The Advanced High-Temperature Reactor

(A New Reactor Concept That Combines Existing Technologies In a New Way)

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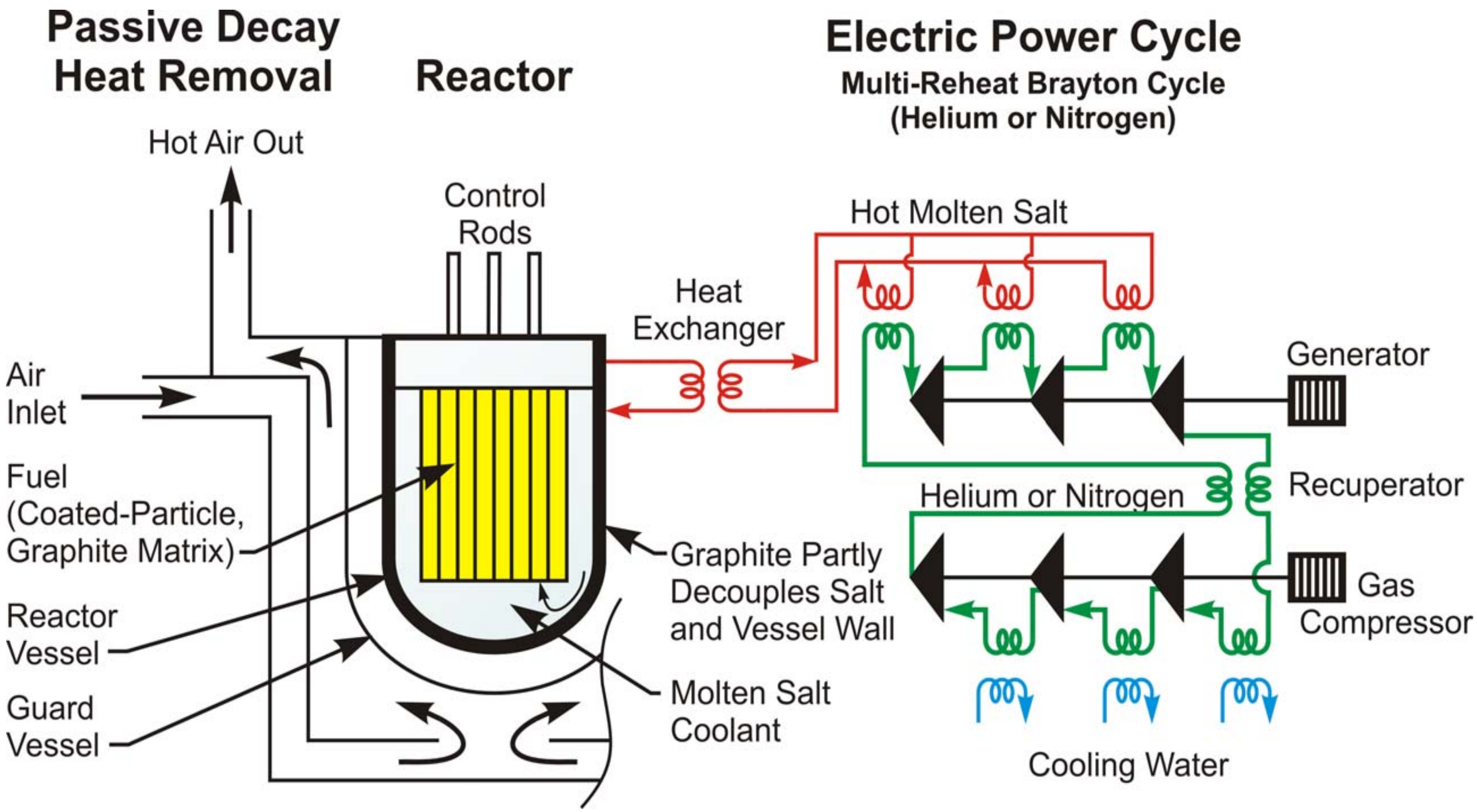
The Advance High-Temperature Reactor Is a Large, Passively Safe, High-Temperature Reactor for Electricity and Hydrogen Production

- A large reactor to improve economics
  - 2400 MW(t)
  - 1150 MW(e)
- Passive safety for improved economics, safety, and public acceptance
  - Safety not dependent upon moving parts or operators
  - Historically passive safety was limited to small reactors
- High temperatures for hydrogen production

The Advanced High Temperature Reactor



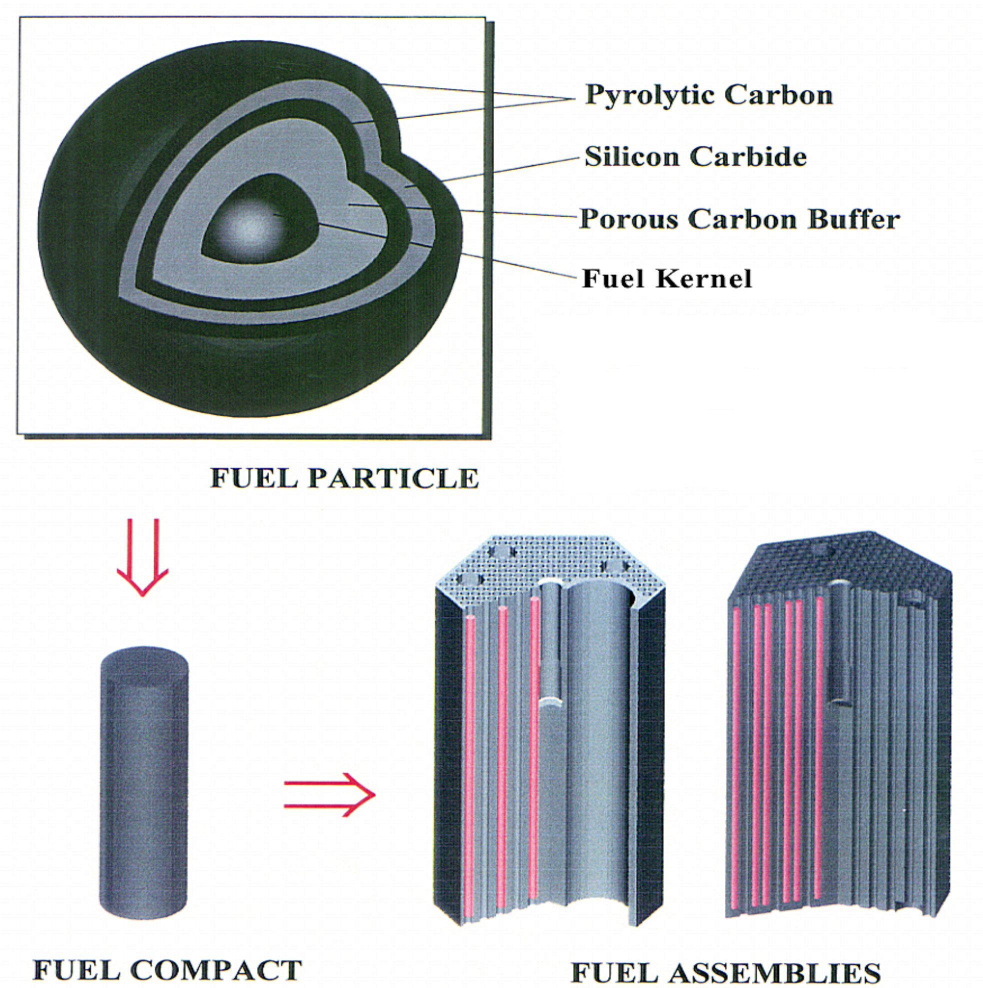
To Produce High Temperatures, A High-Temperature Fuel Is Required

