April 21, 2022

TP-LIC-LET-0017
Project Number 99902100

U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001
ATTN: Document Control Desk

Subject: TerraPower Fuel Cycle: Environmental Impacts Meeting Material

This letter provides the TerraPower, LLC presentation material for the upcoming "Fuel Cycle: Environmental Impacts" pre-application engagement meeting (Enclosures 2 and 3). The presentation material contains proprietary information and as such, it is requested that Enclosure 2 be withheld from public disclosure in accordance with 10 CFR 2.390, "Public inspections, exemptions, requests for withholding." An affidavit certifying the basis for the request to withhold Enclosure 2 from public disclosure is included as Enclosure 1. The proprietary material has been redacted from the presentation material in Enclosure 3.

This letter and enclosures make no new or revised regulatory commitments.

If you have any questions regarding this submittal, please contact Ryan Sprengel at rsprengel@terrapower.com or (425) 324-2888.

Sincerely,

Ryan Sprengel
License Application Development Manager
TerraPower, LLC

Enclosures:
1. TerraPower, LLC Affidavit and Request for Withholding from Public Disclosure (10 CFR 2.390(a)(4))
2. “Fuel Cycle: Environmental Impacts” Presentation Material – Proprietary (Non-Public)
3. “Fuel Cycle: Environmental Impacts” Presentation Material – Non-proprietary (Public)

cc: William (Duke) Kennedy, NRC
Mallecia Sutton, NRC

ENCLOSURE 1

TerraPower, LLC Affidavit and Request for Withholding from Public Disclosure (10 CFR 2.390(a)(4))

Enclosure 1
TerraPower, LLC Affidavit and Request for Withholding from Public Disclosure
(10 CFR 2.390(a)(4))

I, George Wilson, hereby state:

1. I am the Director of Regulatory Affairs and I have been authorized by TerraPower, LLC (TerraPower) to review information sought to be withheld from public disclosure in connection with the development, testing, licensing, and deployment of the Natrium™ reactor and its associated fuel, structures, systems, and components, and to apply for its withholding from public disclosure on behalf of TerraPower.

2. The information sought to be withheld, in its entirety, is contained in Enclosure 2, which accompanies this Affidavit.

3. I am making this request for withholding, and executing this Affidavit as required by 10 CFR 2.390(b)(1).

4. I have personal knowledge of the criteria and procedures utilized by TerraPower in designating information as a trade secret, privileged, or as confidential commercial or financial information that would be protected from public disclosure under 10 CFR 2.390(a)(4).

5. The information contained in Enclosure 2 accompanying this Affidavit contains non-public details of the TerraPower regulatory and developmental strategies intended to support NRC staff review.

6. Pursuant to 10 CFR 2.390(b)(4), the following is furnished for consideration by the Commission in determining whether the information in Enclosure 2 should be withheld:

   a. The information has been held in confidence by TerraPower.

   b. The information is of a type customarily held in confidence by TerraPower and not customarily disclosed to the public. TerraPower has a rational basis for determining the types of information that it customarily holds in confidence and, in that connection, utilizes a system to determine when and whether to hold certain types of information in confidence. The application and substance of that system constitute TerraPower policy and provide the rational basis required.

   c. The information is being transmitted to the Commission in confidence and, under the provisions of 10 CFR 2.390, it is received in confidence by the Commission.

   d. This information is not available in public sources.

   e. TerraPower asserts that public disclosure of this non-public information is likely to cause substantial harm to the competitive position of TerraPower, because it would enhance the ability of competitors to provide similar products and services by reducing their expenditure of resources using similar project methods, equipment, testing approach, contractors, or licensing approaches.

I declare under penalty of perjury that the foregoing is true and correct.
Executed on: April 21, 2022

George Wilson

George Wilson
Director of Regulatory Affairs
TerraPower, LLC

ENCLOSURE 2

"Fuel Cycle: Environmental Impacts" Presentation Material

Proprietary (Non-Public)

ENCLOSURE 3

“Fuel Cycle: Environmental Impacts” Presentation Material

Non-proprietary (Public)

NATRIUM

a TerraPower & GE-Hitachi technology

Fuel Cycle: Environmental Impacts

NATD-LIC-PRSNT-0019

SUBJECT TO DOE COOPERATIVE AGREEMENT NO. DE-NE0009054

Portions of this presentation are considered proprietary and TerraPower, LLC requests it be withheld from public disclosure under the provisions of 10 CFR 2.390(a)(4).

Nonproprietary versions of this presentation indicate the redaction of such information using [[ ]]$^{(a)(4)}$.

