INL/MIS-23-71026-Revision-0

Sustaining and Optimizing the Existing Fleet

July 2023

Bruce P Hallbert

Changing the World's Energy Future

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Idaho National Laboratory
Idaho Falls, Idaho 83415

http://www.inl.gov

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LWRS
LIGHT WATER REACTOR SUSTAINABILITY

Bruce P Hallbert, Ph.D.
Director, Light Water Reactor Sustainability Program
Technical Integration Office

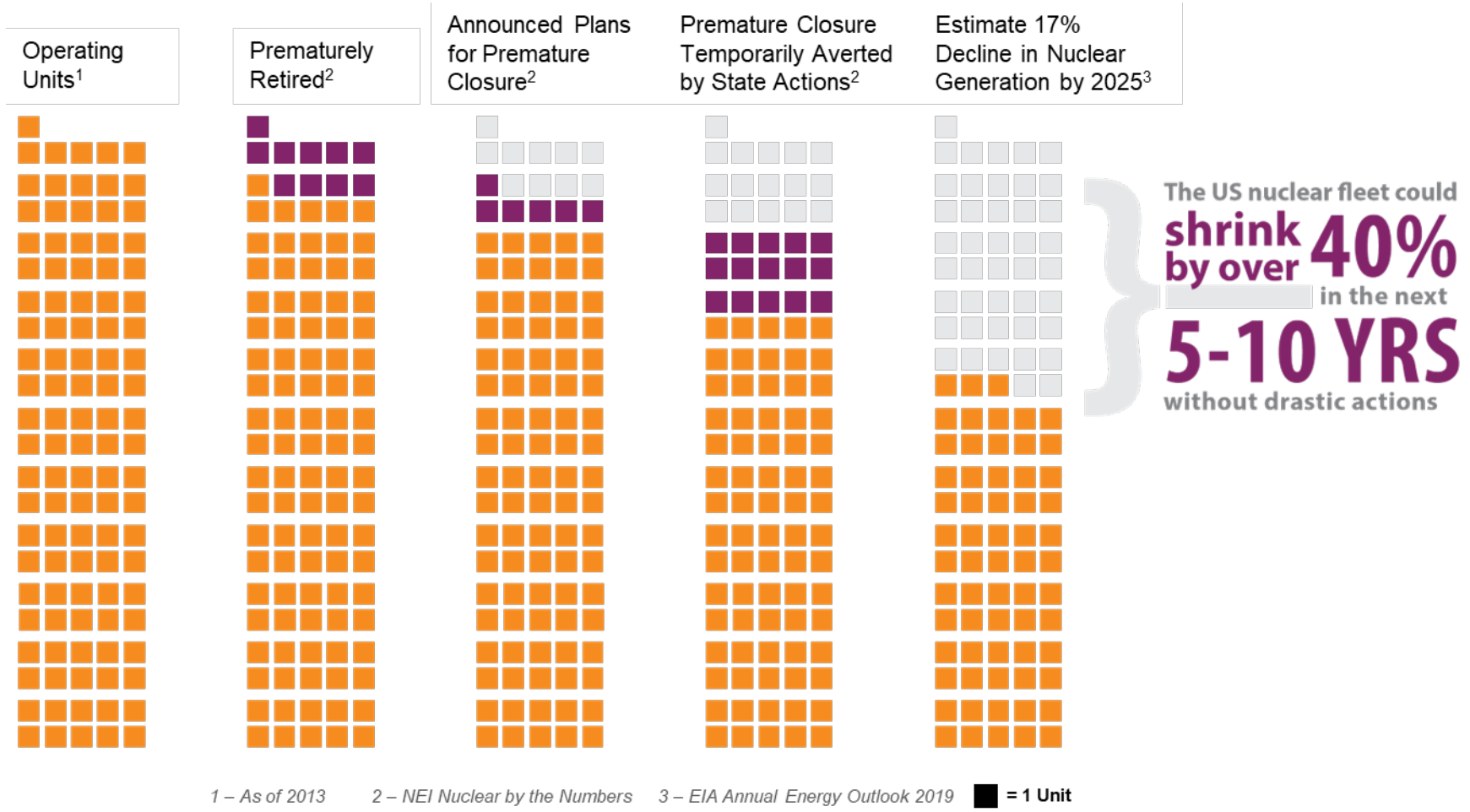
Sustaining and Optimizing the Existing Fleet

The Challenge

"These early retirements are noteworthy, since the cost to construct the reactors is sunk. Even in a market where building a new plant would be unprofitable, the continued operation of a well-maintained and operated plant might be expected to be profitable. A decision to close means the wholesale price of electricity does not even cover a plant's ongoing operating and maintenance costs, including any capital investments needed to keep the facility in safe working order."

