Thermal and Electrical Power for Beyond-Grid Applications Session

Session Lead: Tyler Westover

Al Wilson
Sargent & Lundy

- Summary of Thermal Energy Extraction Studies
  - 30, 50, 70% Thermal Extraction- Sargent & Lundy A/E,

Thomas Ulrich
INL

- Plant Operations Testing – Collaboration with Westinghouse Electric Company & GSE Systems

Levelized Cost of Hydrogen is competitive for markets that value alternative energy products, power, fuels, chemicals, steel.

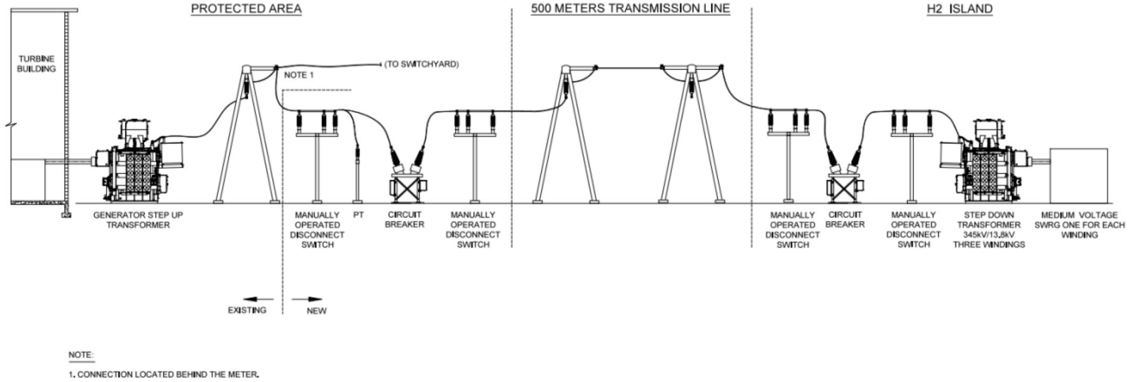
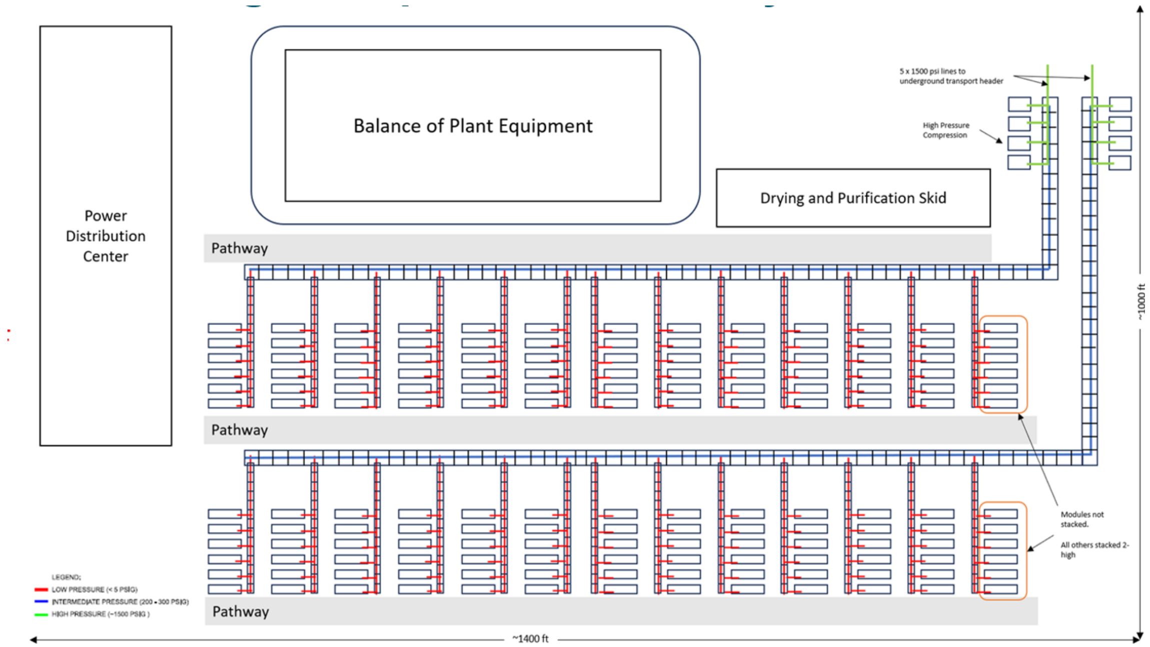
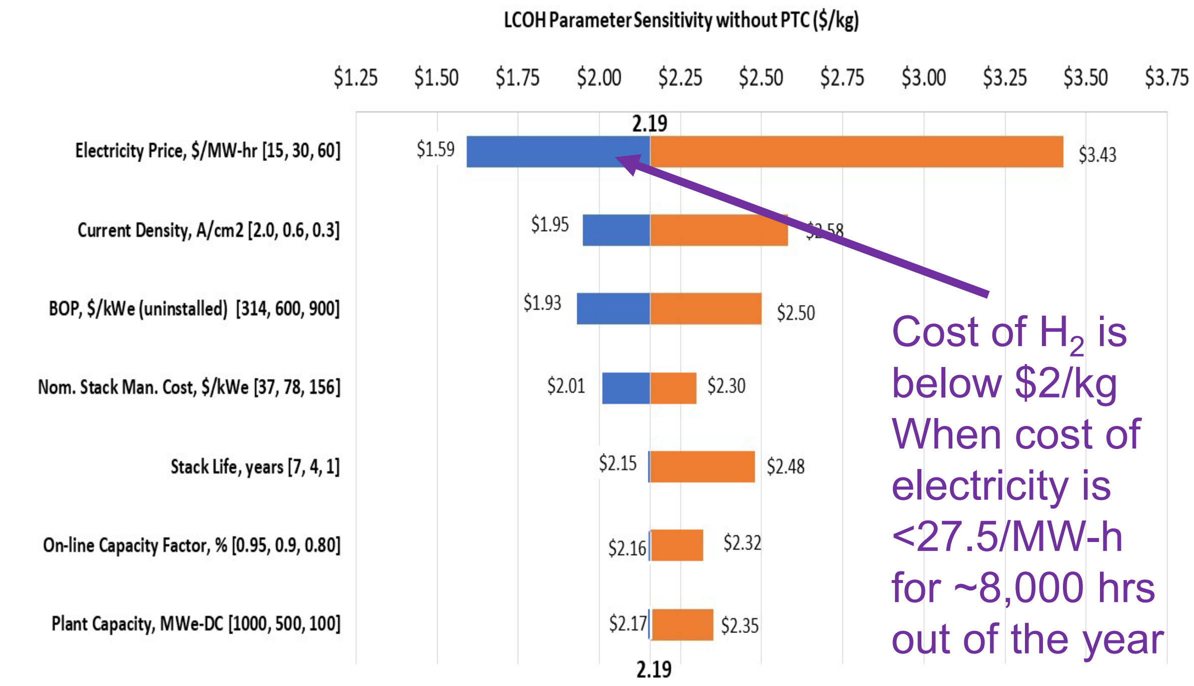


