Spring Review Panel Briefing

LWR Thermal Energy Extraction Pre-conceptual Design Study

Flexible Plant Operations & Generation

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

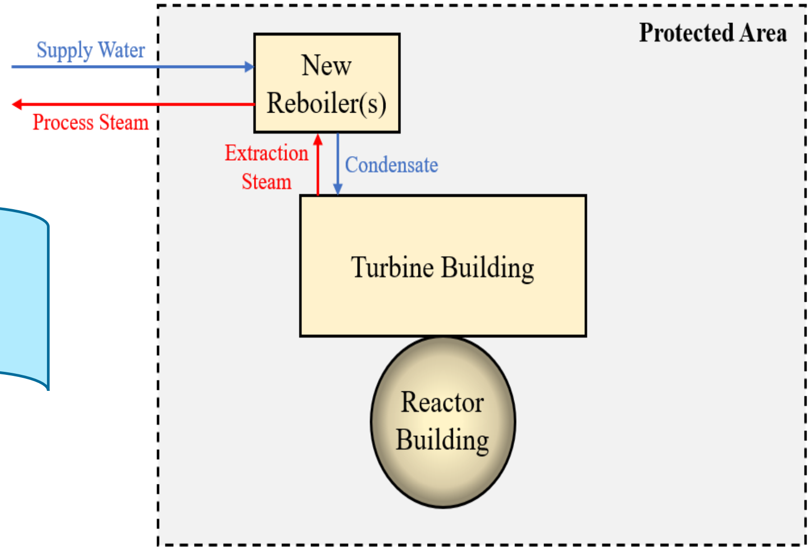
High Volume Thermal Power Dispatch Design (*S&L Report SL-017758*)

Research Objective

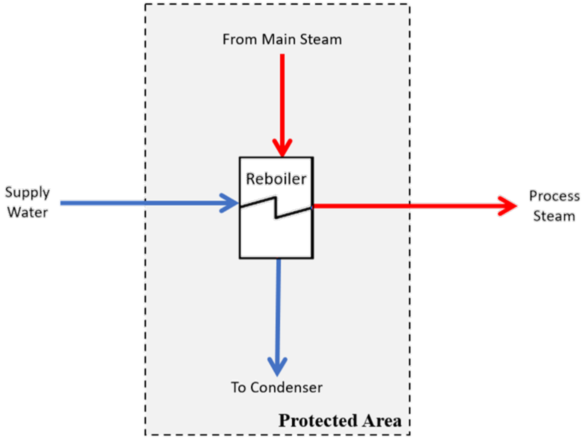
Assess feasibility of extracting large volumes of thermal energy (i.e., steam) from a PWR for industrial steam utilization applications