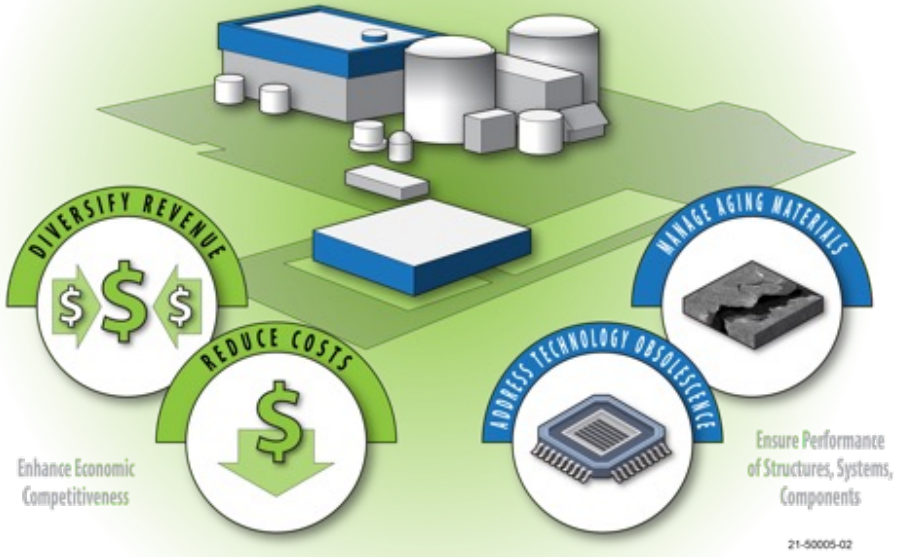
MIT, The Future of Nuclear Power in a Carbon Constrained World

MIT – Massachusetts Institute of Technology
NEI – Nuclear Energy Institute
EIA – Energy Information Agency
US – United States



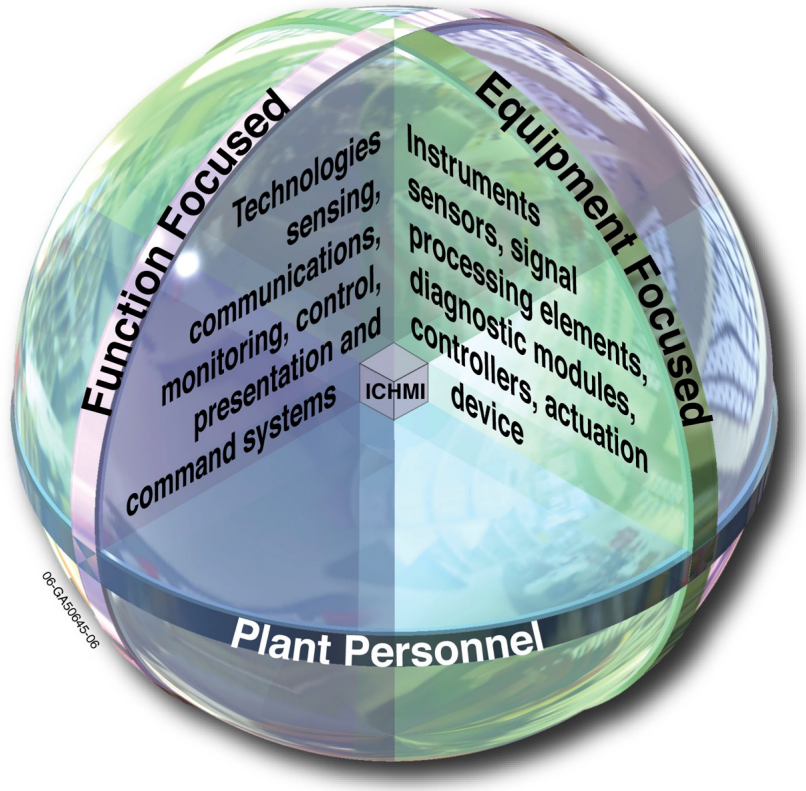
Light Water Reactor Sustainability Program

- Goal
  - Enhance the safe, efficient, and economical performance of our nation's nuclear fleet and extend the operating lifetimes of this reliable source of electricity
- Objectives
  - Enable long term operation of the existing nuclear power plants
  - Deploy innovative approaches to improve economics and economic competitiveness of LWRs in the near term and in future energy markets
  - Sustain safety, improve reliability, enhance economics
- Focus Areas
  - Plant Modernization Research and Development
  - Flexible Plant Operation and Generation
  - Risk-Informed Systems Analysis
  - Materials Research
  - Physical Security



