ADVANCED RESEARCH PROJECT AGENCY – ENERGY (ARPA-E) EFFORTS SUPPORTING *ADVANCED NUCLEAR*

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Outline

Introduction to ARPA-E

ARPA-E Advanced Nuclear Portfolio

Potential Program Development

Final Thoughts

ARPA-E Mission

Goal 1: To enhance the economic and energy security of the United States through the development of energy technologies that—

What Makes an ARPA-E Project?

IMPACT

- High impact on ARPA-E mission areas
- Credible path to market
- Large commercial application

TRANSFORM

- Challenges what is possible
- Disrupts existing learning curves
- Leaps beyond today's technologies

BRIDGE

- Translates science into breakthrough technology
- Not researched or funded elsewhere
- Catalyzes new interest and investment

TEAM

- Comprised of best-in-class people
- Cross-disciplinary skill sets
- Translation oriented

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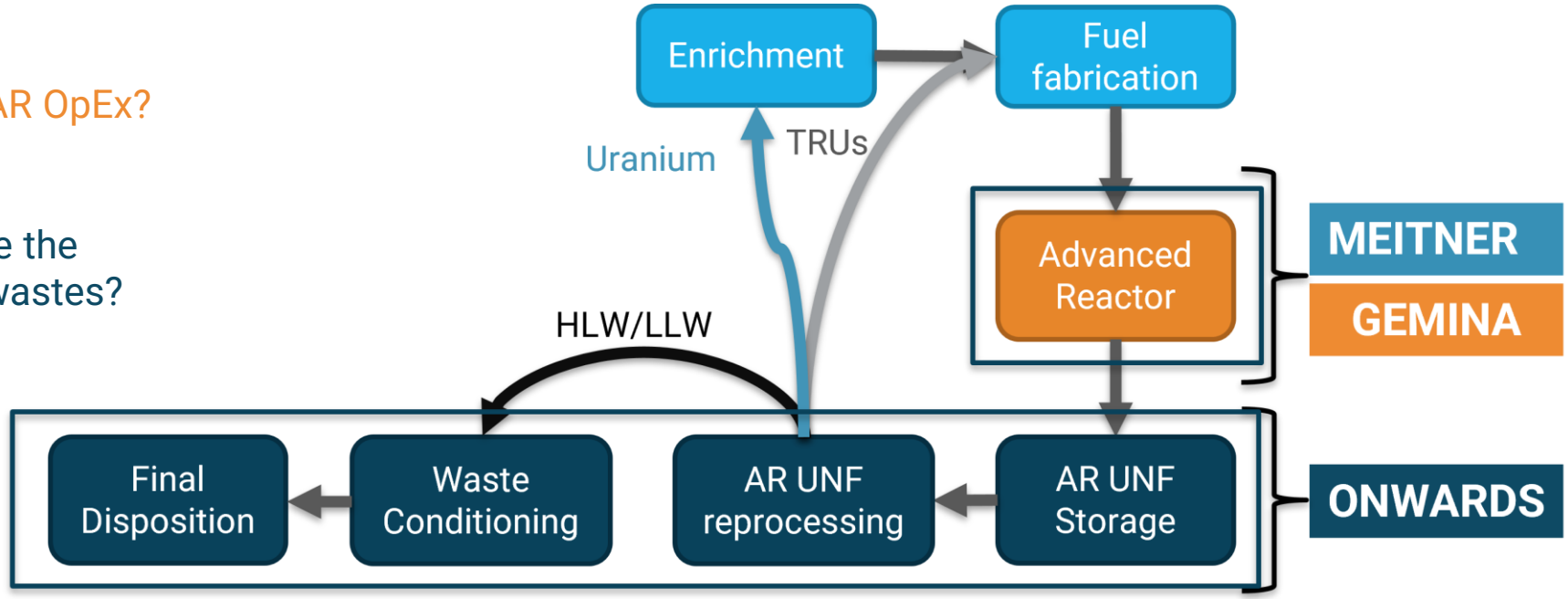
ARPA-E Advanced Nuclear Portfolio

