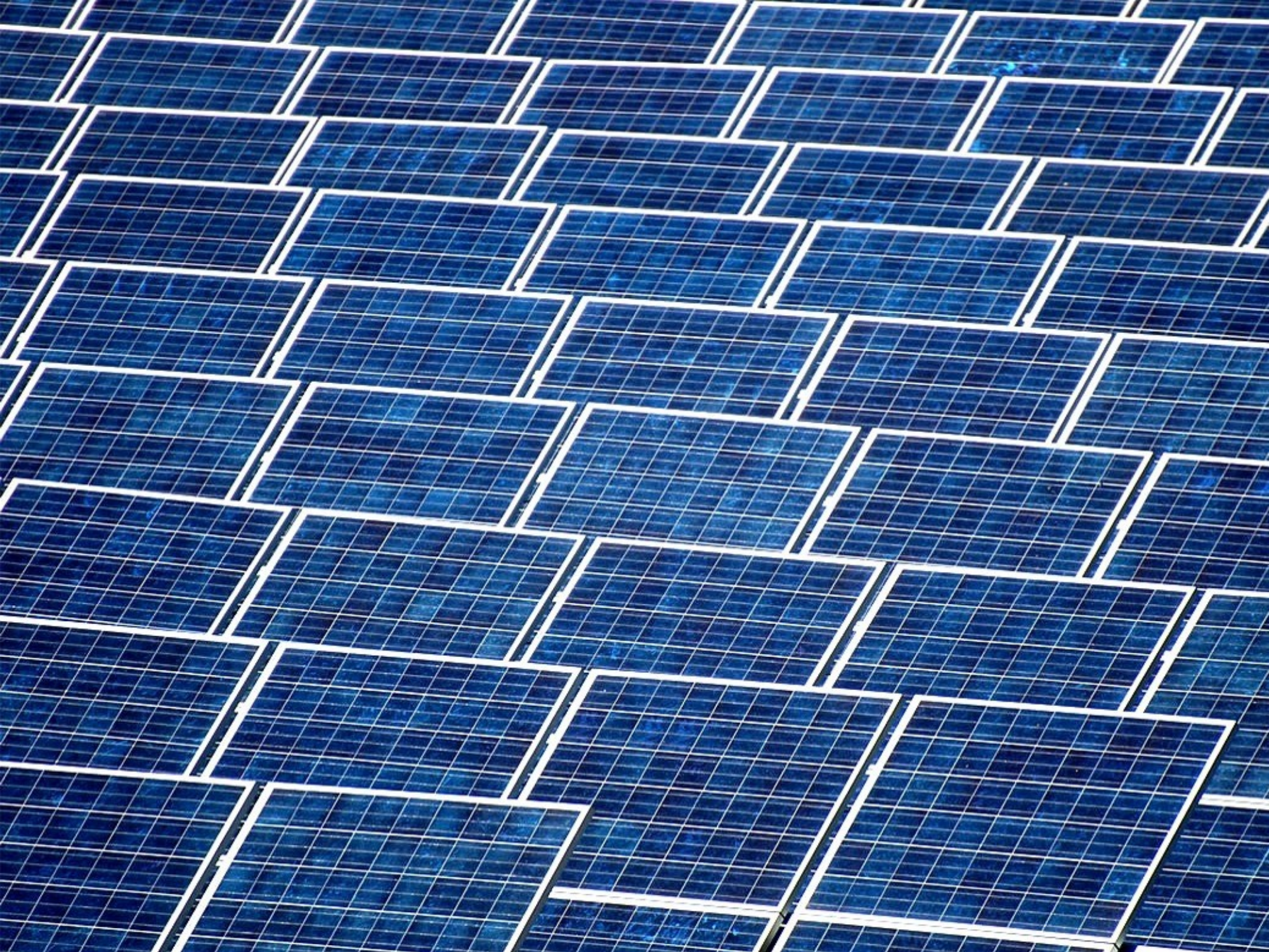
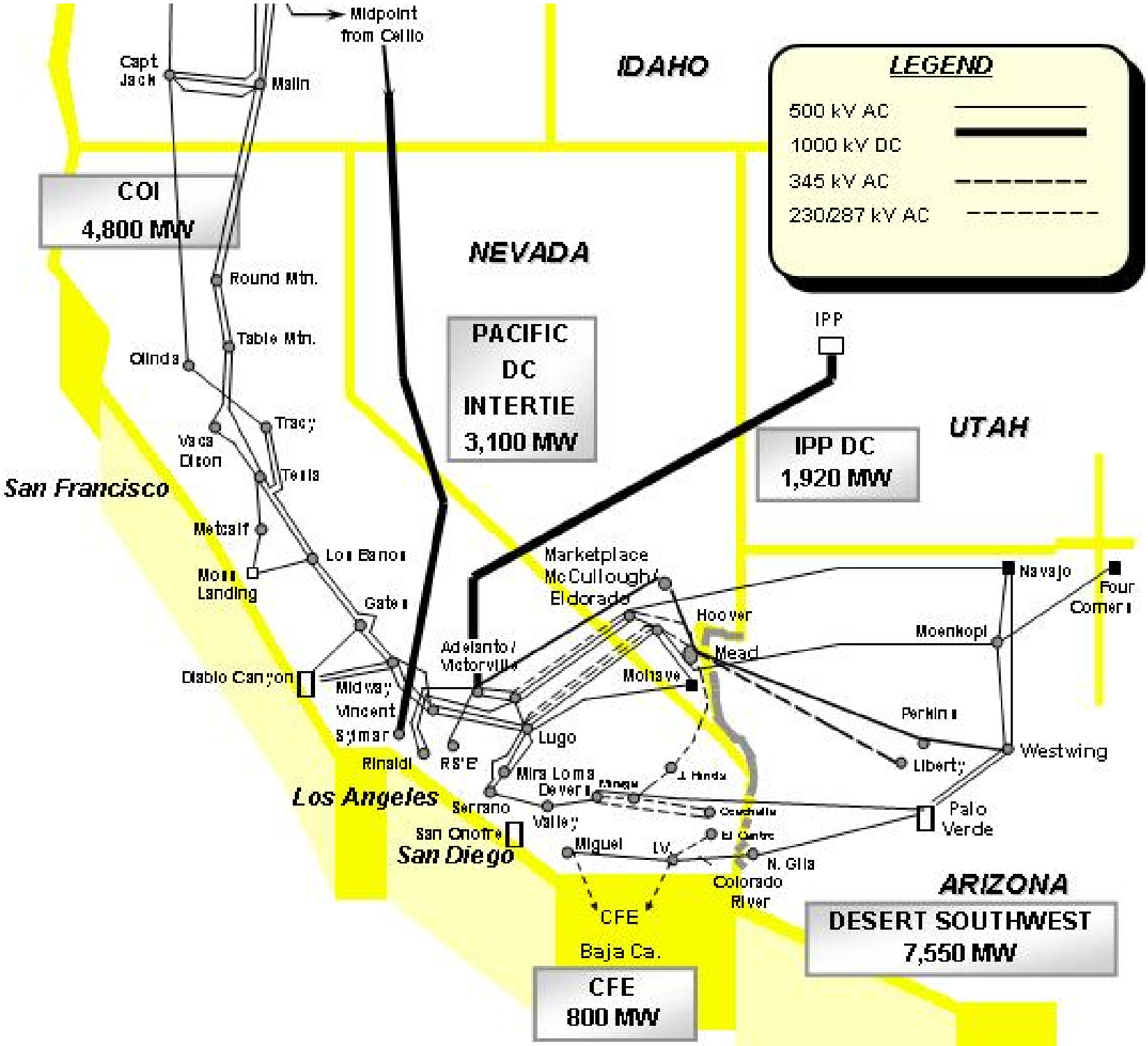
The Liquid-Fluoride Thorium Reactor

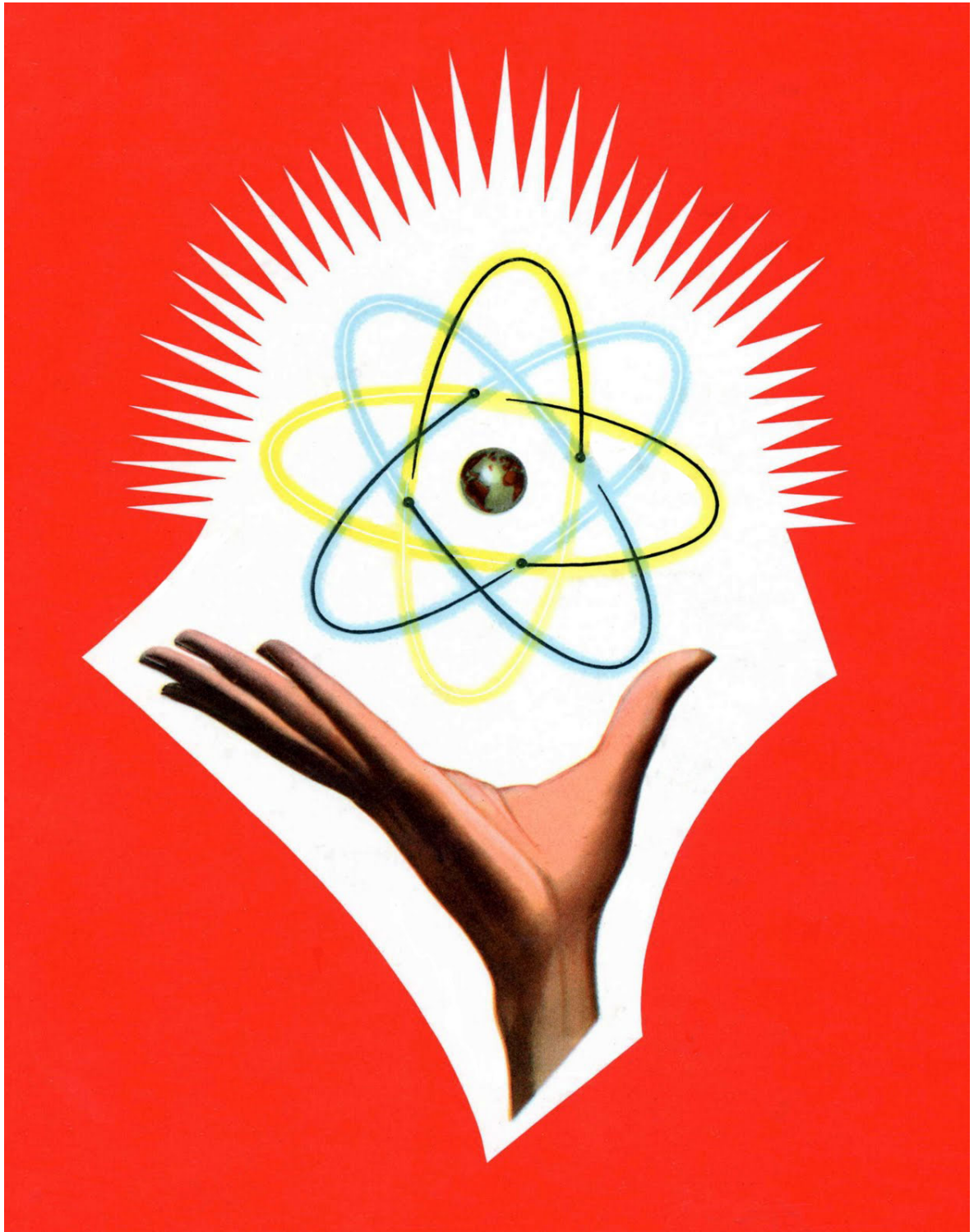
Public Utilities, Energy, and Technology Interim Committee
Salt Lake City, Utah
October 19, 2016

Intermountain Power Plant, Delta, Utah
coal-fired, 1800 megawatts, 2027 shutdown



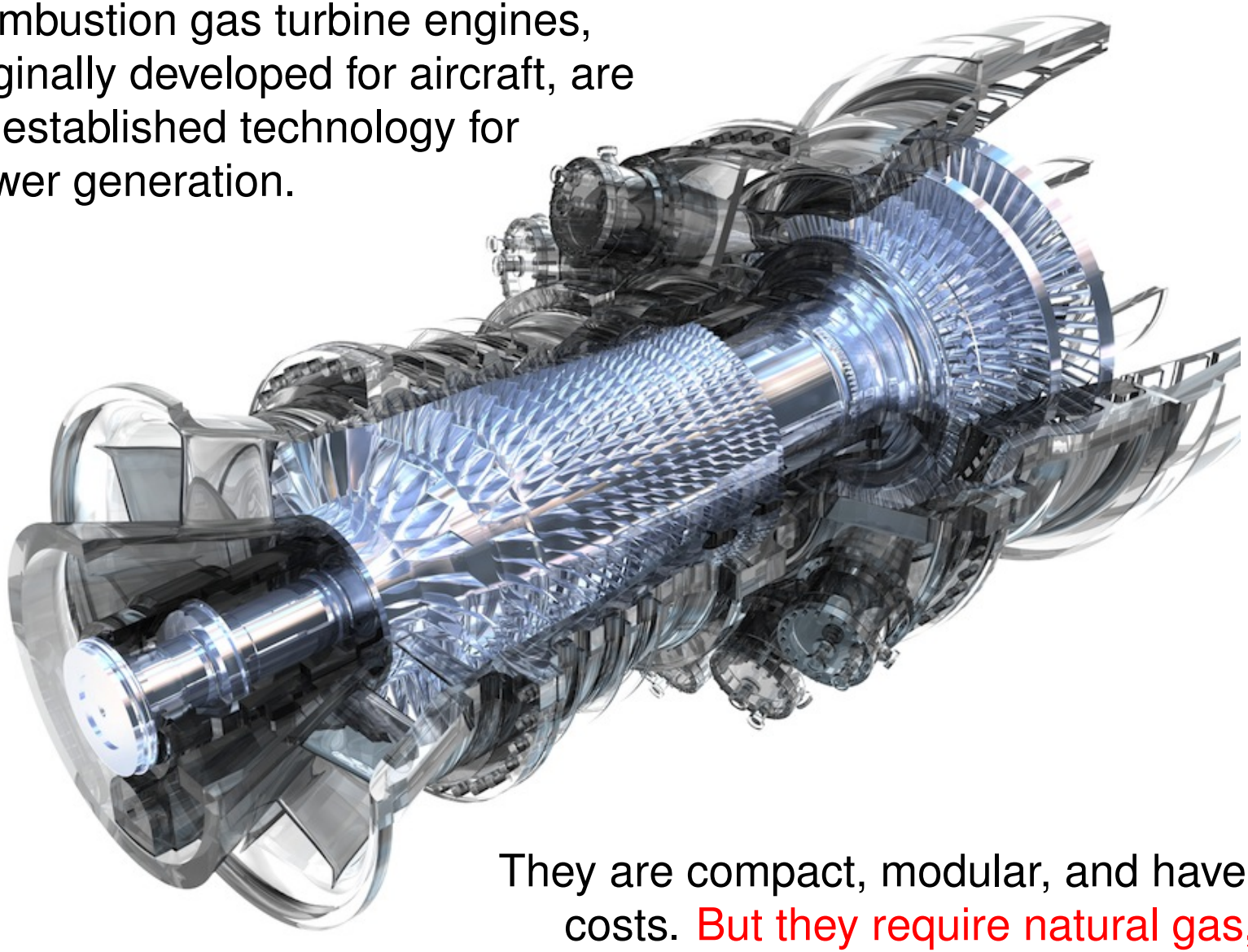
Alternative energy sources like wind are popular in the public's mind, but they are diffuse and intermittent. They cannot produce energy reliably.


