DOE-LSU UPRISE Meeting

May 27, 2026

Capacity Expansion for Data Centers and Industry Energy Demand

Richard Boardman, Svetlana Lawrence, Tyler Westover, Paul Talbot, Jack Cadogan, Jeff Brown Fred Joseck, Brad Adams

Parts: Supply Chain of Equipment for:
- Plant Thermal Efficiency Recovery
- Stretch, Extended, and Advanced Uprates
- New Plants
- Advanced fuels and fuel assemblies

People: Expanded work force:
- Engineers for plant design
- Equipment manufacturing
- Nuclear plant construction
- Plant operations

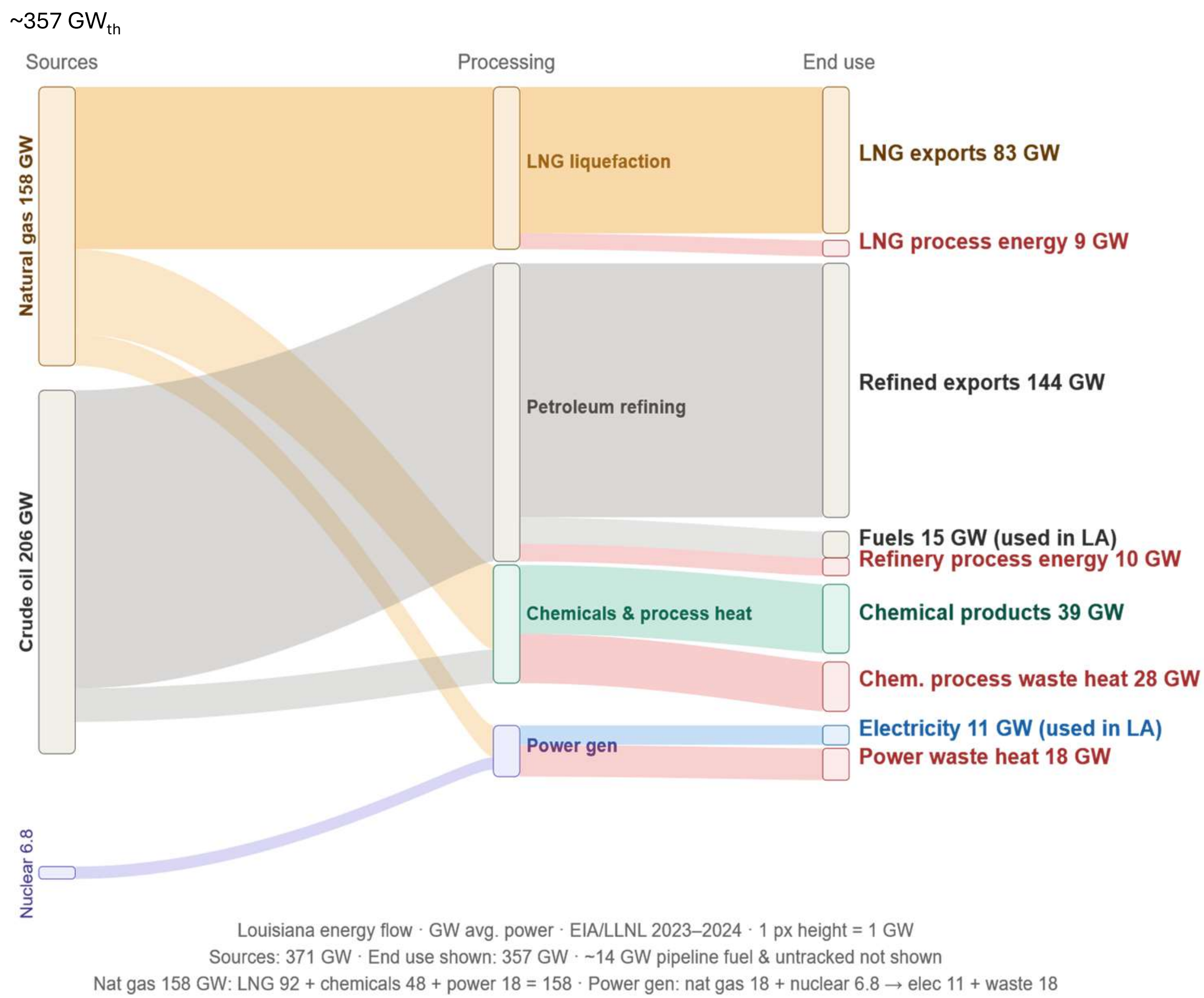
Processes: Preparation and review of NRC License Amendment Requests and PUC/FERC Approvals

Projects: Business case risk reduction and project execution
- Conceptual designs and risk analysis for optimal uprates
- Market studies for economic assessment
- Partnership agreements, and financing
- Final engineering and plant construction

LOUISIANA the

"PROCESS STATE"

- Export LNG and crude distillates.
- We also use NG and crude to make carbon-based chemicals and ammonia.
- We process minerals (Fe, Al, Cl, F, S).
- We use an average of 11 GW of electricity and ~2 GW comes from 2 nuclear power plants.
- Solar and coal also provides some energy, they are relatively small.



LOUISIANA in 2050

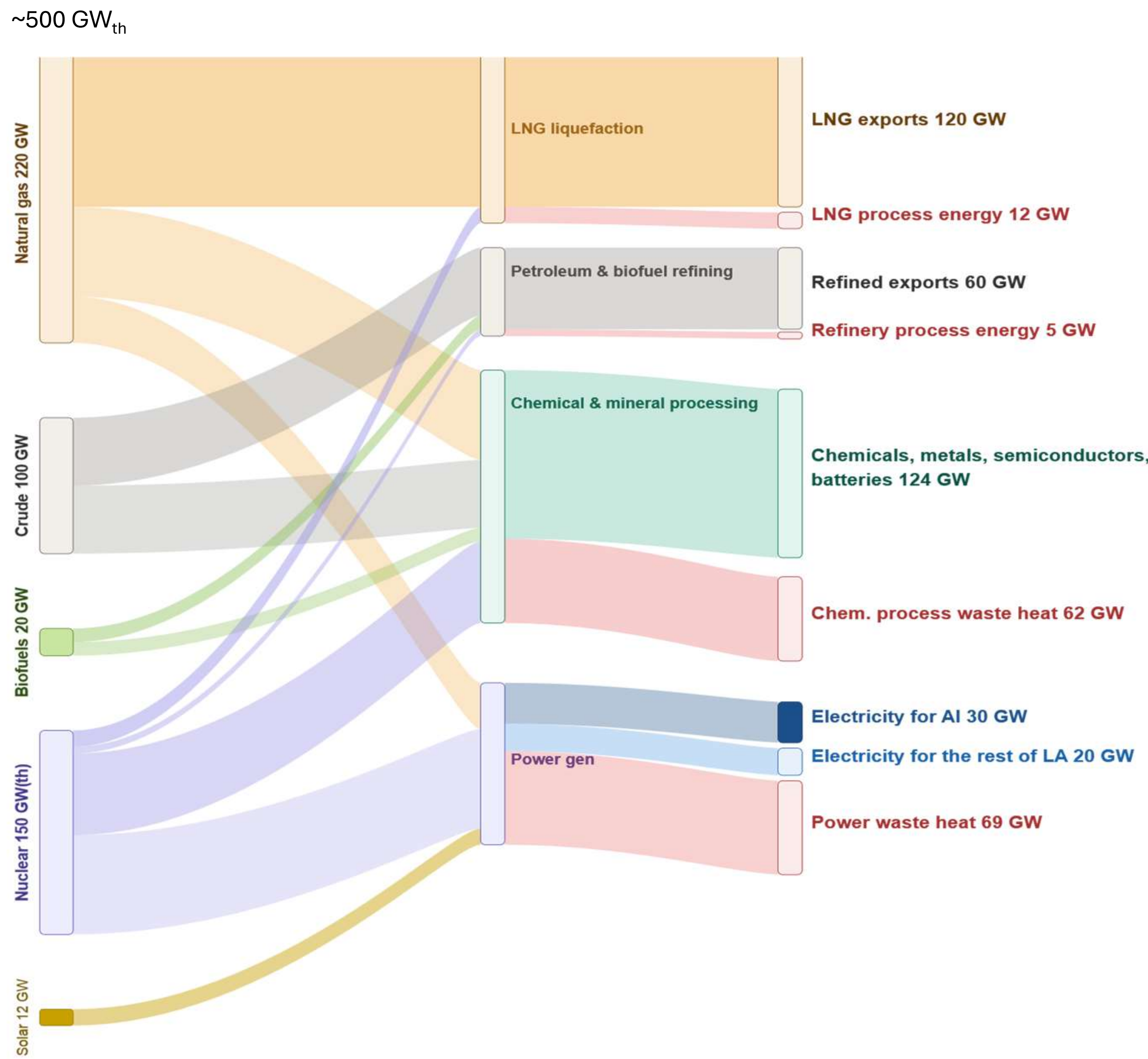
- Total energy increases by 35%

- Sources
  - Natural gas increases by ~40%
  - Crude decreases by ~50%
  - Nuclear grows ~20x (backbone)
  - Solar and bio adds 32 GW

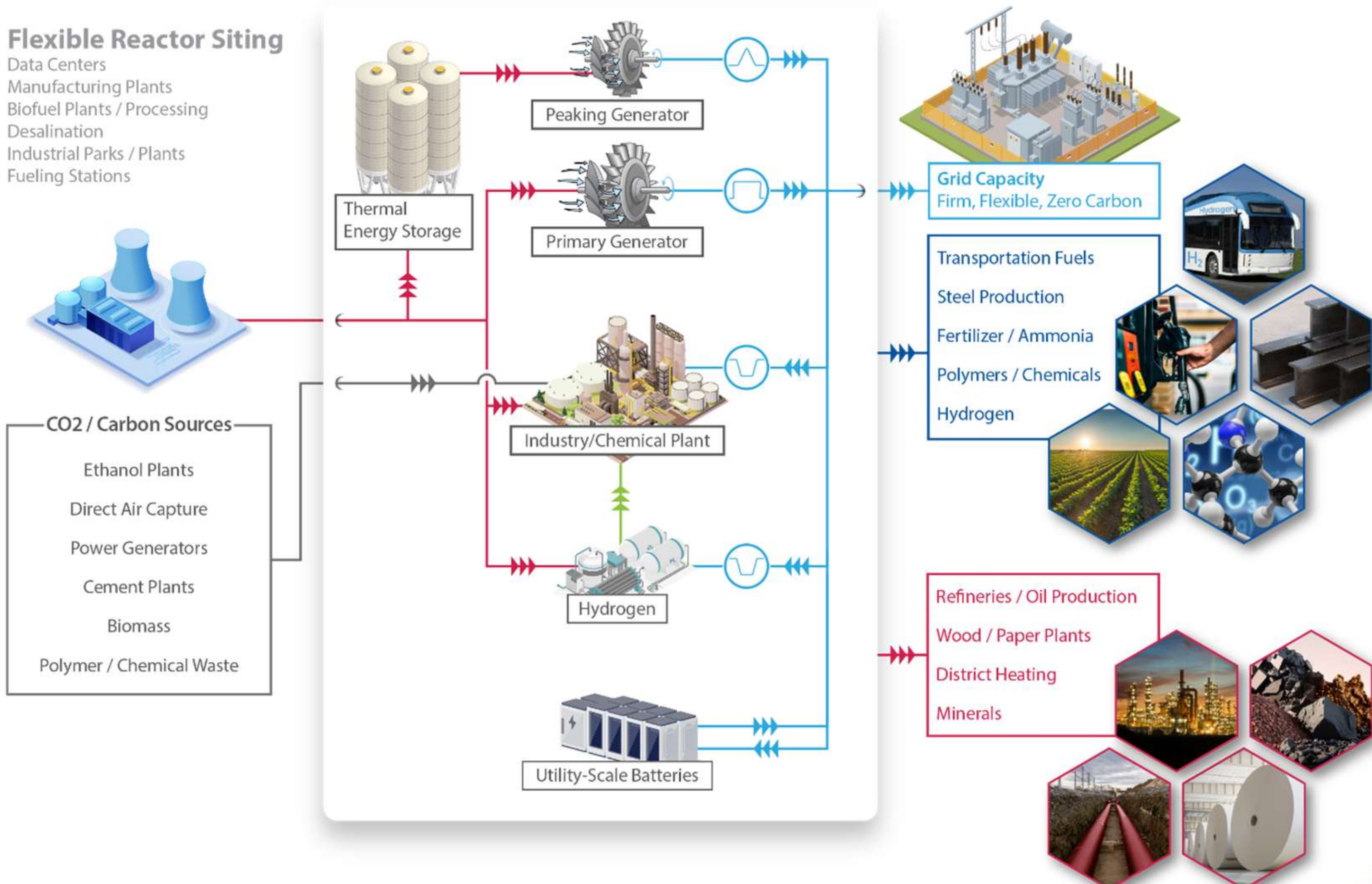
- Export more LNG to Europe and Asia
- Still produce jet fuel from crude
- Still need carbon-based chemicals
  - (shoes, detergents, packaging, battery parts, tires)
- We process more minerals (add Ga, REEs)
- AI will require more electricity (30GW) than the rest of Louisiana (20GW)

AI, energy exports and securing domestic growth in key supply chains add energy demand….

We need more nuclear and better **INTEGRATION.**



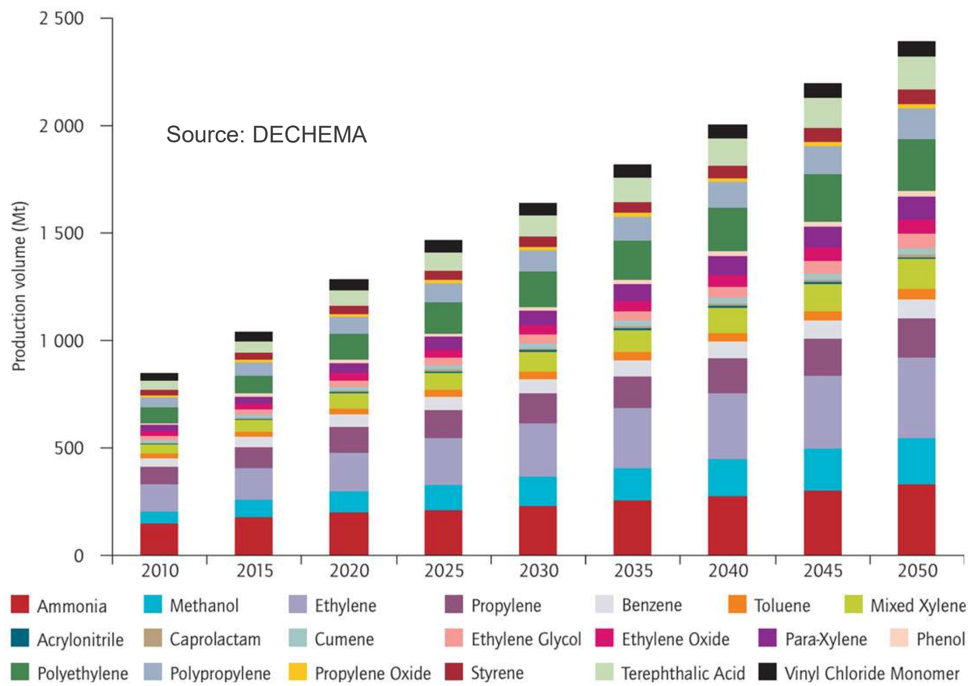
Nuclear beyond electricity enables diversification of light-water reactors to produce non-electrical products



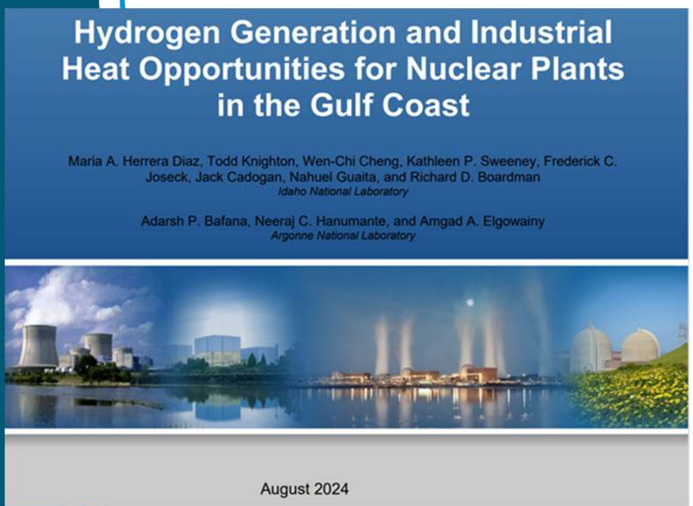
Chemical Manufacturing in the Gulf Shore Region

