Small Modular Reactors: Scalable Nuclear Energy Solutions

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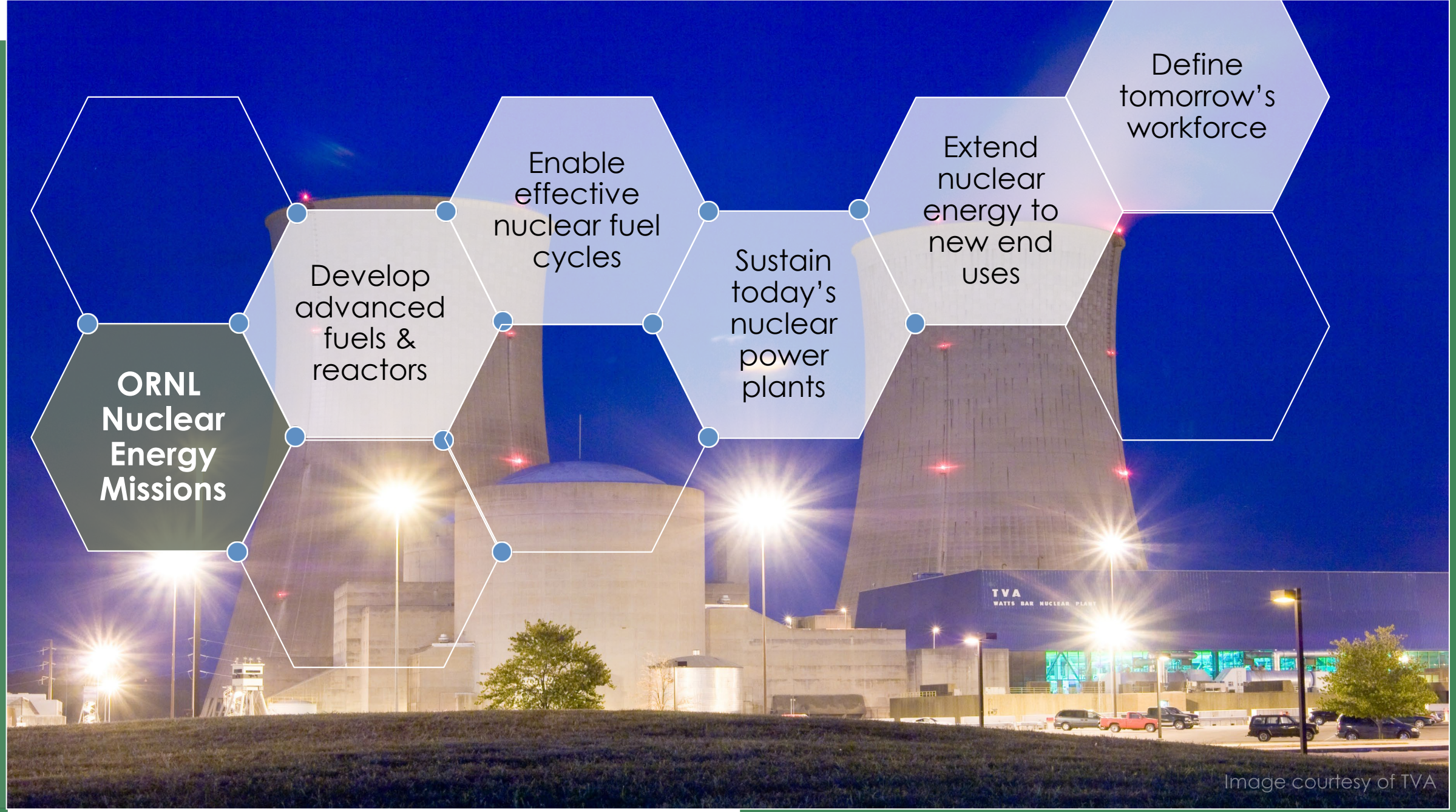
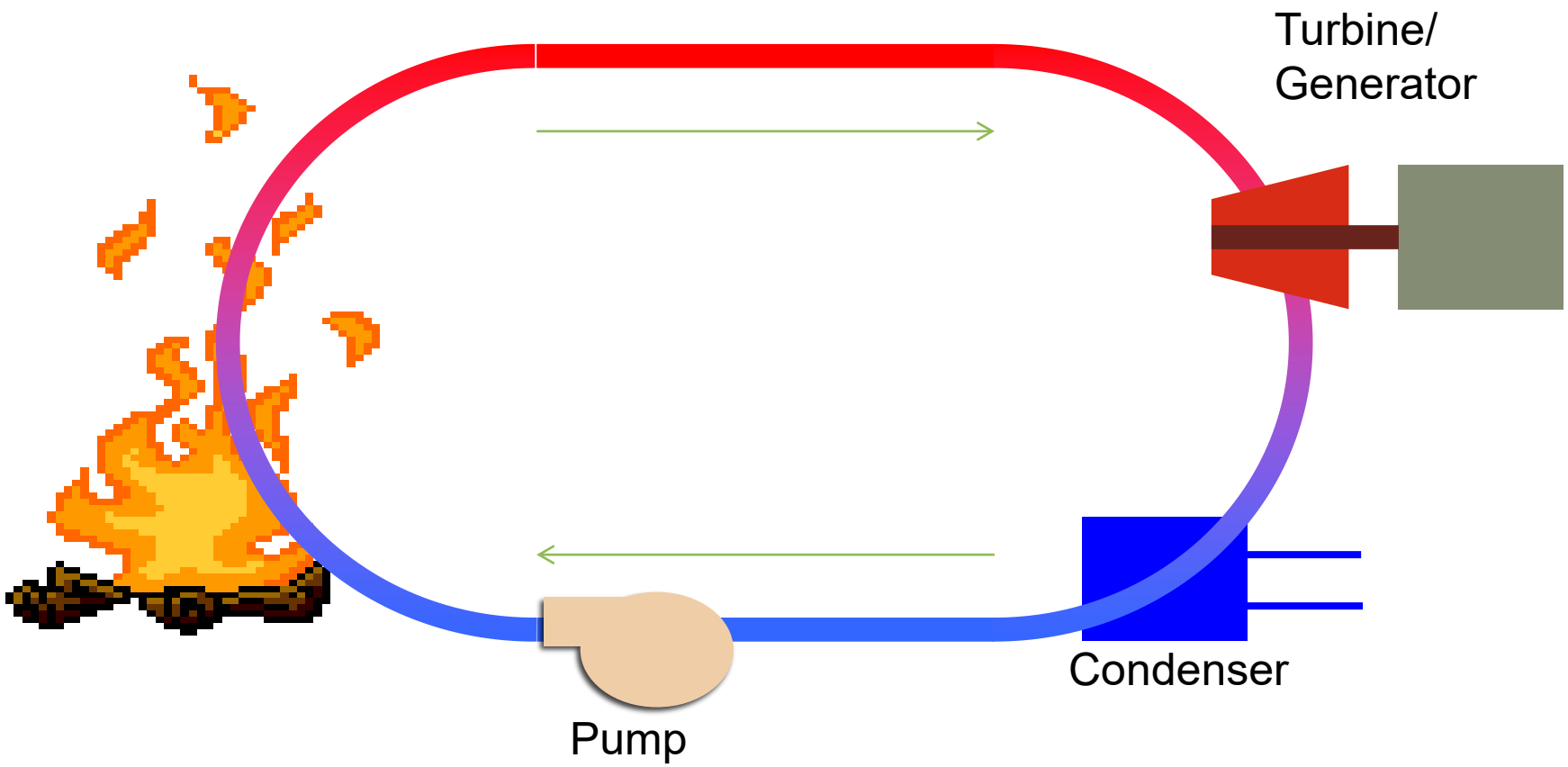
NUCLEAR ENERGY at OAK RIDGE NATIONAL LABORATORY

Realizing our clean energy future by translating groundbreaking science into market-ready nuclear technologies


ORNL Nuclear Energy Missions
Develop advanced fuels & reactors
Enable effective nuclear fuel cycles
Sustain today's nuclear power plants
Extend nuclear energy to new end uses
Define tomorrow's workforce
TVA
WATTS BAR NUCLEAR PLANT
Image courtesy of TVA

- Most of us have some notional idea of how a power plant works
  - Maybe from our college thermodynamics course
  - Maybe reaching further back to middle school



