Small Modular Nuclear Reactors

(often SMR [small modular reactor])

Presented by

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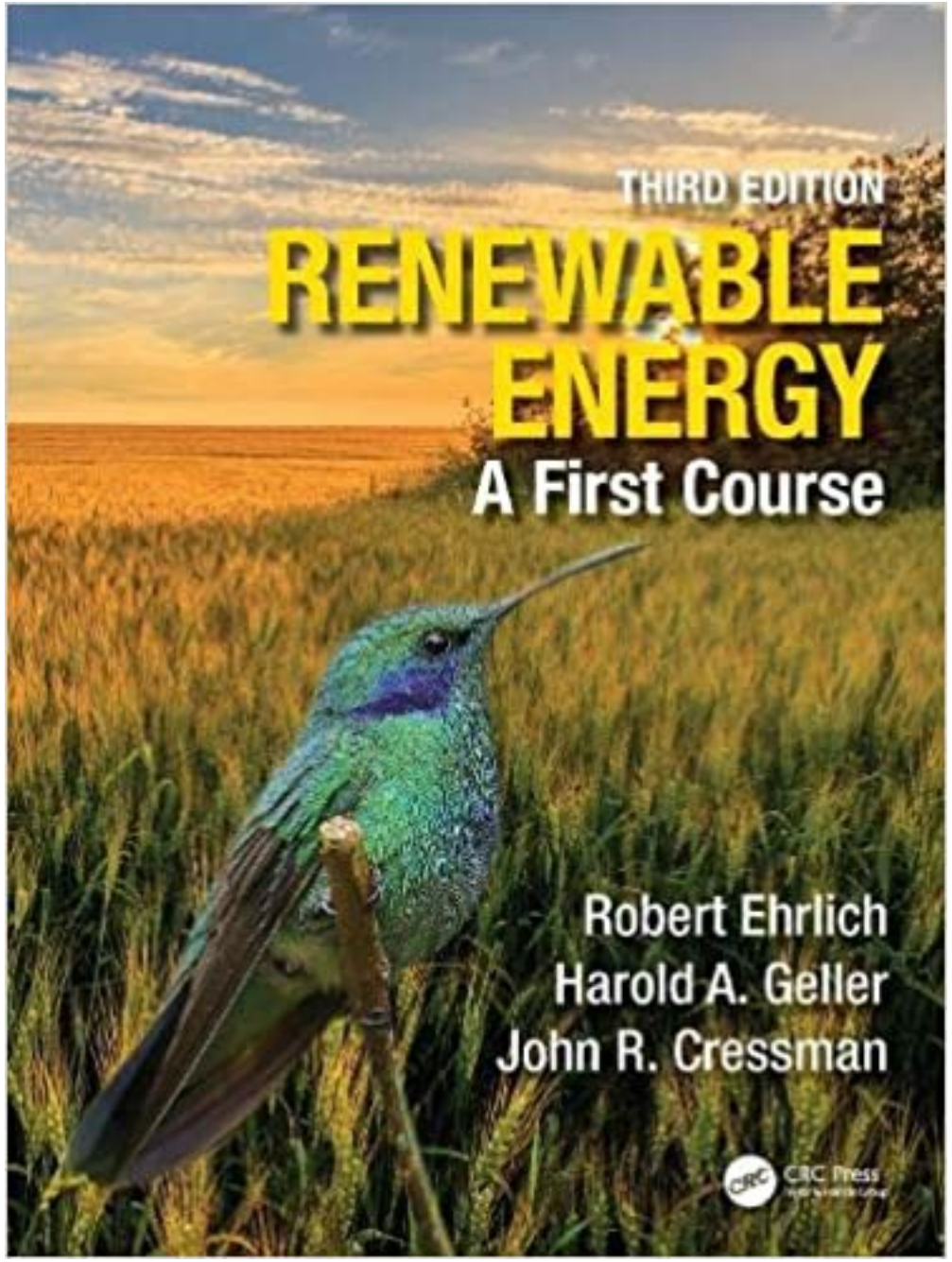
Based upon Renewable Energy by Ehrlich, Geller and Cressman

from CRC Press:



With extensive sections on climate change, nuclear energy, non-renewable and renewable energy resources.