Goal: Delivered heat at temperatures of 750 to 1000ºC (Dependent upon application)

Only one proven nuclear fuel exists for these conditions

The AHTR Uses Coated-Particle Graphite Fuels

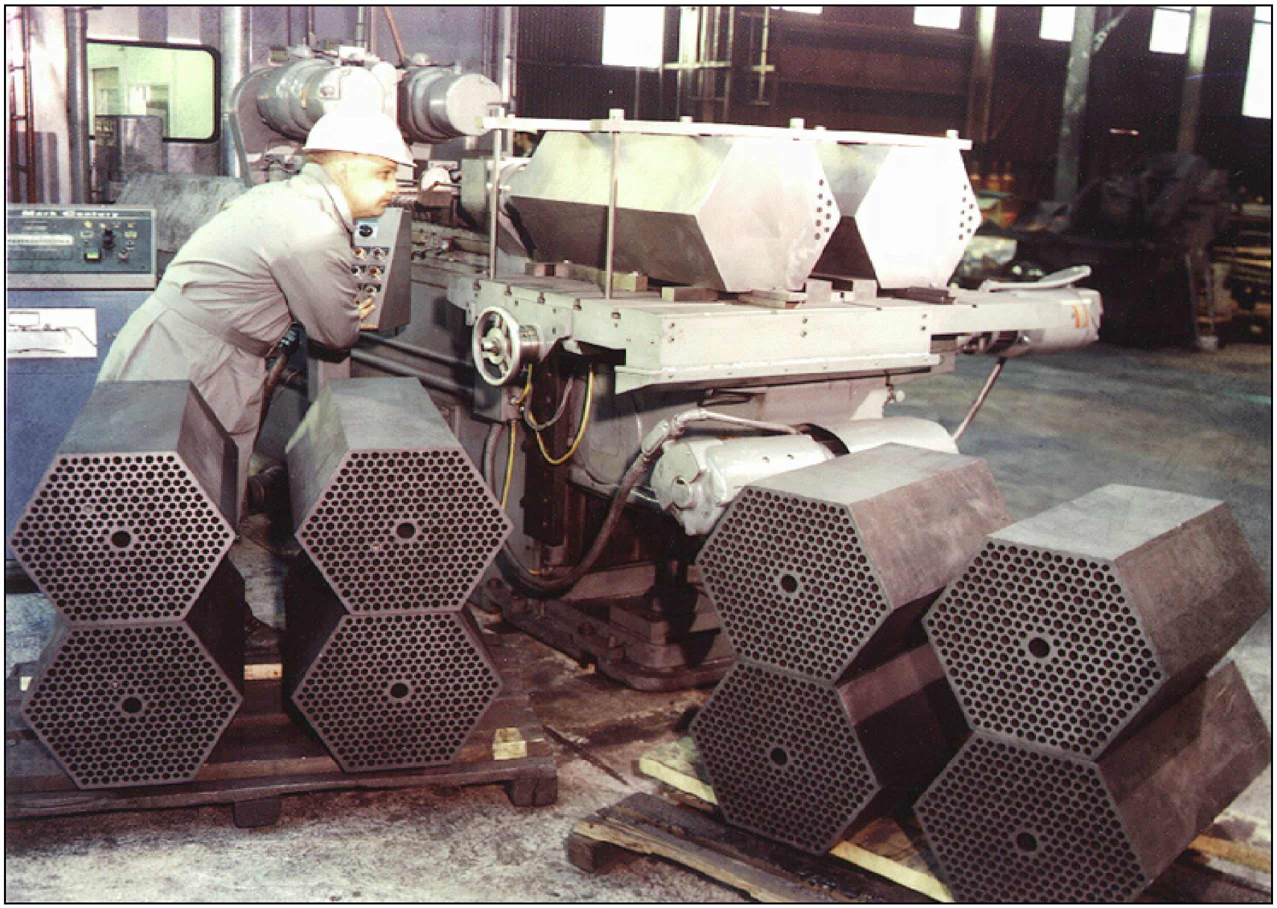
(Peak Operating Temperature: 1250ºC; Failure Temperature >1600ºC)



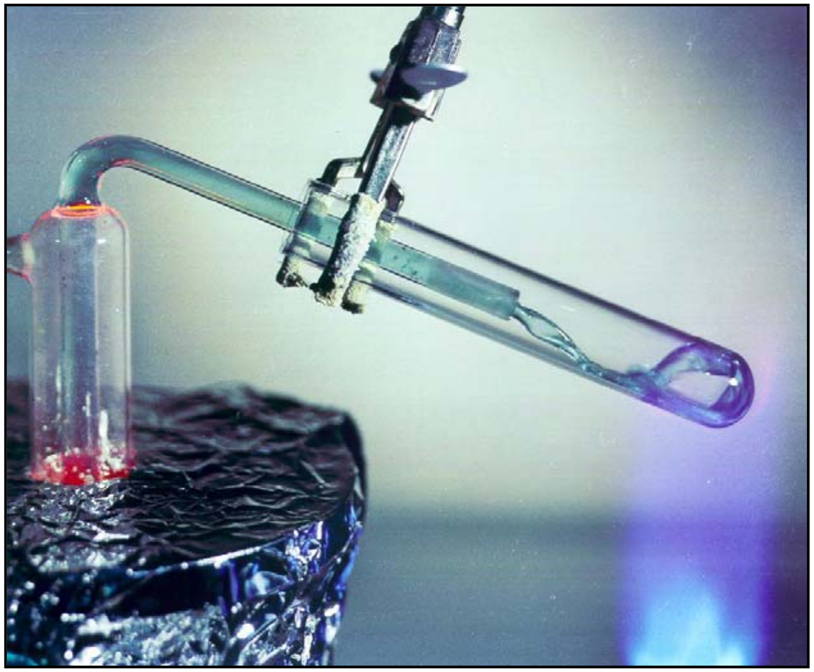
- **Fuel particle with multiple coatings to retain fission products**
- **Fuel compact contains particles**
- **Compacts inserted into graphite blocks**
- **Graphite block supports fuel compacts in arrangement compatible with nuclear reaction and heat transfer to**

The Fuel Was Originally Developed For Gas-Cooled Reactors

(Fuel Element Machining Development for Fort St Vrain Helium-Cooled Reactor)



Two Coolants Are Compatible With High-Temperature Graphite Fuels



Helium

(Traditional Reactor Coolant)