Combustion power drove multiple industrial revolutions

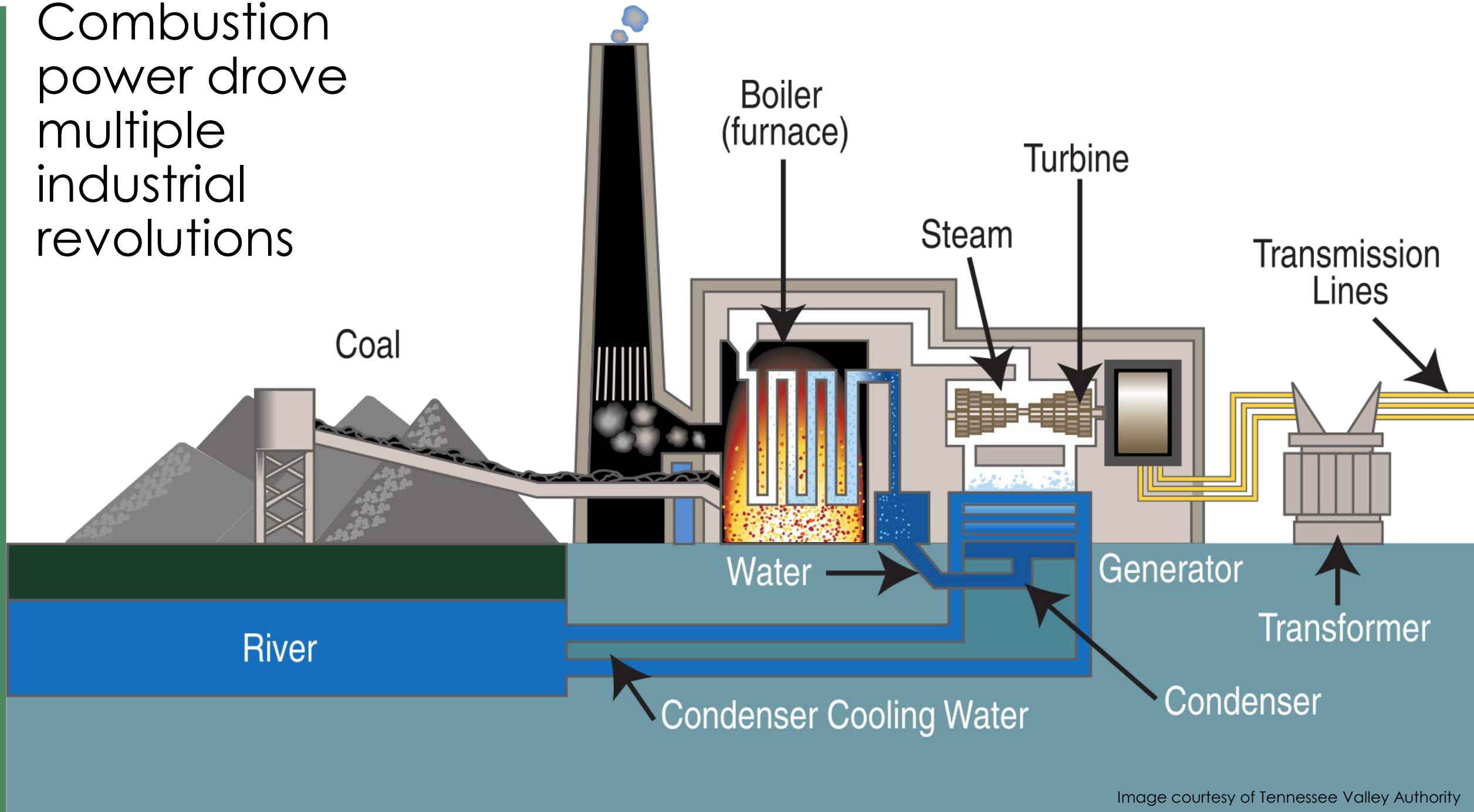
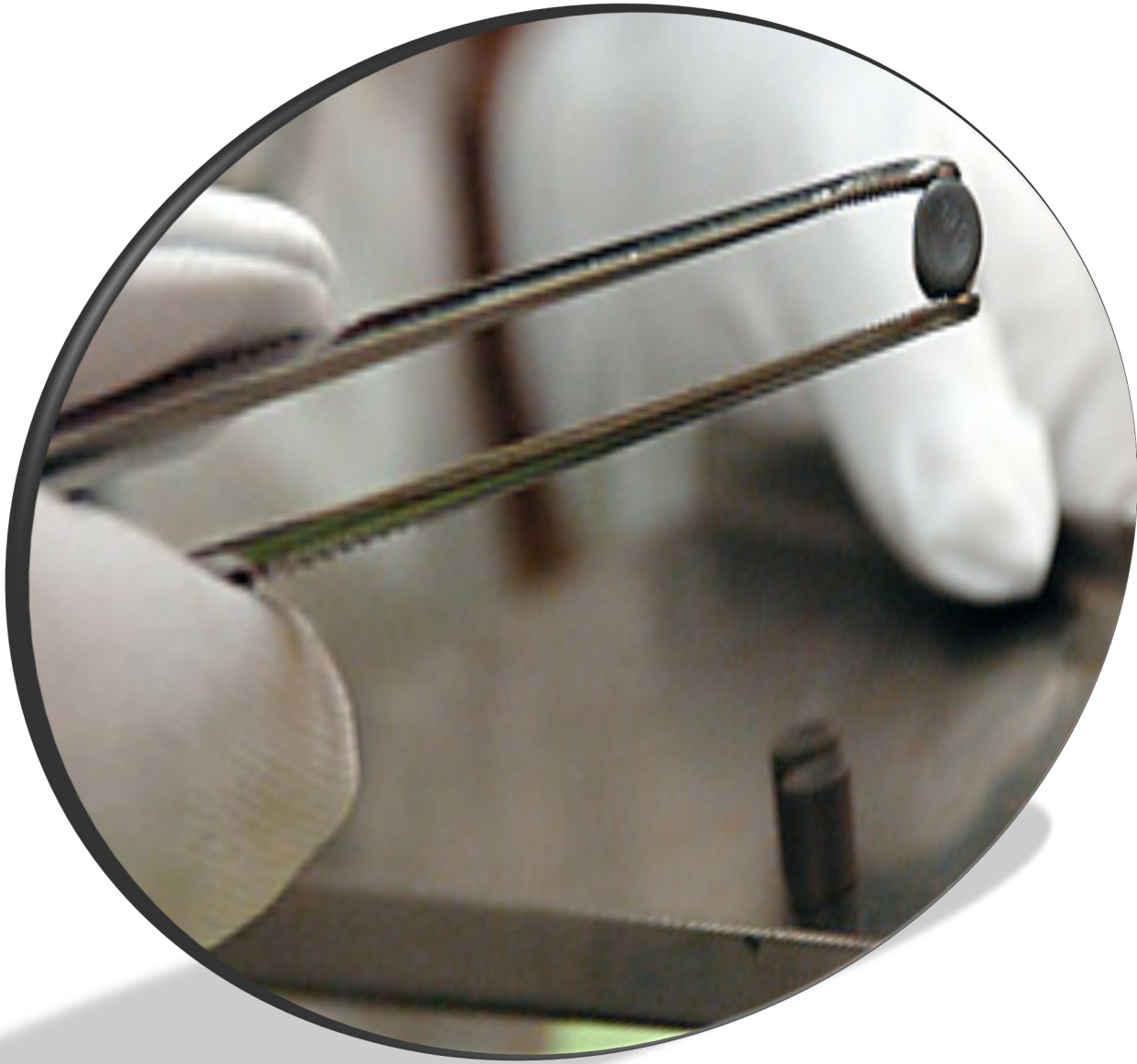


Image courtesy of Tennessee Valley Authority

What makes a nuclear power plant different?

It's the Fuel!

Nuclear power plants use the energy stored in the nucleus of large atoms rather than the energy stored in weaker chemical bonds.