- Fission
  - **MEITNER**
    - Can we greatly reduce AR CapEx?
  - **GEMINA**
    - Can we greatly reduce AR OpEx?
  - **ONWARDS**
    - Can we greatly minimize the disposal impact of AR wastes?
- Fusion
  - BETHE
  - ALPHA
  - GAMOW



MEITNER (Modeling-Enhanced Innovations Trailblazing Nuclear Energy Reinvigoration)

- **Goal:** Develop and demonstrate technologies that **greatly improve advanced reactor** performance

MEITNER is supporting transformative technologies for AR plant designs that simultaneously achieve:

- **Low overnight construction cost**
- **Largely autonomous operations to staffing level**
- **Safety when considering**
  - **time before intervention in an accident**
  - **potential for public exposure to radiation**
- **Very short on-site construction time**
- **Proliferation resistance via safeguards by design**
- **The ability to achieve either or both:**
  - **easy electrical grid integration with intermittent sources such as wind and solar**
  - **availability to provide economical industrial process heat**

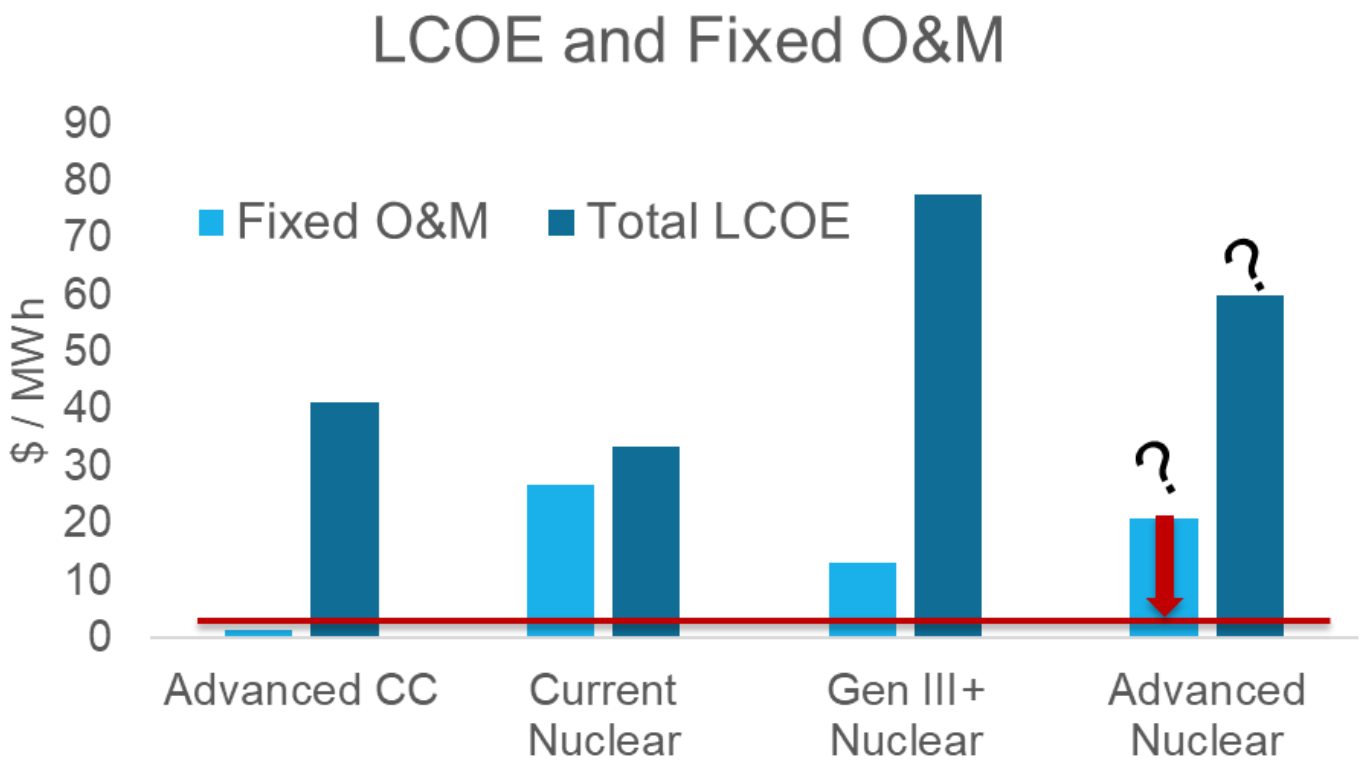
Metric	Units	State-of-the-Art
Overnight construction cost	$/$W_e$	2-7
On-site construction time	Months	> 60
Total staffing level (on-site & off-site)	FTE/GW_e	450-750
Emergency planning zone (EPZ)	Miles	10 and 50
Time before human response required for an accident	Days	3
Onsite backup power	kW_e	> 0 kW
Ramp rate without steam bypass	power capacity/min	5%
Process heat temperature	ºC	N/A

