LWRS
LIGHT WATER REACTOR SUSTAINABILITY

Jeffrey Brown,
Program Lead

March 18 - 19, 2025

FPOG Stakeholder Engagement Meeting
H_2 Production Implementation Guidance

Agenda

- Background
- Implementation Guidance Overview
- Guidance Details – Implementation Strategic Plan to Conceptual Design
- Key Technical Elements for Utility Assessment of Integrated Hydrogen with U.S. Light Water Reactors
- Compilation of Research Results and Summary of Implementation Guidance for U.S. Light Water Reactors (INL/RPT-24-78729, Rev 0, June 2024)

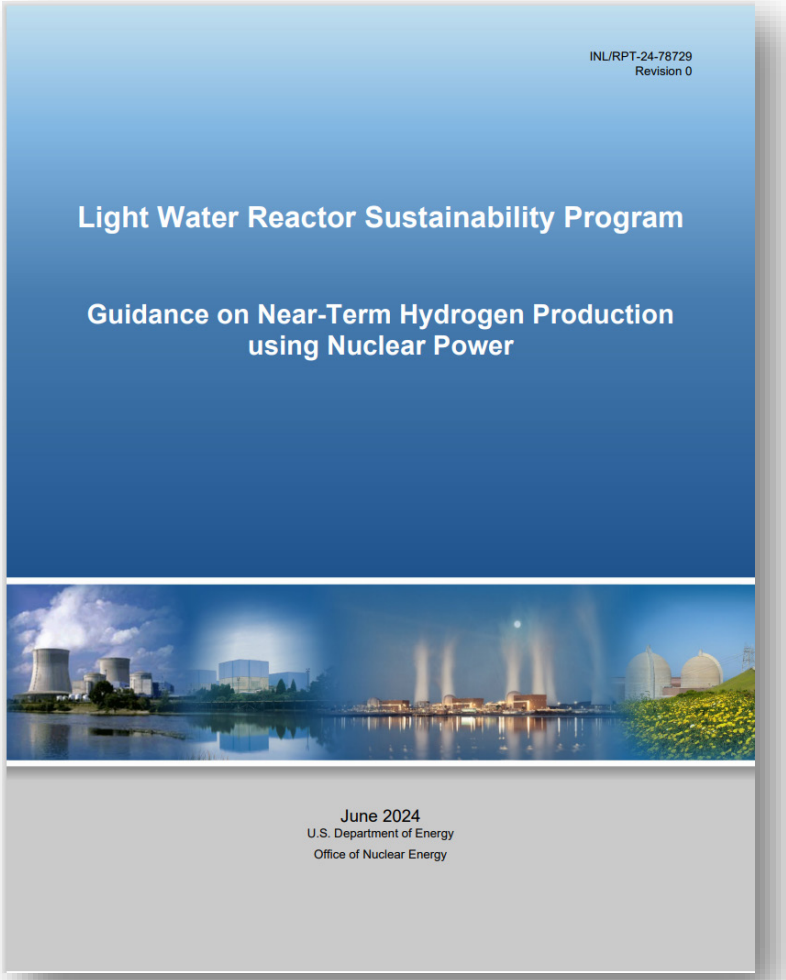
Background

- Department of Energy - Light Water Reactor Sustainability (LWRS) program at Idaho National Laboratory (INL) Flexible Power Operations and Generation (FPOG) Path objectives:
  - Improve nuclear plant economics while accommodating variable renewable generation buildout
  - Advance research and development to assess nuclear power plant (NPP) modifications that enable the use of large-scale thermal energy (steam) and electricity
  - Support technical evaluations for siting, hazards, PRA, Fire Protection, and Licensing of integrated hydrogen systems
  - Support high-temperature steam electrolysis (HTSE) due to its high efficiency and low H2 production cost
- INL Report INL/RPT-24-78729 provides guidance for utilities for developing an Implementation Strategic Plan (ISP) tailored to a specific plant or project
- INL/RPT-24-78729 summarizes the broad technical program results to support utility conceptual plant designs for integrated hydrogen production

Implementation Guidance Overview

- Strategic Planning - Integrated Hydrogen with Nuclear Power
- Initial Business Case Assessment
- Nuclear Plant Assessment – Integrated H_2 Technology
- Utility Design Evaluation - Project Economic Potential

