APPROACHES TO PRODUCING ENERGY FROM FUSION

The main fusion energy system technologies being pursued for near-term commercial deployment can be grouped into three general approaches to producing energy from fusion: magnetic, inertial, and magneto-inertial. The discussion below provides general descriptions and attributes associated with these technologies.

<u>Magnetic confinement</u>

- *General technical approach*: A high-temperature light-nuclei-fueled plasma operating in steady state is contained within a vacuum vessel by a strong magnetic field to heat the plasma. For some designs, an electric current is induced in the plasma, resulting in an increase in temperature through ohmic heating. The plasma is also heated by auxiliary systems, such as electromagnetic waves or accelerated neutral particle beams.
- *Common fuels*: deuterium-tritium (D-T) reaction, which produces helium-4, a neutron, and energy
- *Representative designs*: tokamak, spheromak, stellarator, and some field-reversed configurations

<u>Inertial confinement</u>

- *General technical approach*: A capsule of light nuclei fuel is compressed by laser beams or other means within a chamber to compress and heat the plasma.
- *Common fuels*: D-T
- *Representative designs*: laser, ion-beam, and projectile-driven approaches

<u>Magneto-inertial confinement</u>

- *General technical approach*: Designs combine aspects of magnetic and inertial confinement.
- *Common fuels*: D-T, proton-boron-11 (p-B-11), and deuterium-helium-3 (D-He-3)
- *Representative designs*: Helion Energy's field-reversed configuration design, General Fusion's tokamak design, and Zap Energy's Z-pinch design

All fusion devices create a plasma that consists of charged particles. The charged particles are accelerated to energies high enough to create net energy production from fusion reactions. The fusion reactions produce energy particles with energies in the range of 1 megaelectron volt and above. The resulting high energy particles are used in other nuclear reactions within the fusion energy system, such as reactions to heat and maintain the plasma or to breed tritium using high energy neutrons colliding with a tritium breeding blanket containing lithium. Energy from particles may also be converted to produce heat or electricity.

Using the magnetic confinement system as an example, the components of a fusion energy system can be generally described as follows: The system will consist of a vacuum vessel in which the fuel is injected and where the fusion reactions within the plasma take place. To generate the tritium fuel for continued operation, many designs incorporate a breeding blanket where neutrons generated in the plasma are adsorbed by lithium in the blanket to create more tritium. A fuel handling system will also be part of the facility to extract and process the fuel (i.e., tritium). The vacuum vessel (e.g., tokamak, stellarator) will be housed in a building, typically constructed of concrete, and cooling loops will extract the heat from the fusion reaction.

Another design under development is the field-reversed configuration within the magnetic and magneto-inertial approaches. Field-reversed configuration is an alternative to the confinement concepts of a tokamak in that the magnetic field lines are closed, providing confinement, but the vessel is cylindrical, allowing simpler, easier construction and maintenance. The plasma has the form of a torus. In one design, two plasmas, using aneutronic fuel, are created and accelerated into each other. They are merged into a single plasma that is heated and maintained with particle beams. The hazards associated with this design correspond to the methods used to make the high-temperature plasma and, in the case of D-T fuel, tritium- and neutron-related hazards.

The hazards for the aneutronic concepts mainly relate to the methods for generating the plasma. Low-neutronicity concepts could still present neutron hazards, from secondary reactions, and possibly tritium hazards depending on the fuel cycle used, but the radiological hazards are expected to be lower than those for devices that use D-T fuel.

The United Kingdom Atomic Energy Authority report UKAEA-RE(21)01, “Technology Report – Safety and Waste Aspects for Fusion Power Plants,” issued September 2021 (https://scientific-publications.ukaea.uk/wp-content/uploads/UKAEA-RE2101-Fusion-Technology-Report-Issue-1.pdf), contains further detailed discussion on fusion energy system components.