Factsheet 4

Secure energy: options for a safer world

ENERGY SECURITY AND URANIUM RESERVES

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This factsheet is based on a full technical paper by J. W. Storm van Leeuwen and P. B. Smith, available from the ORG website.

SUMMARY

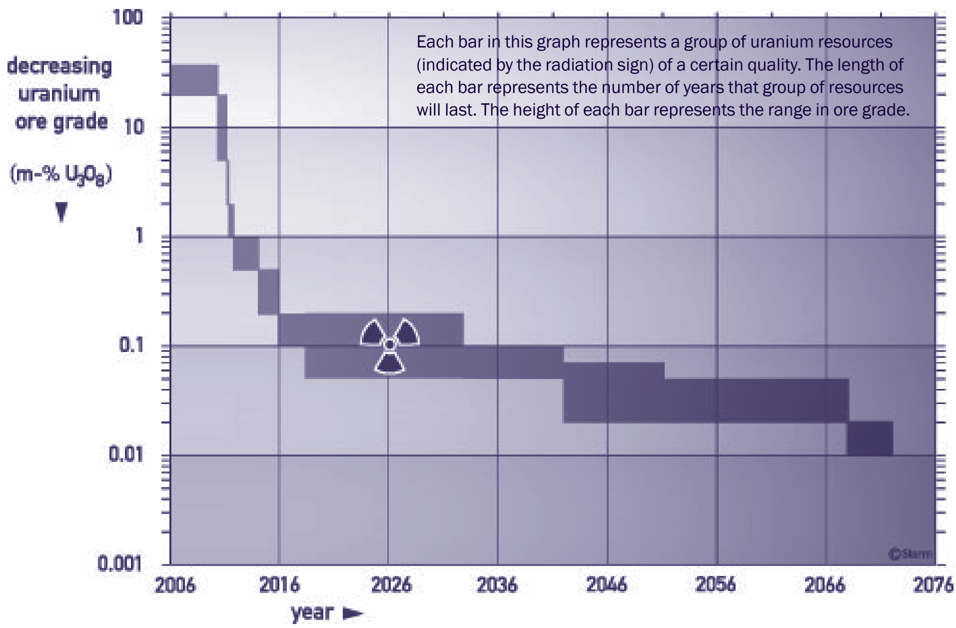
A new generation of nuclear reactors will increase demand for uranium ore to produce reactor fuel. In 2005 the world nuclear fleet consumed about 68,000 tonnes of natural uranium, mostly from mined sources. At the end of 2005 the world known recoverable uranium resources amounted to about 3.6 million tonnes (t). **These resources show a wide variation in ore grade and accessibility. Understanding this variation is essential for assessing nuclear energy security**.

Uranium ore is not an energy resource unless the ore grade is high enough. Below grade 0.02% (U_3O_8Uranium Oxide) more energy is required to produce and exploit the uranium fuel than can be generated from it. Falling ore grade leads to rapidly rising CO_2 emissions from the nuclear energy cycle. Assuming world nuclear generating capacity remains at 2005 levels, after about 2016 the mean grade of uranium ore will fall significantly from today's levels, and even more so after 2034. **After about 60 years the world nuclear power system will fall off the 'Energy Cliff' – meaning that the nuclear system will consume as much energy as can be generated from the uranium fuel.** Whether large and rich new uranium ore deposits will be found or not is unknown.

Once high-grade uranium ores are no-longer available, the nuclear industry will rely on uranium and plutonium from military and civil stockpiles. These will last only a few years, and questions remain about the net energy gain from reprocessing these materials. In the future, it is likely that the nuclear industry and governments will look to MOX fuel – a mixture of uranium and plutonium dioxides. In time, the nuclear industry hopes to develop fast breeder reactors fueled by weapons useable plutonium. The widespread use and production of either fuel has serious implications for nuclear weapons proliferation and the risk of nuclear terrorism.

It is inevitable that replacements for uranium fuel will be sought within the lifetime of any new nuclear build in the UK. It is also inevitable that as high grade uranium supplies decrease, the cost of nuclear power will increase along with nuclear CO_2 emissions. The security risks associated with MOX and plutonium fuel should not be underestimated. These concerns should be reviewed by Government, Parliament and the public before a decision is taken on the future of nuclear power.

Graph 1: Depletion of world known recoverable resources, 2006 - 2076



This graph assumes that no new large and rich deposits are found during the next decades and that world nuclear capacity remains at 2005 levels. It is based on a total resource of about 4.2 millions metric tonnes. (Including resources of lower quality which the OECD / NEA figure of 3.6 million metric tonnes currently excludes.)

Note that the largest uranium deposits have ore grades lower than 0.1%, which is 100 to 1000 times poorer than those used today.

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Nuclear energy security timeline 2006 - 2076

Following the UK Energy Review, this timeline is based on a scenario of ten new Light Water Reactors in the UK to be authorised in 2006, with the first unit going online in 2016 and the 10th (last one) in 2026 (a completion rate of one unit each year). This scenario also assumes that world nuclear capacity remains at 2005 levels.