Figure B-5. 100 MW_{nom} HTEF Feeder Electrical Physical Layout.



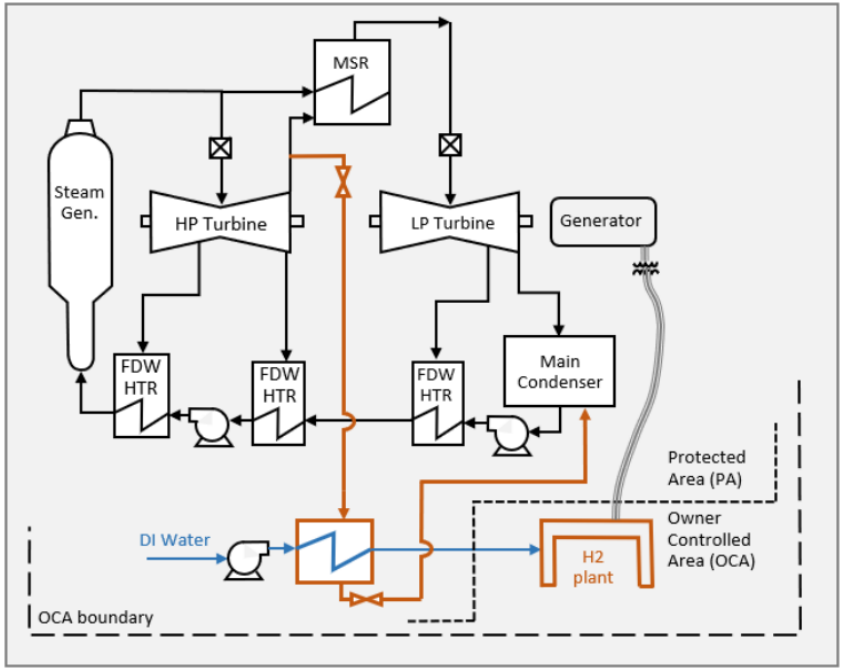


Cost of H_2 is below $2/kg When cost of electricity is <27.5/MW-h for ~8,000 hrs out of the year

