2024 DOE Hydrogen Program Annual Merit Review Presentation

Demonstration of electrolyzer operation at a nuclear plant to allow for dynamic participation in an organized electricity market and in-house hydrogen supply

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Director, Grants R&D and Partnership, Constellation
5/7/2024

Project ID
TA028

Project Goals and scope and overview

Goals/Objectives

- Install a 1MW Polymer Electrolyte Membrane (PEM) electrolyzer and supporting infrastructure at an Constellation nuclear power plant
- Provide economic supply of in-house hydrogen consumption at the plant
- Simulate a scale-up operation of a larger electrolyzer participation in power markets

Timeline and budget

- Conditional award: 10/01/2019
- Removal of condition: 04/01/2020
- Go/No-Go decision made: 07/30/2021
- Project End Date: 10/01/2023
- Total Project Forecast: $14.4M

Questions, challenges

- Site Selection
  - What are the criteria for site selection?
- Regulatory
  - What are the relevant regulations that affect nuclear H2 production?
- Market-related
  - What is the effective electricity price that the electrolyzer pays?

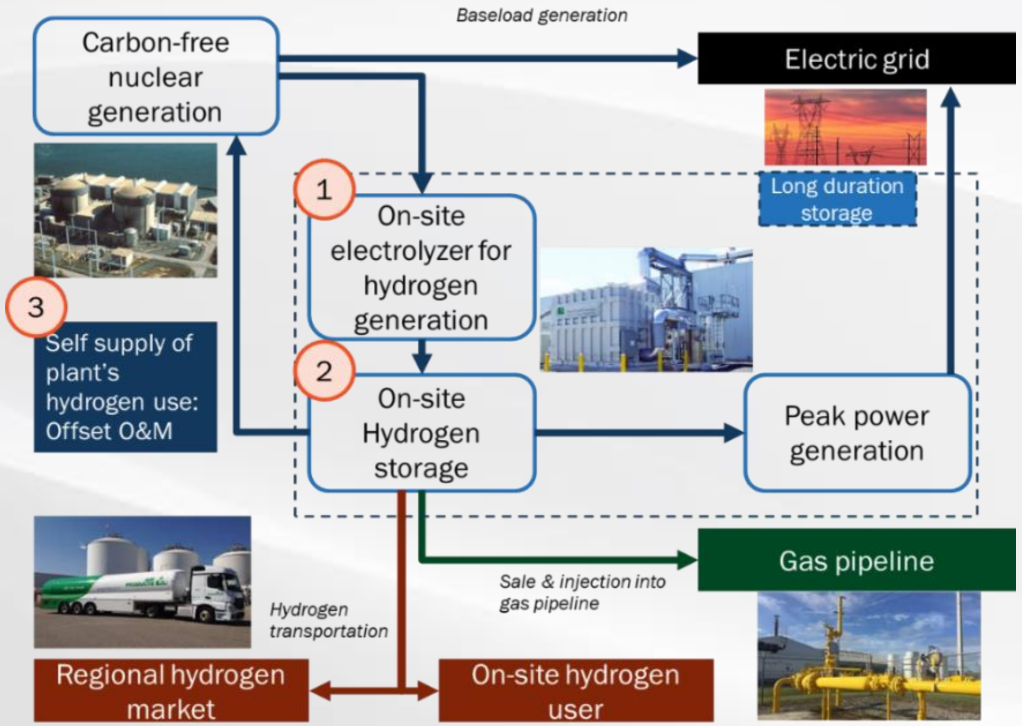
Partners

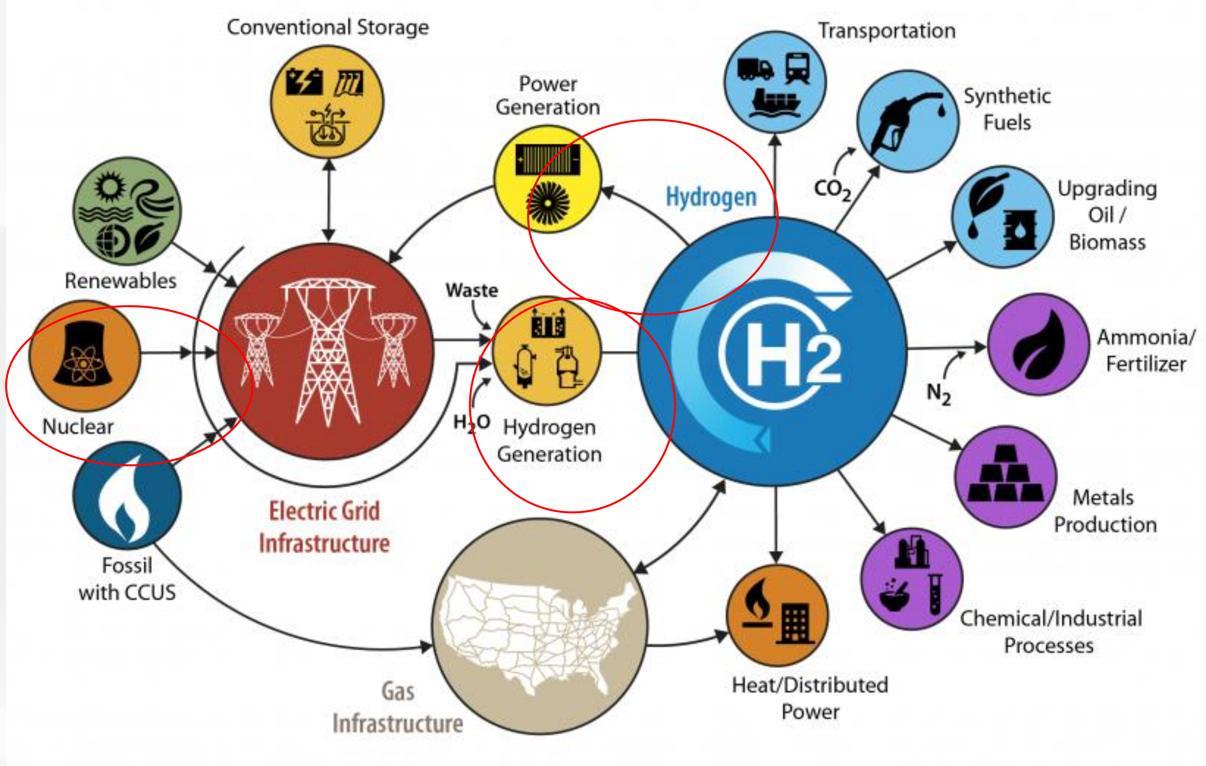
- Constellation Energy Corporation
- Idaho National Laboratory
- National Renewable Energy Laboratory
- Argonne National Laboratory
- Nel Hydrogen

Relevance: The project demonstrates nuclear hydrogen pathway described in H2@scale vision

Technical Goals and Objectives

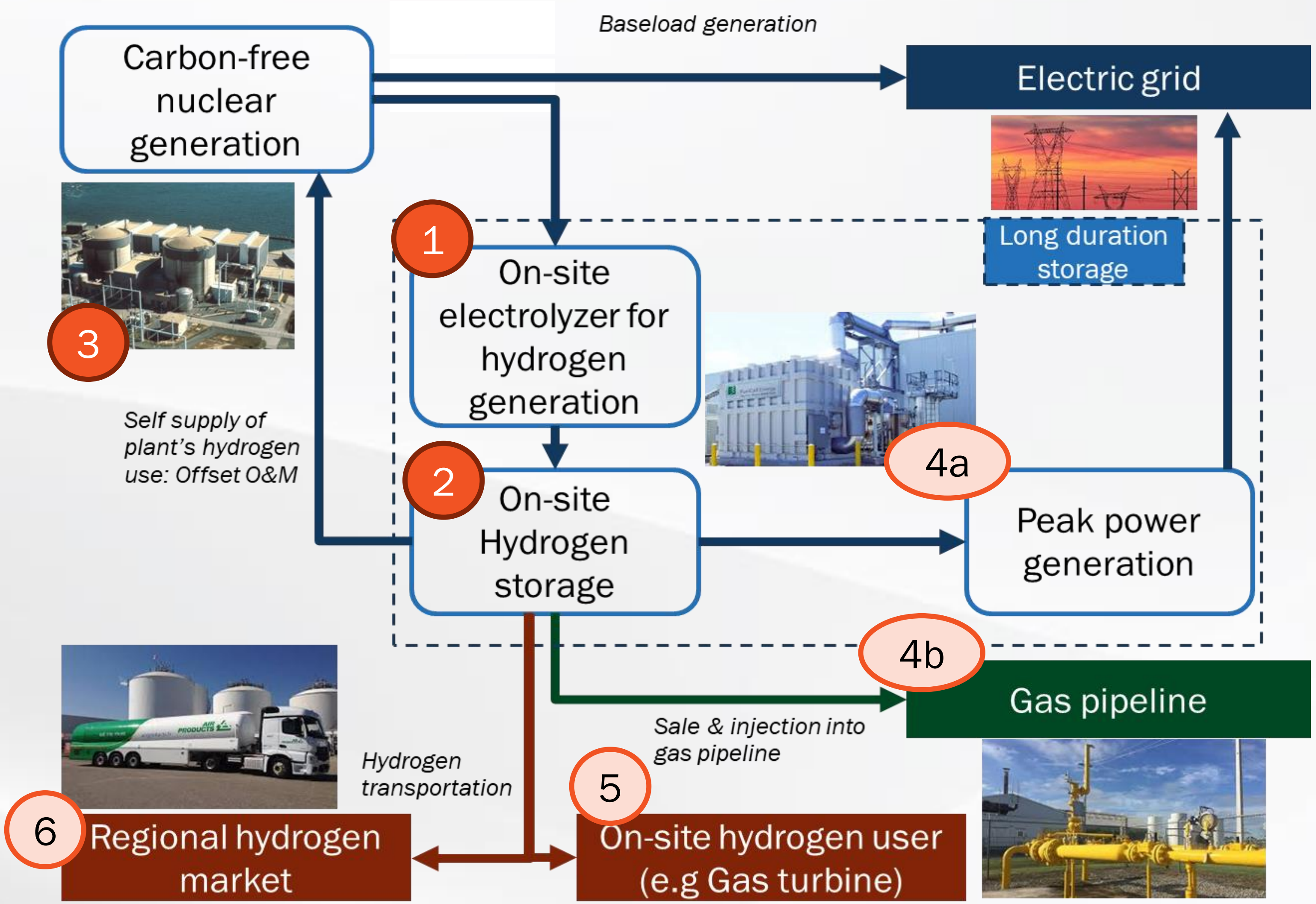
- Install a 1MW PEM electrolyzer and supporting infrastructure at an Constellation NPP
- Provide economic supply of in-house hydrogen consumption at the plant
- Simulate a scale-up operation of a larger electrolyzer participation in power markets





Constellation

Relevance: The project demonstrates nuclear hydrogen pathway



The project will demonstrate pathways 1-3. In budget period 2, the team will implement installation, operation and scale-up analysis. #4 is being pursued with a state grant

Tasks and Milestones

Task #	Task	Description	Verification	Month from start
1.0	**Successful selection of an optimal site.**	Site selection is announced to project partners		1
2.0-A	**30% conceptual engineering design complete**	30% Engineering report is completed		11
4.0	**Demonstrate dynamic operation of a ~1 MW electrolyzer**	Perform factory acceptance testing and demonstrate dynamic operation of a ~1 MW electrolyzer.		11
4.0	**Simulation model of electrolyzer operation**	Verified by inspecting the results of a simulation model of the local electrical grid including interactions between the grid and the nuclear station and a 1 MW PEM system		9
5.0	**Identification of optimal sites for scale-up.**	Verified by a technical report comparing candidate sites and down selecting the optimal location for future scaleup.		11
2.0-B	**Site specific Final Engineering design**	100% design engineering is completed with input from Nel		18
6.0	**Economic feasibility assessment of scale-up**	Verified by a technical report assessing the economic feasibility of future scaleup.		35
8.0	**Start of steady state operation of electrolyzer**	Verified by the steady state hydrogen production		29
9.0	**Demonstration of dynamic operation at site**	Verified by the demonstration of remote connection and dynamic operation of the installed 1 MW electrolyzer.		35
10.0	**Perform a project specific assessment of cyber security issues**	A report documenting a project specific assessment of cyber security aspects in accordance with recommendations		35

