Small Modular Reactors – Too Untested, Too Expensive, Too Risky and Too Uncertain

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The Main SMR Designs Currently Being Marketed

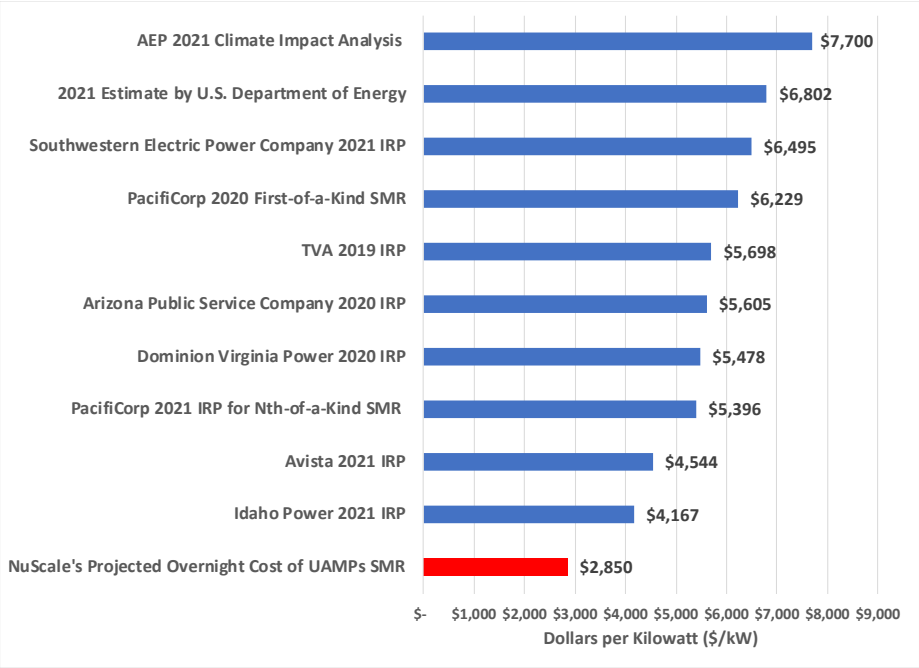
- NuScale SMR
- BWRX-300 Reactor, GE's downsized competitor
- Natrium, the Bill Gates reactor
- Xe-100
- Rolls Royce, an SMR in name only
- EDF's European SMR
- Terrestrial Energy's integrated molten salt reactor
- Kairos' high-temperature, gas-cooled reactor
- TerraPower/Southern molten chloride fast reactor
- Chinese and Russian projects

All these SMRs Represent First-of-a-Kind Designs That Are Untested and Unproven at Commercial Scale

- None of these proposed SMRs have been built, operated or tested at commercial scale.
- Grand claims are being made by promoters but very few details have been provided for almost all these SMR designs – especially concerning costs and construction schedules.
- For example, NuScale claims a lower construction cost and a shorter construction schedule than any reactor has achieved since the early 1970s, and better lifetime operating performance than any U.S. reactor has ever achieved. But these claims are pure speculation.
- In fact, nothing is certain about the actual cost, commercial operation date, operating performance and reliability of all of the other SMR designs.
- New nuclear and non-nuclear plants with first-of-a-kind designs typically experience unanticipated schedule delays, cost increases and problems during both construction and their first years of operations, if not longer.
- There is no reason to expect that the SMRs will be any different.
- SMRs are far more likely to continue the nuclear industry's long history of over-promising and under-producing.

Given the History of the Nuclear Industry, the Construction Costs of Proposed SMRs Should be Expected to Be Significantly Higher Than Their Proponents Now Claim

For example, NuScale's overnight construction cost estimates for its SMR have been remarkably low for a new, yet-unbuilt technology – and are much lower than estimates by disinterested entities.



Overnight construction cost estimates do not include financing costs.

