Advanced and Small Modular Reactors

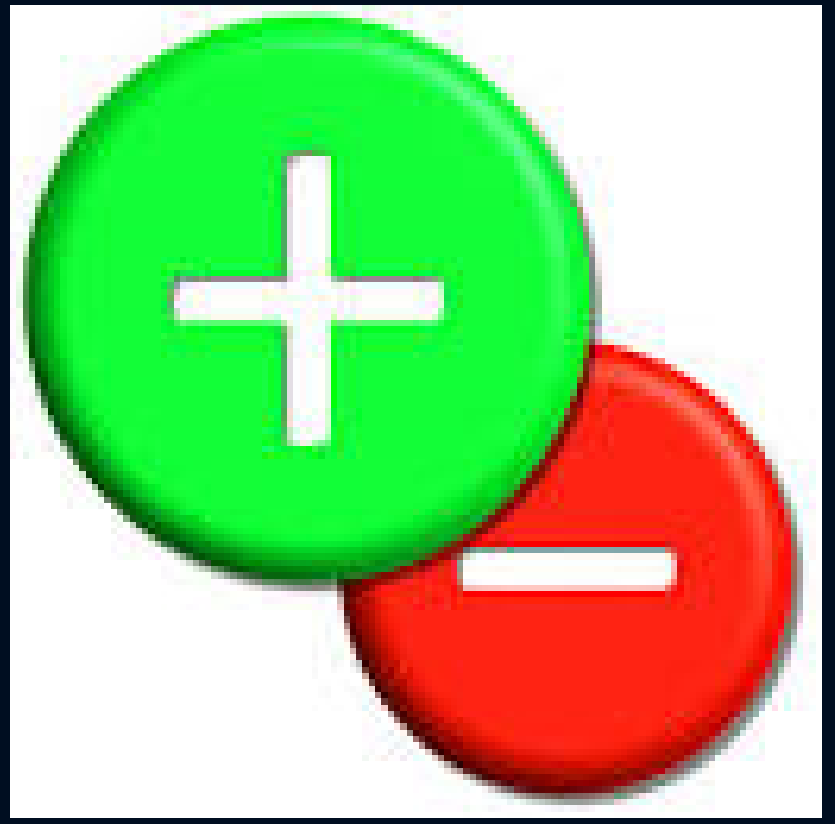
Steve Sheetz
Citizens for Nuclear Technology Awareness
Board of Directors, Chair
sheetz.energy@gmail.com

What Are They?

- Small Modular Reactors (SMRs)
  - **Small** – fraction of power of traditional reactors: 300 megawatts or less
  - **Modular** - factory built and truck or train transportable
  - **Reactor** – nuclear fission to make heat/electricity
  - Includes "Micro Reactors" – Less than 10MWe
- Advanced Reactor Technologies
  - Advanced water-cooled
  - Non-water-cooled (gases, liquid metal, molten salts)
  - Fusion Reactors
  - Most will be SMRs

Pro's and Con's of SMRs

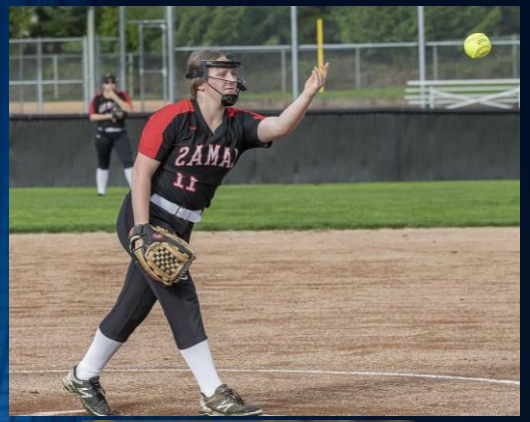
- Pluses:
  - Factory build nuclear cores of a single design
  - Truck or rail major components
  - Employ modular construction techniques
  - Lower capital costs
  - Many are simpler using natural circulation
  - Place on old coal power plant locations
- Minuses:
  - Reduced "Economy of Scale"
  - Slightly less efficient use of fuel – "Neutron Leakage"

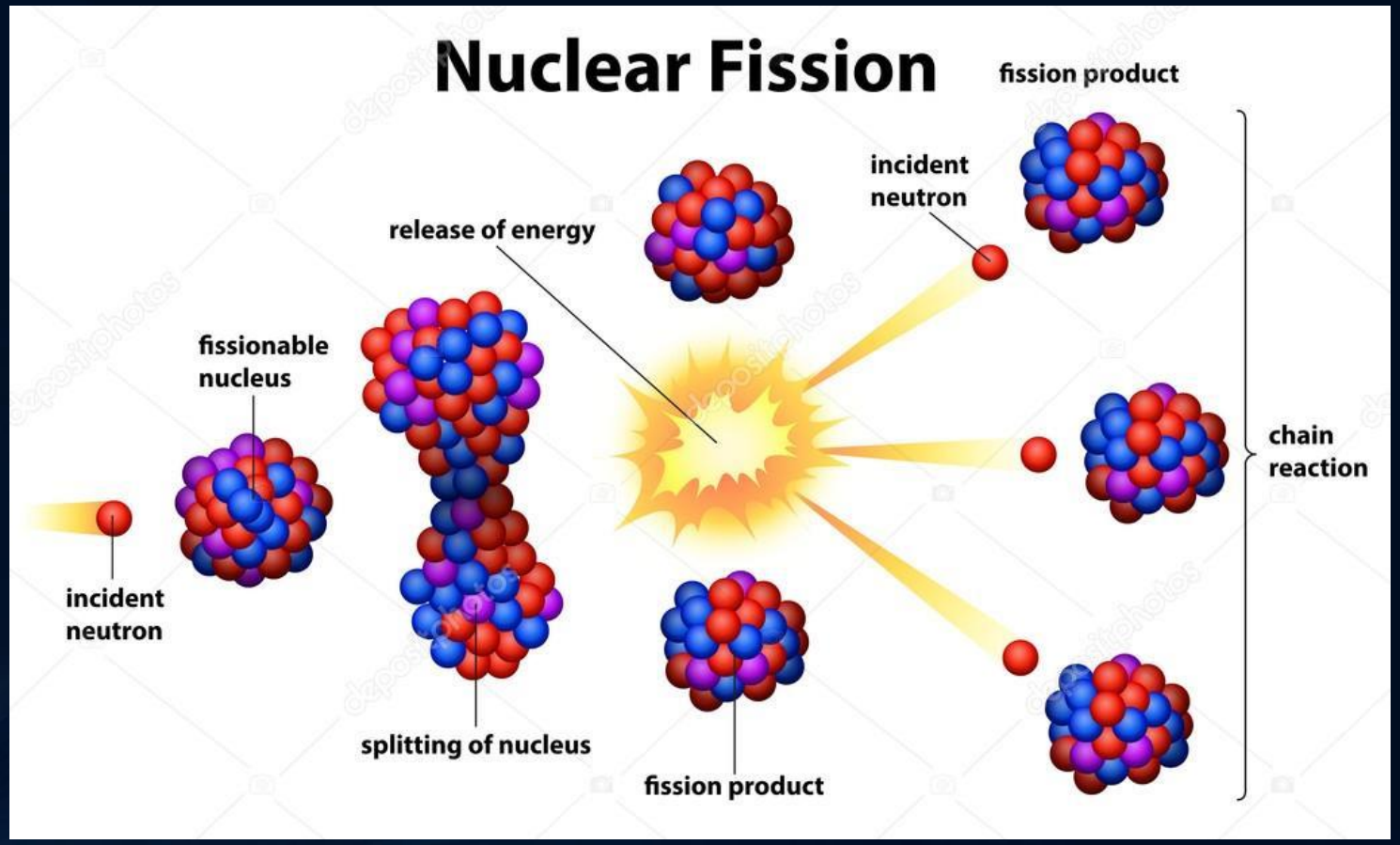


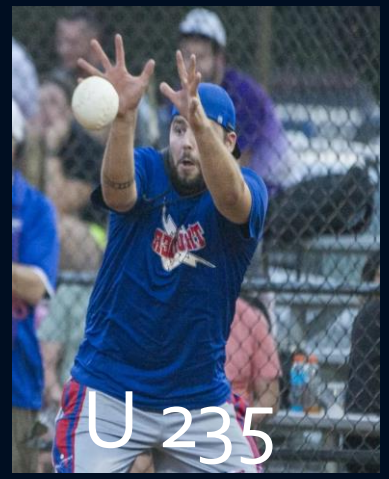
What is Uranium?