Completed

In progress

Not started

Nine Mile Point Hydrogen Production- Hydrogen Safety updates

- Constellation installed a 1.25 MW Nel PEM electrolyzer producing 531 kg/day of clean hydrogen at Nine Mile Point power station in Oswego, New York.
- On March 7th, hydrogen production started.
- Engaged DOE hydrogen safety panel
- Incorporated NFPA guidance into the design
- Incorporated the unit into the plant design so that any changes are reviewed to ensure NFPA standards are maintained
- Added the system into operations training for both new operators and a continuing refresher for current operators
- Reviewed NFPA requirements against Constellation safety procedures

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Responses to 2023 Reviewers' Recommendations

1. In the long term, it would be desirable to see Constellation include clean hydrogen production with carbon capture for the subsequent production of carbon-neutral, non-electric energy products (syngas, methanol, Fischer–Tropsch fuels, etc.) to assist in decarbonization of other sectors. The recommendation is appreciated
2. DOE should ask Constellation if the utility is willing to do a no-cost extension of the schedule to include the collection and dissemination of electrolyzer operational results. More extended-operational data of electrolyzers in real-world applications is needed. - Constellation has extended the period of performance and is in communication with NREL on data sharing.
3. It is recommended that the project revisit the simulation based on the performance observed in the installed dynamic operations. This is (understandably) not included in the scope but should be considered by DOE as a follow-on project.- The recommendation is appreciated
4. The project needs to produce more electrolyzer operating data in the rest of the project time period. The project should specify how waste heat would be utilized for the electrolyzer operation to enhance the overall system efficiency. Please see answer to question 2.
5. There are no recommendations for changes to project scope.

Constellation

Collaboration and Coordination

Partner	Role
Constellation	Lead applicant responsible for overall project, design, installation and operation of the 1MW electrolyzer. Licensing, regulatory market deliverables.
Nel	Vendor supplier for prototype test unit. Providing support for prototype electrolyzer testing
INL	Development of front end controller, dynamic operation of prototype electolyzer
NREL	Development of front end controller, dynamic operation of prototype electolyzer
ANL	Analysis for scaled-up hydrogen production, hydrogen market analysis

Summary of accomplishments, progress, potential impact and future work

- **Project achievements and progress**
  - 100% Final Engineering design completed
  - Installation and start of steady state operation of electrolyzer (started operation on 3/7/2023)
  - ANL has completed mapping hydrogen demand and infrastructure for potential scaleup sites
  - Successfully kicked-off $12.5M follow-on NYSERDA grant to install hydrogen fuel cell at NMP as a long duration storage
  - Submitted hydrogen hub application for Mach H2 based on learnings from the project
  - Received Nuclear Energy Institute's Top Innovative Practice (TIP) award in 2023
- **Potential impact**
  - On March 7th, hydrogen production started clean hydrogen production facility at Constellation's Nine Mile Point Nuclear Plant in Oswego, New York
  - The project leverages DOE grant of $5.8 million to demonstrate hydrogen production and end use for the plant's own consumption of hydrogen
  - The PEM electrolyzer uses 1.25 MW of power behind the meter to produce 560kg/Day of clean hydrogen, more than enough to meet the plant's hydrogen use.
- **Future work**
  - The additional hydrogen production is being explored as a long duration energy storage system in a separate grant project supported by NYSERDA.
  - Constellation has committed to invest $900 million through 2025 for commercial clean hydrogen production using nuclear energy. This includes participation in the Midwest Alliance for Clean Hydrogen (MachH2)
  - Any proposed future work is subject to change based on funding levels

Constellation.

Acknowledgments

- Financial support from DOE EERE Fuel Cell Technology Office under award #**DE-EE0008849**
- DOE program manager: Michael Hahn
- Constellation team and project manager: Robert Beaumont
- National lab teams
- Nel Hydrogen team

Technical backup slides

Technology transfer and commercialization activities

- On March 7th, hydrogen production started clean hydrogen production facility at Constellation's Nine Mile Point Nuclear Plant in Oswego, New York
- The project leverages DOE grant of $5.8 million to demonstrate hydrogen production and end use for the plant's own consumption of hydrogen
- The PEM electrolyzer uses 1.25 MW of power behind the meter to produce 560kg/Day of clean hydrogen, more than enough to meet the plant's hydrogen use.
- The additional hydrogen production is being explored as a long duration energy storage system in a separate grant project supported by NYSERDA.
- Constellation has committed to invest $900 million through 2025 for commercial clean hydrogen production using nuclear energy. This includes participation in the Midwest Alliance for Clean Hydrogen (MachH2)

Constellation

Special recognition and awards: 2023 Nuclear Industry Top Innovative Practice award

- Nuclear Energy Institute Top Innovative Practice Awards
  - These awards highlight the nuclear industry's most innovative techniques and ideas. They promote the sharing of fresh ideas and best practices, and consequently improve safety, work processes and the competitive position of the industry.
- 2023 TIP award was given to "Demonstration of Clean Hydrogen Production at Nine Mile Point"
  - Constellation's Nine Mile Point plant is using PEM electrolyzers behind the meter to produce clean hydrogen to meet it's in-house hydrogen consumption. This project is a first of a kind demonstration in the U.S. that paves the way for scaled-up production of hydrogen from nuclear power.
- Issue Solution Benefit
  - Issue: Hydrogen gas used for chemistry control and turbine generator cooling. Currently, hydrogen is made from fossil fuels and sold by industrial gas companies at expensive price due to long distance transportation
  - Solution: The project leverages $5.8M in DOE funding to produce hydrogen in-house using a PEM electrolyzer connected behind the meter at NMP station to supply the plant's hydrogen consumption
  - Benefit: The electrolyzer saves the plant more than $800k annually in external hydrogen purchase cost. The project is first-of-a-kind demonstration of nuclear hydrogen production in the U.S. and establishes a precedent for scale-up projects

Constellation

Publications and presentations

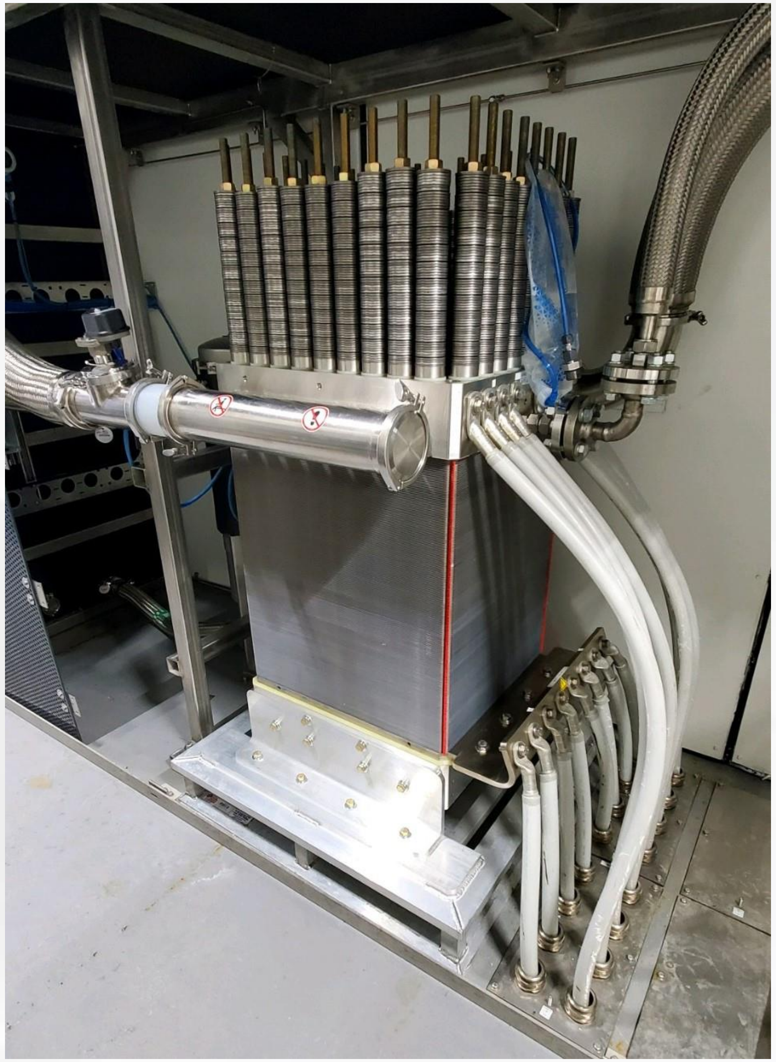
- Organized in-person launch event at NMP in January 2023. Continue media engagements on local and national level: S&P Global, World Nuclear News, Nuclear Engineering International, RTO insider, Utility Dive, Power Engineering, Axios, Oswego County today, The eagle tribune, Power Magazine,
- Continue to attend Conferences, industry events to knowledge share: IAEA, EPRI, ANS, Hydrogen Americas, MIT CANES
- Prepare technical publications in research journals: IEEE
- News articles below

Date	News outlet	Title
10/21/22	Baltimore Sun	Baltimore-based Constellation Energy pursues 'hydrogen economy' to meet global climate goals
10/17/22	Tomorrow's World Today	Nation's First Nuclear-Powered Clean Hydrogen Production Announced
10/07/22	Northern NY Newspapers	Constellation celebrates clean hydrogen production facility at Nine Mile Point
10/04/22	Nuclear Engineering International	Constellation reports progress on the first US nuclear-powered hydrogen facility
09/29/22	Oswego County Business Magazine	Constellation Joins State and Local Officials to Celebrate Progress on Nation's First Nuclear-Powered Clean Hydrogen Facility
09/28/22	Palladium Times	Constellation celebrates progress on hydrogen production facility at Nine Mile Point
09/28/22	WRVO, 89.9 FM (Oswego NPR affiliate)	Oswego County nuclear plant aims to use nuclear power to address climate crisis
09/28/22	Spectrum News 1	Hydrogen production to start next year at Oswego nuclear power plant, CEO says
09/28/22	Syracuse Post Standard	Oswego nuclear plant looks to future, wil be first in U.S. to make hydrogen
09/28/22	Business Wire	Constellation Joins State and Federal Officials to Celebrate Progress on Nation's First Nuclear-Powered Clean Hydrogen Facility

NMP: Hydrogen Pilot Demonstration Project: Project Manager – Robert Beaumont

Pouring concrete for electrolyzer on left, rigging power supply into place on right

NMP: Hydrogen Pilot Demonstration Project: Project Manager – Robert Beaumont



Electrolyzer Area to left: backup generator, power supply, and electrolyzer

Cell stack installed to right.