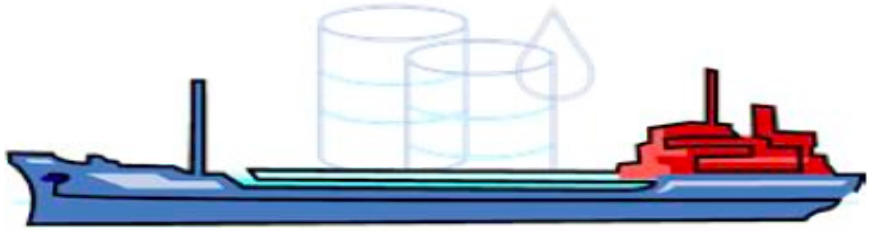


Nuclear fuel is very energy dense

TO POWER 1000 HOMES

150 Tons of Uranium

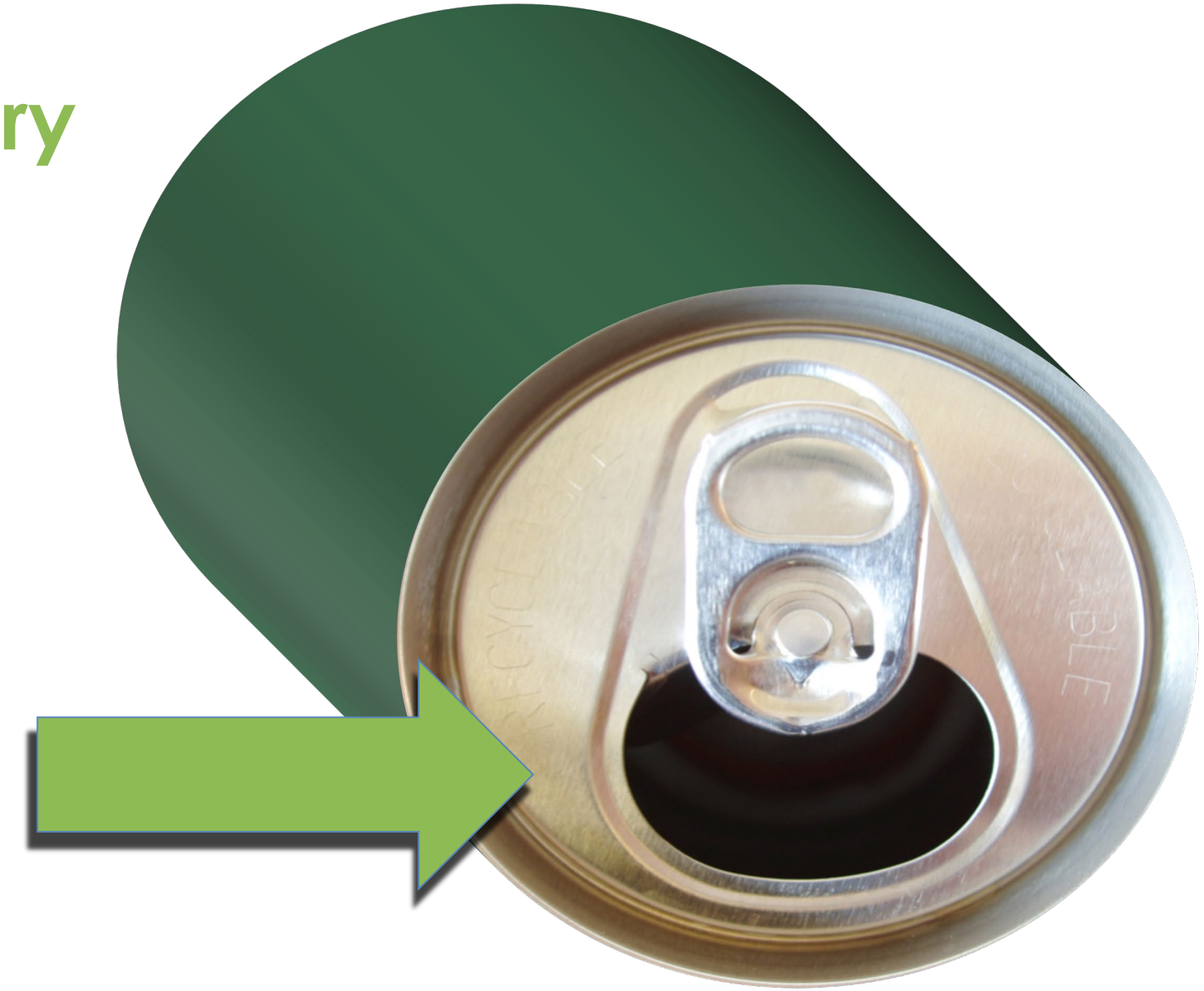
2,100,000 Tons of Coal



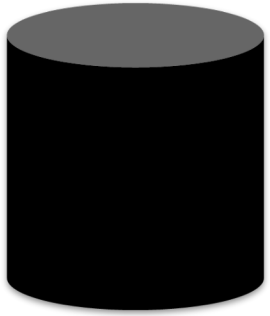
10,000,000 Barrels of Oil

Nuclear fuel is very energy dense

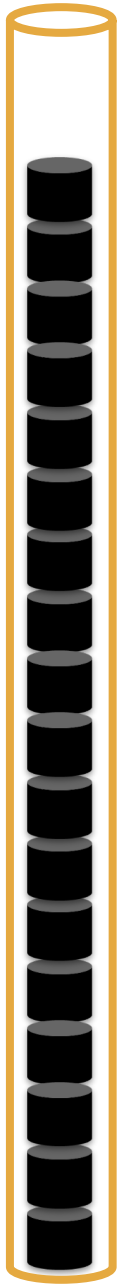
The nuclear fuel used to generate all of the energy used in one American's entire lifetime could fit in here.



Building a Nuclear Power Plant

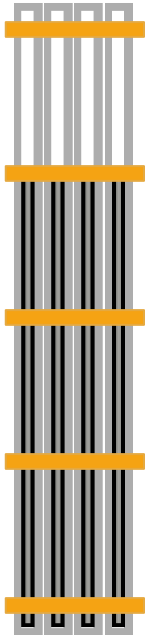


First, ceramic **fuel pellets** are manufactured from **uranium** ore

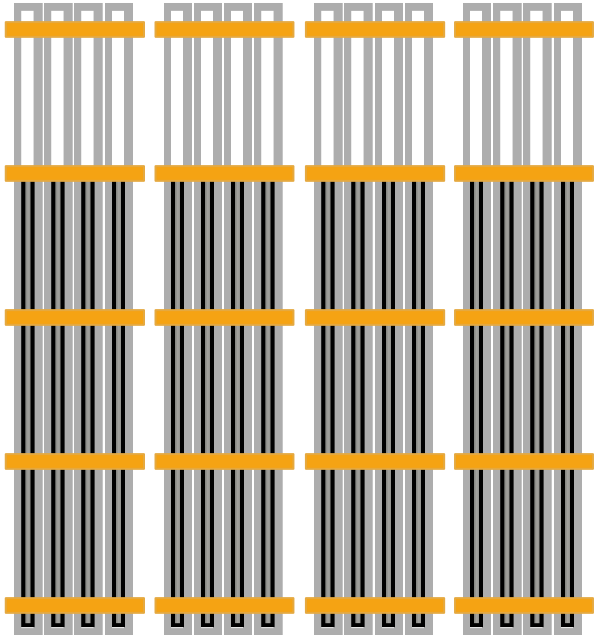


The ceramic **fuel pellets** are stacked in a column

And sealed inside a metallic alloy case, called the **cladding**, to form a **fuel rod**