- 80% of U.S. primary petrochemicals are produced along the Gulf Coast in Louisiana and Texas
- The Industrial sector accounts for:
  - 70% of the energy use in Louisiana and 50% in Texas
  - This is mostly provided by natural gas, as the Gulf Coast accounts for 26% of U.S. consumption
- Base chemical manufacturing in Texas & Louisiana accounts for ~HALF of the industry's U.S. exports and GDP, with significant growth projected
- ~60% growth in global energy demand is expected

Global energy consumption versus production volumes projections



Visit LWRS Homepage for Technical and Economic Assessment Reports


Hydrogen Generation and Industrial Heat Opportunities for Nuclear Plants in the Gulf Coast

Maria A. Herrera Diaz, Todd Knighton, Wen-Chi Cheng, Kathleen P. Sweeney, Frederick C. Joseck, Jack Cadogan, Nahuel Guaita, and Richard D. Boardman
Idaho National Laboratory

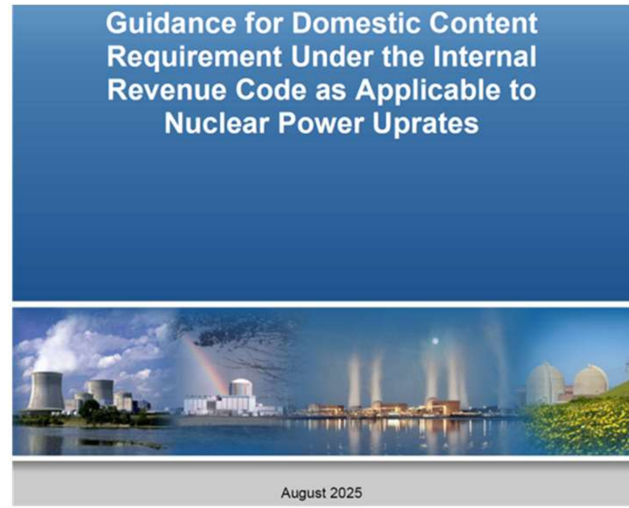
Adarsh P. Bafana, Neeraj C. Hanumante, and Amgad A. Elgowainy
Argonne National Laboratory

August 2024

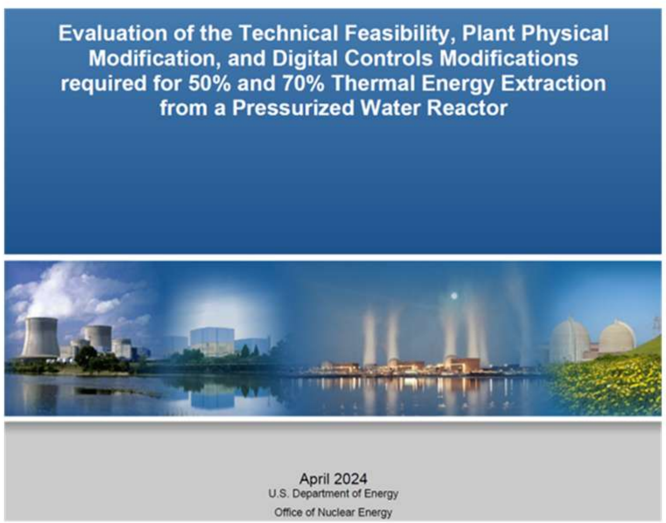

Regional Market Assessment for Power Offtake Agreements

Fred Joseck, Bikash Poudel, Nahuel Guaita, Venkat Durvasulu, Paul Talbot

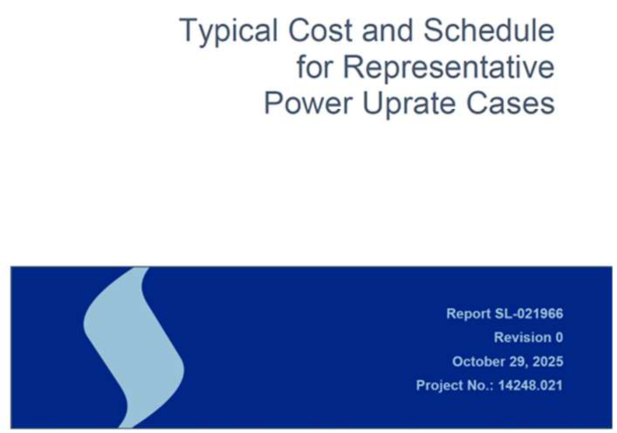
March 2026


Guidance for Domestic Content Requirement Under the Internal Revenue Code as Applicable to Nuclear Power Uprates

August 2025


Evaluation of the Technical Feasibility, Plant Physical Modification, and Digital Controls Modifications required for 50% and 70% Thermal Energy Extraction from a Pressurized Water Reactor

April 2024
U.S. Department of Energy
Office of Nuclear Energy

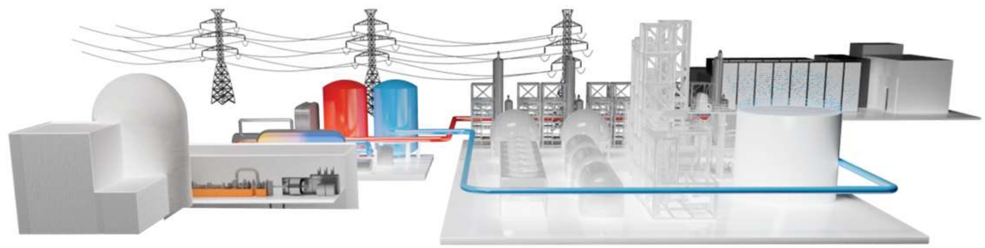

Typical Cost and Schedule for Representative Power Uprate Cases

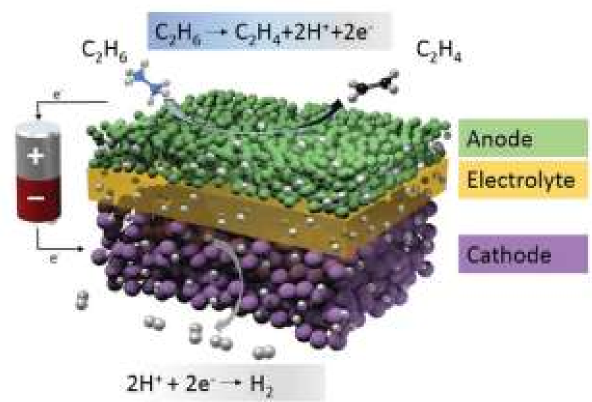
Report SL-021966
Revision 0
October 29, 2025
Project No.: 14248.021

LWRS
LIGHT WATER REACTOR SUSTAINABILITY

Establishing the Business Case for Projects

- **Expansion through uprates and addition of new reactors provide power for:**
  1) Electricity can be used for industry plant loads
  2) Electricity can be used for modern process electrification
  3) Heat in the form of high-pressure steam can be sent directly to the industrial facilities
  4) Heat and electricity can be used for pure hydrogen/oxygen production
- **Value proposition; the stacked value:**
  - Cost affordability
  - Reliability and high availability
  - Project implementation schedule needs to be de-risked



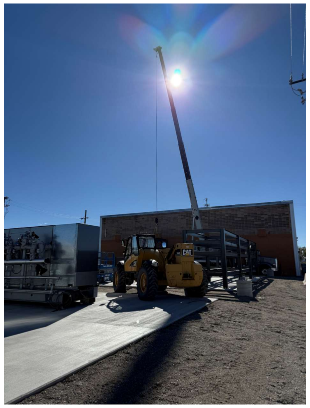


Direct Electrical Coupling → High Pressure Steam Coupling → Refineries and Chemical Plants of the Future

2027 - 2040 | 2030 - 2040 | 2040 - 2050

- ❑ **Water splitting hydrogen**
- ❑ Plastics by alkane de-protonation

Energy Technology Proving Ground

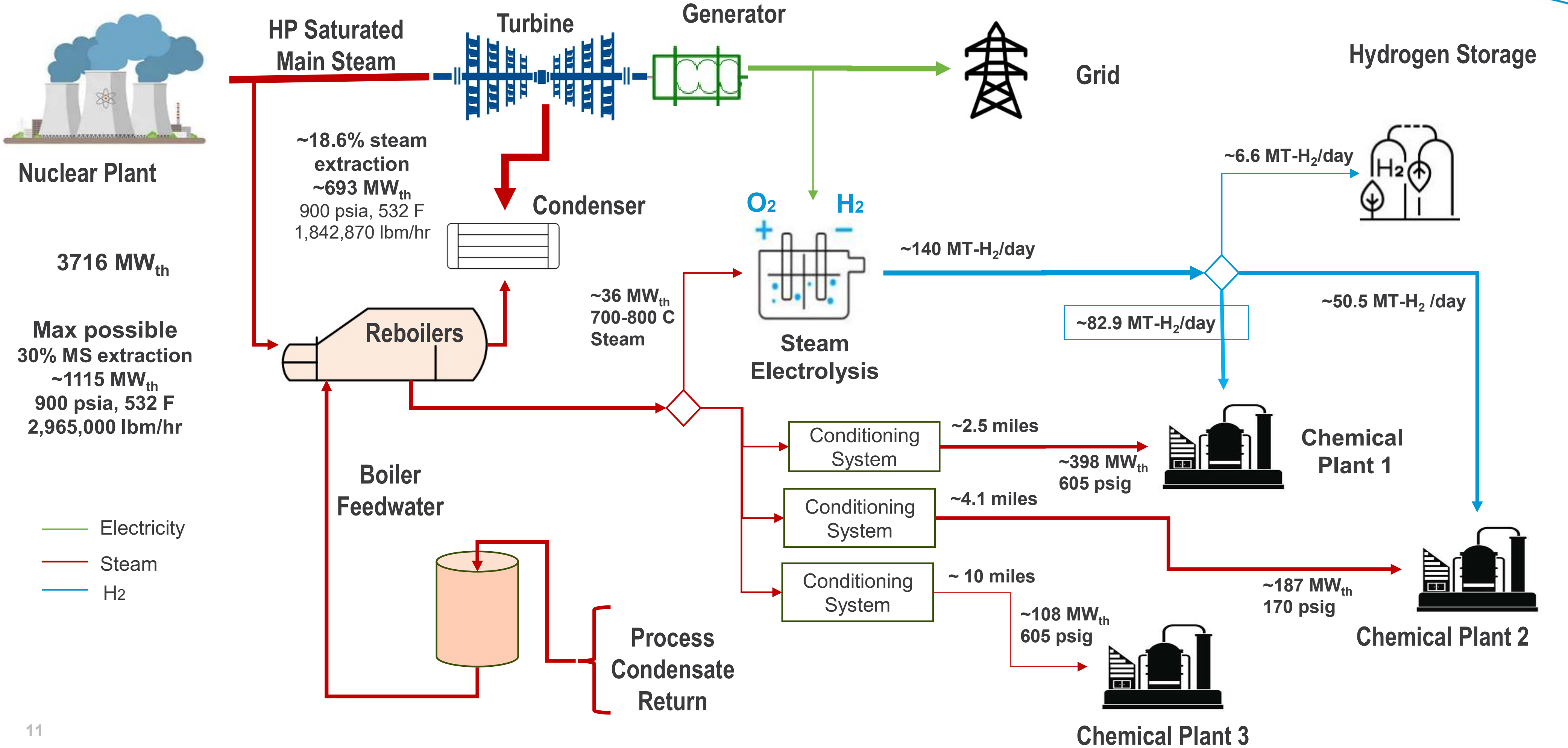


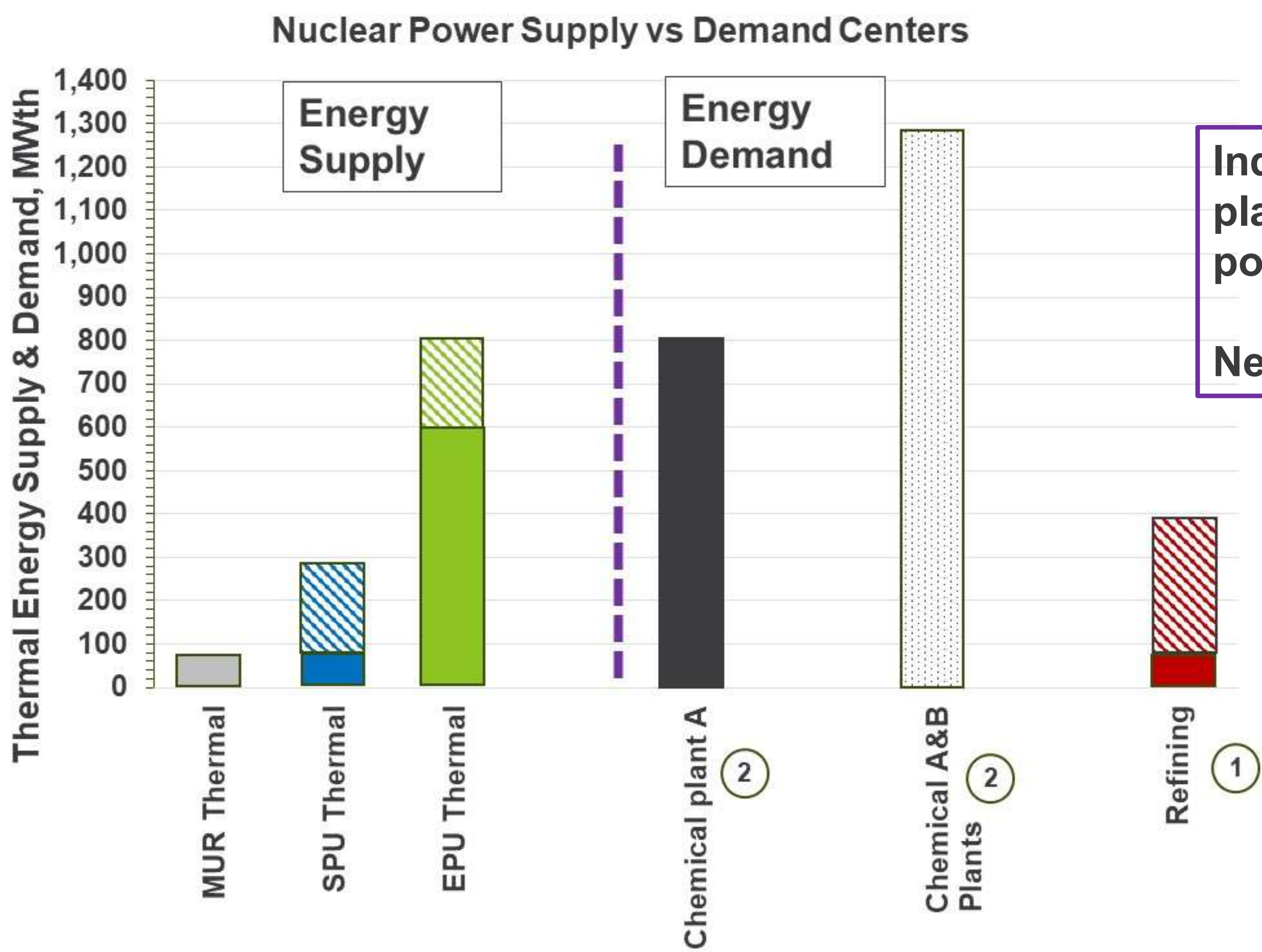
Day 2 and 3 Session at LSU Campus focus on heat exchanger and heat delivery equipment test needs