Constellation

NMP: Hydrogen Pilot Demonstration Project: Project Manager – Robert Beaumont

Electrolyzer and cooling unit to left
Compressor below

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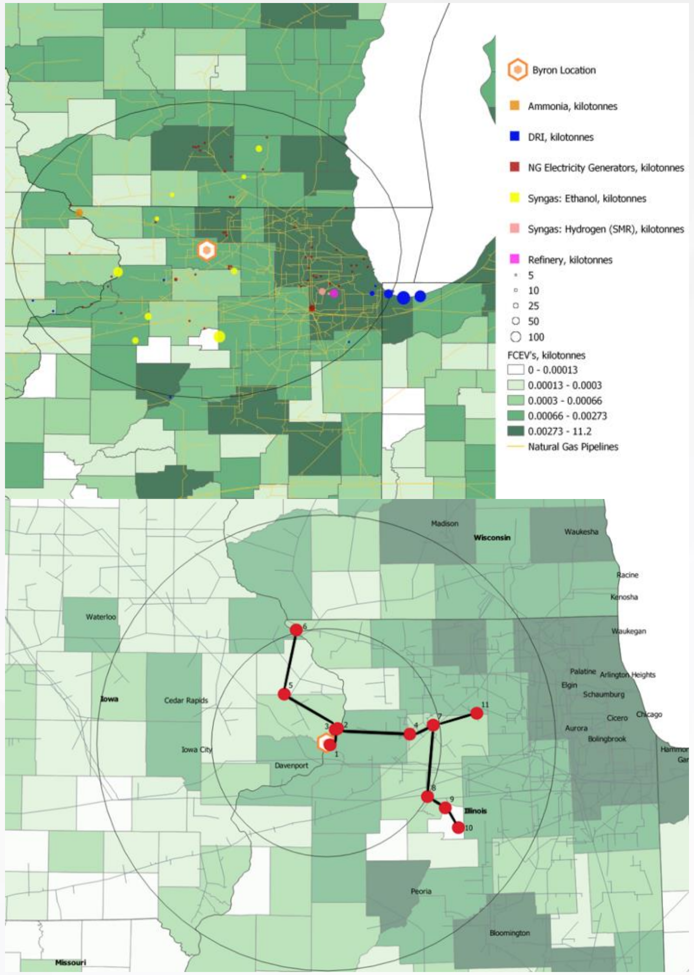
ANL: Market demand, GHG emissions and delivery cost evaluation

H_2 markets and potential demand estimates for following generating station were evaluated:

1) Dresden GS
2) Quad Cities
3) Clinton GS
4) Limerick GS
5) Ginna GS
6) La Salle GS
7) Braidwood GS
8) Byron GS
9) Calvert Cliffs GS

- The potential H_2 market demand was calculated for near-term and long-term opportunities of refinery operations, ammonia production, H_2/NG electricity generators, synthetic fuels (synfuels) near CO_2 sources, direct reduction of Iron and in proximity to these nuclear power plants.
- Life cycle emissions were calculated for nuclear produced H_2.
- Emissions associated with end use applications are evaluated and compared to conventional technologies.
- Delivery costs were evaluated by simulating a pipeline network and using Hydrogen Delivery Scenario Analysis Model (HDSAM).
- Transportation and storage are major cost drivers for utilizing H_2
- Cost of avoided CO_2 was estimated for different end use applications using nuclear-H_2.



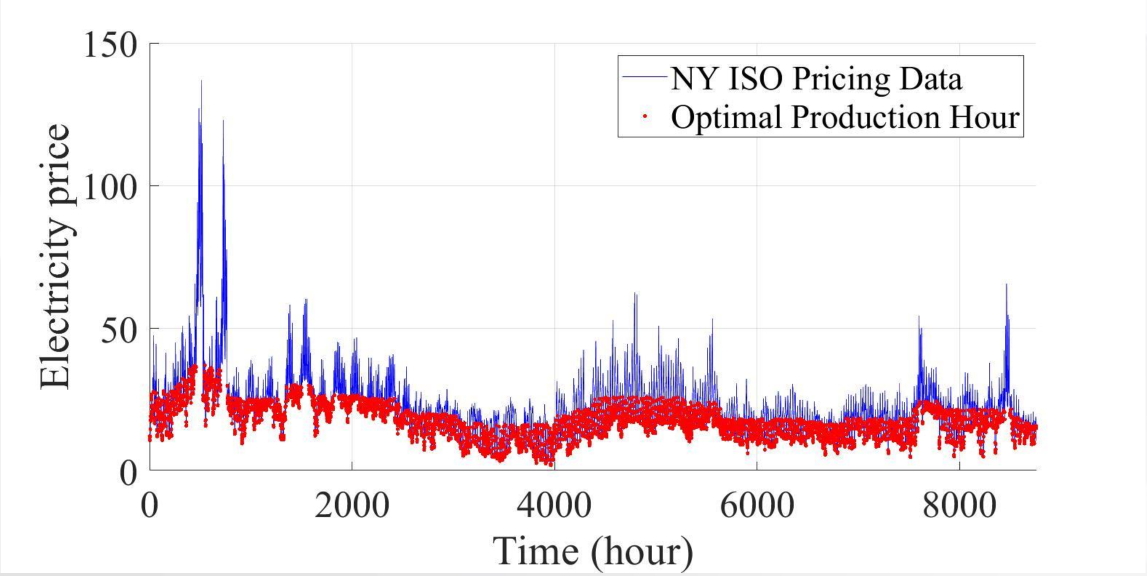
Simulations of Scaled Economic Dispatch Using Front-End

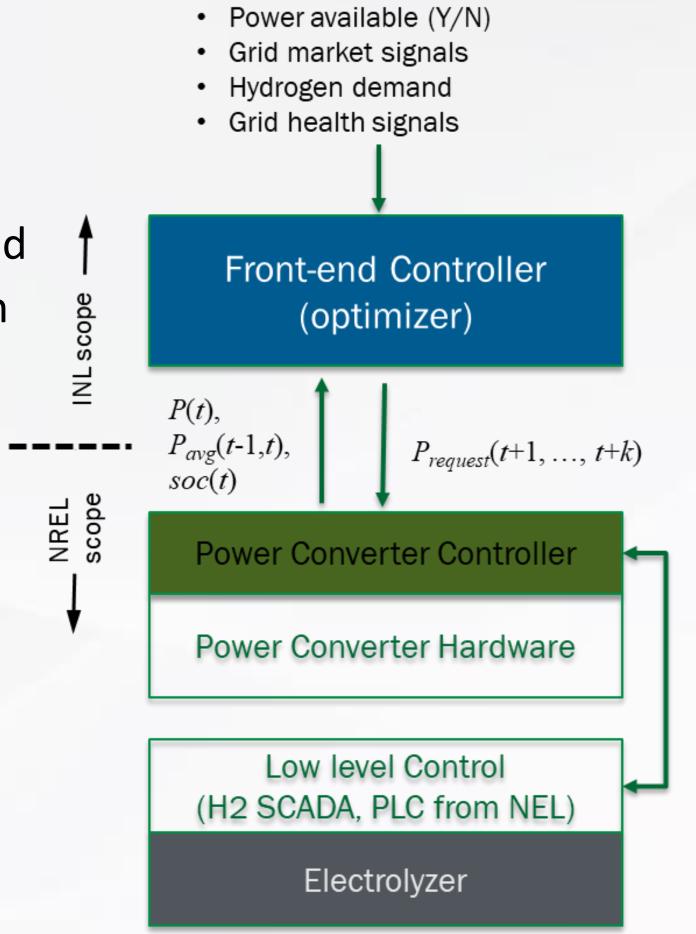
Accomplishments

- Developed and tested front-end controller that uses data from power markets, grid, and the electrolyzer to optimize dispatch of hydrogen production

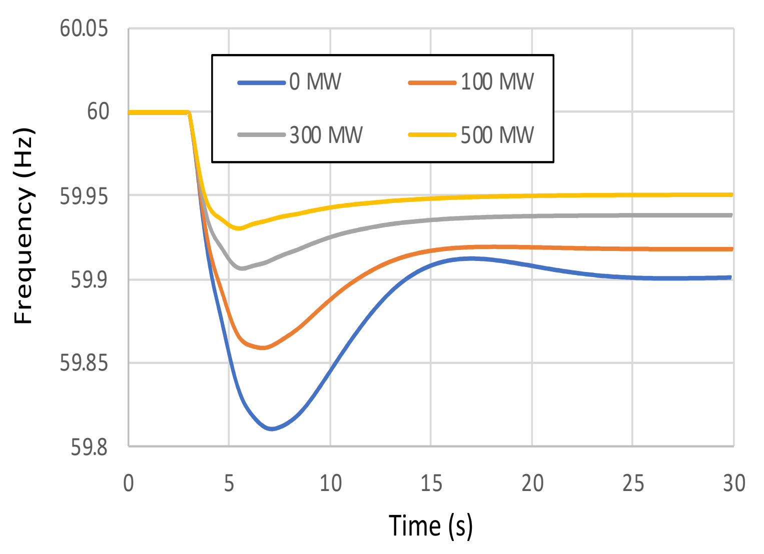
Results

- With fixed H_2 demand, electrolyzer daily capacity factor is ~constant and buffered by storage. Cost projections enable using lowest cost electricity for H_2 production to maximize system profits





Simulations of Scaled Electrolyzer Demand-Response Dispatch

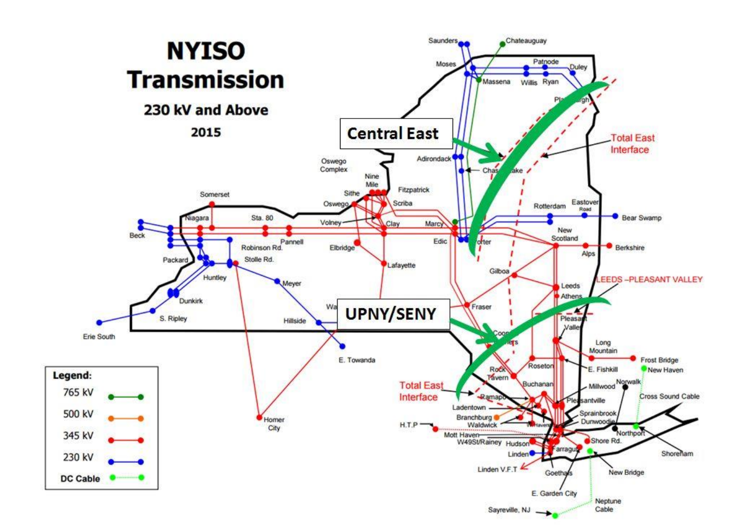


Accomplishments

- Performed transient grid analyses that indicate dynamic operation of scaled PEM system can decrease grid max. frequency delta due to generator fault.
  - Simulation used IEEE 39-bus standard (New-England Power System)
  - PEM system was located at bus 39, connected to a 1 GW nuclear power plant. A droop-based controller provided autonomous demand response
  - A generator fault (N-1 contingency) was simulated at generator 10 (250 MW) on bus 2 to create frequency transients.

Results

- Max. frequency delta decreased from 0.189 Hz without PEM system to 0.069 Hz for 500 MW PEM



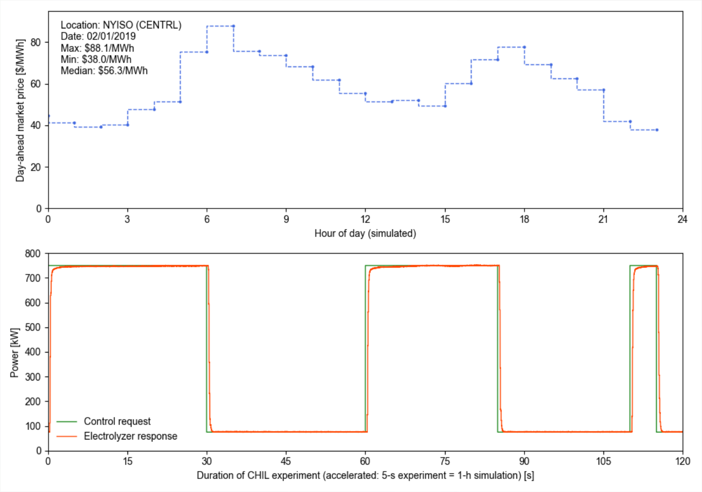
Scenario	Max. Freq. Delta (Hz)
0 MW	0.189
100 MW	0.141
300 MW	0.093
500 MW	0.069

Accomplishments and Progress: NREL

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Accomplishments

- Established a communication link between the front-end controller (FEC) and NREL's electrolyzer testbed with a 750-kW stack
- Refined the power-to-current conversion model with temperature effects
- Performed HIL tests of the electrolyzer system using dynamic control signals from FEC while maintaining operational constraints for hydrogen systems (**completed Milestone 4.2**)
- Shared lessons learned regarding water in systems that can freeze and cause damage before systems are ready for operation