- 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

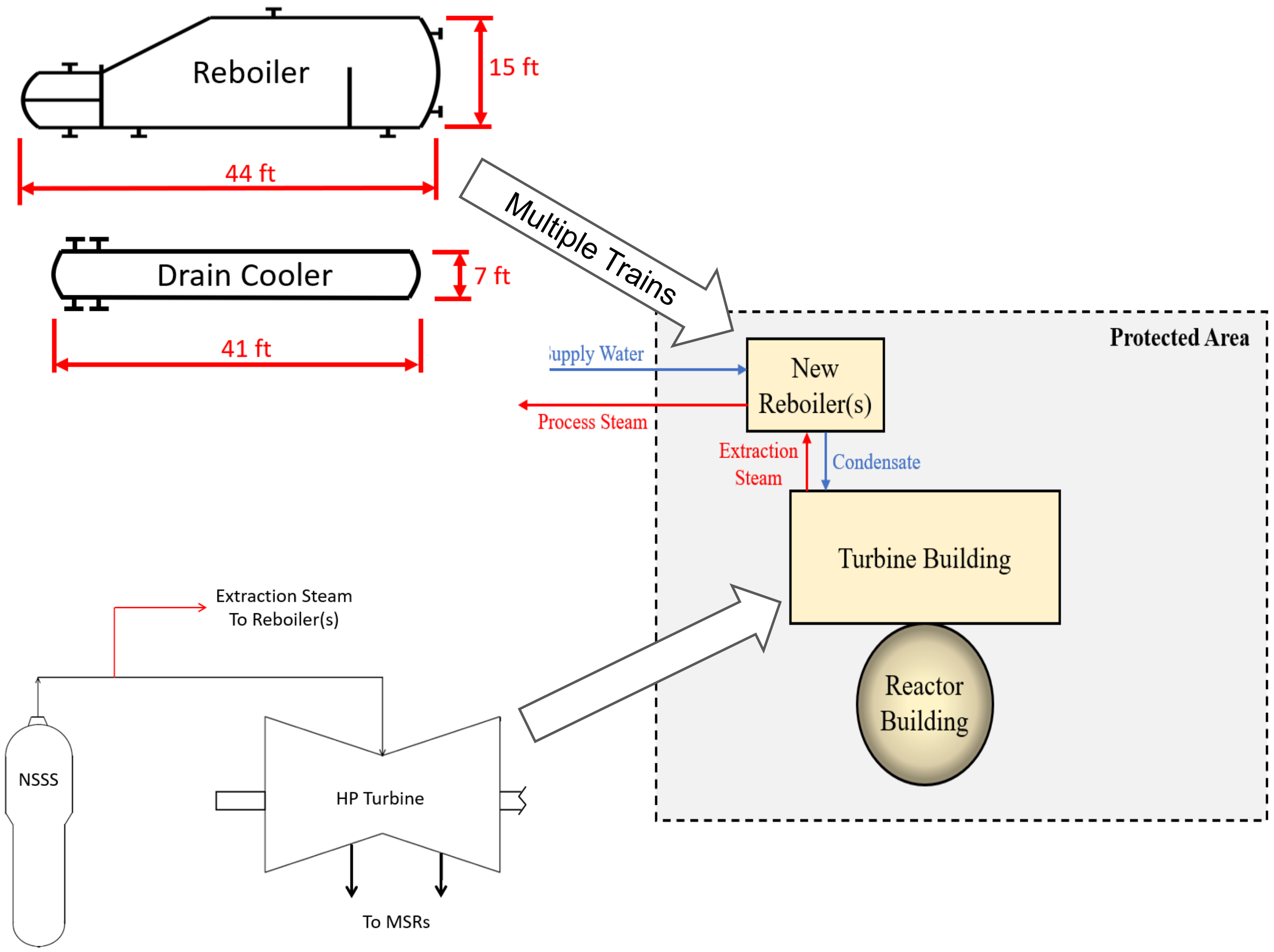
High Volume Thermal Power Dispatch Design (*S&L Report SL-017758*)

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



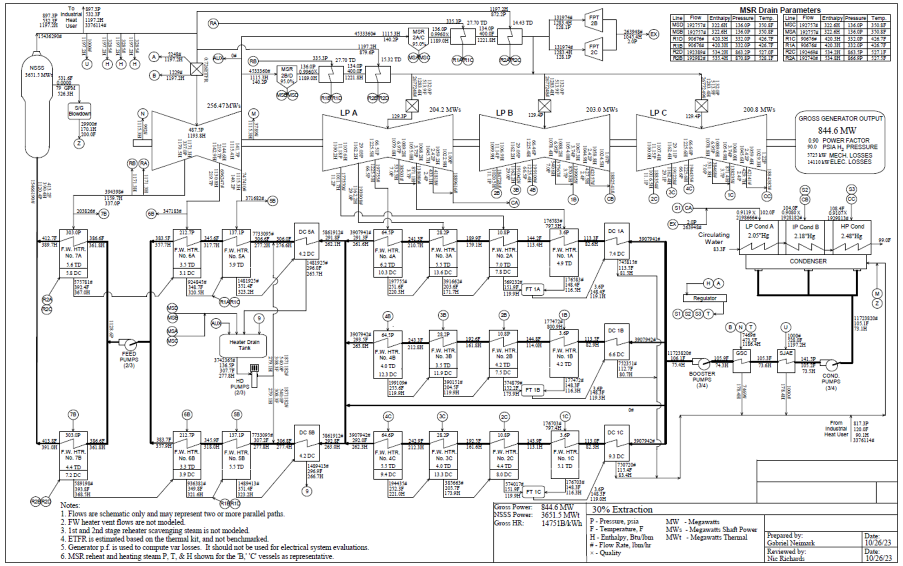
High Volume Thermal Power Dispatch Design (*S&L Report SL-017758*)