Hypothetical Case: Waterford Nuclear Power Plant

INL Gulf Shore Scenario Example

Gulf Shore Study





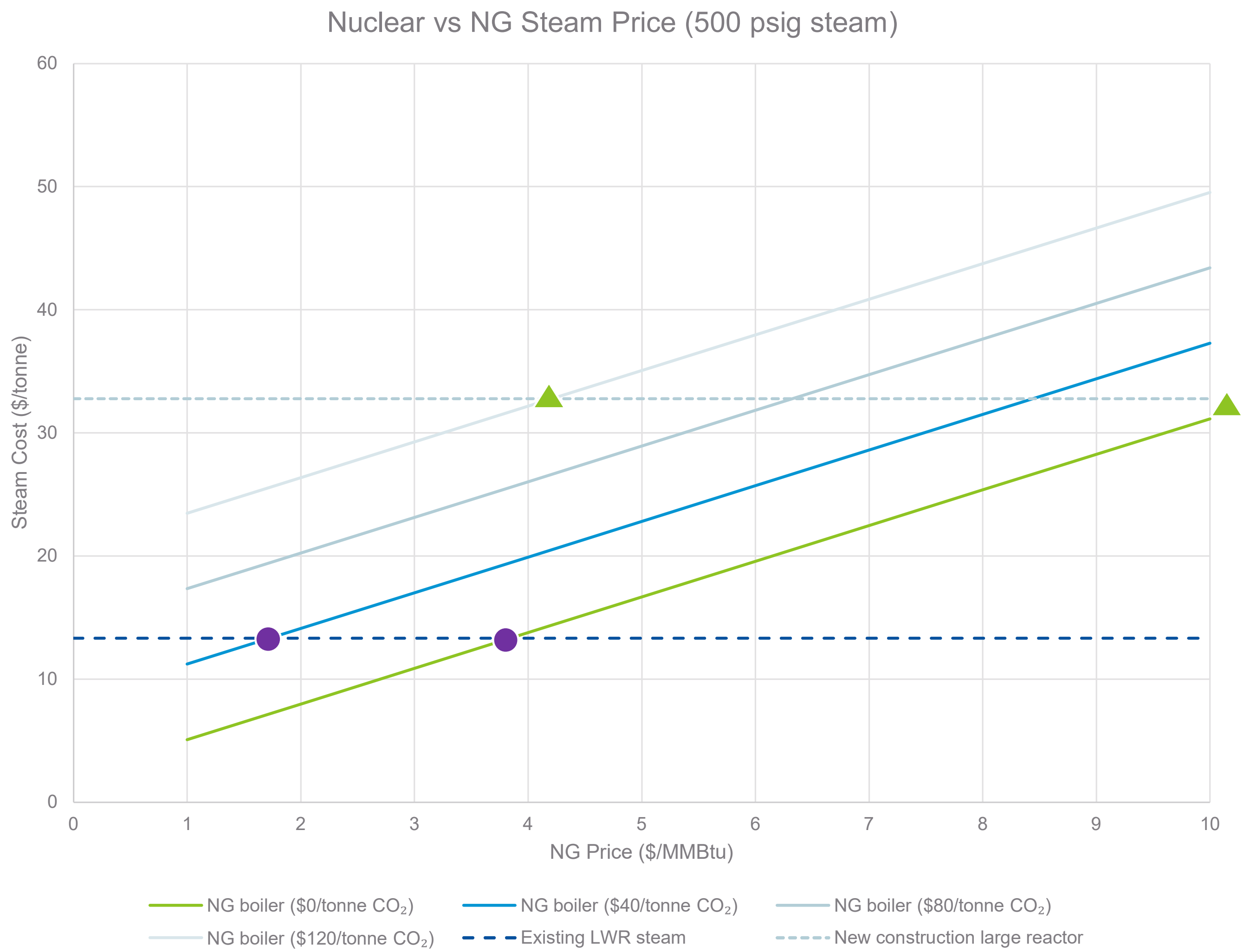
Industry Demand near Waterford plant exceed uprate power potential.

New reactors can be considered.

Sources:

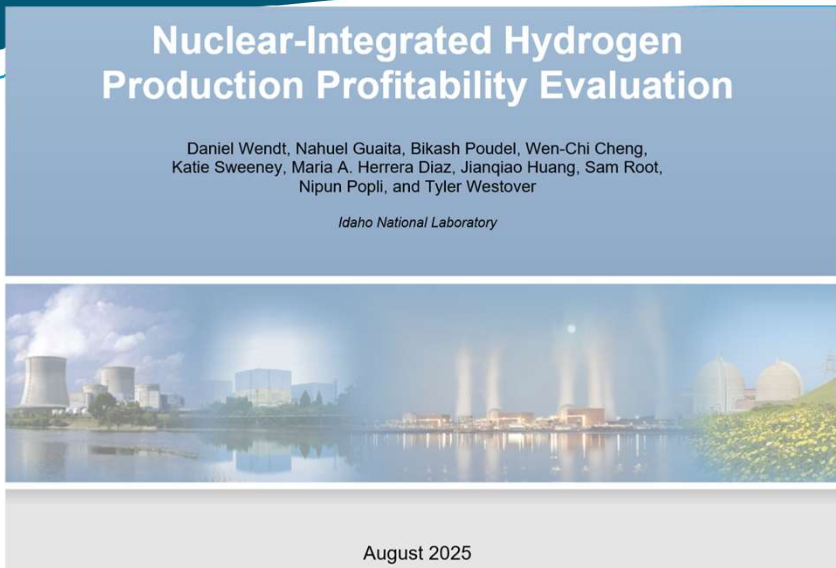
1. Industrial requirements study INL reports
2. Gulf Coast study INL reports

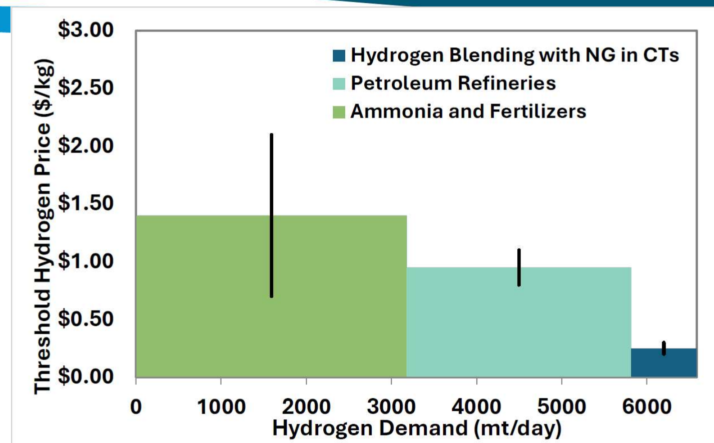
Comparison of Steam Generation Costs



Nuclear steam market depends on a stacked value that considers emissions reduction, gas variability

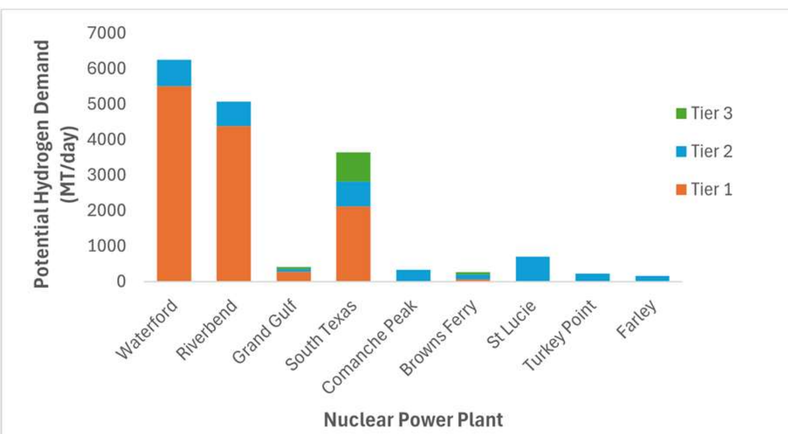
Economic analysis to determine the cost of new reactors at existing nuclear plants is being completed

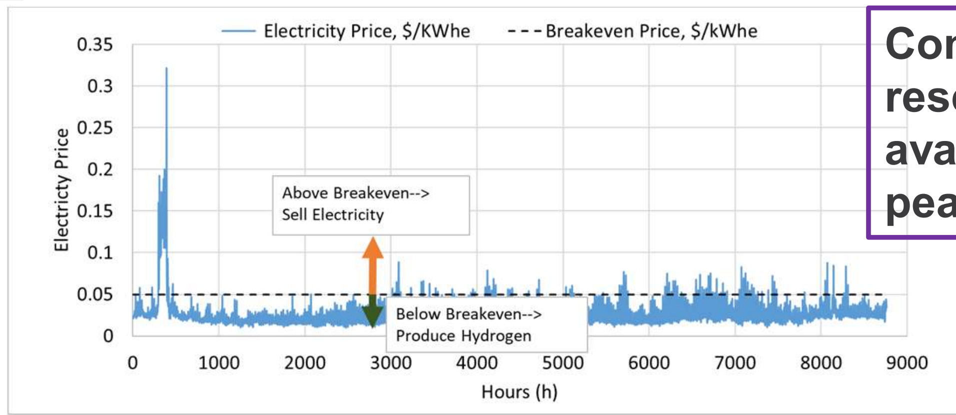




Waterford 3 transportation -adjusted hydrogen demand curve

Study completed for the entire LWR fleet based on regional markets



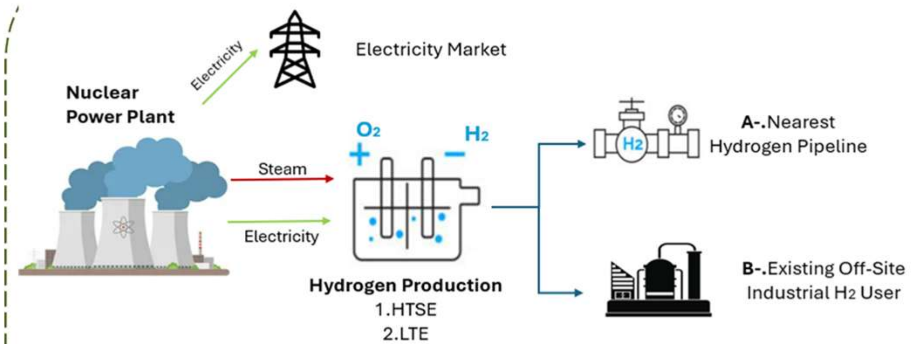


Considered reserve power availability for peak grid loads

Shift to Grid reserve capacity during peaks.
Use pipeline & hydrogen storage in louisiana

Hydrogen Market Assessments

Process



Nuclear Integrated hydrogen production cases	H_2 to nearby pipeline	H_2 to nearby industry
HTSE (Max 351 tons/day of H_2)	Case 1A	Case 1B
LTE (Max 231 tons/day of H_2)	Case 2A	Case 2B

TEA

H_2 Cost Analysis

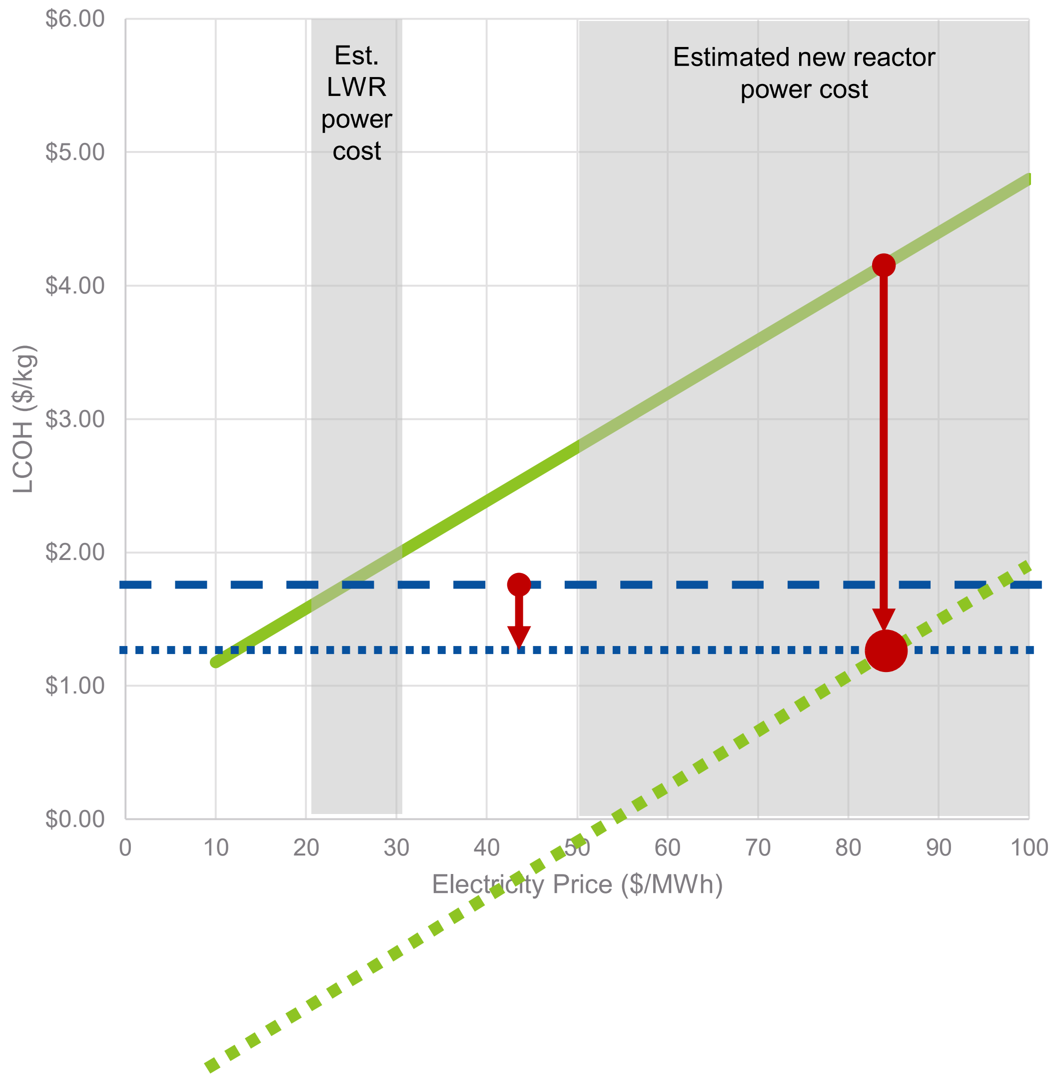
Outputs

- -LCOH
- -H_2 production rate
- -IRR
- -NPV_{H2}
- - NPV_{BAU^*}
- -Sensitivity Analysis
- -Preference Analysis
- -Competitive Analysis

*BAU: Business as Usual

Sensitivity to regional infrastructure, grid market conditions, and IRS Tax Codes

Hydrogen Production Cost Comparison



Nuclear/Electrolysis

Up to $3/kg-$H_2$ for Nuclear

Blue H_2 without 45V Tax Credit

Up to $0.6/kg-$H_2$ for Blue Hydrogen

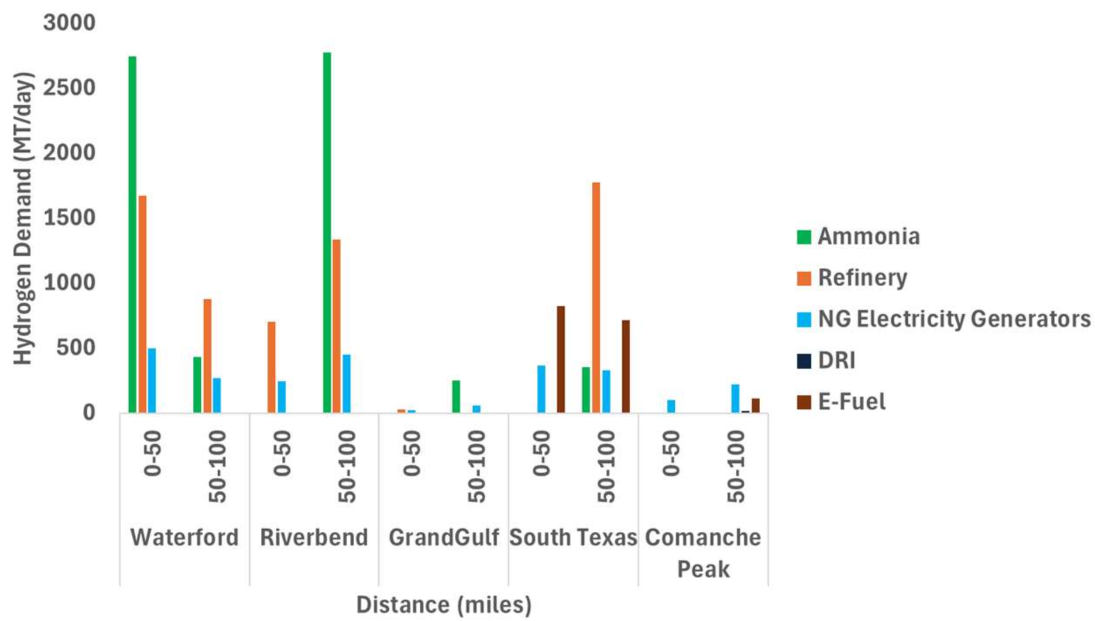
Potential Electrolysis Hydrogen Demand

Existing facilities using hydrogen:

