Kairos Power

Design, Build, Test, Repeat: A Novel Approach to Delivering Advanced Reactor Technology

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TRTR ANNUAL MEETING

30 SEPTEMBER 2024

Kairos Power's mission is to enable the world's transition to clean energy, with the ultimate goal of dramatically improving people's quality of life while protecting the environment.

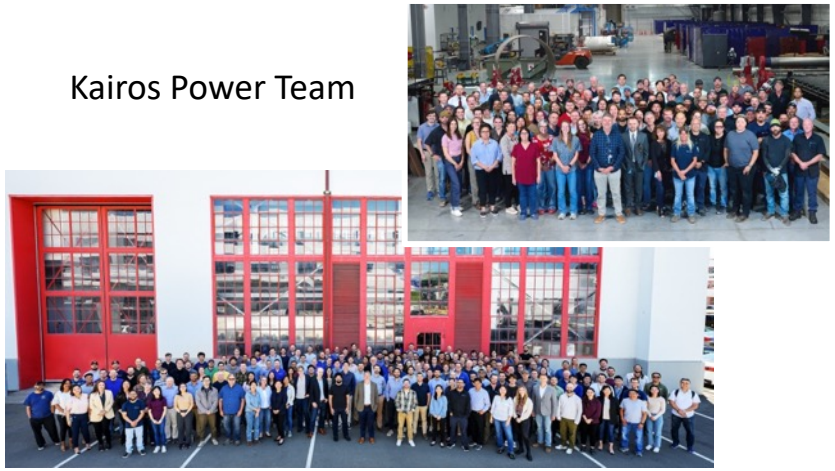
In order to achieve this mission, we must prioritize our efforts to focus on a clean energy technology that is *affordable* and *safe*.

Overview of Kairos Power

- Nuclear energy engineering, design, and manufacturing company ***singularly focused*** on the commercialization of the fluoride salt-cooled high-temperature reactor (FHR)
  - Founded in 2016
  - ~400 Employees
- Novel approach to nuclear development that includes iterative hardware demonstrations and in-house manufacturing to achieve disruptive cost reduction and provide true cost certainty
- Schedule driven by US demonstration by 2030 (***or earlier***) and rapid deployment ramp in 2030s
- Cost targets set to be competitive with natural gas in the US electricity market

Kairos Power Headquarters

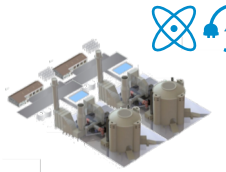
Kairos Power Team



Kairos Power Path to Commercialization

Successive Large-Scale Integrated Demonstrations

PLAN DESIGN BUILD TEST



KP-X
Commercial Plant

KP-X

PLAN DESIGN BUILD TEST

User Facility
Reactor Demonstration Unit
(Non-Nuclear)

U-Facility

PLAN DESIGN BUILD TEST

Hermes Demonstration Reactor Series

Hermes Hermes 2

PLAN DESIGN BUILD TEST

Engineering Test Units
(Non-Nuclear)

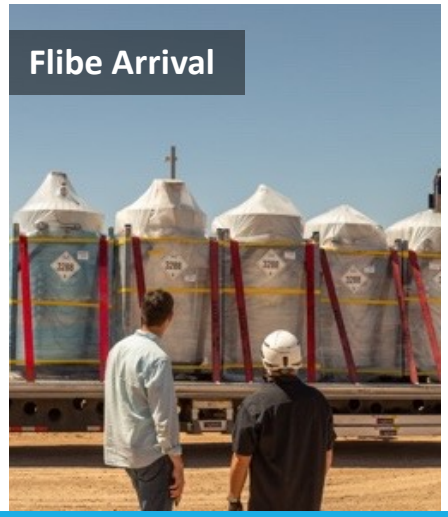
ETU 1.0 ETU 2.0 ETU 3.0

Nuclear

Produces electricity and connected to grid

Engineering Test Unit

Albuquerque, NM



ETU 1.0 Testing Progress

2,000+ Hours of Pumped Salt Operations

- **ETU 1.0 testing highlights at 550+°C:**
  - Loaded 12 metric tons of molten salt into the largest Flibe system ever built
  - Demonstrated online refueling with surrogate fuel via the Pebble Handling and Storage System
  - Achieved highest-ever Flibe flow rate up to 3,000 GPM
  - Logged over 25,000 strokes of the Reactivity Control System
  - Commissioned a first-of-its-kind chemistry control system to continuously monitor purity of Flibe in the system