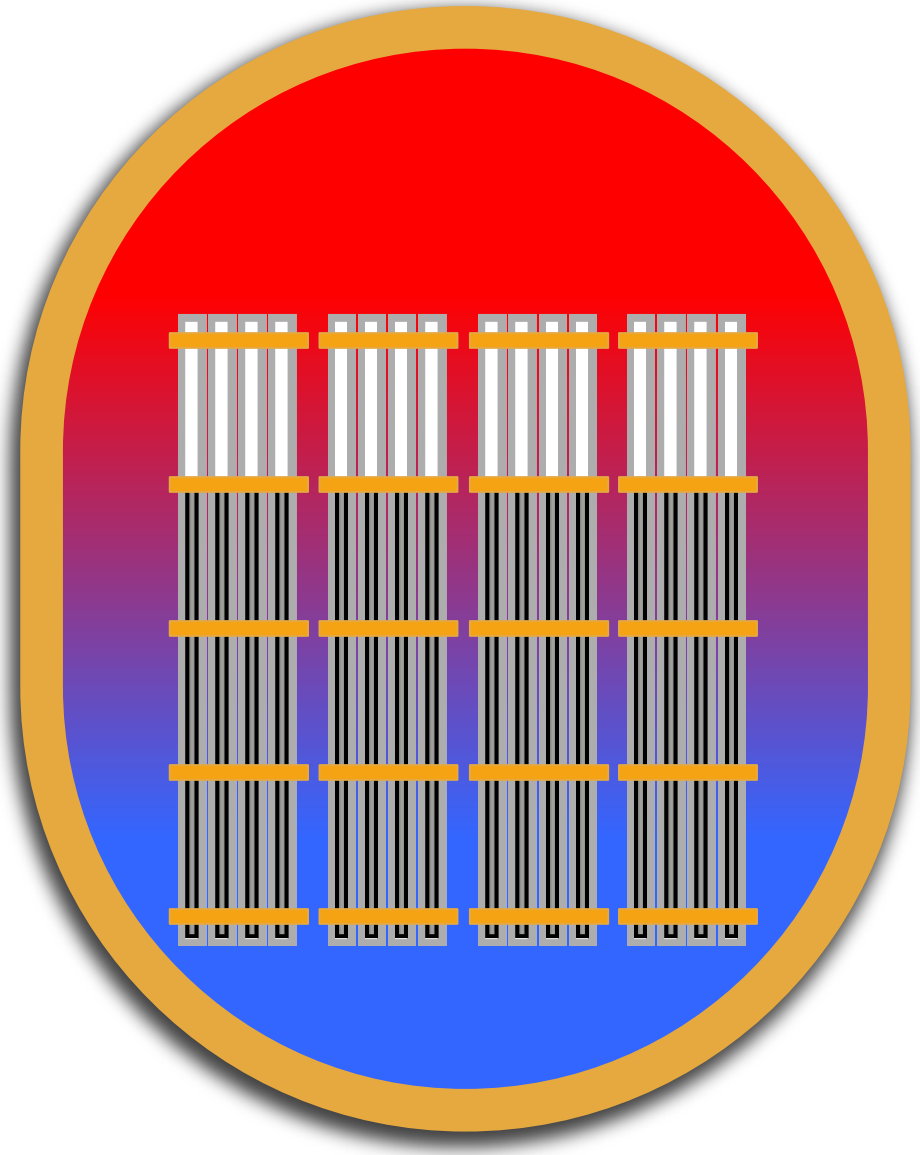


The **fuel rods** are grouped together in a regular array or **fuel assembly**



The **fuel rods** are grouped together in a regular array or **fuel assembly**

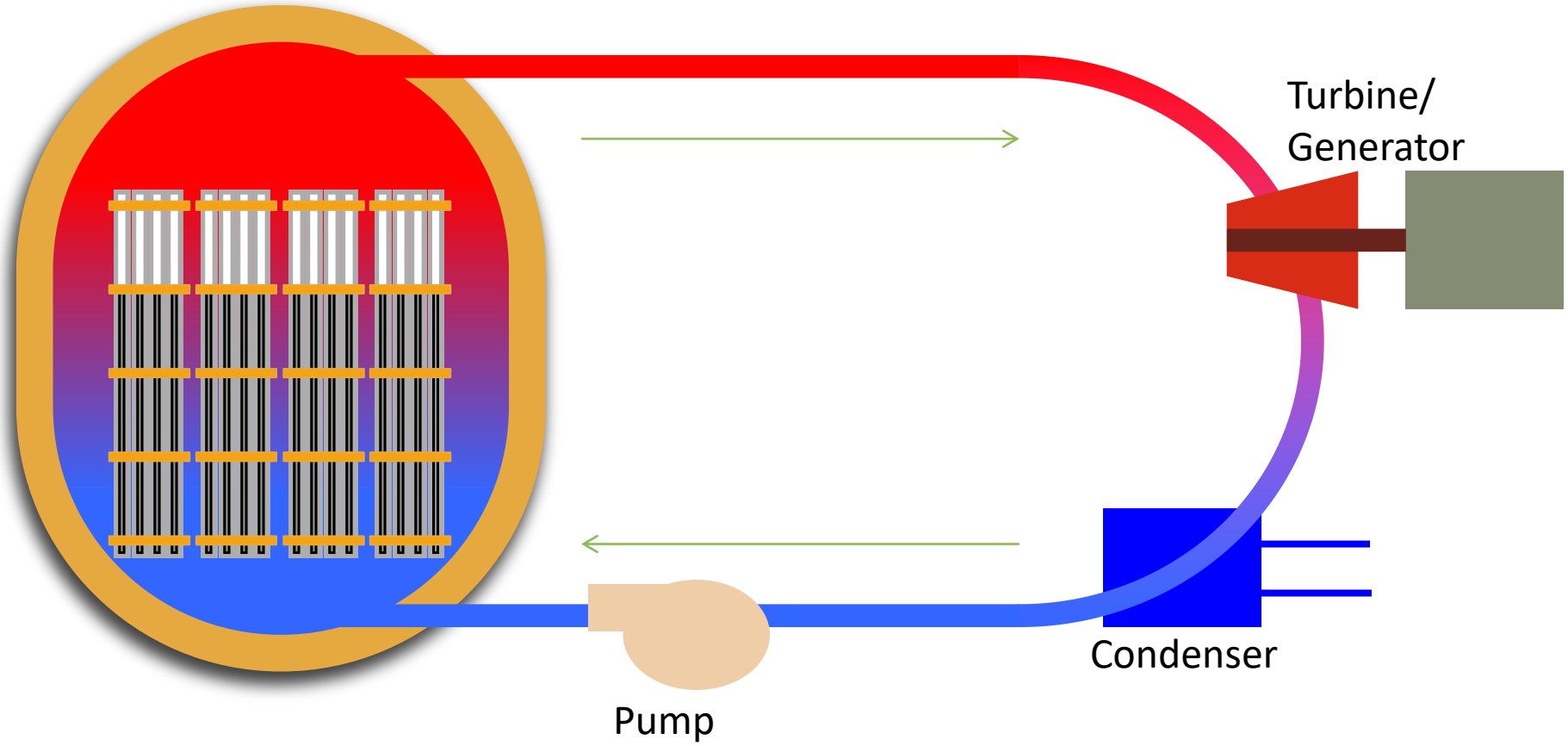
The **fuel assemblies** are arranged in a larger regular array or **reactor core**



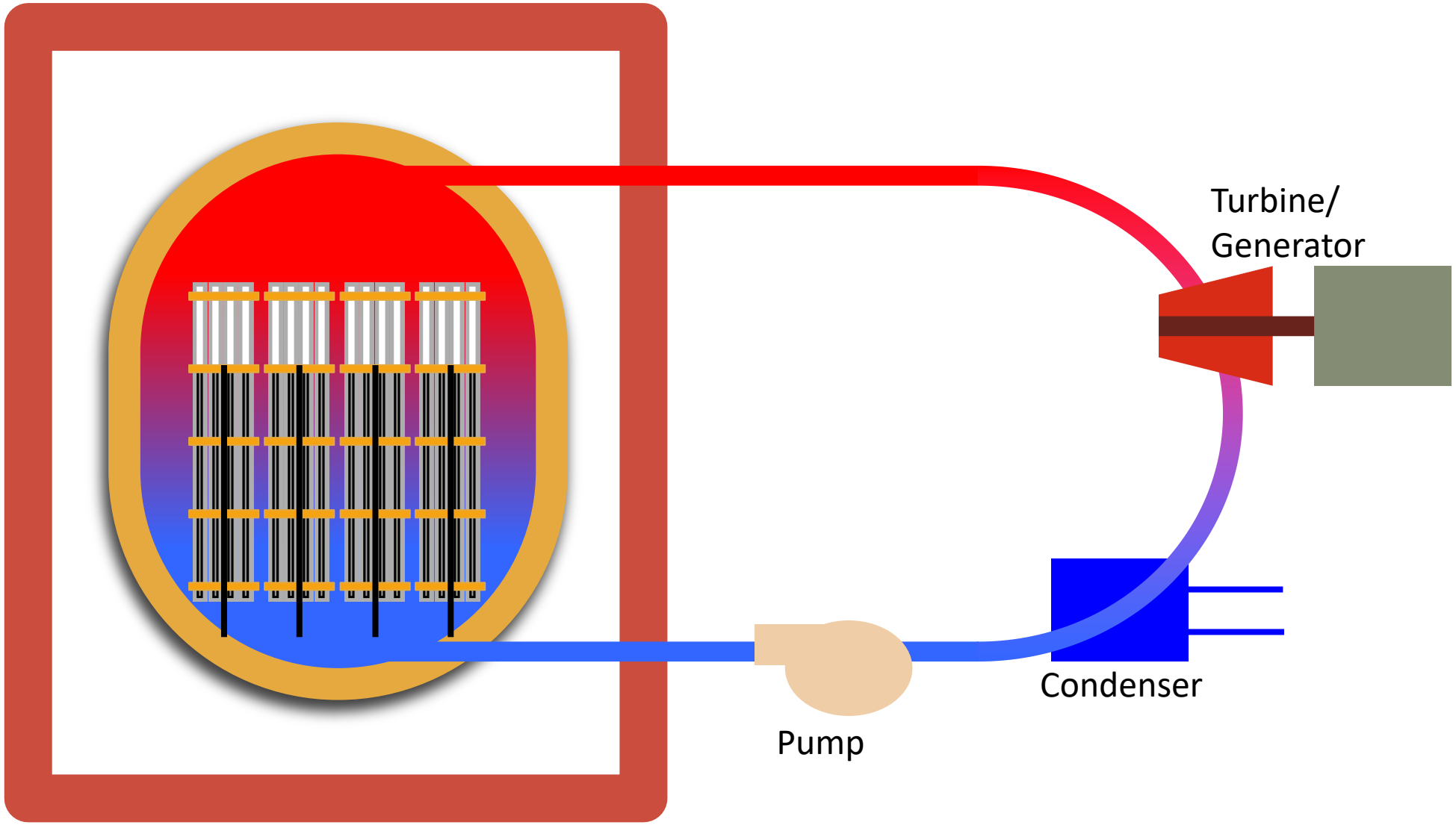
The **fuel rods** are grouped together in a regular array or **fuel assembly**

The **fuel assemblies** are arranged in a larger regular array or reactor **core**

The reactor **core** is contained inside a heavy steel **reactor pressure vessel (RPV)**



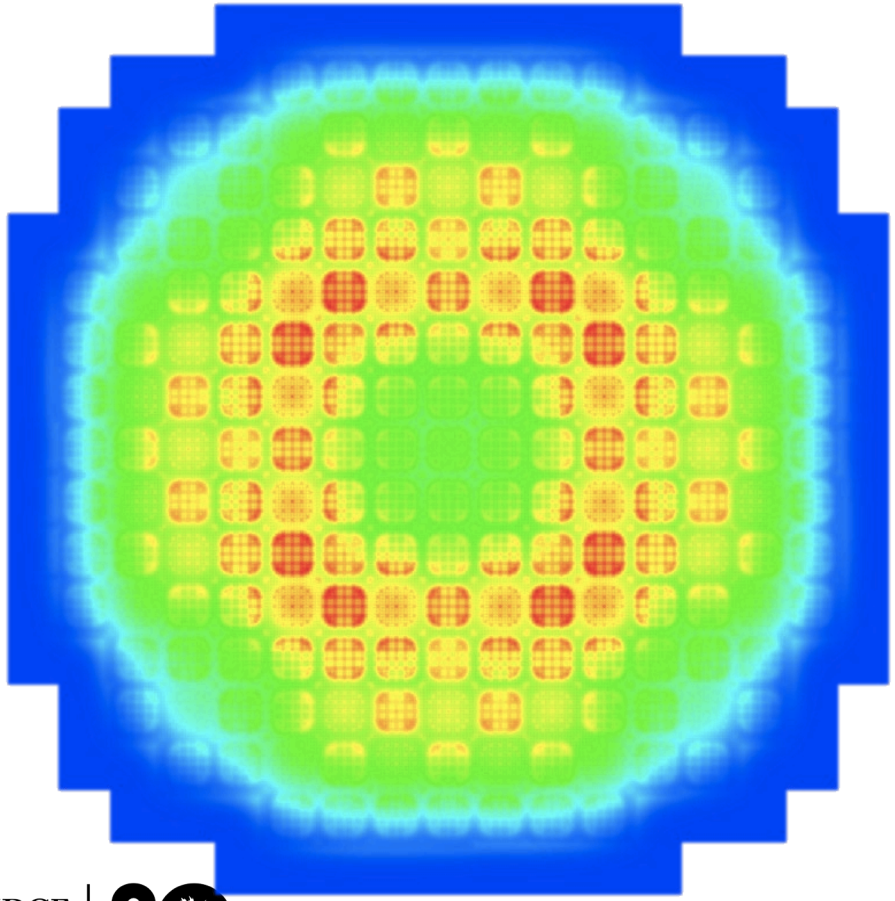
In a nuclear power plant, the **reactor core** is the energy source