- Petroleum refineries
- Ammonia and fertilizer production

Future demand:

- Natural Gas (NG) blending with hydrogen for NG electricity generators
- Direct-reduced iron for metals
- Fuel Cells for Data Centers



LWRS LIGHT WATER REACTOR SUSTAINABILITY

Sustaining National Nuclear Assets

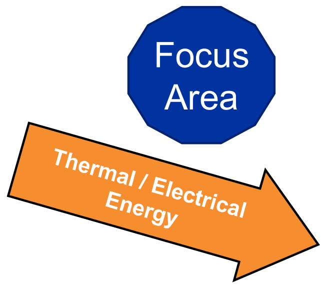
lwrs.inl.gov

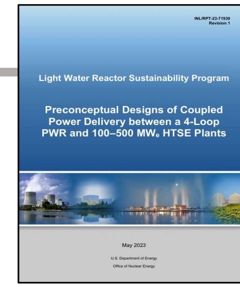
Sargent and Lundy on:
Hydrogen Plant and
Thermal Integration with industry
(10 min, 30 total)

Nuclear Plant Heat Extraction and Delivery

Tom Bartoski
Sargent & Lundy
Director of Power Uprates

Nuclear-Hydrogen Integration Overview [SL-016181, INL/RPT-23-71939]




INL/RPT-23-71939
Revision 1

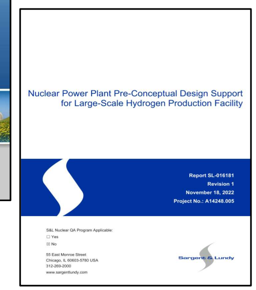
Light Water Reactor Sustainability Program

Preconceptual Designs of Coupled Power Delivery between a 4-Loop PWR and 100–500 MW_e HTSE Plants

May 2023

U.S. Department of Energy

Office of Nuclear Energy


Nuclear Power Plant Pre-Conceptual Design Support for Large-Scale Hydrogen Production Facility

Report SL-016181
Revision 1
November 18, 2022
Project No.: A14248.005

S&L Nuclear QA Program Applicable:
☐ Yes
☒ No

55 East Monroe Street
Chicago, IL 60603-5780 USA
312-269-2000
www.sargentlundy.com

Sargent & Lundy

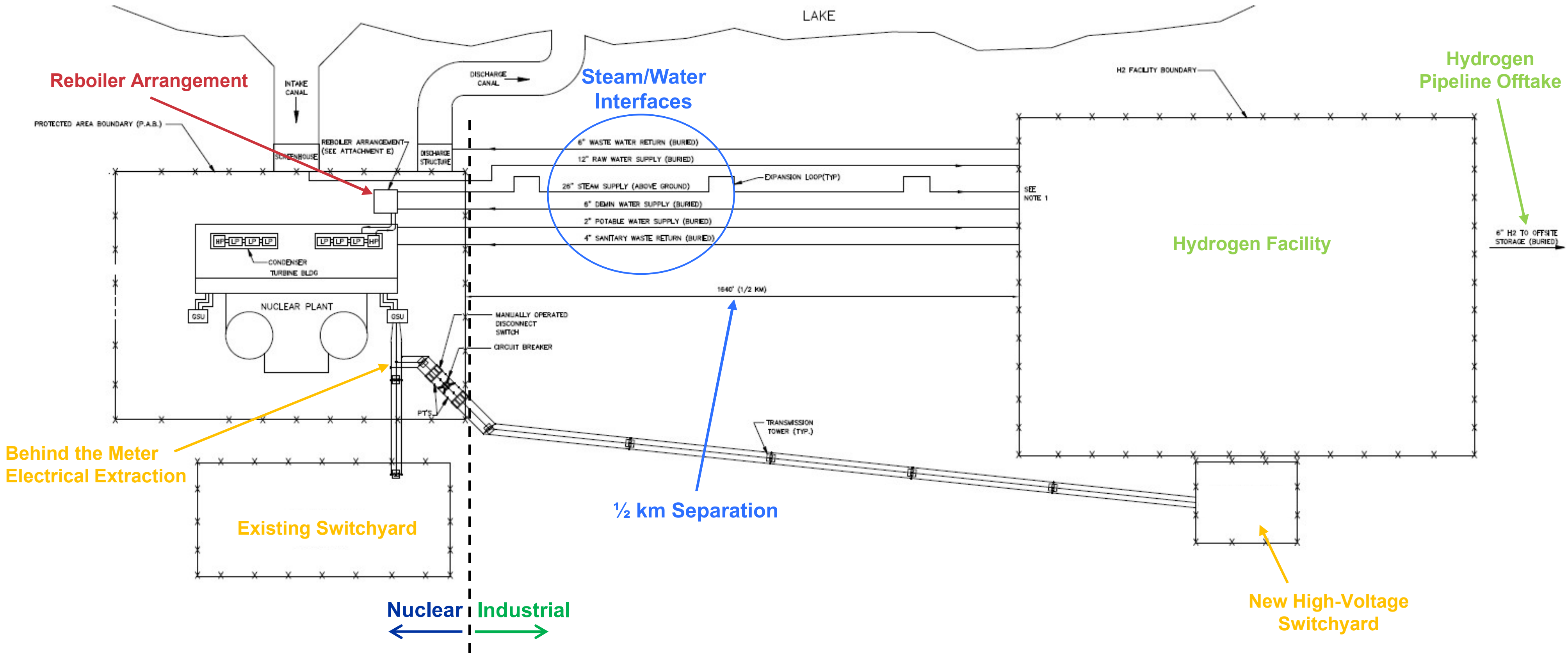
❖NPP Reference Plant

- ➢ Based upon typical US designs
  - Westinghouse 4-loop PWR (1/3 of US fleet)
  - 1,200 MW_e / 3,700 MW_{th} / SWYD: 345 kV

❖Hydrogen Facility Plant

- ➢ 500MW_{DC} High-Temp Electrolyzer Capacity
  - Thermal Load – 100 MW_{th}
  - H2 Production – 320 metric tons/day

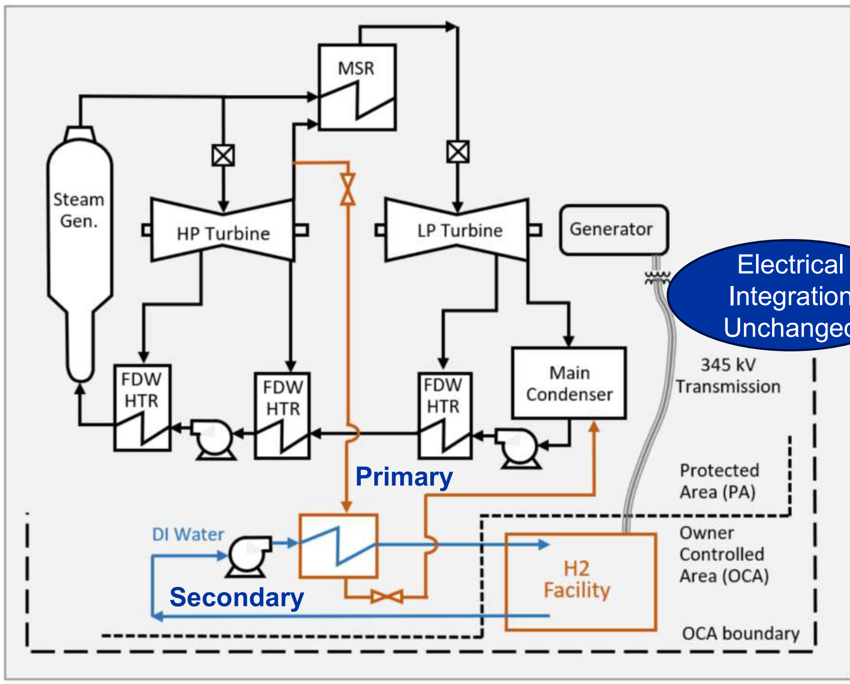
Conceptual Siting of H2 Facility at Nuclear Power Plant



Nuclear Plant Steam Extraction: PWR vs. BWR

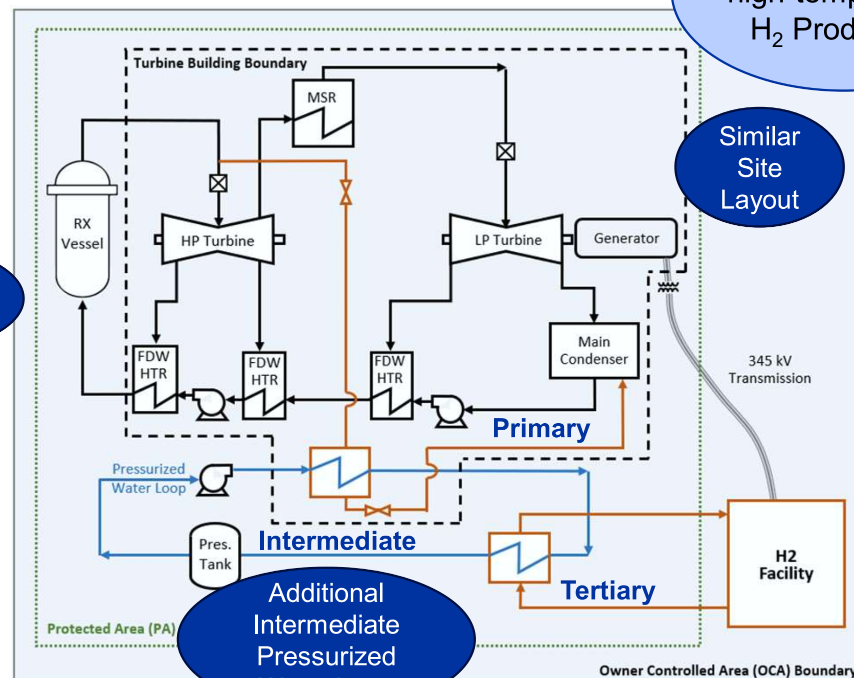
Sargent & Lundy

PWR



Electrical Integration Unchanged

BWR



<5% MS Flow for high-temperature H_2 Production

Similar Site Layout

Additional Intermediate Pressurized Water Loop

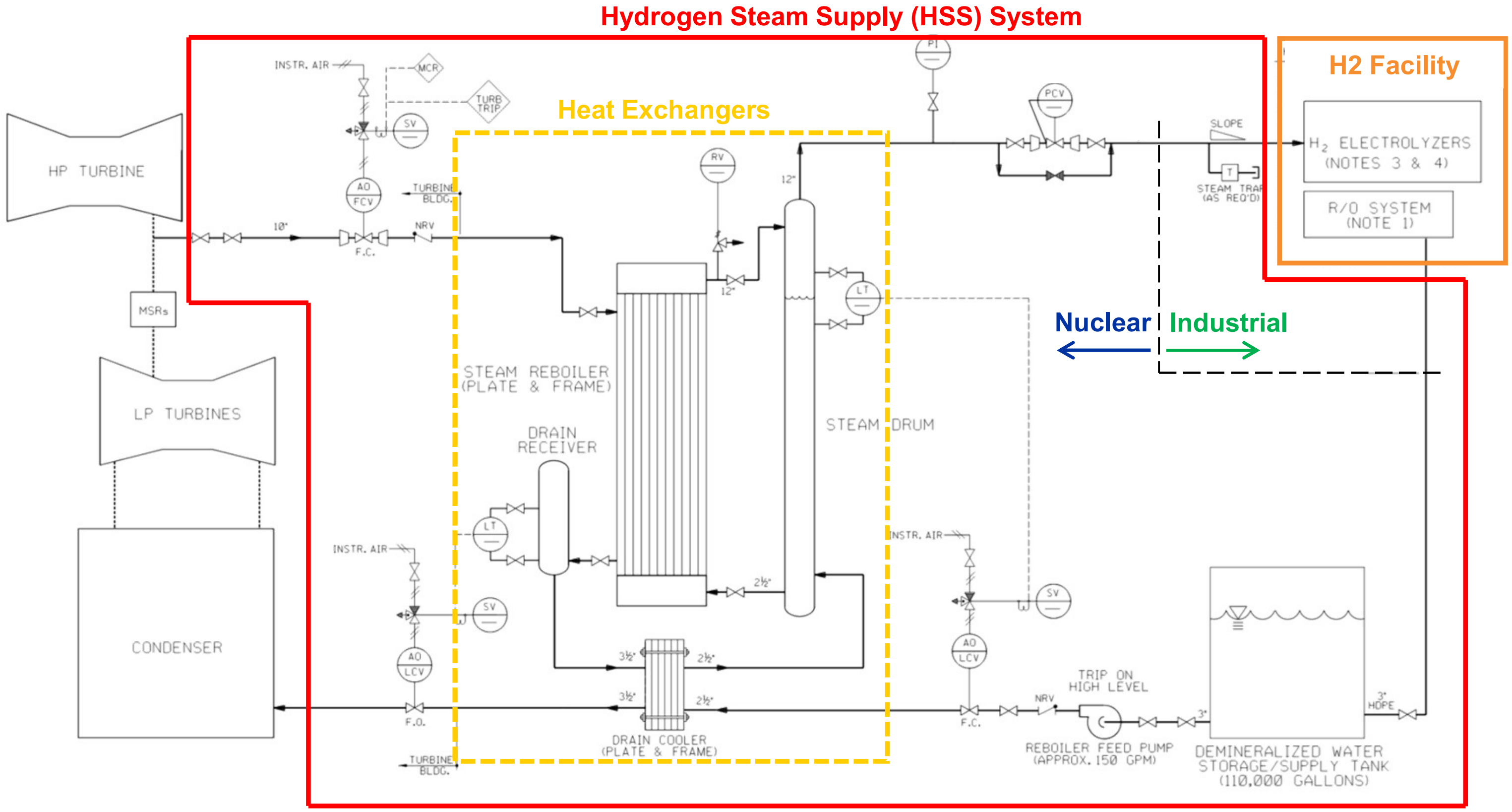
Nuclear-Hydrogen Design and Integration

Sargent & Lundy

Cold Reheat (<5%) and Main Steam (>5%) Extraction is Viable

PEPSE – Thermal Extraction Analysis

AFT Arrow & Fathom – Steam and Water Piping Analysis



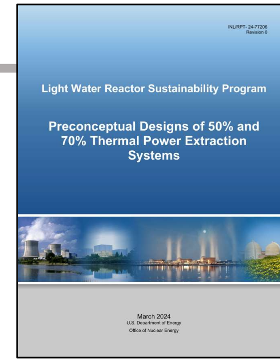
High Volume Thermal Power Extraction (TPE) [SL-017758, INL/RPT-24-77206]

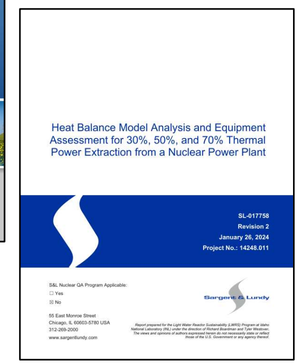
Sargent & Lundy

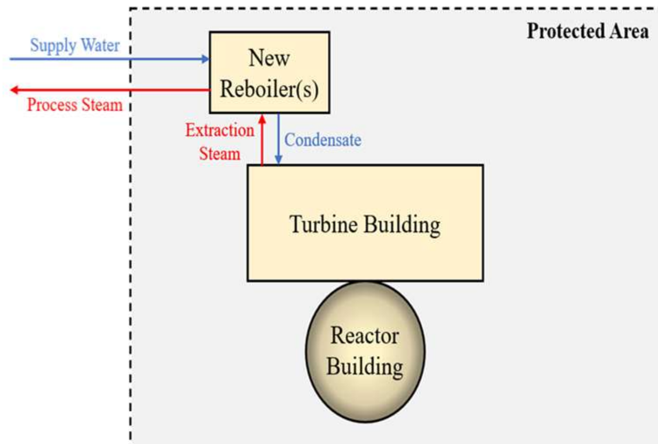
Assess feasibility of extracting large volumes of thermal energy (i.e., steam) from a PWR for industrial steam applications