- Make up of uranium
  - ~99% U-238
  - ~.72% U-235
- Enriched uranium
  - Low Enriched (LEU) .72-5% U-235 - traditional fuel
  - High Assay-LEU (HALEU) 5-20% U-235 – advanced fuel
  - High Enriched Uranium (HEU) >20% - defense use
- Fissile versus Fertile
  - Odd numbers fission easily (U-235, U-233, Pu-239)
  - Even number like U-238 can be bumped to Pu-239

How to split an atom – Thermal versus Fast







Thermal Power Plant

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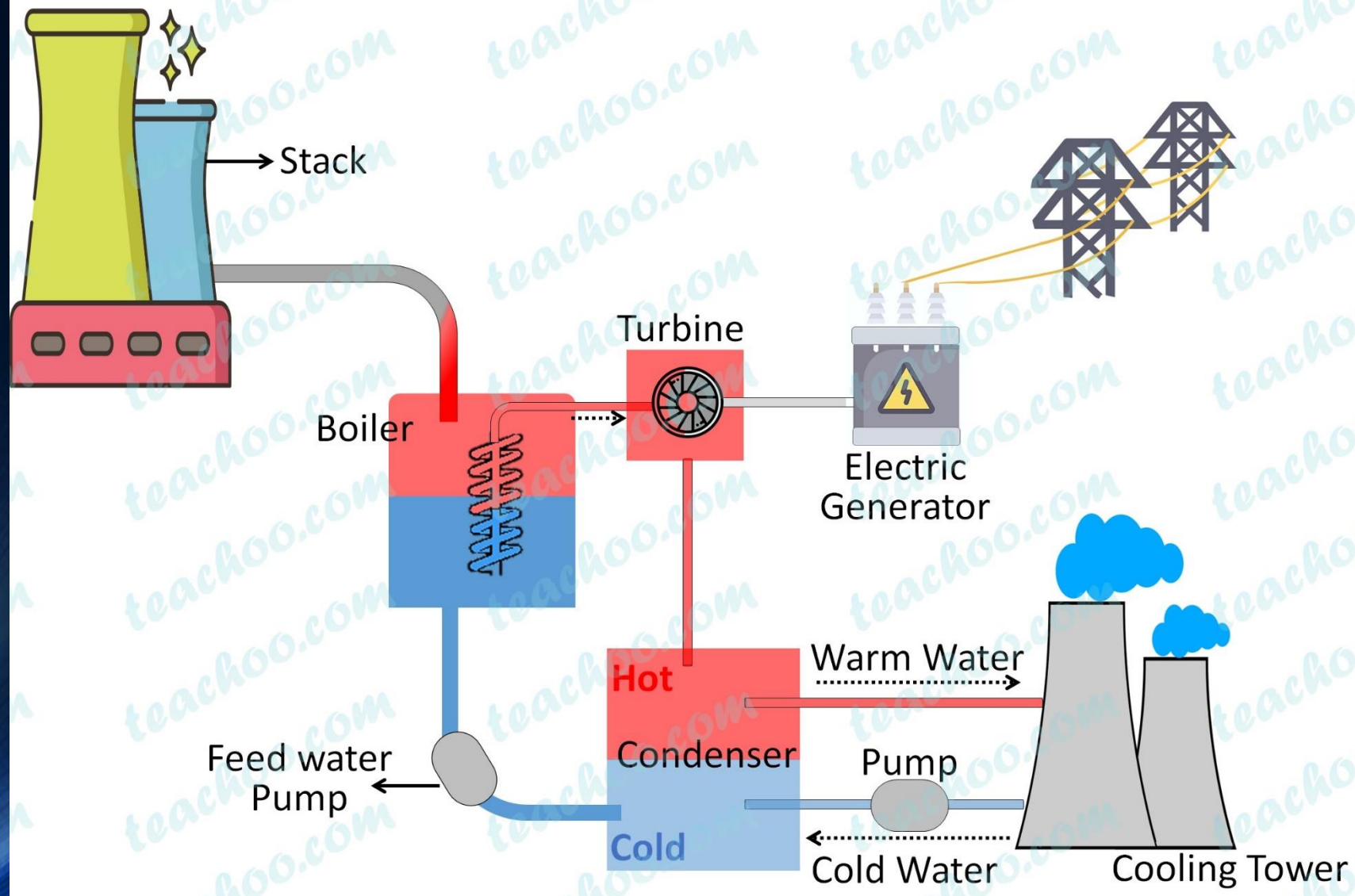
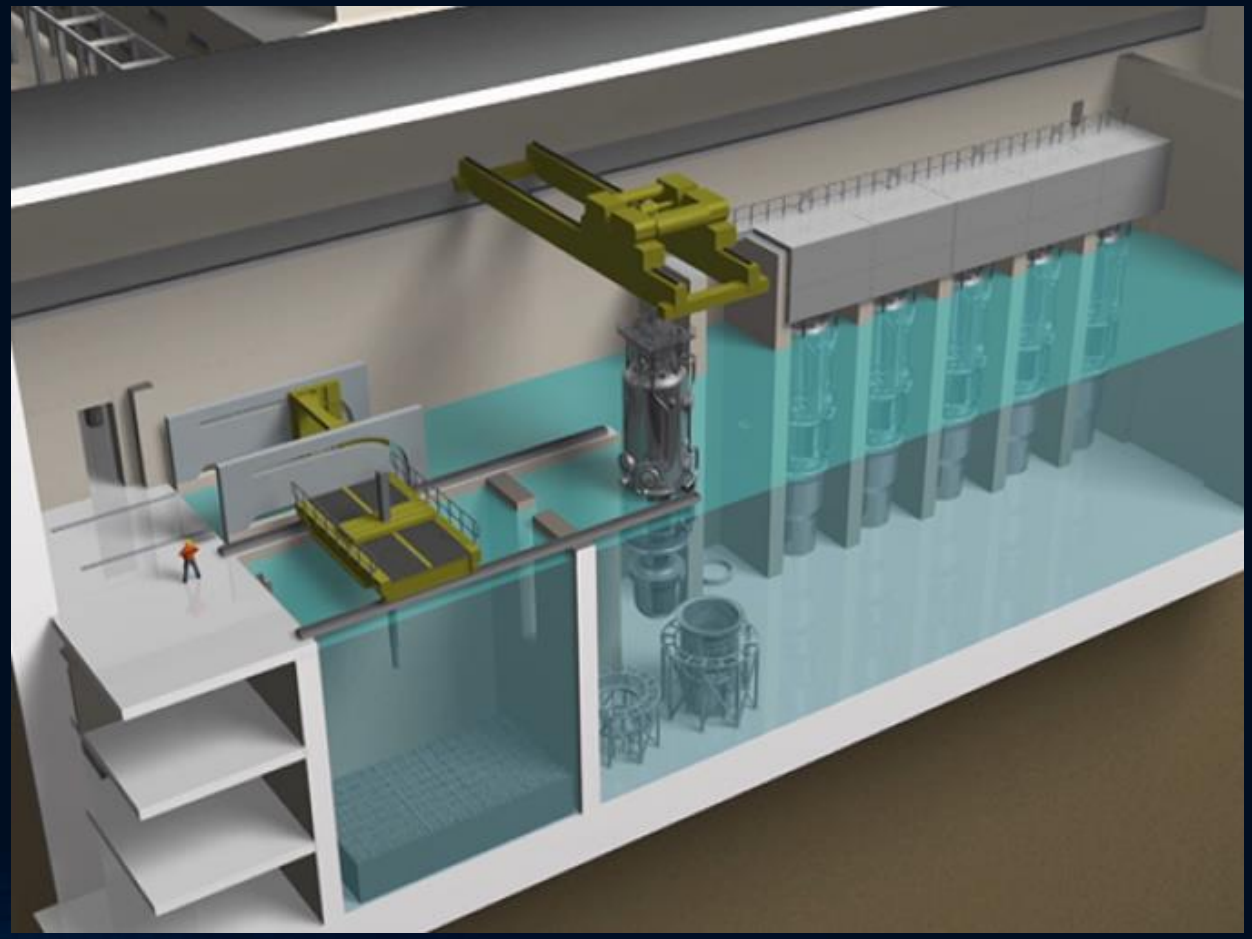


