Hydrogen Regulatory Research Review Group (H3RG)

Flexible Plant Operation & Generation

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Hybrid Plant Operations Can Optimize Revenue

Electrical Grid
Load-Balancing
or Reserve Capacity

Industrial Hydrogen Users
Power, Thermal,
Hydrogen

Hybrid operation of allows nuclear plants to partners to garner high revenue while firming the grid as reserve capacity

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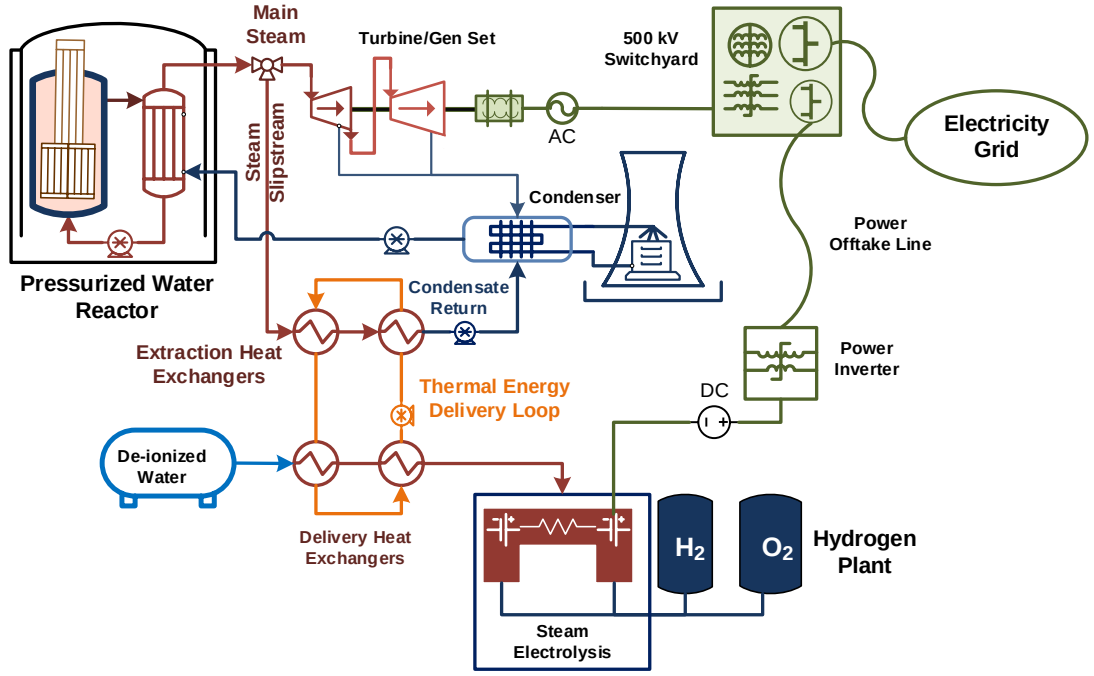
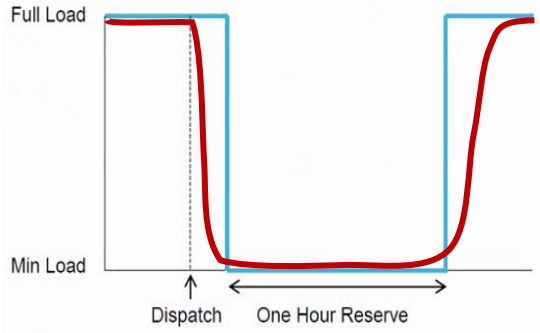
Flexible Plant Operation & Generation

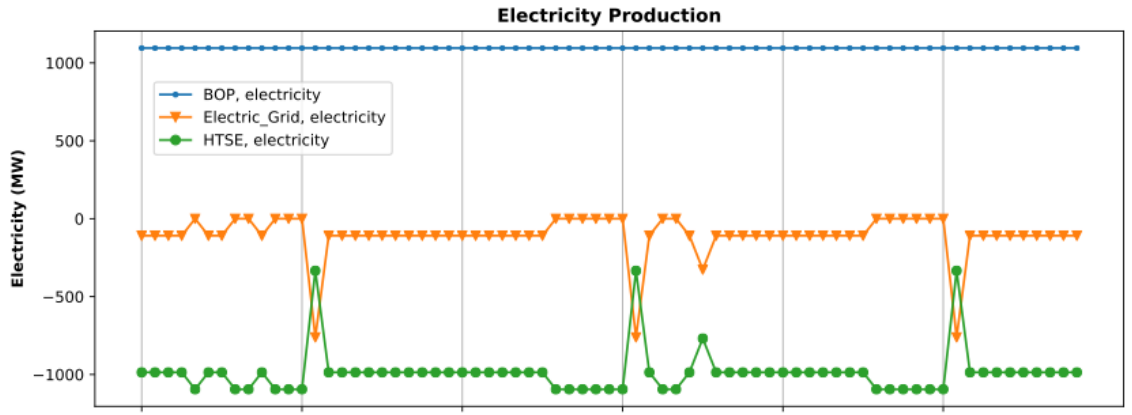
- Goal is to increase nuclear plant revenue and decarbonize the energy sector
- Risks of this new operating paradigm include
  - Hydrogen production and storage safety risks
  - New thermal extraction and delivery systems
  - Modifications to the electricity transmission station
  - Operator control 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