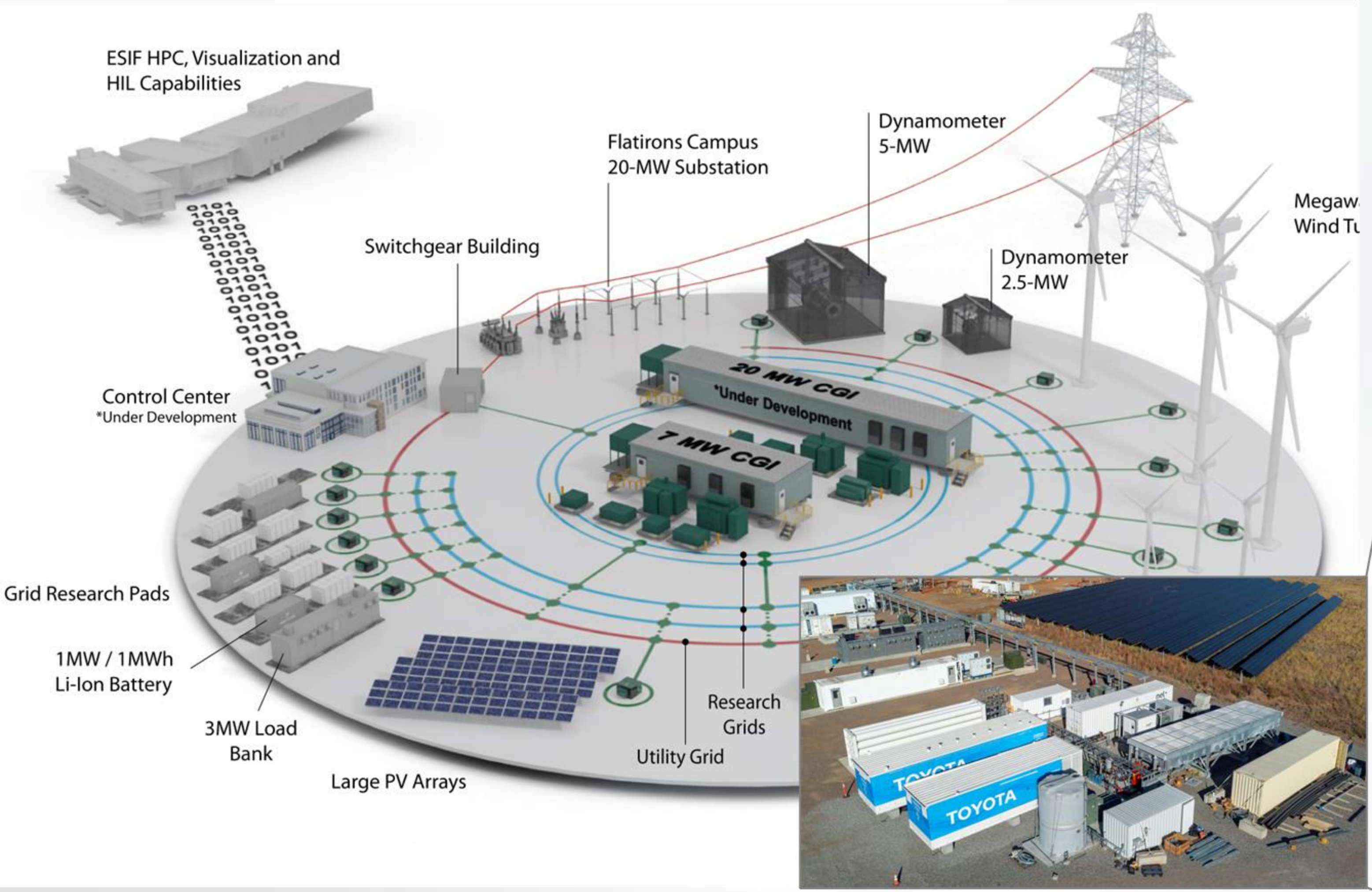


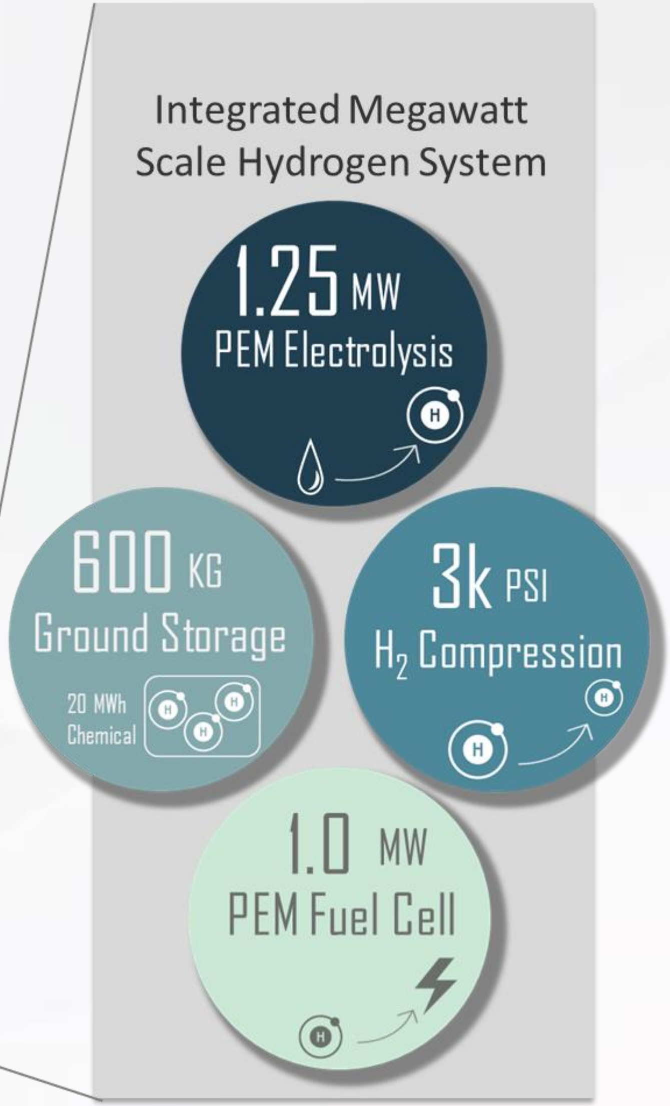
Future Work/In Progress

- Provide hardware validation tests at Flatirons Campus if needed
- Host a site visit NREL Flatirons Campus for the Constellation team to compare operational experience and know-how between the two similar systems

Constellation

MW Scale Hydrogen Systems Capabilities at NREL





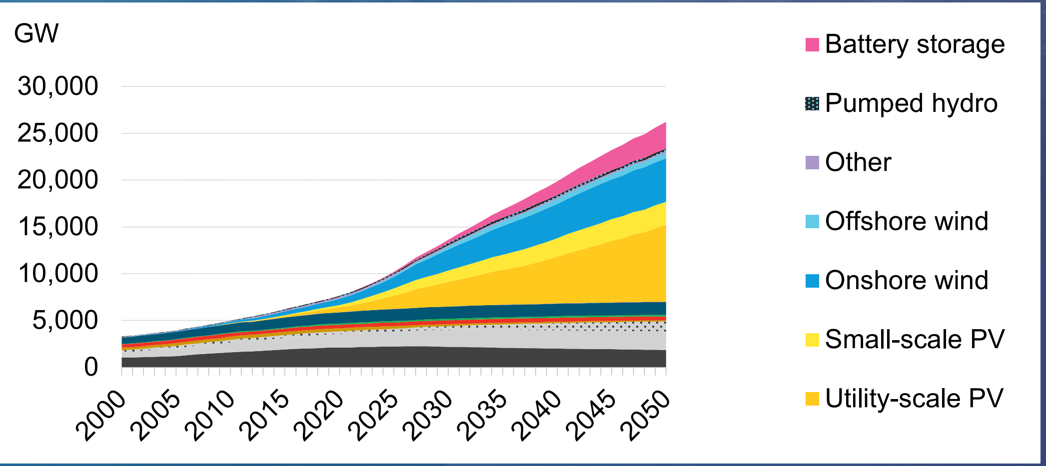
Thermal Energy Offtake and Storage

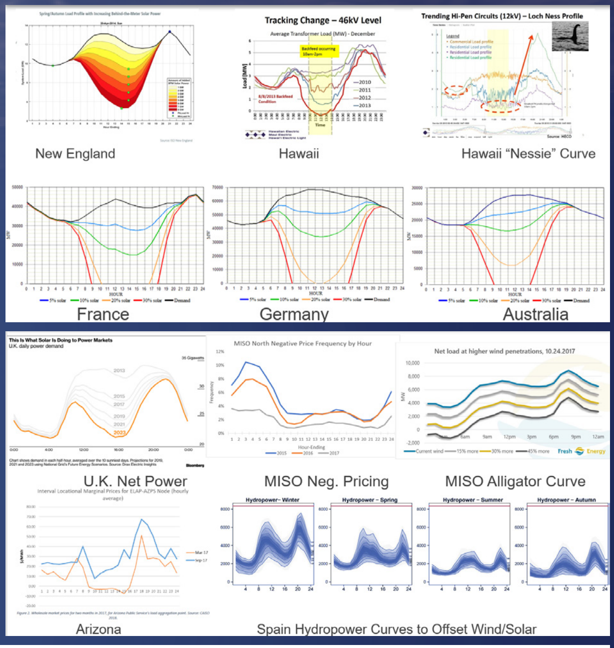
Cory Stansbury
Westinghouse Electric Company

CONTEXT

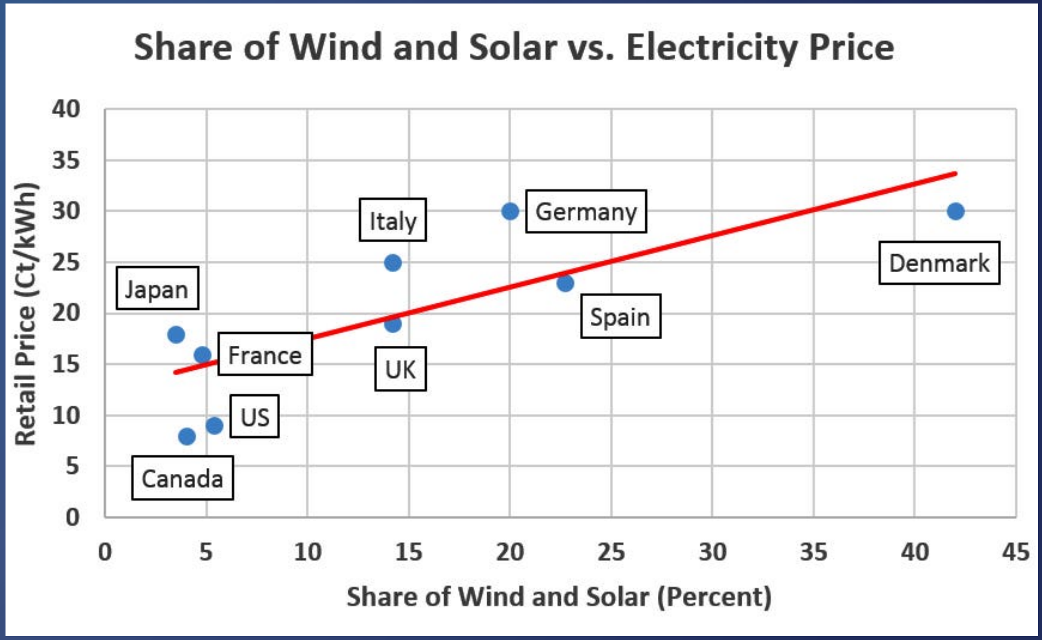
Global installed electric capacity, by technology

