Nuclear Energy – Myth and Reality

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Outline

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- Hang-over plants in Eastern Europe
- US developments: Nuclear Power 2010
- UK: Nuclear power back with a vengeance?
- Olkiluoto: Demonstration of new nuclear technology or that nothing has changed?
- Key determinants of nuclear economics
- Recent studies on nuclear costs
- Need for and extent of public subsidies
- Conclusions

Country	Site	Type	Vendor	Size MW	Const start	% built	Operate
China	Tianwan 2	WWER	Russia	1000	2000	99	2007
China	Lingao 3, 4	PWR	China	2 x 1000	2005, 06	20, 15	2010, ?
China	Quinshan 2-3, 4	PWR	China	2 x 1000	2006, 07	20, 20	2010, 11
	Sanmen 1, 2	AP1000	Whouse	2 x 1100	?	0, 0	2013
China	Yangjiang 1, 2	AP1000	Whouse	2 x 1100	?	0, 0	2013
Taiwan	Lungmen 1, 2	ABWR	GE	2 x 1300	1999	57, 57	2009, 10
Finland	Olkiluoto 3	EPR	Areva	1600	2005	20	2011
France	Flamanville 3	EPR	Areva	1700	2007	0	2012
India	Kaiga 3, 4	Candu	India	2 x 202	2002	98, 82	2007
India	Kudankulam 1, 2	WWER	Russia	2 x 917	2002	76, 66	2009
India	PFBR	FBR	India	470	2005	23	?
India	Rajasthan 5, 6	Candu	India	2 x 202	2002	92, 73	2007
Iran	Bushehr	WWER	Russia	915	1975	95	2007
Japan	Tomari 3	PWR	Mitsub	866	2004	66	2009
Korea	Shin Kori 1	PWR	Doosan	1000	2006	43	2010
Pakistan	Chasnupp	PWR	China	300	2005	25	2011
Romania	Cernavoda 2	Candu	AECL	655	1983	98	2007
Russia	Balakovo 5	WWER	Russia	950	1987	?	2010
Russia	Kalinin 4	WWER	Russia	950	1987	?	2010
Russia	Volgodonsk 2	WWER	Russia	950	1987	?	2008

The World Market for Nuclear Plants

- Reports of a revival in nuclear ordering are premature
- Only 22 units are under construction and three more are on order worldwide compared to 435 already in service
- Of the 22, 16 use Indian, Russian, or Chinese designs
- Of the 22, 15 are in China, Russia or India
- For 7 of the plants, construction has taken or is expected to take more than 10 years

Designs available

3 generation III/III+, on offer in the West:

1. Areva EPR, based on Framatome N4 and Siemens Konvoi. Two orders. Regulatory approval in France and Finland but not USA before 2011
2. Westinghouse AP-1000, based on AP-600. AP-600 abandoned without orders due to high costs. Regulatory approval in USA (Feb 2006) but not offered in Europe
3. GE ESBWR, based on SBWR. No orders for SBWR or ESBWR. US regulatory approval in 2009/10, but not offered in Europe

World market for new nuclear orders

- Western vendors active in Europe—Areva & Westinghouse—have 6 orders: Olkiluoto (Finland), Flamanville (France) China (4 units)
- China, Korea and Japan have consistently over-estimated their ordering rate for 25 years but may order one or two new plants
- No other new orders in prospect except for USA (see later)

Country	Site	Tech	Vendor	MW	Const start	Const stop	% built	Restart expected 2007/08
Argentina	Atucha 2	HWR	Siemens	692	1981	1994	80	Yes
Bulgaria	Belene 1, 2	WWER	Russia	1000	1987	1991	45	Yes
Brazil	Angra 3	PWR	Siemens	1275	1976	?	30	No
N Korea	Kedo 1 2	PWR	S Korea	1000	1997	2003	33	No
Romania	Cernavoda 3, 4, 5	Candu	AECL	655	1983	?	10	No
Russia	Kursk 5	RBMK	Russia	925	1985	?	70	No
Slovakia	Mochovce 3, 4	WWER	Russia	405	1983	1990	40, 30	Yes
Ukraine	Khmelnitsky 3, 4	WWER	Russia	950	1986	1990	30, 15	No

Eastern Europe: Hangover plants

Attractions

- Construction often seems advanced (the shell is completed before internal work)
- Completion of them appears likely to allow lucrative exports of power
- Power from Mochovce & Belene would replace power produced by Bohunice & Kozloduy

But

- Designs out of date. If building to below today's standards was unacceptable, upgrading expensive
- Much of the equipment has been stored for 15 yrs. It could need expensive work or replacement
- Issues about quality of existing work. Showing it is up to standard would be expensive, and remedial work could be very expensive.