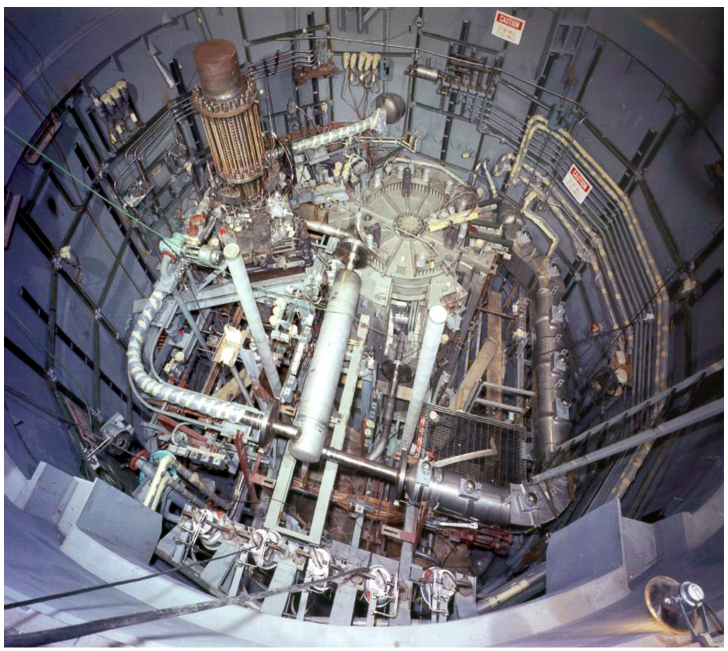
Molten Fluoride Salts

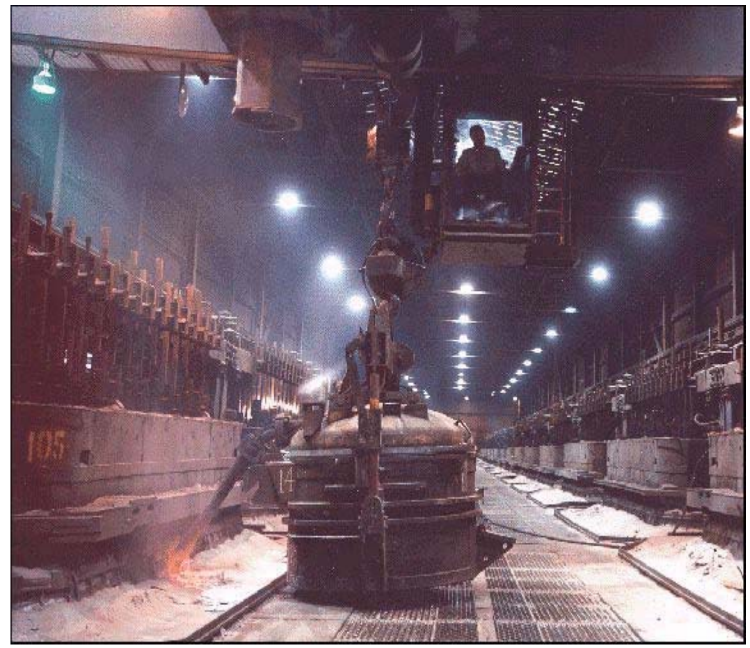
(AHTR)

The AHTR Uses A *Molten Salt Coolant*

Good Heat Transfer, Low Pressure Operation, In-Service Inspection, and Boiling Point ~1400ºC

Molten Fluoride Salts Used in Molten Salt Reactors (Fuel in Coolant)



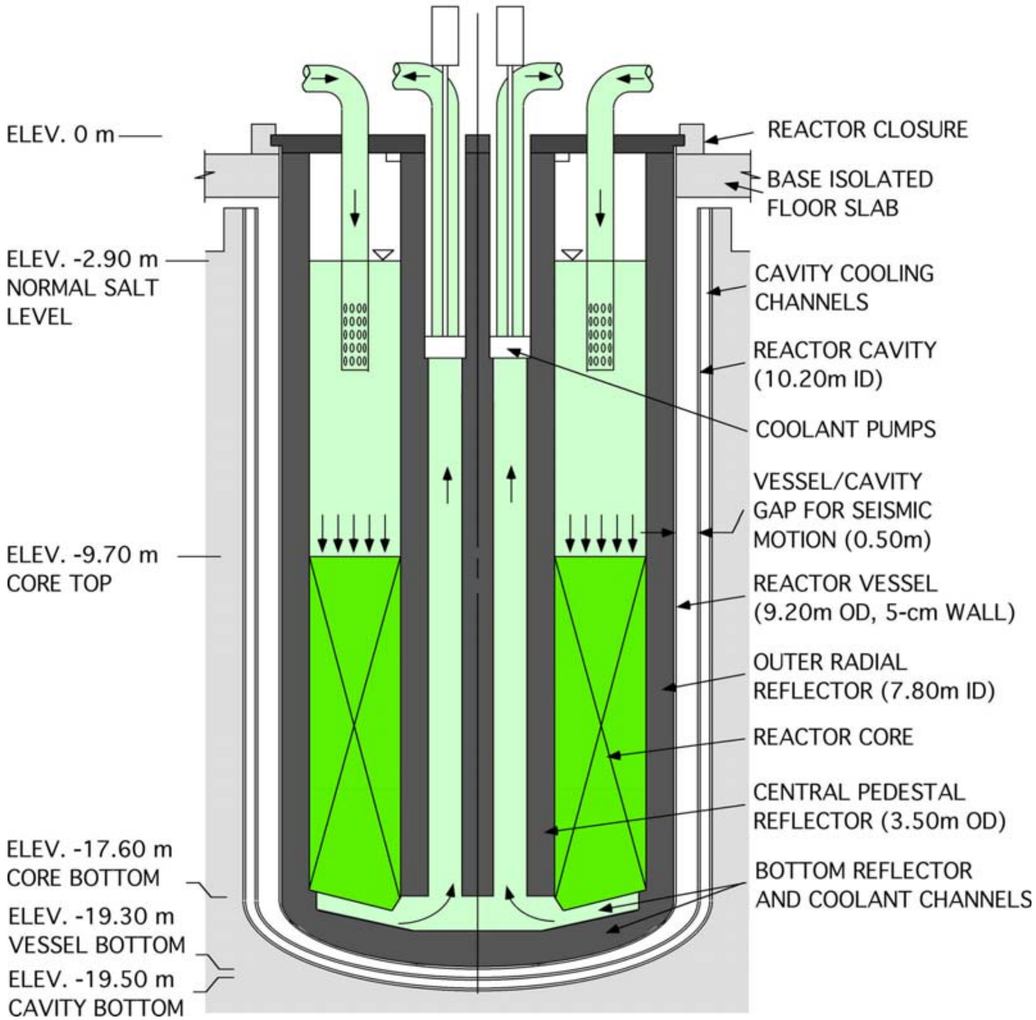


Molten Fluoride Salts Have Been Used For A Century To Make Aluminum

High-Temperature Reactors

Characteristic	*AHTR (New)*	*Helium Cooled*
Fuel	Coated Particle	Coated Particle
Neutronics	Epithermal	Epithermal
Safety System	Passive	Passive
Coolant	***Molten Salt***	***Helium***
Pressure	**Atmospheric**	**High Pressure**
Power Level	**2400 MW(t)**	**600 MW(t)**

Conceptual 2400 MW(t) AHTR Design



- **Transportable reactor vessel**
  - **Same size as S-PRISM 1000 MW(t) vessel**
  - **Similar size to 600 MW(t) GT-MHR reactor vessel**
- **Vessel in underground silo**
- **Vessel insulated from molten salt by graphite layer**

The AHTR Uses Passive Safety Systems

No Moving Parts
No Operator Actions

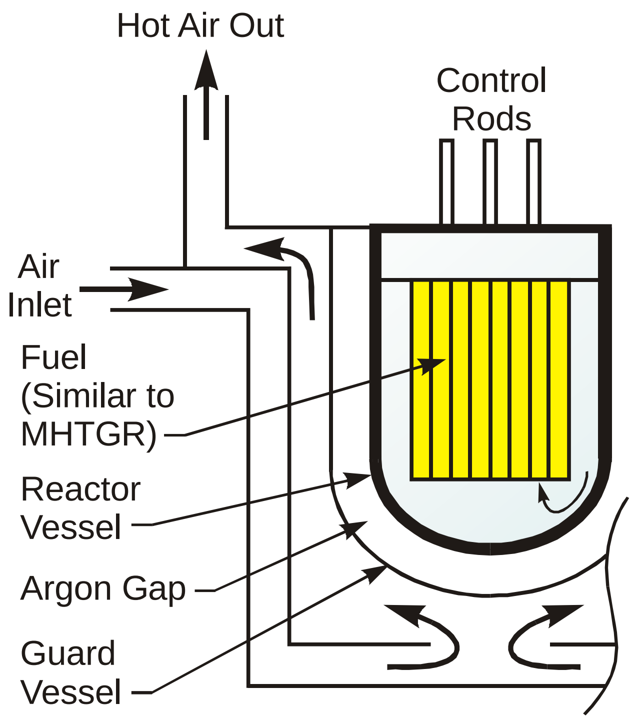
Improve Safety

Improve Economics

Improve Public Acceptance

In an Emergency, Decay Heat is Transferred to the Reactor Vessel and Then to the Environment