LWRS-FPOG Guidance on Near-Term Hydrogen Production using Nuclear Power provides domestic plants the general framework, analysis tools and supporting analysis to assess the economic factors key to a utility business case assessment



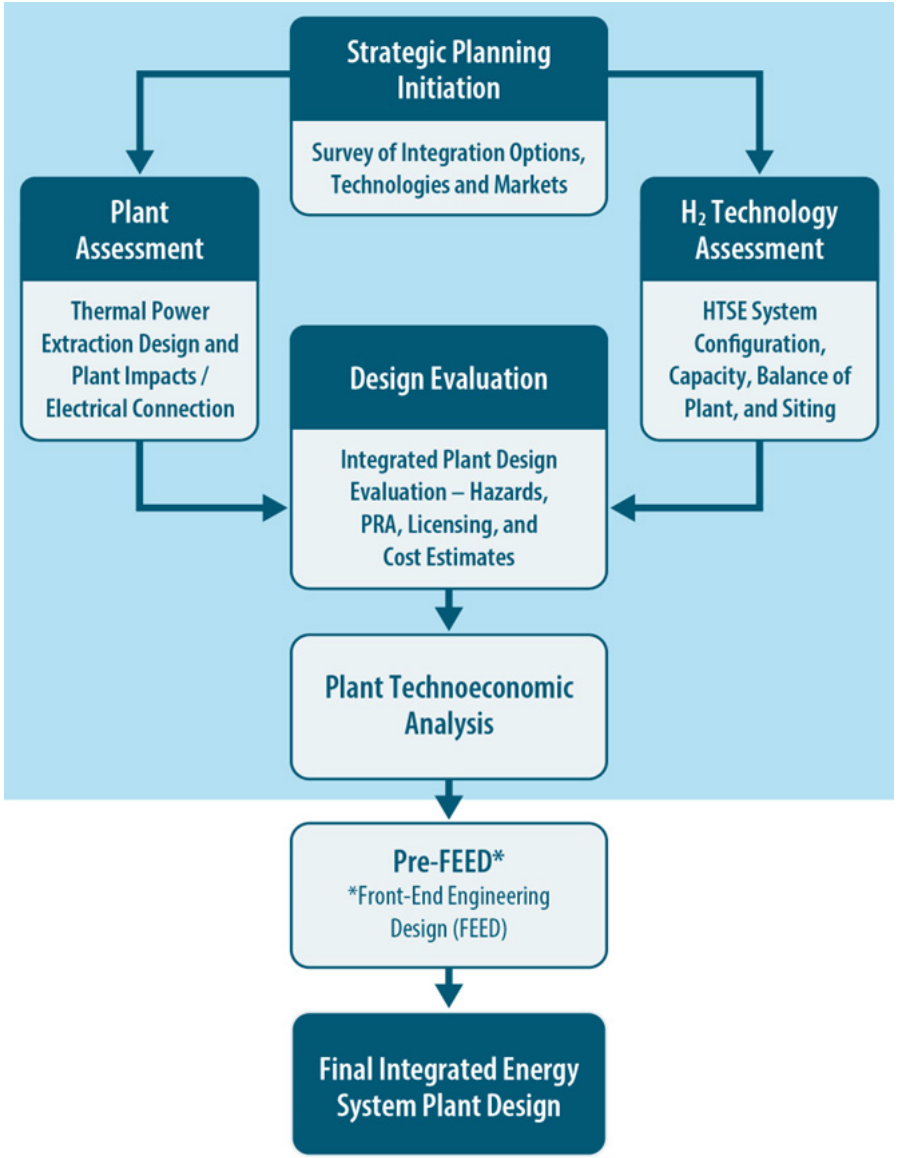
Nuclear Utility Strategic Planning

Strategic Planning - Integrated Hydrogen with Nuclear Power

Initial Business Case Assessment

Nuclear Plant Assessment – Integrated H_2 Technology

Utility Design Evaluation Project Economic Potential



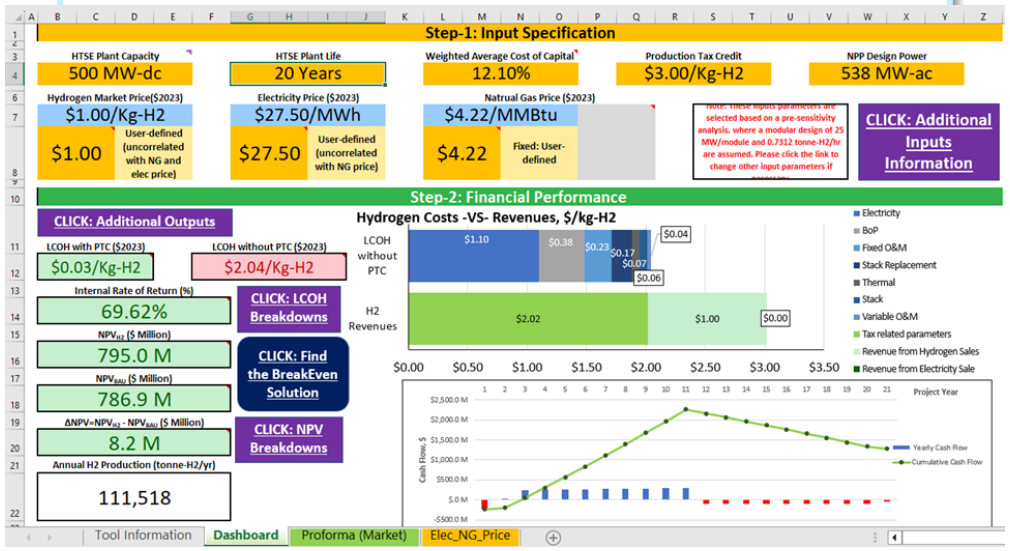
- Strategic planning key items:
  - Utility load and generation forecasts / constraints / grid impacts
  - Assessment of hydrogen integration options / hydrogen technologies