- DOE's goal is to produce hydrogen for less than $2 per kg by 2026
- This goal can be met 95% of the year with LWRs that are dedicated to producing hydrogen.

Preconceptual Designs for Coupling a Pressurized-Water Reactors with a High Temperature Electrolysis Hydrogen Production Plant

- Developed preconceptual designs to couple a pressurized water reactor (PWR) to different high temperature electrolysis (HTE) hydrogen plants.
  - These designs are summarized in report SL-016181, Rev. 01.
  - Evaluated HTE facilities at 100 MW and 500 MW.
  - A 100 MW_{DC} HTE plant requires ≈ 25 MW_{th}, while a 500 MW_{DC} HTE plant requires ≈ 105 MW_{th}.
  - Explored three coupling options. Extracting steam from cold reheat between HP and LP turbines (shown at right) is the preferred option for low levels of steam extraction.
  - Extracting 105 MW_{th} from cold reheat decreases PWR output by 22.4 MW_e.
  - Extracting 105 MW_{th} from main steam decreases PWR output by 35 MW_e.



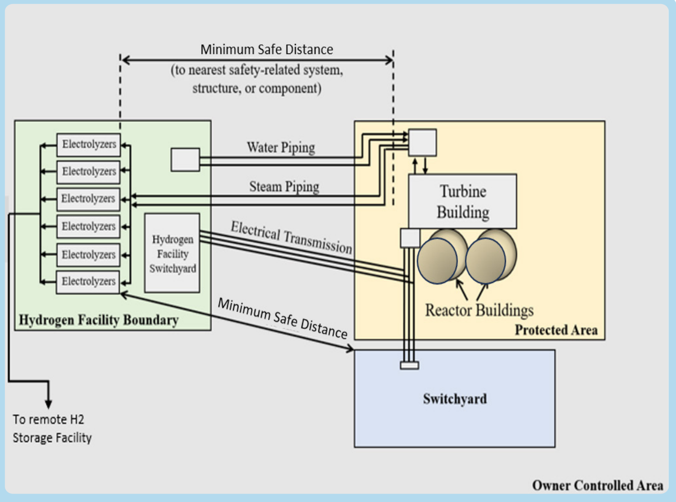
- Design includes a Class 5 cost estimate (-50%, +100%). Estimates include contingencies approximately equal to direct capital costs but exclude financing.
  - Performed estimates for 500 m and 250 m distances between PWR and HTE plants.
  - Standardized cost decreases >3× as scale of HTE plant increases from 100 MW_{DC} to 500 MW_{DC}.
  - Lowest standardized cost of \$61.2/kW_{DC} achieved for 500 MW_{DC} HTE plant that is 250 from PWR.

	100-MW_{DC}, 500-m	500-MW_{DC}, 500-m	500-MW_{DC}, 250-m
Steam direct cost ($MM)	6.1	11.7	9.0
Electric direct cost ($MM)	1.3	1.4	1.2
Indirect & contingency ($MM)	17.2	26.0	20.4
Total cost ($MM)	24.6	39.0	30.6
Standardized cost ($/$kW_{DC}$)	246.0	78.0	61.2

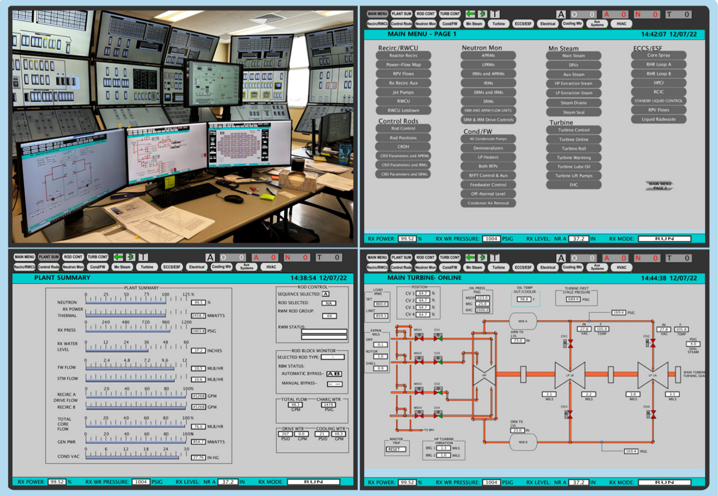
FY24 Major Research Accomplishments

Five Years of Progress:

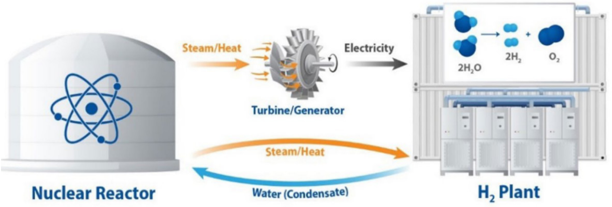
- 30-50-70% thermal energy offtake designs and concepts of operations.
- Guidance report on hydrogen production with nuclear power plants.
- Assessment of Gulf Shore hydrogen and thermal markets.
- Prospector tool for screening FPOG markets.
- Value of nuclear power plants relevance to grid reliability and resilience.
- Evaluation of energy arbitrage based on energy storage options.



Completed A/E design and costing for thermal energy extractions:
1. Hydrogen production.
2. 30, 50, and 70% thermal energy off-take.

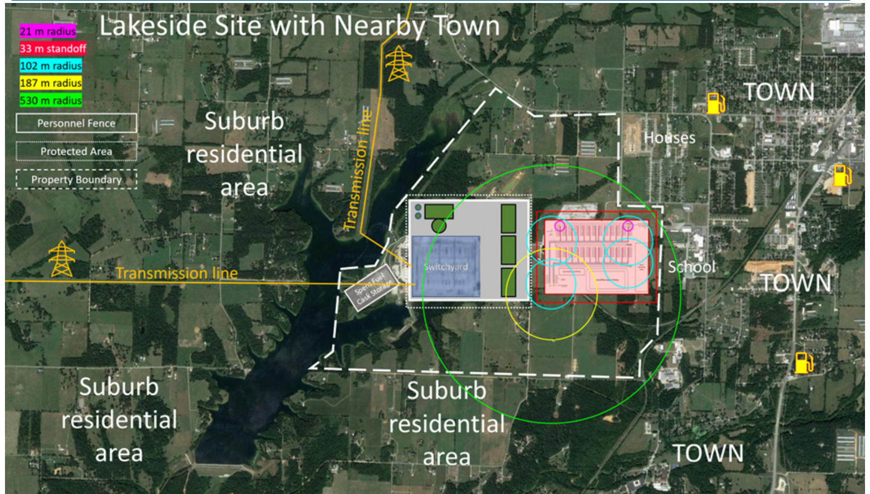


Developed simulators and tested operating concepts for PWR and BWR coupled to electrolysis plants.



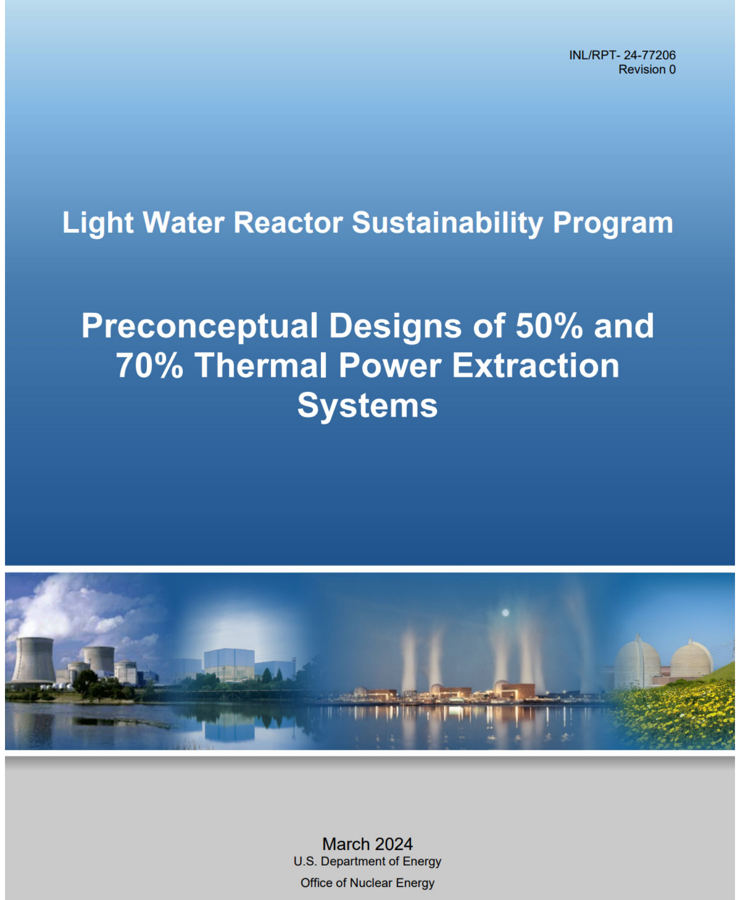
Issued LWRS Report: INL/RPT-24-78729
Guidance on Near-Term Hydrogen Production using Nuclear Power
June 2024