Midpoint from Cellilo
IDAHO
LEGEND
500 kV AC
1000 kV DC
345 kV AC
230/287 kV AC
Capt Jack
Malin
COI
4,800 MW
NEVADA
Round Mtn.
Table Mtn.
Olinda
PACIFIC DC INTERTIE
3,100 MW
IPP
IPP DC
1,920 MW
UTAH
Tracy
Vaca Dixon
Tesla
San Francisco
Metcalf
Los Banos
Moss Landing
Gates
Marketplace
McCullough/
Eldorado
Navajo
Four Corners
Hoover
Mead
Moenkopi
Adelanto/
Victorville
Mohave
Diablo Canyon
Midway
Vincent
Sylmar
Lugo
Perkins
Rinaldi
RSBE
Mira Loma
Devers
Westwing
Liberty
Los Angeles
Serrano
Valley
Palo Verde
San Onofre
San Diego
Miguel
LV
N. Gila
Colorado River
ARIZONA
CFE
Baja Ca.
DESERT SOUTHWEST
7,550 MW
CFE
800 MW



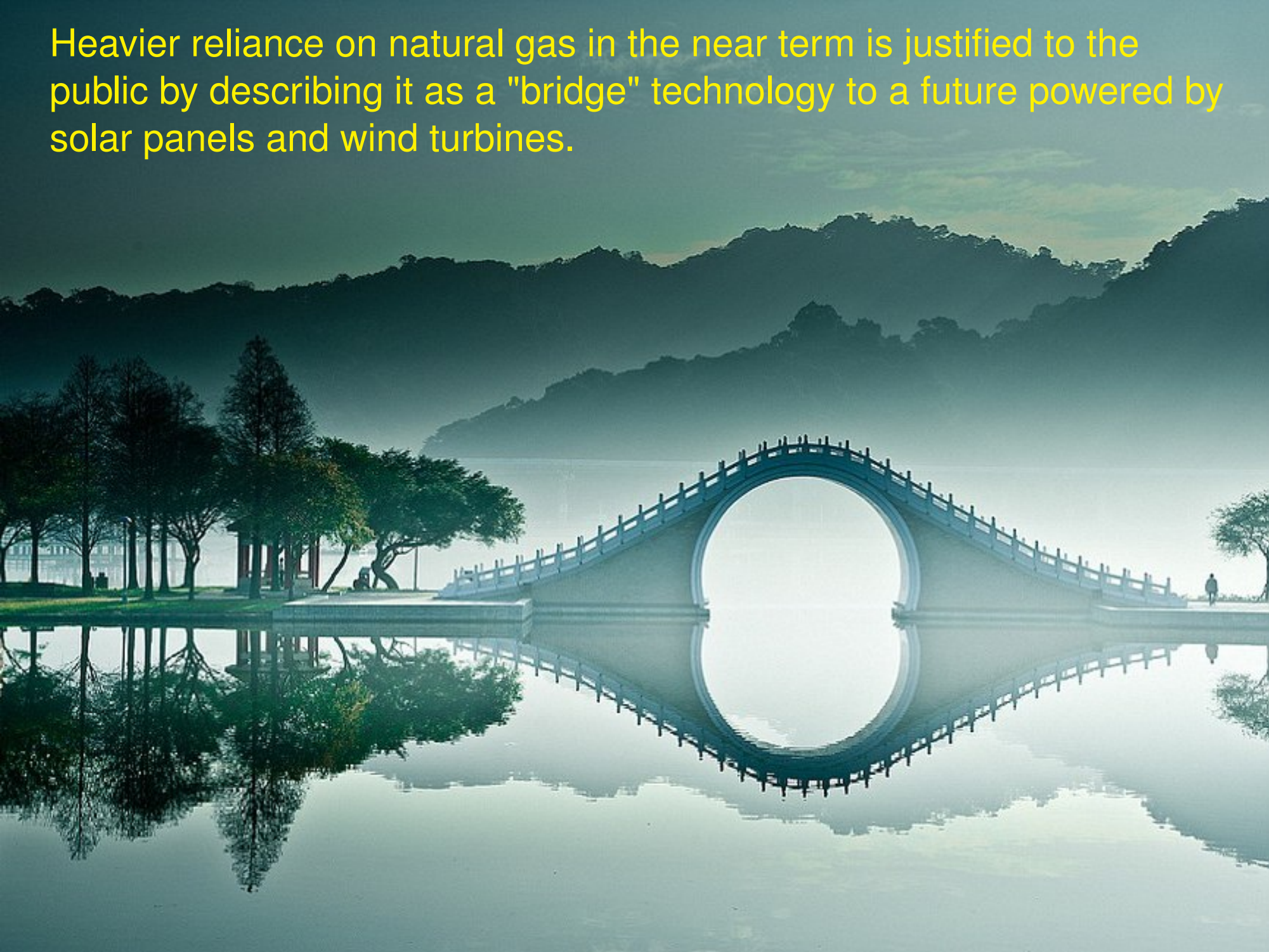
Combustion Gas Turbine Technology

Combustion gas turbine engines, originally developed for aircraft, are an established technology for power generation.



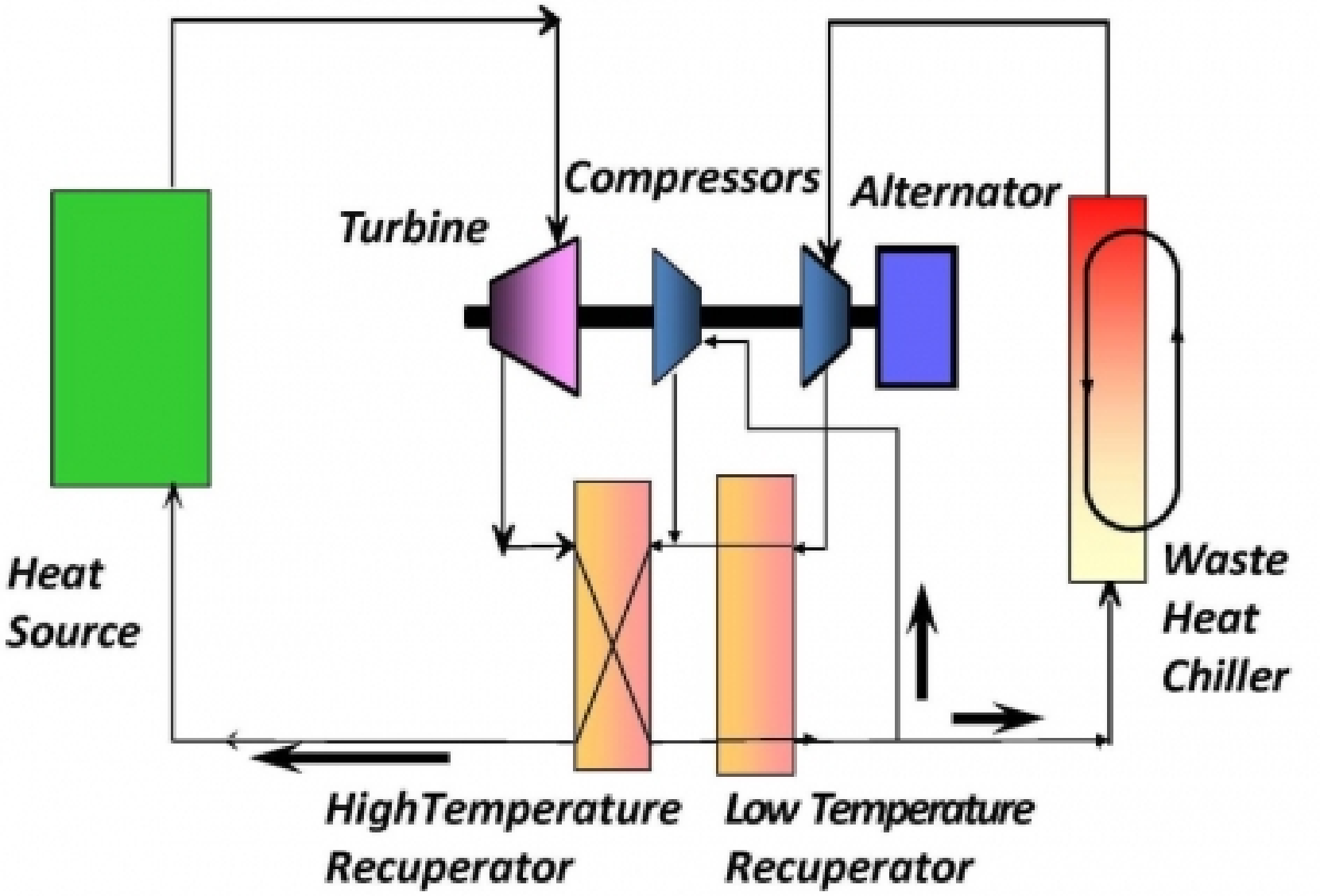
They are compact, modular, and have low capital costs. But they require natural gas, which has demonstrated price volatility.

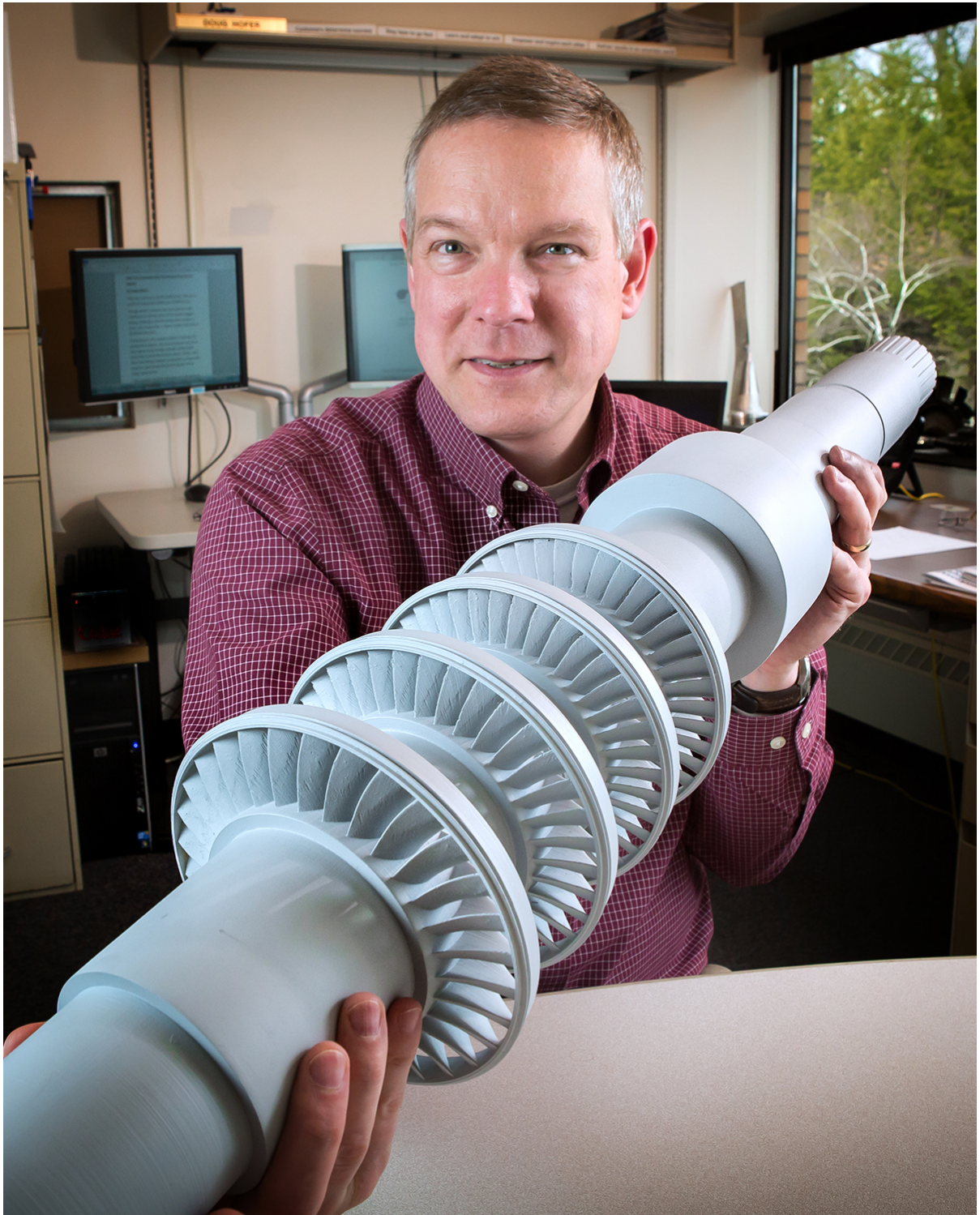
Heavier reliance on natural gas in the near term is justified to the public by describing it as a "bridge" technology to a future powered by solar panels and wind turbines.