Passive Decay Heat Removal **Reactor**

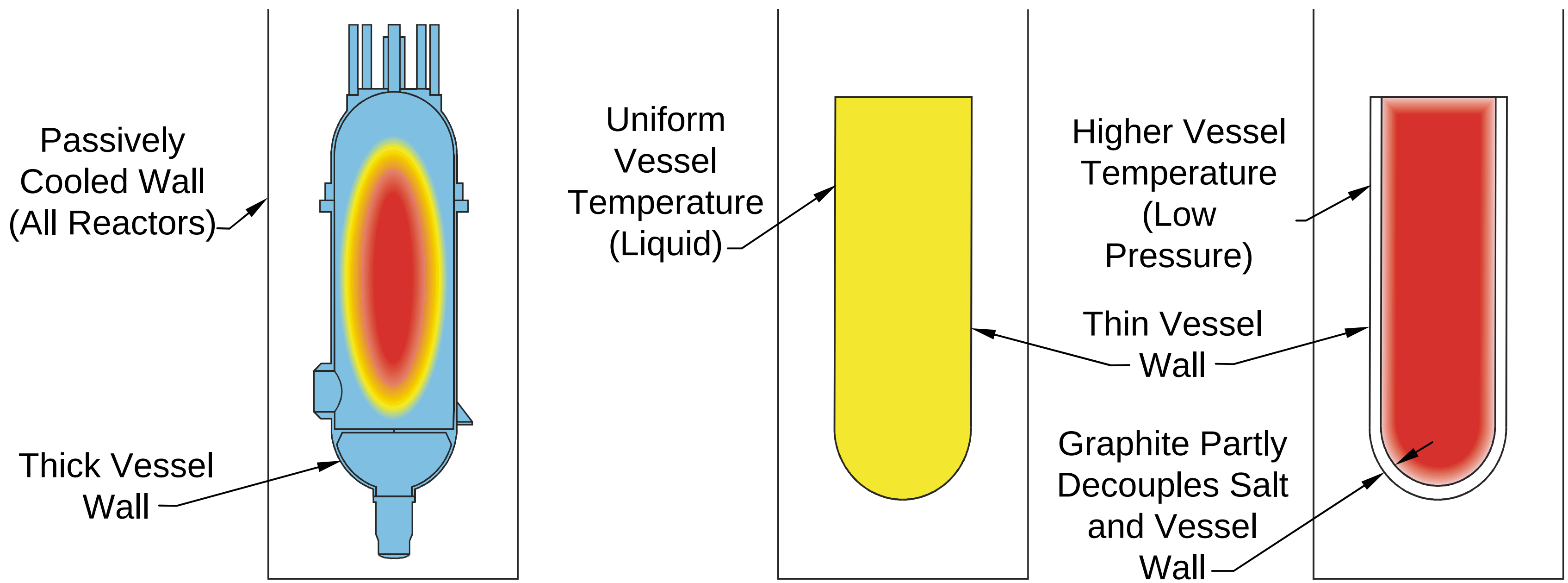


Decay-Heat Cooling System Characteristics

- Similar to GE S-PRISM (LMR)
- Argon Gap
  - Heat Transfer ~T^4
  - Thermal Switch Mechanism
- Heat Rejection: Temperature Dependent
  - LMR: 500-550°C [~1000 Mw(t)]
  - AHTR: 750-1000°C [>2000 Mw(t)]
- High Heat Capacity
  - Molten Salt and Graphite
  - High Temperature (Limited-Insulation of Vessel from Hot Salt)

High-Temperature Low-Pressure Liquid Coolants Enables Design Of Large Reactors With Passive Safety

Reactor	MHTGR	S-Prism	AHTR
Coolant	Helium	Sodium	Molten Salt
Power	600 MW(t)	1000 MW(t)	>2000 MW(t)
Limitation	Conduction	Sodium Boiling Point	Vessel