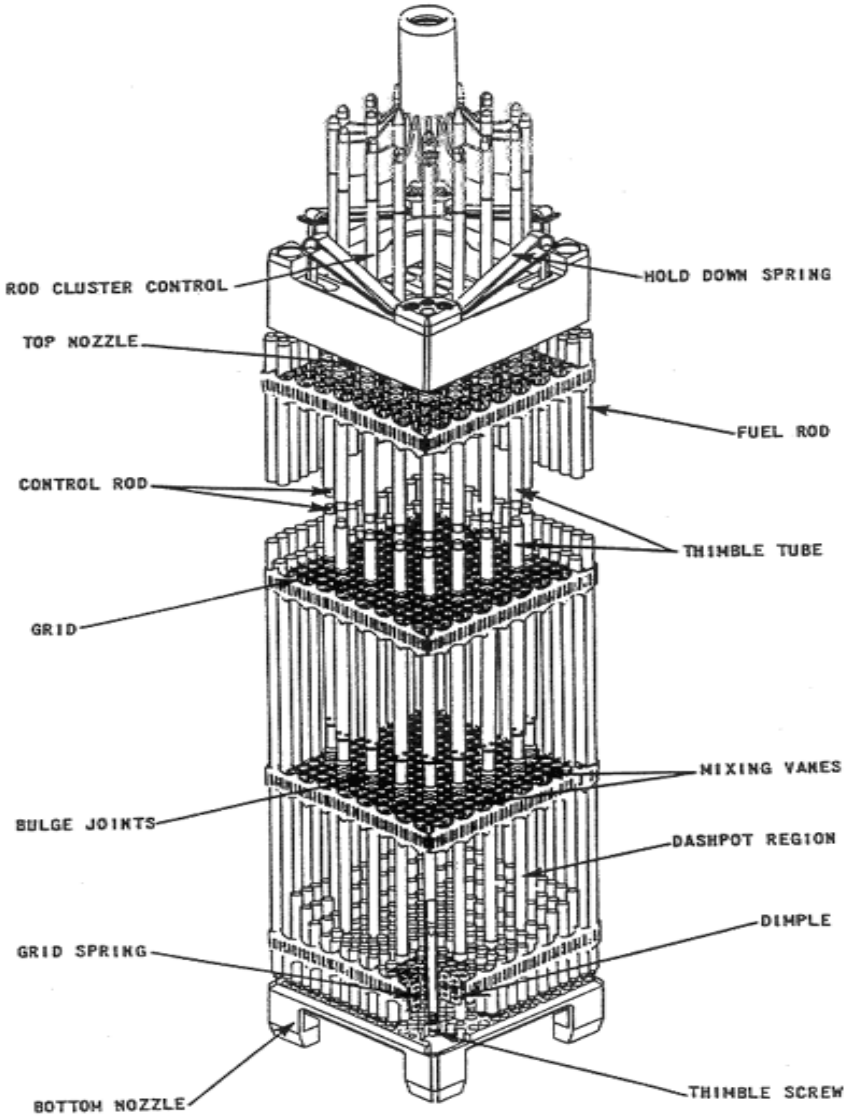


The entire reactor sits inside a large concrete and steel **containment building**

A Reality Check

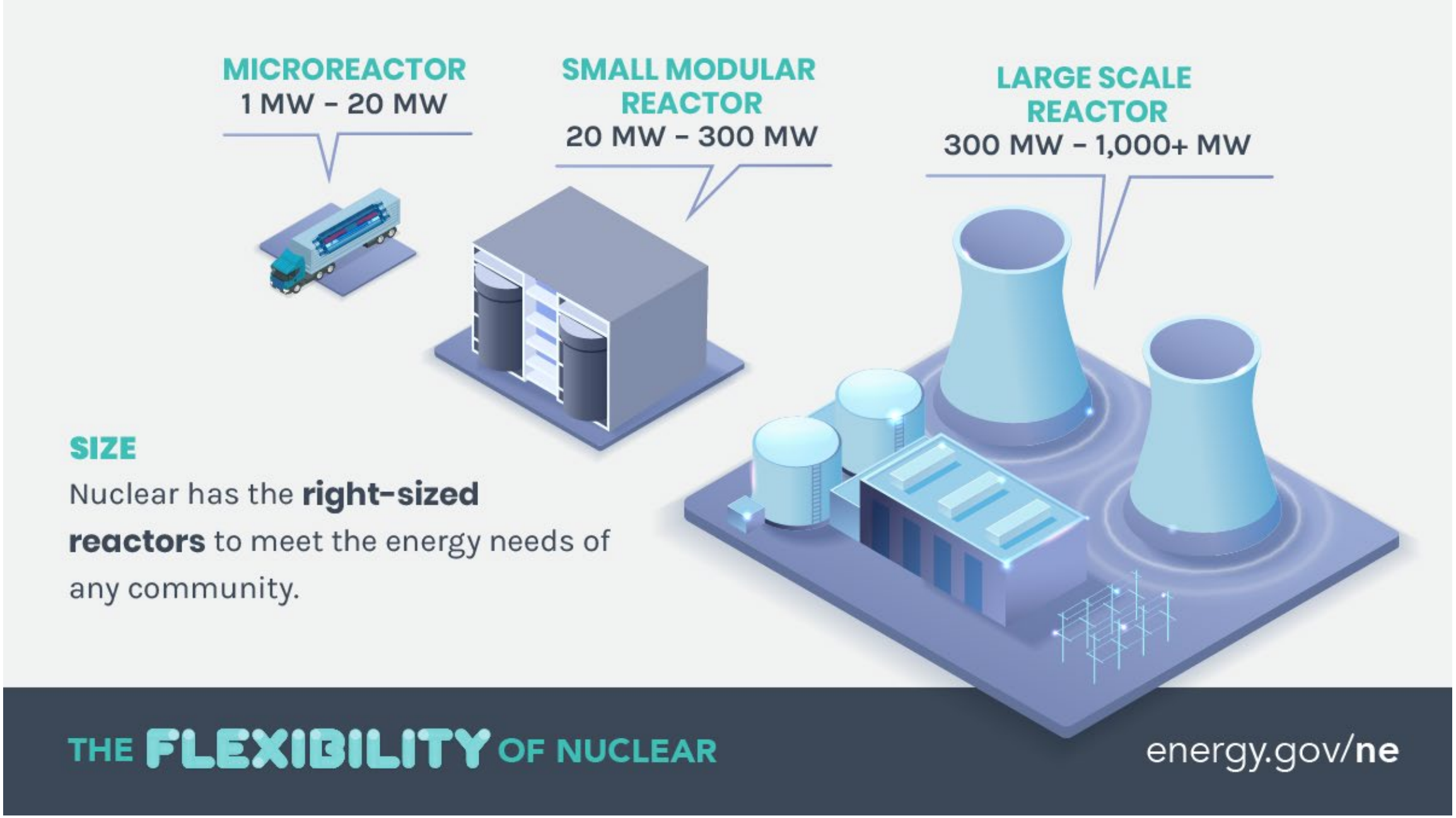
Fuel Assembly and Reactor Core Design are Complex Engineering Challenges