Completed generic PRA completed for hypothetical nuclear-powered hydrogen plant located near community area.



Thermal Energy Extraction and Delivery Accomplishments

- Designed/evaluated short to medium distance energy delivery systems
- Evaluated thermal energy storage options to supply dynamic energy duties to industry
- Evaluated energy arbitrage storage options
- Completed Class 4 cost projections
- Continued to develop control concepts for energy dispatch
- Addressed safety hazards and licensing options and requirements



LWRS LIGHT WATER REACTOR SUSTAINABILITY

Sustaining National Nuclear Assets

lwrs.inl.gov

Idaho National Laboratory (INL)
Battelle Energy Alliance (BEA)

Pre-Conceptual Design for Large-Scale Nuclear Integrated Hydrogen Production Facility

Report SL-018670
Revision 1
June 21, 2024
Project No.: A14248.015

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

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Sargent & Lundy

Report prepared for the Light Water Reactor Sustainability (LWRS) Program at Idaho National Laboratory (INL) under the direction of Richard Boardman and Tyler Westover. The views and opinions of authors expressed herein do not necessarily state or reflect those of the U.S. Government or any agency thereof.

Light Water Reactor Sustainability Program

Guidance on Near-Term Hydrogen Production using Nuclear Power

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

A Human-in-the-Loop Verification of Operating Concepts for a Light-Water Reactor Coupled to a Hydrogen Plant

Scenario-based Dual Simulator Thermal Power Dispatch Concept of Operations Evaluation and Demonstration

Thomas A. Ulrich, Jisuk Kim, Dylan Jurski
Idaho National Laboratory
Roger Lew, Olugbenga Gideon, Zeth Dubois
University of Idaho
Kelly Dickerson
U.S. Nuclear Regulatory Commission
Stephen Hancock
GSE Solutions

September 2024

Idaho National Laboratory
Light Water Reactor Sustainability
Idaho Falls, Idaho 83415

http://lwrs.inl.gov

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

Light Water Reactor Sustainability Program

Flexible Plant Operation and Generation: Hazards and Probabilistic Risk Assessments of a Light-Water Reactor Coupled with Industrial Facilities

September 2024

U.S. Department of Energy
Office of Nuclear Energy

Hydrogen Safety Analysis

Detonation Consequences:

- TNT equivalent method
  - Current standard for the 1.0 psi safe distance in RG 1.91
- Alternate Bauwens method for hydrogen leak jet detonation
  - Hydrogen-specific methodology
  - More precise than TNT equivalence

