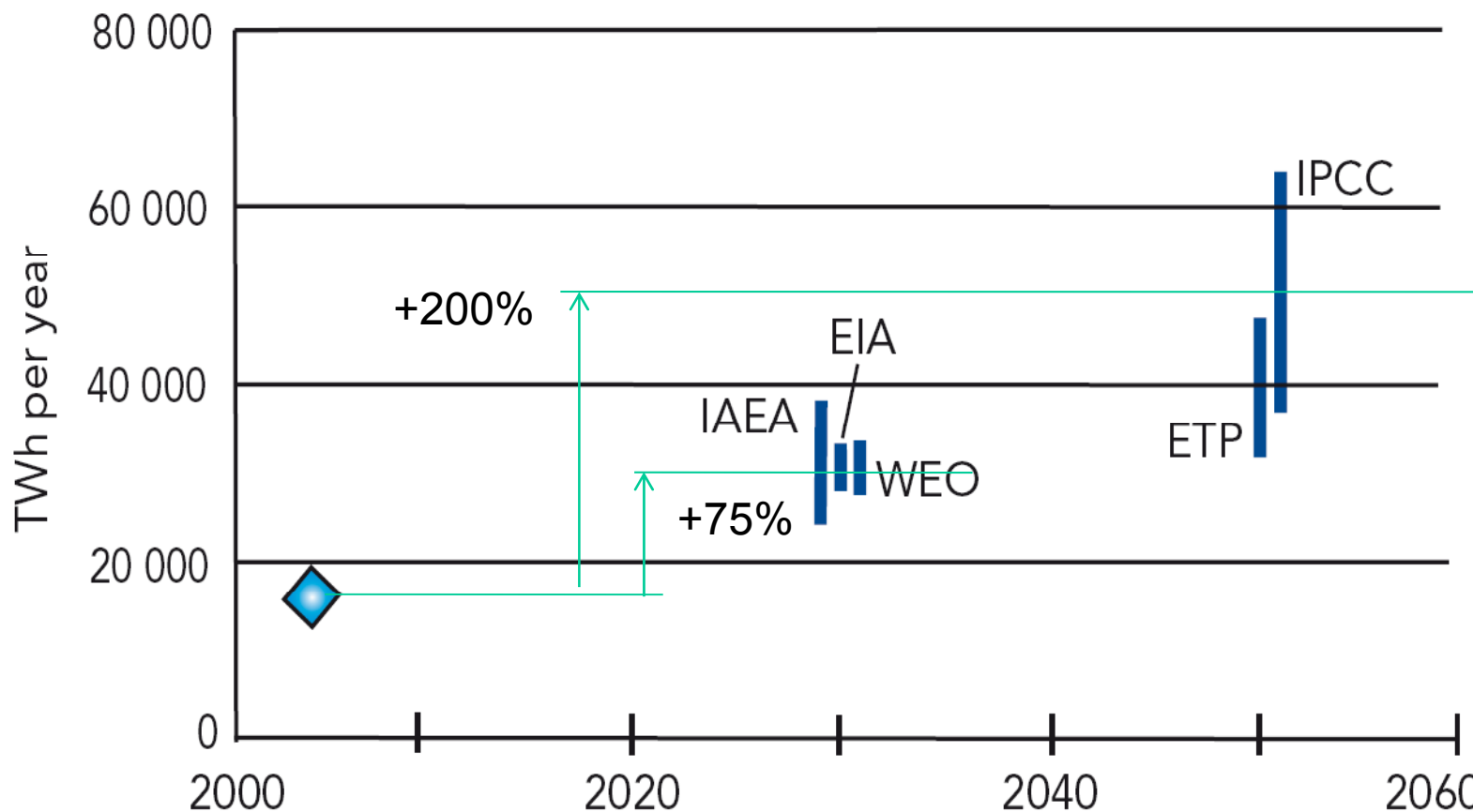
New Construction Forecasts ...