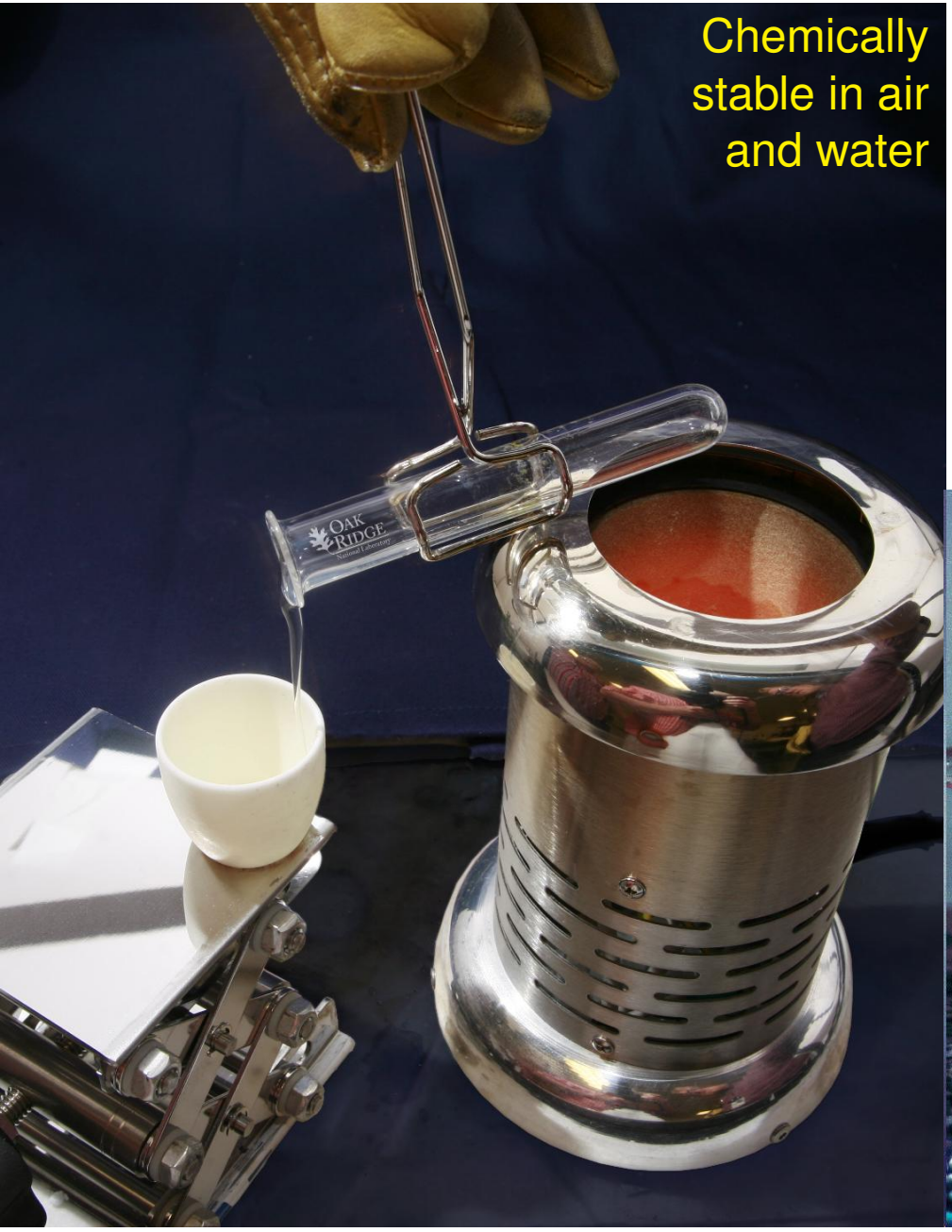

50 t / 175 t
WEYERMANN KRANE
50 t

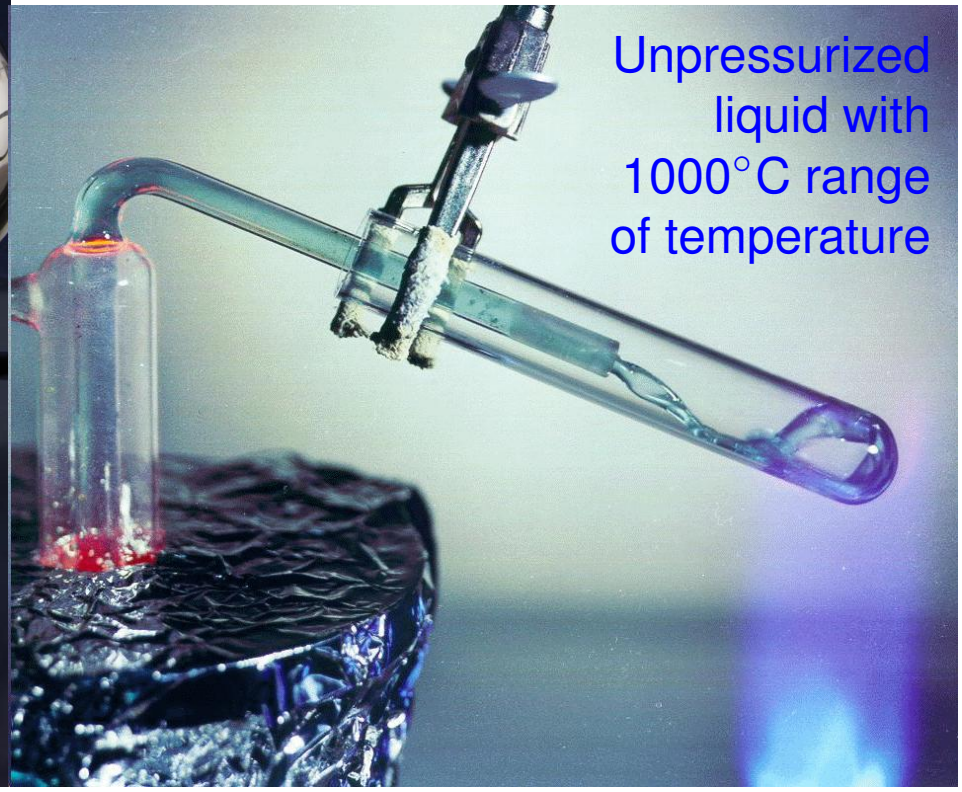
Supercritical CO2 Recompression Cycle



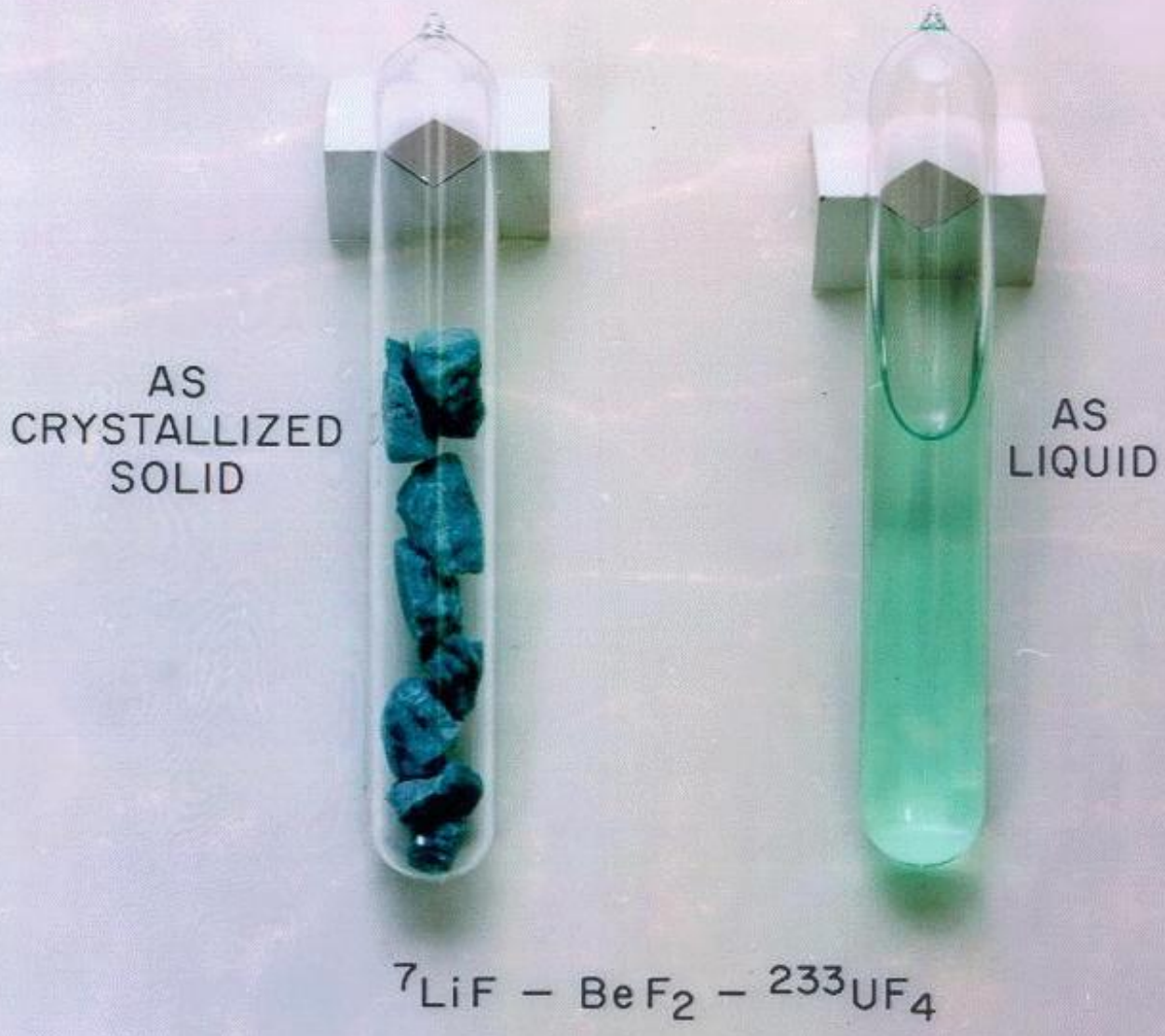


Fluoride salts are safe and versatile





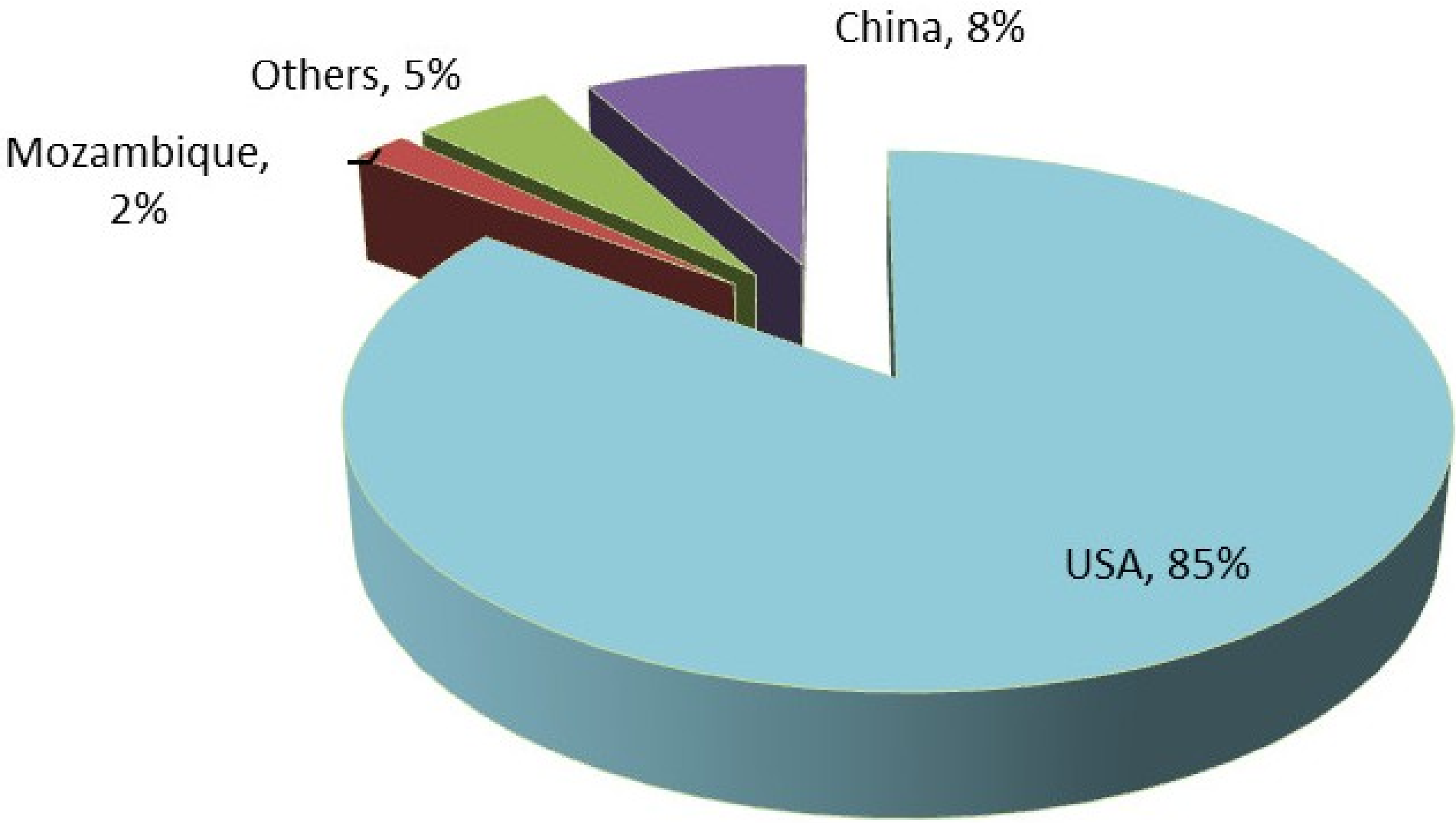
LiF-BeF_2 fluoride salt is an excellent carrier for uranium (UF_4) nuclear fuel.