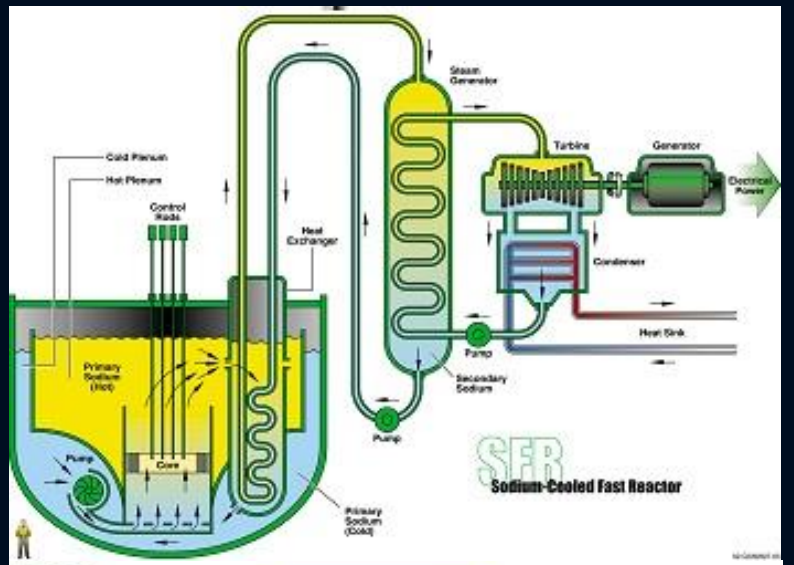
LWR – NuScale Power

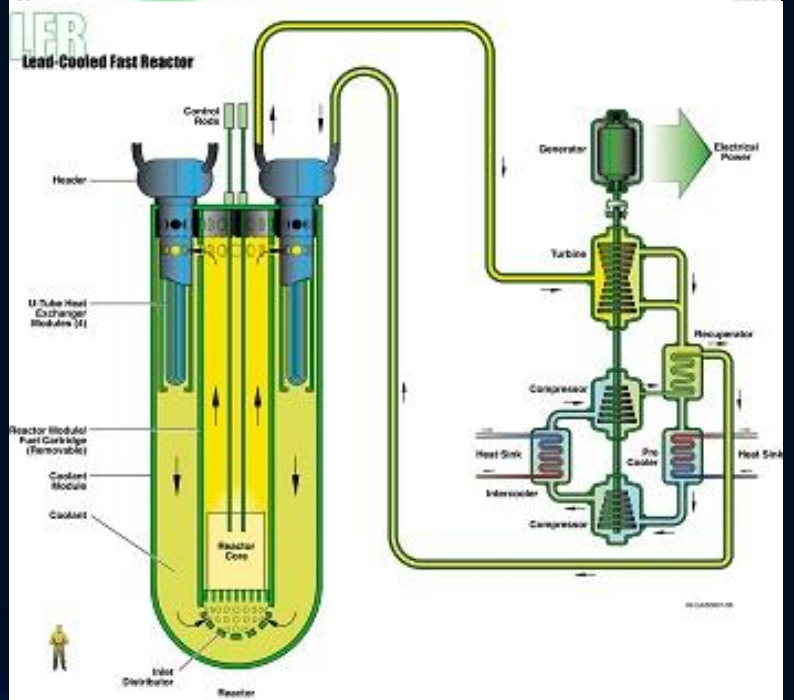
- Light water reactor – natural convection
- Each module is a 60 MW reactor
- 6 or 12 in a large pool
- Taken off-line one at time for refueling
- Pool provides large thermal heatsink for safety
- NRC certified
- First plant – INL or Bulgaria
- Other small LWR designs
  - Holtec
  - Westinghouse
  - GE Hitatchi



Metal Cooled Reactors

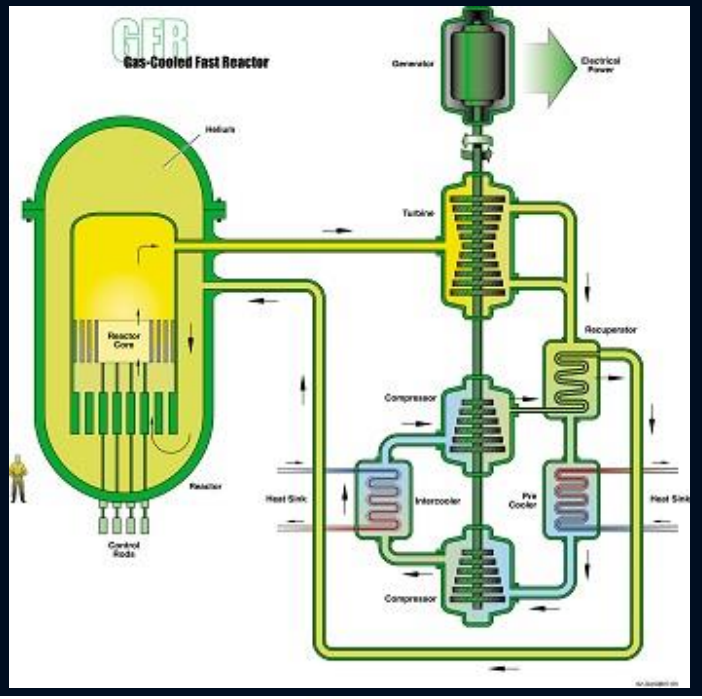
- Use liquid metal as coolant
- Excellent heat transfer and high energy density
- Low pressure & passive cooling
- High temperature for power and industrial use
- Sodium Fast Reactor
  - +Well understood
  - +Minimal corrosion to reactor components
  - -Highly reactive with air and water
  - Oklo, GE-H, TerraPower
- Lead Fast Reactor
  - +Excellent neutron transparency and radiation shielding properties
  - -High melting temp make refueling/service problematic
  - Westinghouse plus other foreign companies