PEPSE Heat Balance Summary

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

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



Example TPD Heat Balance Diagram

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

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

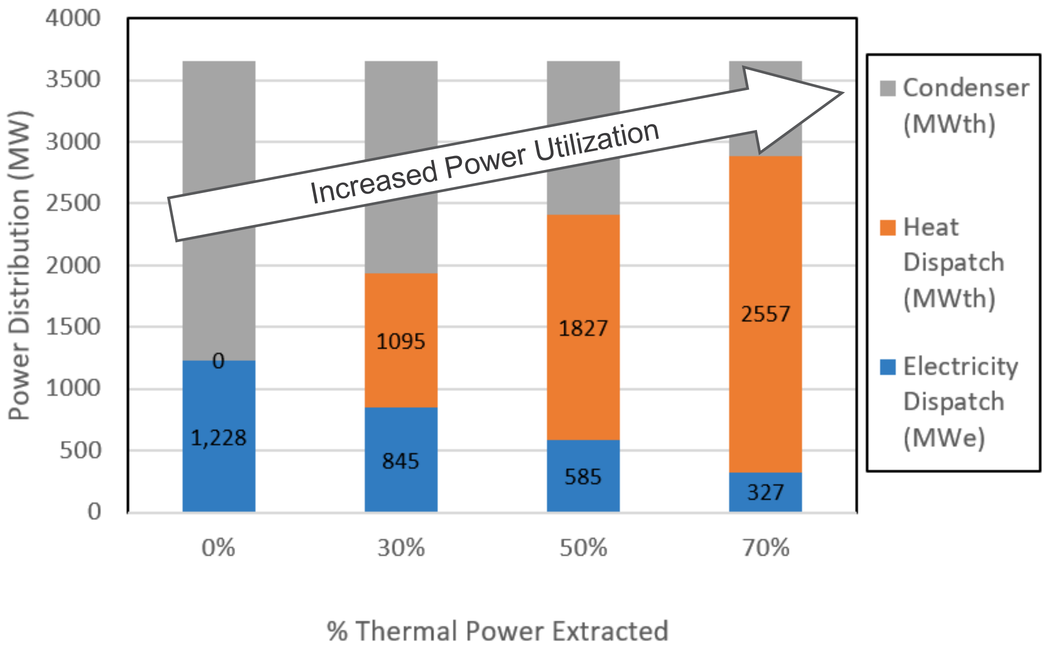
- Significant Adverse Impacts Above 50% TPD
  - ❖ Feedwater Heaters (FWHs)
    - Flow accelerated corrosion concerns due to increased velocities
  - ❖ Extraction Steam Lines
    - Increased pressure drop and liner thickness requirements
  - ❖ FWH Drain Control Valves
    - Increased flow capacity (C_v)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