  - Possible hydrogen opportunities

Initial Business Case and Techno-economics

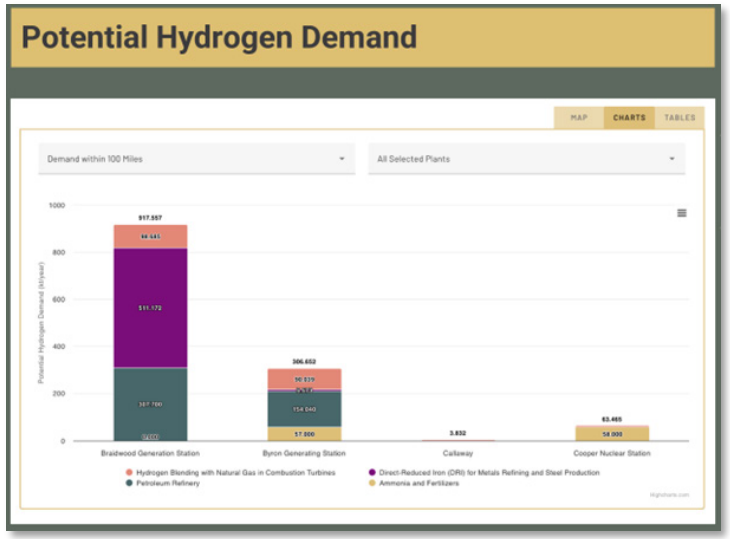
Strategic Planning - Integrated Hydrogen with Nuclear Power

Initial Business Case Assessment

- Assess H_2 market opportunities (market size, growth, competition)
- Evaluate resource availability and attributes (e.g., existing pipelines with capacity, proximity to industrial user, transportation)
- Determine H_2 infrastructure production and distribution requirements
- Evaluate technical options for hydrogen production (electrolysis) and the potential economic benefit of a NPP power uprate
- Electricity vs. H_2 production analysis comparing delta-net present value (ΔNPV) between LWR-HTSE and BAU

