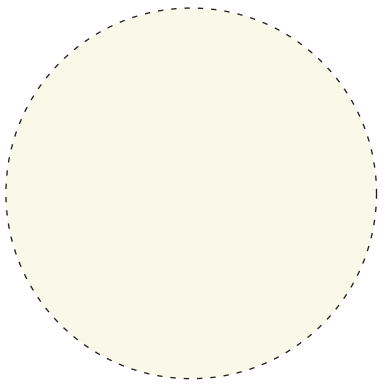
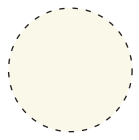
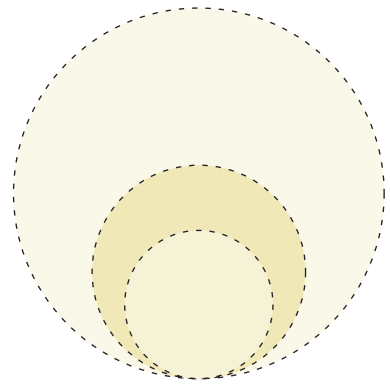
Four types of reactors to power the nuclear future

	Large Power Reactors (current fleet)	Small Modular Reactors	Micro Reactors	Large Advanced Reactors
FOOTPRINT	 1,500 ACRES	 50 ACRES	 LESS THAN AN ACRE	 VARIES
ELECTRICITY (MEGAWATTS)	1,000+	60 or more	20 or less	400–1,400
FUEL TYPE	URANIUM	URANIUM	URANIUM	URANIUM
COOLANT	WATER	WATER GAS METAL SALT	WATER GAS METAL SALT	WATER GAS METAL SALT
EMERGENCY ZONE	10 MILES	0.19 MILES	<0.19 MILES	0.15–10 MILES
CONTROL APPROACH	ACTIVE	MOSTLY PASSIVE	MOSTLY PASSIVE, AUTONOMOUS	MOSTLY PASSIVE
END PRODUCT	ELECTRICITY	ELECTRICITY HEAT STEAM	ELECTRICITY HEAT STEAM	ELECTRICITY HEAT STEAM
APPLICATIONS	 BASE LOAD ELECTRICAL POWER	 BASE LOAD, DEMAND RESPONSE, INDUSTRIAL ELECTRICITY, INDUSTRIAL PROCESSES SUCH AS HYDROGEN PRODUCTION	 POWER FOR REMOTE LOCATIONS, MOBILE, BACKUP POWER, MARITIME SHIPPING, MINING, MILITARY INSTILLATIONS, SPACE MISSIONS, DESALINATION, DISASTER RELIEF	 BASE LOAD, DEMAND RESPONSE, INDUSTRIAL ELECTRICITY, INDUSTRIAL PROCESSES SUCH AS HYDROGEN PRODUCTION
CUSTOMERS	LARGE UTILITIES	UTILITIES, MUNICIPALITIES, INDUSTRY	MILITARY, MUNICIPALITIES, INDUSTRY	MOSTLY LARGE UTILITIES WITH ASSOCIATED INDUSTRIES
CONSTRUCTION	CUSTOM BUILT ON SITE	FACTORY BUILT, MODULAR, ASSEMBLED ON SITE	FACTORY BUILT, MODULAR, ASSEMBLED ON SITE	MOSTLY MODULAR
TIMEFRAME	1950s COMMERCIAL REACTORS BUILT STARTING IN 1950S CURRENTLY IN OPERATION	2024 IN DEVELOPMENT, FIRST REACTORS EXPECTED IN 2024	2025 IN DEVELOPMENT, FIRST REACTORS EXPECTED 2025, DOD REACTORS BY 2027	Now CURRENTLY IN OPERATION OR UNDER CONSTRUCTION OUTSIDE OF THE U.S.
COST	$5 BILLION TO $9 BILLION	$800 MILLION TO $3 BILLION PER UNIT	$49 MILLION TO $86 MILLION	MIXED
SCALABILITY	ADDING NEW REACTORS IS DIFFICULT	DESIGNED TO ADD NEW REACTORS AS DEMAND INCREASES	DESIGNED TO ADD NEW REACTORS AS DEMAND INCREASES	MIXED