The projected cost of the Natrium reactor Is even higher – nearly 11,600 US$/kW

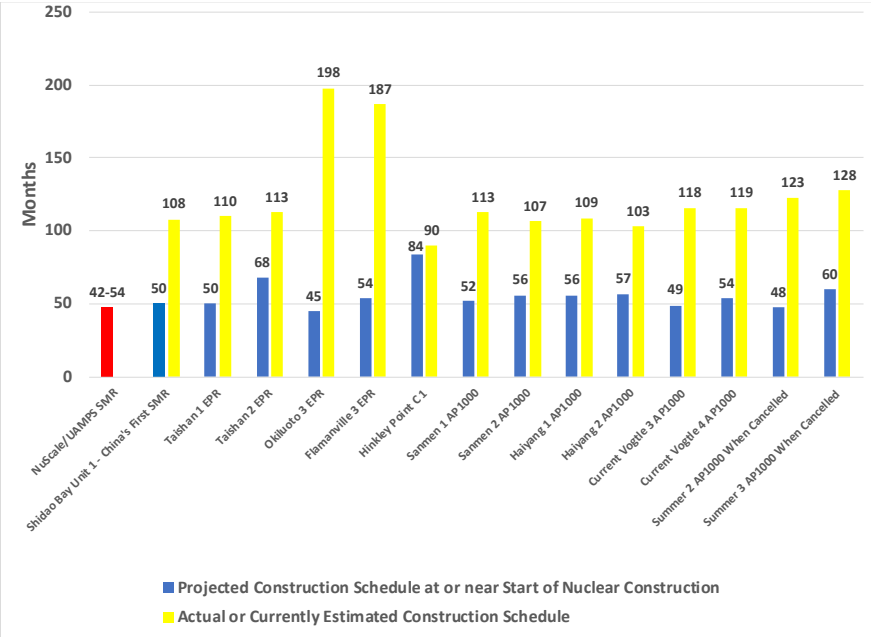
SMR Construction Costs are Unlikely to Decline Significantly Over Time

- Promoters also claim that the costs of building their SMRs will decline over time as more are built.
- However, except perhaps for some reactors built in France, this has not been true in the nuclear industry.
- Moreover, unlike wind and solar resources, it is very unlikely that many units of any single SMR design will be built due to (a) the increasing competition from declining cost renewables and storage and (b) the growing number of proposed SMR designs.
- Promoters of SMRs also claim that through a process call modularization, SMRs will be built in factories and transported to plant sites for installation. However, even NuScale, whose design is furthest along, has acknowledged that there currently is no such factory and that it is unsure when or where there will be one.
- The same claims about the benefits of modularization in terms of lower construction costs and shorter construction schedules were made for the Vogtle nuclear project in the U.S. but it didn't work out so well. Vogtle's projected cost has increased by 140% since nuclear construction began and it is currently over 6 years behind schedule.

Recent Nuclear Plants With New Designs Have Experienced Significant Cost Increases and Construction Delays

- The cost of the Vogtle nuclear project in Georgia has grown by 140% during construction and another two years remain before both units will be in service. Georgia Public Service Commission Staff estimates cost of power from Vogtle will be $150/MWh.
- The cost of the two-unit Summer project in South Carolina rose by 57% before the project was cancelled in 2017.
- The cost of Okiluoto 3 (Finland) has tripled since construction began.
- The cost of the Flamanville plant (FR) has increased by 276%.
- The cost of the Hinkley Point C project (UK) has increased by 22% to 27% in just its first 4 years of construction.

NuScale says that the nuclear construction at its SMR will be completed in less than three years. All recent plants with new designs have taken much longer to build than that.