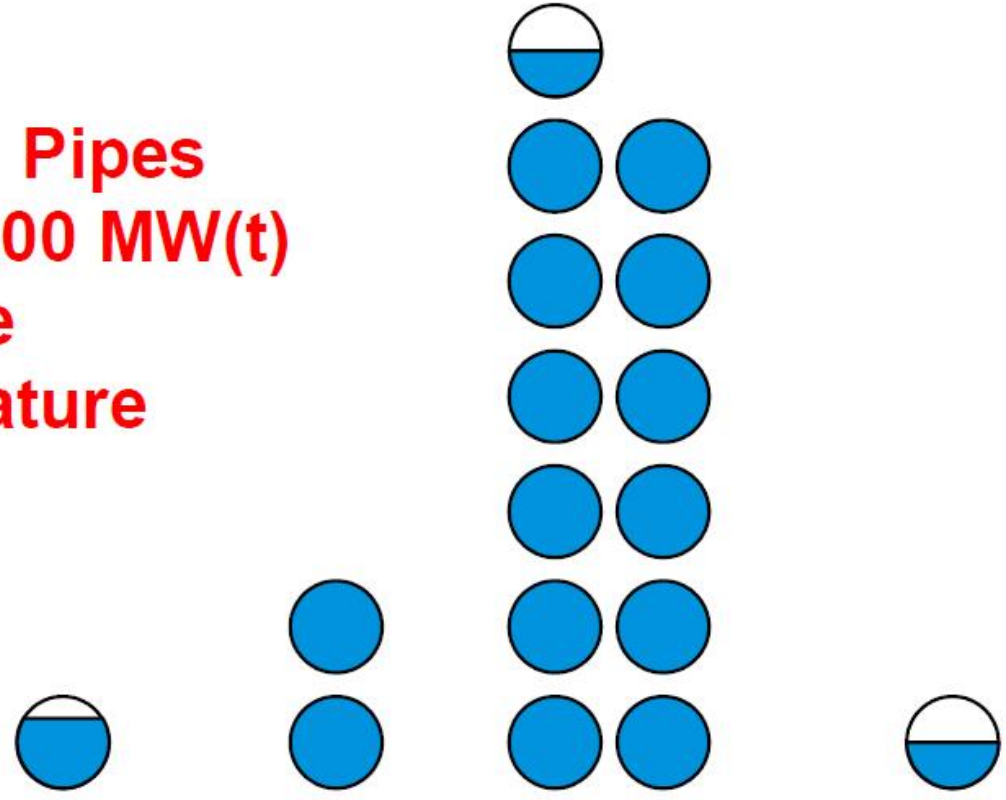
FLUORIDE FUEL FOR A MOLTEN SALT REACTOR

Materion beryllium processing facility, central Utah

Global Beryllium Production

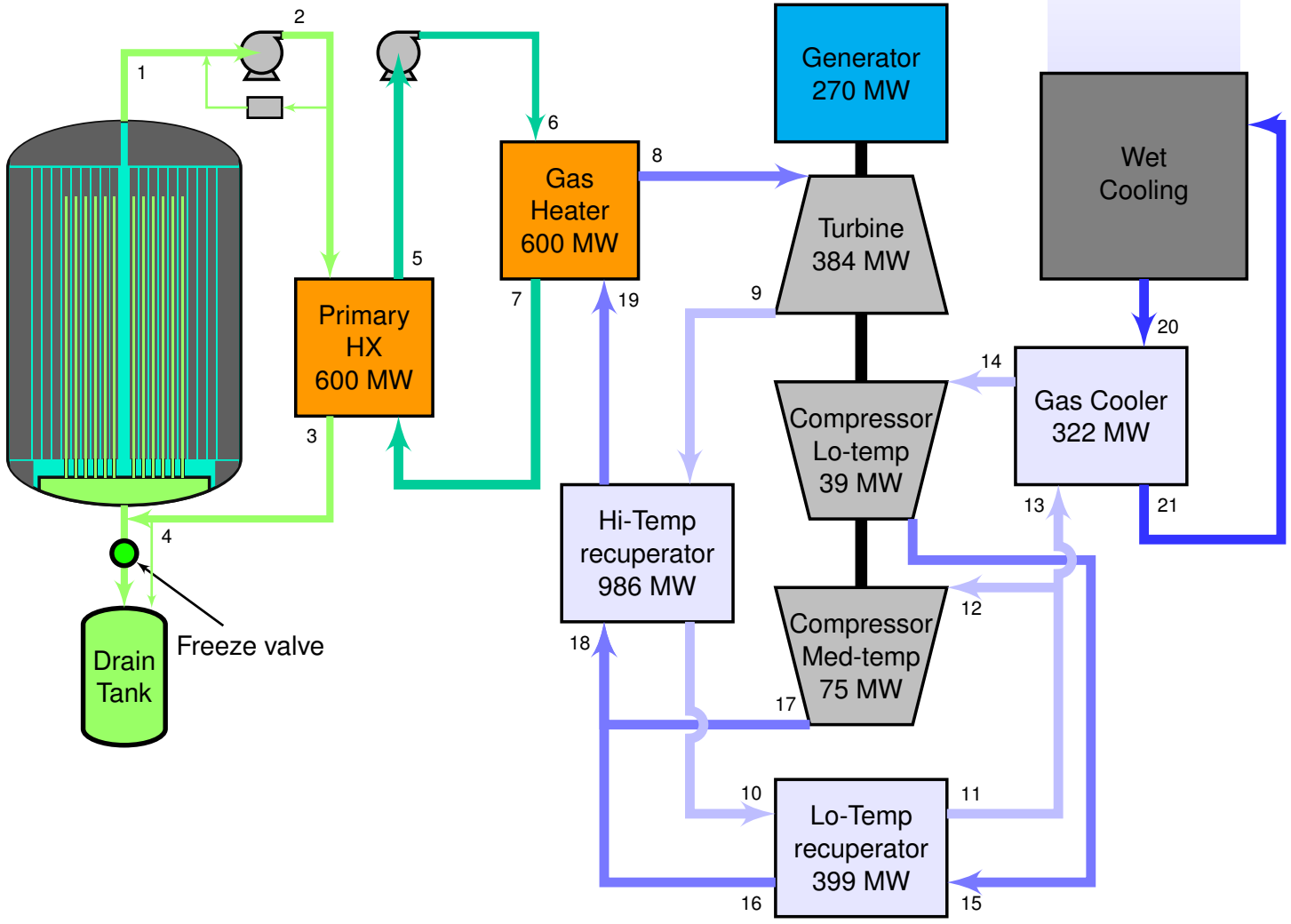


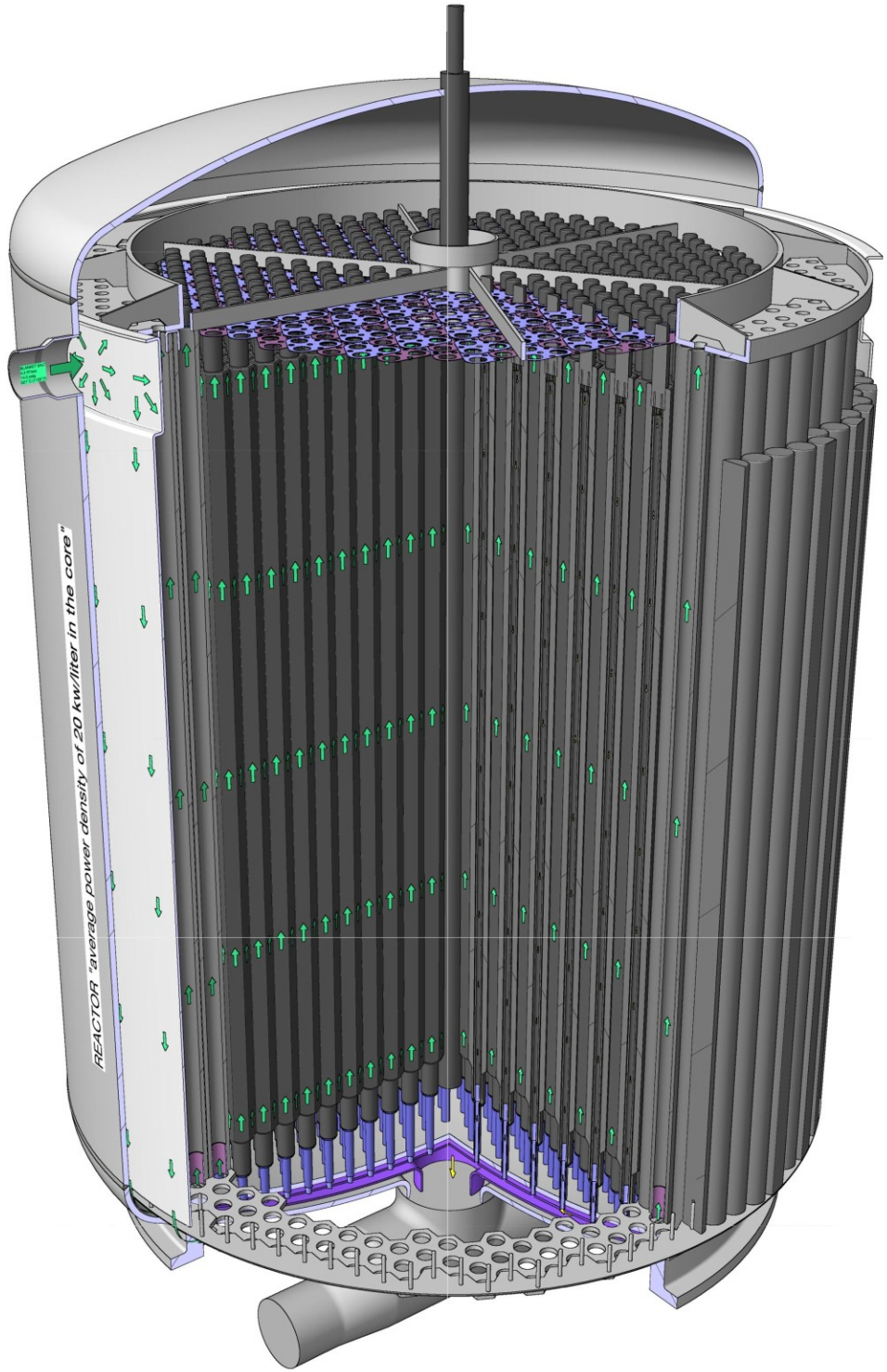
Number of 1-m-diam. Pipes Needed to Transport 1000 MW(t) with 100ºC Rise in Coolant Temperature



	Water (PWR)	Sodium (LMR)	Helium	Liquid Salt
Pressure (MPa)	15.5	0.69	7.07	0.69
Outlet Temp (ºC)	320	540	1000	1000
Coolant Velocity (m/s)	6	6	75	6

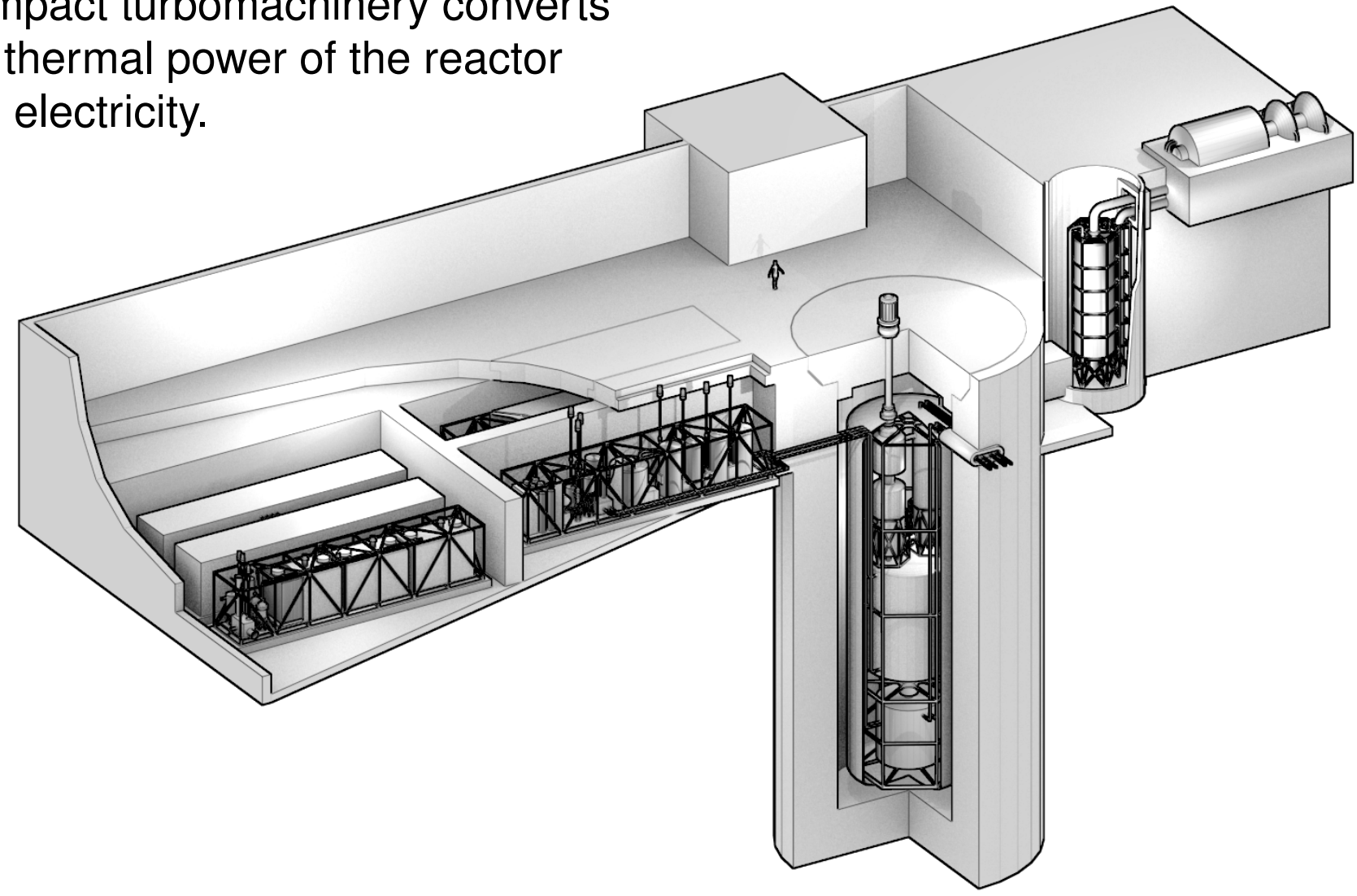
250 MWe LFTR power conversion system




REACTOR "average power density of 20 kw/liter in the core"