- Heat Balance Modeling
- Plant Impacts and Considerations
- 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

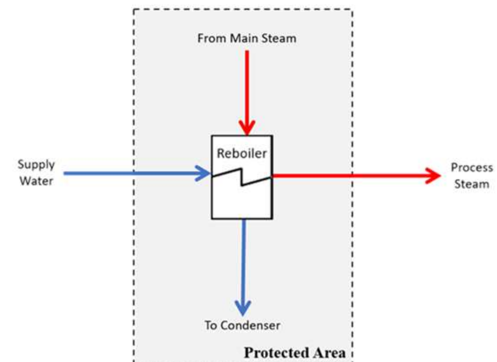
PEPSE – Thermal Extraction Analysis







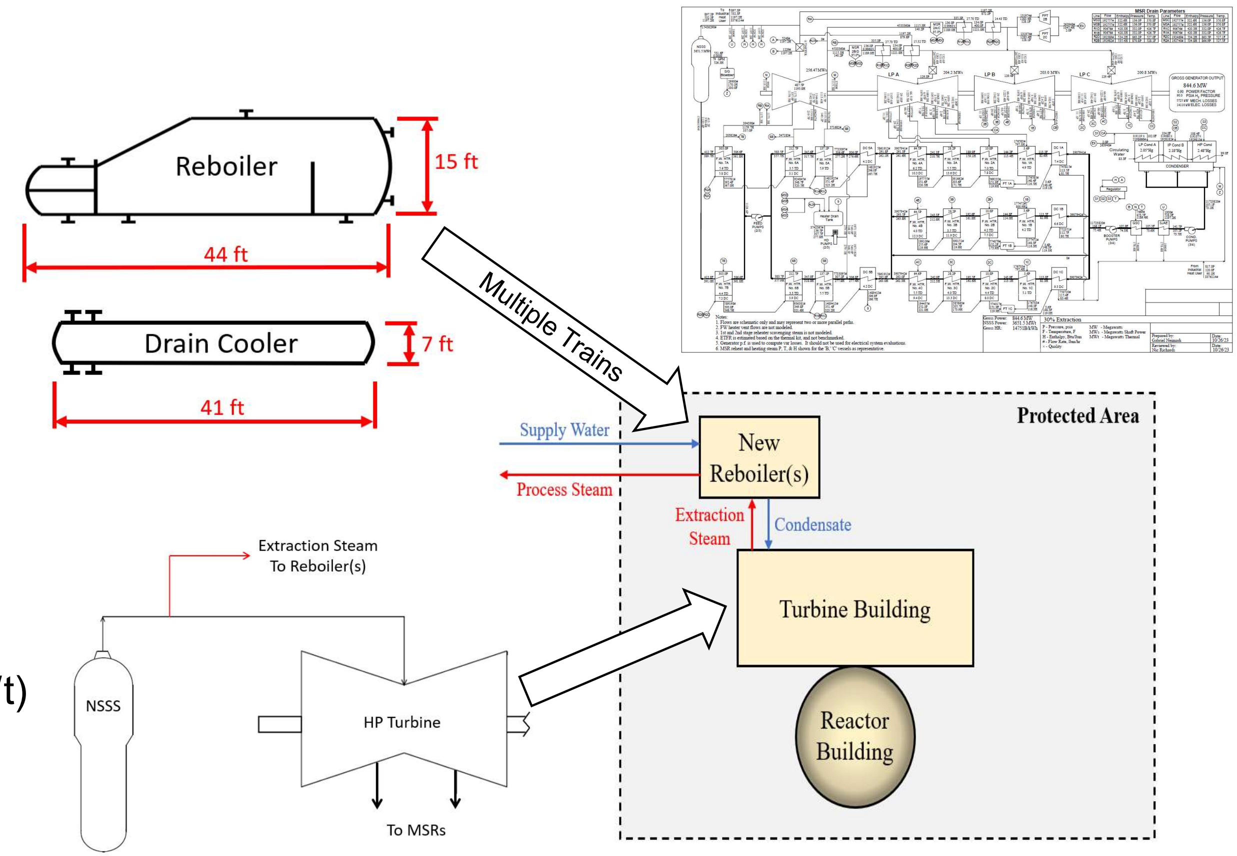
Reference Plant General Arrangement



Supply/Return Locations

Thermal Power Extraction (TPE) Cases

- ❖ TPE Cases
  - ➢ 30% Extraction
    - ~1,100 MWt Extraction
  - ➢ 50% Extraction
    - ~1,825 MWt Extraction
    - Alternate FWH bypass scenario
  - ➢ 70% Extraction
    - ~2,550 MWt Extraction
- ❖ Reference Nuclear Power Plant
  - ➢ Westinghouse 4-loop PWR
    - Capacity: ~1,200 Mwe(3,650 MWt)
    - Main Steam Extraction
    - Condenser Return

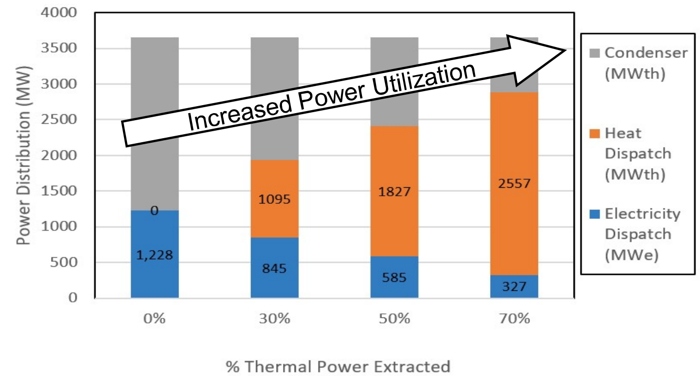


Thermal Power Extraction (TPE)

What is the upper limit of steam extraction?

- ❖Increased thermal power utilization with greater TPE
- ❖**<u>30% TPE is expected to be feasible</u>** for existing PWRs
  - ➢No Major Equipment Replacement Expected
  - ➢Within Control System Design Capabilities
- ❖50% TPE may be feasible for some existing PWRs
  - ➢Minor Equipment Replacement Expected
  - ➢Potential Operating Changes
  - ➢Potential Control System Impacts
- ❖**<u>70% TPE is not expected to be achievable</u>** for most PWRs

Power Distribution for Different TPE Scenarios



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

Thank You

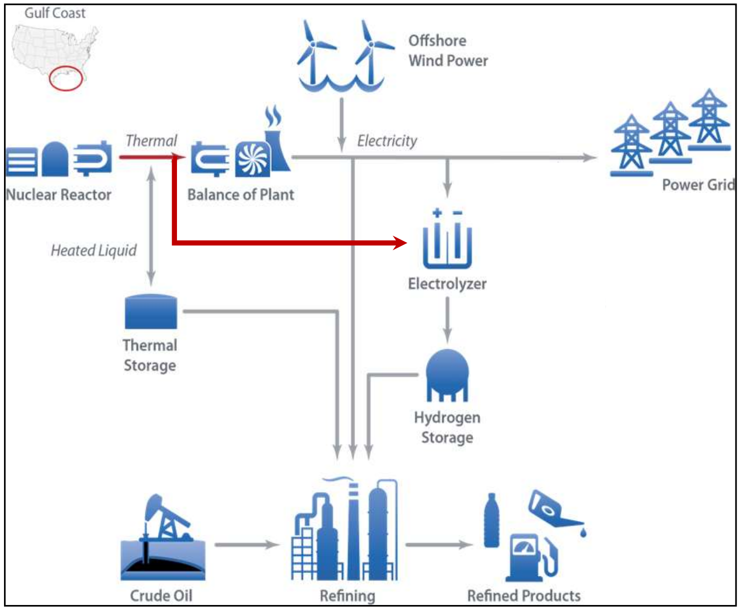
Highlight on Steam –to –Steam heat exchanger designed, built and ready for test by

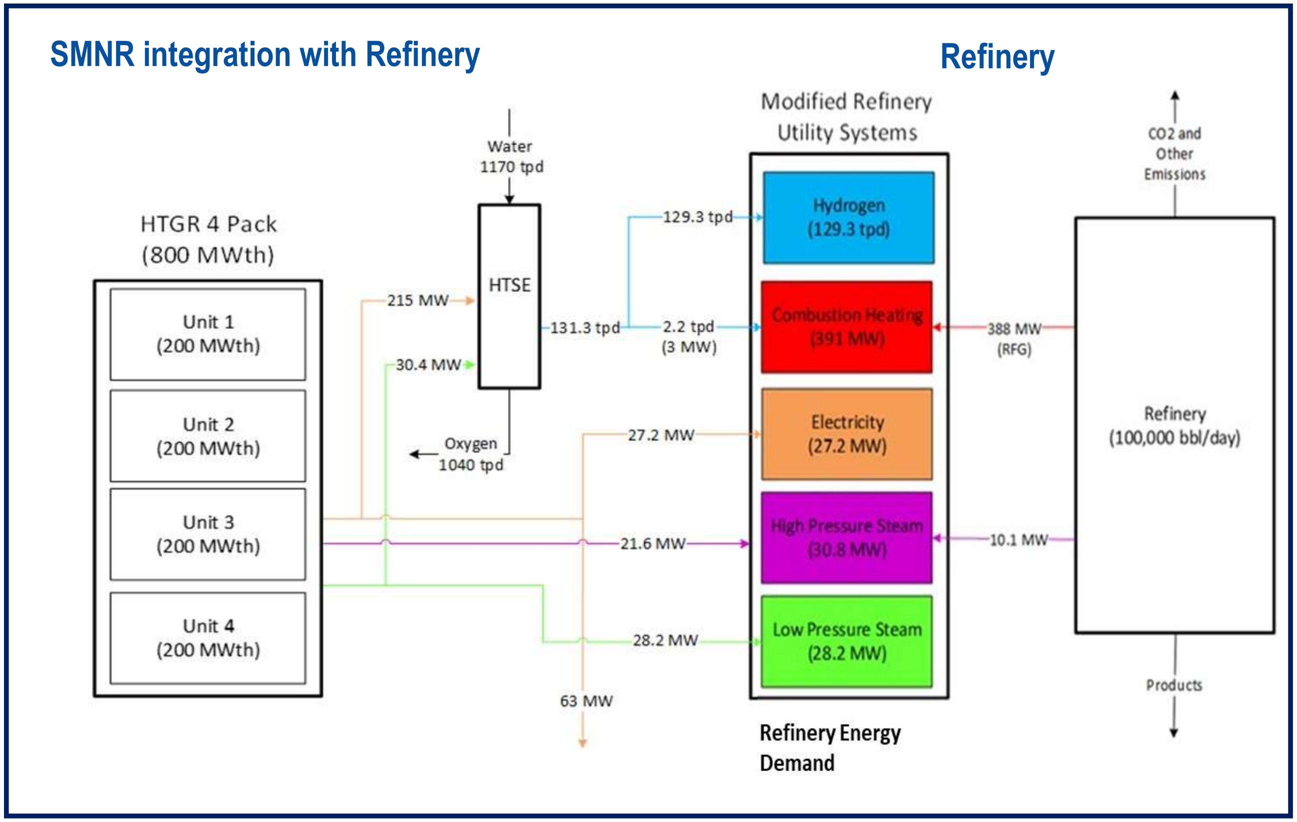
Clean Steam Generator – Eric, Klotzbach, Graham Corporation

Q&A

Extra Slides

Example: Nuclear Integration with Petroleum Refineries





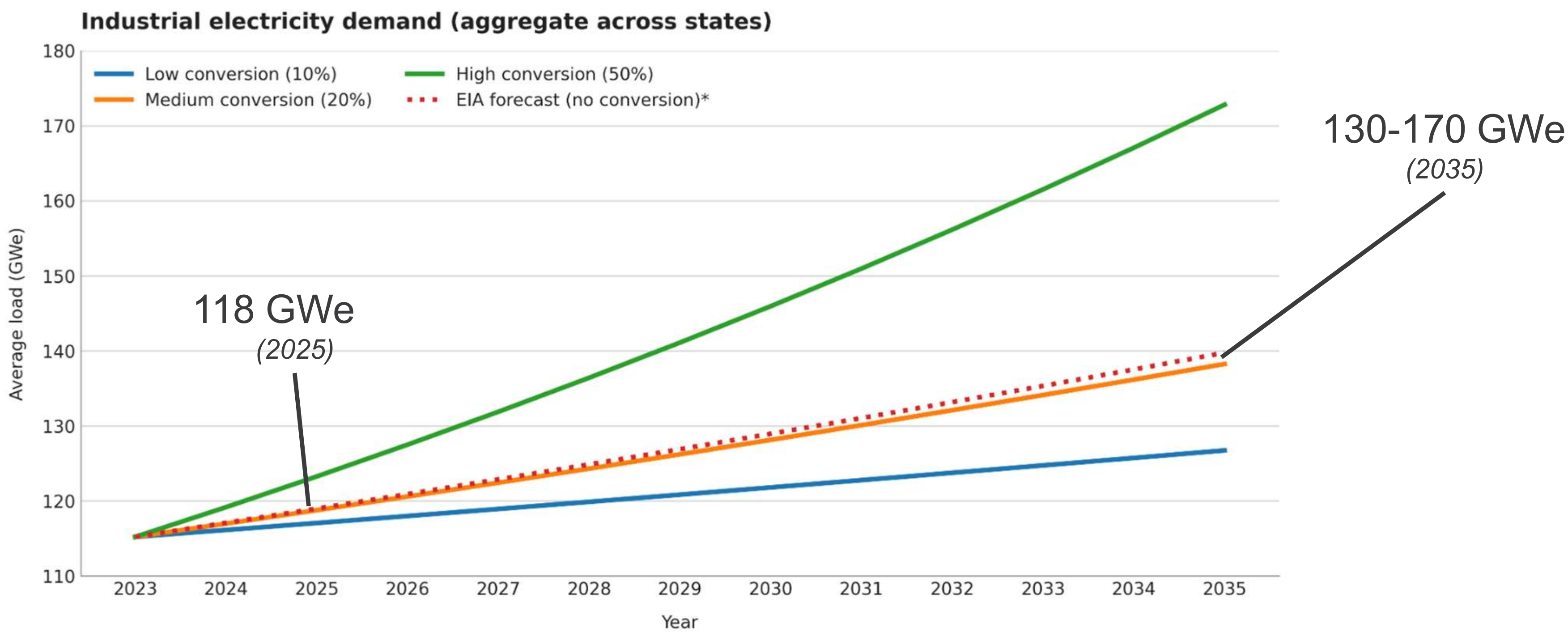
Take aways and inferences

1. Nuclear energy can reduce ~50% of refinery emissions without any modification to the refinery unit operations
2. Nuclear energy can be incrementally added with small modular reactors
3. Deeper emissions reduction requires new approaches to manage refinery by-product fuel gas