Nuclear Promoters Over Hype the Interest in SMRs

- NuScale claims that there is substantial interest in its proposed SMR saying that it has about 20 agreements with utilities or governments in the U.S. and Europe.
- However, apart from a single contract to build an SMR for UAMPS (Utah Associated Municipal Power Systems) the agreements that NuScale has publicized have mainly been MOUs (Memoranda of Understanding) which are not firm contracts to build a new SMR but merely commit the other signing parties to work with NuScale to evaluate SMR as part of their future resources.
- For example, the Vice-President of Strategic Growth for the Dairyland Power Cooperative has said that he would describe its involvement with NuScale "at this state as exploratory… (We) definitely owe it to our members to explore all of the alternatives available."
- And even UAMPs only has been able to convince its member communities to subscribe to barely 100 MW of its proposed 462 MW project with NuScale.
- But even NuScale acknowledges that the future viability of its SMR will depend on its economics relative to other alternatives such as renewable resources and battery storage.

Achieving High Capacity Factors While Load Following Renewable Resources is an Impossible Task

- NuScale claims its SMR will achieve a 95% capacity factor over its entire lifetime—a goal never achieved by a nuclear unit in the U.S.
- Only 5 of the 93 reactors still operating in the U.S. have achieved lifetime capacity factors above 90%. None of of the 22 reactors that have been retired achieved a lifetime capacity factor above 84%.
- In order to achieve such high capacity factors, the SMR must basically run at 100% power in all the hours that it is online and not experience extended outages during its multi-decade-long operating life.
- However, NuScale (and developers of other SMR designs) tells current and prospective participants that the SMR also will be able to load follow and firm up the power from renewable generators.
- In order to do this, the plant must be running at less than full power so that it would have additional power to send into the grid in those hours when the renewable resource is not generating any power.

The Price of Power From An SMR Will Go Up if It Is Used to Load Follow Renewable Resources

- SMR promoters claim they will be able to firm up intermittent wind and solar resources.
- However, most nuclear plant costs are fixed, meaning they don't vary with how much power the plant is producing.

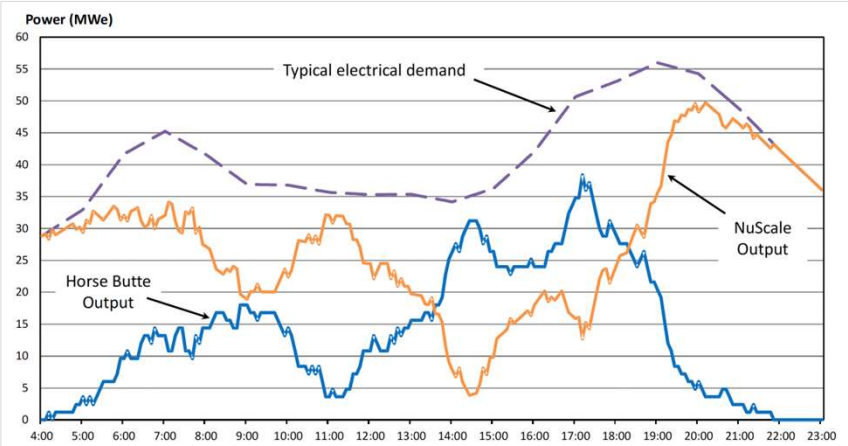
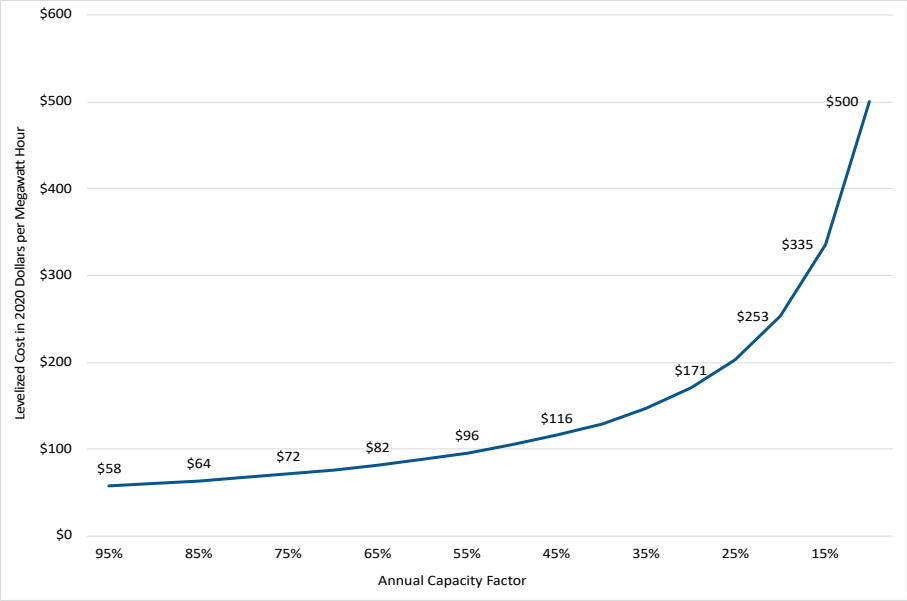


