A critical look at economic claims about the impact of new nuclear reactors in Dukovany

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Outline

- The design options
- What would the construction cost be?
- The proposed finance arrangements
- First Of A Kind costs

Considerations on reactor choice

- Reactor output up to 1200MW – cooling water constraint
- Cost
- Experience of construction & operation
- Review by credible, experienced, independent regulatory body
- Political constraints
- Finance offered

Reactor options

- Areva/Framatome EPR1200
- Westinghouse AP1000
- KHNP APR1000+
- China General Nuclear Hualong One
- Rosatom AES-2006

Framatome EPR

- Areva collapsed in 2016 & French government (majority owner) split the company into a fuel cycle company (Orano) & the reactor business, taken over by EDF & renamed Framatome

- European Pressurised water Reactor (EPR) has 4 coolant loops giving 1600+MW output, too large for Czechia

- 2 EPRs (Taishan) in service in China, 2018-19, 5 years late, costs unknown

- 1 under construction (Olkiluoto, Finland) since 2005. Expected completion 2009 at €3bn. Latest estimate 2022, €11.4bn. Contract was fixed price & a major factor in the collapse of Areva. €700m in loan guarantees given by French & Swedish governments

Framatome EPR

- 1 under construction (Flamanville, France) since 2007. Expected completion 2012 at €3.2bn. Latest estimate 2023+, cost €12.4bn (EDF) or €19.4bn (Cour des Comptes). Significant factor in need to rescue EDF (Operation Hercule)

- 2 under construction (Hinkley, UK) since 2018-19. Expected completion in 2013, 2023 at cost of £14bn. Latest estimate 2026-28, £22-23.7bn

- Serious quality problems on-site & with components. Areva faked QC documentation over decades. Reactor vessel components supplied by Areva did not meet specification & must be replaced where possible

- No likelihood of French government finance

- Design reviewed by Finnish, French & Chinese authorities

Framatome EPR 1200

- Since 2010, Areva/Framatome has been developing an ‘EPR 2’, which would be cheaper (25% less) & easier to build, eg single skin containment, but still too large for Czechia
- Expected availability always a year or two away. No buyers
- Framatome EPR 1200, 3-coolant loop EPR, does not exist
- Framatome developed 1200MW PWR with Mitsubishi, Atmea One. Mentioned as option for Czechia in 2019 but abandoned in April 2020 with no sales or sales prospects
- No other potential customers for EPR1200.
- Development & first of a kind costs would fall on Czechia? Czechia’s safety regulator would be first to review the design

Westinghouse AP1000

- 4 AP1000s in service China (Sanmen, Haiyang) 2018-19, 5 years late, costs unknown
- 2 AP1000s started construction in USA (Summer) 2013-14, cost US$5.2bn completion 2017-18. Project abandoned 2017 when cost expected $25bn. Guaranteed loans offered by US government but not taken up. State regulator promised full cost recovery
- 2 AP1000s started construction in USA (Vogtle) 2013, cost US$6.65bn completion 2017-18. Latest expected completion 2022+, cost $19bn. Guaranteed loans provided by US government. State regulator promised full cost recovery
- Innovative design with more production line content rather than site assembly, reliance on passive safety. Meant to reduce costs & improve QC but costs seem no lower & serious quality problems with factory made components, eg reactor coolant pump
- Design reviewed by US, UK & Chinese authorities

Westinghouse AP1000

- 2015, Westinghouse (owned by Toshiba) signed fixed price contract to complete Vogtle, Summer. 2016, estimates found to be about $6bn too little & Westinghouse filed for bankruptcy protection. Toshiba nearly bankrupted
- 2017, Westinghouse bought by Canadian venture company, Brookfield
- Brookfield making big profits from Westinghouse. How? Brookfield may sell soon
- Why try to sell AP1000s? Brookfield is clear it is unwilling to be exposed to any construction risk
- Trump administration wanted to offer loan guarantees to support US vendors, not clear if Biden administration will do the same

KHNP APR1400

- Licensed from Combustion Engineering (System 80+)
- 2 complete in Korea (Shin Kori 3, 4) after 8-10 years, 2016, 2019. Long shutdown 2018 at unit 3 due to defective pilot-operated stress relief valve (POSRV). Generic issue for all APR1400s
- 2 under construction in Korea since 2012/13 (Shin Hanul 1, 2). Nearly complete 3-4 years late
- 2 more under construction since 2017/18 (Shin Kori 5, 6), 2-3 years late
- 4 under construction in UAE (Barakah) since 2012-15. First in testing since 2020 4 years late
- Large scale QC falsification discovered in 2012 delaying 4 APR1400s. All suspect components replaced
- POSRV is safety critical & despite problem being identified, not clear if it is solved
- Design reviewed by US & Korean authorities. No safety regulator existed in UAE when Barakah ordered

KHNP APR1000+

- Design built so far doesn’t meet European standards, eg no aircraft crash protection & no core-catcher. Described in 2010 by CEO of Areva, Lauvergeon, as ‘like a car without airbags & seatbelts’

- A ‘European’ APR1400 design said to be under development but no customers

- APR1000+ does not exist

- No other potential customers for APR1000+.