tpd: Tons per day
bbl: Oil barrel

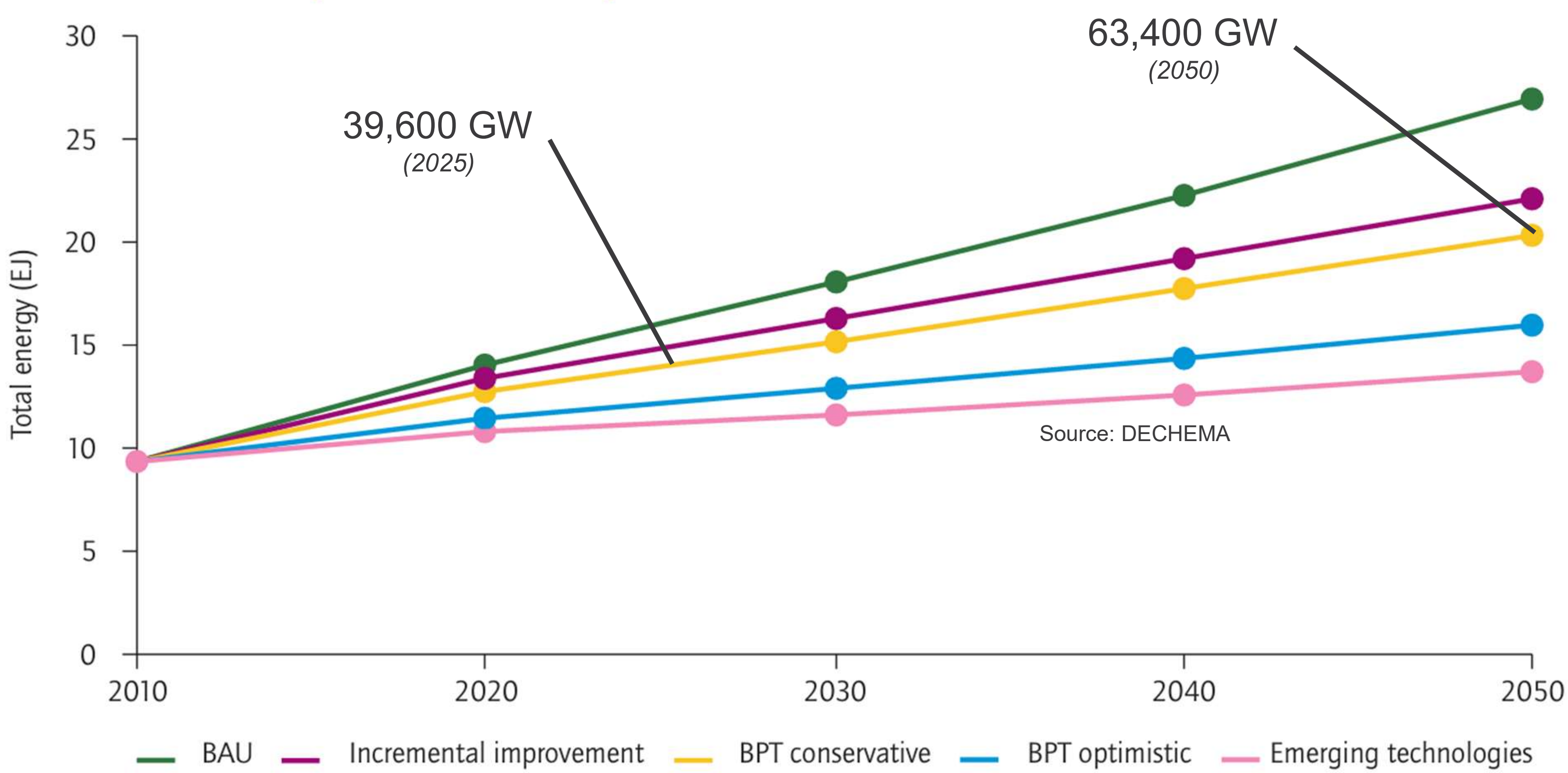
HTSE: High temperature steam electrolysis
SMNR: Small modular nuclear reactor
PRELIM: Petroleum Refinery Life Cycle Inventory Model

U.S. Industry electrical demand projection: 10 - 45% increase by 2035

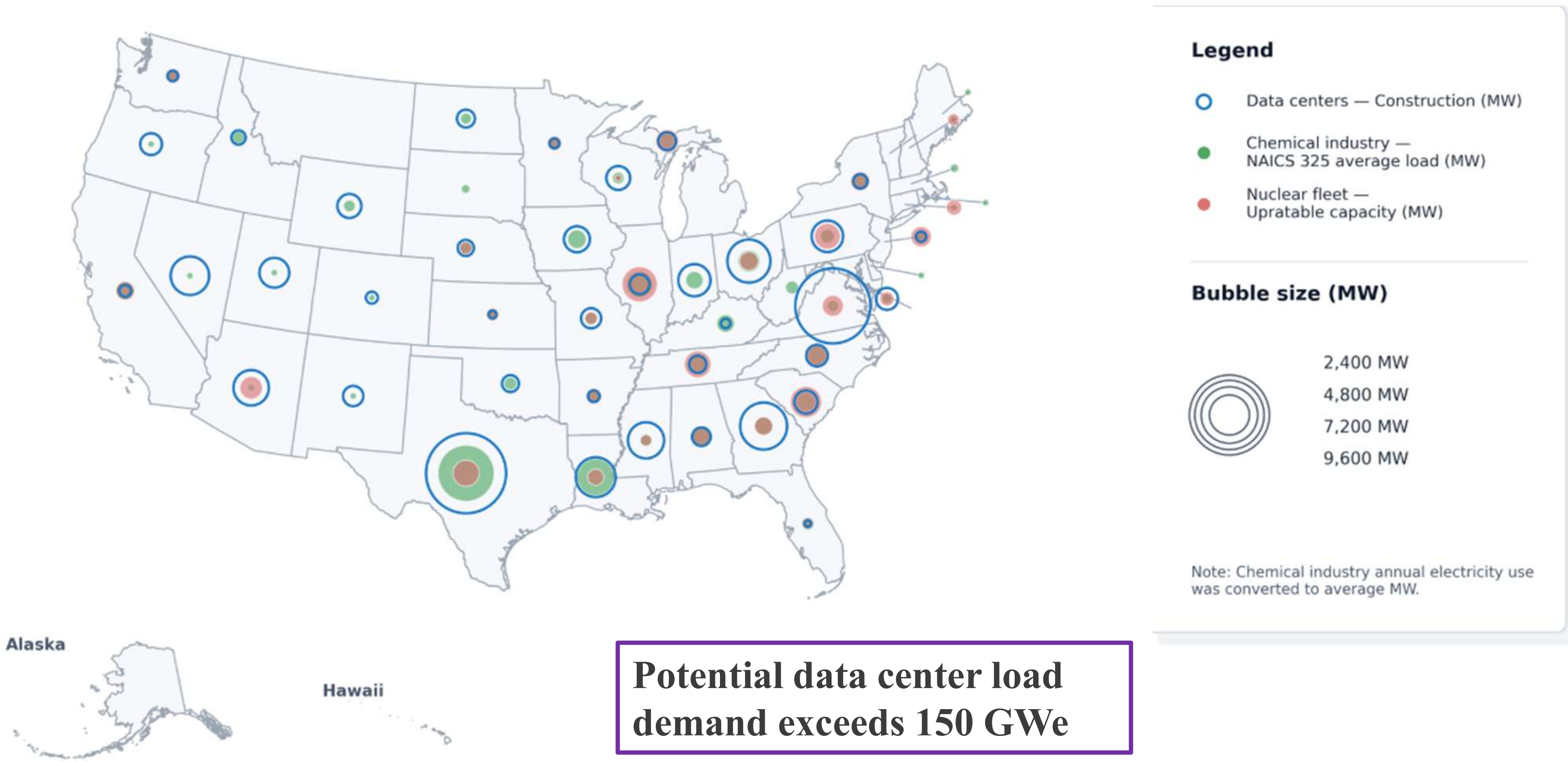


* Forecast only (no conversion assumed); shown as a reference trajectory.

Global energy consumption could rise 60% or more in 25 years

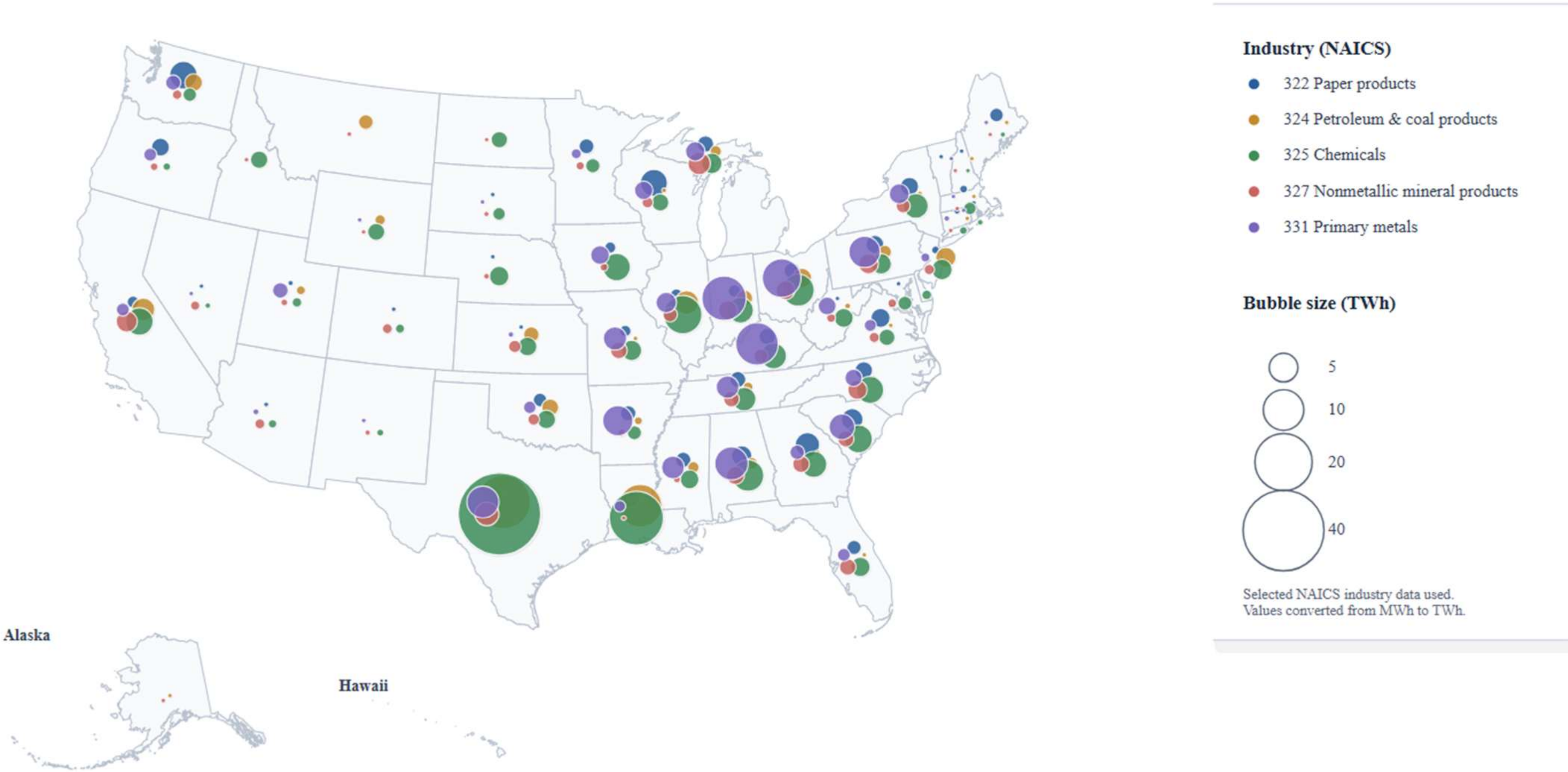


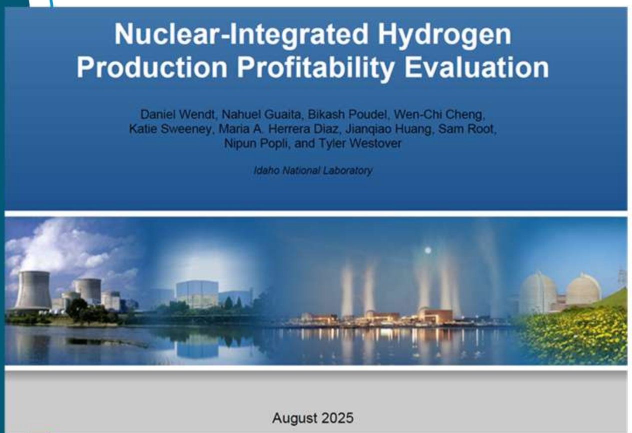
Large electricity demand for data centers loads aligns with nuclear plants nation-wide



Potential data center load demand exceeds 150 GWe

Industrial electricity in Louisiana and Texas is dominated by the Petrochemical Industry





Nuclear-Integrated Hydrogen Production Profitability Evaluation

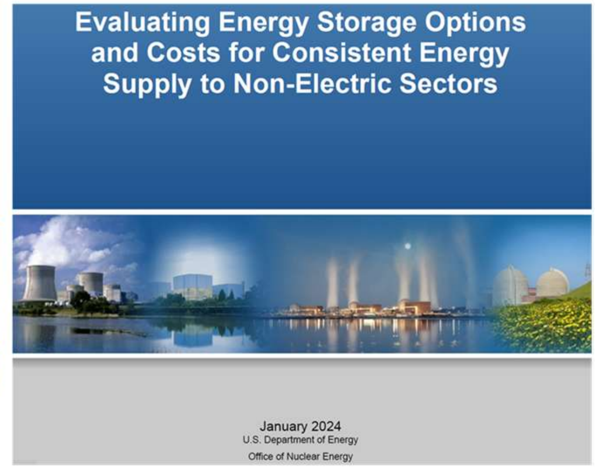
Daniel Wendt, Nahuel Guaita, Bikash Poudel, Wen-Chi Cheng, Katie Sweeney, Maria A. Herrera Diaz, Jianqiao Huang, Sam Root, Nipun Popli, and Tyler Westover

Idaho National Laboratory

August 2025

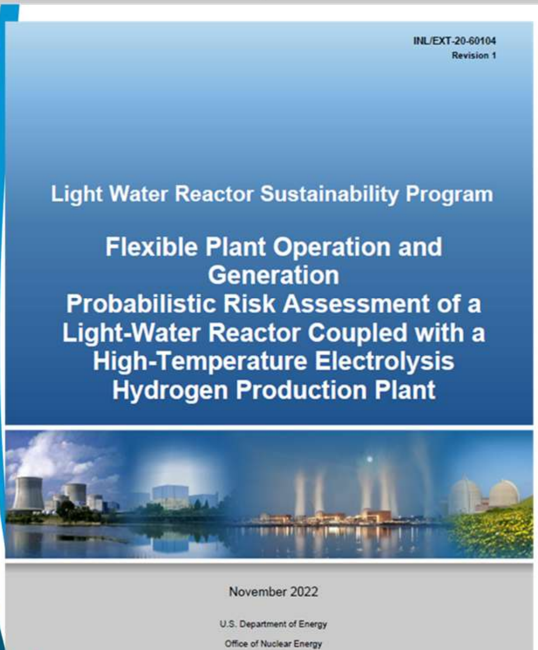
Preconceptual Designs of Coupled Power Delivery between a 4-Loop PWR and 100-500 MW_e HTSE Plants

April 2023



Evaluating Energy Storage Options and Costs for Consistent Energy Supply to Non-Electric Sectors

January 2024
U.S. Department of Energy
Office of Nuclear Energy



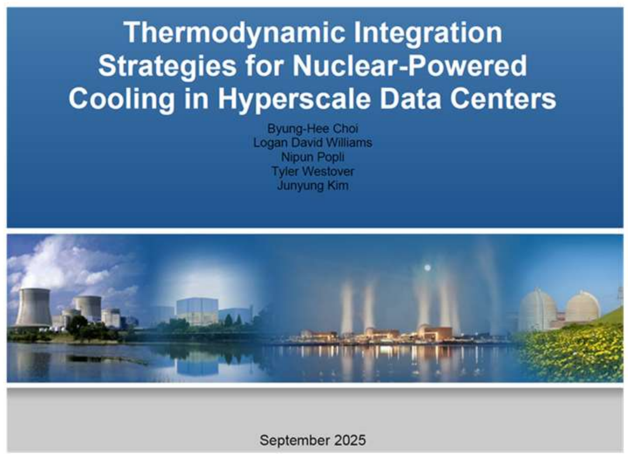
INL/EXT-20-60104
Revision 1

Light Water Reactor Sustainability Program

Flexible Plant Operation and Generation Probabilistic Risk Assessment of a Light-Water Reactor Coupled with a High-Temperature Electrolysis Hydrogen Production Plant

November 2022

U.S. Department of Energy
Office of Nuclear Energy



Thermodynamic Integration Strategies for Nuclear-Powered Cooling in Hyperscale Data Centers

Byung-Hee Choi
Logan David Williams
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September 2025

Preliminary Supply Chain and Cost Reduction Strategies for Advanced Nuclear Reactors

April 2025

Frederick Joseck, Sam J. Root, Eliezer A. Reyes Molina, Rami M. Saeed, Jeffrey Brown, and Todd Knighton

Idaho National Laboratory

LWRS LIGHT WATER REACTOR SUSTAINABILITY

LWR Capacity Expansion Driven by U.S. Industry

- LWRS and CRADA technical and economic analysis for industry along the Gulf Shores has incentivized U.S. industry to consider nuclear plant capacity expansion as a source of low-emissions, cost-affordable, reliable power
- Study outcomes have prompted ongoing discussions between nuclear utilities and large, energy intensive industries for LWR uprate power for:
    - Electricity and industrial-grade steam
    - Hydrogen for chemical processes and high-temperature combustion
- A consortium can collectively advance the business case for nuclear applications with a large "book-order" of reactors