Eastern Europe: Hangover plants

Bulgaria

- Belene construction started 1987, stopped 1991, 45% complete
- Contract awarded to Atomstroyexport in 2006, but can it be financed?

Slovak Rep

- ENEL promised to complete Mochovce 3 & 4 when it bought Slovenske Elektrarne
- Work restarting in 2007

Eastern Europe: Hangover plants

Romania

- Only civil work carried out at Cernvoda 3-5, no equipment, so effectively a new order. Many hurdles to overcome

Russia

- Strong internal pressure to complete Kursk 5 but would it be feasible

Ukraine

- Political pressure for Khmelnitsky 3 & 4 but not a priority

US Initiative: Nuclear Power 2010

Last nuclear order in USA not cancelled was 1974. Extensive guarantees and subsidies back the Bush Nuclear 2010 programme including:

- Production tax credits: €13.5/MWh credit for 8 years for 6-8 reactors: cost to US treasury €4.3bn
- Loan guarantees for 1st 6 reactors. Congressional Research Service estimate liability of €10.5-12bn
- Support framework against regulatory or judicial delays, worth up to €375m for the first two reactors and €188m for the next four;
- Further R&D funding worth €640m;
- Help with historic decommissioning costs up to €1bn
- Total cost of this programme is around €15bn

The US Initiative: Nuclear Power 2010

- Several groups have declared an interest, eg, 'Nustart' consortium and Dominion but progress slow and no commitment to order plants
- CEO of Dominion Thomas Capps said (2005): "We aren't going to build a nuclear plant anytime soon. Standard & Poor's and Moody's would have a heart attack [the debt-rating agencies]. And my chief financial officer would, too."
- Nuclear orders must be placed with the support of financiers, it is not just a decision for utilities
- The financial community sees nuclear as a big economic risk on the basis of its poor track record
- All that these orders can demonstrate is that government can build nuclear plants by compelling taxpayers and customers to pay for them

UK: Nuclear back with a vengeance?

- 8 years needed for designs to be given safety consent and sites to be approved
- First plant not ordered till 2015
- 6 years construction so first power 2021
- 6000MW total new nuclear capacity by 2026
- Decisions to be taken by private companies
- No government subsidies but in central case, nuclear more expensive than gas, so why would a private company choose nuclear?
- In February 2007, High Court said government's consultation process was inadequate and will have to be re-opened, delaying things by at least a year

How are low costs produced? Olkiluoto

- Construction price reported to be €3bn, €2000/kW, higher than all recent forecasts
- Will this cost be met? Is it really fixed?
- Is it a 'loss-leader? EDF has said Flamanville will cost 10 per cent more excluding some things included in the Olkiluoto price
- Export guarantees were given by France (this is subject of an EU state aid investigation) & Sweden
- Bayerische Landesbank (BLB) gave €1.95bn loan (60% of cost) at 2.6% nominal
- TVO, customer, is a not for profit organisation owned by energy intensive companies
- Output is contracted for the life of the plant to TVO owners at prices set to cover all costs

Problems at Olkiluoto

- After 18 months construction (Dec 2006), the plant was a 18 months late
- Areva had lost €700m by Dec 2006 and has an off balance-sheet commitment "in the range of €1.5-2bn"
- In October 2006, Areva replaced the head of project
- In January 2007, Areva said:

Areva-Siemens cannot accept 100 % compensation responsibility, because the project is one of vast co-operation. The building site is joint so we absolutely deny 100% compensation principle

What has gone wrong at Olkiluoto?

- September 2005: Problems with strength & porosity of the concrete for the reactor building base slab and manufacturing of the pressure vessel and steam generators was "some weeks" behind schedule.
- February 2006: Problems with qualifying pressure vessel welds and delays in detailed engineering design
- October 2006: TVO discovers that 3 of 4 of the 'hot legs' were not made to specification
- March 2007: damaged steel liner for the containment must be repaired

What has gone wrong at Olkiluoto?

Seija Suksi, Finnish Radiation & Nuclear Safety Authority:

The time and amount of work needed for the detailed design of the unit was clearly underestimated when the overall schedule was agreed on', Areva 'is not so experienced in construction work. First of all, they didn't understand that the base slab is also safety-related construction and they didn't have enough experience to give advice to the subcontractors. The tight cost frame is also a problem in selecting and supervising subcontractors. They have very often chosen a subcontractor who has given the lowest tender.', 'we had the impression that Framatome tried to show that the concrete problems were all caused by the subcontractor, but the root causes are much deeper in the overall management of this project.' STUK wants TVO 'to communicate more clearly to the personnel on this project that turnkey delivery doesn't mean that they can stand apart from the project. TVO should remember that they are responsible for the safety of the power plant. That responsibility cannot be transferred to the supplier.