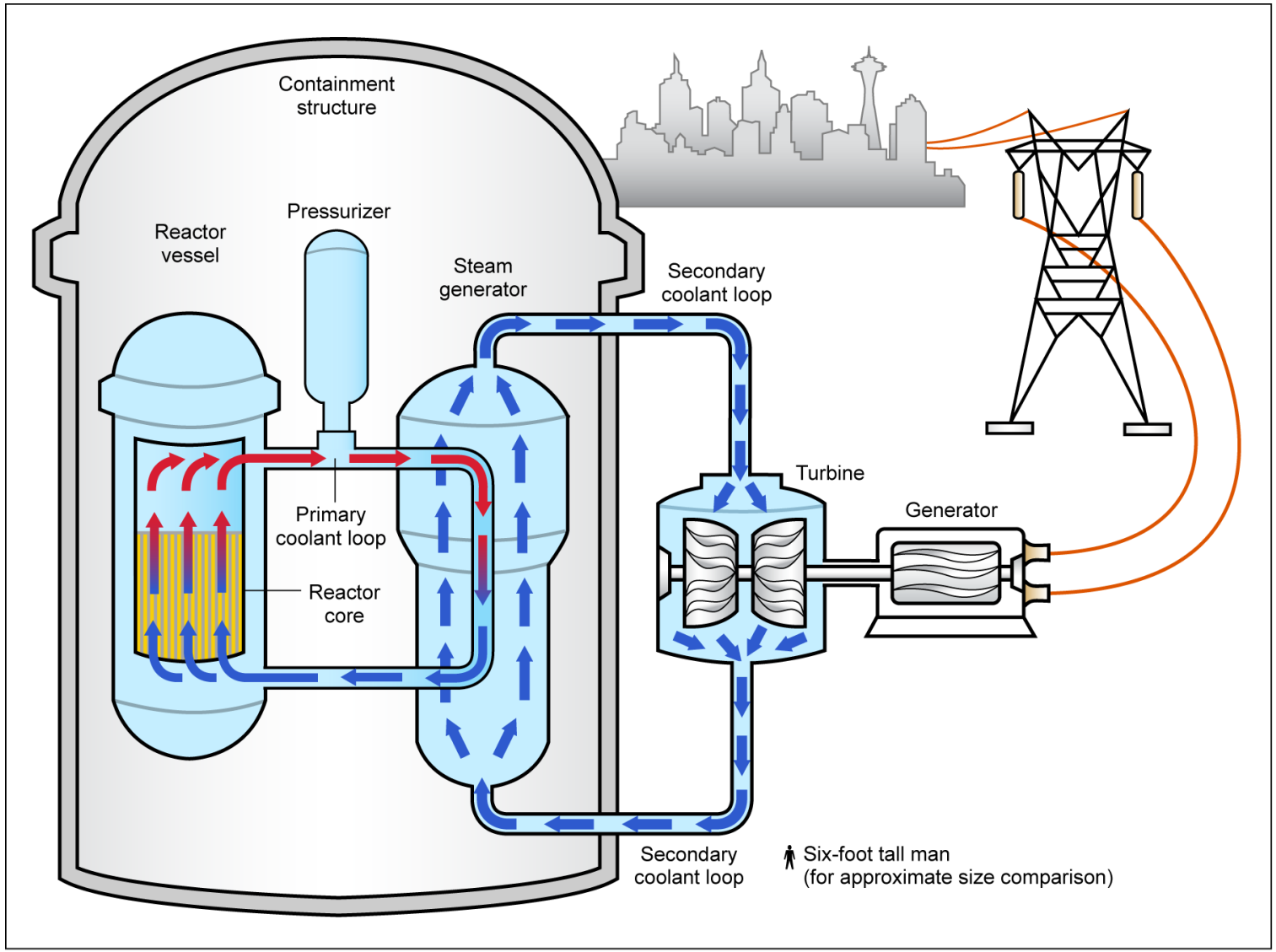


Reactor Fuel Assembly

Variety of design options supports diversity and flexibility in applications

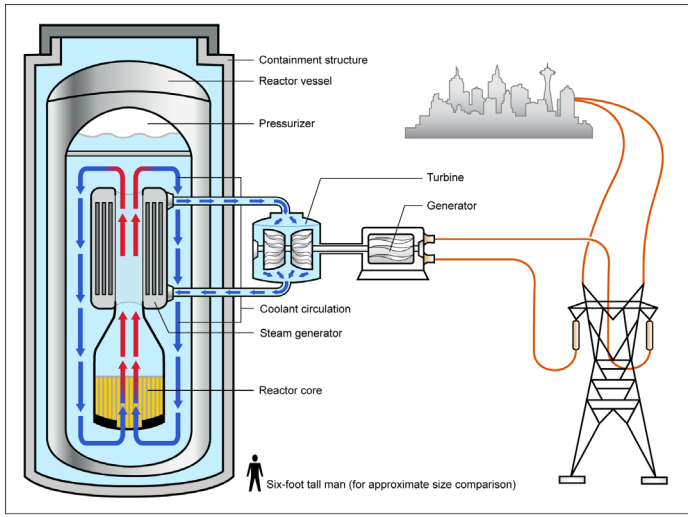

MICROREACTOR
1 MW - 20 MW
SMALL MODULAR REACTOR
20 MW - 300 MW
LARGE SCALE REACTOR
300 MW - 1,000+ MW
SIZE
Nuclear has the right-sized reactors to meet the energy needs of any community.
THE FLEXIBILITY OF NUCLEAR
energy.gov/ne

What are Small Modular Reactors?

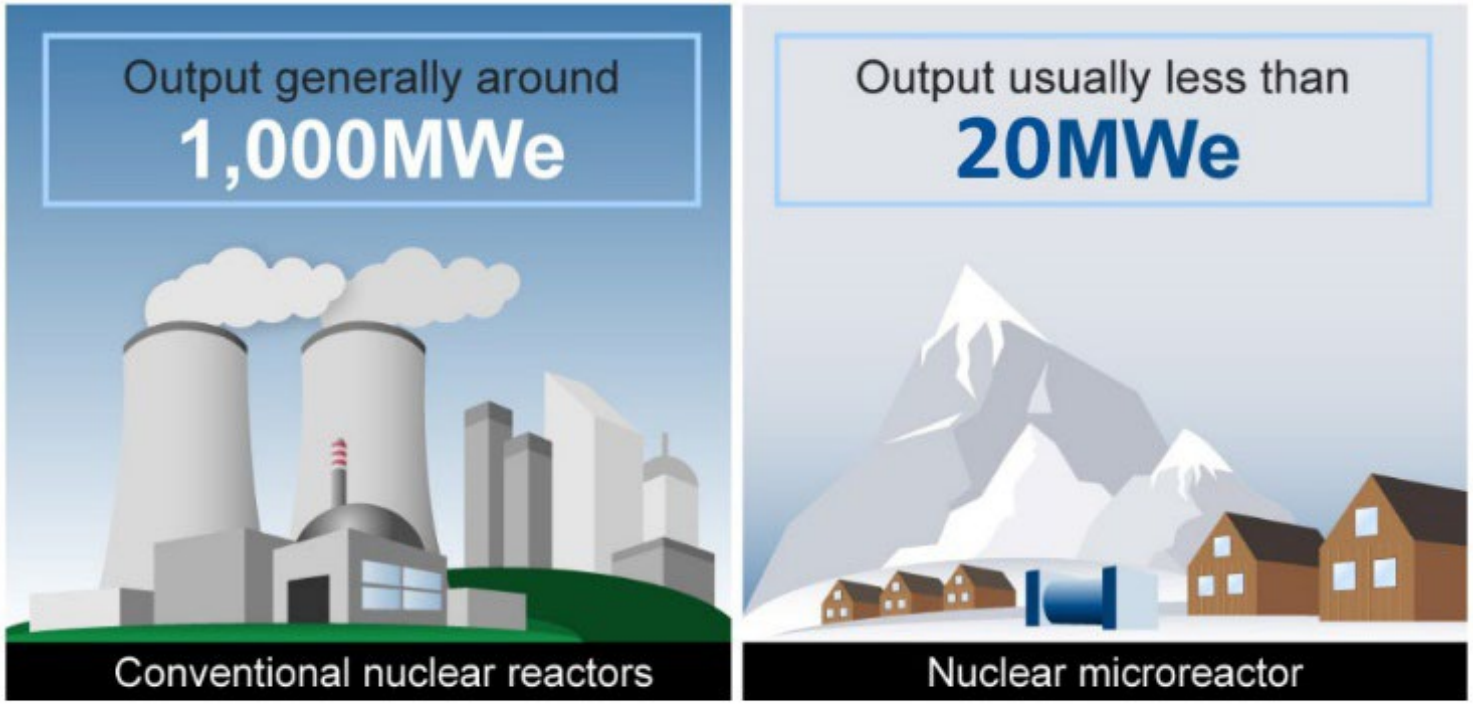


Source: GAO, based on Nuclear Regulatory Commission documentation. | GAO-15-652

- Up to 300 MW_{th}
- Modular Construction modeled after large scale aircraft manufacture
- Reduced capital cost
- Incremental expansion strategies