Open Group has officially launched the Industrial Advanced Nuclear™ Consortium (IANC), *a collaborative initiative to accelerate the deployment of advanced nuclear heat and power solutions for industrial applications. The Consortium founding Members: Chevron, ConocoPhillips, ExxonMobil, Freeport-McMoRan, Nucor, Rio Tinto, and Shell represent large industrial users of power and heat. These Members will leverage their integration and project delivery expertise to define the requirements for the application of nuclear technology to provide process heat and power for their respective industries.*

THE OPEN GROUP INDUSTRIAL ADVANCED NUCLEAR™ Consortium

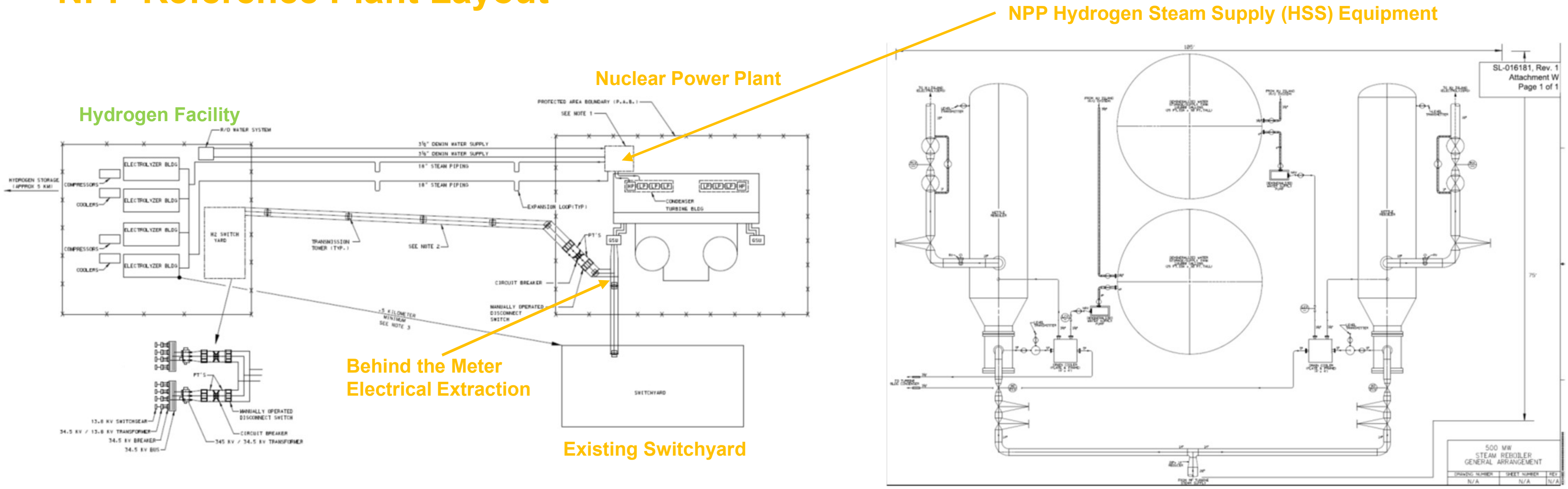
Industrial Advanced Nuclear™ Consortium | www.opengroup.org

Hydrogen delivery from selected NPPs

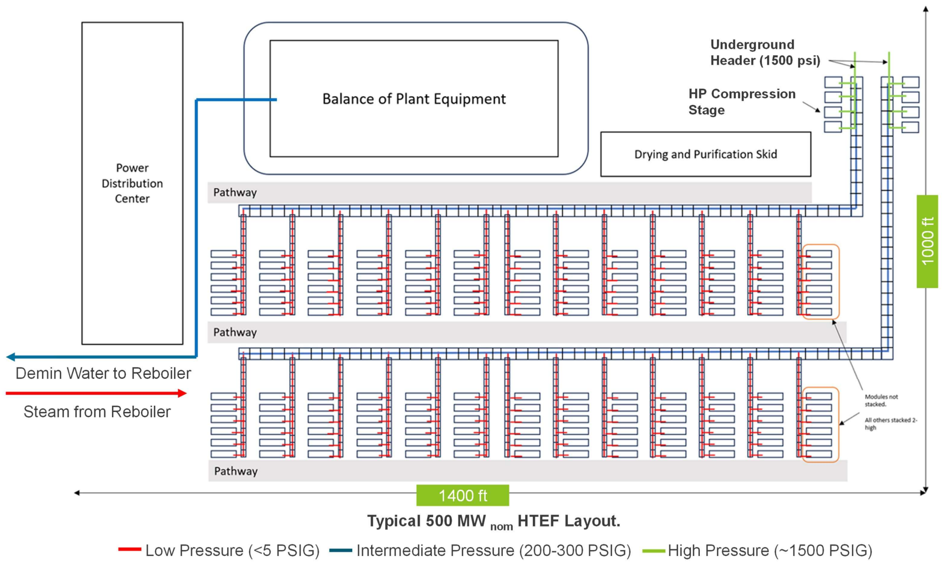
NPP	Name	Demand Type	Market Demand (MT/day)	Maximum H2 supply (MT/day)	Distance (km)	Pipeline Delivery costs from HDSAM ($/kg)
Waterford	Case 1A: Nearby Pipeline	Pipeline	351	351	0.3	$0.09
	Case 2A: Nearby Pipeline	Pipeline	231	231	0.3	$0.09
	Case 1B: Dyno Nobel (Ammonia)	Current	400	351	25.0	$0.10
	Case 2B: Dyno Nobel (Ammonia)	Current	400	231	25.0	$0.10
Riverbend	Case 1A: Nearby Pipeline	Pipeline	351	351	32.0	$0.10
	Case 2A: Nearby Pipeline	Pipeline	351	231	32.0	$0.11
	Case 1B: Exxon Mobil Corp (Refinery)	Current	535	351	39.7	$0.10
	Case 2B: Exxon Mobil Corp (Refinery)	Current	535	231	39.7	$0.11
Grand Gulf	Case 1A: Nearby Pipeline	Pipeline	351	351	169.8	$0.19
	Case 2A: Nearby Pipeline	Pipeline	351	231	169.8	$0.22
	Case 1B: Ergon Inc (Refinery)	Current	28.2	28.2	31.6	$0.24
	Case 2B: Ergon Inc (Refinery)	Current	28.2	28.2	31.6	$0.24
STP	Case 1A: Nearby Pipeline	Pipeline	351	351	40.6	$0.10
	Case 2A: Nearby Pipeline	Pipeline	231	231	40.6	$0.11
	Case 1B: HIF Global (Methanol)	Future	600	351	3.2	$0.09
	Case 2B: HIF Global (Methanol)	Future	600	231	3.2	$0.09
CP	Case 1A: Nearby Pipeline	Pipeline	351	351	431.2	$0.37
	Case 2A: Nearby Pipeline	Pipeline	231	231	431.2	$0.48
	Case 1B: Hereford Renewable (E-fuels)	Future	110	110	158.7	$0.29
	Case 2B: Hereford Renewable (E-fuels)	Future	110	110	158.7	$0.29

S&L Pre-Conceptual Plant Designs

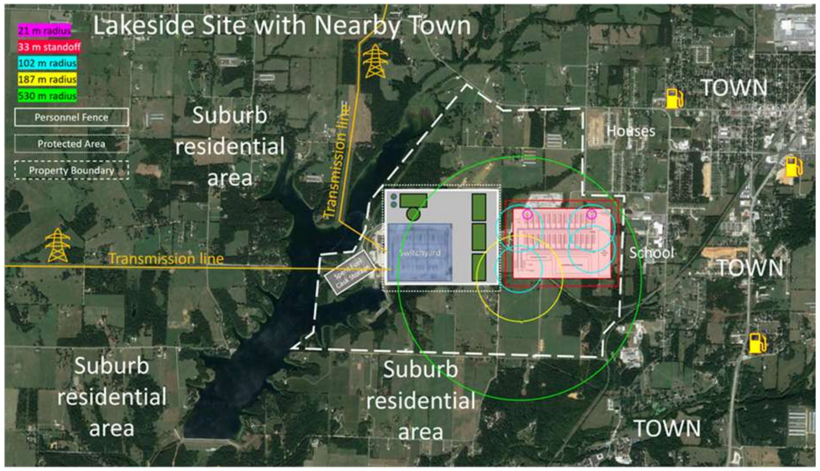
- NPP Reference Plant Layout



Design is being used to estimate costs of hydrogen production and to address safety and licensing consideration

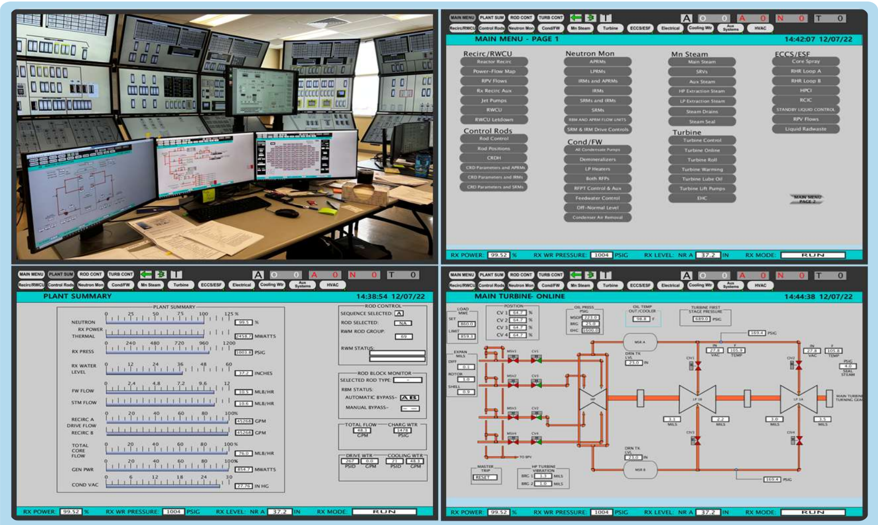


100, and 500 MWe modular high temperature steam electrolysis plant layout and piping

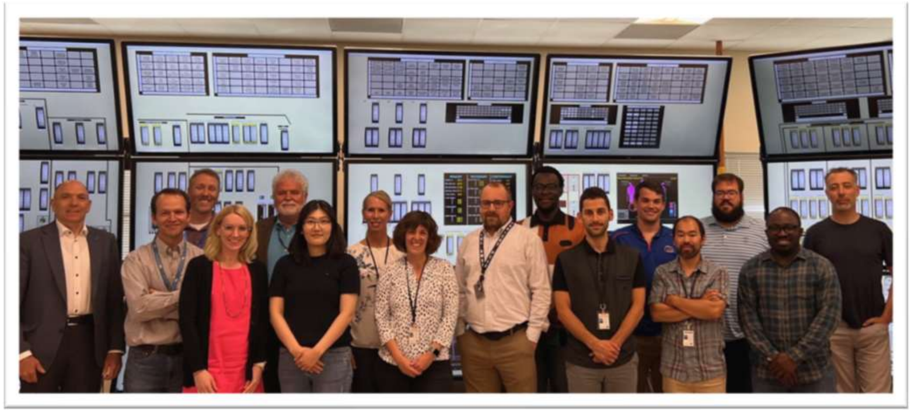


Probabilistic Risk Assessment (PRA) to determine hydrogen plant stand-off distance

Development and Testing of FPOG Operating Concepts



Modified boiling water reactor simulator used in the INL Human Systems Simulation Laboratory



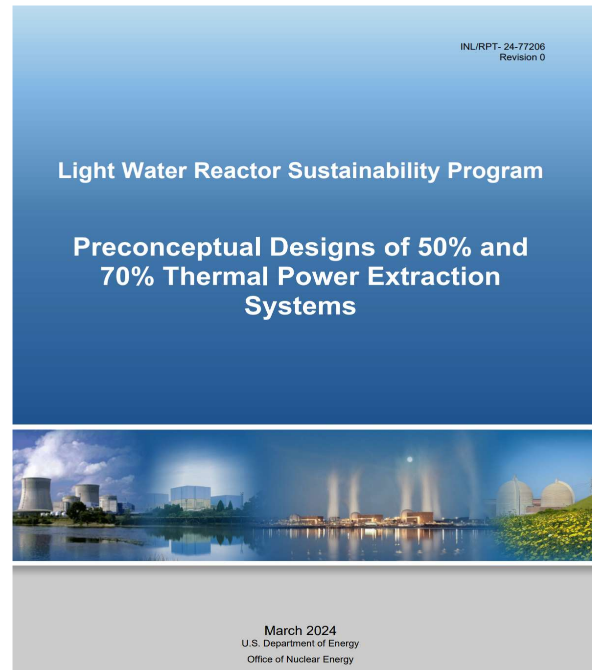
FPOG plant operations concepts testing supported by Westinghouse, GSE, and the University of Idaho

Full-Scope plant simulators were used to successfully test human factors and verify power and steam and be efficiently and safely dispatched to a user connected to the nuclear power plant transmission station.

Nuclear Thermal Power Dispatch (TPD) Studies

- **Completed**
  - **Integrated 4-loop PWR* – 100 MW_{DC} H_2 facility**
  - **Integrated 4-loop PWR – 500 MW_{DC} H_2 facility**
  - **Integrated BWR* – 500 MW_{DC} hydrogen facility**
  - **30% TPD from 4-loop PWR (~1,100 MW_t)**
  - **50% TPD from 4-loop PWR (~1,800 MW_t)**
  - **70% TPD from 4-loop PWR (2,550 MW_t)**
- **Participant Roles**
  - INL: Statement of work and PRA
  - S&L: preconceptual design
  - Westinghouse: Design basis for control system

**PWR: pressurized water reactor; *BWR: boiling water reactor*


INL/RPT- 24-77206
Revision 0

Light Water Reactor Sustainability Program

Preconceptual Designs of 50% and 70% Thermal Power Extraction Systems

March 2024
U.S. Department of Energy
Office of Nuclear Energy

https://lwrs.inl.gov/content/uploads/11/2024/10/Preconceptual_Designs.pdf

- GAIN Voucher

Argonne NATIONAL LABORATORY

CHEMICAL CONVERSION R&D – UNIT PROCESSES FOR NUCLEAR ENERGY

Contributors

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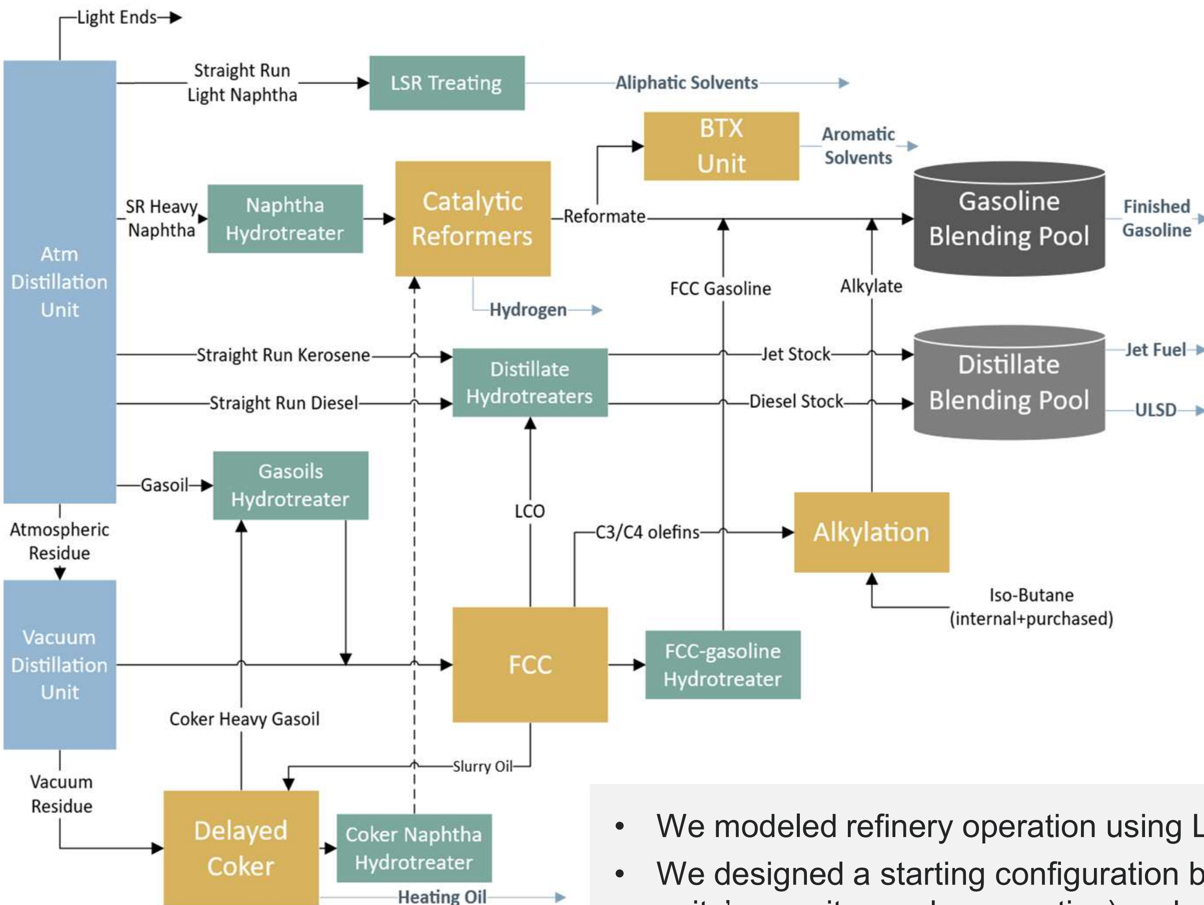
May 20th, 2026