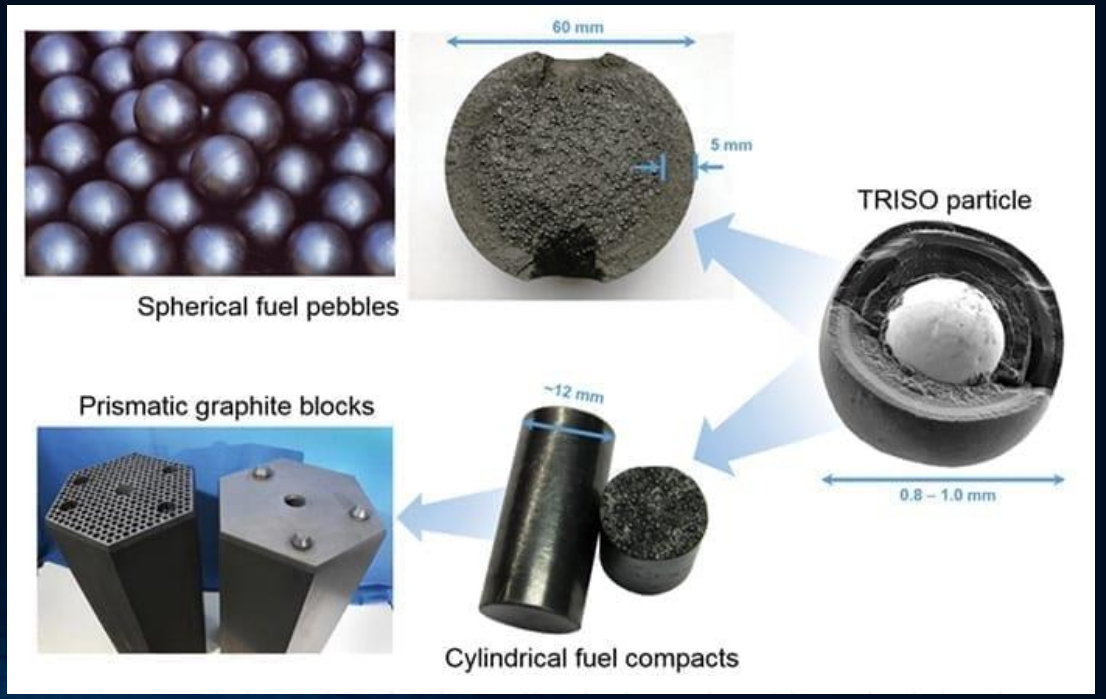




Gas Cooled Reactors

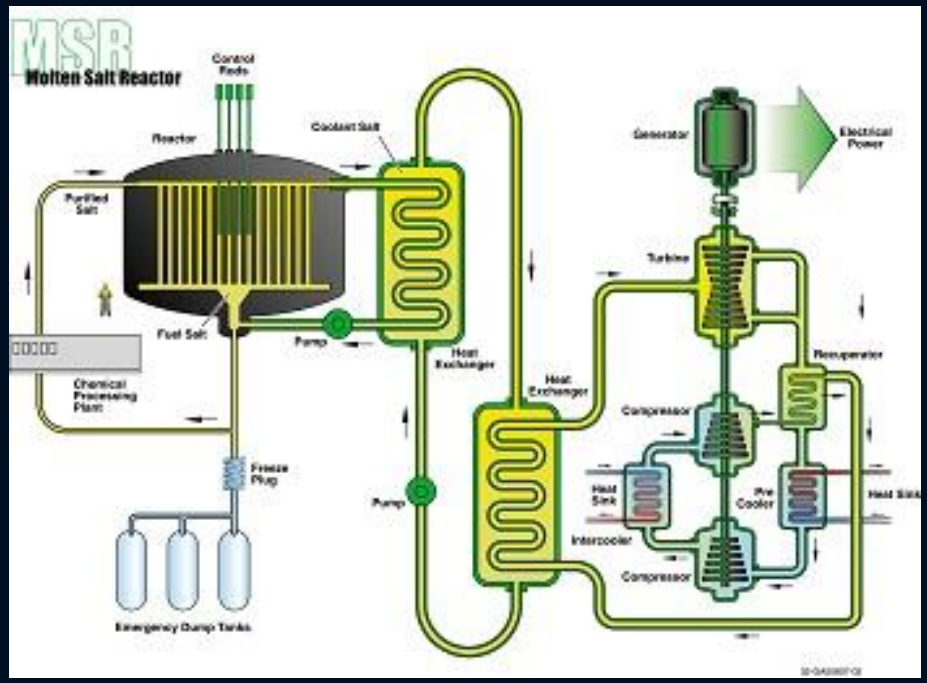
- Helium Gas Cooled
- TRISO fuel particles in graphite
  - Robust 1mm particles
  - Blocks or Pebbles
- High temperature and pressure
  - Higher fuel efficiency
  - Possible industrial purposes
- High Temperature Gas Reactor
  - Thermal needs graphite moderator
  - Fort Saint Vrain, CO 330 MWe
  - X-Energy farthest along
- Gas Fast Reactor
  - Fast neutrons with closed fuel cycle
  - General Atomics





Molten Salt Reactors

- Low pressure, high temperature
- Two types:
  - Molten flouride salts cool the thermal reactor
    - Use graphite fuels – block or pebbles: Kairos
  - Molten salt "fueled" fast reactor
    - Fissile/fertile fuel is dissolved into the salt
    - Fresh uranium or recycled materials
    - Waste burner
    - 1960's at ORNL
    - Several conducting R&D
    - GE-H, Oklo, TerraPower



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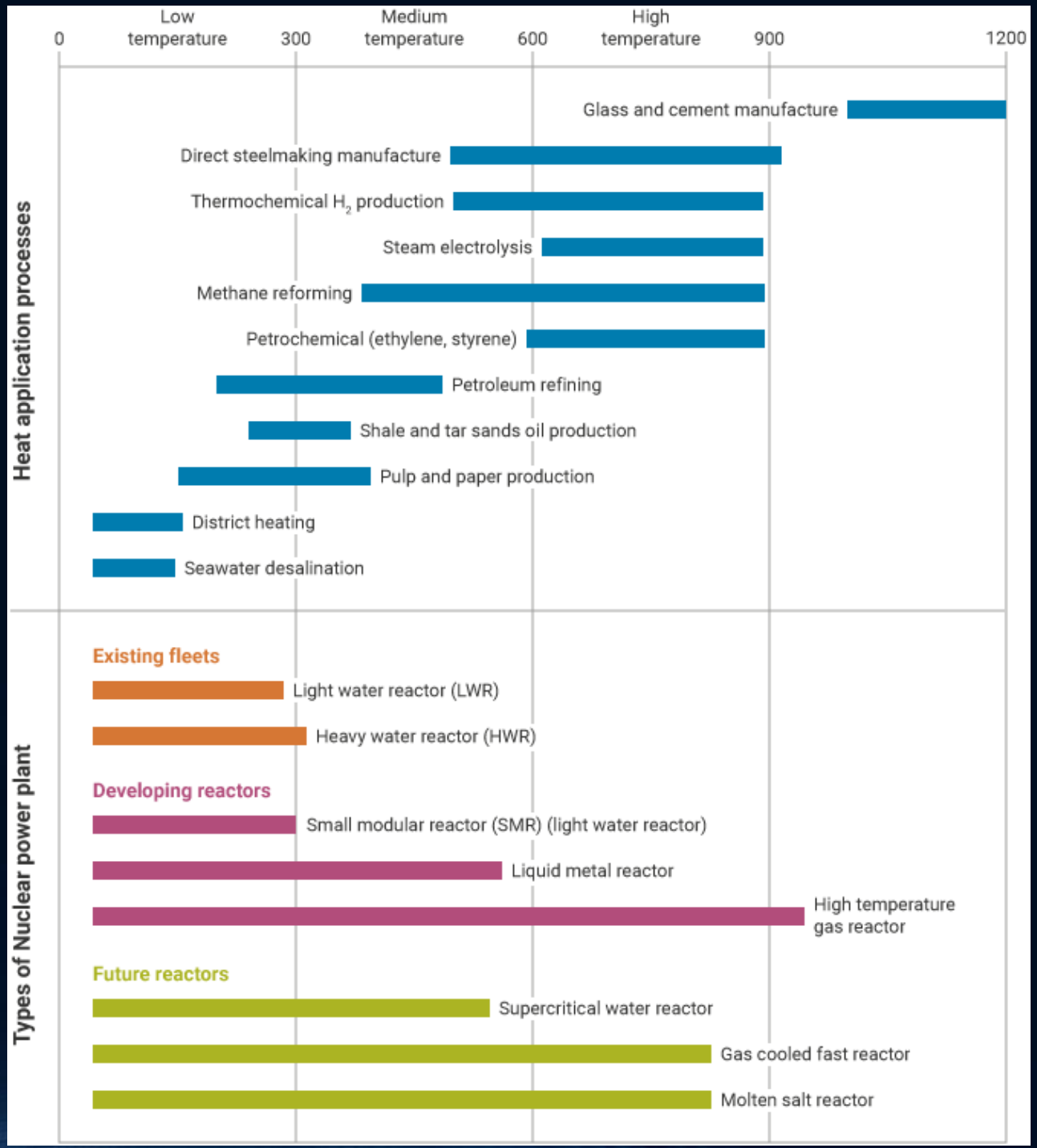
Other than electricity....