Modernization is Key to Transformation

- Modernization is vital to achieve cost-competitive operations
  - Digital technology is familiar to the new workforce
  - Enables digital transformation
  - Key to leveraging innovative approaches to business
  - Reduce or eliminate the many causes of human error
- Modernization is necessary but not sufficient to transform
  - Technology offers opportunities
  - Begin with the end in mind
  - Challenge the status quo as you re-engineer processes



Modernize the Fleet

- First echelon safety instrumentation and control systems on two units
- Conceptual Design Phase complete
- Detailed Design Phase in progress
- Multiple pre-submittal meetings with Nuclear Regulatory Commission
- Human Factors efforts well underway
  - Operating Experience Review (Q3–Q4 of 2021)
  - Function Analysis and Allocation Workshop (March 2022)
  - Task Analysis Workshop (May 2022)
- NRC has accepted Constellation's License Amendment Request (December 2022)
- Dynamic preliminary validation set for week of February 20, 2023 at INL with NRC observation.

Constellation

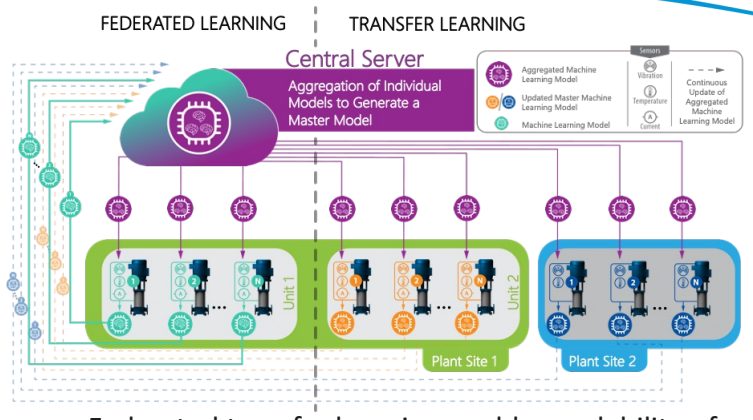
Limerick Generating Station

INL Human Systems Simulation Laboratory Task Analysis Workshop

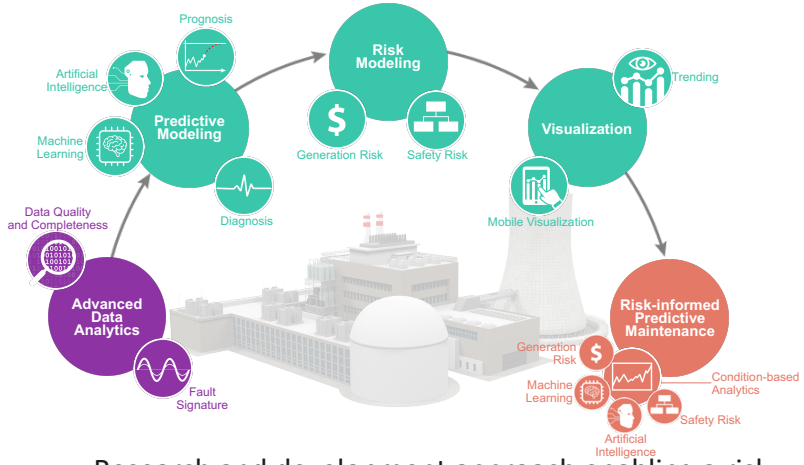
LWRS LIGHT WATER REACTOR SUSTAINABILITY

Risk-Informed Condition Based Maintenance Automation

- The advanced automation technologies developed signifies innovation achieved in
  - Online asset monitoring
  - Predictive data analytics
  - Physics-informed modeling and simulation
  - Risk assessment methodologies
  - User-centric human interface design
- The automation technologies are *scalable* and deployable across plant assets and across the nuclear fleet to achieve risk-informed predictive maintenance strategy
  - Scalability using a Federated Transfer Learning approach was demonstrated on a circulating water system