BloombergNEF New Energy Outlook 2022, Economic Transition Scenario





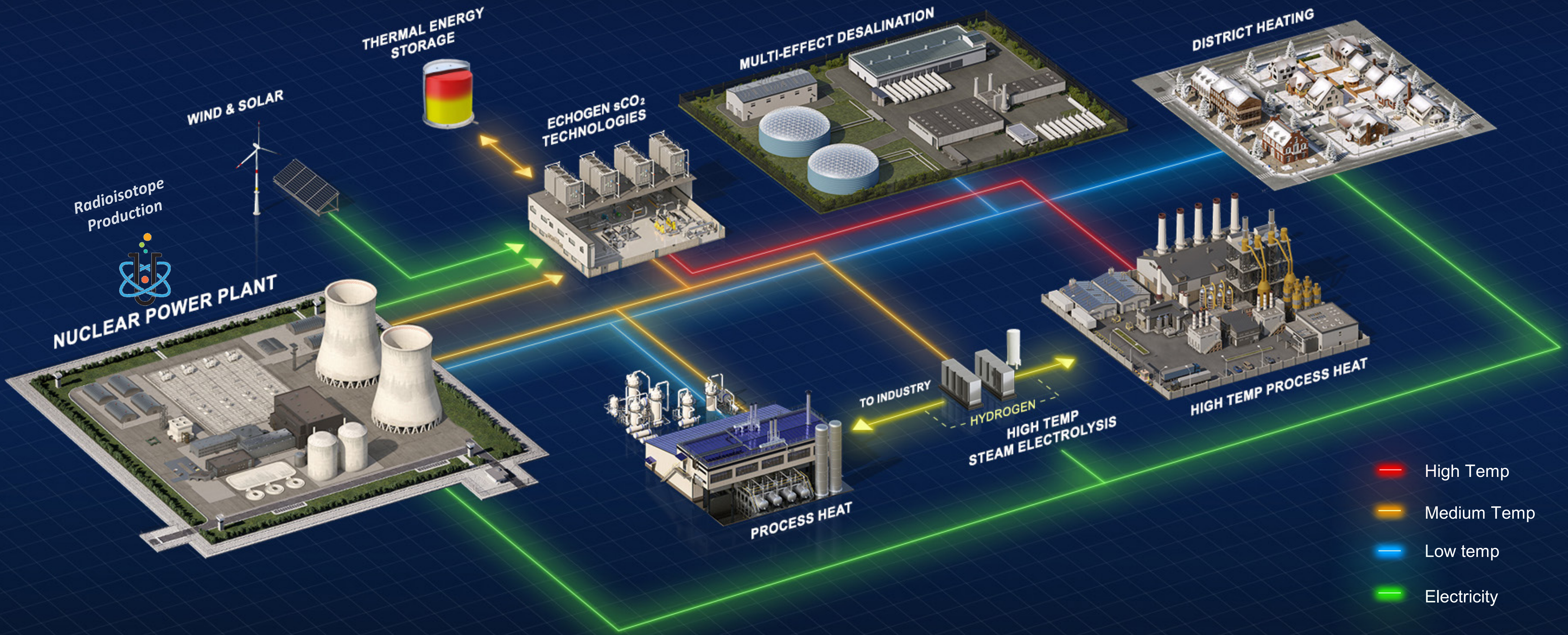
- Historically, Energy is Used as Generated
- Increase in Non-Dispatchable Generation
- Cost of Integration Dwarfs Generation
- Batteries are Expensive (i.e., short duration), Dams are "Impossible"
- Traditional baseload markets are being challenged by increasing use of non-dispatchable generation with correspondingly low/zero marginal cost
- As part of work in support of the DOE's Integrated Energy Systems Expert Group, Westinghouse has developed an entire decarbonizing stack-up



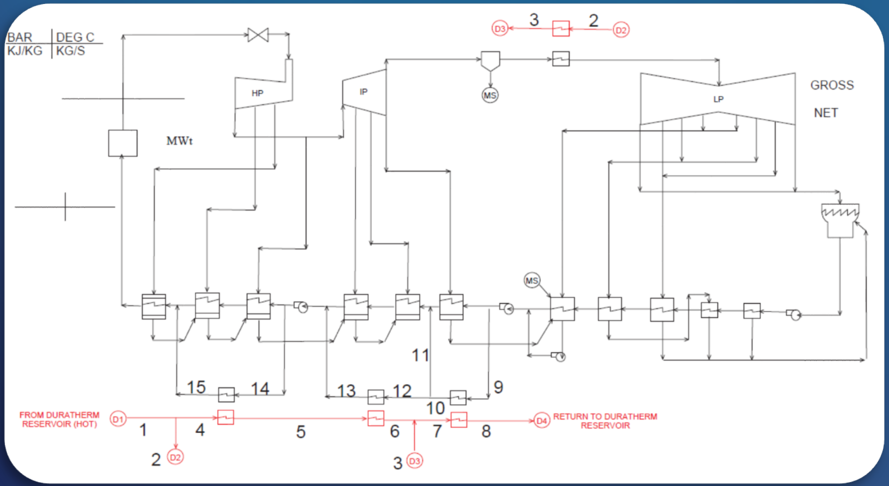
Source: Data from Clean Energy Wire and World Energy Council

Beyond Electricity

Nuclear Power Plants to Serve a wide variety of Decarbonizing Initiatives beyond Low-Cost Electricity



Westinghouse Storage Solution



Example of Integrated Models

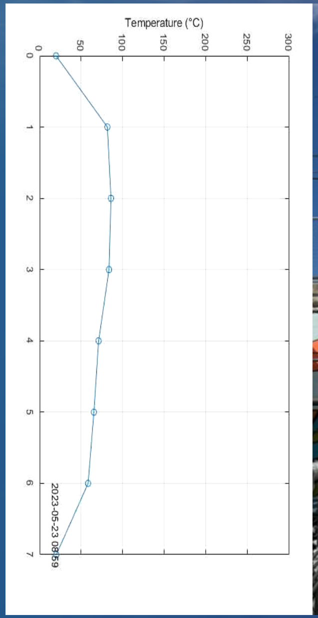
OUR SOLUTION

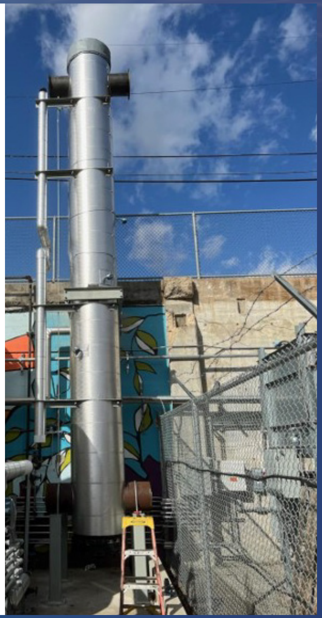
Our technology, related to our stand-alone product, captures heat directly from a nuclear cycle and then produces electricity later using an innovative supercritical CO_2 power cycle

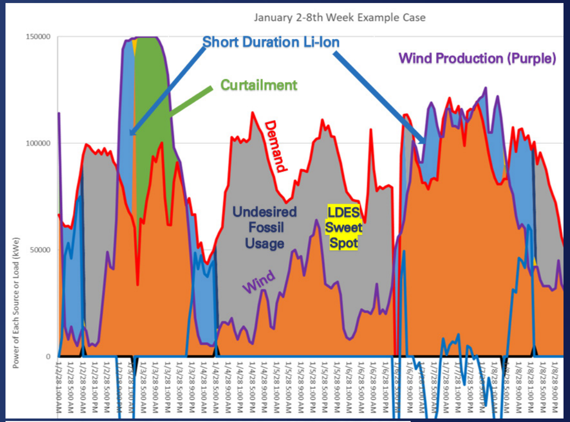
- New Paradigm of Performance Relative to Materials Availability
- Lowers the Cost to Add More / Longer Storage
- Significant Flexibility in Configuration
- Benefits of shared equipment + higher performance than standalone

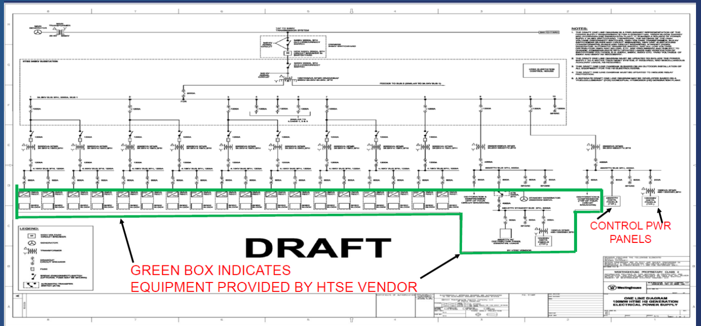
ONGOING WORK

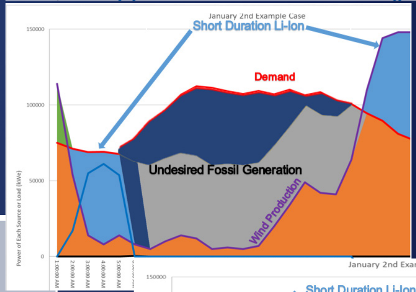
- $50M DOE Award in September, 2023
- 2024 FEED Studies
  - GVEA in Healy, AK: 50 MW / 24 Hr.
  - New York State: ~1.2 GWh
- Research and Development & Market Modeling
  - Comprehensive Testing Program Underway
  - Industry-Leading Modeling Initiatives
  - Other Non-Electric Investigations
    - Supporting INL with control/human factors
    - FOA-1817 on Hydrogen Integration
    - NEUPs
      - Optimization of Storage + Desal
      - ZLD Desal + Brine Mining
    - SBIR: Use of sCO_2 heat pumps for high-grade process heat from LWRs

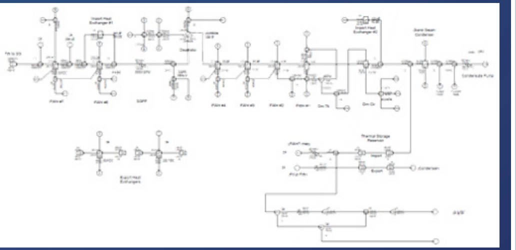


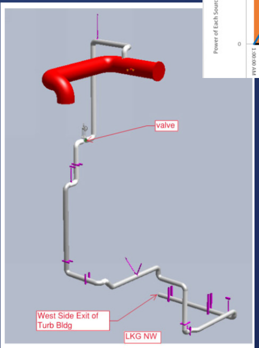


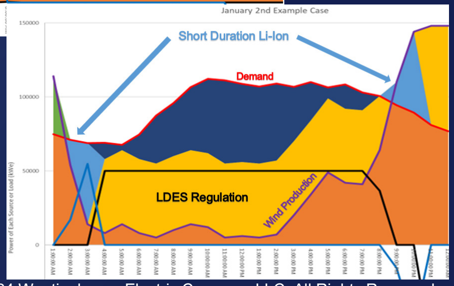












Spring Review Panel Briefing

Flexible Plant Operations & Generation

LWR Thermal Energy Extraction Pre-conceptual Design Study

Alan Wilson
Sr. Vice President
Sargent & Lundy

Wednesday May 1, 2024

Sargent & Lundy (S&L) Areas of Support 2023 - 2024

- **High Volume TPD Analysis from PWR**
  (Completed Q2 2023 – Q1 2024)
  - 30% TPD
  - 50% TPD
  - 70% TPD
- **500MW NPP (PWR) – H2 Integration Design**
  (To be Completed Q2 2024)
  - **Focus Areas**
    - $500MW_{DC}$ Hydrogen Facility Design
    - Update NPP-H2 Facility Integration Design
- **500MW NPP (BWR) – H2 Integration Design**
- **(To be Completed Q4 2024)**
  - **Focus Areas**
    - BWR Thermal Extraction
    - NPP – H2 Integration Design

High Volume TPD Analysis from PWR Overview

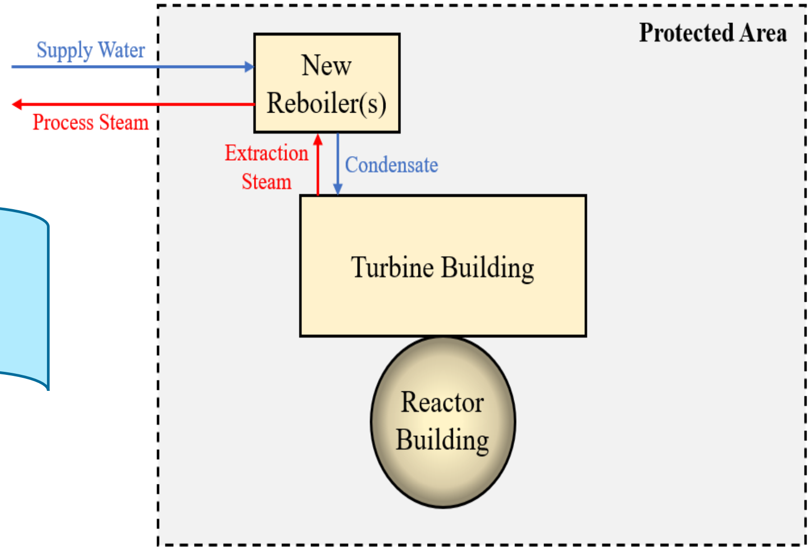
High Volume Thermal Power Dispatch Design (*S&L Report SL-017758*)