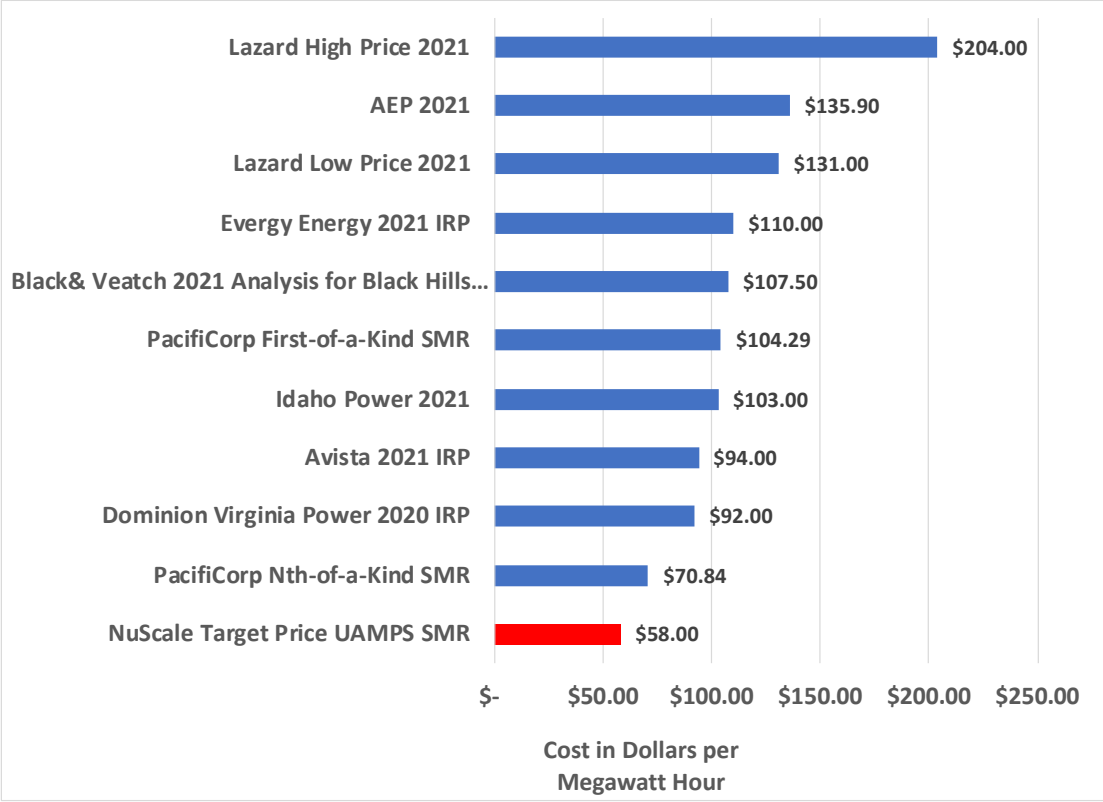
Fig. 5. Example of NuScale module load-following to compensate for generation from the Horse Butte wind farm and daily demand variation.