Federated transfer learning enables scalability of predictive models

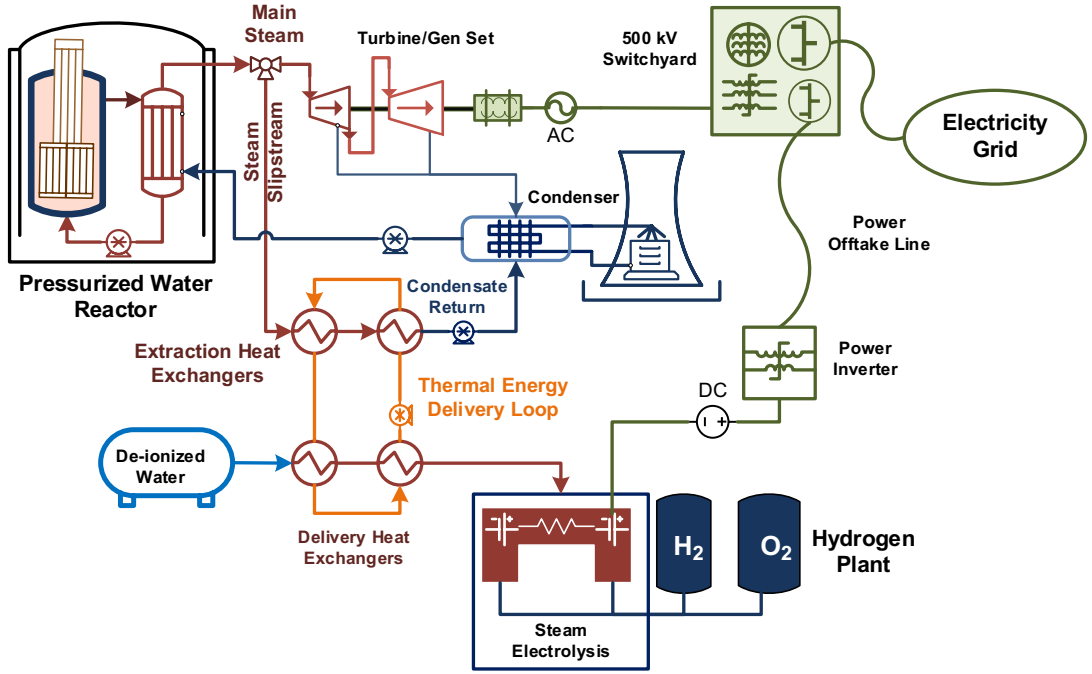


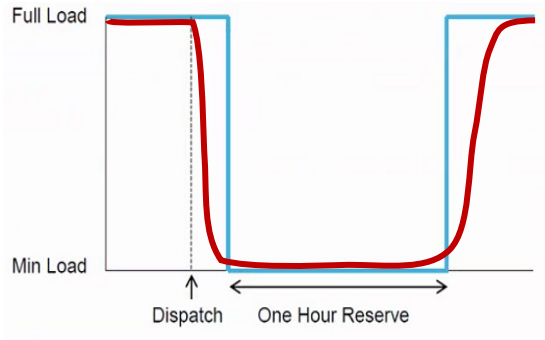
Research and development approach enabling a risk-informed predictive maintenance strategy

The economics of automation achieved through this research is enabling the nuclear industry by transitioning from preventive maintenance program to a risk-informed predictive maintenance strategy

Flexible Plant Operation and Generation

- Goal is to increase nuclear plant revenue and decarbonize the energy sector
- Risks of this new operating paradigm include
  - Hydrogen production and storage safety risks
  - New thermal extraction and delivery systems
  - Modifications to the electricity transmission station
  - Operator control of dynamic dispatch of power
  - New communications between the grid operator and hydrogen plant allow plants to rapidly transition between the grid market and hydrogen production





Nuclear-H_2 Demonstration Projects

Late 2022

Constellation: Nine-Mile Point NPP (~1 MWe LTE)

2023–2024

Energy Harbor: Davis-Besse NPP (~1–2 MWe LTE)

~2024

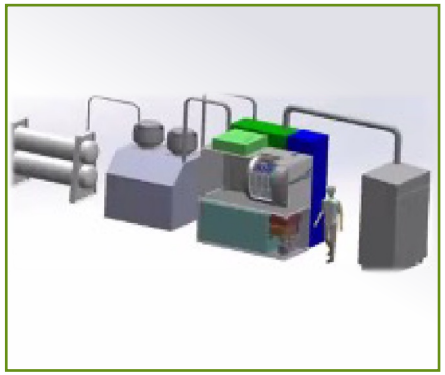
Xcel Energy: Prairie Island NPP ~150 kWe steam

Thermal & Electrical Integration (HTSE/SOEC)

~2024

APS/Pinnacle West Hydrogen: Palo Verde Generating Station (~15–20 MWe LTE)

H_2 Production for Combustion and Synthetic Fuels



FuelCell Energy: Demonstration at INL (250 kW)