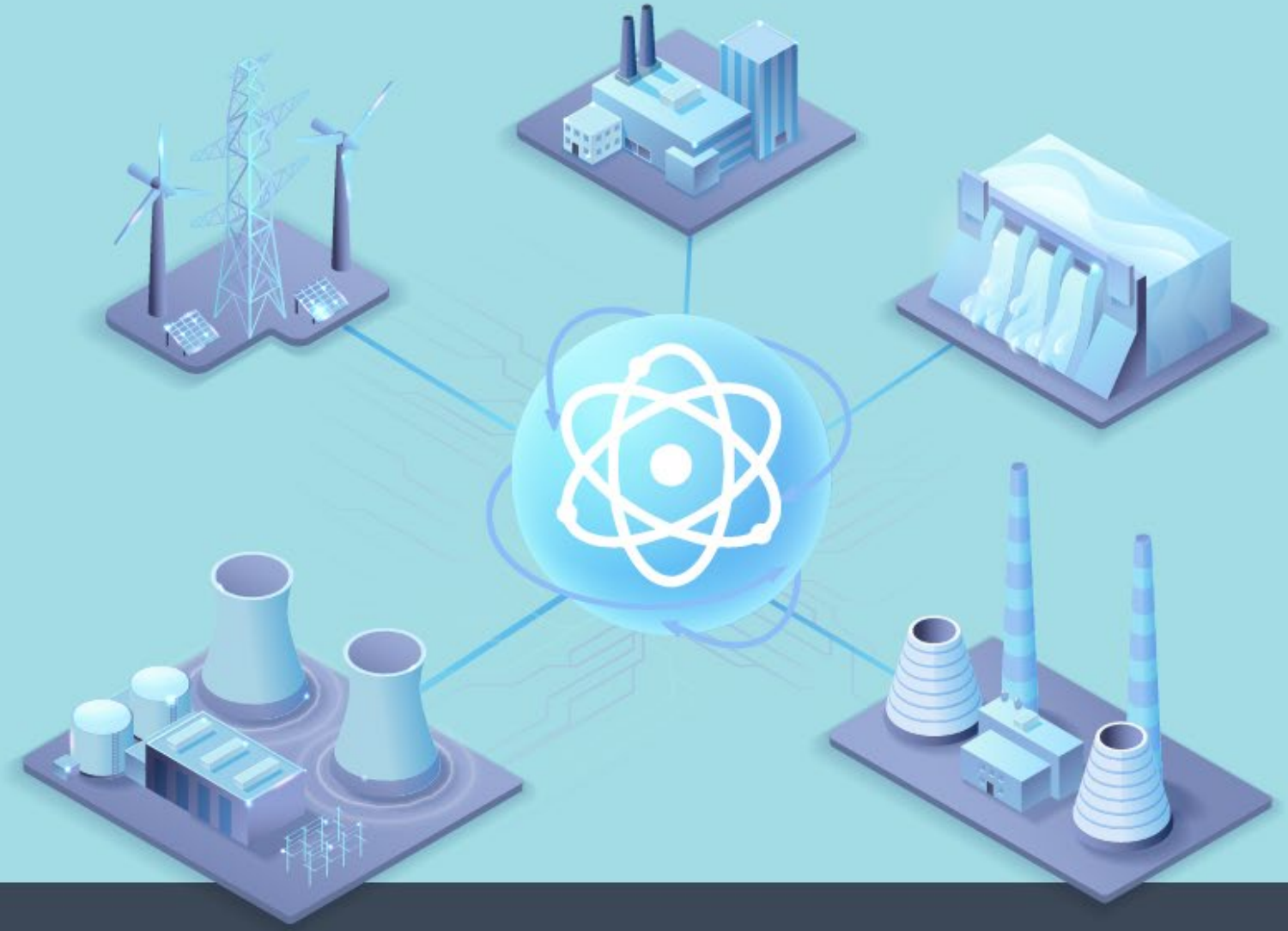
What are Microreactors?



Source: GAO. | GAO-20-380SP

- Small footprint
- Reduced site preparation
- Flexible operation
- Reduced refueling or "nuclear battery" replacement
- Reduced safety and security risks

Nuclear is evolving into **a more flexible energy source** that can work alongside chemical plants and renewable generators to create integrated energy systems.



THE **FLEXIBILITY** OF NUCLEAR

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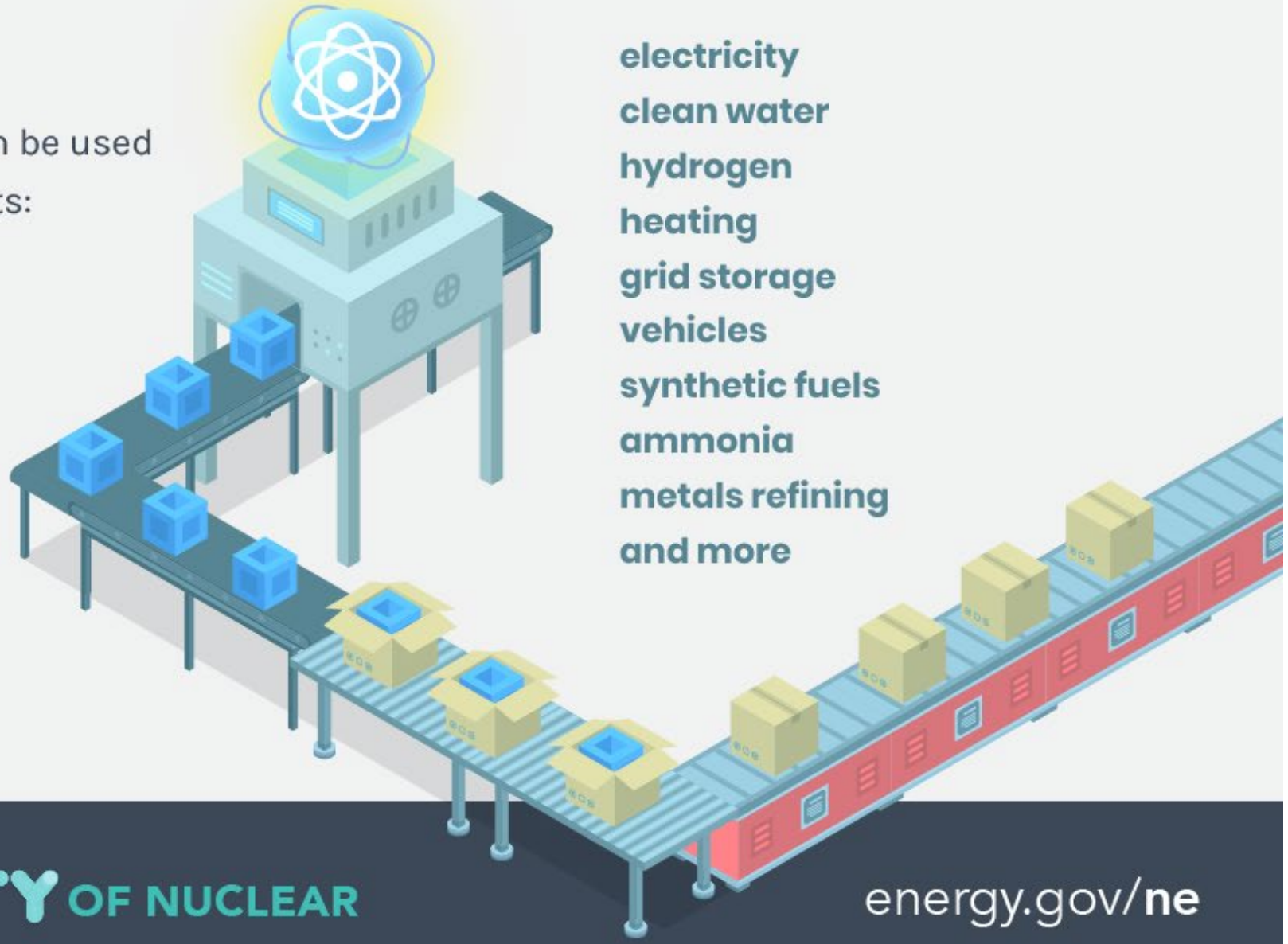
Different Operating Conditions Enable Diversity of Applications

Boiling Water Reactor	Pressurized Water Reactor	Sodium Cooled Reactor	Molten Salt Reactor	Helium Cooled Reactor
75 atm	218 atm	1 atm	1 atm	70 atm
285 °C	375 °C	600 °C	>700 °C	>750 °C

PRODUCTS

Nuclear's **thermal energy** can be used to create many diverse products:



- electricity
- clean water
- hydrogen
- heating
- grid storage
- vehicles
- synthetic fuels
- ammonia
- metals refining
- and more