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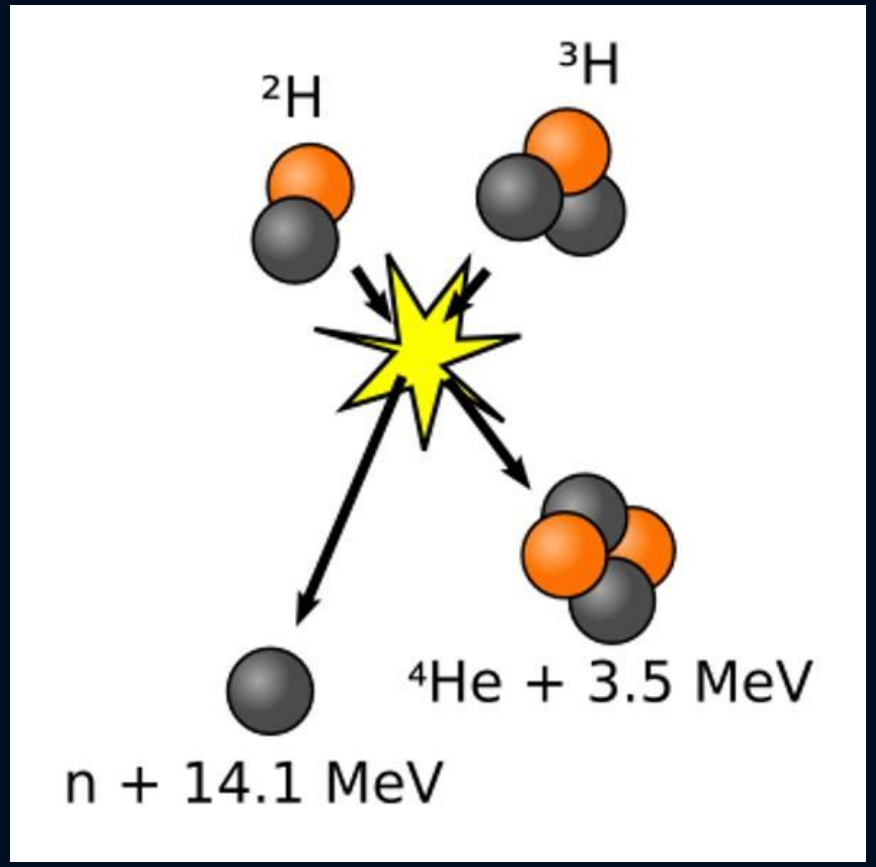
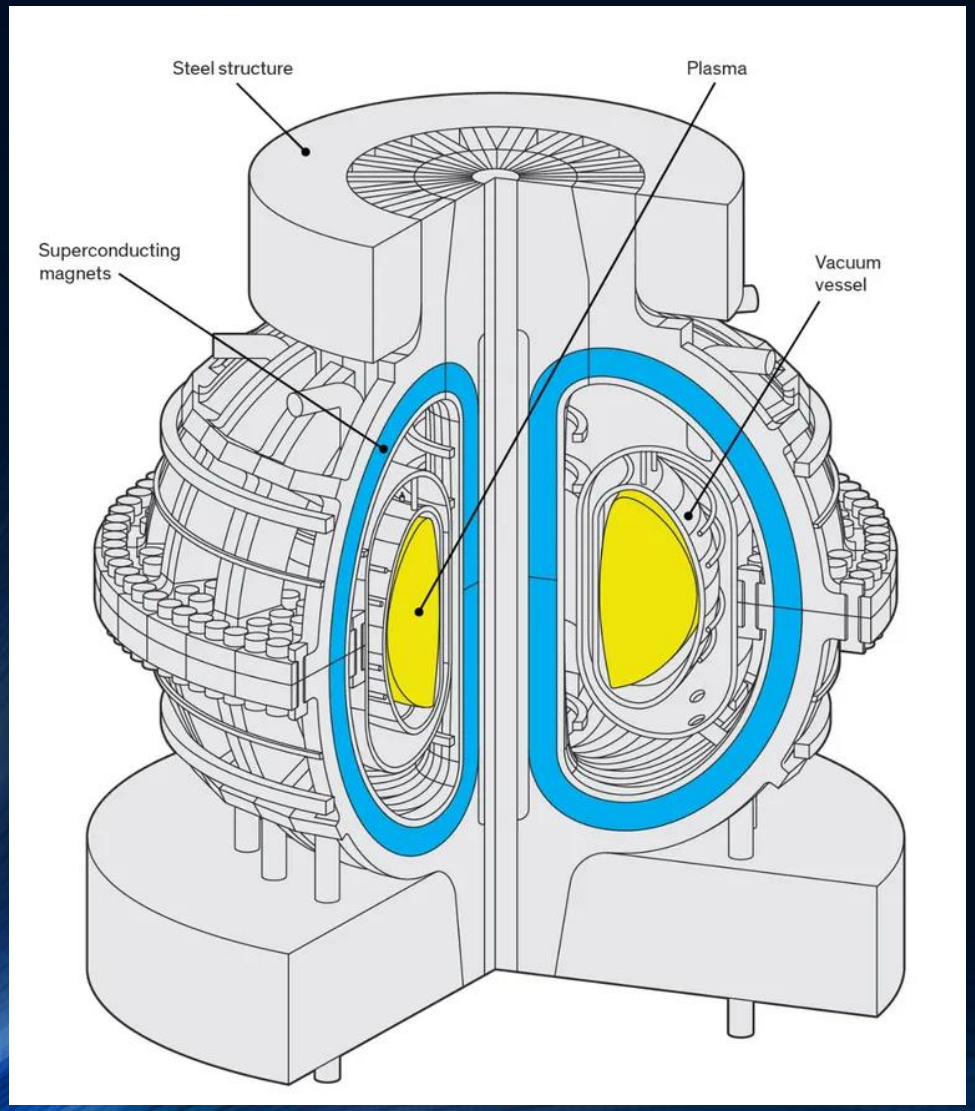
Fusion Energy

- Fuse lighter atoms together
  - Most likely deuterium and tritium
- Takes high energy to force them together
- Extreme heat from reaction ~ 100 million degrees
- Must keep heat/plasma away from reactor walls
  - Magnetic Confinement
    - ITER
  - Inertial Confinement
    - National Ignition Facility