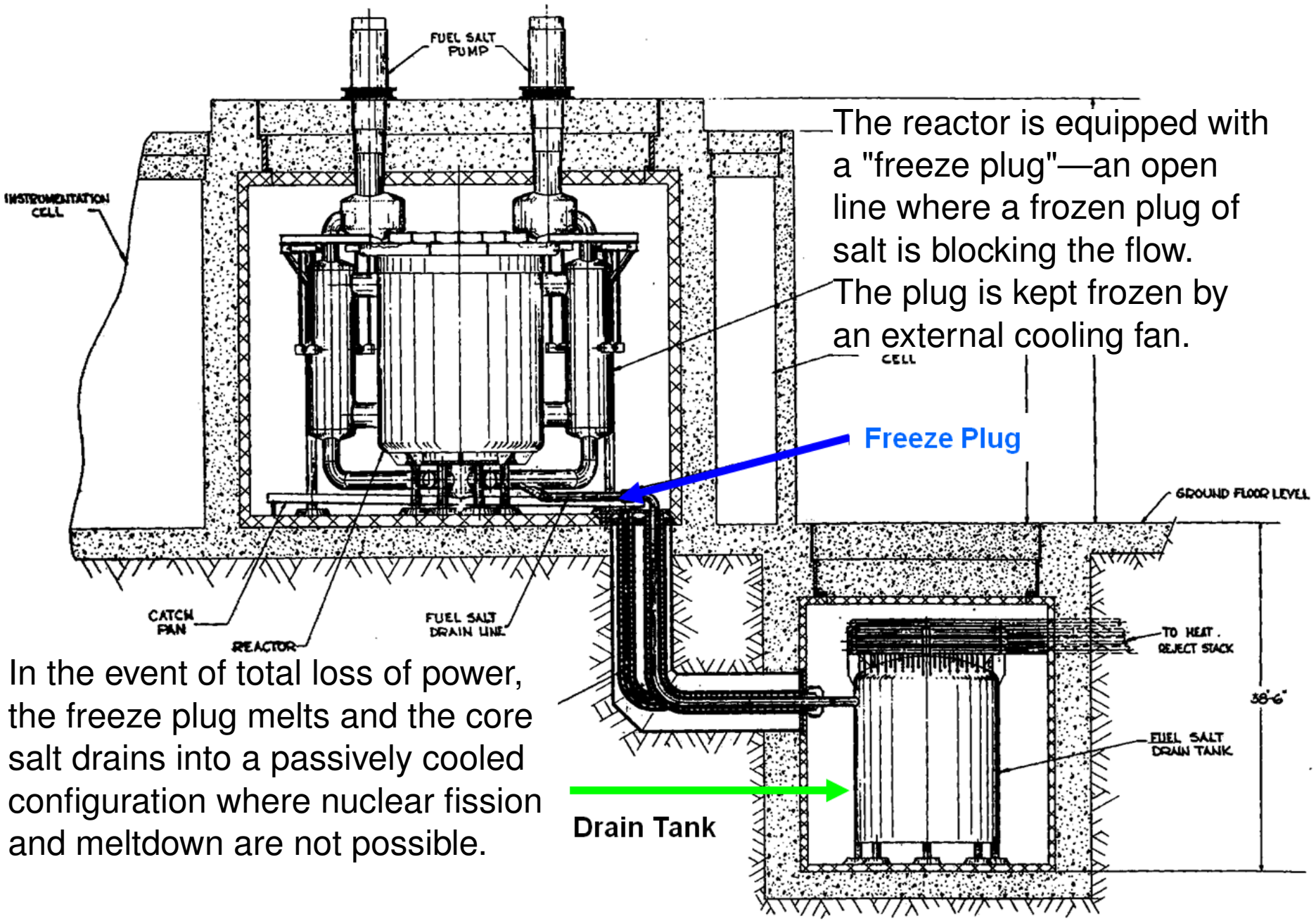
250 MWe LFTR facility concept

Compact turbomachinery converts the thermal power of the reactor into electricity.



The reactor cell is located below ground in a shielded containment structure.

Liquid fuels enhance safety options

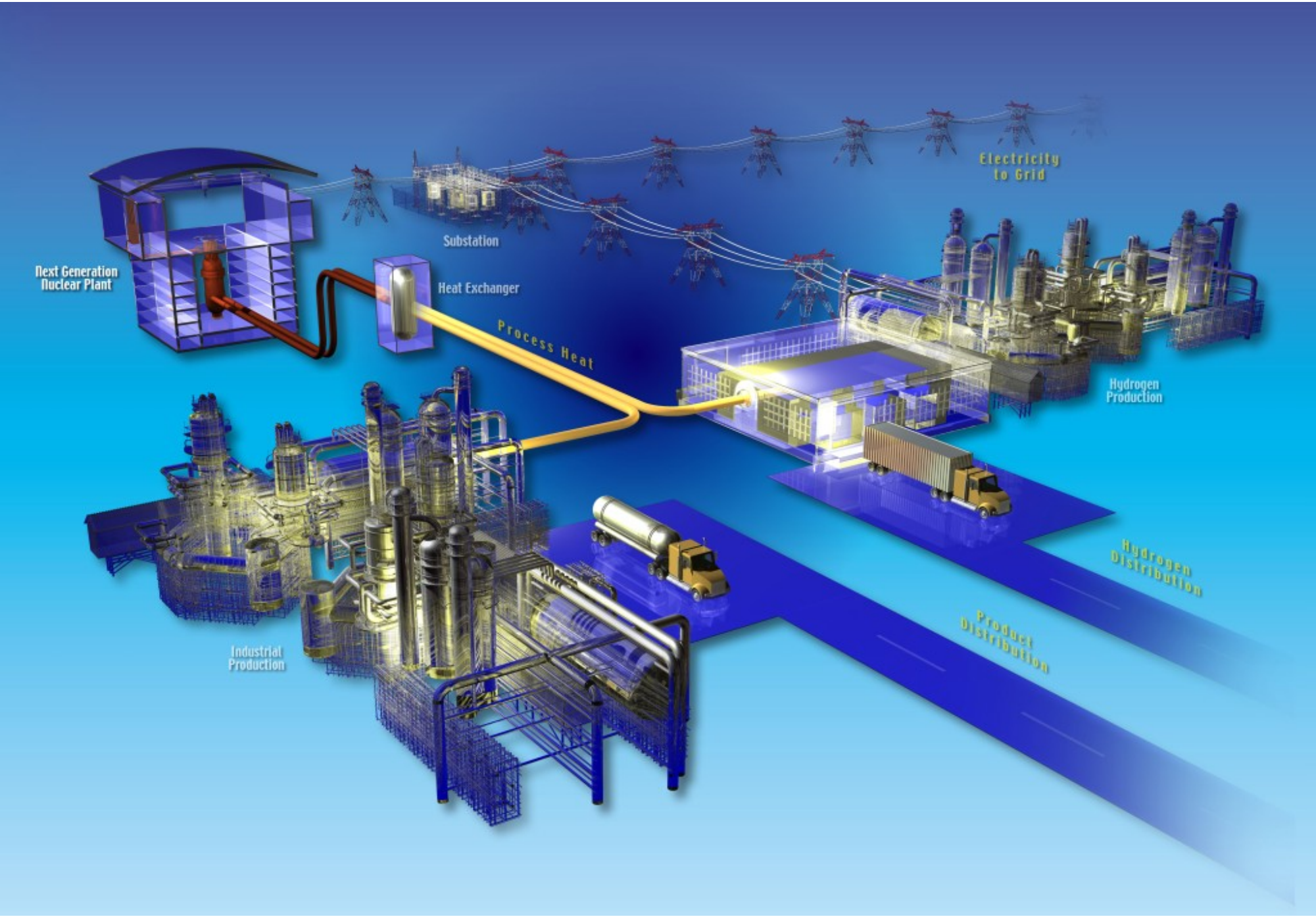


The reactor is equipped with a "freeze plug"—an open line where a frozen plug of salt is blocking the flow. The plug is kept frozen by an external cooling fan.

Freeze Plug

In the event of total loss of power, the freeze plug melts and the core salt drains into a passively cooled configuration where nuclear fission and meltdown are not possible.

Drain Tank

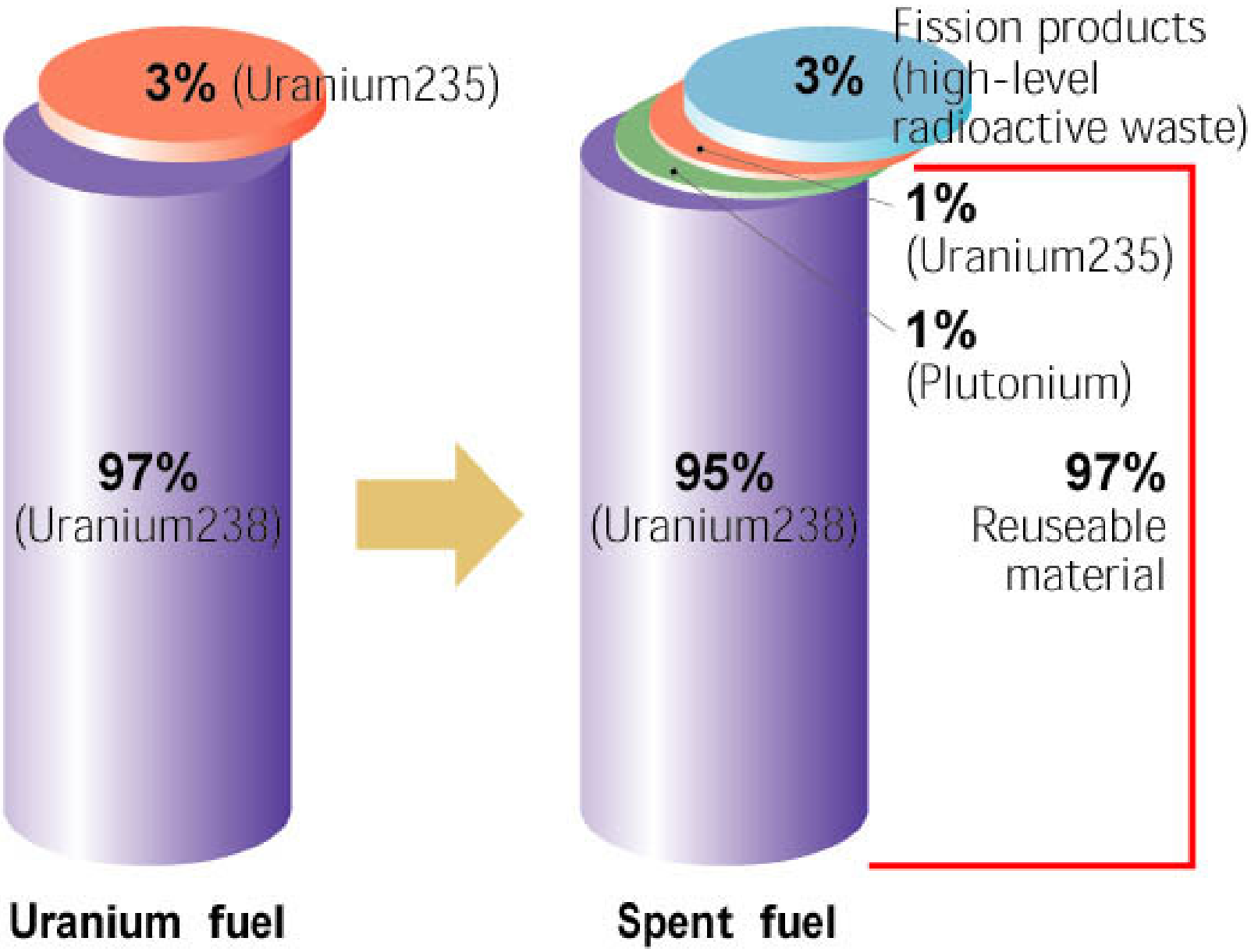

Next Generation
Nuclear Plant
Substation
Electricity
to Grid
Heat Exchanger
Process Heat
Hydrogen
Production
Industrial
Production
Hydrogen
Distribution
Product
Distribution