- Thus, if the plant produces fewer megawatt-hours of electricity when load following renewables, those fixed costs are spread over fewer units of output. As a result, if the SMR produces less electricity the price of its power will go up.

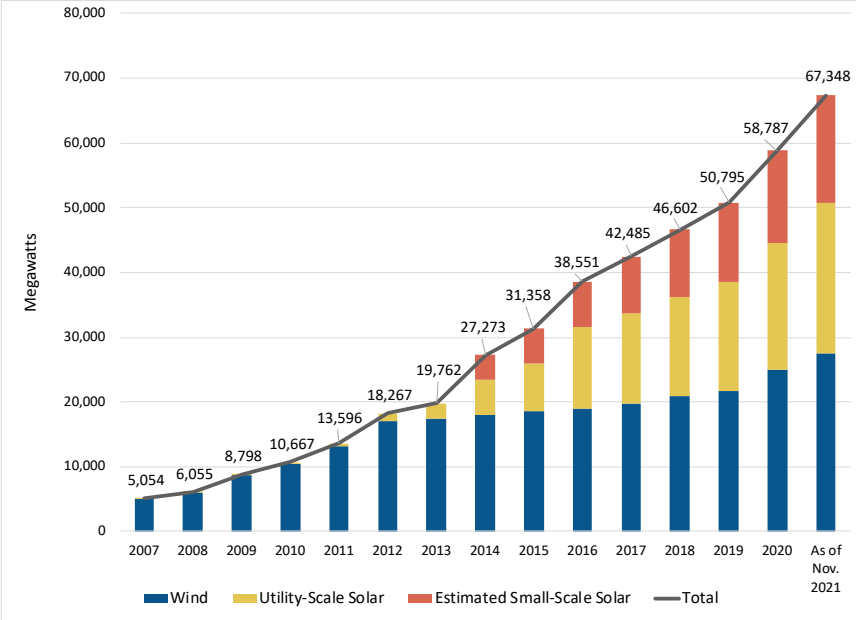


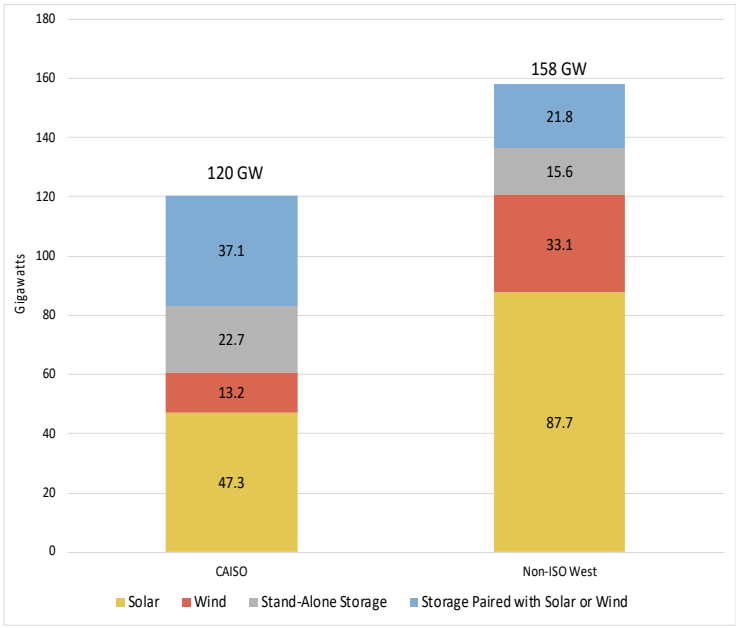
The Cost of Power from SMRs is Likely to be Very Expensive

- NuScale promotes its SMR by claiming it will achieve a $58/MWh estimated target price.
- However, purchasers of the power from the proposed SMR that NuScale wants to build for UAMPS will have to pay the actual costs of the project not this estimated target price, even if the plant is damaged, destroyed or is otherwise unable to deliver power.
- Other, less entangled entities project much high prices for the cost of power from future SMR projects.