Year	Event	Ore grade This refers to the proportion of uranium-235 in 1t of ore. It affects (a) the amount of energy needed to produce uranium fuel, and (b) the amount of CO_2 emissions produced from that fuel. If the ore is 0.1% U_3O_8 then 1t of ore has to be processed to obtain 1kg of uranium.
2006	**Authorise new nuclear build in the UK**	Rich ores in Canada mined. World mean value of available uranium ore grade is 0.15% U_3O_8.
2016	**First new nuclear power plant online**	**Rich ores depleted. Mean available uranium ore grade is equal or less than 0.1%.**
2026	**10th new nuclear power plant online**	Mean grade slowly declining.
2036	**Full fleet in operation**	**Mean ore grade falls to about 0.07% U_3O_8**
2056 - 2066	**First nuclear power plant closes**	**Approaching energy cliff. High CO_2 emissions.**
2066 - 2076	**10th nuclear power plant closes**	**Uranium fueled nuclear reactors have fallen off the energy cliff and produce more CO_2 emissions than a gas-fired power plant.**

Energy costs energy

Generating electricity from uranium fuel depends on a system of industrial processes known as the nuclear process chain. The three main phases are:

1. Converting a uranium bearing rock into nuclear fuel.

2. Constructing, operating, maintaining and refurbishing of the nuclear power plant. The mean operating lifetime is assumed to be 40 years.

3. Waste management, dismantling of the reactor, construction of a geological repository to isolate the waste.

Each process comsumes energy, consequently each process, except the reactor itself, emits CO_2. The process needed to convert uranium into nuclear fuel most likely also emits greenhouse gases (GHGs) other than CO_2.

The energy debt

Uranium fuel production, plant construction and most importantly, dismantling nuclear power plants, needs energy regardless of how much energy is generated by the plant. The amount of energy needed during the operational life of a nuclear power plant is known as the **energy debt**.[1]

Large uncertainties, especially regarding the 3rd phase of the nuclear process chain, obscure energy debt estimates for nuclear power. Our estimates are based on the quantities of materials involved. Judged against official UK decommissioning estimates, our figures are cautious.

Subtracting the energy debt from the energy generated by a nuclear power plant over its lifetime gives the figure for **net energy**.

1. All energy systems produce an energy debt. Using this data it is possible to calculate the energy pay-back time – the time it takes for the energy system to produce as much energy as it comsumes over a full life-cycle. If we assume a nuclear power plant operates for 40 years using today's uranium ore grades (very favourable), the energy pay-back time is 6-14 years. For photovoltaics in the UK it is 4 years and for wind it is less than 1 year.

Net energy and the 'Energy Cliff'

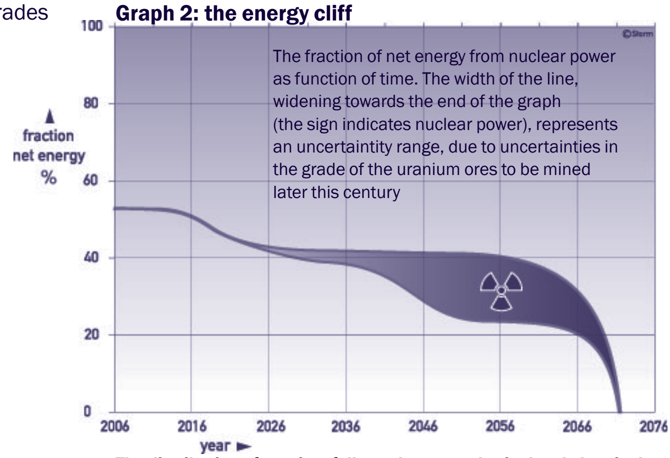
The quantity of energy which can be generated from one metric tonne of natural uranium has a fixed value in a given reactor type. The amount of energy needed to convert a uranium-bearing rock in the ground into nuclear fuel, depends on the ore grade: the lower the grade the more energy the extraction of uranium from its ore consumes, and the lower the net energy a nuclear power plant puts into the grid. As ore grades decline so does net energy, leading to the 'Energy Cliff'.

"At todays generating capacity, nuclear energy will consume more energy than it puts back into the grid by 2070."

If the world nuclear generating capacity stays at the current levels, nuclear power will fall off the 'Energy Cliff' by around 2070 – within the lifetime of new UK nuclear build. Nuclear power then consumes as much energy as it puts into the grid.

Graph 2 is based on the assumption that no new large uranium deposits will be found of the same quality as the currently known high-grade deposits.

Graph 2: the energy cliff



The distribution of uranium follows the same physical and chemical laws as other metals: the richer an ore, the rarer they are. The most easily discoverable and mineable uranium deposits are already in production. The chance of finding new large high-grade ores is unknown.