INTEGRATED ENERGY SYSTEMS

Pillar lead: Pingping Sun, PhD

REFINERY MODEL- CASE STUDY CONFIGURATION



Comparison with reported EIA data

Unit	Model	EIA[1]	Difference
CDU (bpd)	188,890	188,700	0.1%
VDU (bpd)	77,200	77,200	0.0%
Naphtha reformer (bpd)	35,380	35,800	-1.2%
FCC (bpd)	68,460	69,500	-1.5%
Delayed coker (bpd)	41,060	41,150	-0.2%
Hydrotreating units (bpd)	208,900	222,160	-6.0%
Alkylation (production)	22,750	23,000	-1.1%

Products yield and comparison with reported data

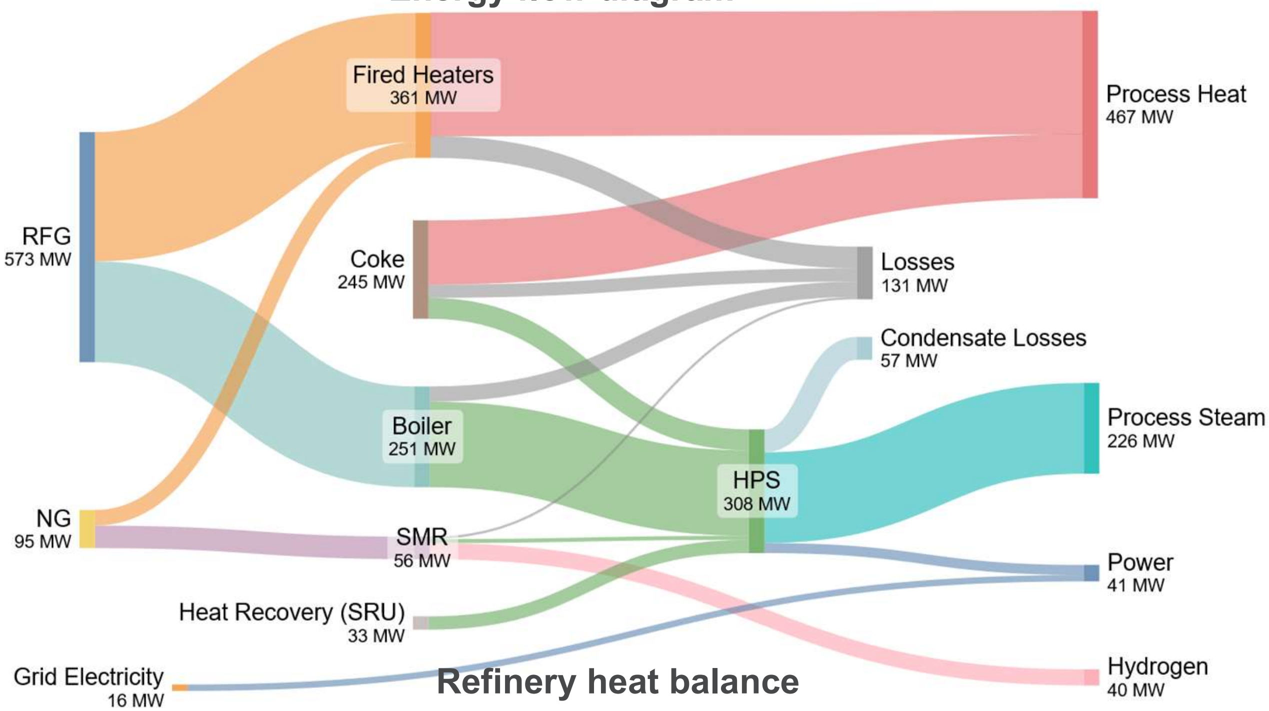
Refinery product	Model	Lemont Data[1,2]
Gasoline (bpd)	87,320	82,760
Diesel (bpd)	53,970	60,240
Jet Fuel (bpd)	19,950	21,010
Bunker Fuel (bpd)	6,711	6,730
Other (Chemicals, LPG) (bpd)	21,456	16,770
H2 from SMR (MMCFD)	10.8	12
Petcoke (bpd)	10,125	12,900
Sulfur (kg/d)	324	440

- We modeled refinery operation using Lemont refinery for case study.
- We designed a starting configuration based on known refinery information (reported units' capacity, crude properties) and general refining principles.
- The configuration was updated iteratively to match product amount, unit emissions and other reported data.

[1]EIA.com (2021)
[2]archieinitiative.org

REFINERY ENERGY DEMAND SUMMARY

Energy flow diagram

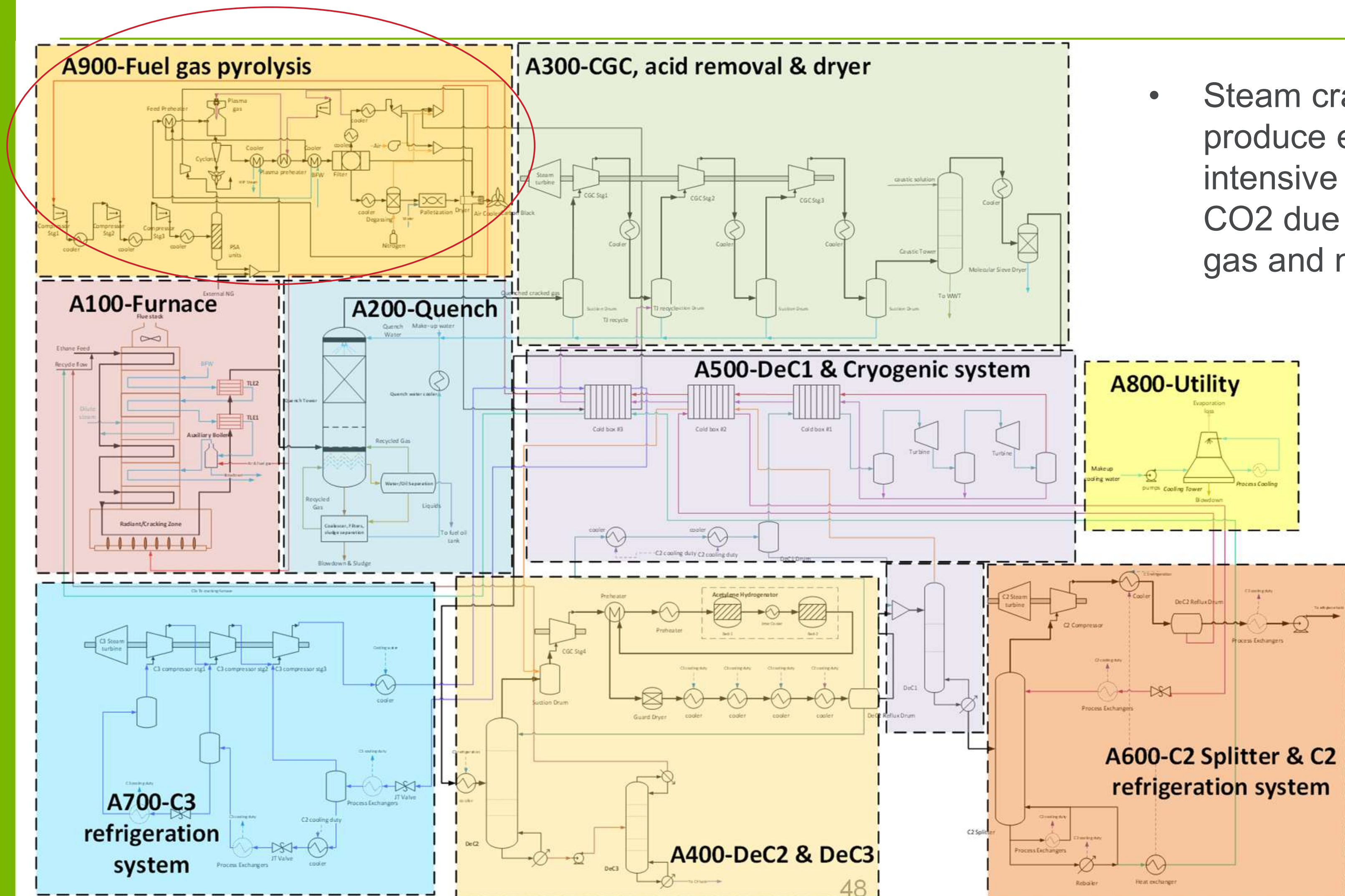


Refinery heat balance

Parameter	Value
Total refinery thermal demand (fired heaters + boiler)	534 MWt
Available heating from RFG	487 MWt
Thermal deficit	47 MWt
Supplemental NG (fired heaters)	4,310 kg/h
SMR feedstock	2940 kg/h
Total NG (fired heaters + SMR feedstock)	**7,250 kg/h**

- Based on first principles-based refinery modeling, we quantified refinery energy balance for heating, steam, H2 and electricity. Most of them is supplied by refinery internal fuels, which are unavoidable and hard to replace directly.
- Such information is essential to understand nuclear application potential, e.g. considering replaceable energy, and heat quality requirement (e.g. steam T and P)

THE INTEGRATED STEAM CRACKING- FUEL GAS PYROLYSIS PROCESS

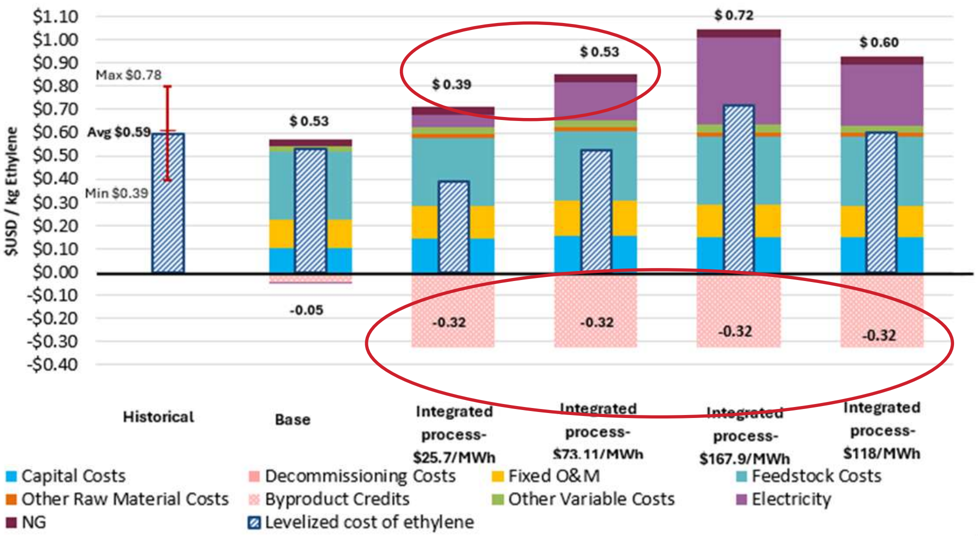


- Steam cracking process (to produce ethylene) is very energy intensive and emits extensive CO2 due to combustion of fuel gas and natural gas (NG).

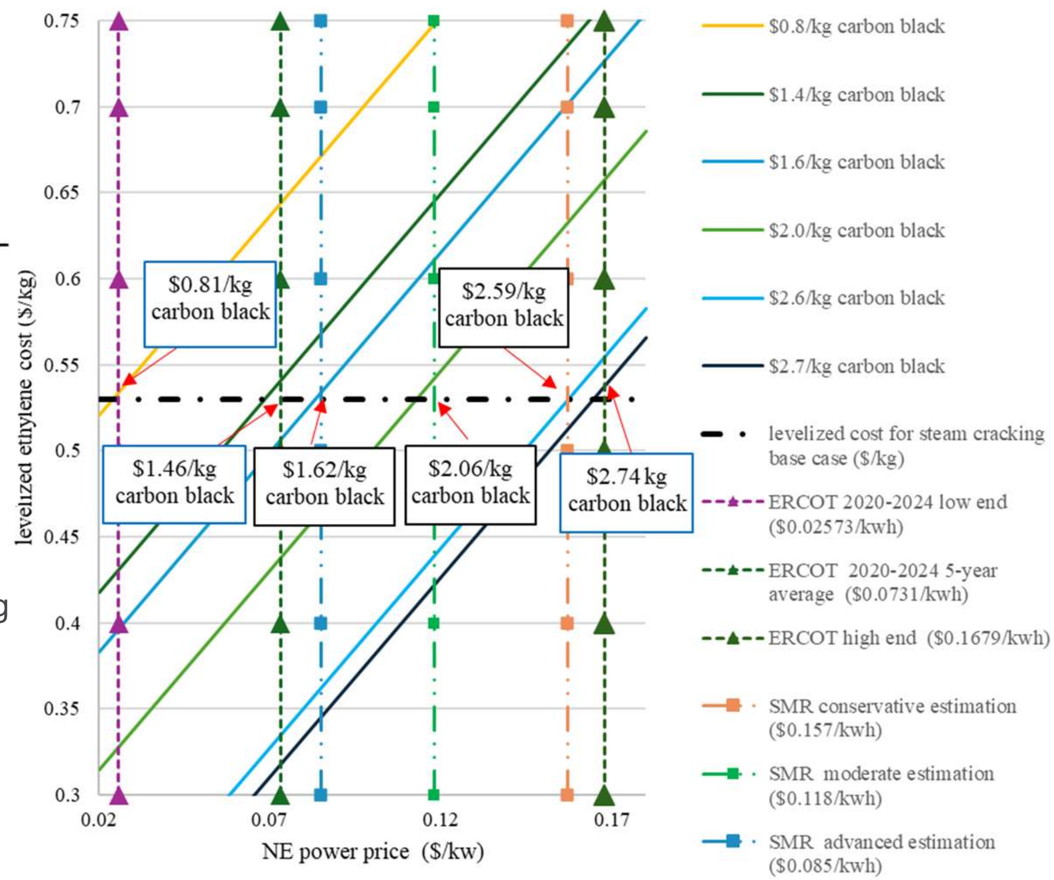
- The fuel gas/NG can be pyrolyzed to form H2 for clean burning and co-produces carbon black to add revenues, shown at A900

TEA OF THE INTEGRATED PLANT

Levelized Cost of Ethylene by different NE prices



Breakeven cost of the integrated system on NE cost and the carbon black market value



- For a steam cracking plant with an annual capacity of **1 MM MT ethylene**, the nuclear energy demand is about **280 MW**, making it suitable for SMNR application.
- The steam cracking-MP process is **economically viable at the current electricity cost** (carbon black >$1.8/kg, NE price is ~$70/MWh in 2025), due to high market price of carbon black.
- The Levelized cost of ethylene is influenced by NE and carbon black prices.
- Direct CO_2 emission is reduced by 98%.

H_2 Market Analysis

Waterford Nuclear Power Plant

- The future potential demand for hydrogen from this plant from facilities within 100-miles is 6498 MT per day.
- More than half of the total hydrogen demand centers are located within 50-miles.