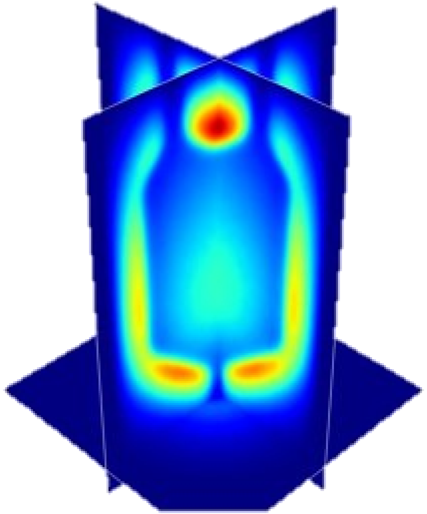
Kairos Power

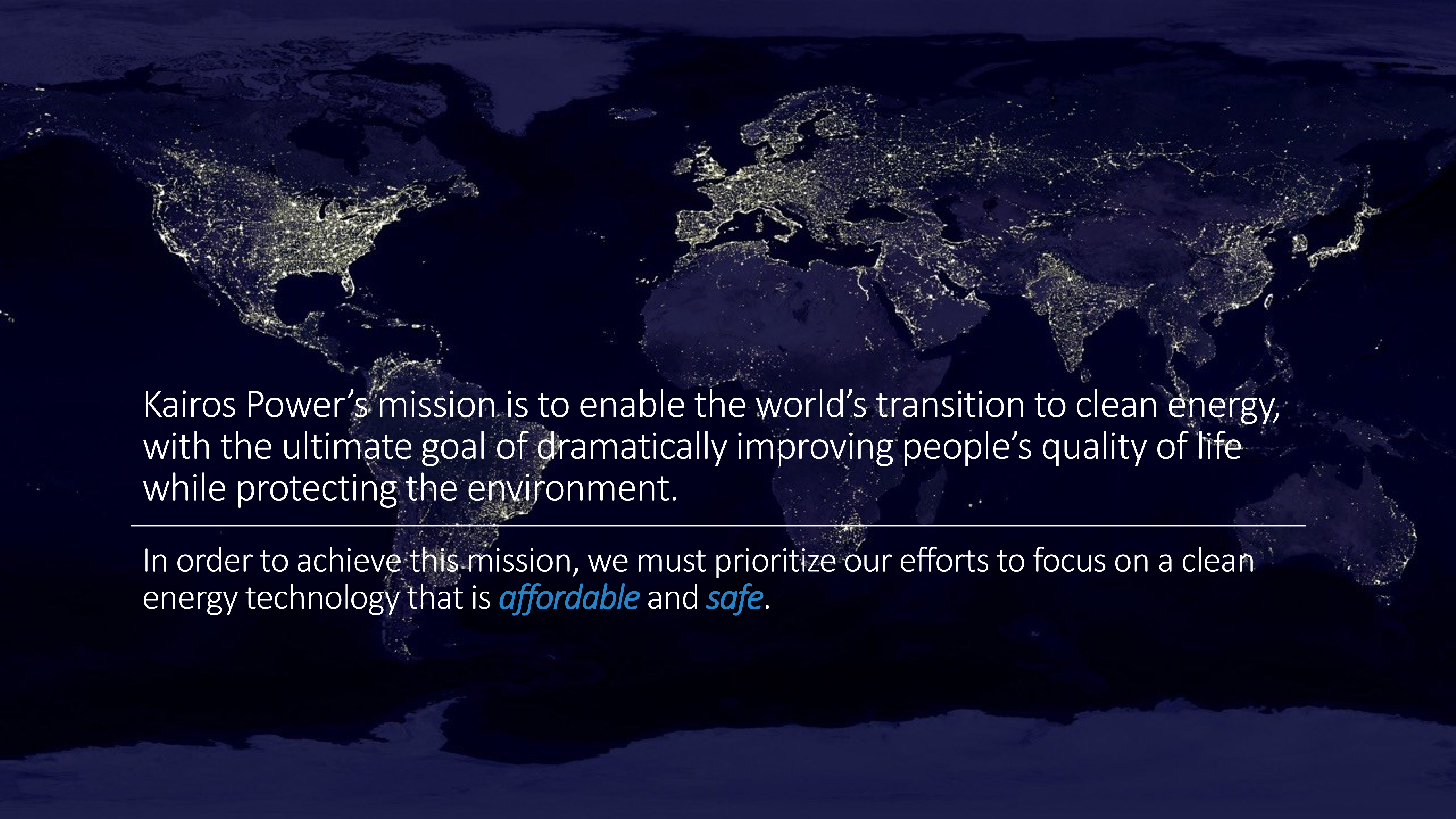


Bridging Gaps: Nuclear data needs for optimized deployment of KP-FHR reactors

WANDA 2025

CHRIS CAMPBELL | NADER SATVAT

NUCLEAR DESIGN & METHODS



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.