Small Modular Nuclear Reactors

- As of 2021
  - At least 11 nations developing SMRs
    - 23 different designs
- Example designs
  - Simplified boiling water reactors
  - Metal and gas-cooled high-temperature reactors
- Goals
  - Relatively cheap
  - Very low maintenance
  - Off-grid facilities for small communities
- Prototype
  - 25 MW eVinci reactor being built by Westinghouse (see next slide)
    - A small liquid metal-cooled reactor capable of producing enough power for around 20,000 homes
    - The core is a monolithic construction with fuel and moderator enclosed within a neutron reflector that enables the core to go critical

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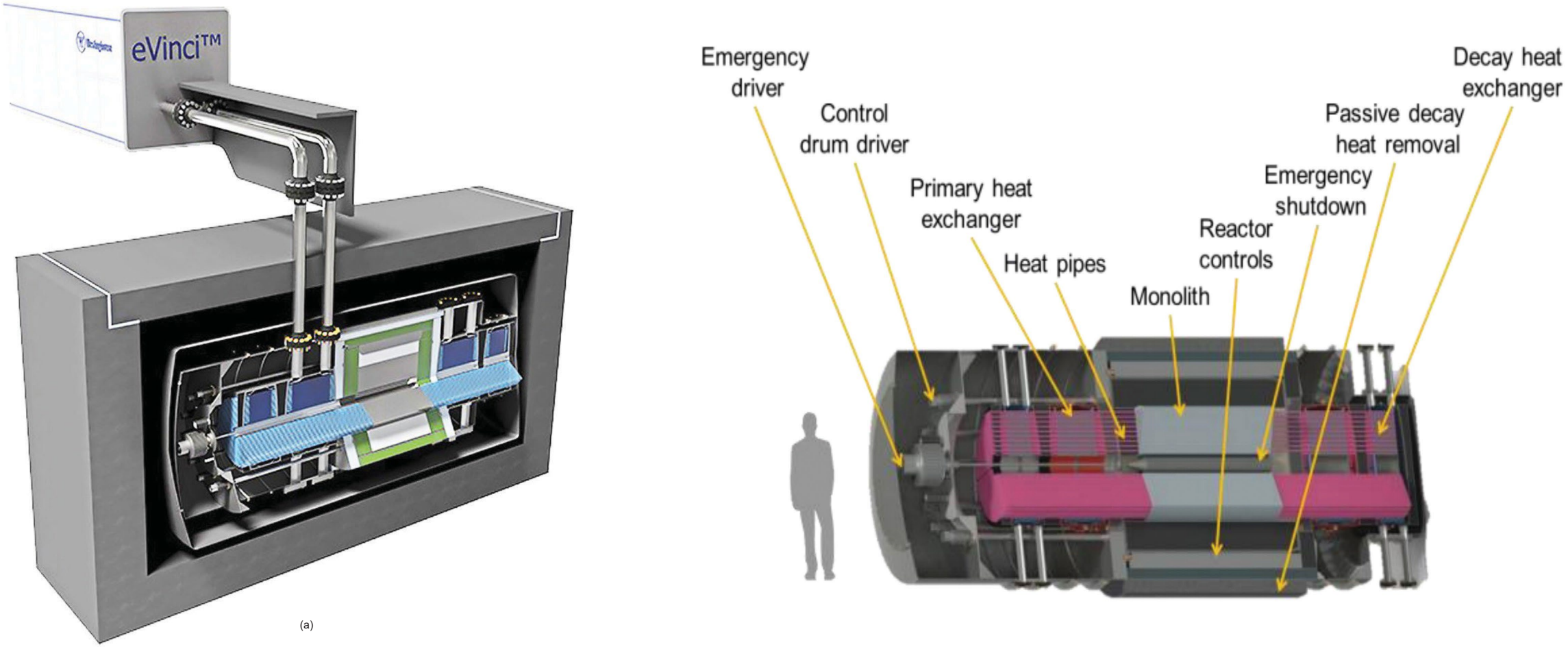

Figure 4.15 Conceptual drawing of Westinghouse's eVinci micro reactor (the central component of its power generating plant) (a), which stands about the height of a human (b). (Westinghouse Electric Co.)