Rare Earth Oxide Powders

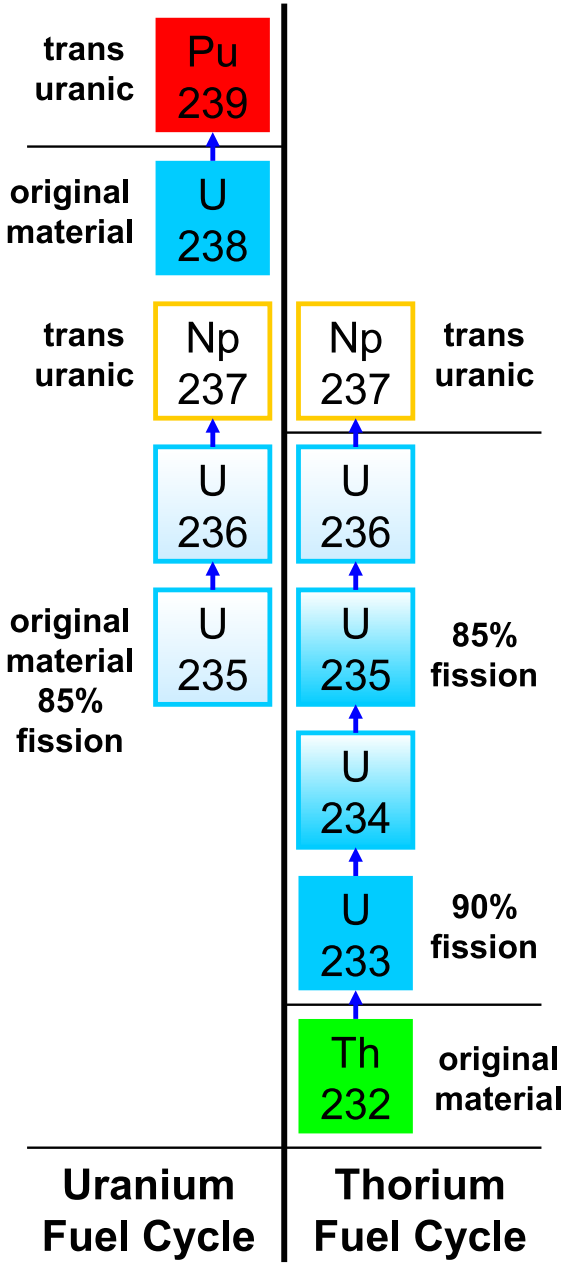
Thorium Storage at La Rochelle, France

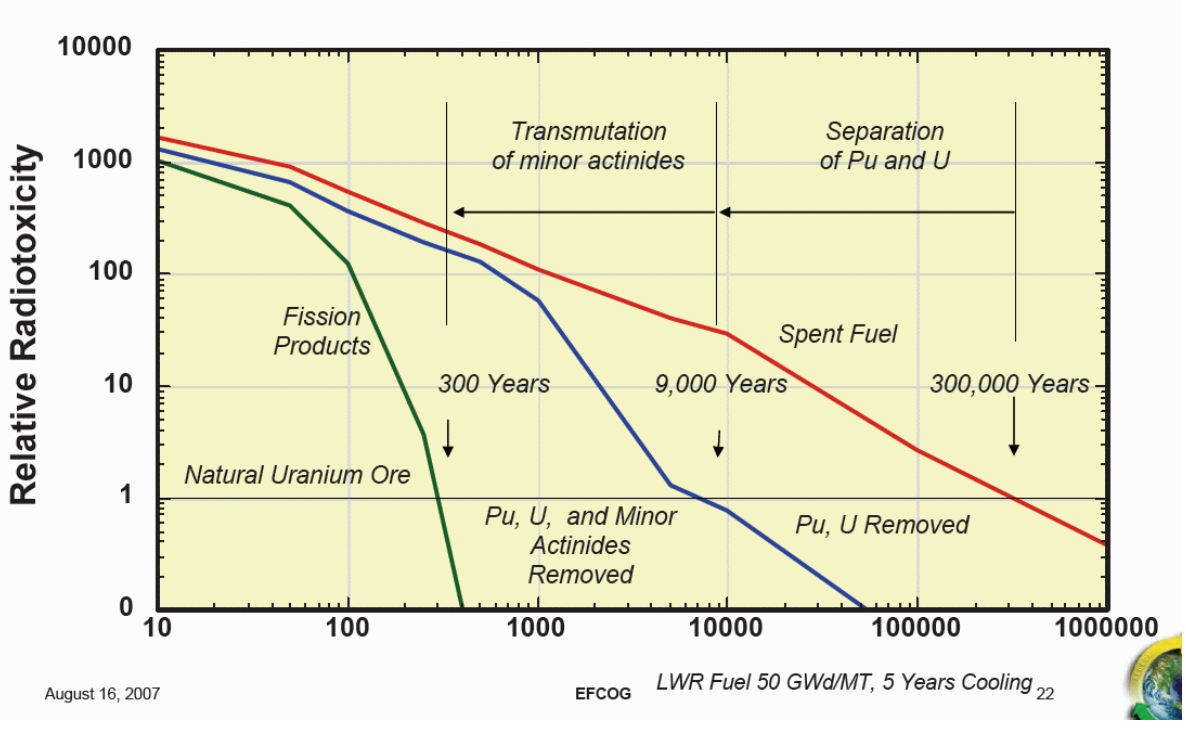
The production of long-lived nuclear waste has been a potent focus of opposition to nuclear power for many years.

Spent Nuclear Fuel Composition

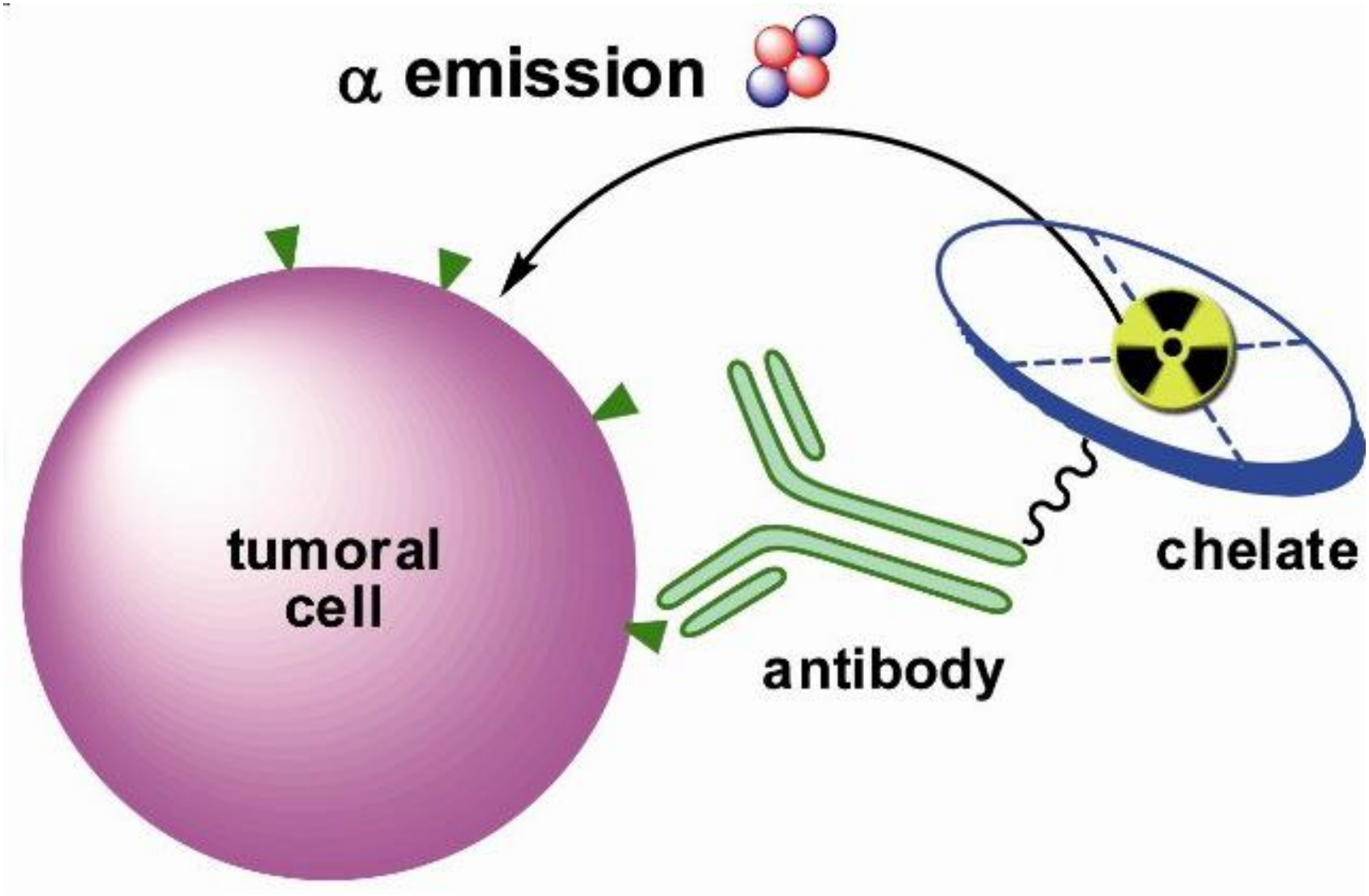


Reducing Long-Lived Waste





Targeted Alpha Therapy



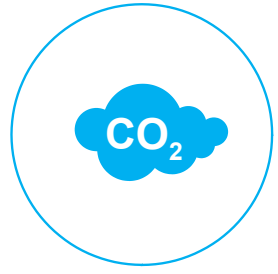
Our Mission, Our Passion

To supply the world with energy, water and fuel that is

Safe

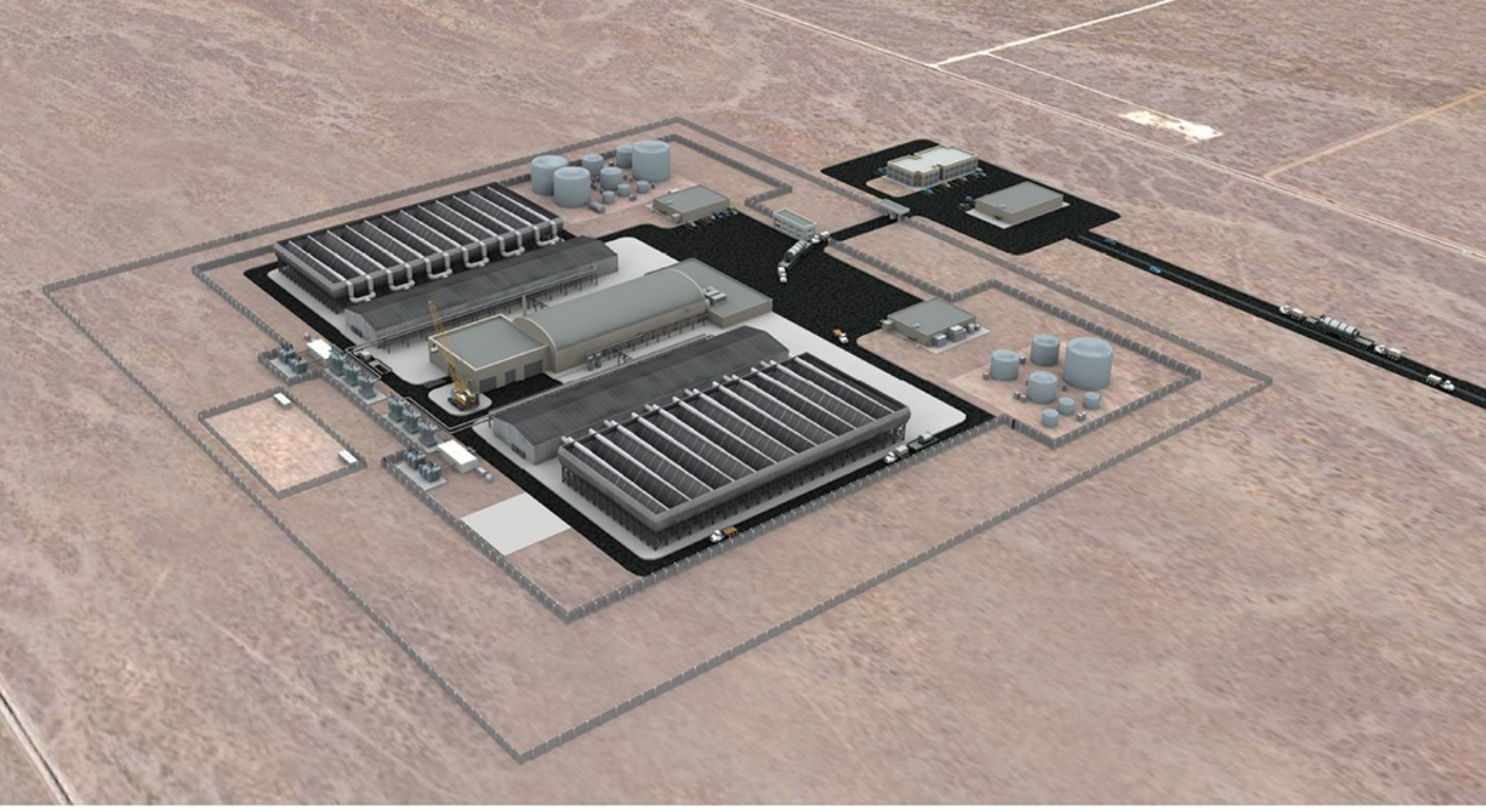
Reliable

Efficient



Sustainable

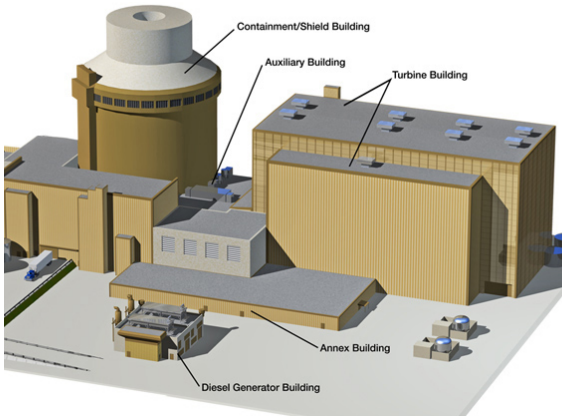
achieved through the Liquid Fluoride Thorium Reactor.



