Taxonomic Guidance on Advanced Reactors

Introduction and Purpose

As the United States and other parts of the world consider plans to decarbonize and mitigate the worst effects of climate change while maintaining energy reliability and security, nuclear energy has reemerged in consideration. Many organizations are increasingly discussing the role of *advanced reactors* as an important zero-carbon, firm energy source. The following industry consensus definition for the term advanced reactor, along with reasoning and additional taxonomic guidance, is offered to assist these discussions by providing context and consistent terminology to distinguish between technically relevant features of advanced reactors.

Advanced Reactor Definition

Suggested:

The term "advanced nuclear reactor" means a nuclear fission reactor with significant improvements, including additional inherent safety features, compared to reactors operating on December 27, 2020, in the U.S.

Alternate:

An advanced reactor is a nuclear fission reactor consistent with the definition of "advanced nuclear reactor" in 42 U.S. Code of Federal Regulations (USC) 16271.

Reasoning and Further Taxonomic Guidance

Additional inherent safety features distinguish advanced reactor designs from those in the current operating fleet. Emphasizing the feature of inherent safety is intended to describe advanced reactors more exactly as a taxonomic class. This “feature-based” approach is meant to describe what the technology is, rather than what it is not; in this way, a feature-based definition enables rather than limits advanced reactors. The suggested definition emphasizes that the key relevant improvement upon currently operating nuclear reactors common to advanced reactors is their inherently safe design. The alternate definition points to 42 U.S. Code of Federal Regulations (USC) 16271, which offers a more extensive list of features. In either definition, a feature-based approach is chosen rather than a pure time-based (date) or size-based (power capacity) definition.

A time-based definition states simply that an advanced reactor is any reactor constructed after a given date. Though temporal limitations are functionally acceptable, a time-based definition does not explicitly address any improvements that have been made to assuage long-held societal hesitancy over nuclear energy.

A size-based definition attempts to create a limitation on the maximum size reactor based on its power capacity. A size-based definition is not recommended because:

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- The amount of electricity generated (MWe) is a different metric than the one used by the NRC to license reactors, which could cause unnecessary regulatory burdens; the NRC licenses the amount of fission energy generated in the reactor, or a reactor's maximum thermal power level (MWt), which is typically around three times the MWe, but depends on the efficiency of the reactor.
- The current advanced reactor industry has a variety of reactor designs, coolants, and power levels; some examples of nominal power levels (not including potential energy storage) being considered are: 1.5 MWe, 5 MWe, 15 MWe, 77 MWe, 80 MWe, 140 MWe, 160 MWe, 300 MWe, and 345 MWe with designs as large as 1110 MWe.
- Limiting reactor choice based on size or power could potentially restrict the best available options or force multiple reactors to be built at a site when a higher power output of a single reactor may be a better choice.

Though other qualifications are not required to define an advanced reactor, there may be a need to add qualifiers to help define the mission for the reactor which consists of the energy production (size based on power output) and temperature output. Though a size-based qualification is not generally recommended, if there is a need to define the reactor by size, the following table may be utilized as agreed upon size ranges.

Size	**Operating** *(MW - thermal)*	**Output** *(MW - electric)*
Micro	<=150	<= 50
Small (SMR)	150 <=900	50 <= 300
Medium	1000 <= 1800	300 <= 600
Large	> 1800	> 600

Many advanced reactors will operate at higher temperatures than current light water reactors, capable of supplying process heat/steam or a combination of both electricity and process heat for industrial and manufacturing processes. For example low temperature H_2 electrolysis for desalination occurs below 300°C (572°F) which can be achieved with current light water reactors. However, high temperature steam electrolysis for H_2 production or petrochemical production occurs above 600°C (1,112°F) which would only be possible using a different reactor technology that can operate at higher temperatures. The potential end use of nuclear energy and required temperature may be important in considering the type of reactor to support the mission.

Other characteristics of advanced reactors depend on engineering and business decisions that are being made by developers of these technologies as they aim to meet certain performance and safety criteria. Though these characteristics do not help define an advanced reactor, a list of these characteristics is provided as reference:

- Coolant – Coolant for advanced reactors will include water, metal (sodium, lead, etc.), gas (helium), and various molten salts.
- Fuel Type – Advanced reactors will use many different fuel types. Some will use traditional Light Water Reactor (LWR) fuel while others will use Tri-structural isotropic (TRISO), metal, or liquid forms.
- Neutron Spectrum – The neutron spectrum can be fast or thermal.

Finally, popular terms have emerged such as, modular (i.e., Small Modular Reactor, SMR, or similar terms) and microreactor to describe advanced reactors or their features. These terms are akin to marketing terminology, and do not functionally define advanced reactors as a class. Use of these terms for any purpose should consider the following:

- The term “modular” does not have a common definition; some reactor designs may build portions of the reactor in a factory and then ship to the site for installation, other designs may build modules near the site and transfer them to the site for installation, and other designs may use new construction techniques at the site.
- The term “modular” does not provide an appropriate limit on reactor designs, as future economics could favor other construction methods.
- The term “modular” does not provide a consistent limit on reactor designs, any reactor site could have multiple reactors installed (at the same time or over many years) given sufficient available land.
- Each reactor design will have its own economic and engineering reasons for the construction method that will optimize either a timeline or cost structure for the specific business model.

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Appendix A: Definition of Advanced Reactor in current U.S. Code of Federal Regulations

42 USC 16271: Nuclear energy
(b) Definitions
In this part:
(1) Advanced nuclear reactor
The term "advanced nuclear reactor" means (A) a nuclear fission reactor, including a prototype plant (as defined in sections 50.2 and 52.1 of title 10, Code of Federal Regulations (or successor regulations)), with significant improvements compared to reactors operating on December 27, 2020, including improvements such as-

- (i) additional inherent safety features;
- (ii) lower waste yields;
- (iii) improved fuel and material performance;
- (iv) increased tolerance to loss of fuel cooling;
- (v) enhanced reliability or improved resilience;
- (vi) increased proliferation resistance;
- (vii) increased thermal efficiency;
- (viii) reduced consumption of cooling water and other environmental impacts;
- (ix) the ability to integrate into electric applications and nonelectric applications;
- (x) modular sizes to allow for deployment that corresponds with the demand for electricity or process heat; and
- (xi) operational flexibility to respond to changes in demand for electricity or process heat and to complement integration with intermittent renewable energy or energy storage;

(B) a fusion reactor; and
(C) a radioisotope power system that utilizes heat from radioactive decay to generate energy.

42 USC 18751: Infrastructure planning for micro and small modular nuclear reactors
(a) Definitions
In this section:
(1) Advanced nuclear reactor
The term "advanced nuclear reactor" has the meaning given the term in section 16271(b) of this title.
(3) Micro-reactor
The term "micro-reactor" means an advanced nuclear reactor that has an electric power production capacity that is not greater than 50 megawatts.
(5) Small modular reactor
The term "small modular reactor" means an advanced nuclear reactor (A) with a rated capacity of less than 300 electrical megawatts; and (B) that can be constructed and operated in combination with similar reactors at a single site.