(Orders; GW Cumulative)



In June 2008, 41 power reactors were under construction in 14 countries

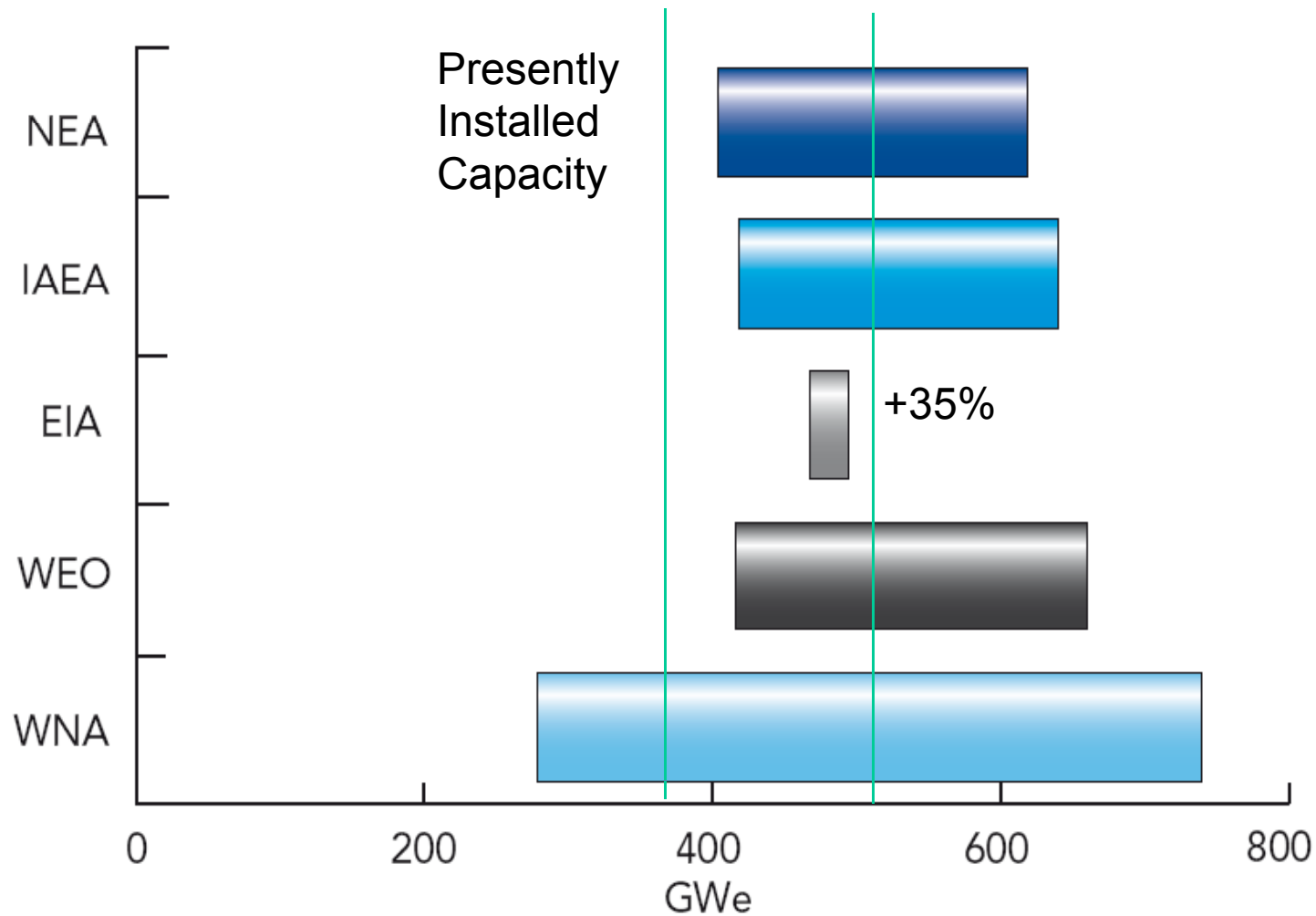
Projected Increase in Electricity Demand Worldwide



Source : OECD/NEA, "Nuclear Energy Outlook", NEA No. 6348

EIA = US Department of Energy, Energy Information Administration, 2007
 ETP = International Energy Agency, Energy Technology Perspectives, 2006
 IAEA = International Atomic Energy Agency, 2005
 IPCC = Intergovernmental Panel on Climate Change, 2007
 WEO = International Energy Agency, World Energy Outlook, 2007

