Uranium costs – Electricity costs

ASPO, Blandow/Zittel, 25 May 2007:
Recent months have seen repeated reports of increasing uranium prices. Indeed, between 2000 and today, these prices have climbed from 7 USD to the present level of some 130 USD/pound (lb). This is nearly equivalent to a factor of 20. It is often argued that this has practically no impact on nuclear power station power-generation costs. We wanted to get to bottom of this and made some calculations of our own.

The following table shows how strongly uranium prices affect power-generation costs; it only takes account of the uranium price as a component in power-generation costs, but not of other cost factors (power station construction, maintenance and operation). The power generating companies themselves put total costs at between 0.03 and 0.04 EUR/kWh$_e$. The figures in the table thus only indicate the straight cost mark-up on actual production costs.

Uranium price [USD/lb U_3O_8]	50	100	200	300	400	500	600	700	800	900	1,000
Share in power generation costs [eurocent/kWh]	0.24	0.49	0.98	1.47	1.95	2.45	2.93	3.42	3.90	4.40	4.88

Table: Impact of the uranium price on power generation in nuclear power stations (average values)

Hence, today's uranium price of 130 USD/lb is reflected in 0.005 EUR per kWh in electricity costs. Should the uranium oxide price increase to 500 USD per pound, the increase in generation costs would already be 0.025 EUR/kWh, which would represent a dramatic 50% to 70% increase in power costs. Critical voices, however, see the economic power generating costs due to nuclear waste and pollution as being much greater than the 0.03 - 0.04 EUR/kWh quoted above.

Anyone believing that such high uranium prices are a figment of the imagination should consider the rapid price increases in recent years, while bearing in mind that about one third

of the uranium required comes from existing stocks which will be used up in the near future. If worldwide uranium extraction cannot be expanded by at least 50% in the next 5-10 years, uranium will inevitably be in short supply.

Even if such an expansion were to be successful, at constant extraction rates the known uranium reserves would only last for a mere 30 years or so, or for some 70 years, if we include the so called 'known resources'. A detailed analysis of these figures can be found in the Energy Watch Group "Uranium Resources" study (www.energywatchgroup.org). If uranium extraction from sea water which is now being discussed as a potential long-term solution for the looming uranium shortage - quite apart from the question of its technological feasibility - becomes reality, costs of several hundred dollars per pound of uranium oxide might soon be expected.

Details of the calculation:

Nuclear power station power generation by 2004: 2,638 TWh
Uranium requirements for these nuclear power stations: 67,320 tonnes
The upshot is that, per 1 kWh of electric energy, requires an average of 0.0255 g of uranium.

The uranium price is given in USD/lb uranium oxide.

1 kg uranium oxide contains 0.848 kg uranium
1 lb = 0.454 kg

This means that a uranium price of 1 USD/lb uranium oxide is equivalent to a uranium price of 2.6 USD/kg. This value must then be converted into euros, taking 1 USD euro as being equal to 0.737 EUR.

In fact, world uranium production fell in 2006. In Australia uranium ore extraction was 20% lower than in the previous year, in Canada it was 15% lower. Together, these two countries represent 44% of the world production. This reduced production rate was not entirely compensated for by increases in production by other countries; world production fell by 5%. Details are given in the following table.

Uranium production [tonnes of uranium]

Country	2002	2003	2004	2005	2006
Canada	11,604	10,457	11,597	11,628	9,862
Australia	6,854	7,572	8,982	9,516	7,593
Kazakhstan	2,800	3,300	3,719	4,357	5,279
Niger	3,075	3,143	3,282	3,093	3,434
Russia (est.)	2,900	3,150	3,200	3,431	3,400
Namibia	2,333	2,036	3,038	3,147	3,077
Uzbekistan	1,860	1,598	2,016	2,300	2,270
USA	919	779	878	1,039	1,692
Ukraine (est.)	800	800	800	800	800
China (est.)	730	750	750	750	750
South Africa	824	758	755	674	534
Czech Republic	465	452	412	408	359
India (est.)	230	230	230	230	230
Brazil	270	310	300	110	190
Romania (est.)	90	90	90	90	90
Germany	212	150	150	77	50
Pakistan (est.)	38	45	45	45	45
France	20	0	7	7	0
World	36,063	35,613	40,251	41,702	**39,655**
in tonnes U_3O_8	42,529	41,998	47,468	49,179	46,765