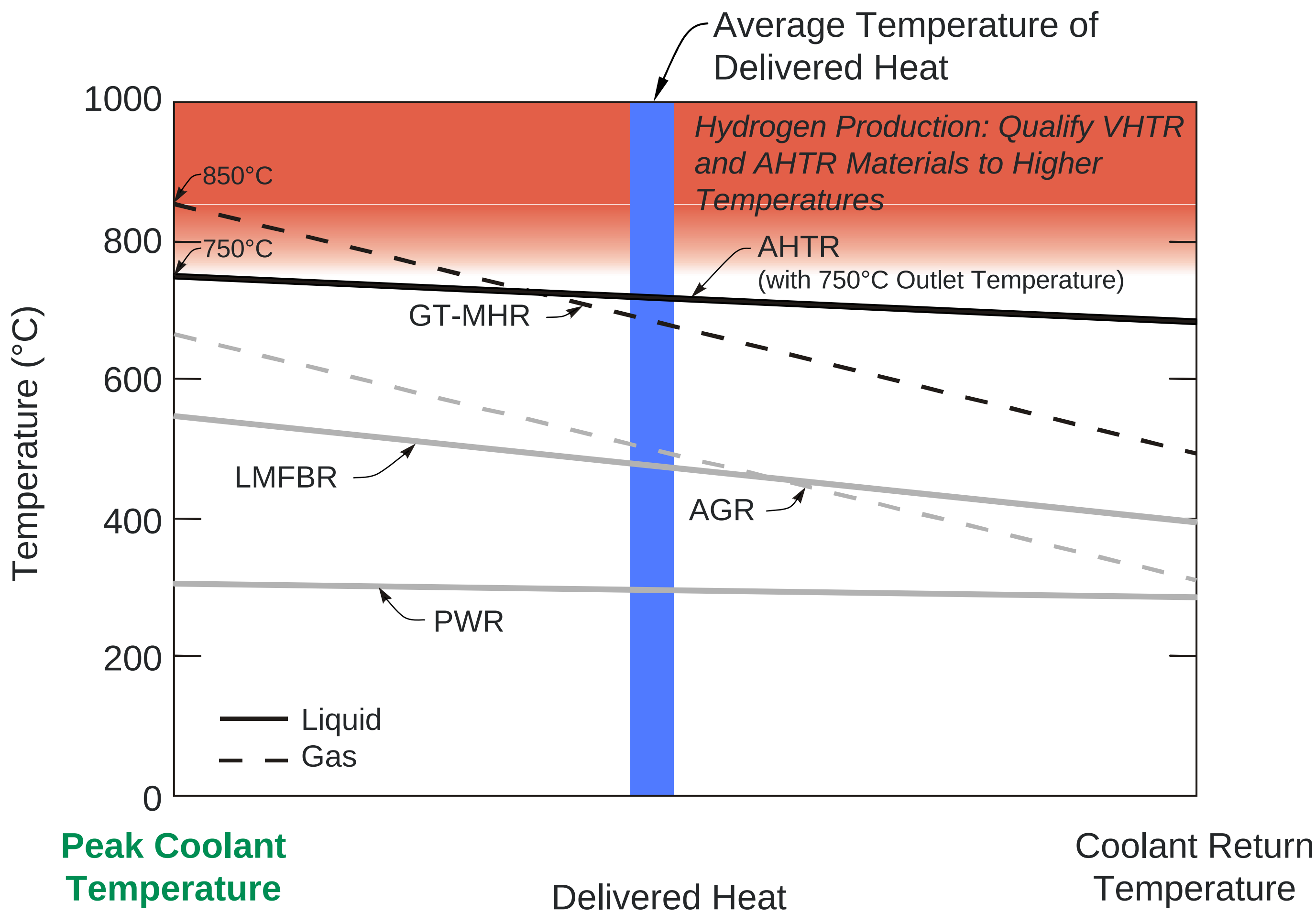


Energy Conversion

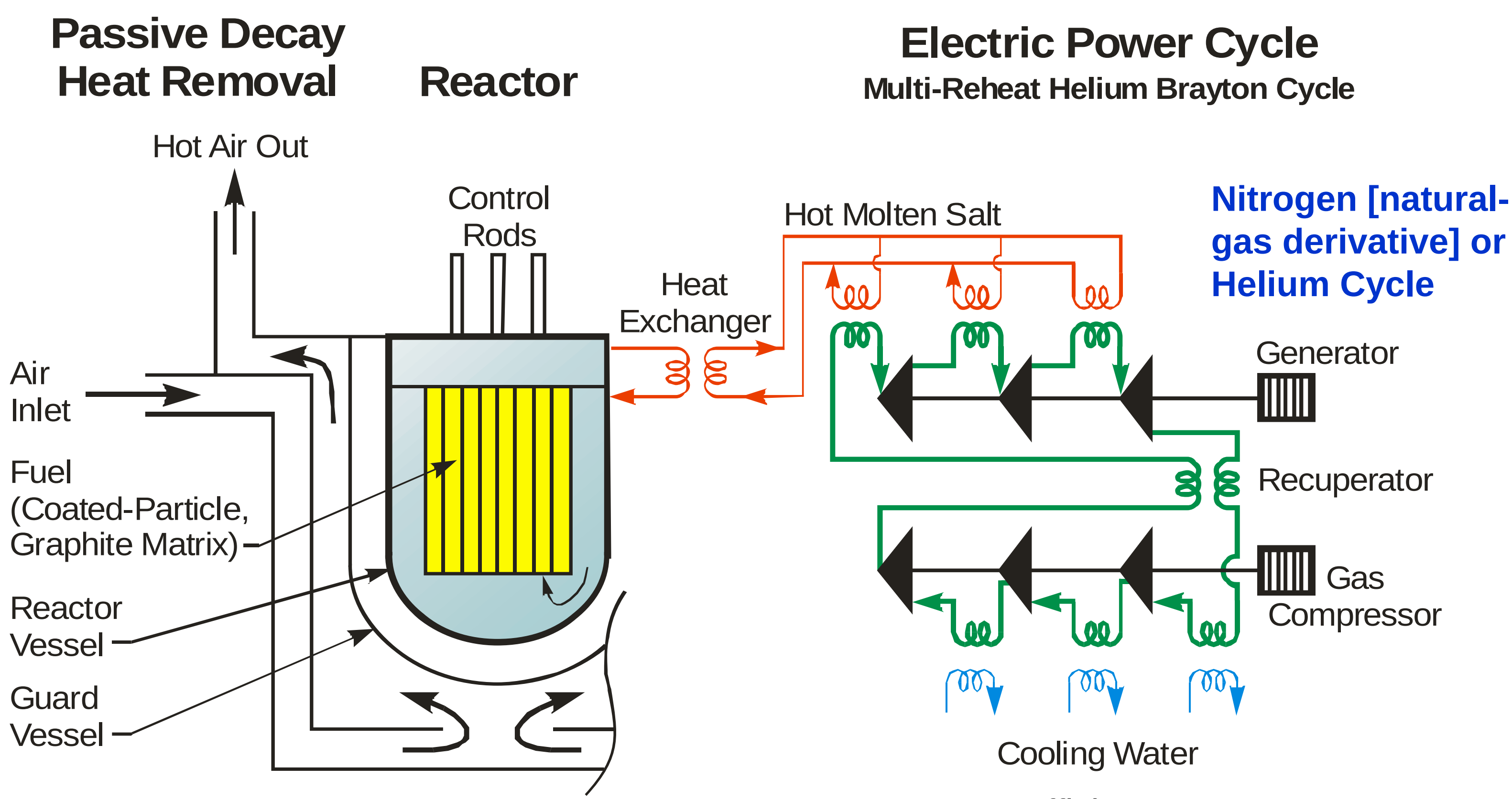
Electricity

Hydrogen

Liquid Coolants Are More Efficient Than Gas Coolants In Nuclear Reactors



A Multi-Reheat Brayton Cycle Is Used For Efficient Electricity Production

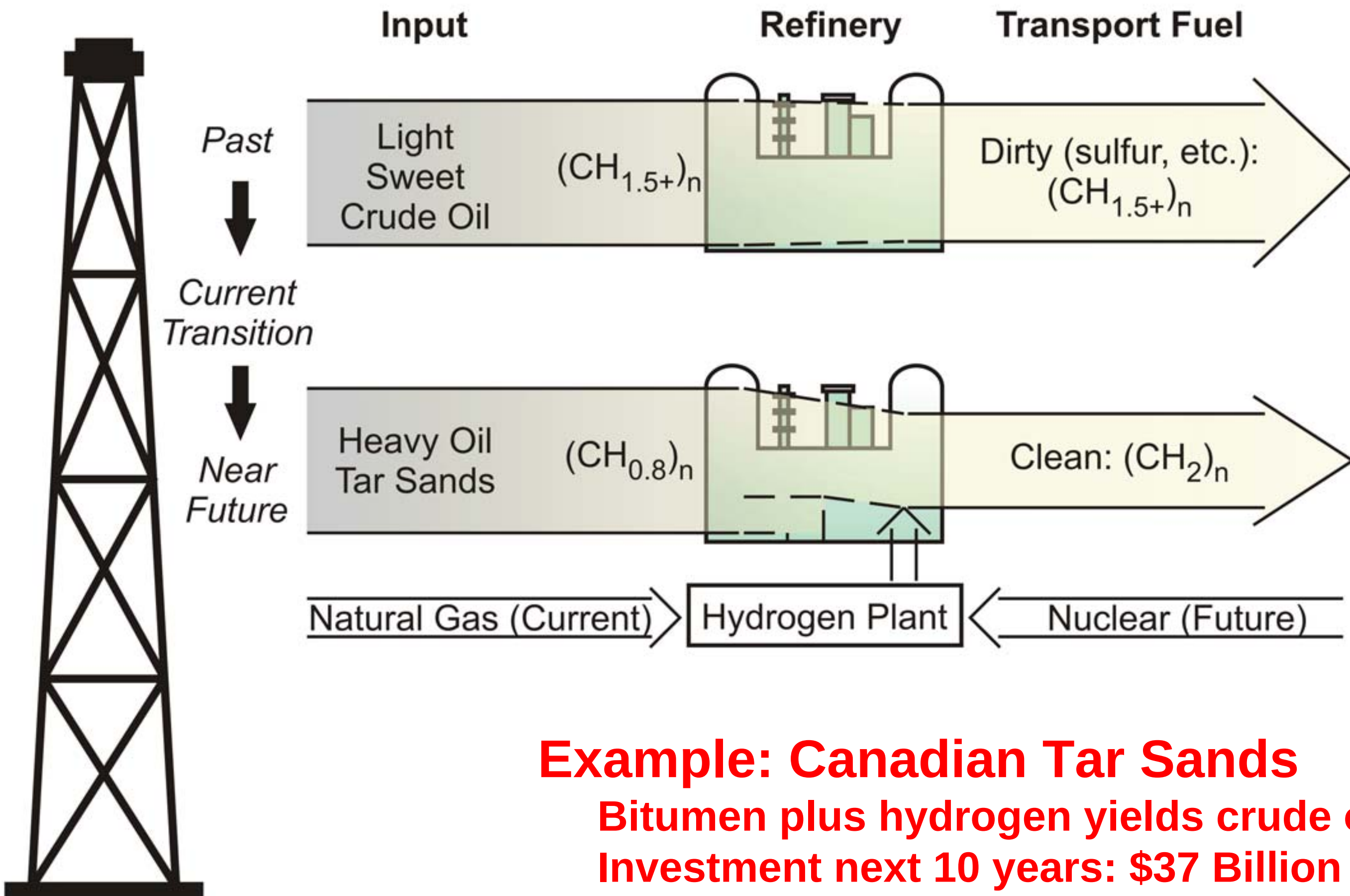


Efficiency
- 48% at 750° C
- 56% at 850° C
- 59% at 1000° C

Hydrogen Production

Massive Quantities of Hydrogen Are Used Today

