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Energy research Centre of the Netherlands

Prospects for Nuclear Energy in Europe

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Outline

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Based on a contribution to a Special Issue on the Prospects of Nuclear Energy of the *International Journal of Global Energy Issues* (Eds. Hans-Holger Rogner and Ferenc Toth)

I. Nuclear power in Europe

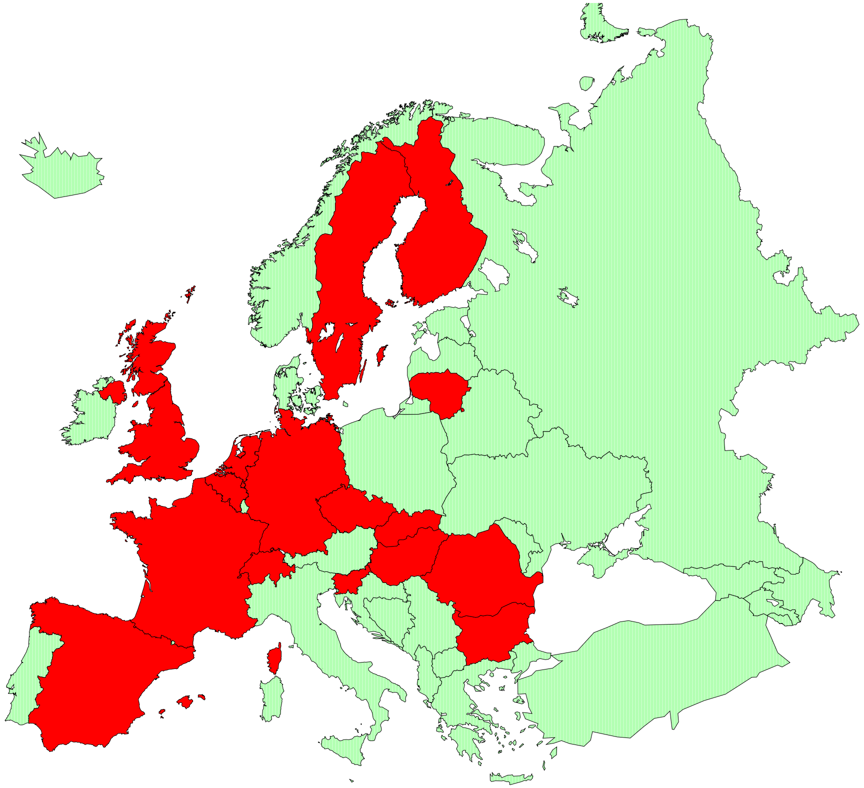

Figure 1. Nuclear power in Europe: 16 countries today produce nuclear energy domestically and 20 countries do not.