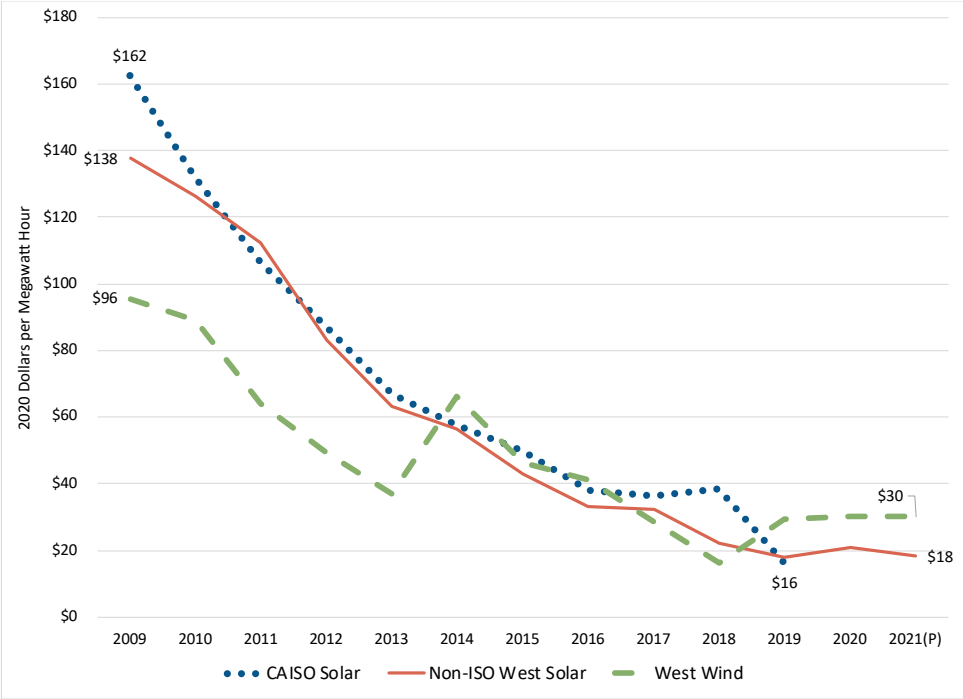
Solar and Wind Capacity in the West Has Increased More Than 12x Since 2007 and Much More Is Planned in Coming Years





- CAISO already added 2,100 MW of battery storage by December 2021 and plans to add another 2,000 MW by this summer.
- As of January 5, 2022, interconnection queues included more than 38,000 MW of standalone storage and almost 59,000 MW of solar and wind paired with storage.

Unlike Nuclear Costs, Wind, Solar and Storage Prices All Have Declined in Recent Years - Further Declines Can Be Expected in the Future



Battery storage prices fell by 72% between 2010-2019, according to U.S. DOE. National Renewable Energy Lab projects storage prices will decline by 28-58% by 2030 and by 28-75% by 2050.