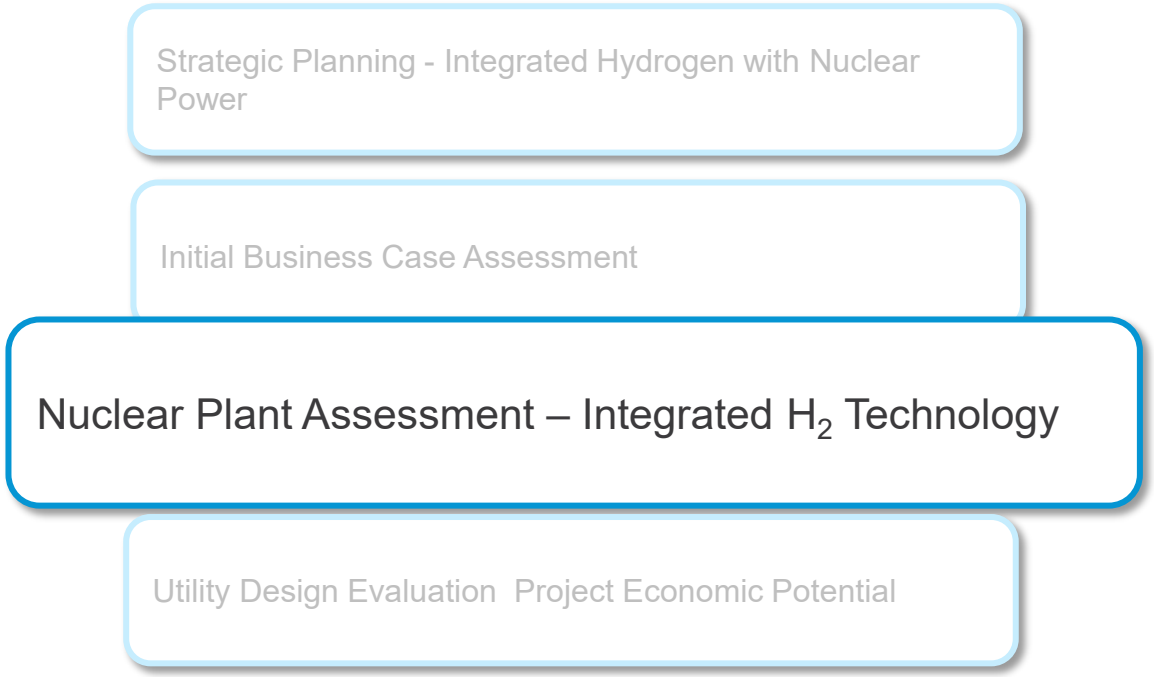


Nuclear Power Plant/HTSE project analysis tool (NPP-HTSE H2 profitability tool)
https://github.com/idaholab/NIHPA



H2 Prospector Database

NPP Plant Modification Assessment and System Impact Analyses



- Thermal Power Extraction (TPE)
- Electrical power distribution and supply
- Siting assessment with hazards analysis
- H_2 technology assessment
- HTSE system operation – plant controls modifications and operations support
- Integrated plant impacts – Plant PRA evaluation and impacts
- Fire Protection Engineering Evaluation (FPEE)
- Regulatory Considerations – Licensing
- Project capital and operating costs assessment

FPOG assessment of all key technology, plant impacts, cost analysis, and regulatory issues supports the necessary evaluations for plant specific integrated hydrogen evaluations with U.S. PWR and BWR plants