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- Prototype eVinci reactor
  - Between the core and the reflector there is a drum mechanism
    - Rotates neutron absorbers, passively in case of a loss of power or emergency, toward the core to reduce its reactivity.
  - Only moving parts
    - Neutron-absorbing shields
      - Cooling is performed by a small amount of sodium fluid in heat pipes running through the core that exchange heat with secondary system to generate power.
  - No pressurization required
    - Due to the high boiling temperature of sodium
    - Additional passive emergency shutdown system uses small amount of fuel such that a meltdown is said to be impossible
  - Westinghouse envisions that the reactors would be made at the factory, shipped in one piece to the site where they will be used, and setup in 30 days
  - Could run with little or no human intervention required during the 5 years for the fuel to burn up

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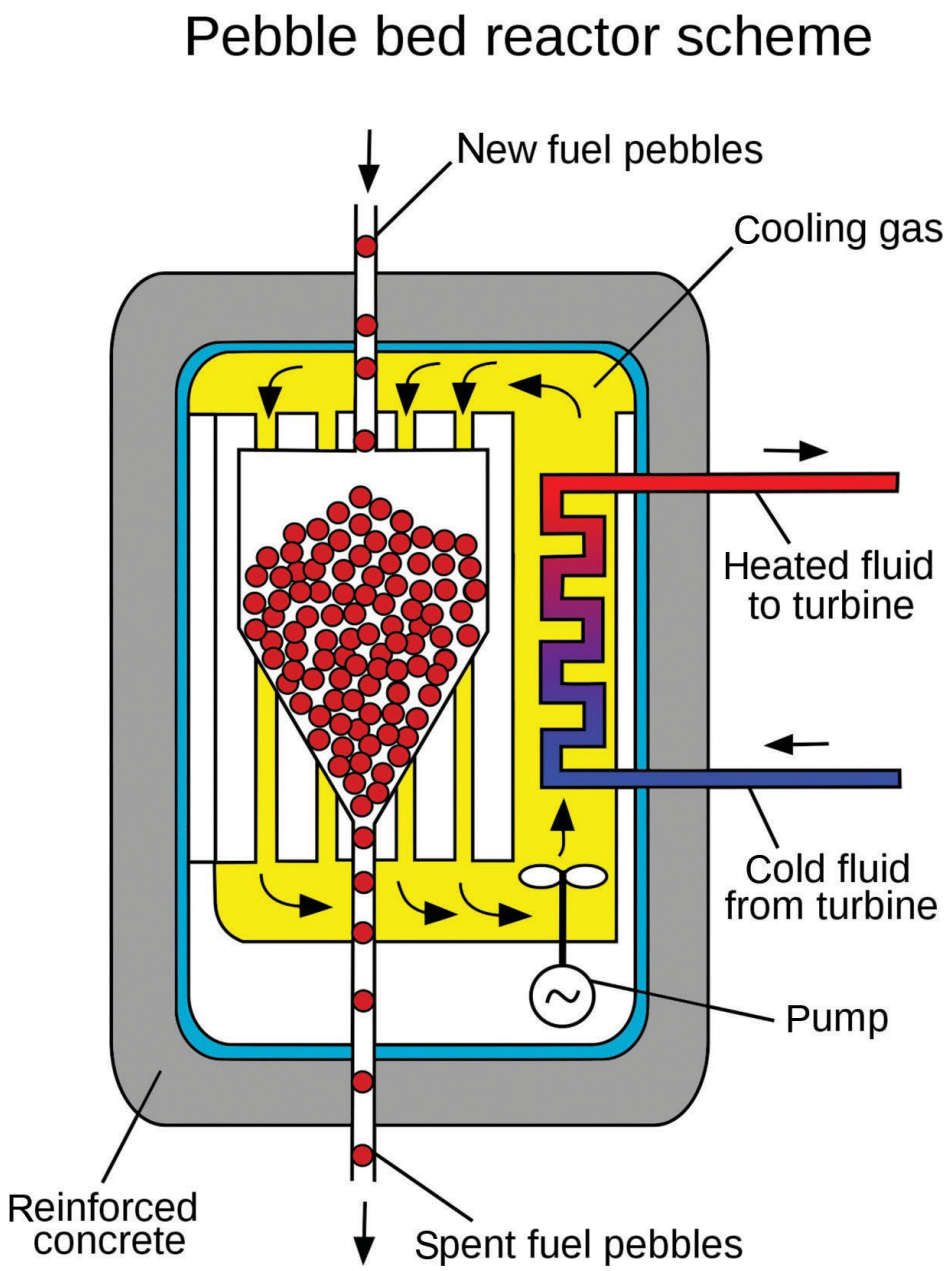
- Prototype eVinci reactor
- After 5-year period
  - Reactor would be shipped back to the factory to have spent fuel replaced
    - Perhaps on a flatbed truck
- Westinghouse goal is to produce power for under 15 cents per kWh
  - Not competitive with grid parity in most areas of the USA
  - Highly competitive for remote off-grid communities and government installations