Research Objective

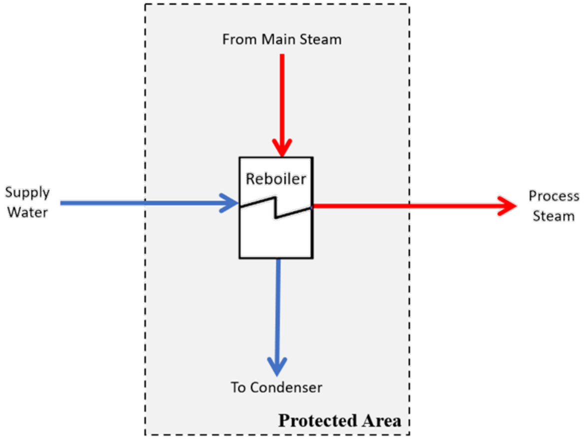
Assess feasibility of extracting large volumes of thermal energy (i.e., steam) from a PWR for industrial steam utilization applications

- Heat Balance Modeling
- Plant Impacts and Considerations
- Plant Secondary Equipment Evaluations
  - ✓ High Pressure Turbine (HPT)
  - ✓ Low Pressure Turbines (LPTs)
  - ✓ Condenser
  - ✓ Power Train Pumps
  - ✓ Moisture Separator Reheaters (MSRs)
  - ✓ Feedwater Heaters (FWHs)
  - ✓ Extraction Steam Lines
  - ✓ Heater Drains

PEPSE – Thermal Extraction Analysis



Reference Plant General Arrangement



Supply/Return Locations

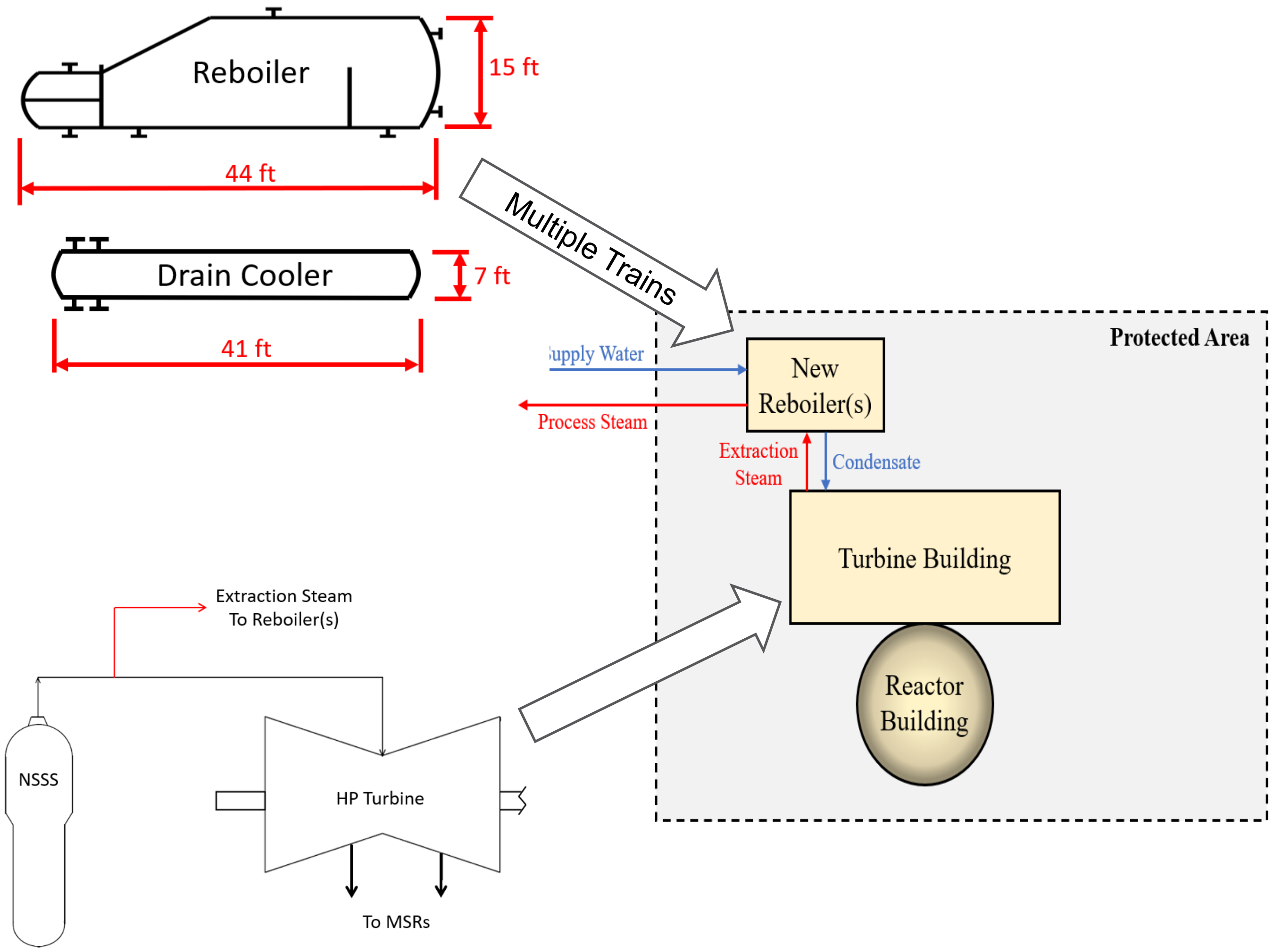
High Volume Thermal Power Dispatch Design (*S&L Report SL-017758*)

Thermal Power Dispatch (TPD) Cases

1. 30% TPD (June 2023)
   - ~1,100 MWt Extraction
2. 50% TPD (November 2023)
   - ~1,825 MWt Extraction
   - Alternate FWH bypass scenario
3. 70% TPD (January 2024)
   - ~2,550 MWt Extraction

Reference Nuclear Power Plant

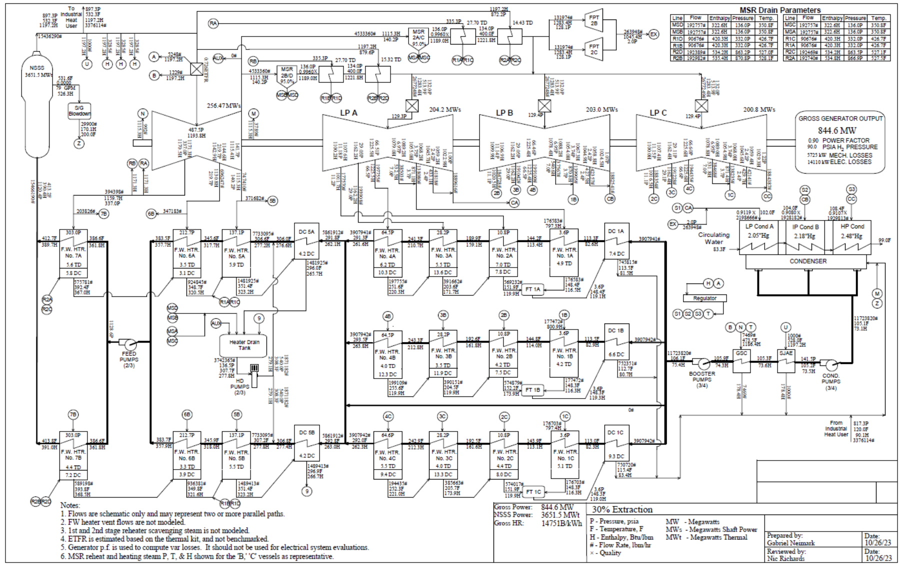
- Westinghouse 4-loop PWR
  - Capacity: 1,225 MWe (3,650 MWt)
  - Main Steam Extraction
  - Condenser Return



High Volume Thermal Power Dispatch Design (*S&L Report SL-017758*)

PEPSE Heat Balance Summary

- Greater TPD leads to:
  - Decreased electrical output and plant efficiency
  - Reduced Main Steam flows
  - Reduced Final Feedwater Temperature



Example TPD Heat Balance Diagram

PEPSE Heat Balance Result Summary

Description	Units	Thermal Extraction Scenario			
		Baseline (0%)	30%	50%	70%
Generator Electric Power	MWe	1,228.0	844.6	585.3	327.3
Thermal Power Extracted	MWt	0	1,095	1,827	2,557
% of Flow - MS	%	0	21.9	37.6	55.0
MS Flow from SGs	lbm/hr	16,037,390	15,436,290	14,952,560	14,316,180
HP Turbine Inlet Flow	lbm/hr	15,218,400	11,272,260	8,615,524	5,893,152
LP Turbine Inlet Flow	lbm/hr	3,673,069	2,677,248	1,980,267	1,230,440
Condenser Duty	BTU/hr	8.21E+09	5.78E+09	4.18E+09	2.57E+09
Final Feedwater Temperature	°F	440.9	413.3	389.0	354.0
Reboiler Inlet Mass Flow	lbm/hr	-	3,376,114	5,629,289	7,878,196

High Volume Thermal Power Dispatch Design (*S&L Report SL-017758*)

Plant Impacts and Considerations

- Mechanical Transients
  - 30% TPD → 22% of Main Steam Flow
  - 50% TPD → 38% of Main Steam Flow
  - 70% TPD → 55% of Main Steam Flow
- Plant Hazards
  - HELB Program impacts
  - Water/steam hammer considerations
- Core Reactivity and Plant Response
  - Startup/shutdown
  - Thermal Load Rejection

30% TPD Operation is Well within NPP Control System Capabilities

50% TPD Operation may Challenge NPP Control System Capabilities

70% TPD Operation expected to Challenge NPP Control System Capabilities

Station Specific NSSS Evaluation Required

High Volume Thermal Power Dispatch Design (*S&L Report SL-017758*)

Equipment Evaluations

- Minimal Adverse Impacts
  - ✓ High Pressure Turbine (HPT)
  - ✓ Low Pressure Turbines (LPTs)
  - ✓ Condenser
  - ✓ Power Train Pumps
  - ✓ Moisture Separator Reheaters (MSRs)
  - ✓ Heater Drain Tanks

- Significant Adverse Impacts Above 50% TPD
  - ❖ Feedwater Heaters (FWHs)
    - Flow accelerated corrosion concerns due to increased velocities
  - ❖ Extraction Steam Lines
    - Increased pressure drop and liner thickness requirements
  - ❖ FWH Drain Control Valves
    - Increased flow capacity (C_v) requirements
    - Operational changes may be required

No Major Equipment Replacements Expected for 30% TPE

Minor Equipment Replacement and/or Operational Change Expected for 50% TPE

Major Equipment Replacement and/or Operational Change Expected for 70% TPE

Additional Minor Upgrades and Maintenance may be Required for Specific Components

High Volume Thermal Power Dispatch Design (*S&L Report SL-017758*)