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

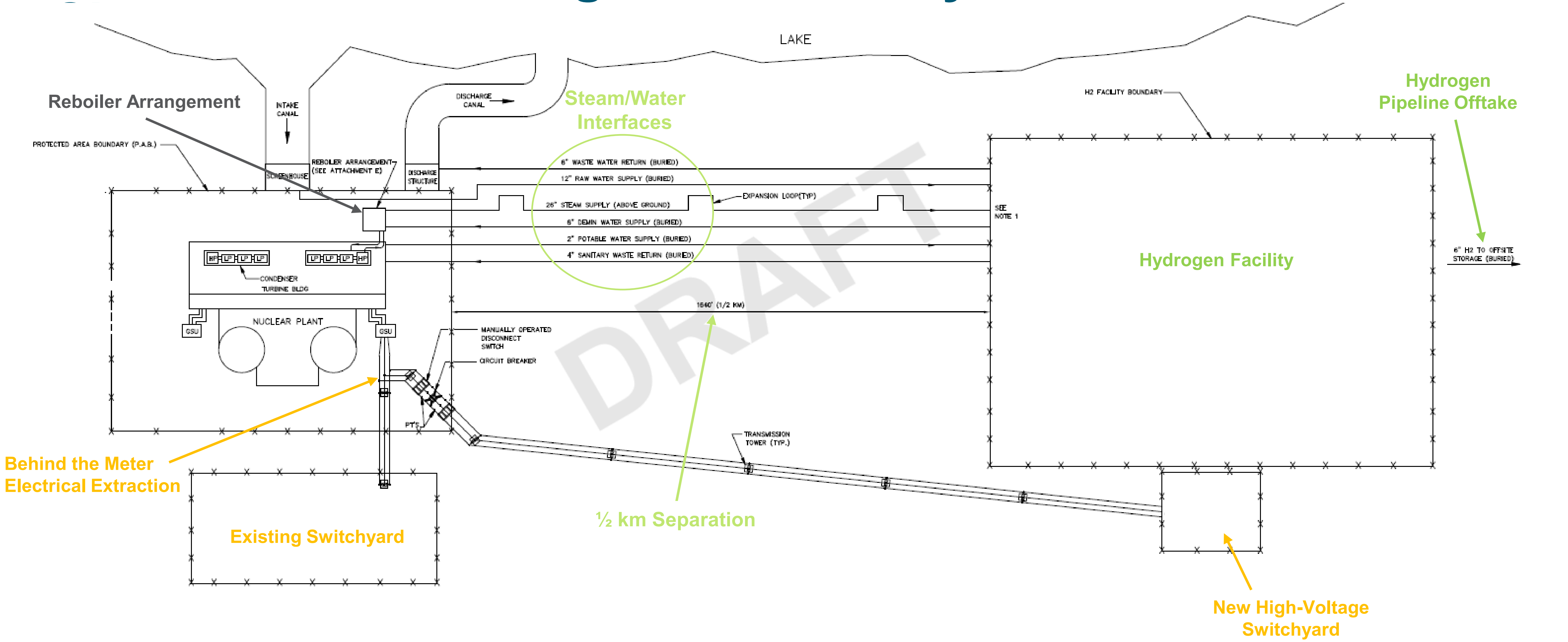
- **NPP Reference Plant**
  - Based upon typical for 1/3 of operating US NPP Units
    - Westinghouse 4-loop PWR
    - 1200MW_e / 3,700MW_{th} / SWYD: 345kV

In Progress Work

- **Hydrogen Facility Plant**
  - 500MW_{DC}
    - Thermal Load – 100MW_{th}
    - Hydrogen Production - 320 metric tons/day