Objectives

- Natrium™ reactor overview

Natrium Fuel Cycle Overview

- Fuel pin and assembly characteristics
- Introduction of Type 1B fuel
- Fuel cycle and waste management

Fuel Fabrication and Transportation

- Fuel fabrication and sourcing
- Shipping container, transportation mode, distance

Spent Fuel Management

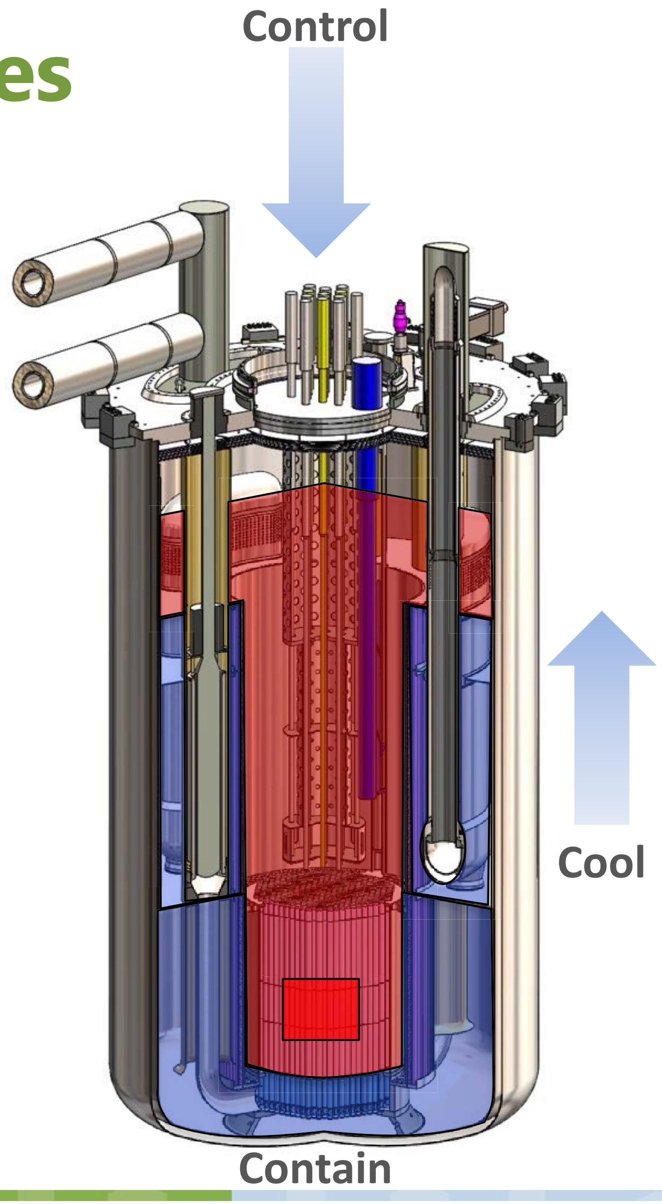
- Spent fuel handling path
- Interim storage and disposal
- Long-term disposal options

Natrium Reactor Overview

- Regulatory Engagement Plan was submitted 6/8/2021
- Construction Permit Application submittal planned for 8/2023
- Pre-application interactions are ongoing, intended to reduce regulatory uncertainty and facilitate the NRC's understanding of the Natrium advanced reactor and its safety case
- The Natrium Reactor is demonstrating the ability to design, license, construct, startup and operate the Natrium reactor within a seven-year timeframe

Natrium Safety Features

- Pool-type Metal Fuel SFR with Molten Salt Energy Island
  - Metallic fuel and sodium have high compatibility
  - No sodium-water reaction in steam generator
  - Large thermal inertia enables simplified response to abnormal events
- Simplified Response to Abnormal Events
  - Reliable reactor shutdown
  - Transition to coolant natural circulation
  - Indefinite passive emergency decay heat removal
  - Low pressure functional containment
  - No reliance on Energy Island for safety functions
- No Safety-Related Operator Actions or AC power
- Technology Based on U.S. SFR Experience
  - EBR-I, EBR-II, FFTF, TREAT
  - SFR inherent safety characteristics demonstrated through testing in EBR-II and FFTF



Control

- Motor-driven control rod runback
- Gravity-driven control rod scram
- Inherently stable with increased power or temperature