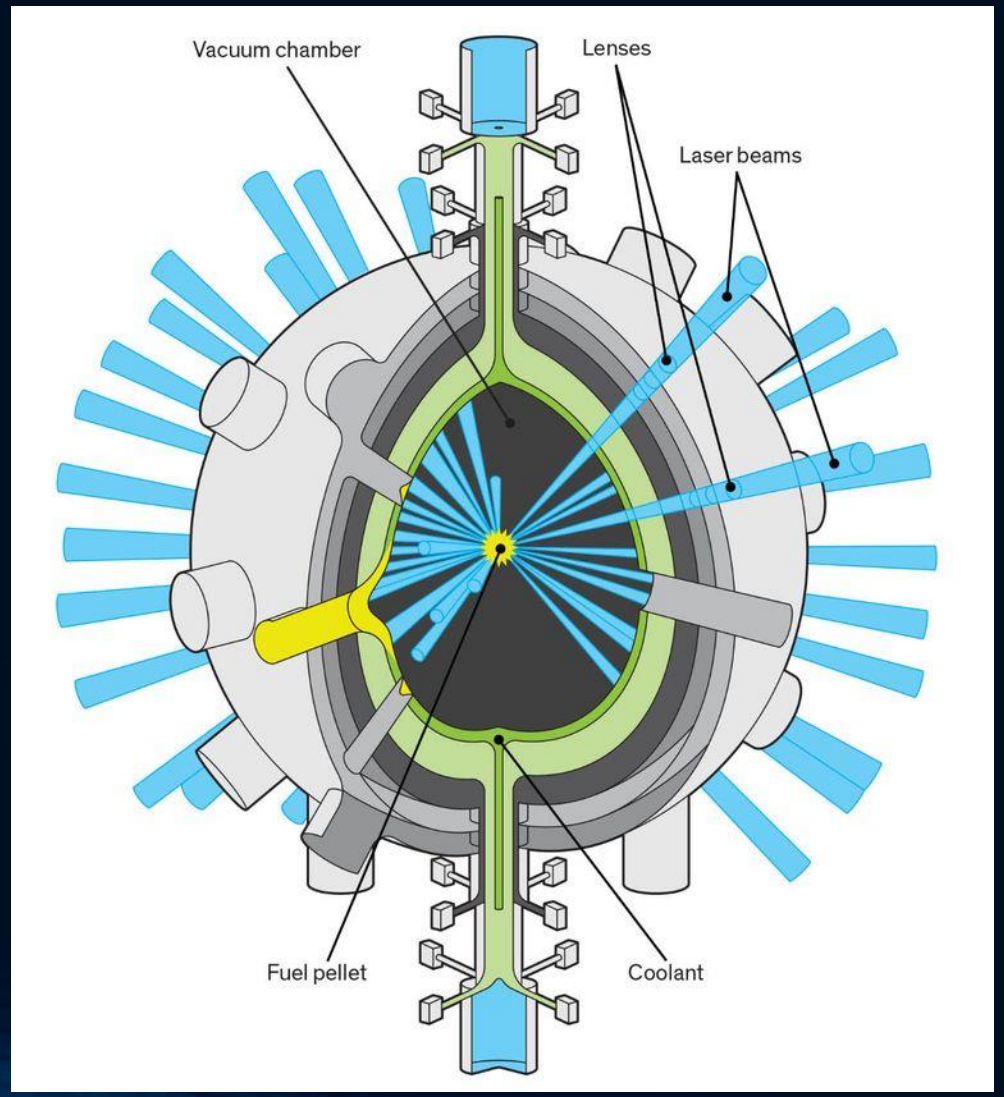


Fusion Reactors

Magnetic Confinement



Inertial/laser Confinement



DOE's Advanced Reactor Demonstration Program

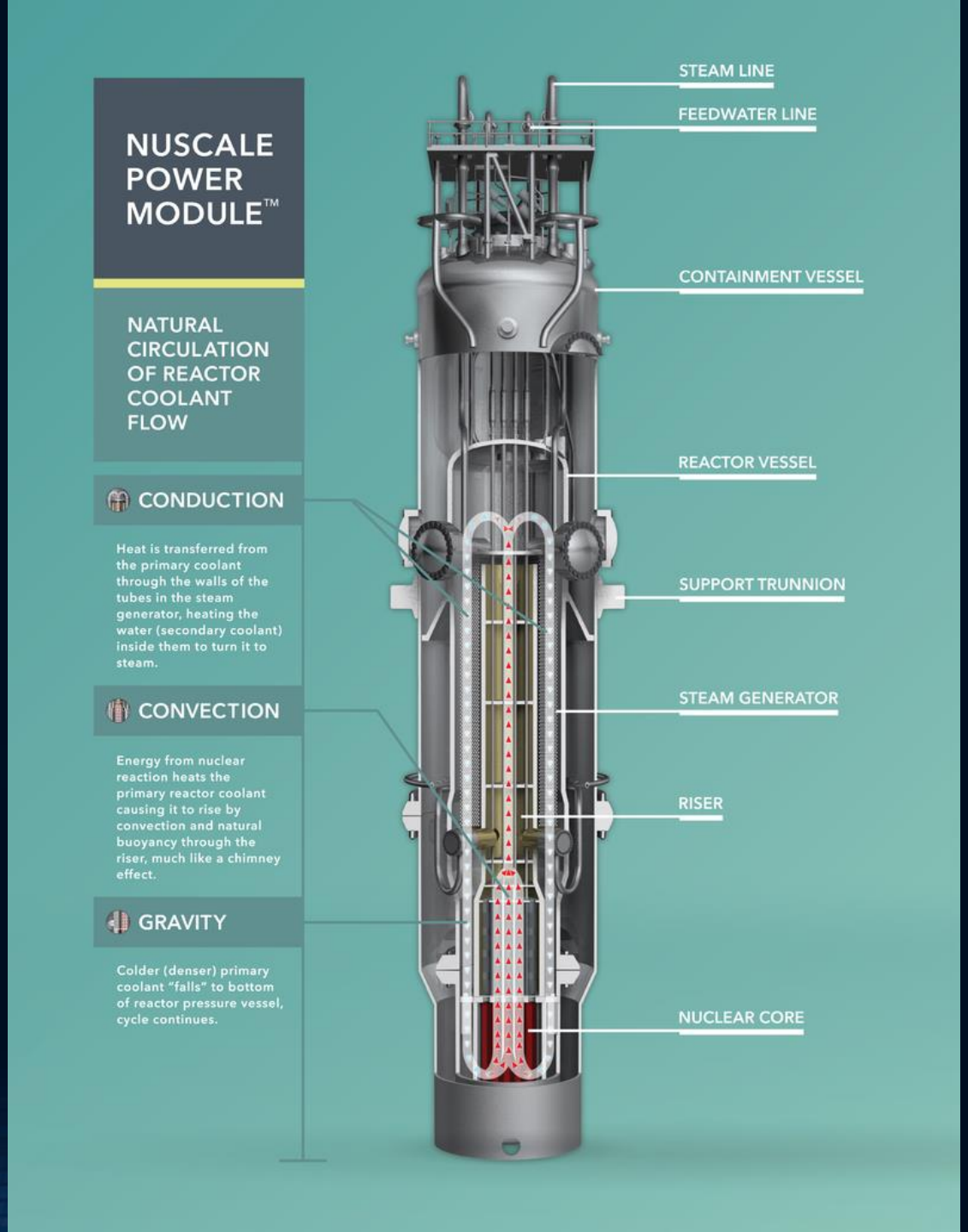
- Funding $160M for advanced reactors
  - TerraPower - SFR
  - X-Energy – Pebble Bed Gas Reactor
- Additional $30M for concepts
  - Kairos Power
  - Holtec
  - Southern Co
  - BWXT
  - Westinghouse Electric Co.
- Funding High Assay LEU production
- DOE also supporting ITER and domestic fusion teams

Discussion

- Questions?
- What are your thoughts on nuclear power?
- Do you think it is important to our energy future?
- What would help increase your knowledge and comfort with nuclear?