Lessons learned from the ETU program will inform the design and operation of the Hermes demonstration reactor in Tennessee

Engineering Test Unit and Hermes Series

Current Statuses

ETU 1.0

- Decommissioning commenced in March 2024 following successful completion of 2000+ hours of molten salt operations

ETU 2.0

- ETU 2.0 modular equipment skids are under construction in Kairos Power's Modular Systems Facility, which opened in May 2024

ETU 3.0

- Civil construction began on the ETU 3.0 facility this summer at Kairos Power's site in Oak Ridge, TN

Hermes

- NRC issued the Hermes construction permit in December 2023
- Kairos Power started excavation and groundwork at the Hermes site in July 2024

Hermes 2

- NRC completed Hermes 2 safety and environmental reviews this summer.
- Construction permits on track to be issued before the end of the year

ETU 1.0 Lessons Learned Highlights

Supply Chain & Procurement

ETU 1.0 Challenges

Lesson: Procuring large quantities of stainless steel, graphite, and other critical materials

- ETU 1.0 provided a vehicle to exercise the supply chain, establish supplier relationships, and better understand lead times
- Challenges:
  - Significant delays due to COVID-19 impacts
  - As a startup, KP had limited visibility with vendors. Procuring from distributors vs. direct from mills resulted in delays and quality issues.
  - ETU 1.0 design was not yet complete during early stages of ordering parts and components
- Wins:
  - Initial concerns about graphite availability were laid to rest through a strategic partnership with Ibiden

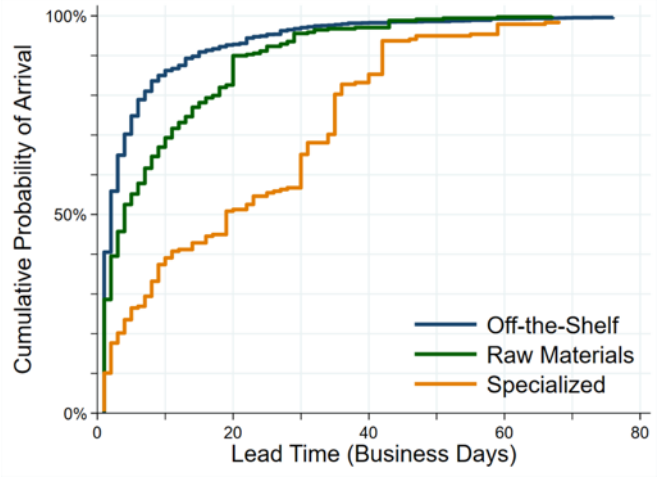
Forging stainless steel vessel heads for ETU 1.1 “little loop”

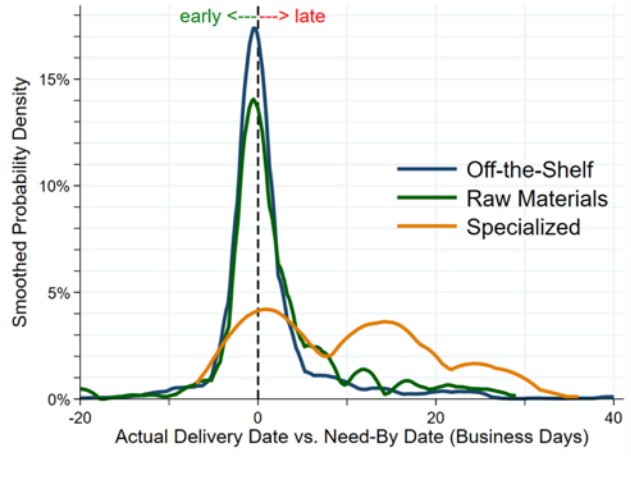
Vessel heads arrive at KP Southwest

Supply Chain & Procurement

ETU 1.0 Lessons Learned

- Improvements to be made in ETU 2.0:
  - Established relationships with major suppliers to order 316H directly
  - More sophisticated ordering procedures
  - Proactive ordering well in advance
  - In-house Quality Control team w/ protocol and equipment to inspect parts on receipt
- ETU 1.0 procurement data reinforces need to vertically integrate the production of specialized parts
  - Raw materials and off-the-shelf parts have much shorter lead times than specialized components
  - More confidence in vendors' promised delivery dates w/ raw materials and OTS parts