Cool

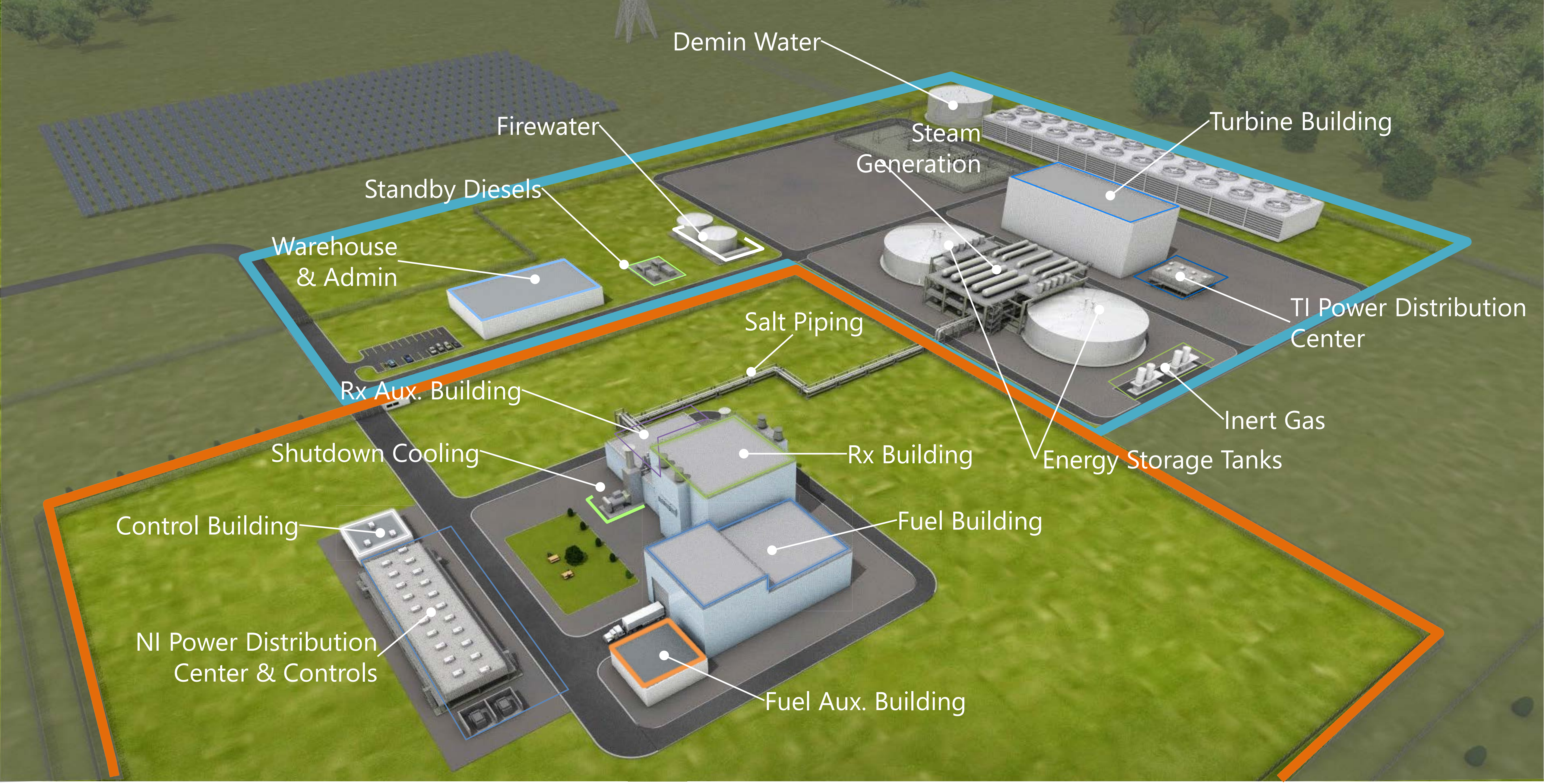
- In-vessel primary sodium heat transport (limited penetrations)
- Intermediate air cooling natural draft flow
- Reactor air cooling natural draft flow – always on