Worldwide Production: 50 Million Tons/Year



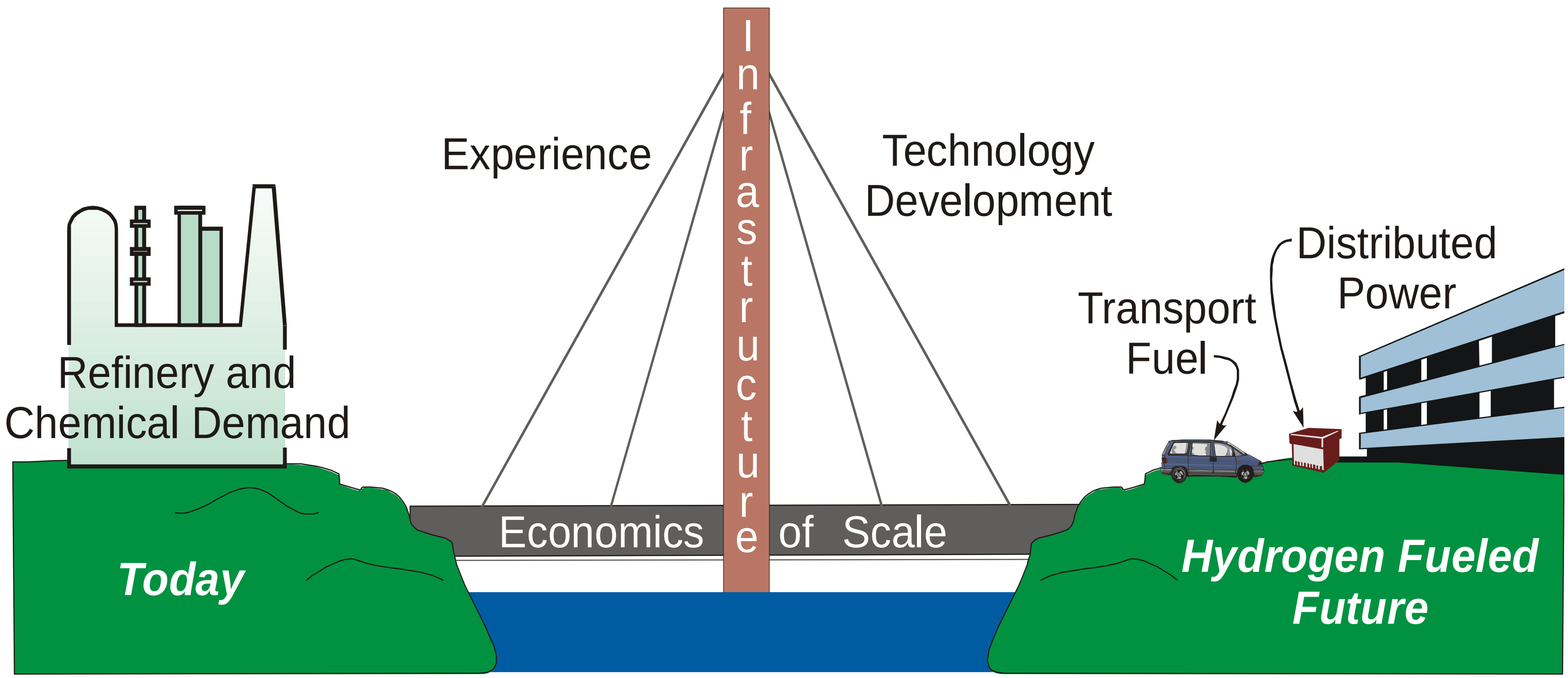
Example: Canadian Tar Sands

Bitumen plus hydrogen yields crude oil

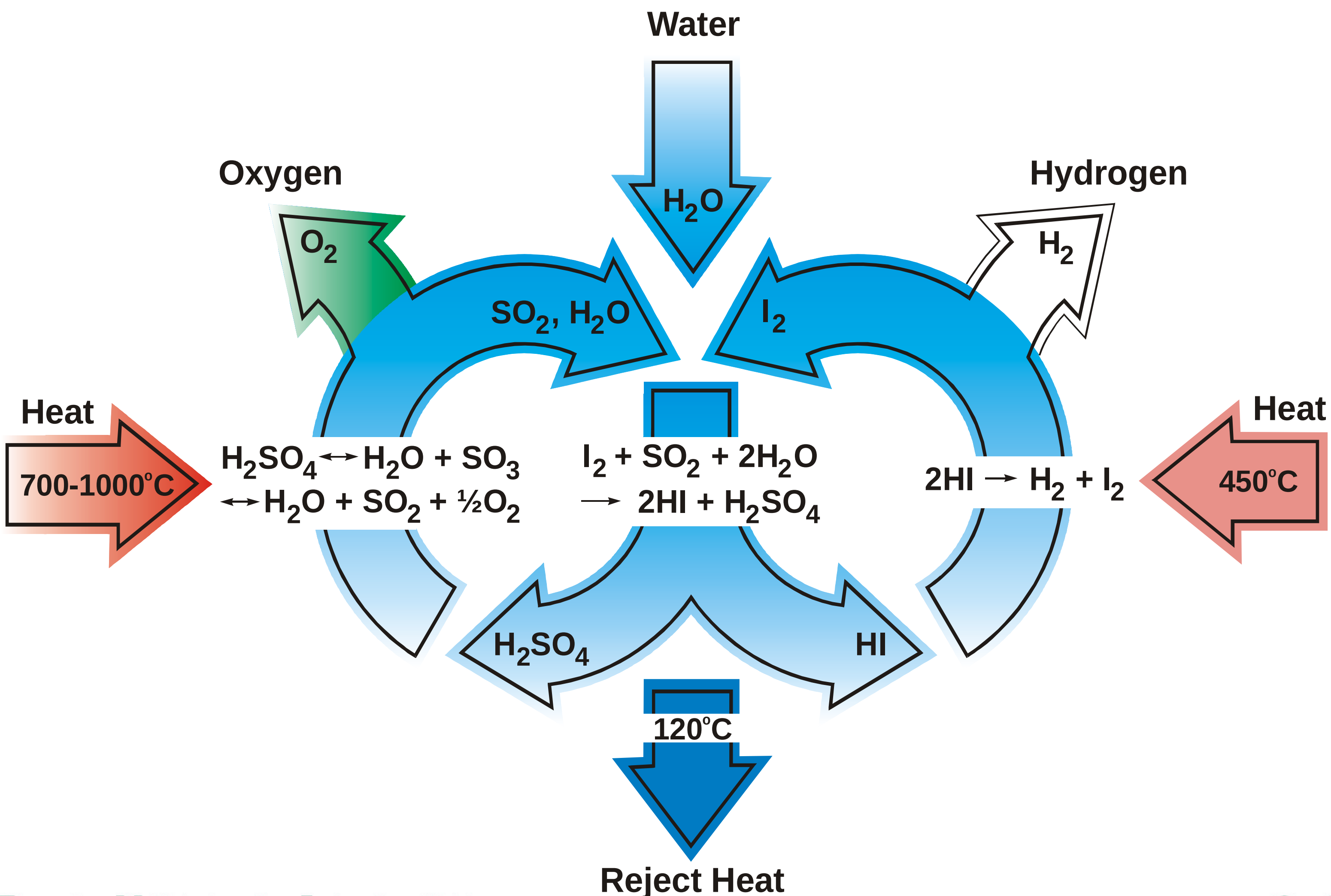
Investment next 10 years: $37 Billion

Oil and Gas Journal: July 28, 2003

The Growing Hydrogen Demand Creates a Bridge to the Hydrogen Economy



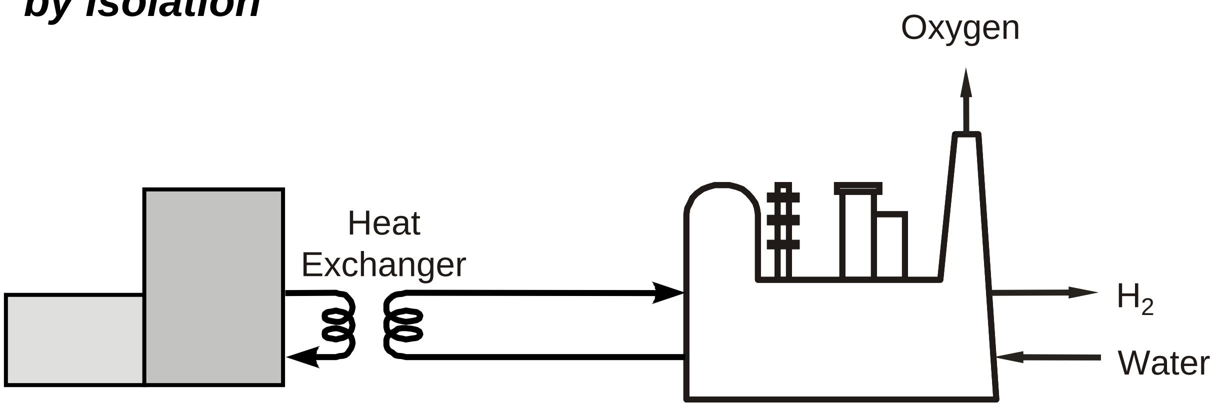
Hydrogen Production Requires High Temperatures