Environmental, Health, and Safety

ETU 1.0 Challenges

Lesson: Implementing Be program at KP Southwest and preparing for large-scale Flibe operations

- Successfully completed ETU 1.0 Flibe operations with zero safety incidents
- Extensive preparation leading up to Flibe ops:
  - Developed and implemented protocols to keep operators safe while being easy to follow
  - Implemented engineering controls and determined appropriate PPE to protect from potential hazards
  - Trained operators on EHS protocols and executed dry runs to practice maintenance procedures in full PPE
- Challenges:
  - Ensuring consistent adherence to safety protocols

An entrant performs maintenance inside the ETU enclosure wearing full PPE

PPE changing room

Environmental, Health, and Safety

ETU 1.0 Lessons Learned

- Improvements to be made in ETU 2.0:
  - Utilize a data-driven approach to drive EHS practices
  - Minimize enclosure entries
    - The engineering design team is working to place non-essential equipment outside the ETU enclosure to reduce entries
  - Unify safety culture across all Kairos Power sites with consistent EHS programs and training to ensure adherence
  - Programs refined at KP Southwest and other Kairos Power facilities to be replicated in Tennessee for Hermes

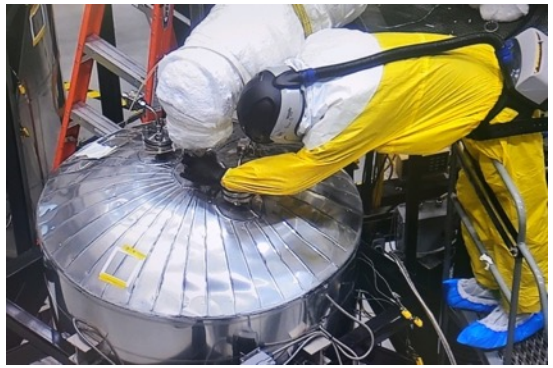
Initiating Flibe Operations

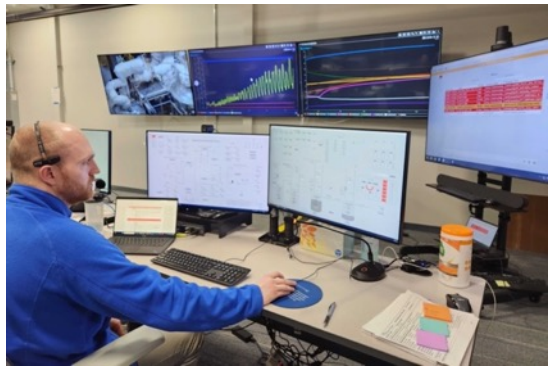
ETU 1.0 Challenges

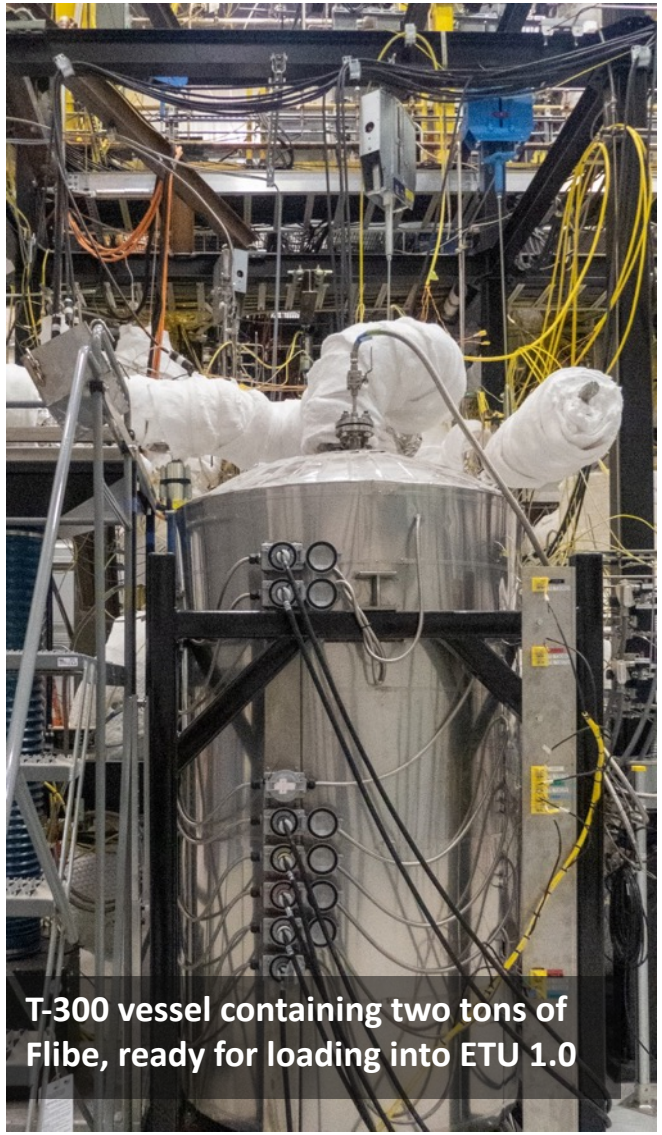
Lesson: Executing the largest transfer of molten Flibe ever performed while protecting personnel from Be and thermal hazards