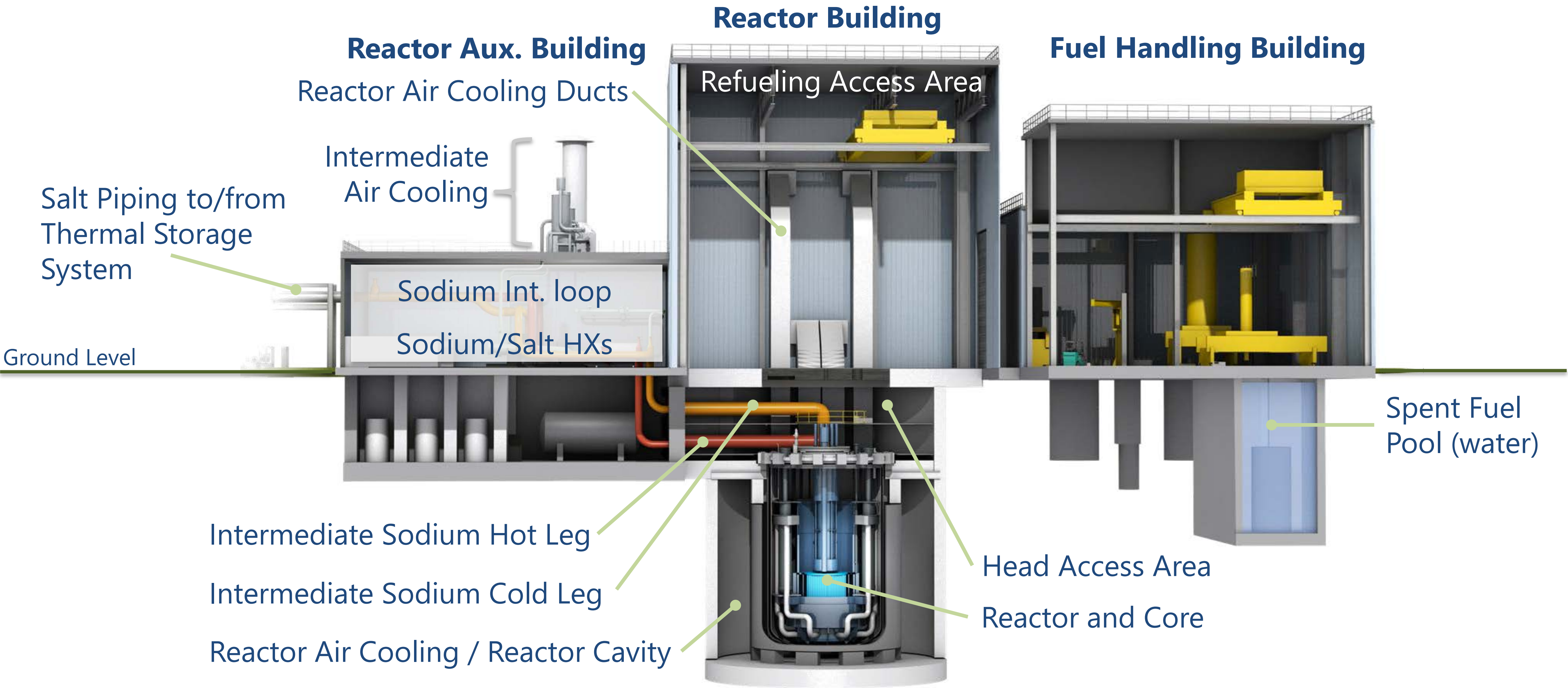
Contain

- Low primary and secondary pressure
- Sodium affinity for radionuclides
- Multiple radionuclides retention boundaries

SUBJECT TO DOE COOPERATIVE AGREEMENT NO. DE-NE0009054

TerraPower NATRIUM


Demin Water
Firewater
Steam Generation
Turbine Building
Standby Diesels
Warehouse & Admin
TI Power Distribution Center
Salt Piping
Rx Aux. Building
Inert Gas
Shutdown Cooling
Rx Building
Energy Storage Tanks
Control Building
Fuel Building
NI Power Distribution Center & Controls
Fuel Aux. Building


Reactor Building
Reactor Aux. Building
Fuel Handling Building
Refueling Access Area
Reactor Air Cooling Ducts
Intermediate
Air Cooling
Salt Piping to/from
Thermal Storage
System
Sodium Int. loop
Sodium/Salt HXs
Ground Level
Spent Fuel
Pool (water)
Intermediate Sodium Hot Leg
Intermediate Sodium Cold Leg
Reactor Air Cooling / Reactor Cavity
Head Access Area
Reactor and Core

Natrium Fuel Cycle Overview

Natrium Commercial Fuel System

- Designed to be the first economically viable, once-through fast reactor fuel system.
- The original fuel development program was designed for the Traveling Wave Reactor (TWR®) with over 500 DPA, 28%+ FIMA burnup, and long time at temperature residences to support breed-and-burn operations.
- However, the Natrium fuel system has substantially lower requirements.
- Significant improvements compared to the legacy sodium bonded, metal fuel pin system:
  – Increase DPA tolerant ferritic-martensitic steels
  – Fuel cladding chemical interaction resistant
  – High burnup U-0Zr, mechanically bonded fuel system

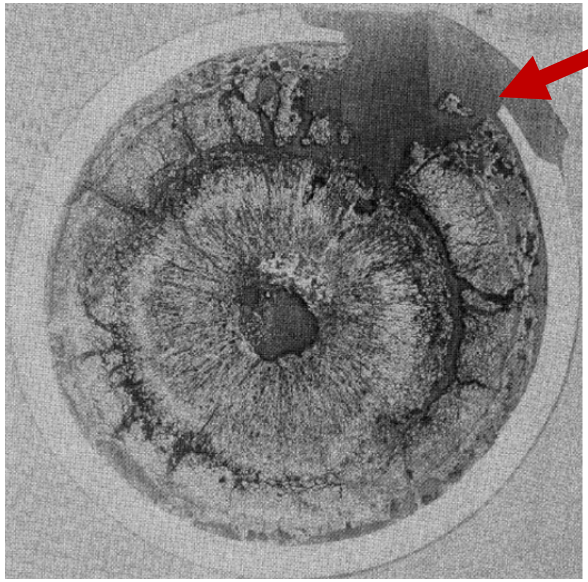
Metal Fuel Cladding Failures Are Non-Eventful