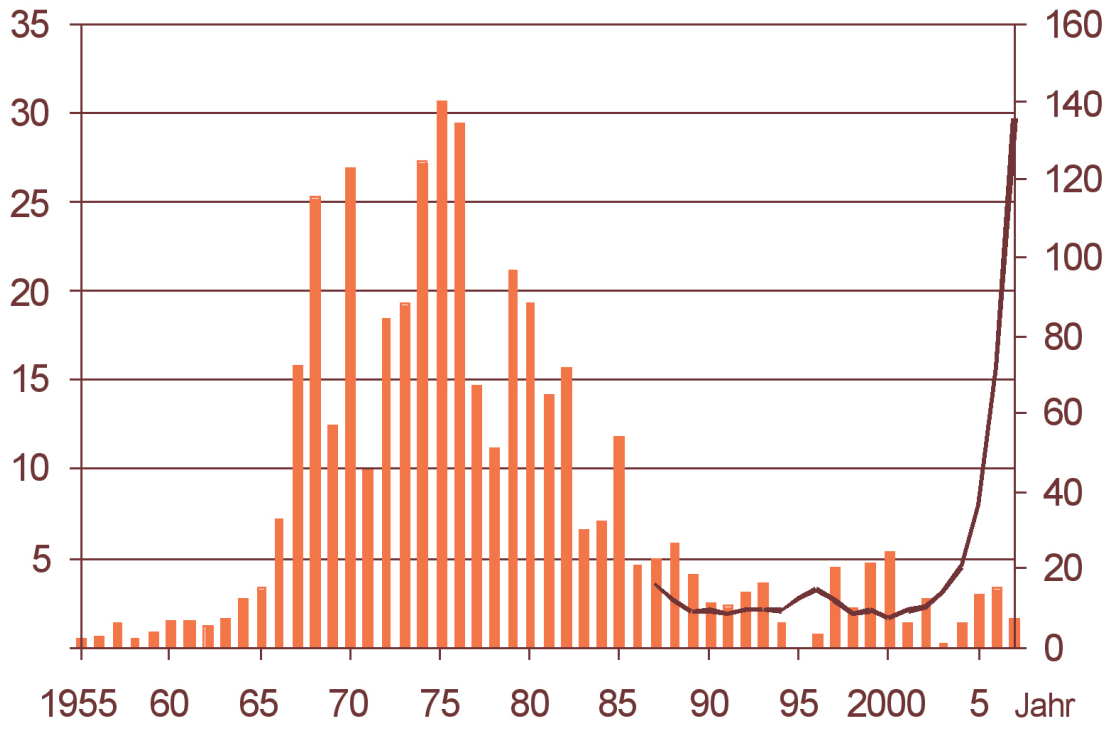
Source: WNA Market Report data (see e.g. http://www.uic.com.au/nip41.htm)

Reserves are shrinking. Only about 60% of uranium needed is mined; the remaining 40% come from reserves, a large part of which accumulated as Russian nuclear weapon material stocks were run down after 1990. The Russian contracts to supply the USA expire in 2013, and Russia has already announced that it does not intend to extend them. (see, e.g. http://www.usec.com/).

This means that in order to satisfy current needs, world production must increase by about 50%. However, this is becoming increasingly difficult as more easily-accessible deposits are worked out, and as merely mines with low ore content are left to be developed. New deposits

are being exploited more slowly than was envisaged because of unforeseen problems, and are proving to be more expensive than originally calculated. A good example is the largest, and only, project with good-quality ore at Cigar Lake in Canada. The original planning foresaw ore extraction beginning in 2007, but water broke in several times resulting in the mine being completely flooded in October 2006. The mine operators now hope that ore extraction will begin at the end of 2010 or 2011. Some observers believe that the mine may have to be given up entirely.