- Safely transferred 12 metric tons of 600˚C molten salt into ETU from seven T-300 transport vessels
- Challenges:
  - Scaling up salt-handling procedures from S-Lab to industrial-scale
    - Fittings used in lab were unworkable at large scale
  - Problematic T-300 tank design
    - Non-uniform melting of Flibe inside
    - Unable to extract half the salt from one canister
  - Transfer from the first Flibe tank took two weeks
  - Horizontal freeze valves difficult to prime

Final Flibe shipment arrives at KP Southwest





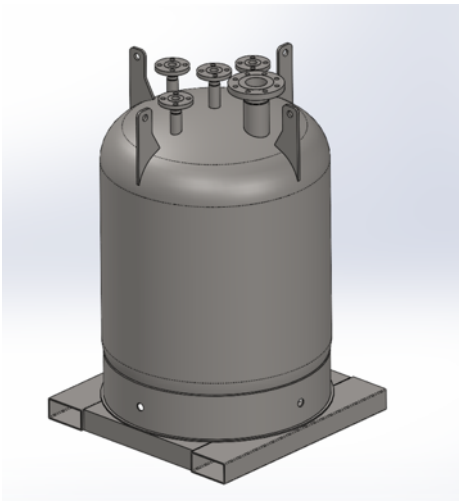


T-300 vessel containing two tons of Flibe, ready for loading into ETU 1.0

Initiating Flibe Operations

ETU 1.0 Lessons Learned

- Improvements to be made in ETU 2.0:
  - Kairos-Power-designed T-301 tanks
    - No integrated heaters
    - Additional nozzles to improve salt and gas flow
  - Optimized salt transfer process more prototypical of Hermes
    - Reduced transfer times from two weeks to four days by simplifying process and eliminating unnecessary steps
    - Bolted flange connections easier to operate
      - No leaks occurred during salt transfer
    - All freeze valves to be oriented vertically
      - Vertical freeze valves performed consistently in ETU 1.0



Pebble Handling and Storage System

ETU 1.0 Challenges

Lesson: Constructing a pebble handling and storage system to circulate and inspect fuel pebbles

- Successfully circulated 1,600+ pebbles, demonstrating the feasibility of online refueling
- Challenges:
  - Waited too long to begin integrated testing due to competing operational priorities
    - Difficulties integrating PHSS control with ETU IC&E
    - Issues with pebbles jamming at accumulation points


Pebble inspection system

Pebble in transport between L-PIM and U-PIM


Jam in pebble inspection system


Debris removal system

Pebble Handling and Storage System

ETU 1.0 Lessons Learned

- Improvements to be made in ETU 2.0:
  - Full-scale integrated test (Adonis) to address design issues and improve performance with multiple iterations prior to ETU 2.0
    - Eliminating accumulation points to reduce jam potential
    - Early integration w/ I&C team to develop control algorithms
  - Get designs in the manufacturing queue early before the surge in production of other ETU 2.0 components
  - Simplify design where possible to improve manufacturing efficiency by reducing machining requirements