Historic test of fuel operation with breached cladding

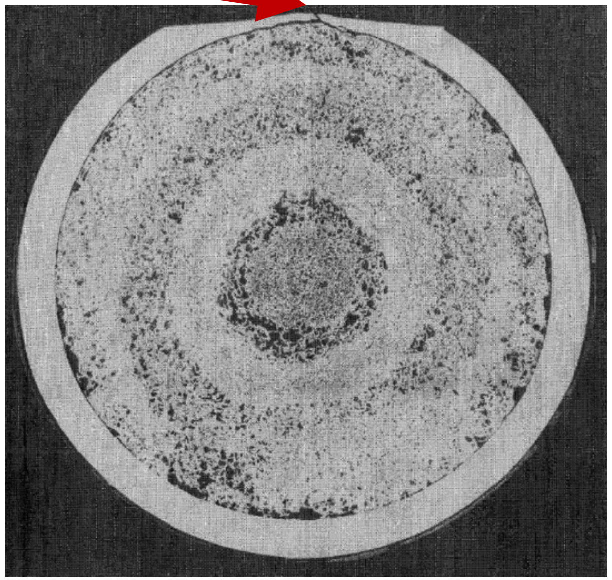
Oxide fuel - 9% burnup
Gross enlargement of breach site due to generation of low-density, sodium-fuel reaction products resulting in fuel loss

Metal fuel - 12% burnup, after 169 days
No indication of breach size increase
Metal fuel compatible with sodium

Engineered defects



If cladding fails and operation at power continues, no fuel is lost to coolant.

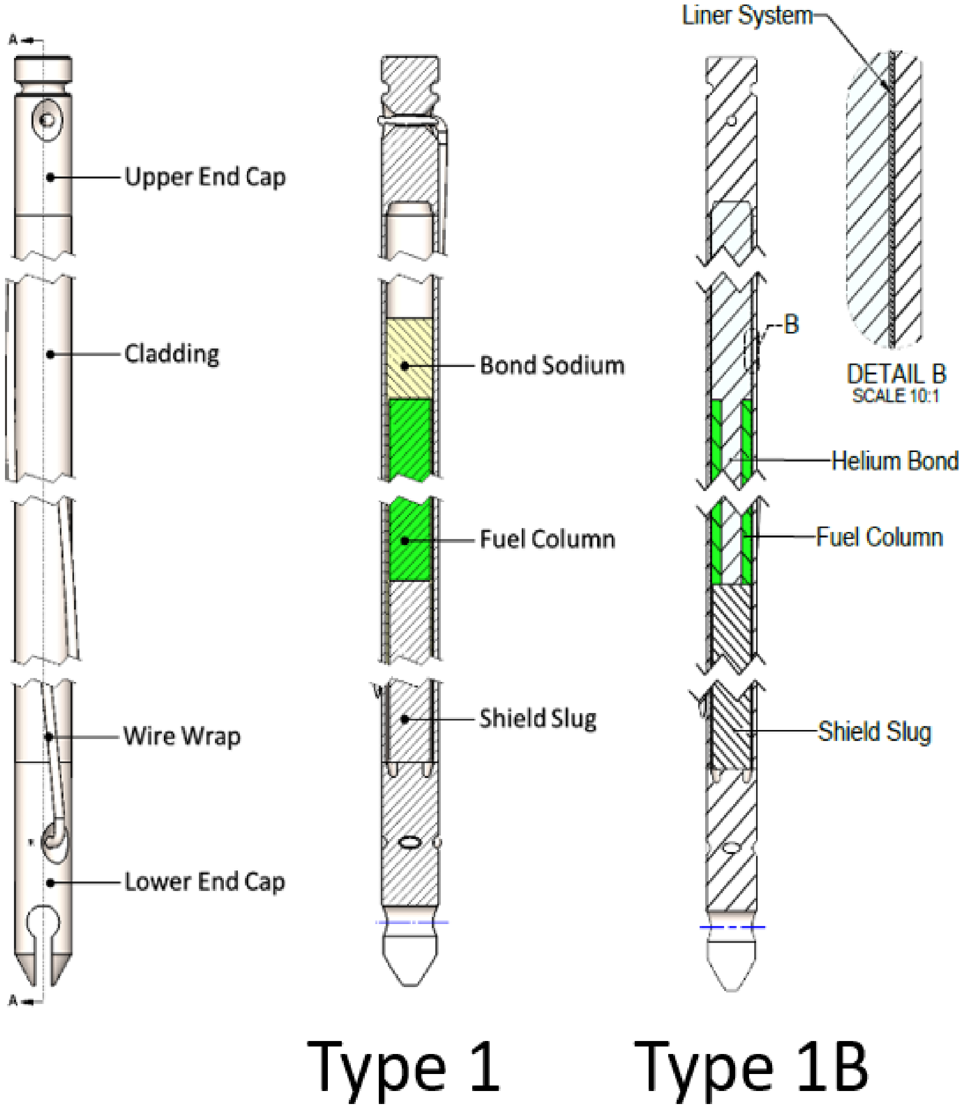


Source of Images: Y. Chang, Nuclear Engineering and Technology, Vol. 39 No.3, June 2007