I. Nuclear capacity in Europe

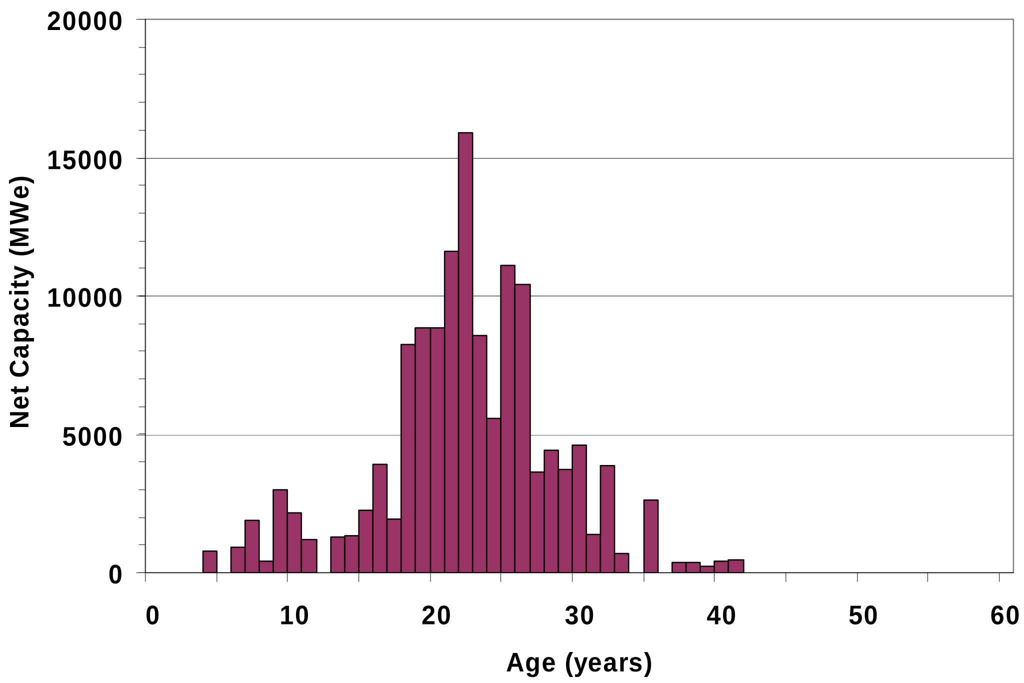

Figure 2. Aggregated net capacity of nuclear power in Europe per age in operation years. *Data from IAEA, PRIS.*

II. Climate change and air pollution

- The expected growth in global energy consumption will lead, in a BAU scenario, to steady increases of GHG emissions.
- Nuclear energy emits essentially no GHG's, even when considering the entire fuel cycle and power plant construction.
- Nuclear power is today the only non-carbon energy source that is deployed on a large scale and can still be significantly expanded.
- Nuclear energy cannot be the panacea to the problem of climate change, but may need to be part of the solution.
- With 137 GWe installed capacity, Europe has the potential to expand the role of nuclear power for climate change control.
- Such an expansion would simultaneously reduce emissions of SO_2, NO_x, Hg, and particulates.

III. Energy security

- Under BAU, the EU's dependency on imported energy would increase from 50% today to about 70% in 2030.
- Nuclear energy can be instrumental in reducing this dependency, even while Europe does not possess large uranium resources.
- Uranium is (I) widely available, (II) easily storable, and (III) cheaply acquirable.
- A diverse roster of stable uranium producers exists, and strategic reserves can easily be built.
- The costs of nuclear power are little sensitive to fluctuations or even significant increases in the price of uranium.

III. Resource availability

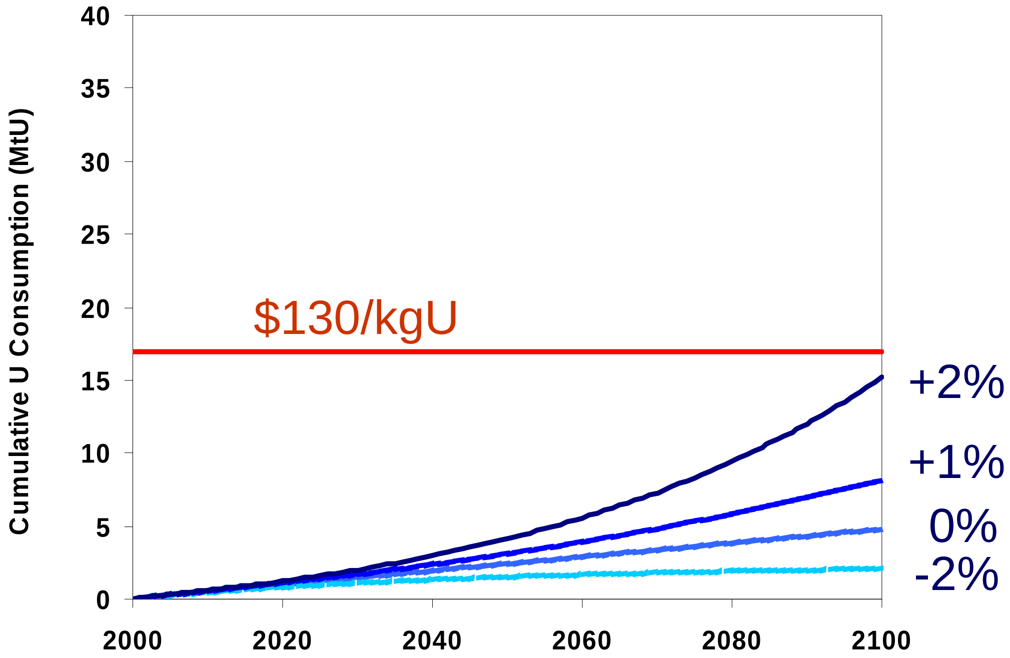

Figure 3. Scenarios of cumulative uranium consumption under annual nuclear electricity production growth rates of -2%, 0%, +1%, and +2% (once-through fuel cycle, 19 tU/TWh, 2500 TWh in 2000).