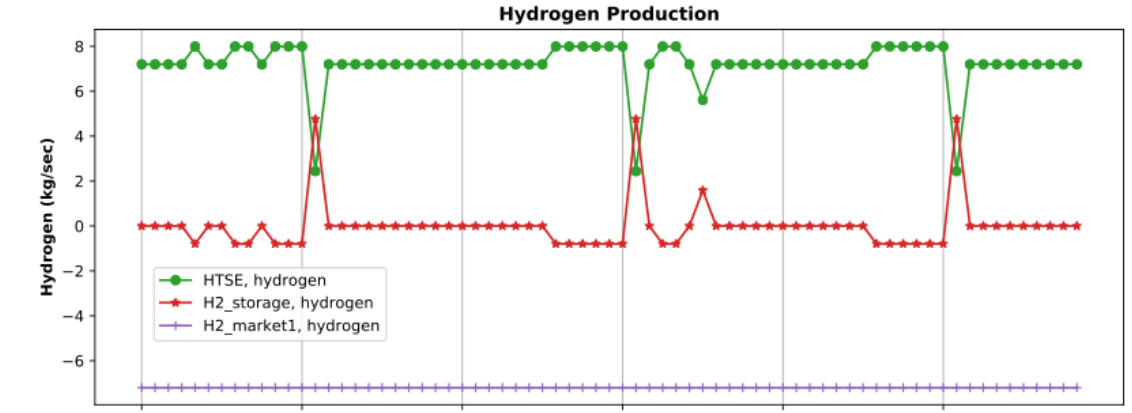


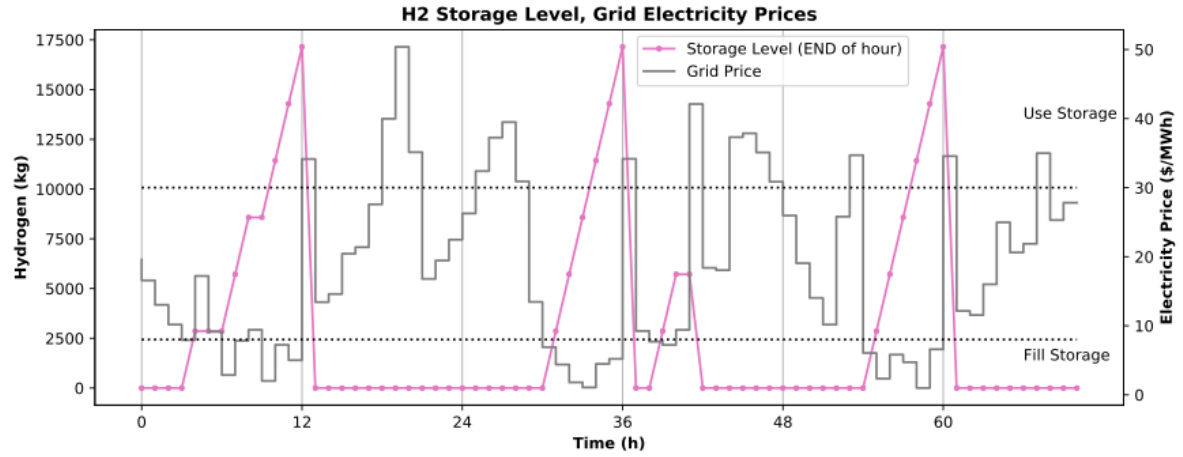


H_2 Production and Electricity Dispatch Schedule

- **Scenario 1. Dispatch between hydrogen production and grid**
  - Co-optimized hydrogen plant scale, storage, and production schedule
  - Ramp rates of 50 MW/min
- **Scenario 2. Electricity arbitrage comparison**
  - Hydrogen production, storage and delayed power production
  - Ramp rates of 5 MW/min