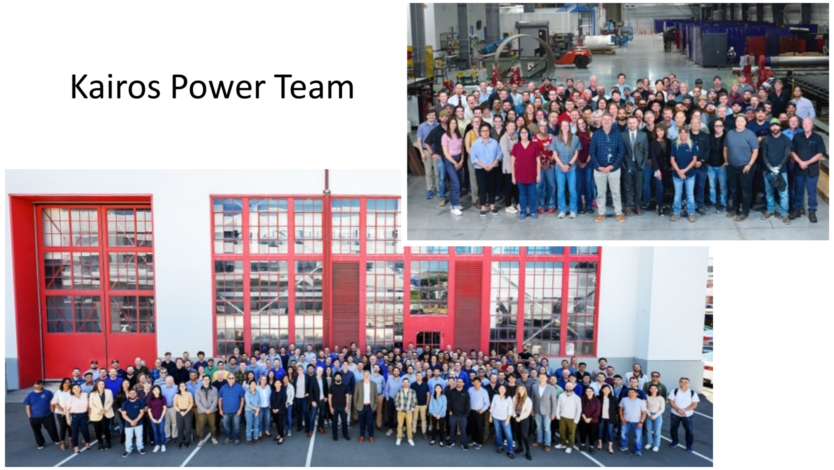
In order to achieve this mission, we must prioritize our efforts to focus on a clean energy technology that is *affordable* and *safe*.

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
  - 450+ Full Time 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