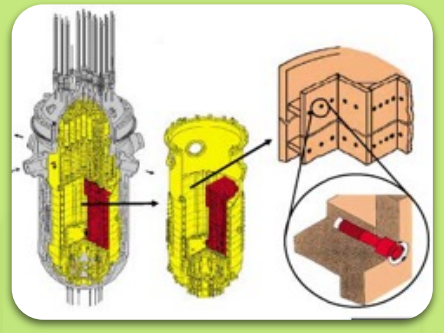
Nuclear energy and SOEC

HTSE – High-temperature steam electrolysis

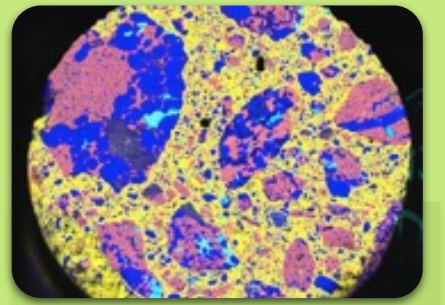
SOEC – Solid oxide electrolysis

Materials Research

Reactor Pressure Vessel

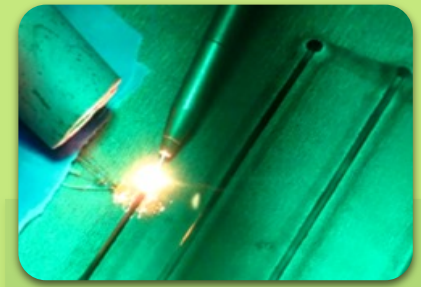


Internals, Pressure Boundaries and Piping



Concrete Degradation

Cable Aging Degradation



Mitigation Methods

Reducing Fuel and Outage Costs

- Evaluations of accident-tolerant fuel with High Burnup
  - Objectives:
    - Economic gains via extended refueling cycle, lower volume of new and spent fuel
- Plant Reload Optimization
  - Objectives:
    - All-inclusive integrated framework for fuel reload analyses
    - Optimization of core configuration to minimize new fuel volume
  - Benefits of Risk-Informed Approach:
    - Allows enhanced optimization of core configuration and further reduction of new fuel volume

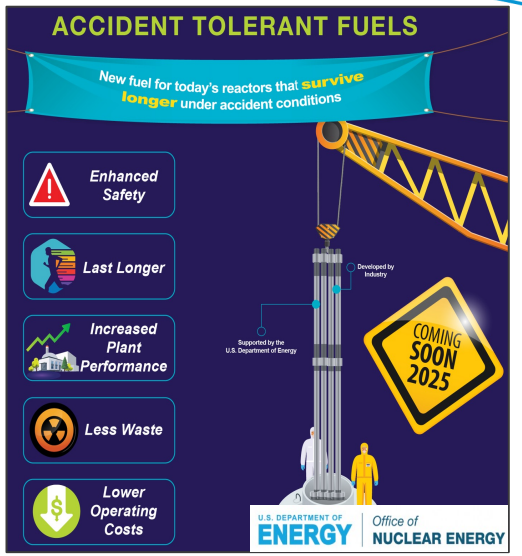
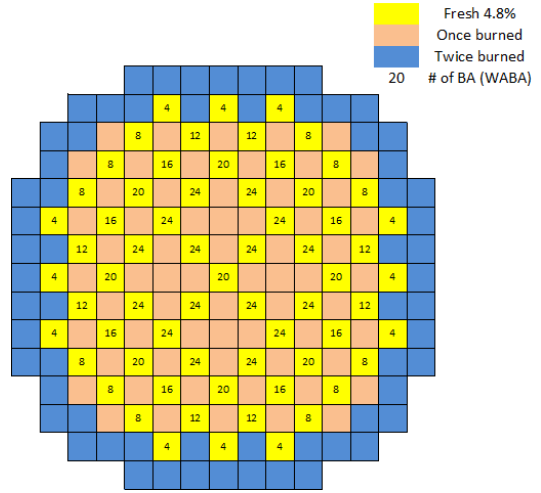


Image Credit: U.S. Department of Energy (link)



Configuration of Reactor Core

Stakeholder Engagement

Develop critical research areas and agreements for demonstrations

+

Develop approach for projects

+

Coordinate project development and deploy results across industry

MOUs with NRC and EPRI

Summary

- Collaborations with industry facilitate progress and exchange in areas of vital common interest
  - Materials, Modernization, Risk-Informed Research, Diversification of Products, Physical Security
- Need for clean and reliable energy from nuclear power underscore the need to address existential challenges facing the existing fleet
  - LWRS research addresses highest priority issues for continued viability and role of nuclear energy
- Projects follow timelines to impact economic competitiveness and long-term operation
  - Address critical needs in aging and obsolescence
  - Demonstrate the means to substantially reduce the costs of ownership
  - Lead transformation from a labor-centric to technology-centric business model

Sustaining National Nuclear Assets

lwrs.inl.gov