Idaho National Laboratory

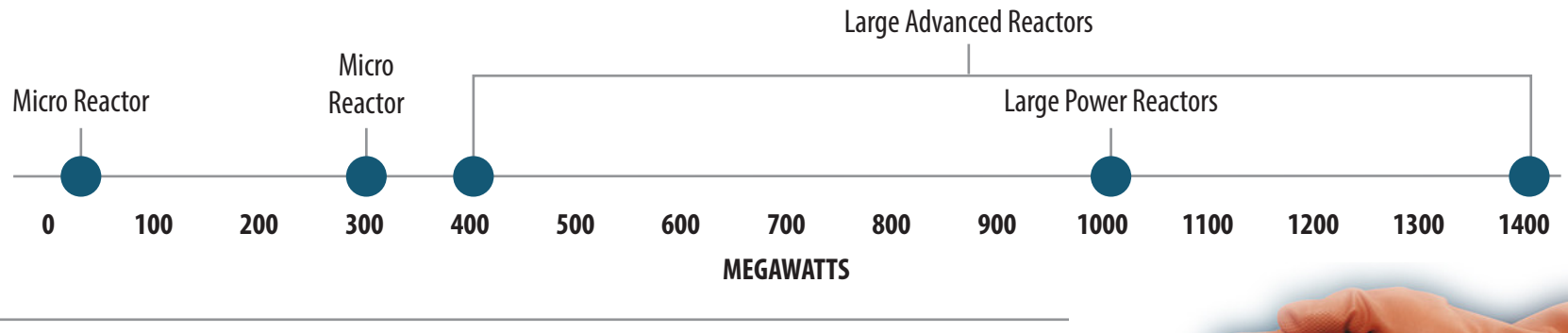
Four types of reactors to power the nuclear future.

Large Power Reactors
Conventional light water, 1,000-plus megawatt reactors have powered the U.S. nuclear power fleet since the 1950s and typically serve a single purpose: base load electrical power. Newer designs incorporate passive safety features and next-generation materials to decrease the chance of an accident.

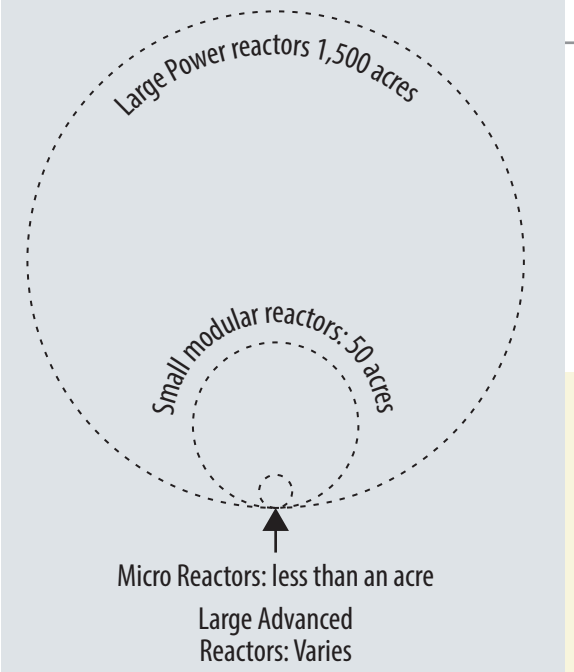
Small Modular Reactors
Factory-assembled small modular reactors (SMRs) produce 60 megawatts or more using a variety of coolants and fuels for baseload, load following or industrial power. Passive safety features and next-generation materials decrease the chance of an accident and allow for a smaller footprint. Reactor modules can be added as power demand increases.

Micro Reactors
Like SMRs, micro reactor designs use a variety of coolant and fuel types, incorporate the latest safety features and are assembled in a factory. Unlike SMRs, micro reactors produce less than 20 megawatts for a wide range of uses from remote military bases and mining operations to disaster relief and space exploration.

Large Advanced Reactors
Ranging from 400 to 1,400 megawatts, large advanced reactor designs use a variety of coolants, fuels and safety features to produce electricity, heat or steam for a wide range of large-scale power applications including base load power and industrial processes such as hydrogen production.



What is a reactor's footprint?



What fuels do reactors use?

While most fuel used in today's nuclear reactors is comprised of uranium oxide, researchers are developing a number of advanced fuel technologies with the goals of increasing safety and performance.