- Development & first of a kind costs fall on Czechia? Czechia’s safety regulator would be first to review the design

CGN Hualong One

- Is a Chinese design politically acceptable?
- 2 versions of Hualong One, CGN & China National Nuclear Corporation (CNNC). Significant differences between the 2, eg number of safety systems. Design still evolving.
- CGN version: 4 under construction, 2 since 2015/16 (Fuqing 3, 4), 3 since 2019/20 (Taipingling, Sanaocun). None complete yet
- CNNC version: 2 under construction, 1 testing. Not more than a year late
- Only Chinese reactor exports to Pakistan, terms unknown
- Review of CGN design in UK nearly complete

Rosatom AES-2006: St Petersburg

- Is a Russian design politically acceptable?
- 2 versions, St Petersburg & Moscow. Significant differences. St Petersburg seems more likely
- According to Rosatom figures, slightly higher accident risk than Moscow version
- 1 complete St Petersburg (Russia) 2018, poor reliability in year 1 (74%), 1 testing. Both 5 years late
- Belarus, 1 testing, 1 in construction, both 3 years late. Quality problems
- Orders for Finland (Hanhikivi), Hungary (Paks x 2), Egypt (El Dabaa x 4)
- Design under review in Finland & Hungary

Rosatom AES-2006: Moscow

- 2 complete Novovoronezh (Russia) 2017, 19, 3-5 years late. Unit 1, poor reliability (74%)
- 2 under construction 2018, 2020 & 2 more on order Akkuyu (Turkey)
- 2 under construction 2017/18 Rooppur (Bangladesh), 2 years late
- Design reviewed by Turkey

What would the construction cost be?

- Costs vary from project to project for the same vendor for several reasons:

1. Local conditions, eg seismicity, cooling water
2. National regulatory requirements
3. Currency rate fluctuations
4. Contract conditions, e.g., how fixed are prices
5. Different contract dates & inflation
6. Competence of the buyer

- Reliable cost information not available from Russia & China. Korean data are for design that needs safety upgrades

- No vendor will give a genuine ‘turnkey’ (fixed price) contract, Westinghouse & Areva were bankrupted by losses from such contracts

- Bid prices are a poor guide to actual prices, but all projects in countries that do provide reliable price data have gone horribly wrong

- Contract prices increasing in real terms, eg Olkiluoto/Flamanville contract price €3bn per reactor, Hinkley, €8bn

What would the construction cost be?

- 2008, UK government assumed 2 EPRs cost £5.6bn, 2013 deal based on £14bn, 2017 increased to £19.6bn, 2019 increased to £21.5-23.2bn, 2021 increased to £22-23.7bn (2015 money) or £25.5-27.5bn (2020 money), about €30bn
- Cost estimate for Hinkley when construction started (2019) £21.5-23.2bn in 2015 money. €9100/kW in 2020 money, about half the price assumed by Czech government
- US, French, Finnish costs no lower than UK costs
- What is the basis for €4500-5000/kW? Old data or data on old designs, or from countries which don't give reliable data
- The average for Vogtle, Hinkley, Olkiluoto & Flamanville is €7200/kW
- As UK found, it is politically difficult to back out of a project when costs rise

What would the construction cost be? Experience from KHNP

- Barakah price $3600/kW (2010 prices) or $4800 (€4000/kW) in 2020 money
- Was the deal a loss-leader? Only Korean attempt to export reactors
- Actual cost not known but it is 4 years late so cost overruns inevitable

What would the construction cost be? Experience from Rosatom

- Most Rosatom exports assume Russian loans (typically 3-4% interest) paying for 80-90% of the project so can therefore deduce cost estimate when deal signed
- Akkuyu (Turkey) 4 reactors signed 2010 at expected cost of $5.5bn/reactor, but project wholly owned by Rosatom, so no reason to publish cost estimates
- Roopur (Bangladesh) 2 reactors signed 2013 at cost of $4-6bn/reactor, estimate 2015, $6.6bn
- Paks (Hungary) 2 reactors 2014, $6.7bn/reactor, completion 2030, 5 years late
- Hanhikivi (Finland) 1 reactor 2015, $7-7.5bn, completion 2028, 6 years late
- El Dabaa (Egypt) 4 reactors, 2016 cost $7.4bn, completion 2027
- Russian costs appear similar to Framatome/Westinghouse

Finance

- Nuclear projects are almost invariably completed significantly over budget, late & at kWh costs higher than low-C alternatives. They cannot compete in a market so power purchase agreement essential
- Therefore financial institutions will not lend to nuclear projects unless the financial risks are borne by somebody else
- This can be through guaranteed cost pass through, in short, consumers must pay whatever costs are incurred
- Or through sovereign loans or loan guarantees from the vendor's home government. So if the project fails financially, financial institutions will be repaid by taxpayers
- Russia & China facilitate loans from state-owned banks or funds. These loans are usually underwritten by the government of the country buying the reactor so if the project goes wrong, Russia/China will be repaid by taxpayers of the recipient country