IV. Levelised costs

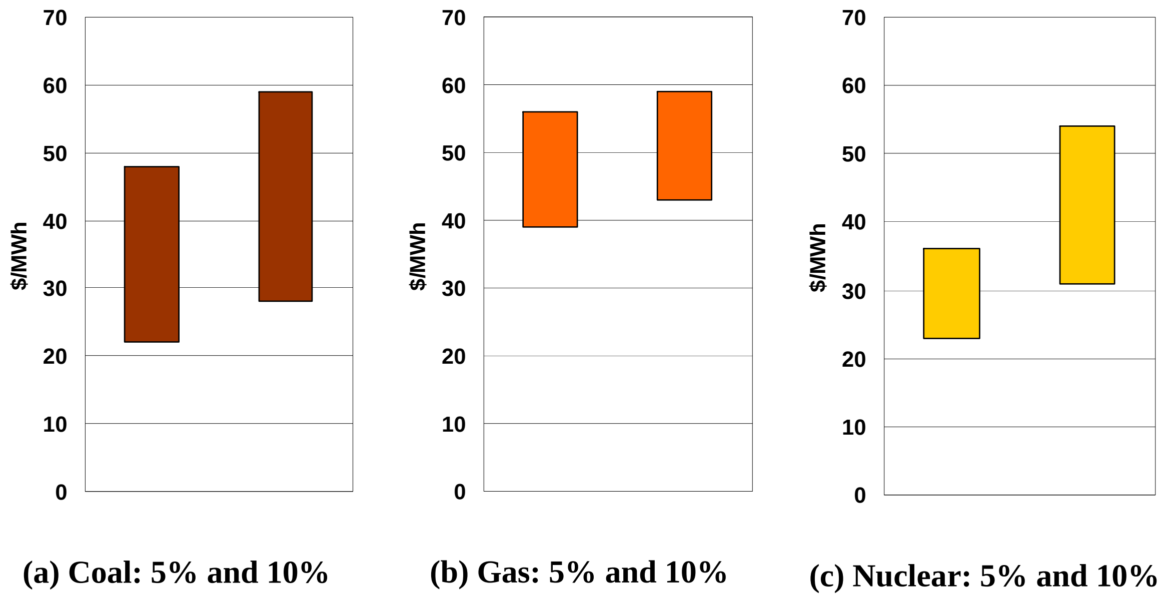

Figure 4. Range of total levelised electricity generation costs (in US$/MWh) for (a) coal, (b) natural gas, and (c) nuclear power plants for two values of the discount rate (left bar 5%, and right bar 10%). *Data from: OECD, 2005.*

Nuclear power is well able to compete with its two main counterparts in the electricity sector (oil and gas prices prior to 2005).

IV. Economic competitiveness

- High capital cost requirements for nuclear power plant construction often impede investments in nuclear energy.
- Regulatory, legal, and political incertitude, as well as market liberalisation, disadvantage new investments in the nuclear sector.
- An active role of government is indispensable, as recently demonstrated by Finland and France.
- Plausible reductions in power plant construction costs may reduce the investment gap between nuclear and fossil-based power.
- CCS application, economic valuation of CO_2 abatement, and the EU ETS may benefit investments in new nuclear power plants.

V. Radioactive waste, nuclear proliferation, and reactor accidents

- The problems related to these three intrinsic nuclear drawbacks are real, significant, and will never be solved entirely.
- Still, they are dynamic: they have evolved substantially over the past decades, and more progress can be made.
- The waste problem can be mitigated through e.g. lifetime reduction (transmutation) and regional disposal options (IMWRs).
- The proliferation problem can be reduced by new reactor types (Gen-IV) and expanded mandate of supranational means (IAEA).
- Accident risks can be reduced by use of passive safety features and reactor operation improvement and coordination.

V. Current and new reactors

	Today	Short to medium term	Long term
Generation	**I and II**	**III**	**IV**
Reactor type	PWR (92) WWER (22) BWR (19) AGR (14) GCR (8) LWGR (1) PHWR (1) FBR (1)	EPR (PWR) AP1000 (PWR) WWER (PWR) ABWR (BWR) ESBWR (BWR) HTR (pebble bed)	GFR LFR MSR SFR SCWR VHTR

Table 1. Nuclear reactor types in Europe: currently deployed, deployable in the short-medium term, and possibly developed in the long term. *Sources: IAEA-PRIS (2006) and NERAC/GIF (2002).*

VI. Prospects for nuclear power in Europe

- For the short run (2025), Europe's nuclear energy capacity is unlikely to be very different from that of today.
- For the medium run (2050), the relative weights attached to its benefits and drawbacks will determine its future in Europe.
- For the long run (2100), the extent to which nuclear power can contribute to sustainable development is the determinant factor.