UAMPS’s 570 MWe NuScale Power Plant
12x50 MWe units, uranium-fueled, steam-turbine

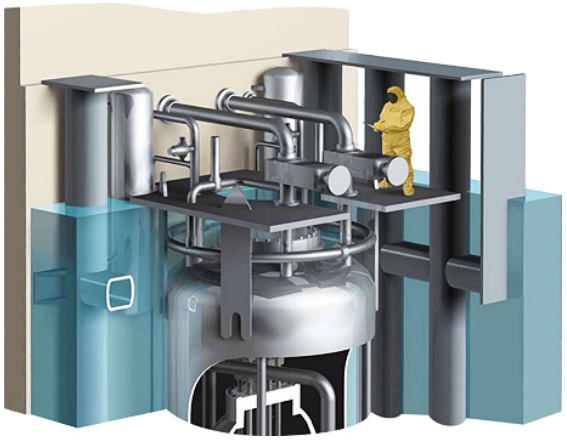
Smartphones did more, so must reactors

large pressurized light-water reactor



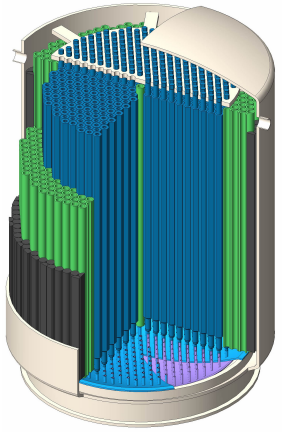
1970s technology
electricity

small modular pressurized light-water reactor



early 2000s
electricity

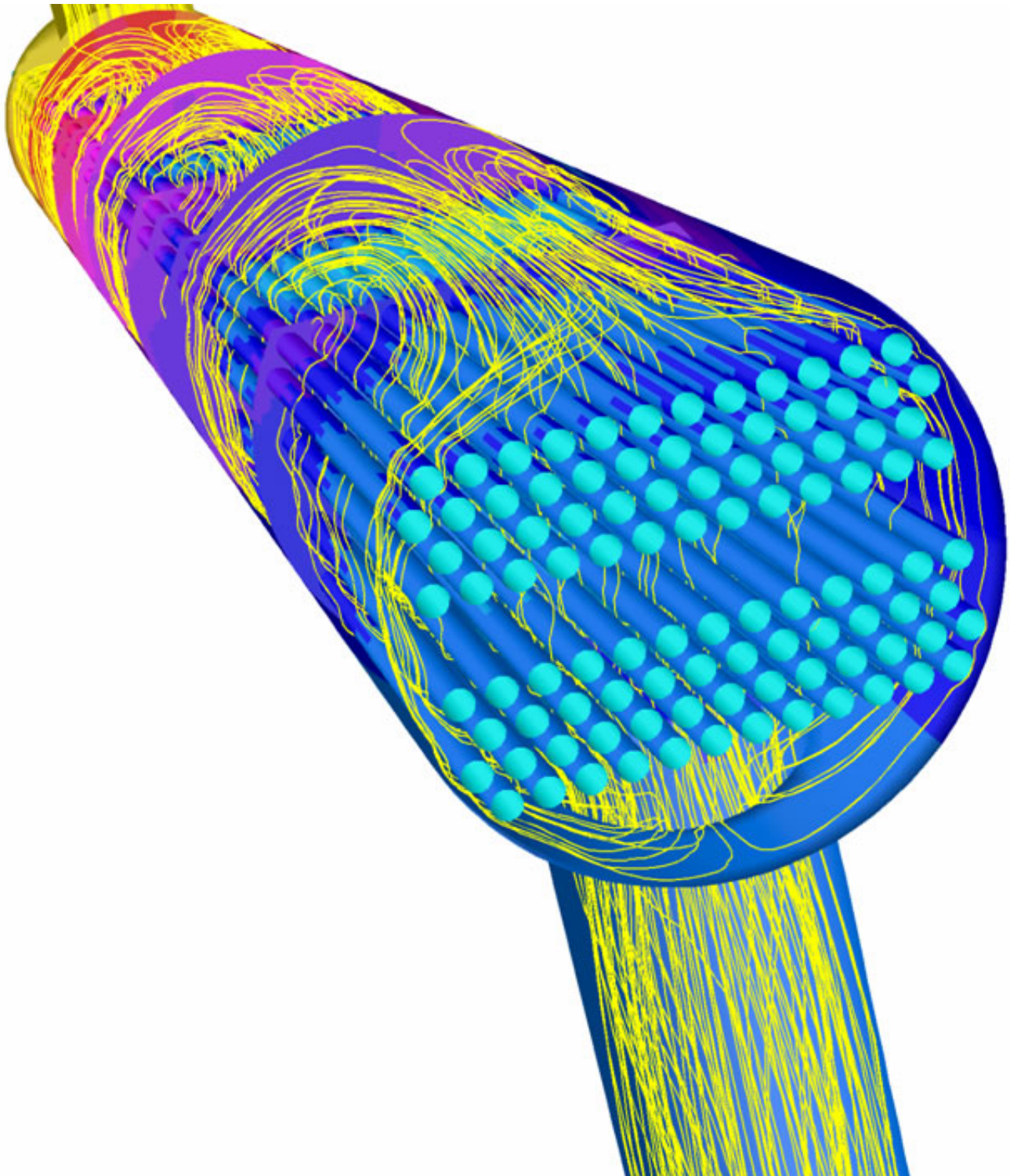
small modular liquid-fluoride thorium reactor

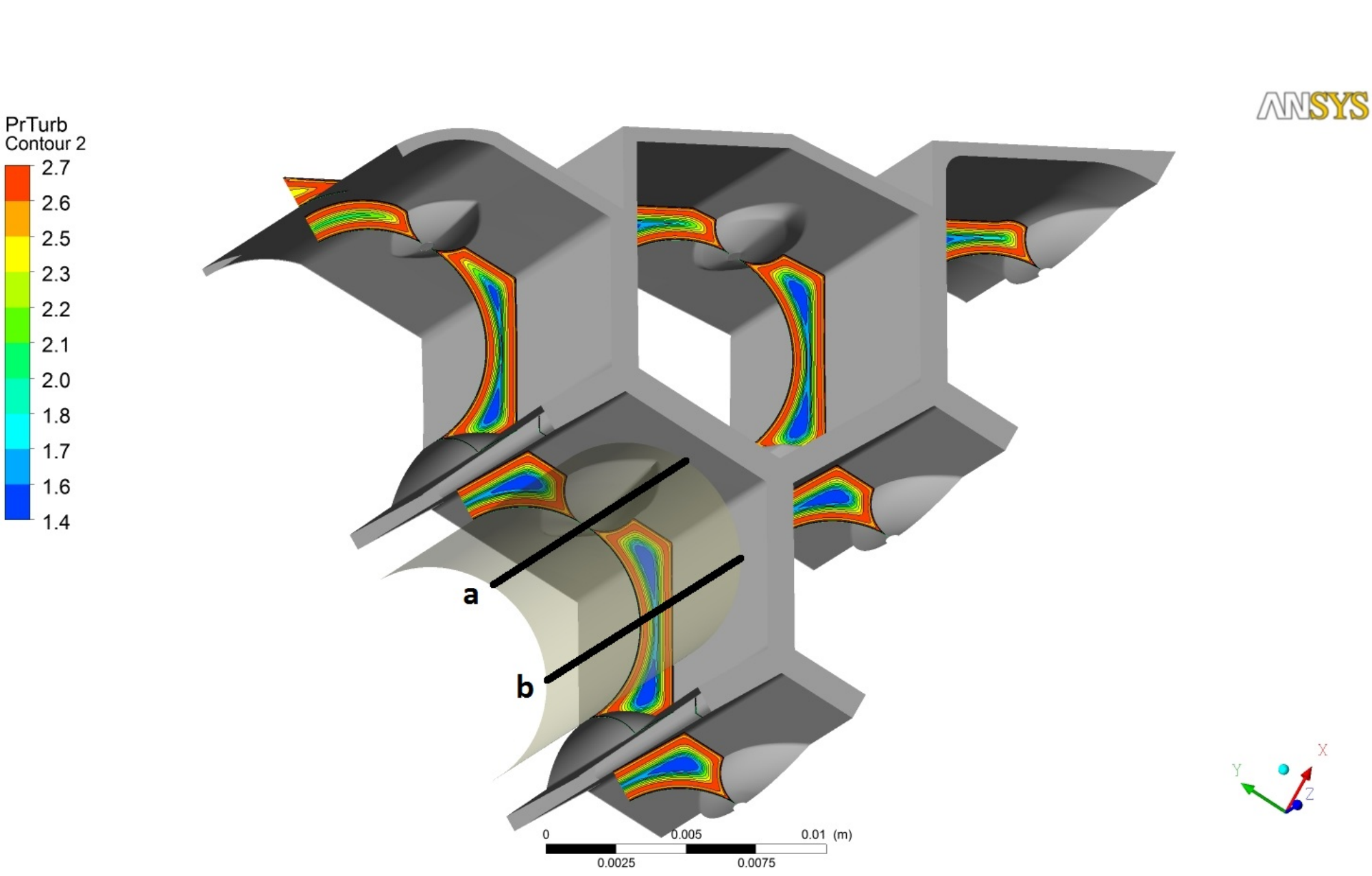


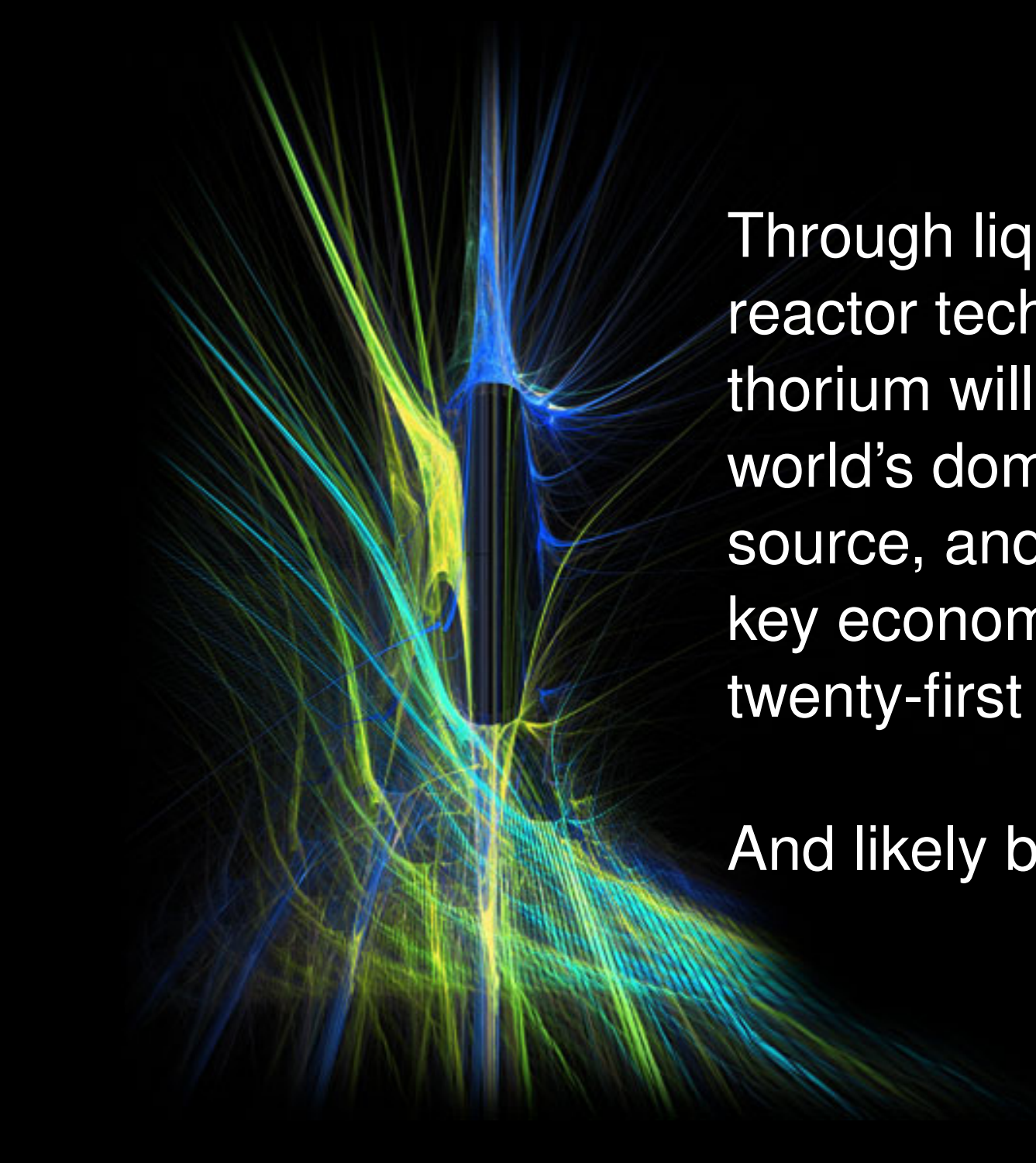
2030 and beyond
medicine, electricity, heat, water, and more

US Nuclear Power Plants

The Intermountain West is conspicuously absent in the national deployment of conventional nuclear reactor technology.




PrTurb
Contour 2
2.7
2.6
2.5
2.3
2.2
2.1
2.0
1.8
1.7
1.6
1.4
a
b
0
0.005
0.01 (m)
0.0025
0.0075
X
Y
Z

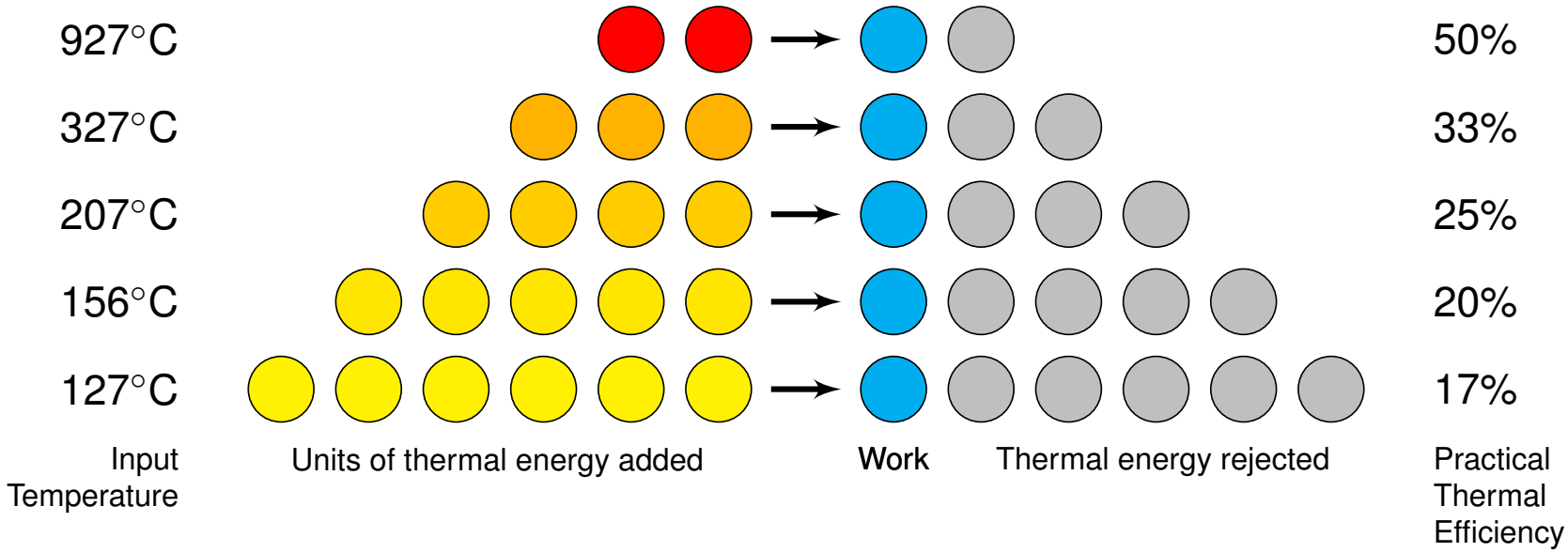


Through liquid-fluoride reactor technology, thorium will become the world's dominant energy source, and this will be the key economic driver of the twenty-first century.