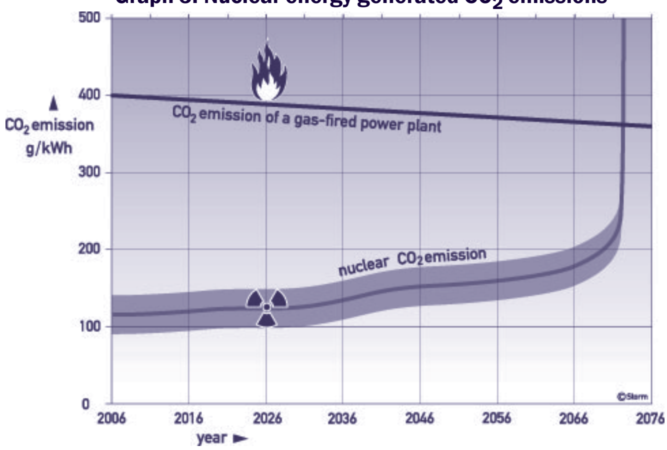
CO_2 emissions and nuclear power

Nuclear power emits CO_2 and other GHGs. On a global scale its contribu-tion to mitigating emissions of GHGs is negligible and will remain so.

The level of CO_2 emission by the nuclear system depends upon the operational lifetime of the nuclear power plant and the grade of the uranium ore used to obtain the uranium fuel. The operational lifetime is important because the construction and dismantling of a nuclear power plant uses a fixed amount of energy and produces fixed CO_2 emissions, regardless of the lifetime of the power plant. So, as the lifetime and efficiency of the power plant decreases, the proportion of CO_2 emissions increases.

The grade of the uranium ore determines the amount of fossil fuels needed to extract the uranium from rock, which leads to CO_2 emission per kg uranium. As the quantity of electricity generated from 1kg uranium has is fixed value. CO_2 emission (gram CO_2 per kWh) increase with decreasing ore grade.

Graph 3: Nuclear energy generated CO_2 emissions [2]



By the time a full fleet of 10 new reactors is operational, mean ore grade will drop leading to a significant increase in nuclear powered CO_2 emissions.

2. Specific emission of carbon dioxide by nuclear power (radiation sign) versus time. During the next decades the emission will rise, due to poorer ores to feed the nuclear system. The emission by combined-cycle gas-fired power plants (burning flame) will decrease somewhat, due to improving efficiency. The dark shaded area represents the uncertainty range of the nuclear CO_2 emission, due to several uncertainties in the nuclear fuel cycle, among which dismantling and waste storage.

Conclusions

About the author
Jan Willem Storm van Leeuwen is a senior scientist at Ceedata Consultancy. He works for the Open University at Heerlen and is secretary of the Dutch Association of the Club of Rome.

Storm is one of the international group of expert reviewers of the Fourth Assessment Report (AR4) of the International Pabel on Climate Change (IPCC).

He published numerous reports and articles on topics related to energy and environment.

Reducing CO_2 emissions
A new nuclear build in the UK cannot make a significant contribution to reducing UK or global CO_2 emissions. Within the lifetime of new nuclear build, sufficiently high grade uranium resources will become severely depleted. The use of lower grade uranium would increase nuclear CO_2 emissions to the level of a gas-fired power station by 2070.

Increasing energy security
Nor would nuclear energy increase the UK's energy security over the coming decades. There are no indigenous uranium supplies, and dwindling known resources of high grade uranium will lead to future price rises and fluctuations, and resource competition.

Opportunity costs
Large-scale investment in nuclear power would remove the opportunity for the UK to join with other countries in leading on developing an energy supply independent of exhaustible mineral energy resources, as China is doing for instance.

Implications for UK and global security
A new nuclear build would lead to an incremental increase of the risks of nuclear terrorism in the UK and from global nuclear weapons proliferation. Is an incremental increase to present threats manageable? Or, are current risks associated with proliferation of nuclear technology and weapons-usable materials already unacceptably high?

"The question is whether an incremental increase to present threats is manageable? Or, whether current risks to UK and global security are already unacceptably high?"

Previous Secure Energy factsheets by ORG

Factsheets 1, 2 and 3 address the security the risks associated with a new nuclear build. Specifically, they focus on (1) the consequences for nuclear weapons proliferation and nuclear terrorism of fueling nuclear reactors with MOX fuel and weapons-usable plutonium, (2) the proliferation risks associated with reprocessing spent fuel, and (3) trends in paramilitary violence and nuclear terrorism. For copies of these factsheets, please contact ORG.

About the ORG "Secure Energy: Options for a Safer World" project

With this project ORG aims to inform public debate and Government decision-making concerning the future of civil nuclear power. We hope to raise understanding and awareness of the extent to which a new nuclear build would increase the risks of nuclear weapons and technology proliferation, and of nuclear terrorism.

To achieve this we are producing a series of factsheets on different elements of the security and civil nuclear power axis, including vulnerabilities to terrorism, safeguarding nuclear materials, trends in paramilitary violence, energy security and the potential of renewable technology.

For more information, please contact:

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