Some uranium fuels are encased in compounds containing carbon or other elements to help moderate the absorption of neutrons and/or provide an additional level of safety.

Another type of reactor, the molten salt reactor, uses fuel that's mixed into the molten salt coolant.

What cools the reactors?

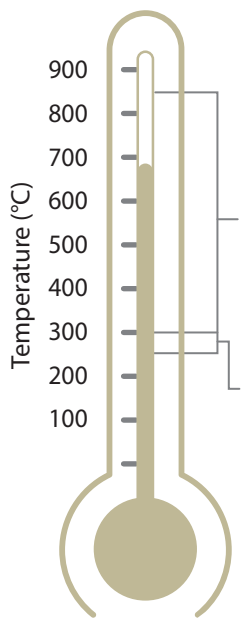
Water:
Large Power Reactors
Small Modular Reactors,
Micro Reactors,
Large Advanced Reactors

Gas:
Small Modular Reactors,
Micro Reactors,
Large Advanced Reactors

Liquid Metal:
Small Modular Reactors,
Micro Reactors,
Large Advanced Reactors

Molten Salt:
Small Modular Reactors,
Micro Reactors,
Large Advanced Reactors

How hot?



Large Advanced Reactors, Micro Reactors, and Small Modular Reactors, 250 to 850°

Large Power Reactors, 250 to 300°

What is the end product?

Electricity
All types of reactors

Heat
Small, Micro, and Large Advanced Reactors

Steam
Small, Micro, and Large Advanced Reactors

What are the applications?

Large Power Reactors:
Base load electrical power

Small Modular Reactors:
Base load, demand response, industrial electricity, industrial processes such as hydrogen production

Micro Reactors:
Power for remote locations, mobile, backup power, maritime shipping, mining, military instillations, space missions, desalination, disaster relief

Large Advanced Reactors:
Base load, demand response, industrial electricity, industrial processes such as hydrogen production

What do reactors cost?

Large Power Reactors:
$5 billion to $9 billion

Small Modular Reactors:
$800 million to $3 billion per unit

Micro Reactors:
$49 million to $86 million

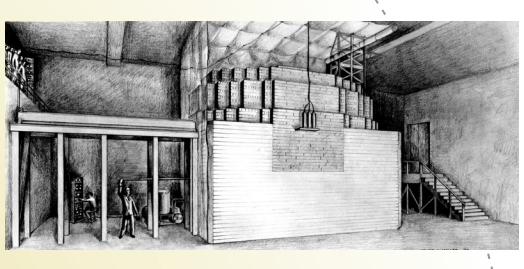
Large Advanced Reactors:
mixed

What is the timeframe?

1950s
Large Power Reactors
Commercial reactors built starting in 1950s currently in operation.

2024
Small Modular Reactors
In development, first reactors expected in 2024

1940 1950 1960 1970 1980 1990 2000 2010 2020



Now
Large Advanced Reactors
Currently in operation or under construction outside of the U.S.

2025, 2027
Micro Reactors
In development, first reactors expected 2025, DOD reactors by 2027

Large Power
Reactors can require up to a 10 mile Emergency Planning Zone. **Small** and **Micro Reactors** require 1,000 feet or less.

Emergency Planning Zone

Room to Grow?

Most small modular reactors and micro reactors designs allow for the inclusion of additional reactors to meet increasing power needs. As a city grows, the power plant can grow with it.

Custom vs. Modular

To date, the large light water power reactors currently operating in the U.S. have been custom designed and constructed on site. One potential advantage of small modular reactors and micro reactors is that they could be built in a factory under controlled conditions and shipped out to the site, which could lower costs and increase reliability.

Control Approach:

Active vs. Passive

Passive safety systems require no emergency AC power, no pumps and minimal intervention from human operators. Reactors with passive safety systems are oftentimes located underground and rely on gravity-based systems to cool a reactor in case of an emergency.

Active safety systems present in some older reactor designs typically rely on emergency AC power, pumps and significant external intervention from operators in the event of an accident.

Some proposed micro reactors would be autonomous, meaning they could operate without need for human intervention.

Who are the Customers?

Large Power Reactors:
Large Utilities

Small Modular Reactors:
Municipalities, utilities, industry

Micro Reactors:
Military, municipalities, industry

Large Advanced Reactors:
Mostly large utilities with associated industries

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