Can we afford nuclear to save us from global warming?
Steve Thomas

Climate Crisis: Why Nuclear is not Helping
Vienna October 7th 2019

Steve Thomas (stephen.thomas@gre.ac.uk)

Emeritus Professor of Energy Policy

PSIRU (www.psiru.org), Business School

University of Greenwich

Outline

- What determines the cost of a kWh of nuclear power?

- How are construction costs measured & what experience is relevant?

Realistic reactor options

- Framatome EPR
- Westinghouse AP1000
- Korean APR1400

- Conclusions

What determines the cost of a kWh of nuclear power?

In a conventional nuclear project appraisal (discounted cash flow), costs fall into 3 categories

Crucial

- Construction cost
- Cost of borrowing

Quite important

- Non-fuel operations & maintenance cost

Minor importance

- Fuel purchase
- Spent fuel disposal
- Decommissioning

Why are decommissioning & spent fuel disposal costs unimportant in conventional analyses?

- Spent fuel disposal untested & minimal experience with decommissioning, intermediate level waste disposal. But, decommissioning likely to cost €bns per reactor, spent fuel also expensive

- Decommissioning likely to happen 100+ years after plant start-up, unknown when spent fuel disposal will happen (also 100+ years?)

- In ‘discounted cash flow’ calculations, basically assume real/notional fund created, earning interest till funds required. A fund earning 3% real over 100 years will have grown 20-fold.

- So if decommissioning a reactor costs €2bn, the fund need only have €100m when reactor starts up

Will this work?

There will only be enough money if:

- The cost estimates are not too low;
- The fund, if there is one, is kept secure & not lost;
- The fund earns the expected positive real interest rate for the period required;
- A future generation is prepared to wait to be rid of it till there is enough money;
- The plant operates & takes money from consumers for as long as expected;
- The plant owner does not go bust;
- + + + +

Cost of borrowing

- Cost of borrowing depends on several factors but crucially on how risky the project is to the lender

- No bank will lend money to a nuclear project unless the risks fall on someone else, eg, taxpayers through loan guarantees or electricity consumers by guarantees they will pay whatever the plant costs

- Loan guarantees & cost pass-through are huge subsidies not offered to other options like renewables

Construction cost

- Usually reported as the ‘overnight cost’ of 1kW of capacity, usually in US$ - a 1000MW plant costing $5000/kW would cost $5bn
- Overnight costs exclude interest charges during construction. Depending on the interest rate, these might be expected to add 50% to the overnight cost
- Overnight cost is useful for analytical purposes but consumers must pay the interest charges so overnight costs can hide the real cost
- Construction delays dramatically increase interest costs
- The promise of the latest generation of designs, like EPR, AP1000 etc was costs not much more than $1000/kW

Relevant experience

- Relevant experience only in countries that publish reliable costs & building modern designs

- Most plants in past 20 years not in this category, eg, China, Russia, India, Korea. These countries have monopoly utilities with discretion to set their own tariffs

- EPR: 2 reactors completed (China), 2 reactors under construction (Finland, France), 2 reactors just starting construction (UK)
- AP1000: 4 reactors completed (China), 2 reactors under construction (USA), 2 reactors abandoned (USA)
- APR1400: 2 reactors completed (Korea), 4 reactors under construction Korea, 4 reactors under construction UAE

Areva EPR

- Olkiluoto (Finland). 2002, plant approved, cost €2.5bn; 2005, construction start, cost €3bn, completion 2009; 2019, cost €11.4bn, completion 2020+ (costs include finance). Loan guarantees & cost pass-through

- Flamanville (France). 2005, plant approved, cost €3bn; 2007, construction start, cost €3.3bn, completion 2012; 2019, cost €10.9+bn, completion 2022-24

- Hinkley Point C x 2 (UK). 2008, cost £4bn; 2010, completion 2017; 2013 when power purchase price set, cost £14bn; 2019 construction start, completion 2025-27, cost £21.5-22.5bn. Loan guarantees probable & take-or-pay 35-year fixed real price contract

- Taishan x 2 (China). Construction start 2009-10, completion 2018-20

- 2016, Areva collapsed in large part due to Olkiluoto losses. Now owned by EDF & likely to be nationalised

AP1000

- Summer x 2 (US): 2012, construction/operation license, cost $9.8bn. Construction start 2013 expected completion 2017-18. Early 2017, completion expected 2020. Late 2017, project abandoned. Cost estimates up to $25bn. Who will pay? Cost pass-through

- Vogtle x 2 (US): 2012, construction/operation license. 2008, estimated cost $14.2bn. Construction start 2013. 2016, $8.3bn loan guarantees given. 2017, $3.7bn additional loan guarantees. 2019, construction cost $23-27bn, completion late 2021, late 2022. Loan guarantees & cost-pass-through

- Sanmen x 2, Haiyang x 2 (China): Sanmen construction 2009 to 2018, Haiyang construction 2009-10 to 2018-19

- 2017, Westinghouse files for bankruptcy due to losses on Vogtle & Summer. Now owned by Canadian company but unlikely to pursue new orders

APR1400

- Seen as a cheaper, easier to build option than EPR or AP1000 on basis of rapid construction in Korea and low bid for UAE

- Licensed from Westinghouse System 80+, given generic approval by NRC in 1997, APR1400 approved by NRC 2019, but no US customers

- 2010, KEPCO bid $3600/kW for 4 reactors for UAE, 30% lower than Areva EPR

- KEPCO acknowledges design for Korea & UAE lacks safety features required for Europe, notably a core-catcher & a reactor shell able to withstand an aircraft impact: like a car without seat-belts and air-bags (Lauvergeon)

APR1400

- Shin Kori 3, 4 APR1400s complete (2016, 2019) in Korea after 8-10 years construction, Shin Hanul 1,2 under construction still after 6-7 years, Shin Kori 5,6 just started construction.

- Delays due to discovery in 2012 of large-scale falsification of QC documents (thousands of parts) requiring affected components to be replaced & problems with pilot operated safety relief valves (POSRV)

- Barakah x 4. Construction start 2012, 13, 14, 15, expected completion 2017-20. Delays initially claimed due to lack of operators, now clear also quality problems. POSRV & cracks in all containment buildings. Completion 2020 onwards

- Europe versions has no customers & design not specified in detail or costed

Conclusions

- Reactors have taken 8-15+ years to complete
- Costs have increased 90-500+% from project agreement to completion
- All European & US projects have been built on the basis of sovereign loan guarantees and/or promises of full cost recovery from consumers
- Losses essentially bankrupted the world's largest reactor vendors, Areva & Westinghouse
- Hinkley Power contracted on 35-year take-or-pay contract at £92.5/MWh (2012 money). Latest UK off-shore wind prices, <£40/MWh (2012 money). Onshore wind & energy efficiency likely to be cheaper still