And likely beyond.

Principle of Thermal Efficiency

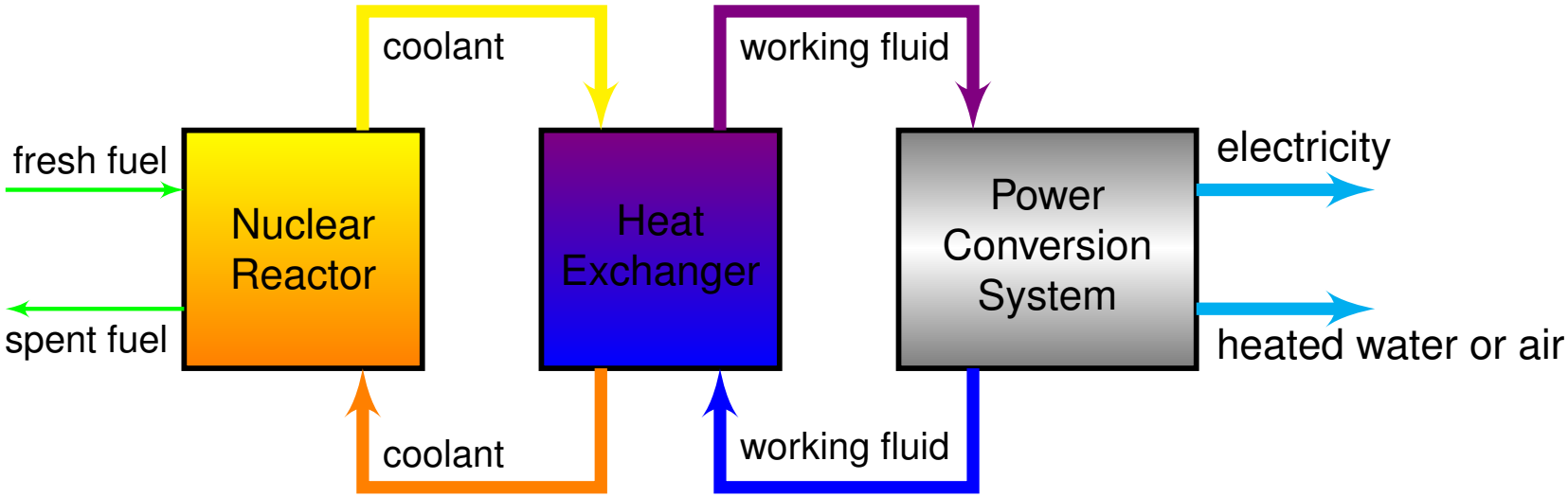
Each unit of thermal energy added to a heat engine represents a "cost", whether produced by combustion, fission, or concentrated solar.



No matter the source, the lower the temperature, the less thermal energy can be usefully converted to work. The rest is considered a necessary loss as "waste heat."

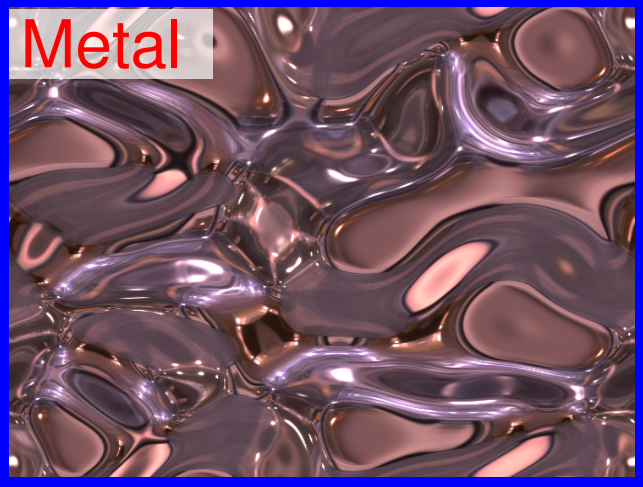
Fundamental Nuclear Reactor Concept

In its simplest form, a nuclear reactor generates thermal energy that is carried away by a coolant. That coolant heats the working fluid of a power conversion system, which generates electricity from part of the thermal energy and rejects the remainder to the environment.

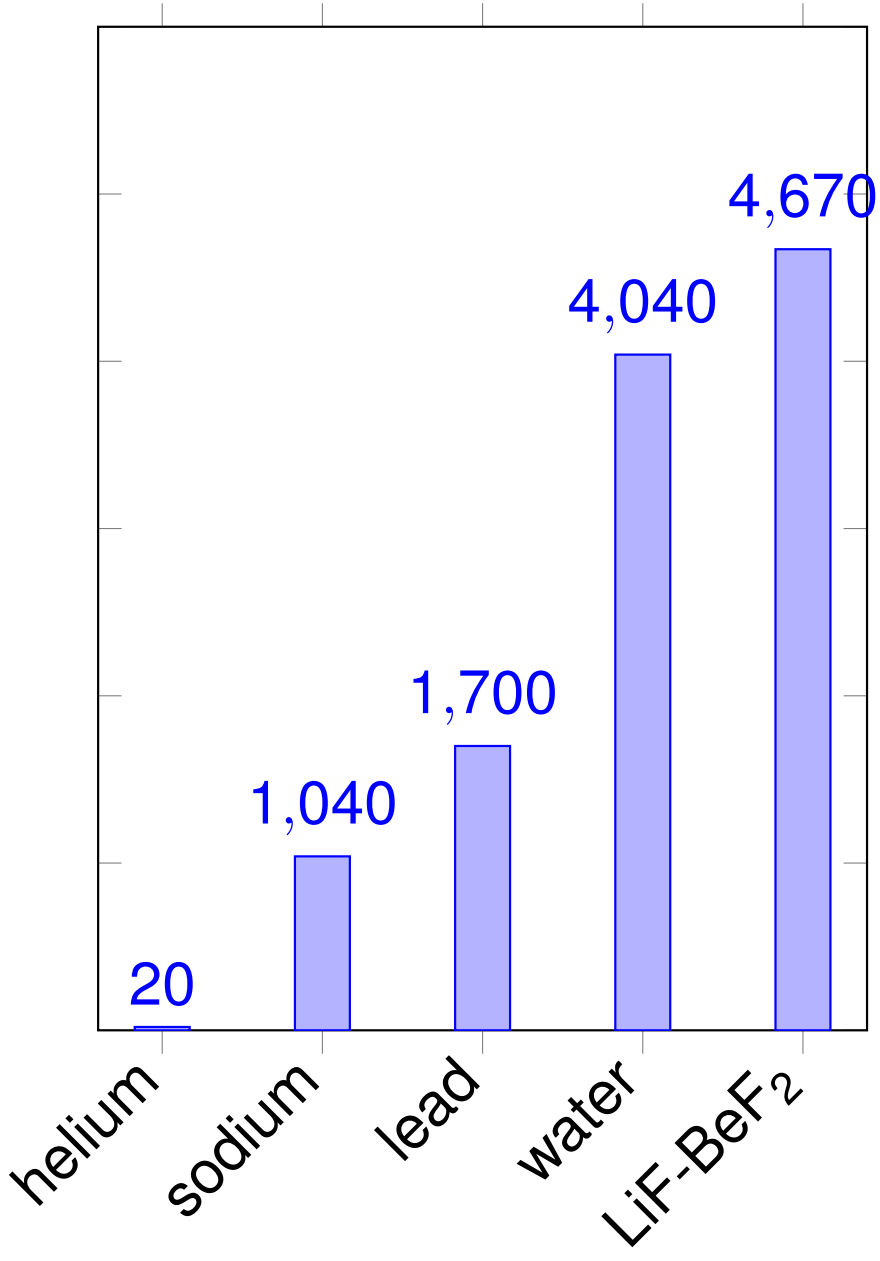


The primary coolant chosen for a nuclear reactor determines, in large part, its size and manufacturability. The temperature of the coolant determines the efficiency of electrical generation.

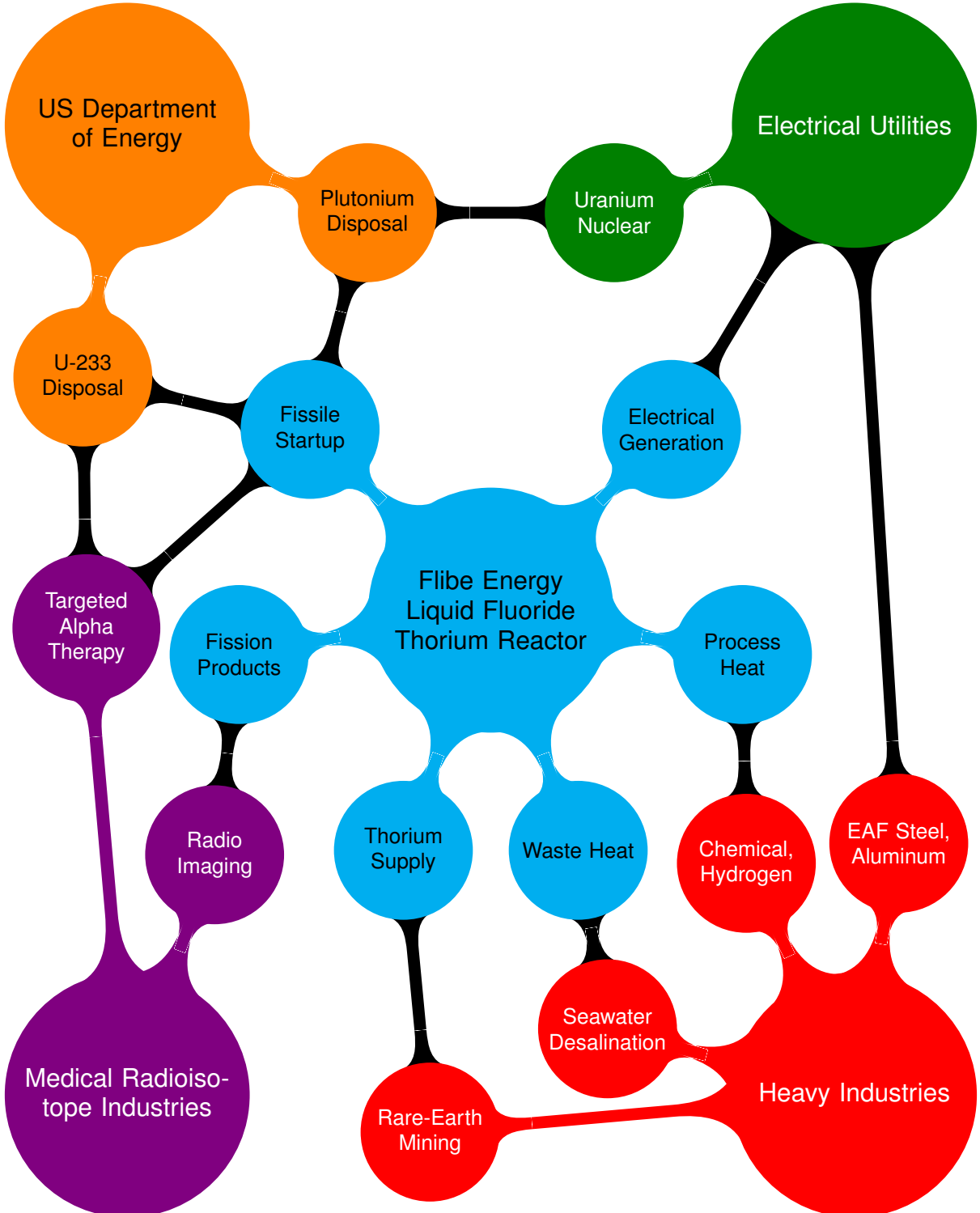
Coolant Choices for a Nuclear Reactor

	atmospheric pressure operation	high-pressure operation
moderate temperature (250-450°C)	Metal 	Water 
high temperature (650-900°C)	Salt 	Gas 

Volumetric Heat Capacity of Coolant Options



Of the four coolant options, a fluoride salt ($LiF\text{-}BeF_2$) has the greatest volumetric heat capacity (thermal energy per unit volume). It can also carry this thermal energy at a low—essentially ambient—operating pressure.


US Department of Energy
Plutonium Disposal
Uranium Nuclear
Electrical Utilities
U-233 Disposal
Fissile Startup
Electrical Generation
Targeted Alpha Therapy
Fission Products
Flibe Energy Liquid Fluoride Thorium Reactor
Process Heat
Radio Imaging
Thorium Supply
Waste Heat
Chemical, Hydrogen
EAF Steel, Aluminum
Seawater Desalination
Medical Radioiso-tope Industries
Rare-Earth Mining
Heavy Industries