TerraPower NATRIUM

Natrium Fuel System – Fuel Pins

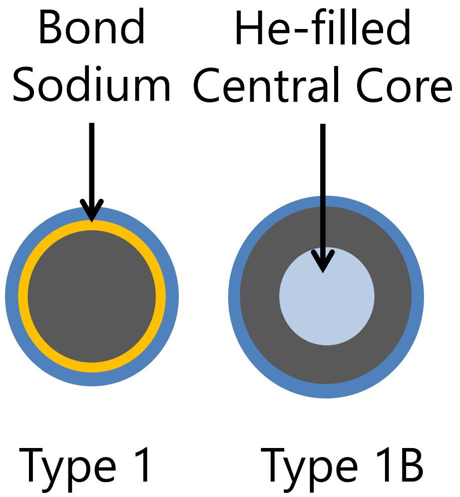
- Natrium fuel pins employ a metal fuel system instead of oxides
  - U-10Zr fuel for the Type 1 fuel system
  - U-0Zr fuel for the Type 1B fuel system
- Type 1 fuel is based on previous fast reactor experience
  - Sodium bonded, slug metal fuel
  - Shield slugs within the pin with fission gas plenum
- Type 1B is a next generation fuel system
  - Mechanically bonded, no zirconium, annular fuel
  - Liner system to prevent Fuel Cladding Chemical Interactions (FCCI)
  - Shield slugs within the pin with fission gas plenum
  - Allows for significant increase in fuel pin lifetime to support high burnup, high DPA fuel system

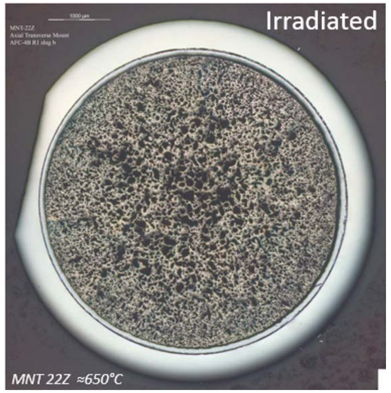


Type 1B Fuel Design

[[

- Larger diameter
- No zirconium alloying
- Annular fuel
- Lower smear density (cross-section fraction of fuel to cladding interior)
- No sodium bond
- [[ ]](a)(4) cladding
- Liner system





]](a)(4)

* Values under evaluation for Natrium Demo

TerraPower NATRIUM

Achieved Type 1B Peak Burnup in Fuel Irradiation Tests

[[

]](a)(4)

Achieved Type 1B Peak Burnup in Fuel Irradiation Tests

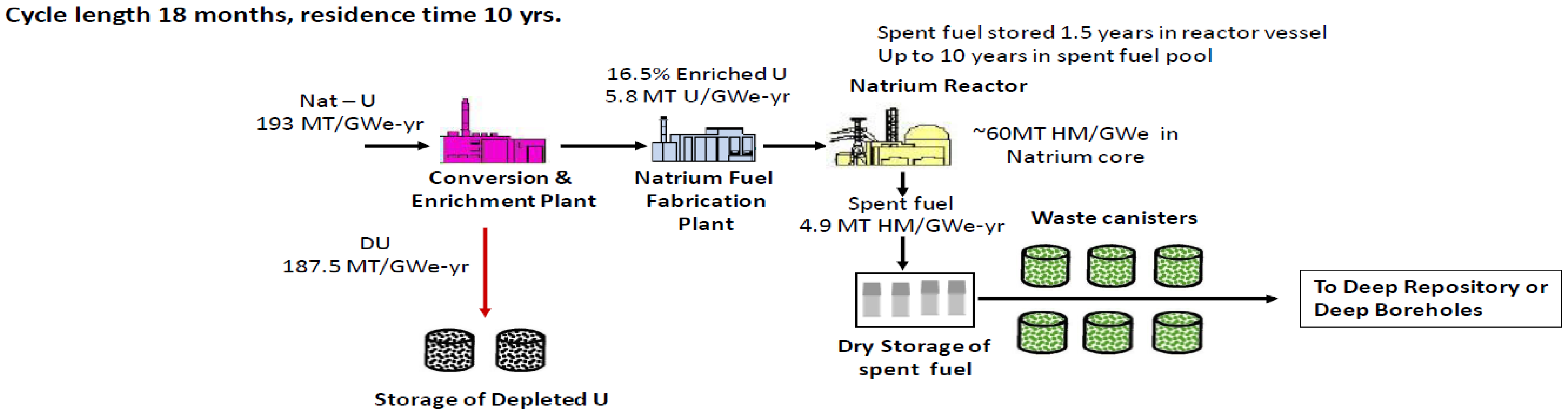
[[

]](a)(4)

Natrium Fuel Cycle Example (18 months)

[[

]](a)(4)



Fuel Fabrication and Transportation

Fuel Form for Initial Core (ARDP Deliverable)