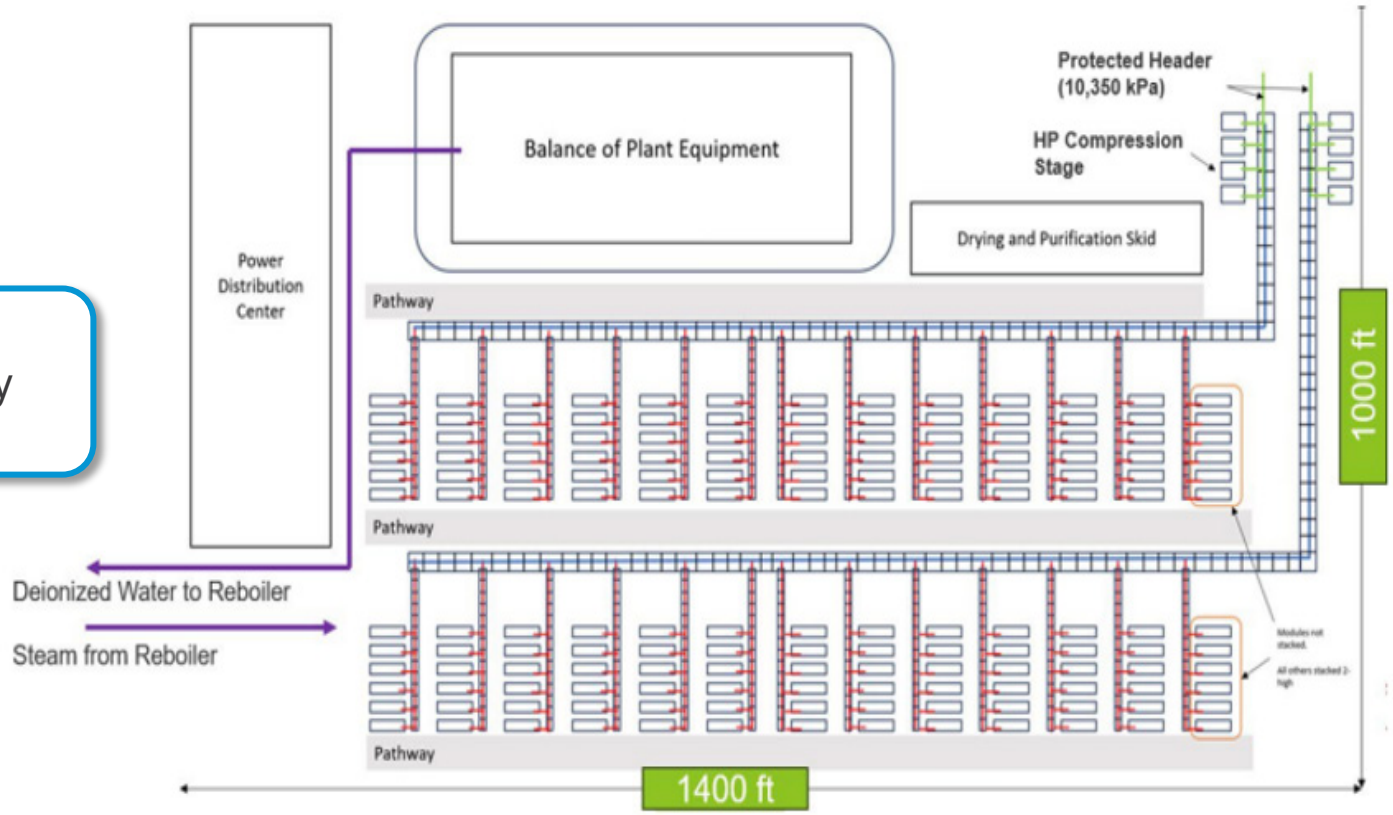
H_2 Facility Layout

Strategic Planning - Integrated Hydrogen with Nuclear Power

Initial Business Case Assessment

Nuclear Plant Assessment – Integrated H_2 Technology

Utility Design Evaluation Project Economic Potential



Sample 500 MW $_{nom}$ High Temperature Electrolysis Facility Layout.

Low Pressure (< 5 psi) Intermediate Pressure (200-300 psi) High Pressure (1500 psi)