My guess:

World-wide until 2050 nuclear power contribution is likely to remain between lower bound of constant capacity (in absolute terms) and upper bound of constant share (in relative terms).

VII. Nuclear power in Africa

What are the prospects for nuclear power in Africa?

- South Africa is the only nuclear energy country on the continent.
- Others are unlikely to follow soon (Egypt, Libya, Sudan,…).
- Large centralised power production is so far of limited use.
- Technologically less advanced options are more attractive.
- There is an abundance of renewable energy resources.
- Nuclear energy is undesirable in regions of armed conflict and requires stable institutions.

VII. Nuclear power in Africa

Overall, the prospects for nuclear power in Africa are limited.

Yet, Africa possesses the oldest (natural) nuclear reactor: Oklo (Gabon).

VII. The Oklo natural nuclear reactor

- 2 billion yrs ago, the concentration of U-235 in natural uranium deposits was around 3% (0.7% today), as the half-life of U-235 (700 million yrs) is shorter than that of U-238 (4.5 billion yrs).
- In the Oklo area, the presence of water constituted a natural moderator for the slowing down of neutrons produced during the fission of U-235 nuclei.
- The resulting reactor(s) operated at an average power of 100 kW, producing a total of 15 GW-yr of energy, with self-regulatory cycles of 0.5-2.5 hours.

The Oklo reactors show how 'natural' nuclear power is, and how well radioactive waste can be contained for billions of years.

VII. Africa and nuclear non-proliferation

- South Africa is the only country to construct nuclear weapons and subsequently voluntarily abandon its weapons programme.
- Since that decision in the early 1990s (F.W. de Klerk), South Africa has promoted nuclear non-proliferation / disarmament globally.
- In 1996, South Africa and 42 other African states signed the African Nuclear-Weapon-Free-Zone Treaty.
- This ‘Pelindaba Treaty’ gathers the largest group of declared nuclear-weapon-free countries, but has so far not been ratified.

VII. Role of Africa globally

For at least three reasons, Africa remains relevant on the international nuclear scene:

- Export of nuclear technology and materials from South Africa, especially to developing countries (e.g. high temperature pebble bed reactor, uranium products);
- Large uranium resources, especially in South Africa, Niger and Namibia, whose importance will increase if nuclear power revives and/or reserves elsewhere are depleted;
- In terms of nuclear non-proliferation and disarmament, Africa has an opportunity to expand its exemplary role (South Africa, Libya, Pelindaba Treaty,…).

VIII. Conclusions

The future of nuclear power will significantly be determined by the extent to which the public will accept:

- the current solutions for the treatment and disposal of radioactive waste,
- the inherent risks associated with the proliferation or terrorist diversion of nuclear technologies and materials,
- the non-zero probability for the occurrence of reactor incidents and accidents,

and the further progress booked in these areas, in perspective of the risks / disadvantages of other energy resources.

Will all countries fulfill their NPT obligations, and are we able to fairly and transparently internationalise the nuclear fuel cycle?

VIII. Publications

Sailor, W.C., D. Bodansky, C. Braun, S. Fetter and B.C.C. van der Zwaan, 2000, A Nuclear Solution to Climate Change?, *Science*, Vol. 288, 19 May, pp. 1177-1178.

Bruggink, J.J.C. and B.C.C. van der Zwaan, 2002, “The role of nuclear energy in establishing sustainable energy paths”, *International Journal of Global Energy Issues*, vol.18, 2/3/4.

van der Zwaan, B.C.C., 2002, “Nuclear Energy: Tenfold Expansion or Phaseout?”, *Technological Forecasting and Social Change*, 69, 287-307.

Rothwell, G. and B.C.C. van der Zwaan, 2003, “Are light water reactor systems sustainable?”, *Journal of Energy and Development*, vol.29, no.1, pp. 65-79.

Bunn, M., S. Fetter, J.P. Holdren and B.C.C. van der Zwaan, 2005, “The Economics of Reprocessing vs. Direct Disposal of Spent Nuclear Fuel”, *Nuclear Technology*, 150, pp. 209-230.

van der Zwaan, B.C.C., “Prospects for nuclear energy in Europe”, *International Journal of Global Energy Issues,* forthcoming.