The two following diagrams show that the increasing uranium price is not a result of additional atomic power station building but of a decreasing fuel supply without any atomic power “renaissance”. The first compares new atomic reactor construction worldwide with recent uranium price increases. In the first half of 2007 no more nuclear power stations were begun than there were, on average, during the previous 20 years. As it takes at least 5 years to complete a nuclear power station, it is safe to conclude that this will not be sufficient to even maintain the number of reactors worldwide. That means that uranium requirements will remain approximately unchanged, which should mean that there should be no great changes to the uranium price.



Start of new reactor building and uranium price (worldwide)

Sources:

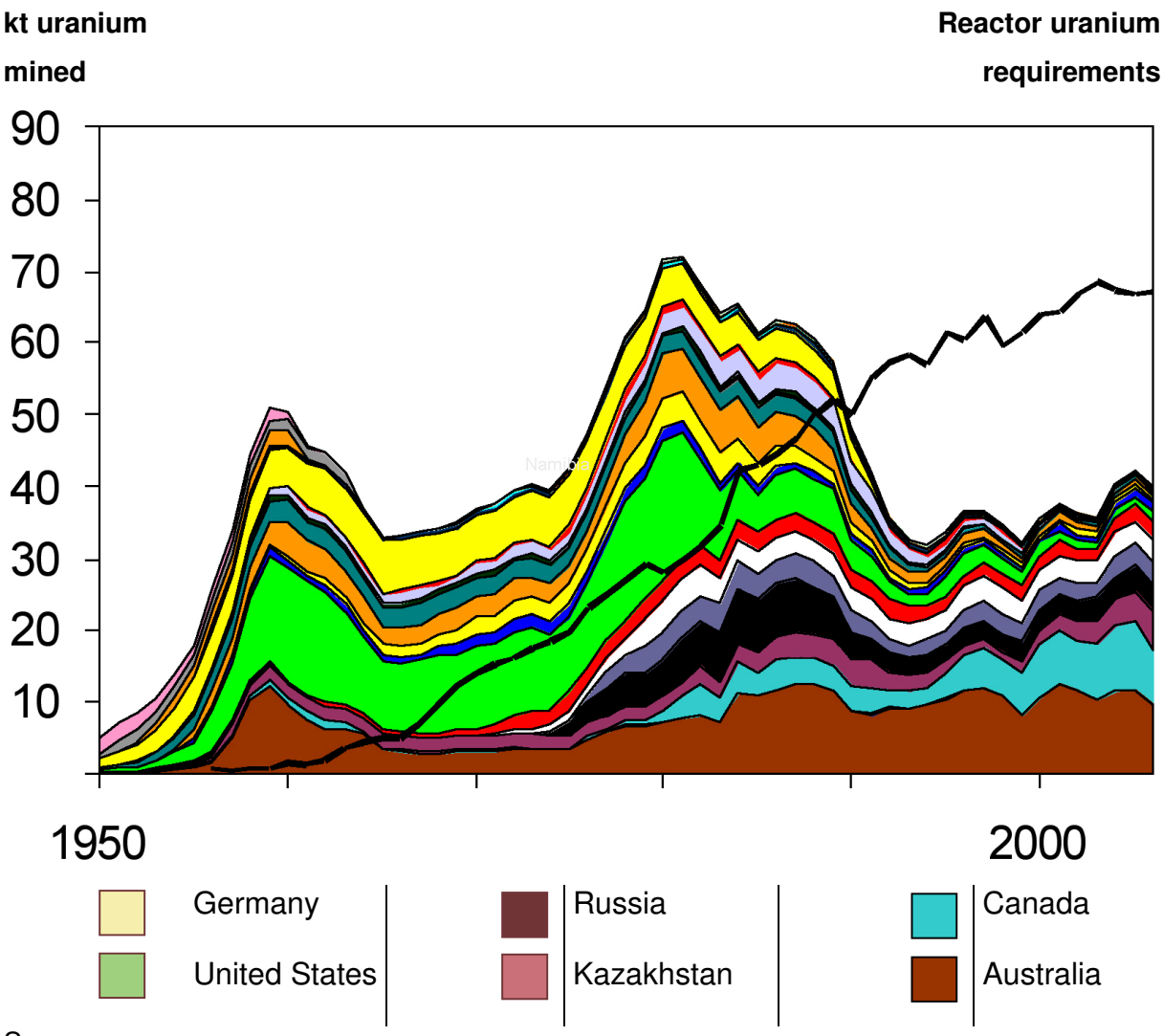
Reactors: International Energy Agency, data for 2007 to 25 June inclusive www.Iaea.org