Proposal for Dukovany

- Who would own the plant? Is CEZ willing?
- Relying on the government of the vendor to provide finance would reduce the field to Rosatom (Russia) & China General Nuclear (CGN). Both potentially politically not feasible
- First proposal (May 2020), 70 % of costs covered by state loan, interest rate 0% during construction & 2% during operation for 60 years. 30% by ČEZ, interest rate between 9-14%. WACC 4-6%
- Latest proposal (Jan 2021), 100% covered by state loan, interest rate 0% during construction & 2% for operation
- The forecast power price is €50-60/MWh with a 60 year power purchase agreement under these assumptions
- Under this proposal, any of the five vendors expressing an interest would be possible

State-aid

- Hinkley deal referred to EC Competition Directorate to determine if it represented illegal state-aid. Main concern offer of sovereign loan guarantees
- EC said it was state-aid & required the fee for the guarantees to be increased from 2.15% to 2.75% (~£50m) so insignificant
- However it said that the Euratom Treaty required Member States to promote nuclear & the Lisbon Treaty gave member states right to determine energy mix, so blocking a nuclear deal would break those Treaties
- Offer of loan guarantees not taken up, EDF unwilling to provide the cash collateral UK government required
- The 2 Czech proposals, 70% state funding & 100% state-funding, both with huge interest rate subsidies would represent an order of magnitude more aid. Would the Commission be willing to allow this?

Who would bear the risk of the financing model proposed?

- CEZ seems unwilling to own the plant. Its cost of equity would increase cost of finance especially if its equity is not zero interest during construction
- Two main power purchase cost models: cost plus & fixed cost
- Cost plus model (used in Vogtle & Summer (USA) & proposed for Sizewell C (UK)) would place all the risk on electricity consumers
- Fixed cost model (used for Hinkley (UK)) places all the risk on the plant owner. EDF claims this risk added 20% to the fixed price agreed for Hinkley. Construction costs have increased by up to 70% since the deal was done so 20% a major underestimate. For the Czech model, if the government owned the plant, risk would fall on Czech taxpayers

First Of A Kind (FOAK) costs

- Vendors usually claim their technology is proven when they are selling it but when costs escalate, it is because the reactor is a FOAK
- EDF claims Hinkley is a FOAK but 4 reactors of the EPR design had been under construction for 6+ years when the order was placed & 9+ years when construction started. So how is it a FOAK?
- Every reactor has unique features partly due to site differences, partly to national regulatory requirements, partly due to experience with the design elsewhere
- EDF claimed 20% of the per kWh cost was due to FOAK risk.
- It claims Sizewell will 20% cheaper than Hinkley because it will be a copy. But expected cost of Sizewell is 22% more in real terms than the expected cost of Hinkley when the Hinkley deal was done

The Hinkley price

- Set in 2013 at £92.5/MWh 2012 prices, take-or-pay terms indexed to inflation. In 2020 money, £111.7/MWh/€130/MWh, cf £48/MWh for offshore wind
- Risk of construction cost or time increasing falls on EDF. Operating costs can be reviewed after 15 & 25 years
- Since the deal was done, the completion date has gone back 5 years, real construction costs have increased by 52-68%. The extra costs fall on EDF
- No breakdown of £92.5 at the time. Only said that price would go down by £3/MWh if Sizewell built. Contribution for decommissioning & spent fuel disposal claimed to be about £2/MWh
- In 2020, EDF offered a breakdown of the cost. This appeared to be a post-rationalisation rather than the actual cost elements & is mean to show that power would be much cheaper if the risk did not fall on EDF

EDF’s breakdown of the Hinkley power price

	Cost £/MWh
Construction risk premium FOAK	18
Construction risk premium other	18
Financing cost without risk premium	26
Operations & Maintenance cost	19.5
Capital construction cost excluding finance	11
Total	92.5

Conclusions (1)

- Of the 5 designs under consideration:

1. EPR1200 & APR1000 would be untested designs based on scaled-down designs with poor history with first of a kind costs falling on Czechia
2. Experience with AP1000 & AES-2006 is poor. No independent review of AES-2006 complete yet
3. First CGN Hualong One is not yet complete & little information exists on construction experience. UK safety review is not complete

- Serious quality issues have occurred with all options except Hualong One

Conclusions (2)

- Assumed construction cost, €4500-5000/kW, is unrealistic, only about 2/3 of known prices for modern technology. Even with huge finance subsidies offered, a realistic power price would be much higher than the €50-60/MWh claimed

- The proposed finance arrangements represent a huge subsidy. EDF estimates that finance doubles the ‘overnight’ construction cost & while market interest rates are currently low, 2% for the life of the loan would be a massive subsidy. Would it break EU state-aid legislation?

- Reactor vendors usually claim their designs are proven when selling them but when costs turn out high, they say this was because of FOAK costs & the next plant will be much cheaper