GEMINA (Generating Electricity Managed By Intelligent Nuclear Assets)

- **Goal:** Develop the tools and cost basis for ARs to **achieve fixed O&M costs of $2/MWh** without shifting costs to other parts of LCOE

Awardee teams are developing the following for one or more of the most promising AR designs:

- **Digital twins for advanced reactor systems**
- **Relevant cyber physical systems**
- **O&M approaches for advanced reactors**
- **Cost models and design updates**

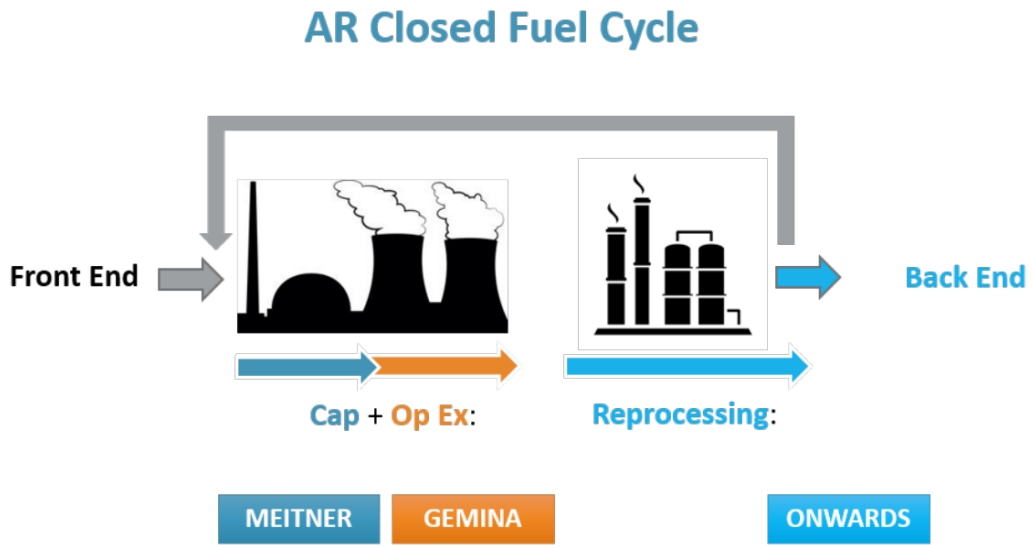


ONWARDS (Optimizing Nuclear Waste and Advanced Reactor Disposal Systems)

- **Goal:** Develop technologies to **significantly minimize the disposal impact** of wastes from ARs while maintaining disposal costs in the range of **$1/MWh**

ONWARDS seeks to support the development of technologies that enable:

- **10x reduction in waste volumes or repository footprint with no weakening of safeguards standards**
  - **Better than 1% accuracy in fissile mass measurement in UNF processing in high-radiation backgrounds**
- **Improving proliferation resistance of U and TRU materials recycling**
  - **No pure fissile material streams produced during processing (< 0.1% actinides by mass in waste streams)**
- **High performance waste forms for AR HLW across multiple disposal environments.**



The production of new waste streams is required to be minimal relative to a once-through fuel cycle and have an established path to a robust waste form or final disposition.