Backup Slides

Nuscale



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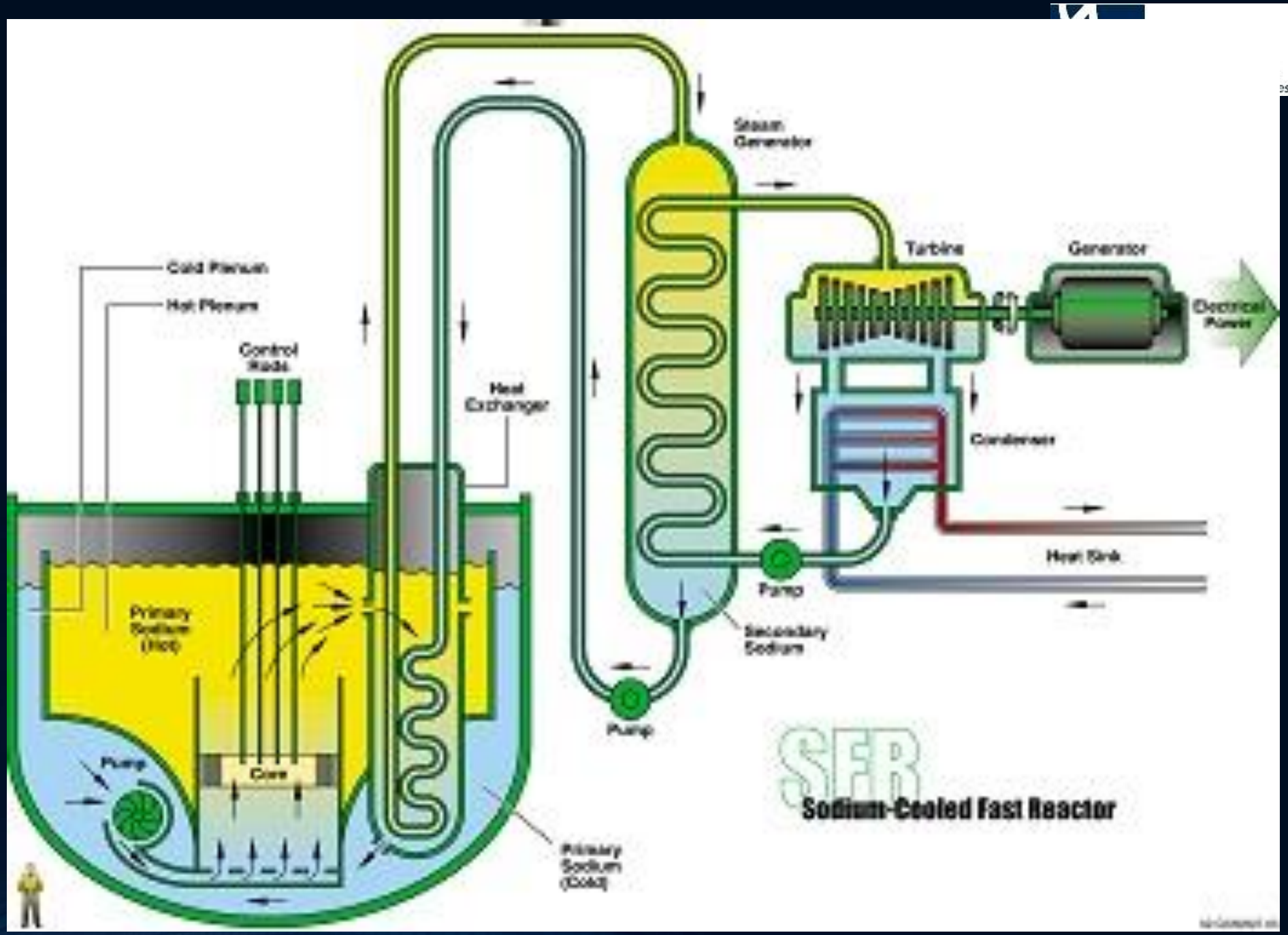
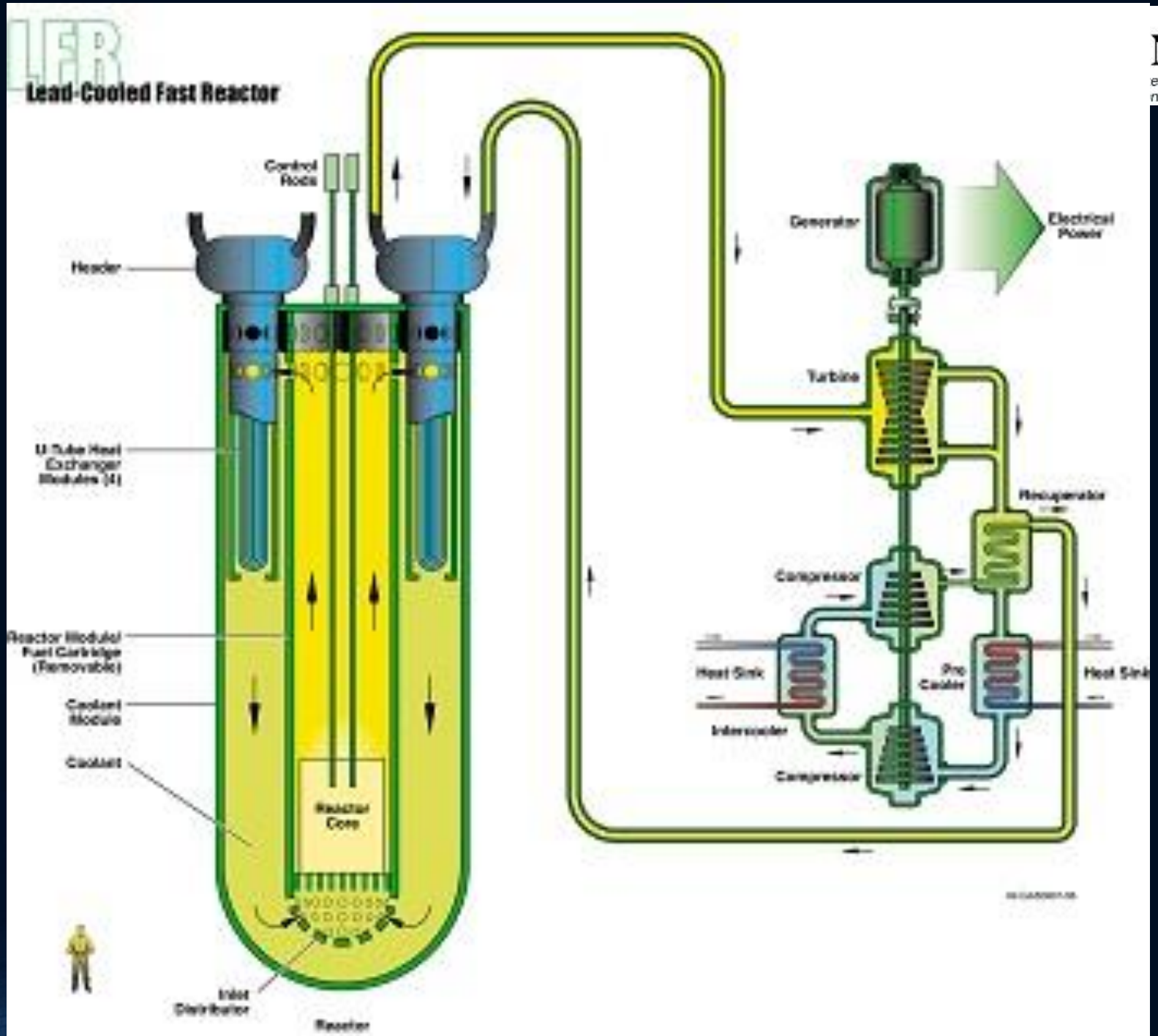
Sodium Cooled Fast Reactor



