Advanced Modular Reactors: Are they a realistic option?

Presentation to NuLeaf, June 14, 2023

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Semantics

Meaningless

- Advanced, Smart, proven technology

Need clarification

- Standardisation, modular, production line, streamlining planning, cutting red-tape

Misleading

- Passive safety

Fool me twice? Gen III+ promises

- Generation III+ reactors were new versions of PWRs & BWRs that were promoted from about 2000 onwards based on extraordinary promises on cost & performance

- On the basis of these promises, UK & US launched major reactor sales programmes that almost completely failed

Promises

- Simpler, modular, therefore cheaper ($1000/kW), quicker (4 years) & easier to build (no cost & time overruns), passive safety

Reality

- Not simpler
- Costs typically $10,000/kW, all plants over-budget
- Construction time 10-20 years, even in China and Russia 10 years
- Many of the designs had little passive safety

- Some designs from large vendors completely failed to win sales, eg GE-Hitachi ESBWR, Hitachi-GE updated ABWR. Losses on EPRs & AP1000s contributed to the financial collapse of Areva & Framatome

- Few sales prospects for Gen III+ designs now so vendors need a new story

Thorium cycles

- Seen as possibly a good idea 50 years ago. Still no more than possibly a good idea
- Thorium cycle would require reprocessing & would lead to proliferation risks
- No interest in UK

Generation IV designs

- In 2001, Generation IV International Forum (GIF) launched funded by 13 major nuclear-using nations inc. UK, USA, Russia, China. AMRs are all Gen IV designs

- Gen IV designs claimed to have: increased safety; improved economics for electricity production & new products such as H2 for transportation applications; reduced nuclear wastes for disposal; & increased proliferation resistance

- 6 promising designs identified: gas-cooled fast reactor (GFR), lead-cooled fast reactor (LFR), molten salt reactor (MSR), sodium-cooled fast reactor (SFR), supercritical water cooled reactor (SCWR), very high temperature (gas-cooled) reactor (VHTR/HTGR)

- In its 1st annual report, GIF expected these designs to be commercially available by 2030. None will be close to being available by then

Generation IV designs

- Initially not necessarily small or modular. In 2007, most expected to be 1200MW. Now, taking advantage of the publicity for SMRs, increasingly small & modular
- Fast reactors (GFR, SFR, LFR, most MSRs & most SCWRs) require reprocessing of spent fuel to produce fissile Pu or Th. Proliferation issues. Technical & economic record of reprocessing poor
- GFR, SCWR not commercially pursued so not discussed
- SFRs & HTGRs built as prototype & demo plants but with poor results. Programmes abandoned (US, Germany, UK, Japan, France). VHTR (outlet temperature 1000C) now likely to operate at 700-950C reflecting technological challenges of operating at high temperatures
- In UK, Dragon was prototype HTGR & Dounreay had a prototype & a demo SFR
- MSRs and LFRs long talked about but never built as power reactors

UK Interest in Gen IV SMR designs

- SMRs are conventionally defined as having an electrical output of 20-300MW. Smaller reactors are generally known as micro-reactors

- 2 Gen IV designs advanced to phase 2 of the AMR programme & have received small amounts of funding from the UK government, U-Battery, 3MW HTGR & the Westinghouse 450MW LFR

- A 3rd design was the Tokamak fusion reactor. Fusion is always 50 years away

Westinghouse LFR

- 450MW design, operates at 630C (low for H production) as a grid power source
- Developed primarily by Ansaldo (Italy) & Westinghouse UK (Springfields)
- In July 2020, awarded £10m for development by BEIS.
- Phase due for completion summer 2022. No mention of a follow-up phase since
- BEIS April 2022: ‘In December 2021, following underpinning analysis and a Call for Evidence, the focus for the programme was confirmed as High Temperature Gas Reactor (HTGR) technology’
- Little interest outside UK

U-Battery

- 4MW design, operates at 750C. Suitable for process heat & remote locations
- Developed by Urenco
- In July 2020, awarded £10m for development by BEIS in phase 2 of the AMR programme.
- Phase due for completion summer 2022. No mention of follow-up funding since

UK Interest in Gen IV designs

- In Jan 2023, UK gov't announced 4 Gen IV designs had applied to be assessed by the ONR under the Generic Design Assessment programme. By May 2023, the British government had not responded to these requests

1. Cavendish Nuclear/X-Energy are offering an 80MW HTGR designed to operate at 750C & to be built in clusters of 4 reactors
2. GMET nuclear. Details on its NuCell design are sketchy but it appears to be a 35MW
3. Newcleo is 30MW LFR which may be developed into a 200MW design
4. UK Atomics is offering a LFR using a thorium cycle of about 30MW

- These applications seem to have more to do with PR purposes than a serious attempt to have a commercially ready design evaluated

- Only the X-Energy design, based on a German design from the 1980s, appears to be close to being developed sufficiently for a GDA process to be contemplated. Other appear to be barely conceptual designs

Conclusions

- Great British Nuclear is expected to take on the role of funding development of AMRs but it is not clear when the legislation needed to allow it to be set up will be passed & when it will become functional

- GDA says it does not know what the waste legacy will be. Recent research (authored by a former NRC commissioner) suggests Gen IV designs will create a greater waste problem than large PWRs or BWRs

- There is little prospect that AMRs will be in service before 2040, if ever

- They are technologically & economically unproven & experience with such designs suggests there is a high chance they never will be

- Most require reprocessing of spent fuel, a process that has proved hazardous & expensive & which poses a serious proliferation risk