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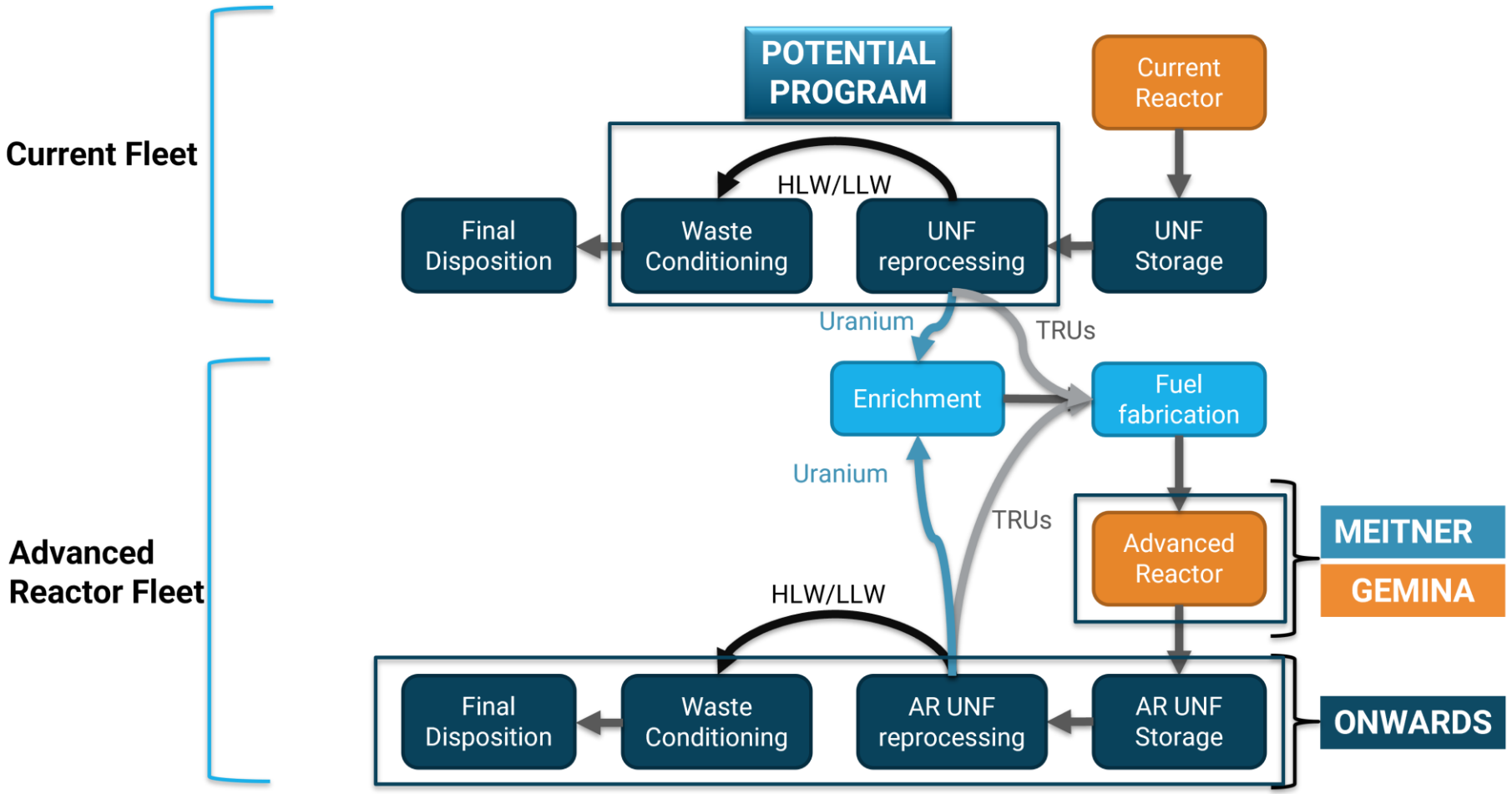
Potential Program Opportunities

- Safeguards & Security
  - Can we enable near real-time detection of diversion and intrusion?
- Waste Management
  - Can we improve HLW/LLW management while supporting advanced nuclear?
- Economics
  - Can facility CapEx be managed to stabilize a cost-competitive & secure domestic fuel supply for ARs?