Lead Cooled FR



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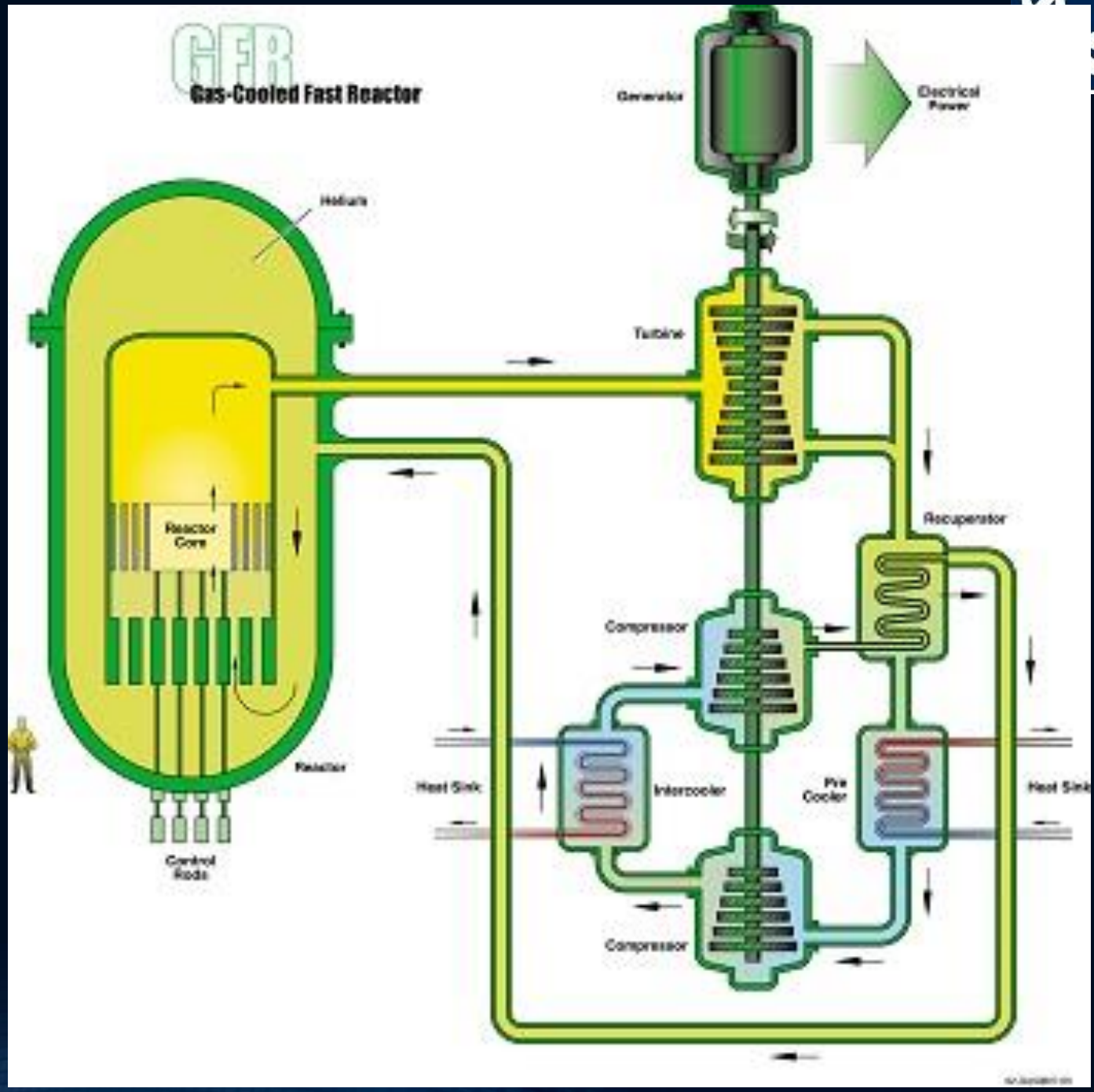
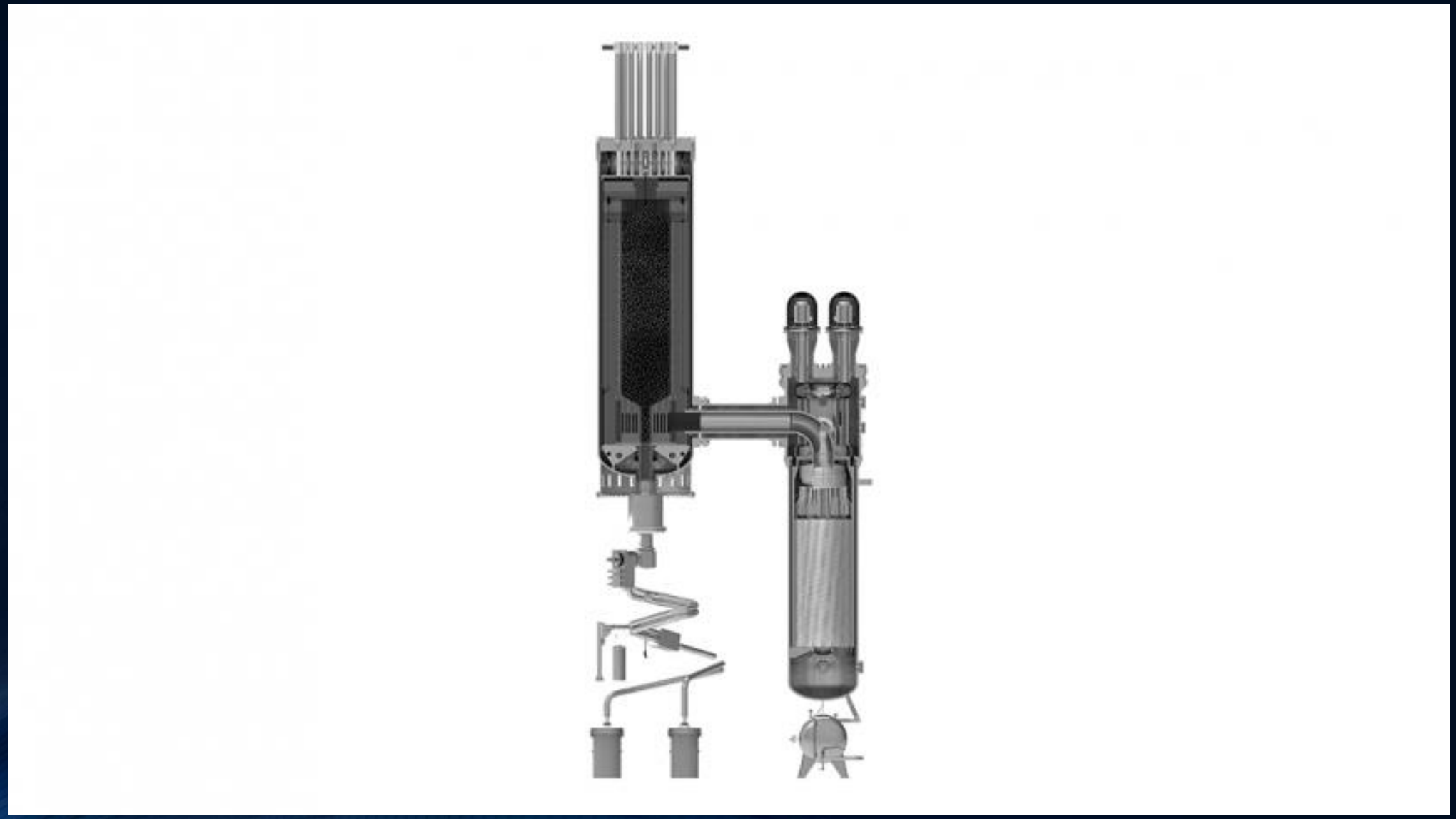
Gas Cooled Fast Reactors



X-energy Xe-100 Pebble Bed Reactor



Molten Salt Reactor