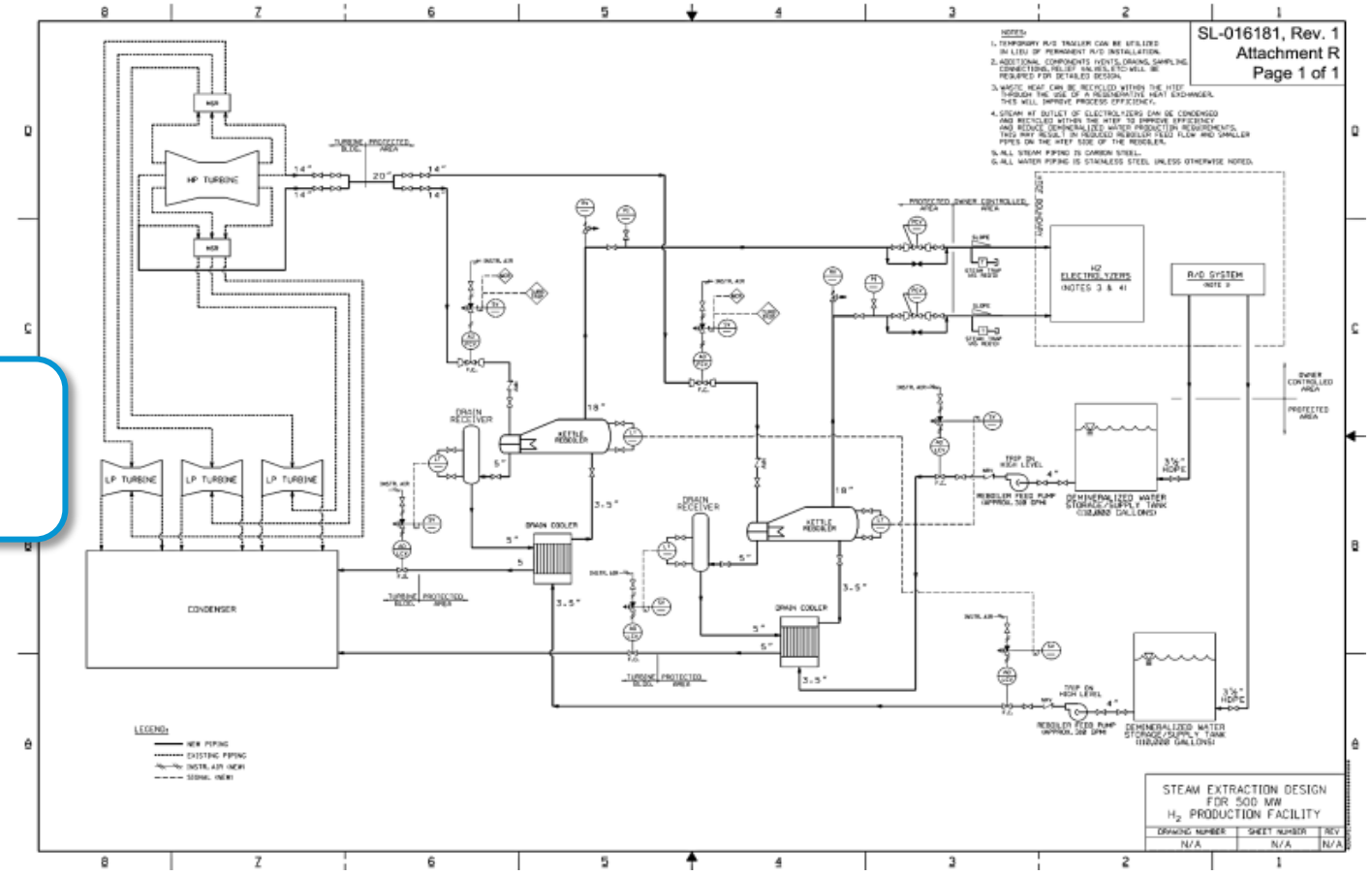
Thermal Extraction Analysis

Strategic Planning - Integrated Hydrogen with Nuclear Power

Initial Business Case Assessment

Nuclear Plant Assessment – Integrated H_2 Technology

Utility Design Evaluation Project Economic Potential



Integration Analysis – Siting and Safety Risk Assessment

Strategic Planning - Integrated Hydrogen with Nuclear Power

Initial Business Case Assessment

Nuclear Plant Assessment – Integrated H_2 Technology

Utility Design Evaluation Project Economic Potential

NRC RG-1.91 example analysis for a 1000 MW_{nom} HTEF site – fire siting requirements (NFPA 55) distance requirements will be slightly less)