(Example: Hydrogen Production Using the Sulfur Iodine Process)



AHTR Matches Thermochemical Hydrogen Production Heat-Transfer Requirements

Nuclear Safety by Isolation

Hydrogen Safety by Dilution



Loop Heat Transfer Comparison [50 MW(t)]

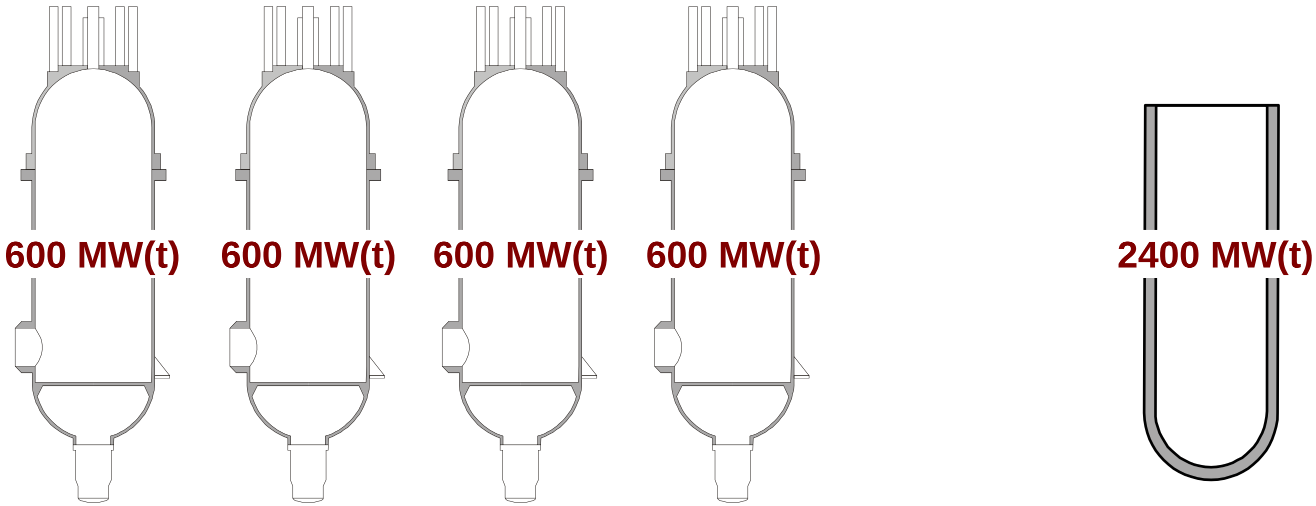
Characteristic	Salt	Helium
Pressure (bar)	1	70
Velocity (m/s)	4	40
Temperature Drop (°C)	200	200
Pipe Diameter (m)	0.25	1.2
Relative Pumping Power	1	45