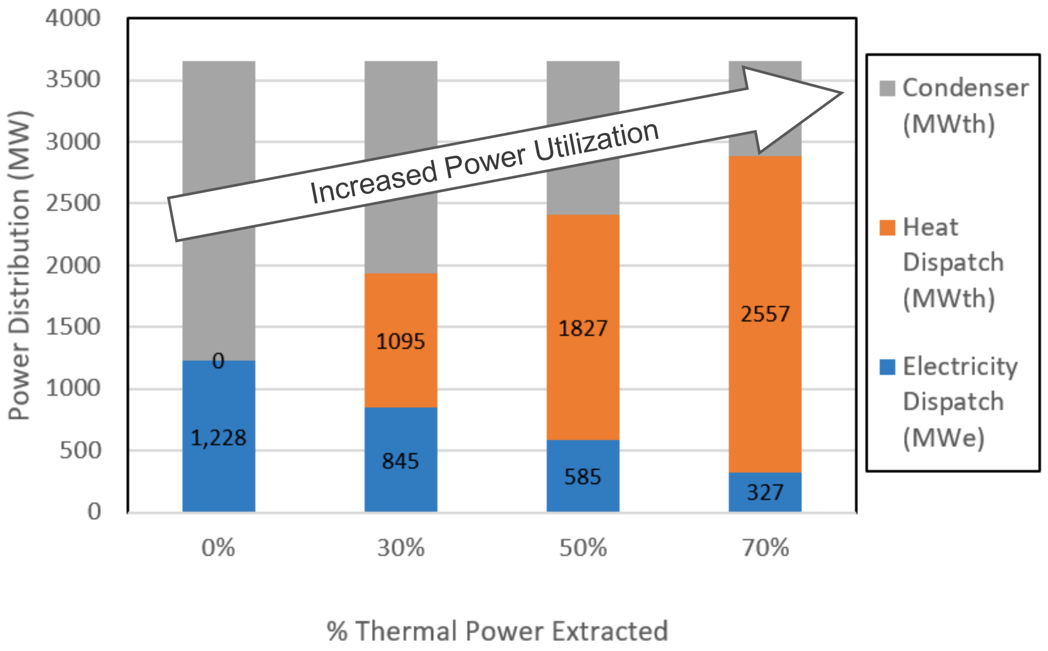
Conclusions

- Increased thermal power utilization with greater TPD

- 30% TPD is expected to be feasible for existing PWRs
  - ❖ No Major Equipment Replacement Expected
  - ❖ Within Control System Design Capabilities

- 50% TPD may be feasible for some existing PWRs
  - ❖ Minor Equipment Replacement Expected
  - ❖ Potential Operating Changes
  - ❖ Potential Control System Impacts

- 70% TPD is not expected to be achievable for most PWRs
  - ❖ Significant Equipment and Controls Impacts



Power Distribution for Different TPD Scenarios

500MW NPP (PWR) – H2 Integration Design Overview

500MW NPP – H2 Integration : SOEC Plant Design

Thermal / Electrical Energy

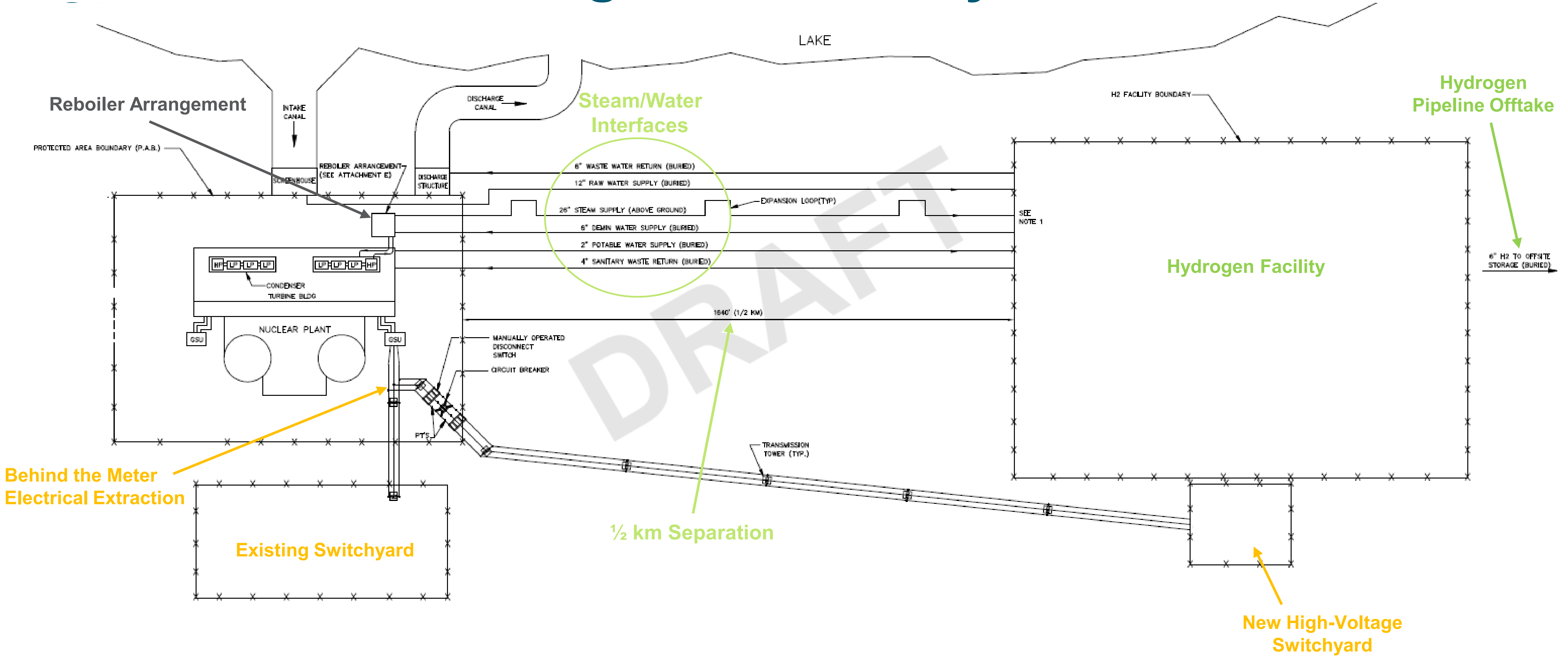
In Progress Work

Focus Area

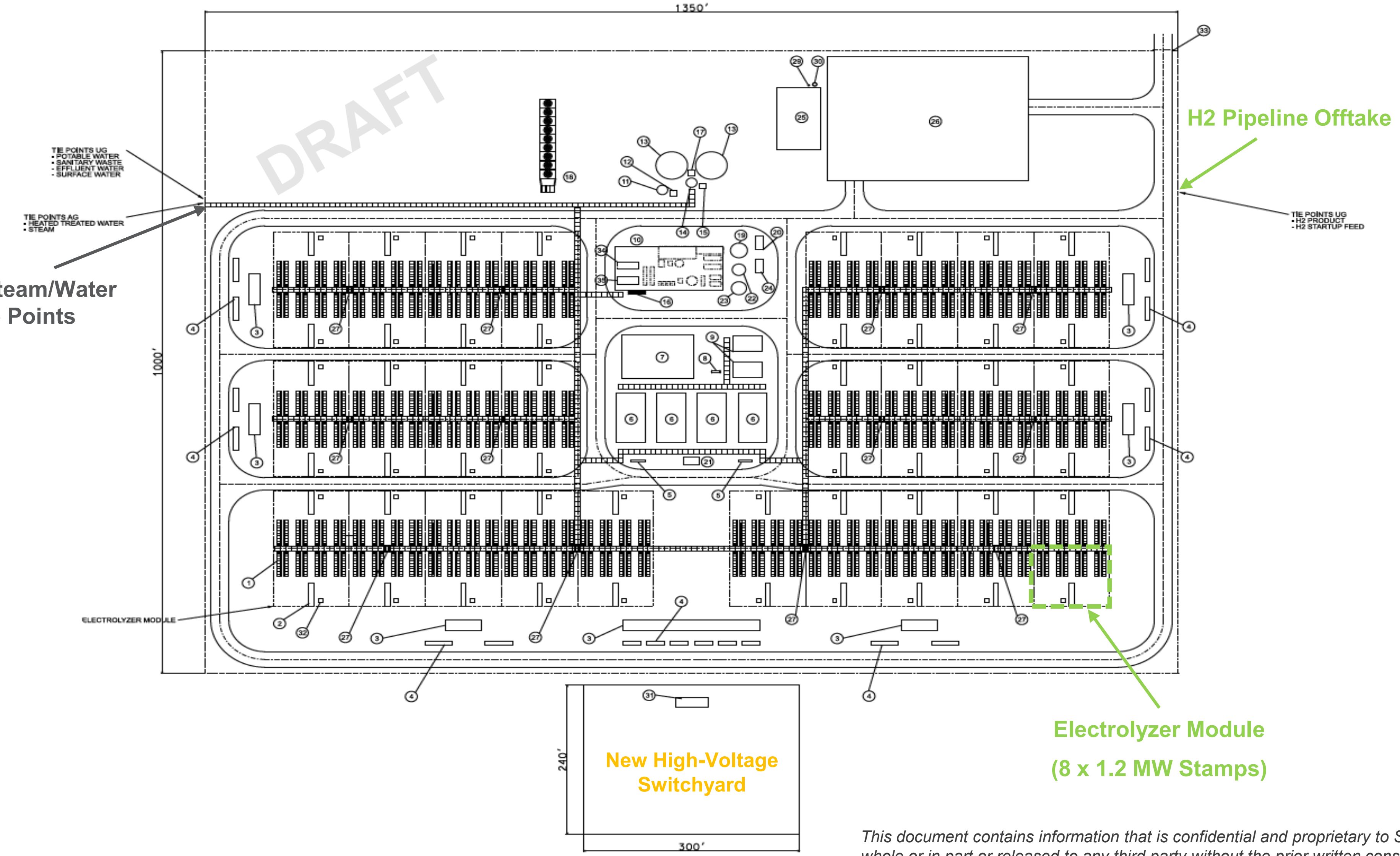
- **NPP Reference Plant**
  - Based upon typical for 1/3 of operating US NPP Units
    - Westinghouse 4-loop PWR
    - $1200MW_e$ / $3,700MW_{th}$ / SWYD: 345kV

- **Hydrogen Facility Plant**
  - $500MW_{DC}$
    - Thermal Load – $100MW_{th}$
    - Hydrogen Production - 300 tons/day