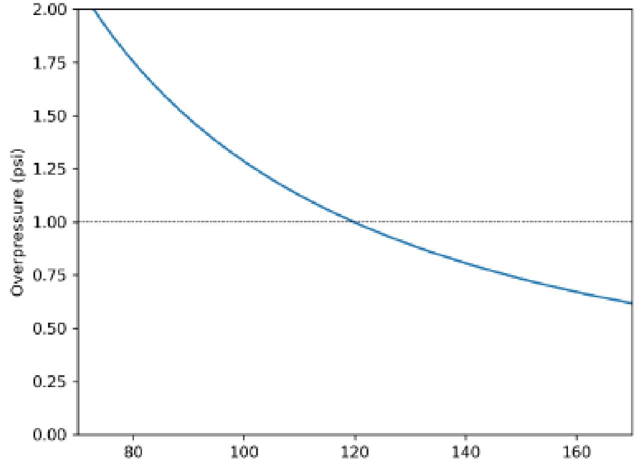


Figure E-15. Scenario 15 Separation Distance Results

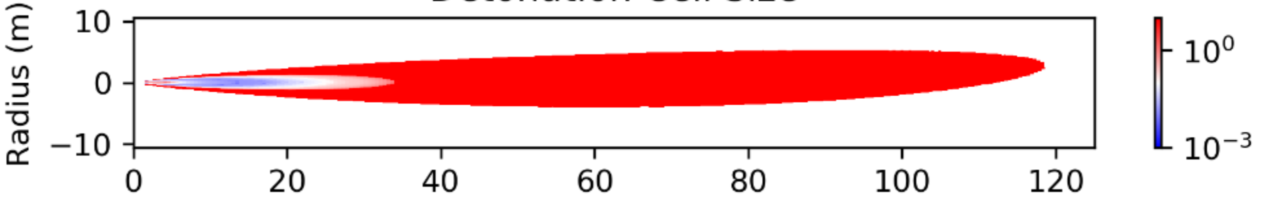
Hydrogen Fuel Production Risks

Very difficult to detonate an uncontrolled leak in open air

- Low ignition event frequency
- Lower detonation event frequency

Contained hydrogen can detonate as a cloud

- NFPA standards primary concern is to avoid structures that can contain the hydrogen



Hydrogen to Synfuels

- IES and LWRS 2022 Study

ANL-22/41

The Modeling of the Synfuel Production Process

Techno-Economic Analysis and Life Cycle Assessment of FT Fuel Production Plants Integrated with Nuclear Power

June | 2022

Hernan E. Delgado, Vincenzo Cappello, Pingping Sun, Clarence Ng, Pradeep Vyawahare, Amgad Elgowainy

Systems Assessment Center, Energy Systems and Infrastructure Analysis Division, Argonne National Laboratory

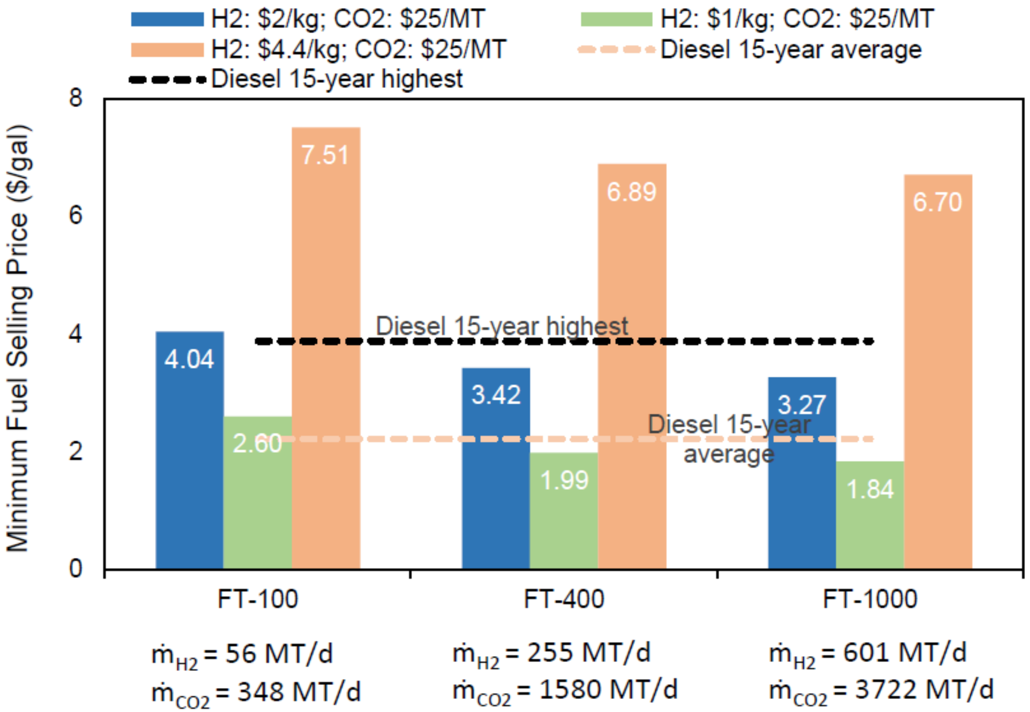


Figure I. Production cost of FT fuel at different plant scales and H_2 prices.