Nuclear Plant and H_2 Controls Systems

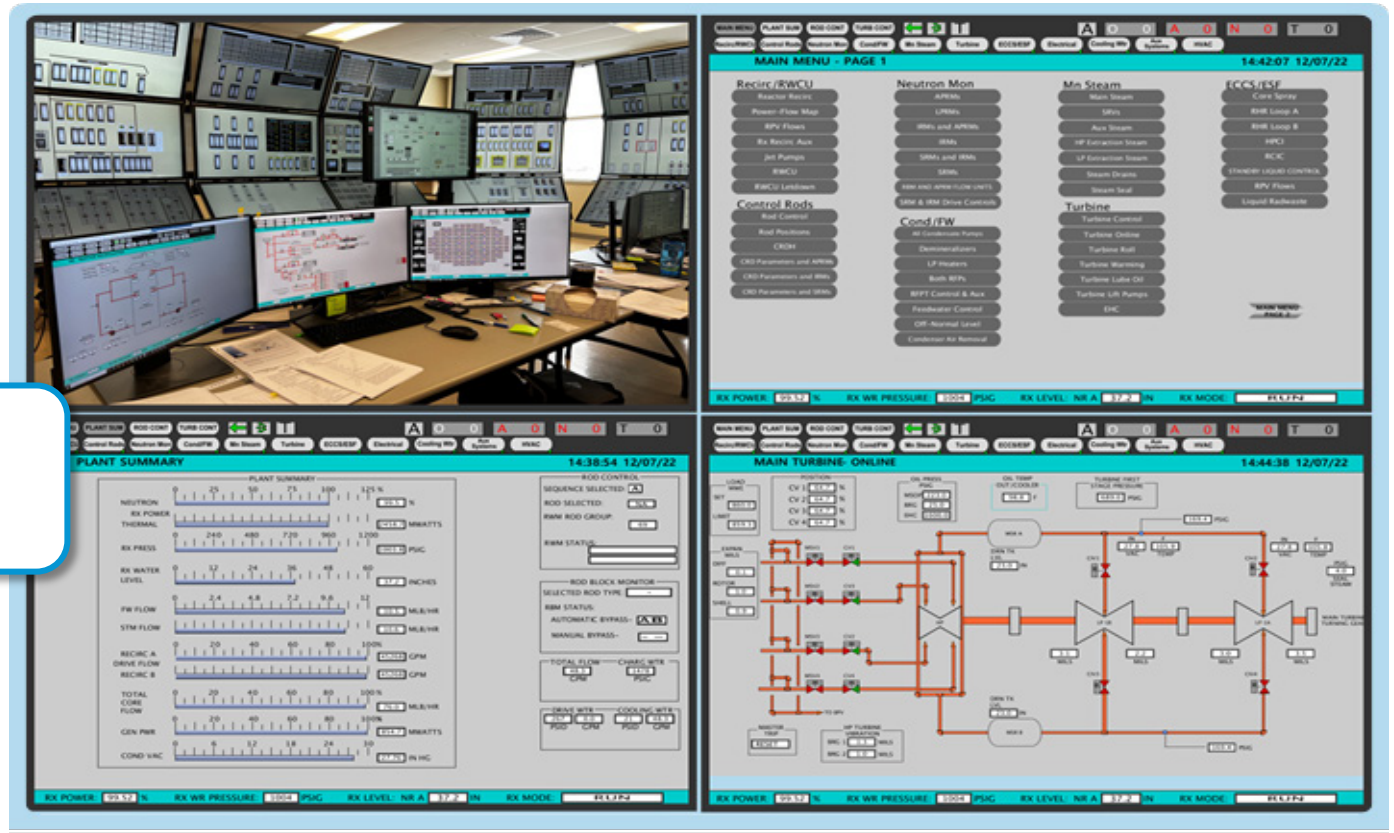
Strategic Planning - Integrated Hydrogen with Nuclear Power

Initial Business Case Assessment

Nuclear Plant Assessment – Integrated H_2 Technology

Utility Design Evaluation Project Economic Potential

Plant specific technical assessment for integrated H_2 system based on INL reference plant analysis and methodology



GSE Systems Inc. Modified Boiling Water Reactor in the Human Systems Simulation Laboratory

Supporting Technical Reports

Strategic Planning - Integrated Hydrogen with Nuclear Power

Initial Business Case Assessment

Nuclear Plant Assessment – Integrated H_2 Technology

Utility Design Evaluation Project Economic Potential

https://lwrs.inl.gov/flexible-plant-operation-and-generation-reports/

Utility Assessment

Strategic Planning - Integrated Hydrogen with Nuclear Power

Initial Business Case Assessment

Nuclear Plant Assessment – Integrated H_2 Technology

Utility Design Evaluation - Project Economic Potential

Final Utility Business Case for Integrated Hydrogen with Nuclear Power

Detailed TEA Analysis to support utility business operations and long-term resource planning assessment business case

- Plant specific analysis based on siting and thermal and electrical integration of an integrated high temperature steam electrolysis (HTSE) system
- Utility load and renewables forecasts / utility portfolio assessment
- Capacity and dispatch optimization with utility assets
  - Option - Hydrogen market opportunities
  - Option - Capacity expansion and peaking
- Integrate final optimized hydrogen system with utility Business Operations and Resource Planning analyses
  - Utility long range assessment of integrated system NPV or Revenue Requirement

Sustaining National Nuclear Assets

Richard.Boardman@inl.gov

lwrs.inl.gov