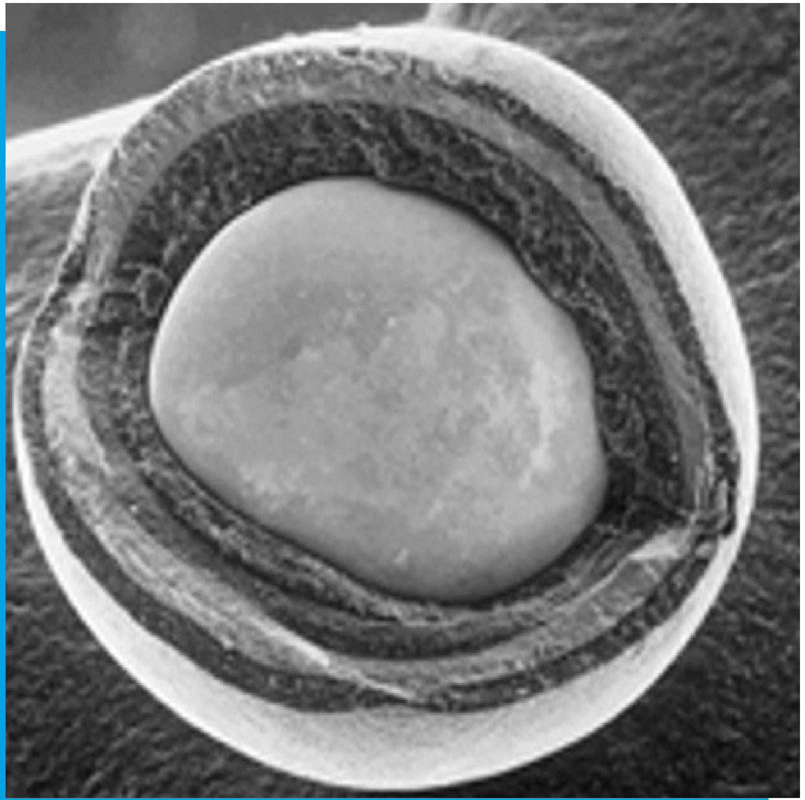
Kairos Power Headquarters

Kairos Power Team



Fluoride Salt-Cooled High Temperature Reactor

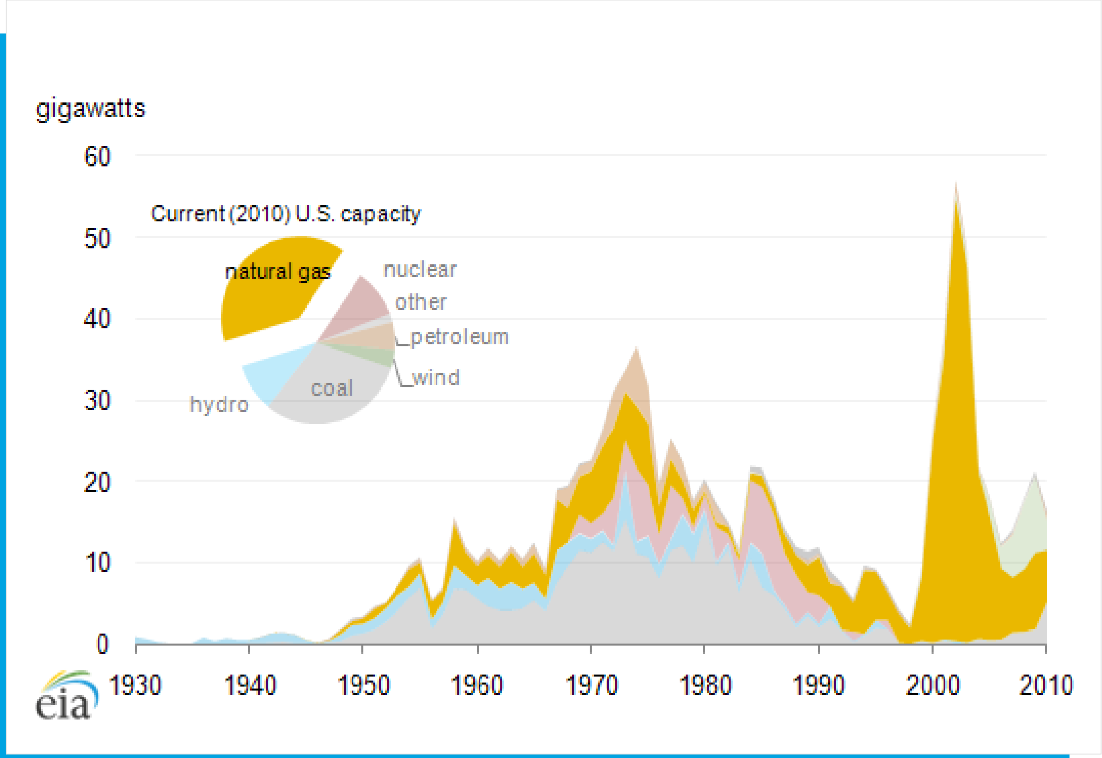
Technology Basis



Coated Particle Fuel
TRISO

Liquid Fluoride Salt Coolant
Flibe ($2LiF\text{-}BeF_2$)