Uranium price: The Ux Consulting Company.UC; year end prices; for 2007, 25 June 2007 www.uxc.com

Diagram: www.Energywatchgroup.org

The second diagram shows world uranium production until 2006 and reactor uranium requirements. The gap of fuel supply is not getting smaller, while in 2013 a big share of todays uranium stock piles will be emptied. If new mines will not bring additional supply until then, first reactors have to be shut down from 2013 due to lack of fuel. This already makes uranium markets nervous and lead to sharply rising prices.

Uranium mining per country 1950 – 2006 and reactor uranium requirements



Source:

NEA 2006, for 2008 data from www.uic.com / Chart and analysis LBST June 2007

Proportion of uranium costs in nuclear power station power generation costs.

1. How much uranium is needed to produce 1 kWh electricity?

To find this value in average, the worldwide power generation and nuclear power stations uranium requirements from 2004 are taken into account:

Nuclear power station power generation: 2,638 TWh
Uranium requirements of nuclear power stations: 67,320 tU

Source: Uranium 2005: Resources, Production and Demand (Red Book), IAEA/OECD, 2005

specific uranium requirements per kWh

= 67,320 tU/2,639 TWh = 67.32 gU/2,639 kWh = 0.0255 gU/kWh

Uranium / kWh:
On average, generating one kWh of electricity
require 0.0255 g uranium.

2. How to compare Stock market price for a pound uranium oxide with kilogram Price for Uranium:

The stock market uranium price is usually stated in US-Dollar per pound (USD/lb U_3O_8). This price for the British pound (lb) uranium oxide (U_3O_8) is converted to USD per kilogram uranium (USD/kg) as follows:

1 kg uranium oxide (U_3O_8) contains 0.848 kg uranium (U).

Calculation process: 1 kg U_3O_8 = 3*238/(3*238 +8*16) kg U = 0.848 kg U

1 lb = 0.454 kg

	USD 1 / lb U_3O_8
=	USD 1 / 0.454 kg U_3O_8
=	USD 1 / 0.454/0.848 kg U
=	USD 2.60/kg U

Stock market price per kg uranium:
The uranium price of USD 1/lb U_3O_8
is equivalent to a price of USD 2.6/kg uranium.

3. Conversion from dollars to euros:

The exchange rate on 25 April 2007 was USD 1 = EUR 0.7365
(source: www.google.de)

4. Examples

The following Table shows the impact of the price of uranium on power-generation costs. This calculation is made according to the method described above.

Uranium price [USD/lb U_3O_8]	Uranium price [USD/kg U]	Specific uranium demand [gU/kWh]	Share of power-gen. costs [USD/kWh]	Exchange rate [USD/EUR] (25.04.07)	Share in power-gen. costs [EUR/kWh]
50	130	0.0255	0.0033	0.7365	0.0024
100	260	0.0255	0.0066	0.7365	0.0049
200	520	0.0255	0.0133	0.7365	0.0098
300	780	0.0255	0.0199	0.7365	0.0147
400	1,040	0.0255	0.0265	0.7365	0.0195
500	1,300	0.0255	0.0332	0.7365	0.0245
600	1,560	0.0255	0.0398	0.7365	0.0293
700	1,820	0.0255	0.0464	0.7365	0.0342
800	2,080	0.0255	0.0530	0.7365	0.0390
900	2,340	0.0255	0.0597	0.7365	0.0440
1,000	2,600	0.0255	0.0663	0.7365	0.0488

On 23 April 2007, the price of uranium was USD 113/lb U_3O_8
(http://www.uxc.com/review/uxc_Prices.aspx).

The result is a share of EUR 0.055 in power generation costs.

In general, the formula for converting the uranium price

from USD/lb U_3O_8 to EUR/kWh is:

x * USD/lb U_3O_8 = 0.00663 * x * pc * EUR/kWh

with

x = uranium price in USD/lb U_3O_8 (currently: 113)

pc = exchange rate USD/EUR (currently: 0.7365)

Data compilation and examples:
J. Schindler, W. Zittel, LBST, 25 April 2007