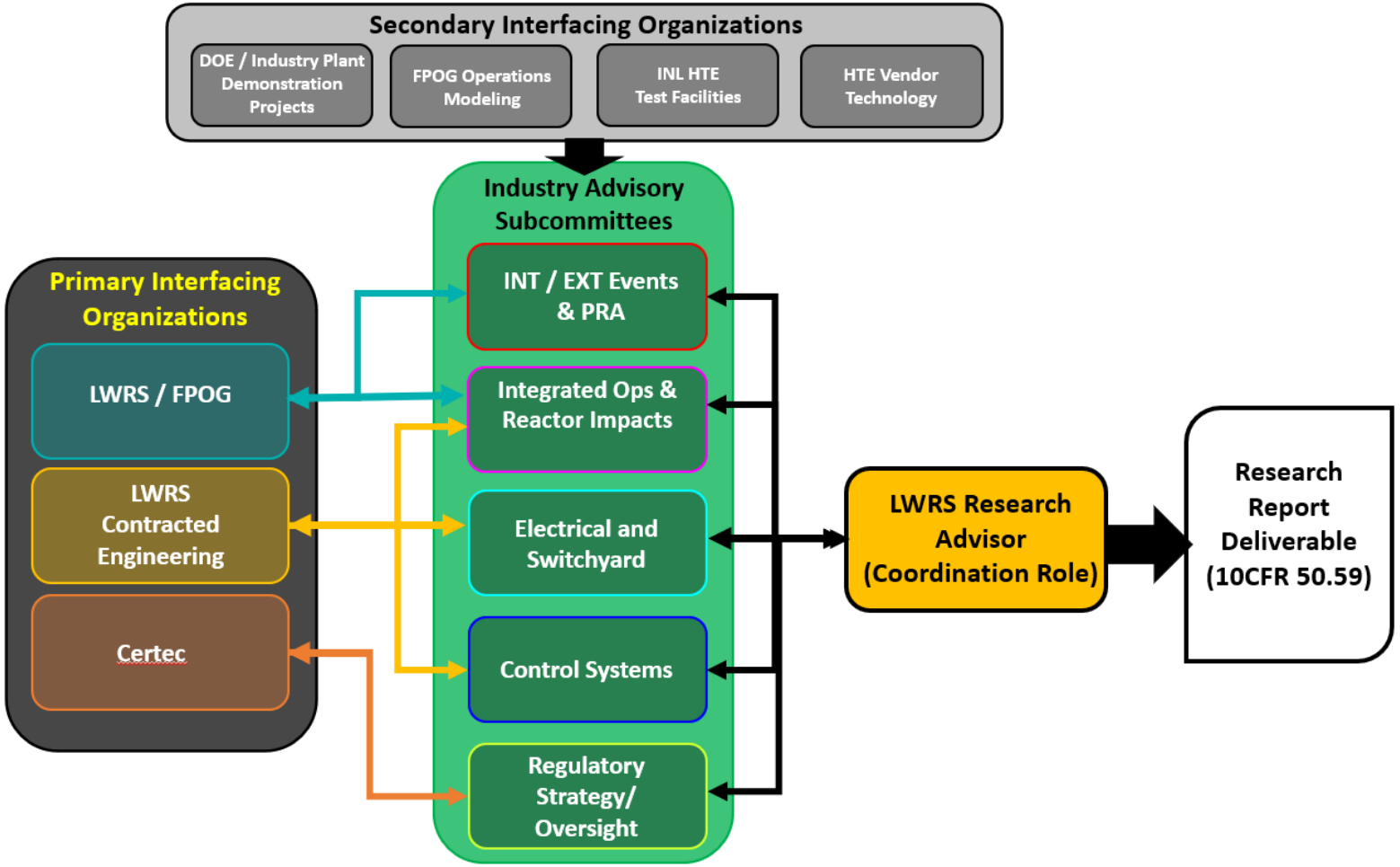


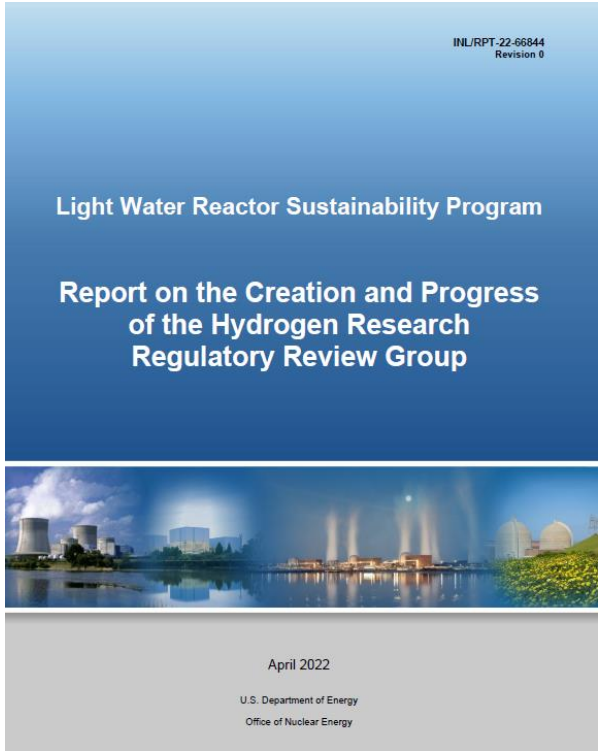




Structure and goals of H3RG

- Gather experience-based insights from LWR plant owners and operators applicable to regulatory approval of planned flexible hydrogen operations at nuclear facilities
- Provide expert regulatory, design, and operational input to inform the work of laboratory scientists and contracted architect engineers tasked with pre-conceptual nuclear integrated HTE designs and 10 CFR 50.59 deliverables





H2 Regulatory Review Research Group

- Task 1: Regulatory User Group Formation
  - Preliminary alignment and industry technology learning phase
  - Scoping and Integration Roadmap Agreement
- Task 2: Provide input and agreement on 10 CFR 50.59 elements for LTE and HTSE designs
  - Review and comment on Lab-directed AE proposed licensing documents
  - Proposed HTSE areas requiring further licensing development
- Task 3: Identify possible license amendment triggers and solutions for large scale fully integrated HTSE or other heat–based product generation

1. Identify and inform research-related licensing approaches (**based on traditional USNRC licensee requirements**) that support introduction of hydrogen production by HTE as an alternate energy stream at nuclear facilities.
2. **Reference Case**: 4-loop pressurized water reactor (PWR) plant design is being used as the research model to characterize how a generic nuclear integrated hydrogen design concept may be implemented as a nuclear facility change under 10 CFR 50.59.
3. **Architecture Engineering Pre-Conceptional Engineering Design** for steam line connections and mass steam flow for operational and faulted conditions
4. Consideration of steam leak assumptions on existing plant analyses
5. Secondary plant dynamics and operator control issues
6. Analog and digital control schemes and limits of manual control including human system dynamics
7. Operational considerations related to thermal energy extraction including any effects on the reactor core
8. Dispatch limitations and transitions between electrical and hydrogen production
9. Electrical system design interactions and power off-take dynamics
10. **Hydrogen equipment physical plant stand-off requirements** and on-site storage limits based on detonation analysis design requirements

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- Plant probabilistic Risk Assessment (PRA) considerations – Core Damage Frequency (CDF) and Large Early Release Frequency (LERF), Maximum Credible Accident (MCA)