ECONOMICS
– The Critical Issue –

Larger Reactors Have the Potential for Lower Capital and Operating Costs

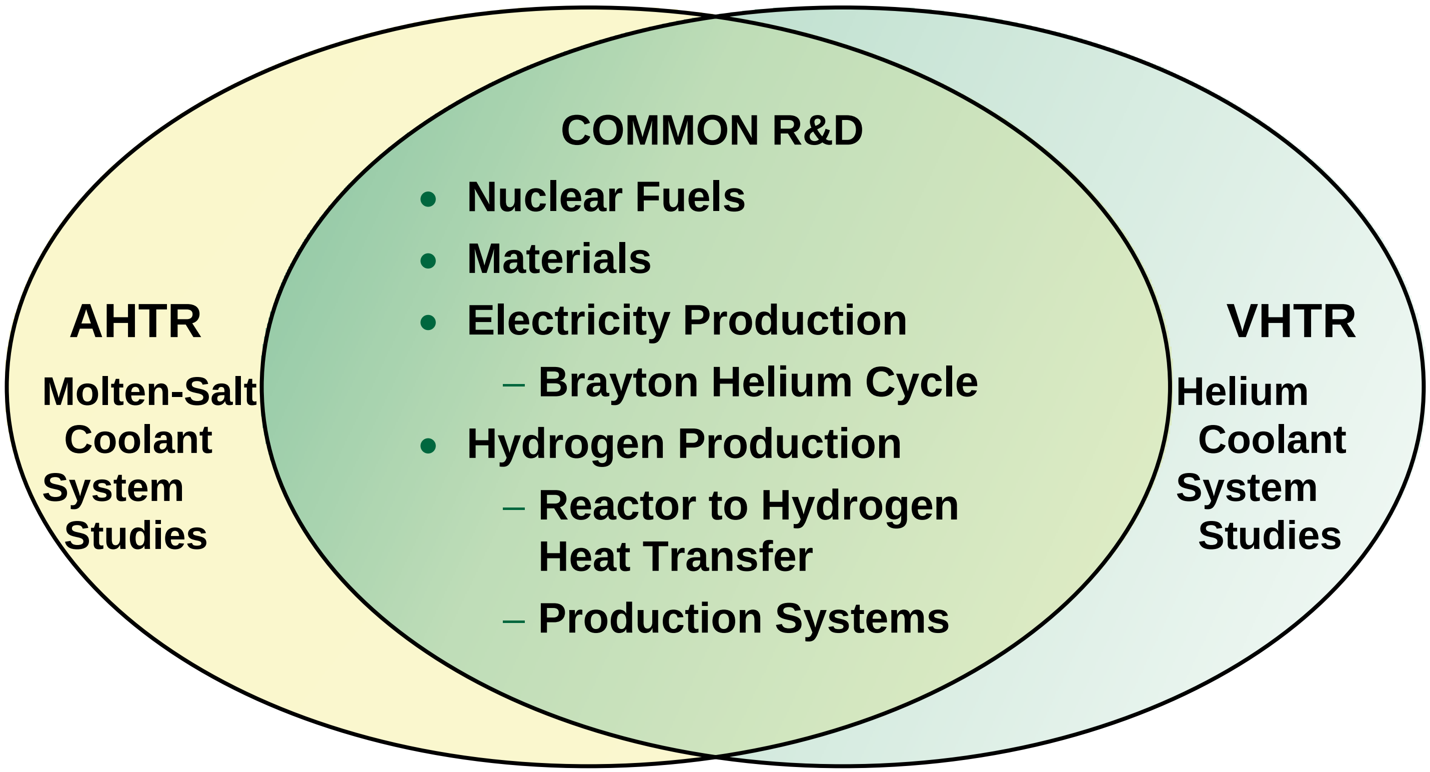
AHTR Capital Cost Per MW(t) Are Expected To Be Less Than Modular High-Temperature Reactors

Pressure Vessels For 2400 MW(t) of MHTGR | *Low-Pressure Vessel For 2400 MW(t) of AHTR*



Simple scaling laws estimate AHTR per kilowatt capital costs at 60% of a Modular High Temperature Gas-Cooled Reactor

The R&D Requirements for the Molten-Salt-Cooled AHTR and Helium-Cooled VHTR Have Much In Common



Conclusions

- The AHTR is a new reactor concept based on combining existing technologies
- The unique feature of the AHTR is that it combines three characteristics into a single reactor
  - High temperature
    - Required for hydrogen production
    - Efficient electricity production
  - Passive safety (public acceptance and economics)
  - Large size (economics)
- Development has just begun

BACKUP

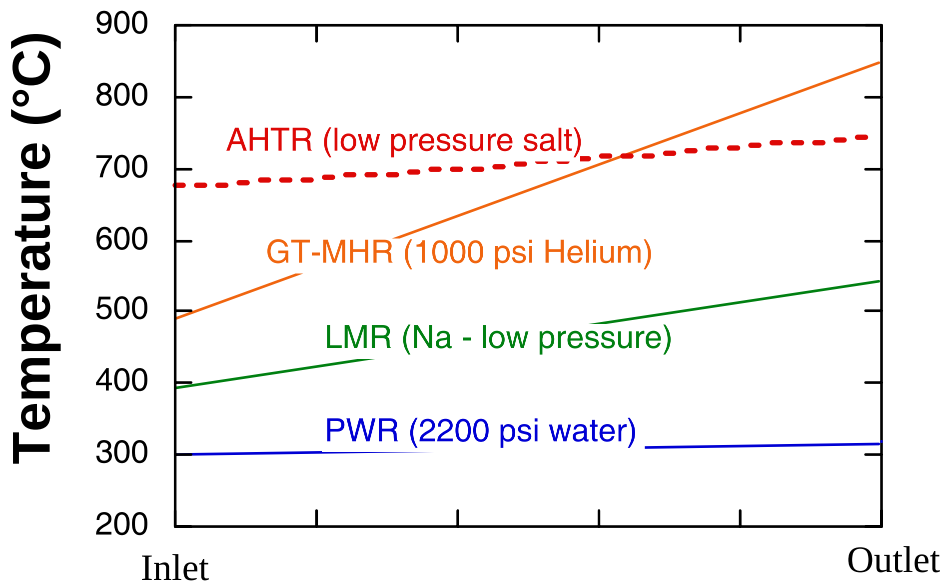
Potential for Better Economics Than Light-Water Reactors (Same Size Reactor)

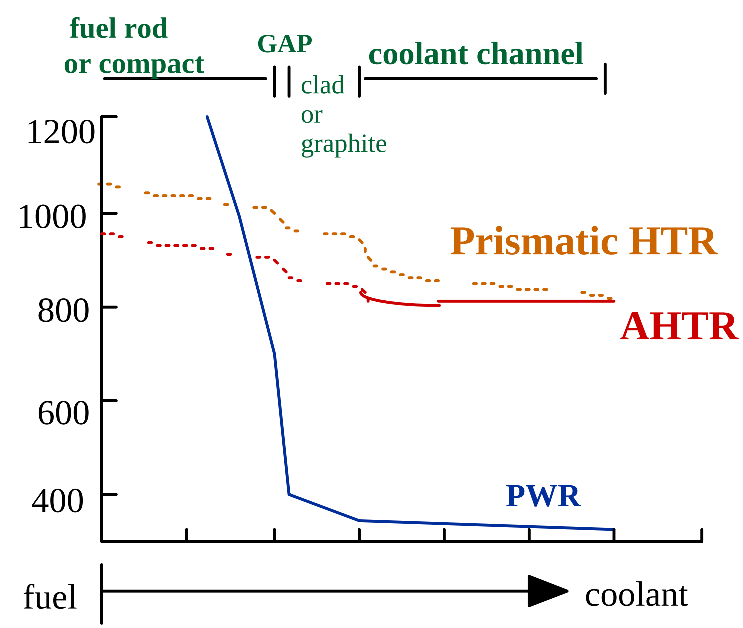
- **Potential economic advantages of AHTR**
  - **Higher thermal-electric efficiency (50% versus 33%)**
    - Fuel savings
    - Smaller secondary systems
  - **Brayton helium cycle (Smaller than steam turbine)**
  - **Low pressure containment**
- **But no definitive economic comparison**
  - **LWR technology is significantly different; thus, simple scaling comparisons can not be made**

Development Challenges/Issues

- Very-high temperature materials
- Molten salt selection/handling/transients
- Safety system design (controls ultimate reactor size and thus economics)
- Integration of multiple technologies
- Plant design
- Choice of demonstration plant size
  - What size is required to demonstrate key technologies?

Liquid-Coolants Deliver and Remove Heat More Effectively Than Gas Coolants





Coolant temperature drops are smaller, cycle efficiency is proportional to average coolant temperature.

Fuel and cladding can be kept cooler with liquid coolants. Passive cooling is more effective.

END