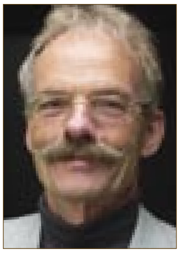
End of the days of ore?

Jan Willem Storm van Leeuwen is not convinced that there is sufficient uranium to support an expanding world nuclear programme



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Will there be sufficient uranium to accommodate an expanding world nuclear programme? A common viewpoint is that there are billions of tons of uranium present in the earth's crust. Extracting it is just a matter that relates to uranium prices. Even without fast breeder reactors we can feed a large fleet of nuclear power plants for hundreds of years.

However, it is not the quantity, but the quality of the uranium resources which determines the future of nuclear power. The above viewpoint ignores the fact that the generation of useful energy from uranium resources is a physical process. Whether or not a uranium deposit can be a net energy source depends on the physical properties of that deposit.

To release the energy potential from uranium and to convert it into useful energy, an extensive series of industrial processes is required, each of which consumes energy and materials. Jointly, these processes form the nuclear cycle, the most complex energy system ever designed.

There are uranium resources that, when exploited, turn out to be a net energy sink over a subsequent nuclear fuel cycle instead of a net energy source. Obviously, an energy system which absorbs fully its own useful energy production, just to sustain itself, cannot contribute to the economy as a whole.

The effort required to obtain a given amount of pure uranium strongly depends on the grade (and other physical properties) of the ore the uranium is extracted from. The net energy from the nuclear cycle declines with decreasing uranium concentration of the resources. Below a certain ore grade limit the net energy balance falls to zero and the nuclear cycle becomes an energy sink. This limit is called the 'energy cliff'.

At a grade of some 200g uranium per tonne of rock, as much uranium ore has to be mined and processed for one nuclear reactor as the mass of coal that is burned in a coal-fired plant to generate the same amount of electricity. In other words: uranium ore at a grade of 200g uranium per tonne of rock has the same net energy content as coal.

There are mines today mining ores at grades of some 100g uranium per tonne of rock, well below the coal limit and at or beyond the energy cliff.

Piles of uranium ore lie beside an abandoned mine, Edgemont, South Dakota: the possibility of new drilling in the area is being explored as world demand for uranium increases

The currently available information points to a rapid decline of the world average quality of uranium resources during the next decades. This phenomenon is caused by the fact that the easiest mineable deposits, that require the least effort and have the highest return on investments, are mined first. The chances of new discoveries of high-quality uranium resources are utterly unknown. The decline in the ore quality is accompanied by a steep rise in the CO_2 emission of nuclear power, eventually surpassing that of gas-fired power plants.

Breeder reactors, also called fast reactors, promised to utilise uranium far more efficiently than the currently operating reactors, most of them being light-water reactors. A fast reactor can only be a breeder as part of a flawless operating cycle of three interdependent processes: reactor, reprocessing and fuel fabrication. If one component fails, the whole system fails.

Breeders exist only on paper. Fifty years of intensive research in seven countries (for example, Dounreay in the UK, now closed) and investments of more than a $100bn dollars have failed to deliver an operable breeder cycle, due to insurmountable technical hurdles. The development has not been halted because of economic reasons, on the contrary, the breeder concept became uneconomic because it turned out to be technically unfeasible.

Allowing for the uncertainties in regard to nuclear power, it does look as though we are now at or beyond the peak in the supply of useful uranium. This means that nations that attempt to expand, or even to sustain, their nuclear industries by building nuclear power plants will face a zero net energy balance within the lifetime of new nuclear build.

Apart from the ever-increasing cost of operation, these nations will be left with a huge 'energy debt': the cost of dealing with the radioactive waste the reactors have produced during their short operational lifetime. ■