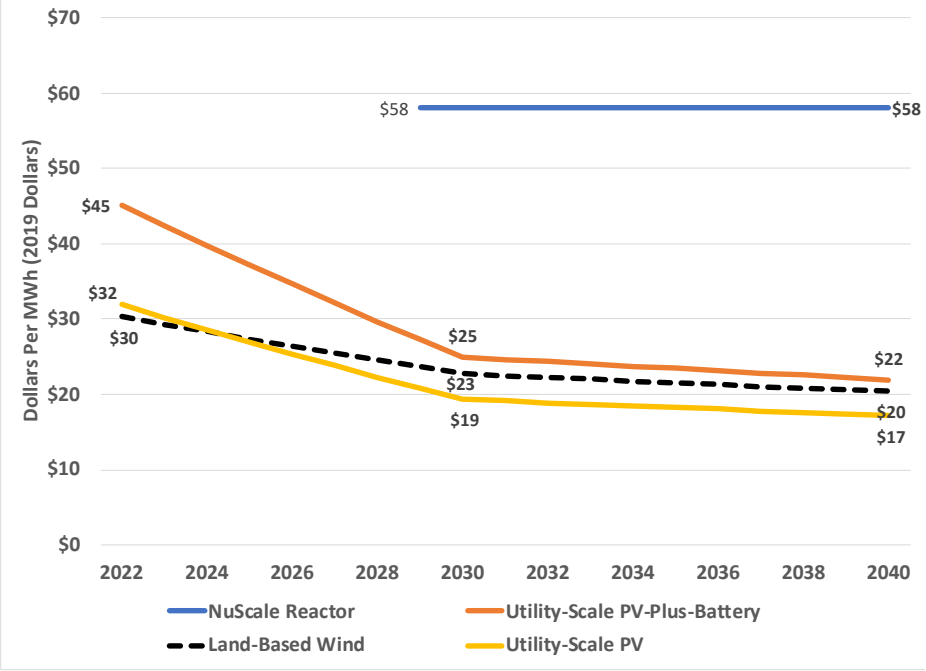
Renewable Resources and Battery Storage Will Provide Reliable Electricity at Lower Cost Than NuScale's SMR

- The growth in renewable solar, wind and battery storage resources will reduce the West's CO_2 emissions and eliminate any need for the NuScale SMR.
- Renewable and battery storage resources have several advantages over the SMR:
  - They can be built faster, thereby being available to the grid in significantly less time than the SMR, which NuScale says won't be fully available until 2030.
  - They have a proven track record of declining costs over the long term.
- By 2030, there will be significantly more utility-scale wind, solar and battery storage capacity installed across the western U.S. There also will be considerably more distributed solar capacity. These will put downward pressure on power prices and rachet up the commercial competition for NuScale.
- The Western grid also will be better integrated and more reliable.

Solar and Wind Generation, Storage and Load Management Can Provide Essential Grid Reliability Services

- It is true that solar and wind are variable generating sources—that is, the sun doesn't shine at night and the wind doesn't blow all the time—but several factors enhance the capacity of the grid to reliably integrate growing amounts of these renewable resources.
- The development of advanced inverter power controls has enabled stand-alone wind and solar resources to respond almost instantaneously to threats to grid stability posed by imbalance between supply and demand that arise, for example, when a large generator goes. In fact, the technical ability of standalone wind and solar resources to provide essential reliability services has been extensively demonstrated through studies, tests and operating experience.
- Steep declines in battery costs and an increased need for grid flexibility have led to a dramatic increase in storage because fast-acting grid-scale battery storage can provide services including, but not limited to, firming the variability in solar and wind generation and providing essential grid reliability support.

NuScale's Estimated Target Price for the Power From its SMR Is Much More Expensive than the Projected Costs of Power From Renewable Alternatives



Even if NuScale were to achieve its estimated power price of $58/MWh, that would still be much more expensive than the cost of solar, wind and storage resources.

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A copy of the IEEFA Report on the NuScale SMR is available at:

www.ieefa.org/SMR

APPENDIX – Other SMR Options

Other SMR Options - BWRX-300 Reactor

- Developed by General Electric and Hitachi (GEH).
- Reactor is a small version of the economic simplified boiling water reactor (ESBWR), a 1,520MW behemoth certified by NRC in 2014.
- Reactor is 300MWe; NRC licensing process started in 2019.
- GEH says reactor will be “factory built” and have “flexible baseload/load following” capability.
- These are key issues for its economic competitiveness case - company says its target is $3,000/kW.
- Selected by Ontario Power Generation in 12/2021 for a new build; work to begin this year, with commercial operation “as early as 2028.”
- TVA said in February 2022 it was considering the BWRX at its Clinch River site.
    - Build decision will take two years; if decision is yes, TVA hopes to have the reactor in operation by 2032.