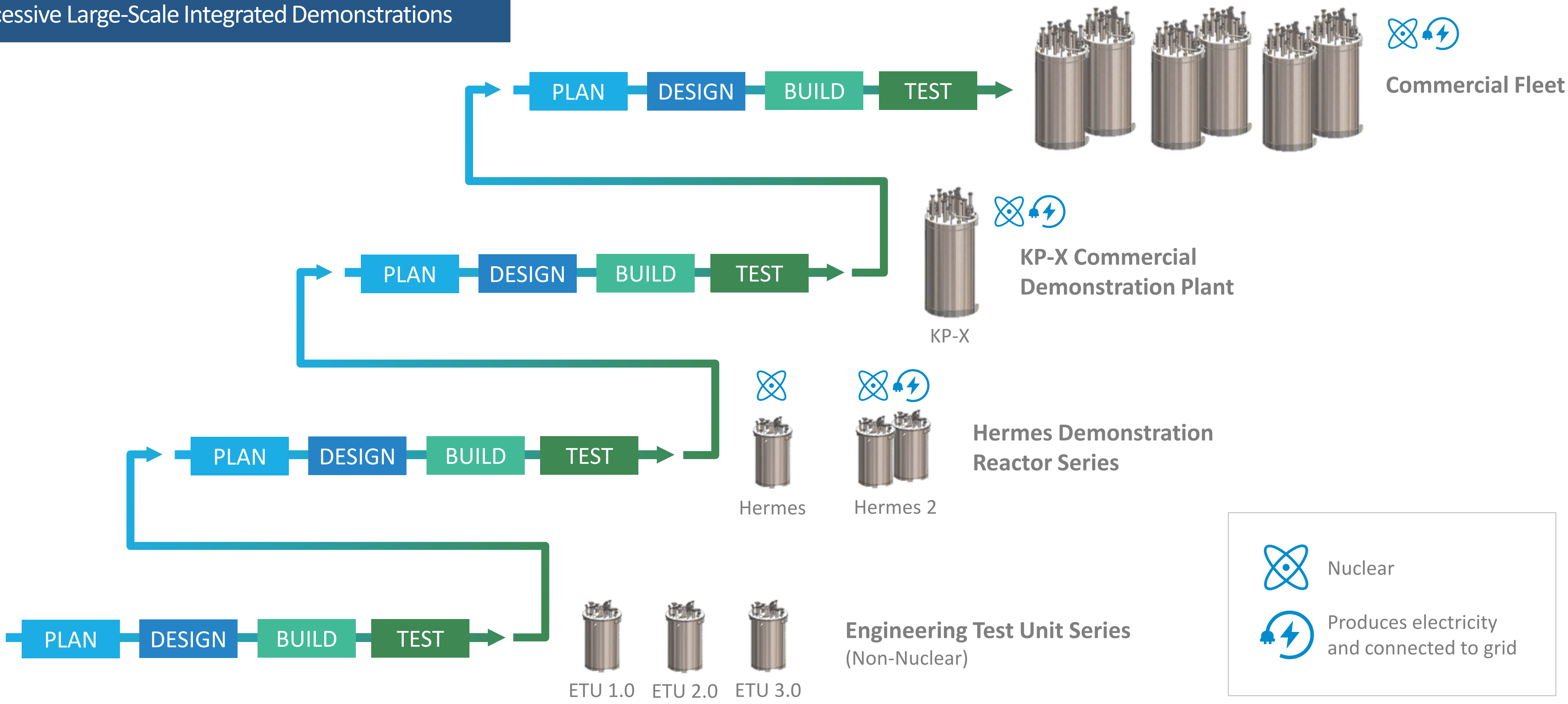
kai·ros (def.): the right or opportune moment



U.S. Electricity Generation by Initial Year of Operation and Fuel Type

Kairos Power Path to Commercialization

Successive Large-Scale Integrated Demonstrations



Hermes Demonstration Reactor

Oak Ridge, Tennessee

Google and Kairos Power Partner to Deploy 500 MW of Clean Electricity

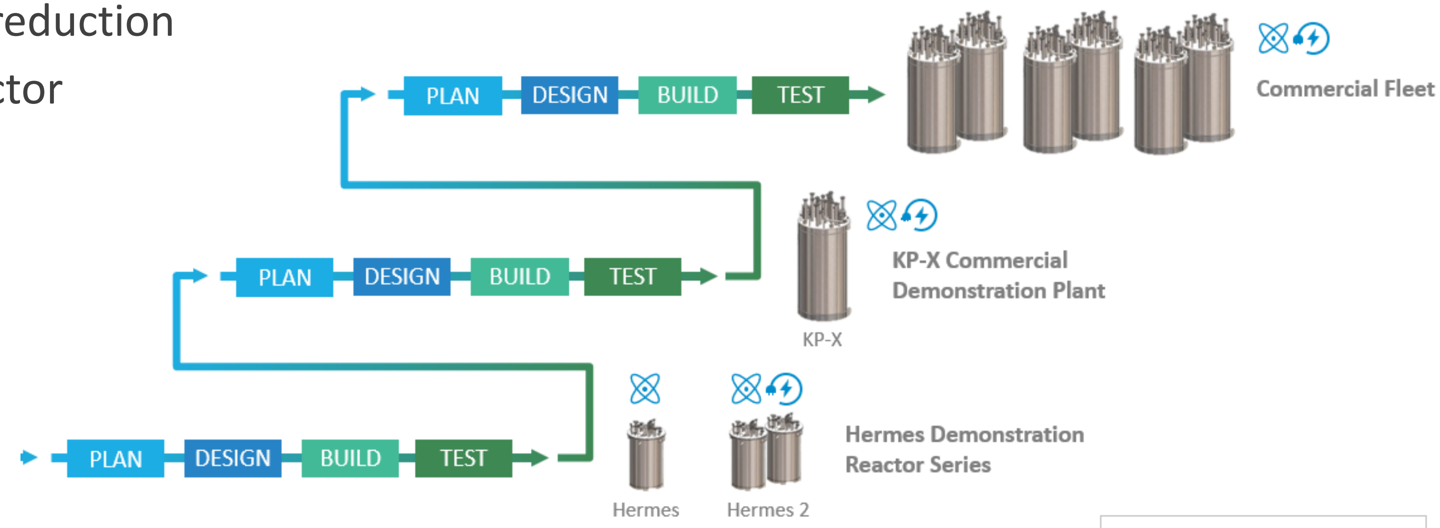
First Corporate Agreement for Multiple Advanced Reactor Deployments