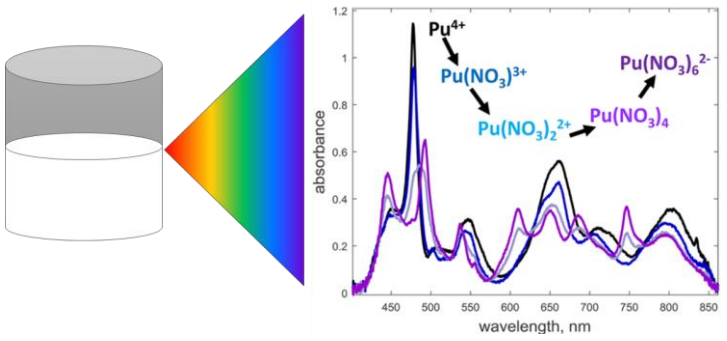
arpa·e CHANGING WHAT'S POSSIBLE

Safe, Secure, and Affordable Technology is the ARPA-E hard problem

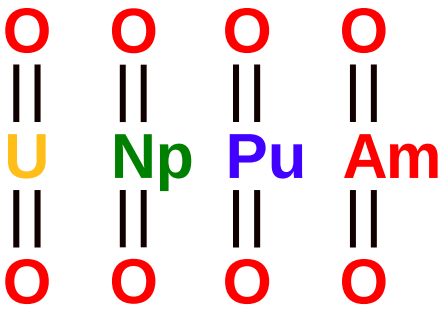
Areas for transformational change

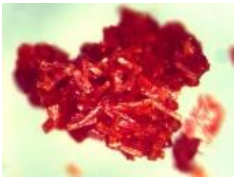
- Conducted 60+ stakeholder interviews
- Issued RFI on reprocessing and safeguards technology gaps, reprocessing facility design, AR fuel needs, and economics
- Held two-day workshop with 100+ nuclear and non-nuclear stakeholders

Sensors/Online Monitoring



Chemistry





Modular & Safeguards Based Design

Automation / AI / Digital Solutions

Promising Approaches

Multimodal Sensors

- Decrease cost by minimizing lab footprint, improving management timelines
- Facility and materials security

Process Intensification

- Compression of front-end unit operations
- Remove reagents to shrink waste and footprint
- Aqueous and fluoride volatility have options for transuranic co-recovery

Facility Design

- Old vs New Fuel
- Modularity & PI needs to be considered
- Safeguards by design
- Valuable byproduct recovery

Processing using **real-time monitoring**, with **transuranic co-recovery**, and eliminating **material accumulation** enables advanced nuclear energy by providing defense in depth for materials and facilities, minimizing the disposal impact of legacy nuclear materials, while securing AR fuel needs and establishing **U.S. leadership**

Current Status

- **Goal:** To enable environmentally responsible, economic, and secure recycling of the Nation's existing 86,000 MT of commercial LWR UNF to minimize its disposal impact, improve resource utilization, and support advanced reactor fuel needs.

Potential technologies that support this would provide

- A **10x reduction in** waste volumes or repository footprint
  - Enable ***complete*** (>99%) actinide consumption
- ***Real-time*** or ***near real-time*** detection of UNF diversion
- ***Global system disposal costs*** of ~$1.00/MWh
- A co-recovered ***U/TRU product***
- A ***cost-competitive source*** of HALEU fuel

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ARPA-E seeks technical solutions to make a transformational impact in support of nuclear energy and waste management.

- Program Directors are provided resources to identify new technical white spaces
- Interactions with DOE-EM are initiating
- Coordination between DOE offices and agencies are crucial
  - DOE-NE
  - DOE-NNSA
  - DOE-SC

U.S. DEPARTMENT OF ENERGY

https://arpa-e.energy.gov