Adonis test stand


Pebble inspection system


Insulation completed
Sept 2024

Looking ahead to ETU 2.0

Vessel Manufacturing

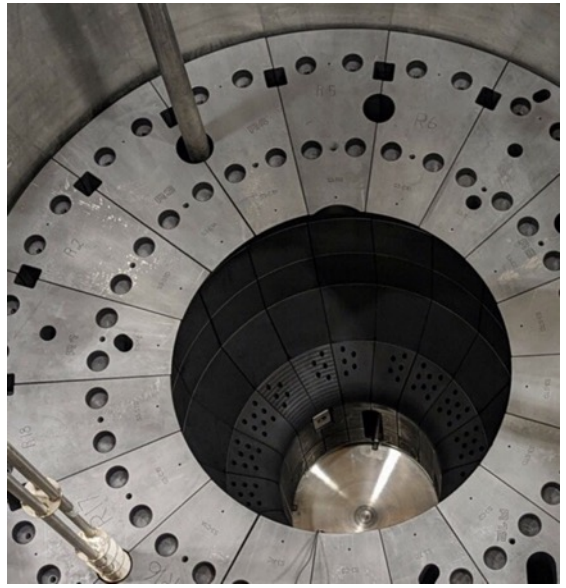
ETU 1.0 Challenges

Lesson: Pivoting manufacturing strategy to better control quality, cost, and schedule

- ETU 1.0 reactor vessel arrived out of tolerance. Graphite reflector blocks did not fit correctly inside.
- Rather than ordering a new vessel, Kairos Power re-machined the graphite blocks in-house at a fraction of the cost, saving months of delay

Outcome:

- **Decision to bring vessel manufacturing in-house to mitigate cost and schedule risk for future iterations**
- **Decision to fully vertically integrate graphite machining**



Vessel Manufacturing

ETU 1.0 Lessons Learned


Bost vertical turning lathe


Welding


Robotic welder


FERMAT variant floor mill

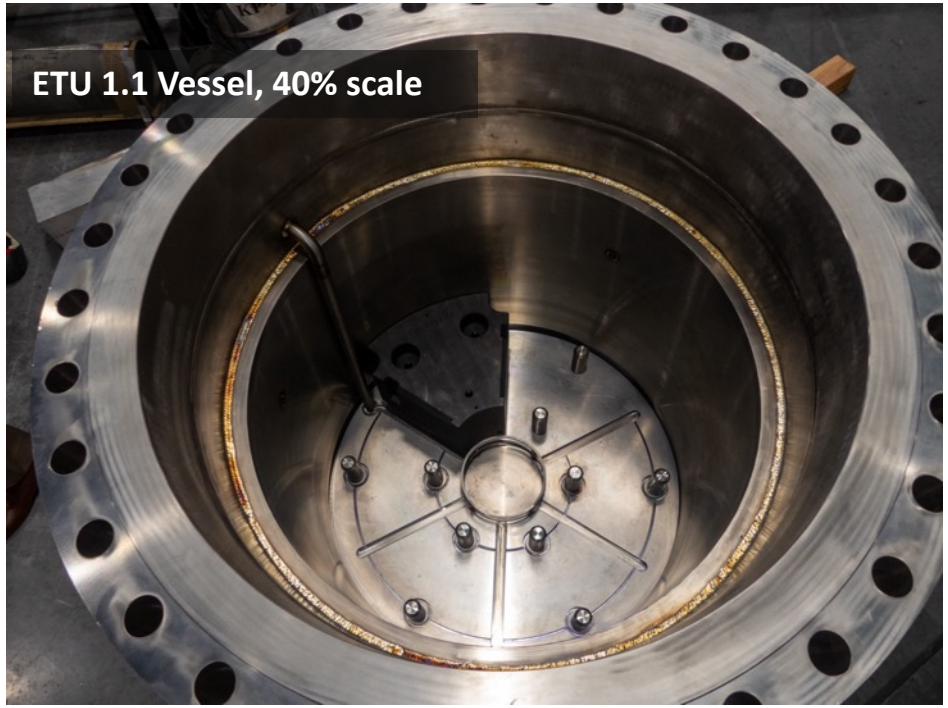

Davi Roller

Vessel Manufacturing

ETU 1.0 Lessons Learned

Lesson: Learning to manufacture reactor vessels in-house that meet precise specifications

- Iterative prototyping at reduced scale with less expensive materials allows us to quickly gain manufacturing experience and optimize processes through “little loops”
- Each little loop accomplishes new objectives, yielding insights on which to build
  - ETU 1.1 addressed initial design and manufacturing challenges
  - ETU 1.1B involved rolling cylinders of varying cylindricity to establish confidence in equipment and processes
  - ETU 1.2 will use match machining to ensure a correct fit between graphite reflector blocks and the vessel wall to minimize bypass flow