Other SMR Options - Natrium Sodium-Cooled Fast Reactor

- Developed by Bill Gates backed TerraPower and GEH
- Reactor is 345MWe, based on a design by GEH; proposal is to build the first unit at the site of the Naughton coal plant in Wyoming. Owned by PacifiCorp, that plant is scheduled for closure.
- TerraPower plans to have the reactor operating by 2028.
- Reactor will require high assay low enriched uranium (HALEU) for fuel; U.S. does not currently produce this fuel, which is enriched to up to 20% compared to conventional nuclear fuel (3-5% U-235).
  - Was originally going to get HALEU fuel from Russia but now will not. Admits that this created an "emergency situation" regarding schedule.
  - "This was always a project that was ambitious in terms of its time frame, and we needed lots of things to go right for us."
- Very high estimated construction cost - $4 billion for 345 MW plant.
  - This averages $11,600 per kilowatt.

Other SMR Options - Natrium Sodium-Cooled Fast Reactor

- Earlier sodium-cooled reactors – Phenix in France, Monju in Japan and Fermi 1 in the U.S. have not performed well.
- Concept of a fast reactor isn't new, the first was built in the U.S. in 1946.
- Sodium reacts violently when exposed to either air or water, heightening safety concerns.

Other SMR Options - Xe-100 High-Temperature Gas-Cooled Reactor:

- Developed by startup X-energy.
- Reactor is 80MWe; proposal is to build the plant in conjunction with Energy Northwest in Washington state.
- Designed to be continuously refueled (95% availability); billed as a cost savings by proponents, seen as a safety threat by others due to potential fuel tracking problems.
- Reactor will use HALEU fuel and require construction of a facility to make X-energy's proprietary TRISO (TRi-structural ISOtropic particle) fuel.
- Company was selected by DOE in 2021 for a $1.23 billion grant under the Advanced Reactor Demonstration Program (ARDP).

Other SMR Options – Rolls Royce SMR

- Reactor is 470MW, not really an SMR at all.
- Design is a small pressurized water reactor.
- Project is in the early licensing stage in the U.K..
- Other backers include U.S.-based Exelon Corp. and BNF Resources.
- Group says it is planning 16 SMRs, with installed cost after the 5th unit of $5,100/kW.
- Costs are dependent on modularization and rapid construction (500 days).

Other SMR Options – Nuward SMR

- Proposed by EDF.
- Reactor is touted as the European Pressurized Water SMR, capacity would be 340MW consisting of two 170MW reactors.
- Goal is to have first reactor built by 2030.

Other SMR Options - Integrated Molten Salt Reactor

- Developed by Canadian company Terrestrial Energy.
- Reactor design is 390MW, with two 195MW units.
- Reactor would use molten fluoride salt—pitched as stable, inert and with strong coolant properties, fuel is low-enriched uranium.
- Developer says would operate at high temperatures (700C), boosting efficiency to as much as 48% compared to mid-30s for conventional units.
- All reactor components would be in a sealed, replaceable core that would be swapped out every seven years.

Other SMR Options - Low-Power Molten Salt High Temperature Gas-Cooled Reactor

- Developed by Kairos, reactor is dubbed the Fluoride Salt-Cooled High Temperature Reactor (KP-FHR).
- Reactor would be 140MWe, but initial test reactor (Hermes) is just 50MW (thermal).
- Design was awarded $303 million in DOE development funding in 2020.
- Reactor will be tested by Kairos and TVA - test reactor is scheduled to be complete in 2026.

Other SMR Options - Molten Chloride Fast Reactor (MCFR)

- Molten Chloride Fast Reactor (MCFR).
- Developed by TerraPower with support from Southern Company.
- Reactor work is in the early stages of development.