Pebble Bed Modular Reactor

- A higher power SMR (~200 MW) of a novel design is the pebble bed modular reactor (PBMR)
  - First developed in Germany
    - Now being pursued by the United States and China
  - Cooled by helium gas
  - Fuel is in the form of spherical pellets about the size of tennis balls
    - Each pellet consists of the nuclear fuel, surrounded by a fission product barrier, and graphite moderator.
    - Simply piling in enough pebbles will allow the reactor to approach criticality.
    - The pellets never get hot enough to melt, so that a meltdown is said to be impossible.
    - Should there be a coolant failure, the effect would be to slow the reaction rate and cause the reactor to shut down.



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Pebble bed modular reactor.

Pebble Bed Modular Reactor

- The PBMR passive safety feature is diametrically opposite the unfortunate design feature of Chernobyl-type reactors, which become more reactive when they heat up.
  - At any one time, the reactor vessel contains around 450,000 of the pellets, with new ones continually entering from above and spent ones leaving from the bottom of the reactor vessel.
  - The reactor is continually being refueled online, and costly shutdowns for refueling are never necessary.
- Defects in the production of pebbles can cause problems
  - An accident at a German PBMR in 1986 resulting from a jammed pebble did cause a shutdown and resulted in a release of radioactivity.

What's Wrong With Pebble Bed Modular Reactors?

- The pebble bed reactor has been touted as nearly "accident proof" and is being hailed as a savior of the nuclear industry.
- Those who oppose PBMRs point to the following:
  - It has no containment building.
  - It uses flammable graphite as a moderator.
  - It produces more high level nuclear wastes than current nuclear reactor designs.
  - It relies heavily on nearly perfect fuel pebbles.
  - It relies heavily upon fuel handling as the pebbles are cycled through the reactor.
  - There's already been an accident at a pebble bed reactor in Germany due to fuel handling problems.

Small Modular Nuclear Reactors

- Other types of SMRs of a more conventional light water reactor design better lend themselves to being scalable so as to provide large amounts of power when a number of them are added as the demand grows
  - e.g. SMRs by NuScale Power and by Westinghouse
- Virtually all the SMR designs rely on passive safety features (no operator intervention required) to maintain safe operation and prevent a catastrophic meltdown

Small Modular Nuclear Reactors

- SMR passive safety features rely on either the laws of physics, the properties of particular materials, or the reactor design to prevent accidents.
- Other SMR advantages
  - SMRs can be placed very close to the need
    - Requiring smaller transmission costs and fewer new power lines
  - SMRs can be thought of as “nuclear batteries,” having an energy density millions of times greater than normal batteries that can also provide backup to intermittent renewable energy sources.

Small Modular Nuclear Reactors

- The future of SMRs look bright
  - SMRs will probably not come on line for another decade
    - Due to the lengthy NRC approval process required
      - This process is necessary for usage either in the United States or in other nations in order to comply with IAEA safeguards.
  - US Navy has had a long experience with small reactors
    - Fuel configuration and enrichment levels required for civilian commercial use are different, which is the reason that a lengthy process of evaluating new designs is necessary.

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- When considering the economics of SMRs
  - Many new technologies fail to live up to initial expectations.
  - Recall that large-scale nuclear power, initially said to be “too cheap to meter,” may turn out to be too expensive to compete
  - Cannot be certain about either the economics or the public acceptance of modular reactors until they meet the realities of the marketplace

End of Presentation on
Small Modular Nuclear Reactors