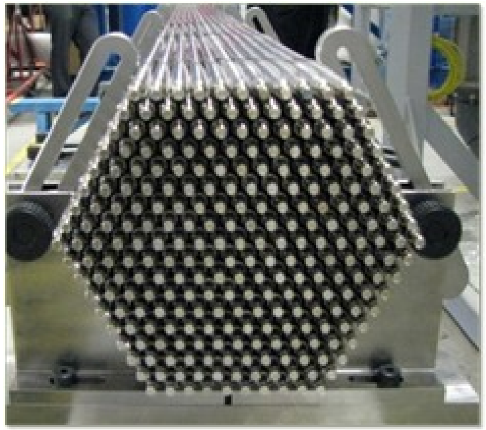
Input feed stock form

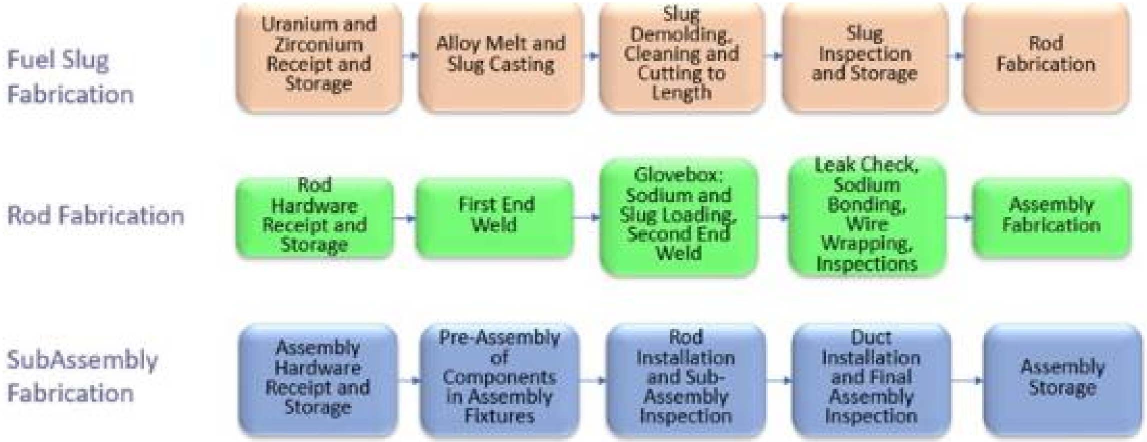
- Metallic fuel with sodium bonding
- Up to 19.75% enriched feed material

Metallic fuel fabrication

- Feed material cast with melted zirconium to form a slug, processed into a rod
- Up to 19.75% enriched fuel rods
- [[

]](a)(4)



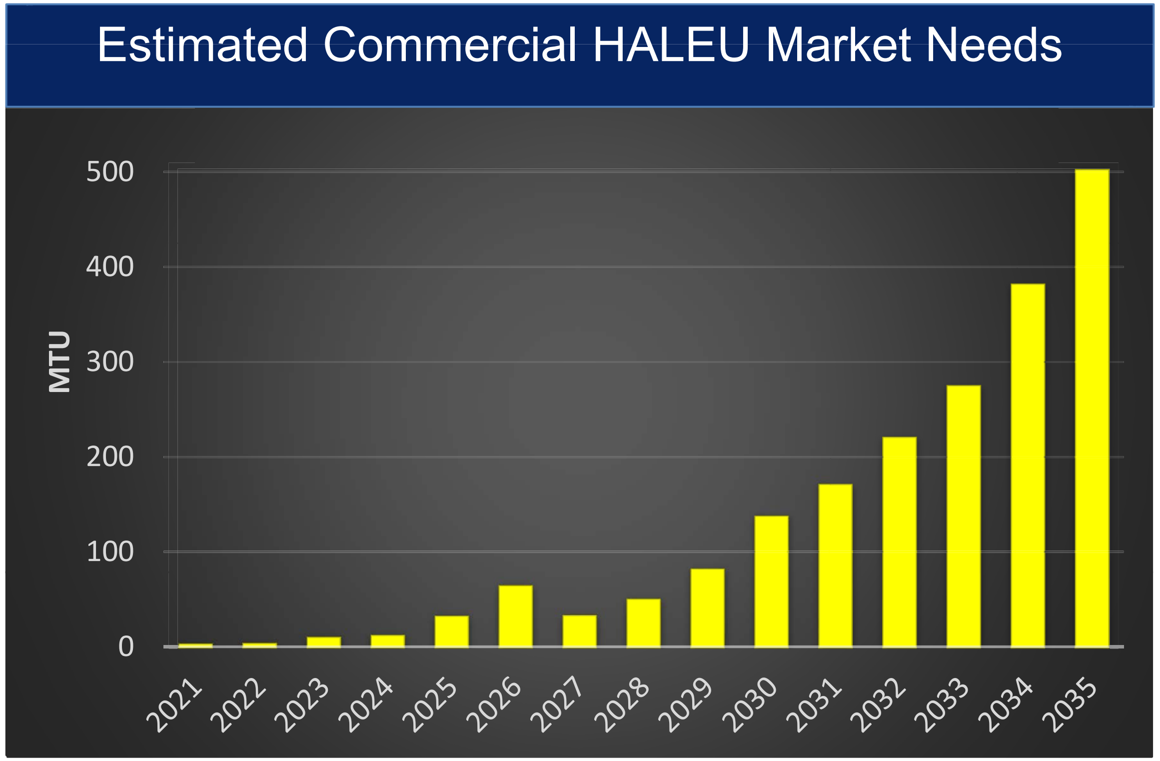


Why Higher Assay LEU?