Why disagreement on nuclear costs?

- There has always been an assumption that new plants would be much cheaper and more reliable than existing plants
- Forecasts of nuclear costs and performance are generally made by those with a vested interest in nuclear and have invariably been optimistic
- Few orders have been placed in the past two decades on which to base forecasts
- Very little real data on construction and operating cost is published
- All the designs being considered in the West are unproven. Only one plant worldwide of modern design is under construction

Most important economics factors

- Construction cost and time. Repaying construction cost and interest is expected to account for about 2/3 of the cost of power from a nuclear plant
- Cost of capital. Nuclear power is the most capital intensive generation option. For a publicly owned company in a monopoly, the cost of capital is low (5-8%) but for a private company in a market, it is high (>15%). Utilities with guaranteed markets will be rare
- Operating performance. The reliability of the plant (load factor) determines how much output it produces. The more output, the more thinly fixed costs can be spread. Load factors were expected to be about 90% but only in a few countries has this level been reached

Other important factors

- Operations and maintenance (O&M) cost. Many people assume nuclear power is essentially free once the plant is built. British Energy went bust because it could not even cover its operating cost from revenue.
- Decommissioning & waste disposal provision. If cost is accurately forecast and provisions are collected and invested safely, this is not a major cost.
- But there is no experience of high-level waste (HLW) disposal and little experience of decommissioning so cost estimates are guesses. Britain's decommissioning provisions have been lost 7 times and there few provisions for HLW disposal

Less important factors

- Assumed lifetime. Especially with high costs of capital, the expected economics are determined by what happens in the first 10-15 years.
- Fuel cost. Nuclear fuel purchase is a small part of the generation cost. Spent fuel disposal costs are expected to be relatively small but are very uncertain
- Insurance and liability cover. International treaties mean governments bear the main risk but even limited cover is expensive.
- Output rating. Earlier generations of plant often did not operate as designed, for example, not reaching their design rating. This is now less likely to happen

	Construction cost (€/kW)	Real cost of capital (%)	O&M cost €/MWh	Generation cost €/MWh
Benchmark	1875/2025/4000	12-15	15-30	?
Lappeenranta	1875	5	18	23
PIU	1200	15	?	55
UK Energy Rev	2000	?	?	56
Scully Capital	725-1160	?	12	?
MIT	1600	11.5	11	67-79
RAE	1660	7.5	22	41
RAE (update)	1520	10	23	41
Chicago Univ	800-1450	12.5	12	42-57
Canadian Nuc	1550	10	11	27
IEA/NEA	1600-3600	5-10	8-22	17-55
Oxera	1670-2350	?	17	?
UBS	2050	?	?	30

How do forecasts give low costs?

- The UK PIU (2002) used construction cost <€1200/kW. Sizewell B cost >€4200/kW and Olkiluoto is forecast to cost at least €2000/kW
- The UK Energy Review used Olkiluoto construction cost but produced same generation cost as PIU, what else had they changed?
- Scully Capital (2002) had 4 construction cost scenarios, €700-1100/kW
- MIT (2003) assumed €1540/kW and O&M costs 25% less than current plants
- RAE (2004) assumed 7.5% cost of capital and O&M costs a third of current UK plants

How do forecasts give low costs?

- Chicago University (2004) assumed construction cost of €770-1400/kW
- Canadian Energy Research Institute (2004) assumes construction cost of about €1400/kW
- IEA/NEA (2005) has a range of scenarios with very low options, eg 5-10% cost of capital
- OXERA (2005) assumes O&M costs are less than a third of current UK plants and load factor is 95%

Need for subsidies and guarantees

- 15 year power purchase agreement indexed to costs
- Turnkey construction contract
- Performance/reliability guarantee
- A guarantee on operating costs
- A cap on decommissioning liabilities and waste (esp spent fuel)
- Insurance guarantees against regulatory and judicial delays and the consequences of events elsewhere in the world

Conclusions (1)

- Cost-reducing factors - learning, technical change, scale economies, economies of number - have had little impact on nuclear costs. Why?
- Skills in the nuclear area are eroding rapidly and 'forgetting' is more likely than 'learning' (Olkiluoto)
- Economies of number impossible for ages
- Little experience with current designs
- Waste, decommissioning costs are guesses
- Even where there is experience, costs are not available or not reliably reported

Conclusions (2)

- Liberalisation of electricity industries raises the cost of capital and shifts economic risk to share-holders
- Olkiluoto is unique. In most other countries, nuclear orders would need public subsidies and guarantees
- The favourable forecasts of nuclear costs published in the past 5 years have all been based on highly optimistic assumptions
- Guarantees are needed to deal with the economic risks.