- A sensitivity study element will be included in the architect engineer modeling to identify any limits for percent-of-plant thermal power (steam extraction) that may define what regulatory approval processes would be required.
- As a starting premise: **A formal 10 CFR 50.59 evaluation will likely be required.** The hydrogen facility must be screened for effects on the existing facility and procedures as described in the UFSAR, as well as the integrated licensing bases.
- In support of informing regulatory approval approaches under the 10 CFR 50.59 process, **expert review is being leveraged for:**
  - Comparative reviews of historical industry examples where approval of changes to the facility were appropriately completed under 10 CFR 50.59—especially for first-of-a-kind and fundamental operating approach changes.
  - Detailed reviews of historical 10 CFR 50.59 Nuclear Regulatory Commission (NRC) industry feedback and lessons learned on the limits of use of the 10 CFR 50.59 process for approving changes to the facility.
  - Review of ongoing industry 10 CFR 50.59 evaluations that are being issued in support of LTE modifications or small-scale (kW level) HTE demonstrations.
  - Consideration of historical regulatory challenges related to combustible gas concerns at nuclear facilities.

Sample Early Input from H3RG Subcommittees

- The approval feasibility of the envisioned pre-conceptual mechanical, electrical, and controls changes under a 10 CFR 50.59 evaluation process will ultimately be determined from an integrated design perspective
- Each station shall expect to require UFSAR revisions related to the proposed electrical infrastructure expansion
- Hazards analysis, including a Failure Modes & Analysis Effects (FMAE)
- Identification and impacts of jurisdictional boundaries
- Identification of NPP critical structures and their fragilities
- Follow “traditional” PRA and compare with Modern/Theoretical SAFHIRE PRA
- Institute of Nuclear Plant Operations (INPO) IER 17… concept of maintaining a line-of-sight to the Reactor Core with respect to managing reactivity through operation crew performance, teamwork, and fundamental operator behaviors and knowledge.
  - Control scheme within the main control room (MCR) to initiate the flow of electricity and steam to the hydrogen plant
  - Each nuclear utility and plant will establish communications protocol to declare times of availability to support electrolysis

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