- Kairos Power and Google have signed a **Master Plant Development Agreement**, creating a path to deploy a U.S. fleet of advanced nuclear power projects totaling 500 MW by 2035
- Under the agreement, Kairos Power will develop, construct, and operate a series of advanced reactor plants and sell energy, ancillary services, and environmental attributes to Google under Power Purchase Agreements (PPAs)
- This innovative, multi-plant agreement supports technology development by extending Kairos Power's iterative demonstration strategy through its first commercial deployments

Google | Kairos Power

Optimized Deployment of KP-FHRs

- Reactor physics modeling and licensing
  - Demonstration reactor – high uncertainty with large margins
  - Optimized commercial deployment in the 2030s – efficient operations using improved data
- Infrastructure for fuel life-cycle
  - Transportation of fresh and spent fuel
  - Fabrication, processing, volume-reduction
  - 100,000s of fuel pebbles per reactor



Data Requirements for Reactor Physics

- How do we deal with the data uncertainties now?
  - Available data give us ample confidence in the safety of Hermes
  - Uncertainty quantification
  - Initial plants will operate with large margins.
- The Hermes demonstration reactor
  - Nuclear data adjustment using integral experiments: criticality, flux wires, etc.
  - Uncertainty adjustment for figures of merit
- Transition to *optimized* deployment is enabled by measurements from operation and updated nuclear data.
- Convert large margins into operational efficiencies

Conventional nuclear data needs for reactor physics

- FLiBe - Cross sections of 19F, 9Be, 6Li, 7Li
  - The major source of uncertainty in Flibe is ^{7}Li capture cross section
  - Coolant temperature and density reactivity coefficients
  - Tritium production for source term
- Nail down carbon cross-sections
- Thermal scattering data – Graphite
  - Densities <100%
- Thermal scattering data – Molten Flibe
- Radiation damage in steel (dpa, He)

Reaction	Uncertainty, pcm
^{7}Li capture	1,240
^{235}U nu	379
^{238}U capture	214
^{19}F capture	172
^{235}U capture	157
^{235}U fission	138
^{12}C capture	138
^{12}C elastic	121
Total	1,380

Shi et al. 2018, Sensitivity and Uncertainty Analysis of the Pebble-Bed FHR
See also NUREG/CR-7289.

FHR and fluoride molten salt reactors share similar data needs

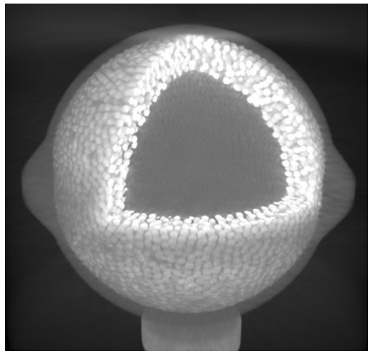
Uncertainty from nuclear data for the effective multiplication factor of the Molten Salt Reactor Experiment

Reaction	Uncertainty, pcm
^{235}U nu	373
^{12}C elastic	263
^{238}U capture	257
^{7}Li capture	197
^{235}U capture	171
^{19}F elastic	143
^{235}U fission	120

D Shen and et al. “ZERO-POWER CRITICALITY BENCHMARK EVALUATION OF THE MOLTEN SALT REACTOR EXPERIMENT”

Data Requirements for Criticality Safety

- Massive scale-up of HALEU/TRISO transportation capability necessary
  - 100,000s of fuel pebbles per reactor
  - Transportation solutions for HALEU advanced reactor fuel are limited (ORNL/TM-2024/3248)
- National labs are evaluating existing data and DNCSH is enabling new benchmarks.
- Characteristic KP-fuel transport conditions involve:
  - Graphite moderation | Graphite-water moderation for upset conditions
  - Annular fuel pebbles with TRISO fuel, 19.75% enrichment
  - Steel structural components
  - Boron absorbers



Conclusions

- Nuclear data needs for FHRs are not unique
- Demonstration reactors will be used to bridge gaps in nuclear data, where possible
- Optimized deployment of advanced reactors requires improvements in nuclear data
- Massive ramp-up in the 2030s requires work to begin now
- Cross-community collaboration will be vital

Questions?