Ranges of Projected Installed Nuclear Capacity in 2030

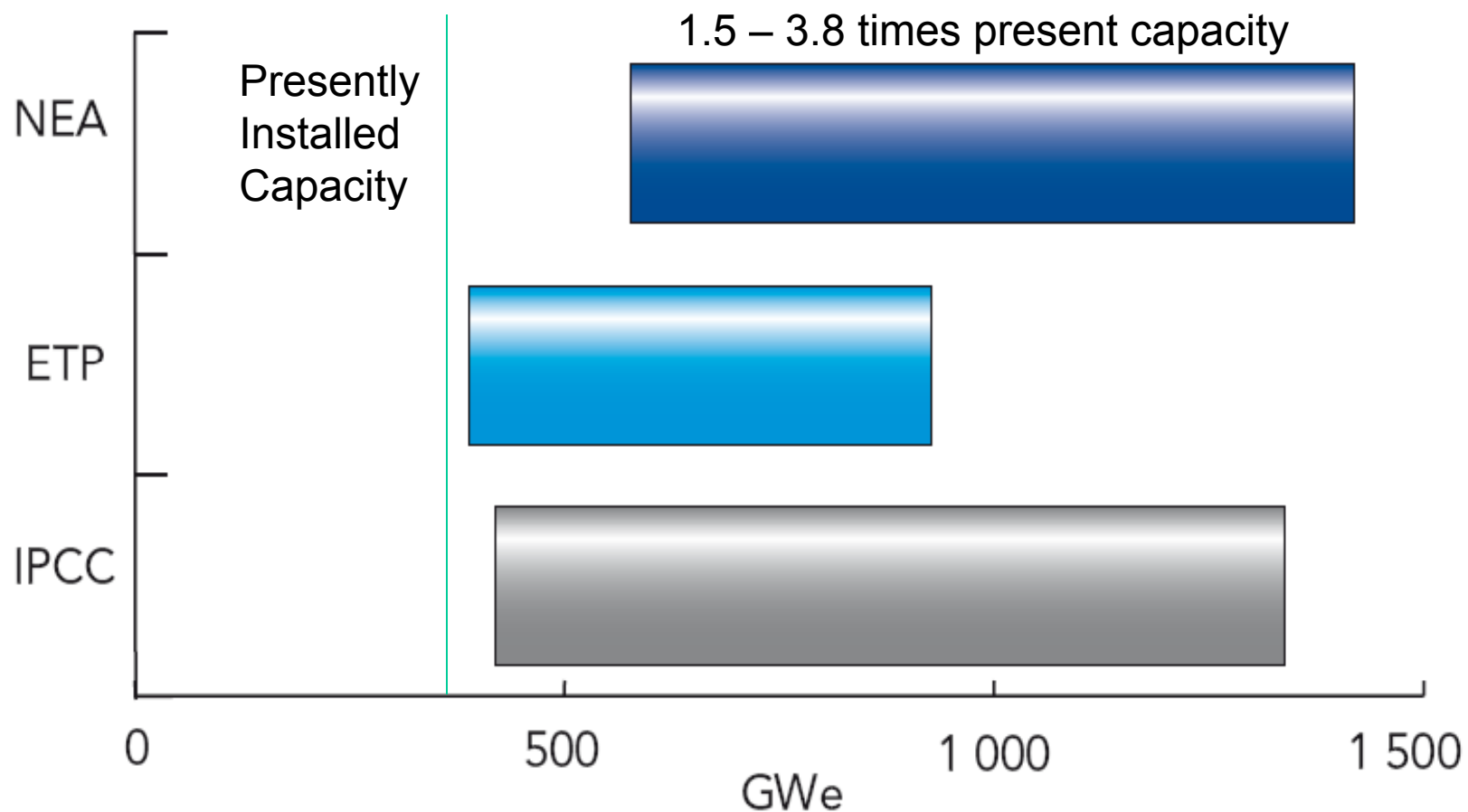


Back

Source : OECD/NEA, "Nuclear Energy Outlook", NEA No. 6348

WNA = World Nuclear Association, 2005

Back



Source : OECD/NEA, "Nuclear Energy Outlook", NEA No. 6348

Renaissance for nuclear power?

- Finland: applications for reactor units 6-7-8. France: construction of EPR at Flamanville. England: decision in principle on new NPP units
- Germany, Belgium: Nuclear phase out.
- Holland considers expansion.
- Rapid growth in SE Asia: China +120 GWe, India +50 GWe in 2030.
- Russia: +20 GWe in 2020?
- USA: Applications for COL for up to 32 units. Life extension for existing reactors.
- Italy, Poland consider nuclear option
- Sweden NPP uprates. February 2009: political decision on replacement of existing 10 reactor units when retired.
- Denmark?

Thank you for your attention!