THE **FLEXIBILITY** OF NUCLEAR

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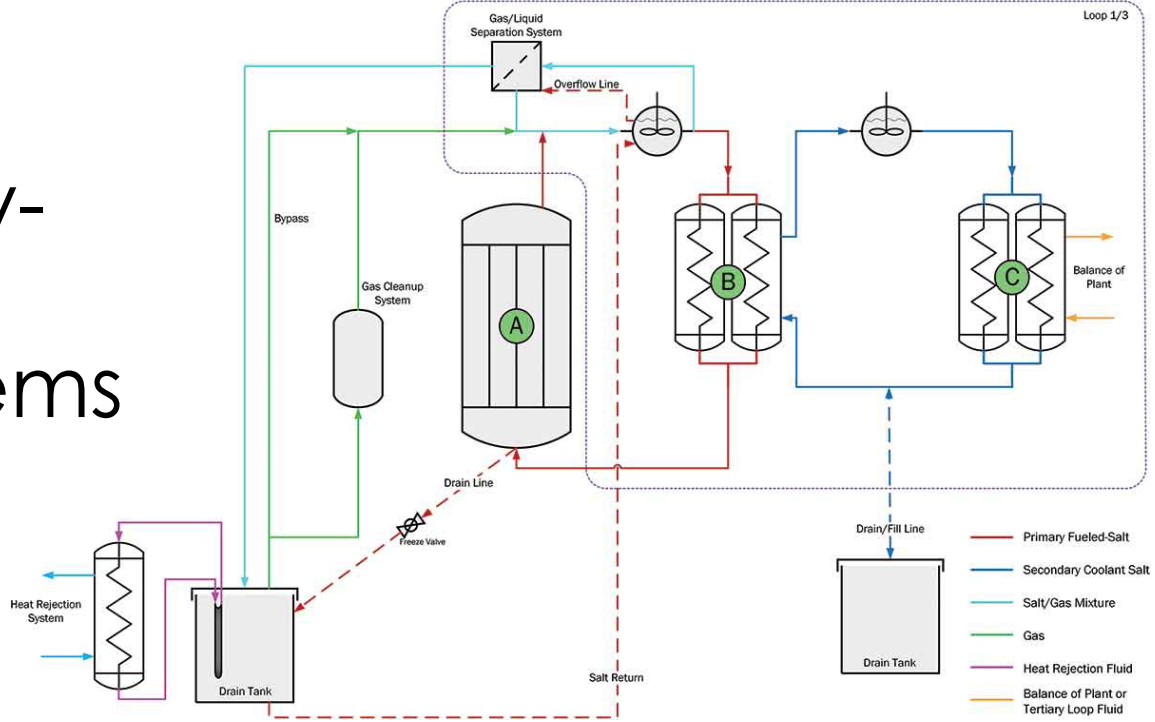
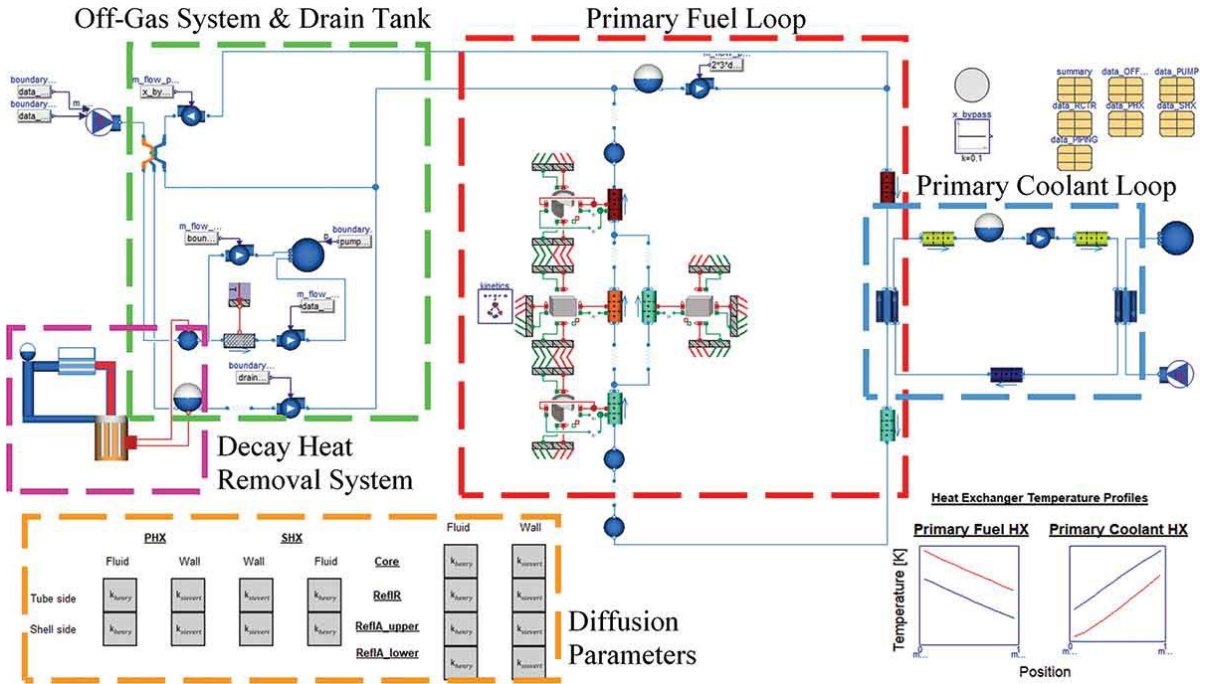
TRANSFORM
enables component-by-component models of integrated energy systems

- Develop integration strategies
- Optimize operations
- Plan for maintenance
- Evaluate performance





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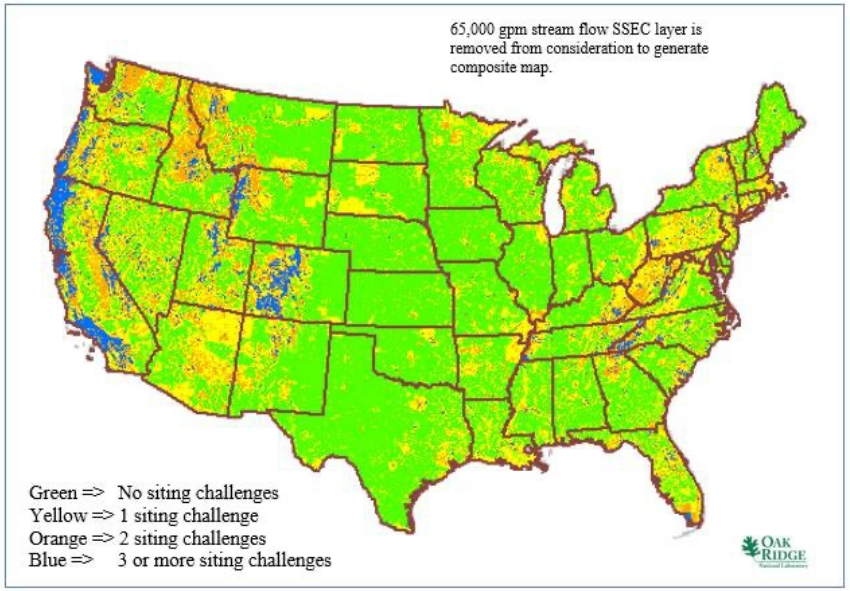
Selection, Siting and Integration of Nuclear Power Plants

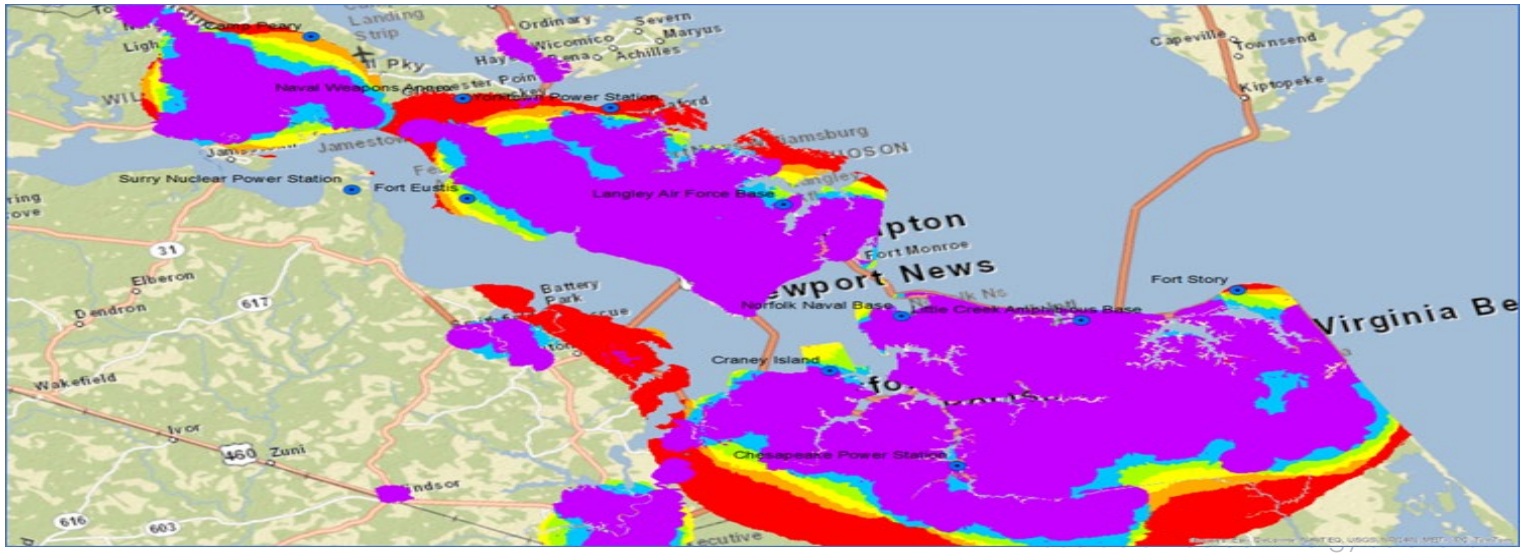
- Consider many drivers
  - Mission and cost
  - Safety
  - Security
  - Environment
  - Socio-economic impacts
- Integrate many data sources
  - Design data
  - Geographical data
  - Geological data
  - Population data
  - Environmental and ecological data
  - Transportation and logistical data

OR-SAGE

Figure 6-43: The TVA Clinch River layer results for floodplains (left) and protected lands (right) indicates limited site impact beyond the central site area.

Figure 6-44: The TVA Clinch River layer results for wetlands and open water (left) and slope (right) indicates limited site beyond the central site area.





How does nuclear drive your clean energy future?

Images courtesy of US DOE Office of Nuclear Energy GAIN program and ThirdWay

Questions?

We solve problems and protect people
We are ONE ORNL
We debate with purpose, passion and respect
We build new materials atom by atom