500MW NPP – H2 Integration Site Layout

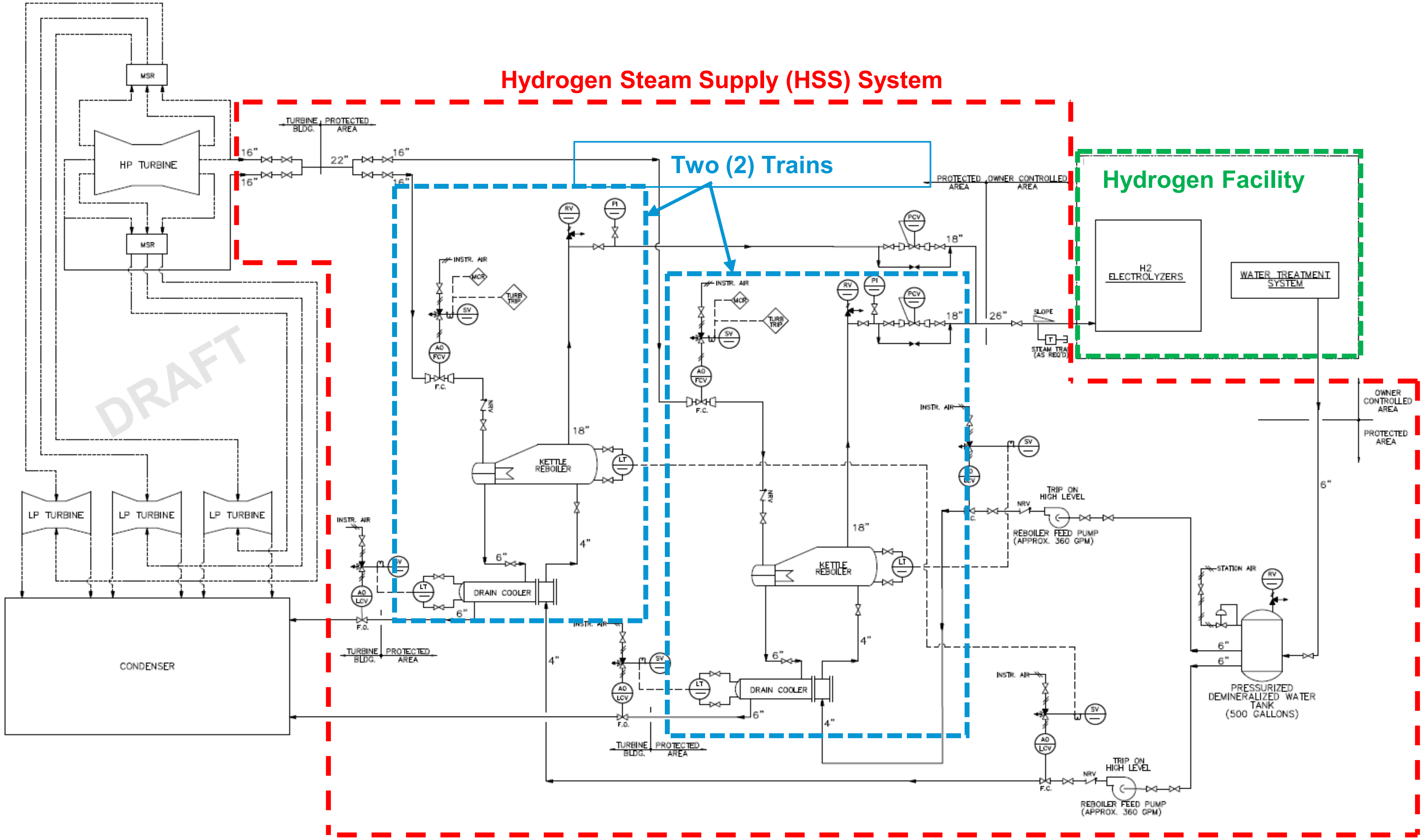


Hydrogen Facility General Arrangement



LEGEND	
01	1.2MW ELECTROLYZER STAMP (QTY 416)
02	RECTIFIER/TRANSFORMER (QTY 52)
03	PDC
04	TRANSFORMER
05	HEAT EXCHANGER
06	LOW PRESSURE COMPRESSION
07	PURIFICATION AND DRYING
08	HYDROGEN BUFFER VESSEL
09	HIGH PRESSURE COMPRESSION
10	UTILITY AIR AND WATER TREATMENT BLDG.
11	SLUDGE HOLDING TANK
12	FILTER PRESS FEED PUMPS
13	CLARIFIER
14	CLEARWELL
15	CLARIFIED WATER PUMPS
16	NITROGEN PRESSURE VESSELS
17	CLARIFIED SLUDGE PUMPS
18	COOLING TOWER
19	SERVICE/FIRE PROTECTION TANK
20	FIRE PROTECTION PUMPS
21	CONDENSATE RECOVERY SUMP
22	TREATED WATER TANK
23	EFFLUENT TANK
24	WATER PUMP HOUSE
25	ADMINISTRATION/CONTROL BUILDING
26	PARKING AND STAGING AREA
27	MODULE CONDENSATE SUMP
28	SWITCHYARD
29	POTABLE WATER BLADDER TANK
30	SANITARY LIFT STATION
31	HIGH VOLTAGE PDC
32	TELEMETRY CABINET (QTY 52)
33	ENTRY GATE
34	INSTRUMENT AIR SKID
35	NITROGEN SKID

Nuclear Plant Thermal Integration P&ID

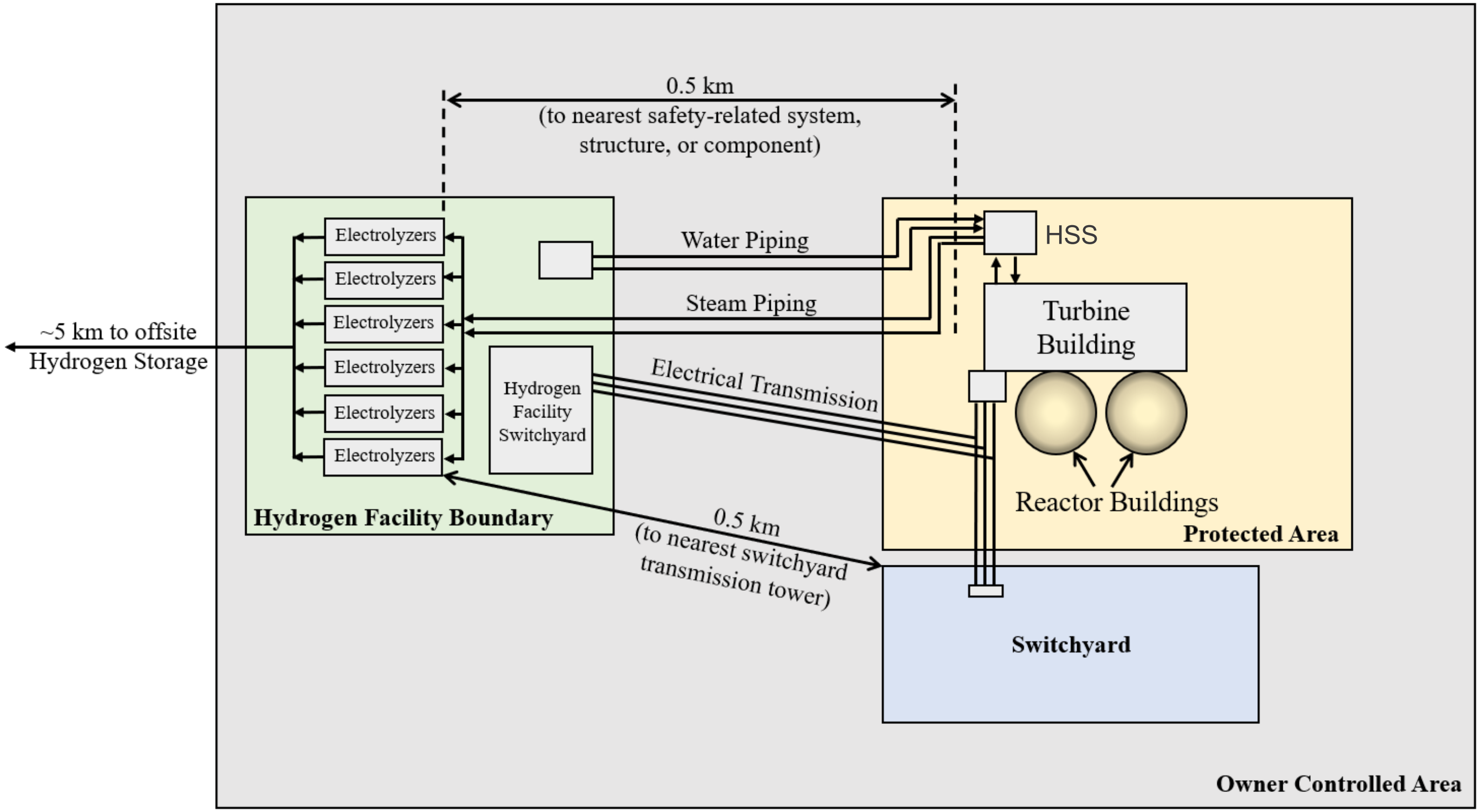


500MW NPP (BWR) – H2 Integration Design Overview

S&L Pre-Conceptual Plant Design

In Progress Work

- **NPP (BWR) Reference Plant**
  - Typical US BWR Units
    - GE Type 4 BWR
    - 1,100MW_e / 4,000MW_{th}
    - Hydrogen Steam Supply (HSS) Equipment
- **Hydrogen Facility Plants**
  - 500MW_{DC}
    - Thermal Load – 100MW_{th}
    - Hydrogen Production - 300 tons/day



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LWRS LIGHT WATER REACTOR SUSTAINABILITY

Sustaining National Nuclear Assets

lwrs.inl.gov

U.S.NRC
UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

NRC Staff Perspectives on Hydrogen Production at Nuclear Power Plants

Gerond A George
Branch Chief
Licensing Projects Branch
Office of Nuclear Reactor Regulation

LWRS MOU NRC/DOE

ML21124A125

- The purpose of the MOU is to coordinate DOE and NRC technical readiness and sharing of technical expertise and knowledge on advanced nuclear reactor technologies and nuclear energy innovation.
  - NRC’s Role for this discussion
    - Provide current information on licensing and regulatory reviews of emerging technologies to prioritize regulatory needs

Current Activities for H_2 generation

- The NRC is currently monitoring H_2 generation implementation activities and reviewing information shared through the MOU.

- Specifically, for the H_2 generation activities, NRC staff from different NRC offices have been meeting frequently to determine if any licensing and oversight impacts will appear from these emerging technologies.

NRC Regulatory Framework

- Existing NRC regulatory framework adequately supports installation and operations associated with hydrogen production and storage.

- Need for a License Amendment Request (LAR) prior to installation and operation will be determined by site specific license basis considerations.

- Topical Reports can be used as a basis for LARs to alleviate potential licensing uncertainties within the general aspects of designs.

- Those changes to facilities that do not need LARs could potentially be reviewed during the NRC oversight activities.

Licensing Basis and Facility/Procedure Changes

- **Changes governed by 10 CFR 50.59**
  - Technical Specifications changes will require a LAR
  - Facilities and Procedures described in Updated Final Safety Analysis Reports must be evaluated against guidance approved in RG 1.187

- **Other License Basis Changes**
  - Quality Assurance Plan
  - Fire Protection Plan
  - Emergency Plan / Emergency Response Facilities
  - Security Plan / Target Set
  - Independent Spent Fuel Storage Installations (ISFSIs)

Updated Final Safety Analysis Report Potential Impacts

- Hydrogen production and storage at a site has the potential to impact accidents, transients, and other discussions in the Updated Final Safety Analysis Report (UFSAR):

  – Excess Steam Flow
  – Loss of Load / Load Rejection
  – ATWS considerations (HTEF only)
  – High-Energy Line Break (HTEF only)
  – Loss of Offsite Power
  – Turbine-Generator Trip
  – Internal Flooding
  – Impact to Accident Indications
  – Control Room and Plant Operations

  *LIST IS NOT ALL INCLUSIVE

Fire Protection Considerations

- Changes that impact onsite fires and explosions are governed by site specific fire protection program license conditions.
- Focus is on maintaining provisions of General Design Criterion (GDC) 3, “Fire Protection,” of Appendix A to Part 50, “General Design Criteria for Nuclear Power Plants.”
- NRC guidance found in:
  - RG 1.189, Revision 5 “Fire Protection for Nuclear Power Plants” (ADAMS Accession No. ML23214A287)
  - RG 1.205, Revision 2, “Risk-Informed, Performance-Based Fire Protection for Existing Light-Water Nuclear Power Plants” (ADAMS Accession No. ML21048A448)

Emergency Plan Considerations

- Changes to emergency plans are governed by 10 CFR 50.54, "Conditions of licenses" (specifically 10 CFR 50.54(q))
- Changes to a licensee's emergency plan that reduce the effectiveness of the plan may not be implemented without prior approval by the NRC.
- NRC guidance found in RG 1.219, Revision 1 "Guidance on Making Changes to Emergency Plans for Nuclear Power Reactors" (ADAMS Accession No. ML16061A104)
- As an example, consider impacts to Emergency Response Facilities and Emergency Action Levels

Security Plan Considerations

- Changes to that impact the safety / security interface are governed by 10 CFR 73.58, “Safety / security interface requirements for nuclear power reactors”
- Licensees shall assess and manage the potential for adverse effects on safety and security before implementing changes.
- NRC guidance found in RG 5.74, Revision 1 “Managing the Safety / Security Interface” (ADAMS Accession No. ML14323A549)
- As an example, consider impacts to target sets, staging areas, response times and locations, and barriers.

ISFSI Considerations

- Changes that can impact ISFSIs are governed by 10 CFR 72.48, “Changes, tests, and experiments,” and 10 CFR 72.212, “Conditions of general license issued under § 72.210.”
- 10 CFR 72.48 discusses when a LAR is needed prior to making changes.
- NRC guidance found in RG 3.72, Revision 1 “Guidance for Implementation of 10 CFR 72.48, Changes, Tests, and Experiments” (ADAMS Accession No. ML20220A185)
- As an example, consider impacts to facility / cask designs which may differ from safety-related SSCs.

Questions?