Vessel Manufacturing

Quality Control

Lesson: Building Kairos Power's quality program to deliver ETU 2.0 and beyond

- Kairos Power received ASME BPVC Section VIII certification to produce U and U2 stamped vessels in 2022
- ASME BPVC Section IX welding program
- Developing ISO 9001 quality program to be integrated into all design and manufacturing activities
- ASME BPVC Section III-based quality control manual to be developed for Hermes

First U-stamped vessel to be used in operations (2024)

ETU 2.0 vessel

Vessel Manufacturing

Quality Control

Learning by building:
How we get from ETU 1.0 to Hermes

	Non-Nuclear			Nuclear	
	ETU 1.0	ETU 2.0	ETU 3.0	Hermes	KP-X
ASME B31.3 Process Piping					
ASME BPVC Section VIII					
ASME BPVC Section IX					
ASME BPVC Section III Division 5					
ASME Section XI Division 2					

None	Basic Demonstration of Inspection Capability	Partial	Full Implementation

Build Modularity

ETU 1.0 Challenges

Lesson: Going from a stick build to modular construction

- ETU 1.0 construction sequence had no buffer for delays because almost everything was a critical path item
- System interfaces were not fully understood, hampering the integration effort

Outcome:

- **Decision to pioneer modular design with ETU 2.0 skids that can be built in parallel**
- **Investment in Modular Systems Facility**
- **More sophisticated integration process**

Build Modularity

ETU 1.0 Lessons Learned

- Improvements to be piloted in ETU 2.0:
  - Modular design with nearly 30 skids will enable a faster construction timeline
  - Dedicated team and processes to streamline system integration
  - Improved tolerances to ensure modules align and connect correctly
  - Improved remote handling capabilities to reduce entries into the ETU enclosure and make operations/maintenance more efficient
  - Modular design will enable modules for ETU 3.0 and Hermes to be built in Albuquerque and shipped to Oak Ridge for installation, reducing the need for on-site construction


Modular Systems Facility opened for use in May 2024

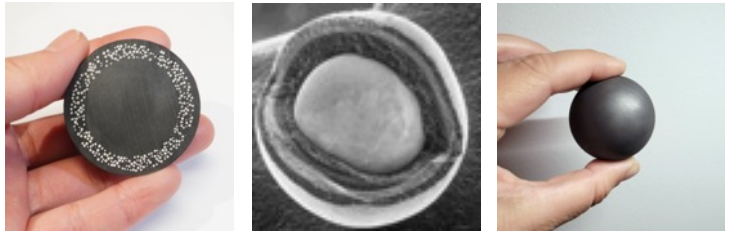

ETU 2.0 skids under construction

Early integration meetings with the PITA team

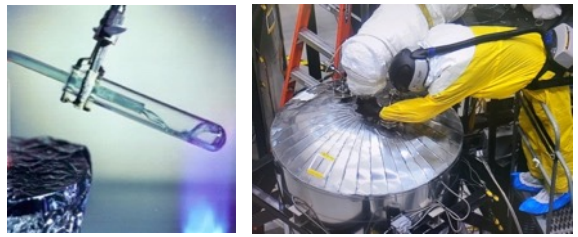
Kairos Power in Albuquerque

Albuquerque Campus Supports Hermes

Fuel Fabrication Process Development & Moderator Pebble Production



Flibe Coolant Production



Advanced Reactor Component Manufacturing

Modular Reactor Construction

Graphite Machining

Vessel Manufacturing

Components and materials manufactured in Albuquerque, New Mexico will directly support the Hermes Low-Power Demonstration Reactor in Oak Ridge, Tennessee

Kairos Power's Commitment to the Community

Embedded in Our Mission

Everything we do at Kairos Power is driven by our mission to **improve people's quality of life while protecting the environment**

Our Commitment:

- Engage and support local communities
- Prioritize diversity, equity, and inclusion
- Selectively build on brownfield sites
- Deliver high energy density with low land use

1 fuel pebble = 4 tons of coal

Headquarters
Alameda, CA


KP Southwest
Albuquerque, NM


K-33 Site
Oak Ridge, TN