Sodium fast reactors require a higher U235 density to maintain criticality

Solution: HALEU

- Metallic uranium fuel requiring assays up to 19.75 wt% U235
- HALEU commercial market is expected to grow



This projection does not account for potential DoD needs

Source: NEI Letter to DOE Secretary Brouillette (July 23, 2020)

TerraPower NATRIUM

Fuel Fabrication for Unirradiated Natrium Fuel Assemblies

- [[
  ]](a)(4)

- License application will be submitted to US NRC for review and approval

Shipping Container Package for Unirradiated Natrium Fuel Assemblies

- GNF-A will design and test a new fresh fuel shipping container per applicable NRC regulations

- License application will be submitted to NRC for review and approval

- Approach is similar to current shipping container packages for LWRs

Fresh Fuel Transport Mode and Distance

- Proposed transportation is via truck, similar to LWR fresh fuel
- Security measures will be taken per applicable NRC requirements
- Transport distance between [[ ]](a)(4) and Kemmerer, WY is approximately [[ ]](a)(4)

Spent Fuel Management

Natrium Spent Fuel Path

1. In Vessel Storage
2. Ex-vessel Storage Tank
3. Pool Immersion Cell
4. Spent Fuel Pool
5. Independent Spent Fuel Storage Installation (ISFSI) Cask Loading
6. ISFSI Storage
7. Ultimate Disposal

SUBJECT TO DOE COOPERATIVE AGREEMENT NO. DE-NE0009054

Interim Storage and Disposal Approach

- The Natrium fuel composition is different from conventional commercial nuclear fuel:
  - Metal fuel material (vs. ceramic)
  - Sodium bond in Type 1 startup fuel
  - Higher burnup resulting in higher fission product inventory per unit mass
  - Ferritic-martensitic cladding material (vs. zirconium)
  - Assembly shape and heat load are different
  - Lower quantity of spent fuel for continued operation with Type 1B fuel

- Although these differences require special consideration, the approach remains similar to an LWR
  - Interim Storage: pursuing dry storage/transportation casks; design of the dry storage system will need to account for Natrium-specific fuel differences
    - Evaluate canister designs for:
      - long term storage given spent fuel differences
      - transportation suitability
  - Disposal: pursuing direct disposal in a geological repository, evaluating:
    - Sandia's 3 repository models
    - Finland's HLW repository model (ONKALO)
    - Deep Isolation's updated deep borehole model

Next Steps

- Dry storage system design and analysis supporting NRC licensing of the storage system
- Planning to transition to Type 1B fuel to lower spent fuel volume
- Repository performance assessments to demonstrate Natrium fuel can meet repository criteria, such as acceptable dose rate at receptor site
- Engagement with DOE spent fuel program regarding the Standard Contract for Natrium SNF and acceptability of the Natrium approach
- Future engagement with NRC by several organizations will be needed to establish the licensing paths under 10 CFR 71 and 72 for the packaging and transportation systems and interim storage of Natrium SNF
- 2022 Q4 Natrium demonstration project pre-application meeting to discus fuel transfer from in-vessel to ex-vessel storage

Questions?

Acronym List

ARDP – Advanced Reactor Demonstration Program
DOE – Department of Energy
DPA – Displacement per Atom
DU – Depleted Uranium
EBR – Experimental Breeder Reactor
FCCI – Fuel Cladding Chemical Interactions
FFTF – Fast Flux Test Facility
FIMA – Fissions per Initial Metal Atom
GNF-A – Global Nuclear Fuels – Americas LLC
GWe – Gigawatt Electric
GWe-yr – Gigawatt Electric Year
HALEU – High-Assay Low-Enriched Uranium
HLW – High-Level Waste
HM – Heavy Metal
HX – Heat Exchanger
INL – Idaho National Laboratory
Int. – Intermediate
ISFSI – Independent Spent Fuel Storage Installation
LEU – Low-Enriched Uranium
LMP – Licensing Modernization Project
LWR – Light-Water Reactor
MT – Metric Ton
MTU – Metric Ton Uranium
NRC – Nuclear Regulatory Commission
SFR – Sodium Fast Reactor
SNF – Spent Nuclear Fuel
TREAT – Transient Reactor Test
TWR – Traveling Wave Reactor