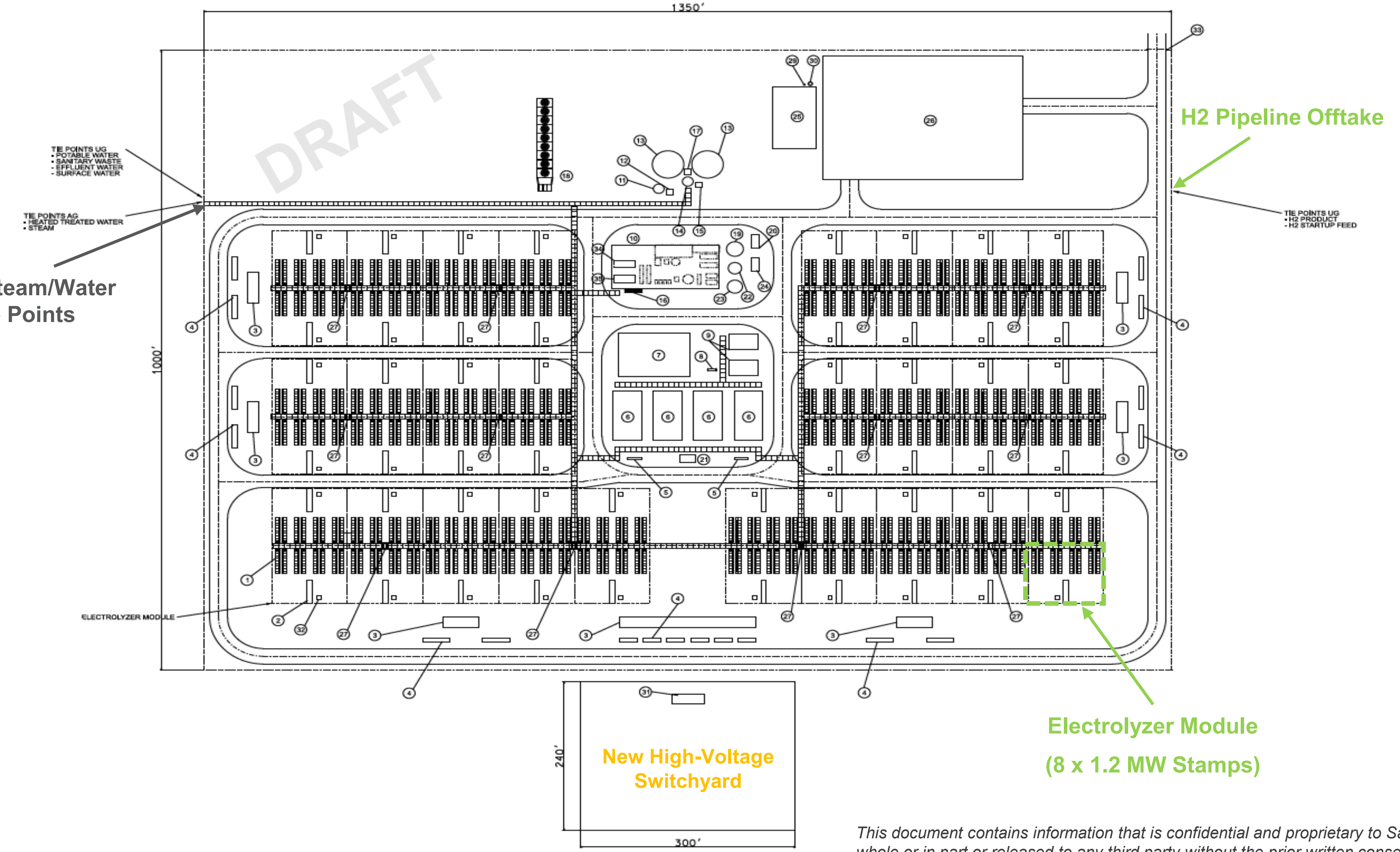
Focus Area

500MW NPP – H2 Integration Site Layout



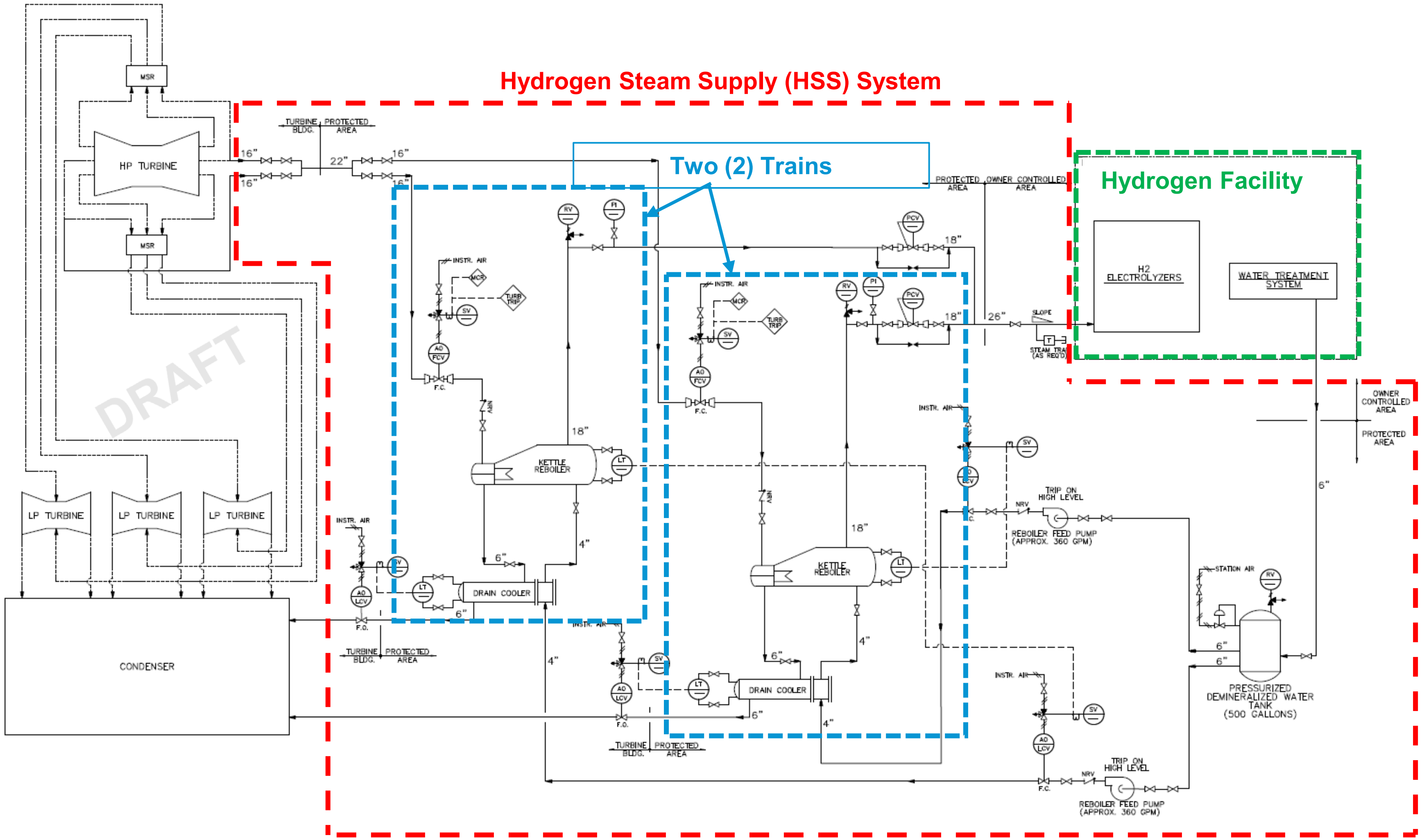
LWRS LIGHT WATER REACTOR SUSTAINABILITY

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

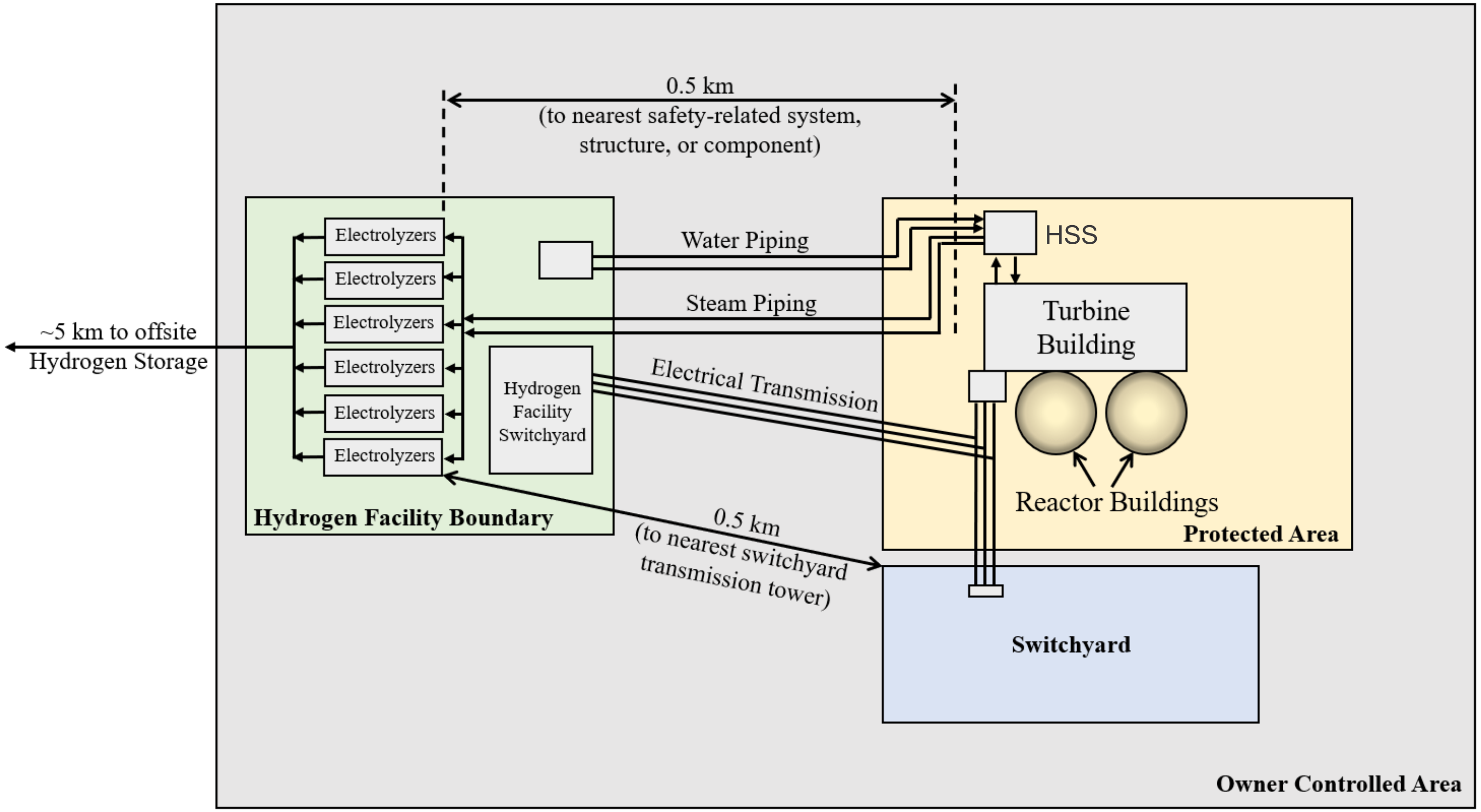


500MW NPP (BWR) – H2 Integration Design Overview

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: ~320 metric tons/day



Sargent & Lundy LWRS Hydrogen Design Team Leads:

Alan J. Wilson, PE, Principal Investigator, alan.j.wilson@sargentlundy.com

Steven Malak, Sr. Project Manager, steven.malak@sargentlundy.com

Henry Fidlow, Responsible Engineer, henry.r.fidlow@sargentlundy.com

Pawel Kut, Thermal Analysis Lead, pawel.kut@sargentlundy.com

Richard Lindberg, Mechanical Engineering Lead, richardel.c.lindberg@sargentlundy.com

Hassan Abughofa, Electrical Engineering Lead, hassan.abughofah@sargentlundy.com

Casey Loughrin, Hydrogen System Design Lead, casey.j.loughrin@sargentlundy.com

Mark Prasse, Hydrogen SME, marc.g.prasse@sargentlundy.com

LWRS

LIGHT WATER REACTOR SUSTAINABILITY

Sustaining National Nuclear Assets

lwrs.inl.gov