Merchant Hydrogen at Scale: A Technical-Economic Case Study of the Potential for Nuclear Hydrogen Production

2019 Fuel Cell Seminar
H2@Scale Meeting, November 5, 2019

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Overview of project scope

Timeline and budget

- Project Start Date: 06/18/2018
- Project End Date: 05/17/2019
- Total Project Budget: $1,575,000
  - Total Recipient Share: $650,000
  - Total Federal Share: $925,000
  - Total DOE Funds Spent*: $0

Barriers

- Flexible operation of nuclear power plants
- Thermal energy integration with high temperature electrolysis
- Commercial manufacturing pathway for electrolysis modules

DOE sponsors

- EERE- Fuel Cell Technology Office
- NE- Cross-Cutting Technologies

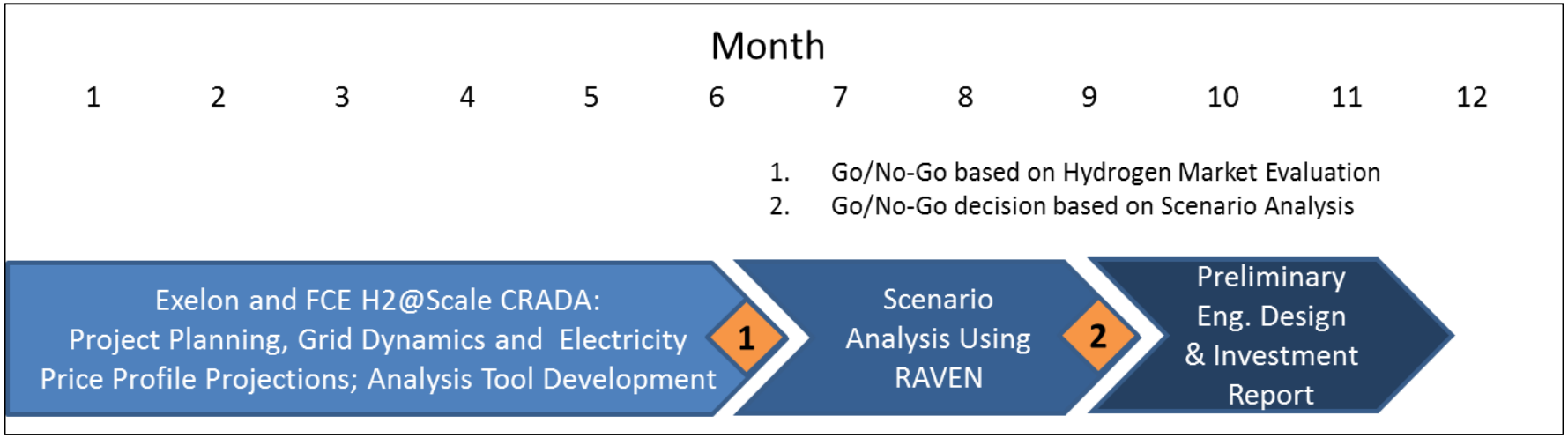
CRADA partners

- Exelon Corporation
- FuelCell Energy
- Idaho National Laboratory
- National Renewable Energy Laboratory
- Argonne National Laboratory

Project objective scope and timeline

This project plans to evaluate the technical and economic potential for expanding the markets for existing nuclear reactors. This evaluation provides a basis for converting baseload nuclear plants into hybrid plants that produce hydrogen, resulting in commercial investments and industry growth in the United States.

- Evaluate technical and economic feasibility of integrated nuclear-renewable-hydrogen plant operation
- Assess hydrogen market in region of an Exelon nuclear plant
- Complete preliminary engineering design of thermal and electrical energy integration with FuelCell Energy High Temperature Steam Electrolysis
- Evaluate logistics of dynamic hydrogen product, storage, delivery, and use by industry (e.g., steel manufacturing)
- Complete investor-grade study with preliminary design



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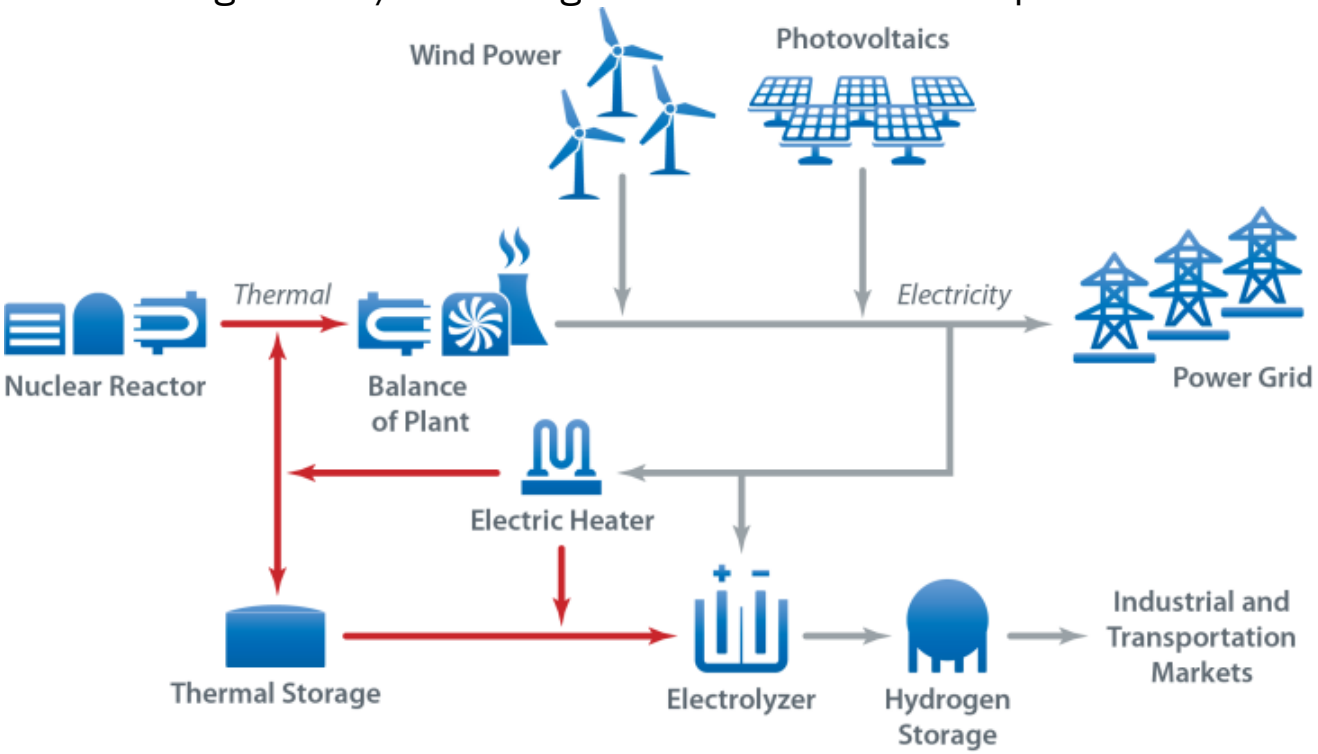
Cross Lab Coordination

- **INL**- Process Modeling, Plant Design, System Optimization with RAVEN
- **NREL**- Renewables Resources Data, Grid Capacity Modeling and Unit Commitment Daily Profiles
- **ANL**- Life Cycle Assessment and Energy Storage
- **SNL-** Codes and Regulations/Permitting Joint Nuclear-Process Operations



Idaho National Laboratory NREL NATIONAL RENEWABLE ENERGY LABORATORY Argonne NATIONAL LABORATORY Sandia National Laboratories

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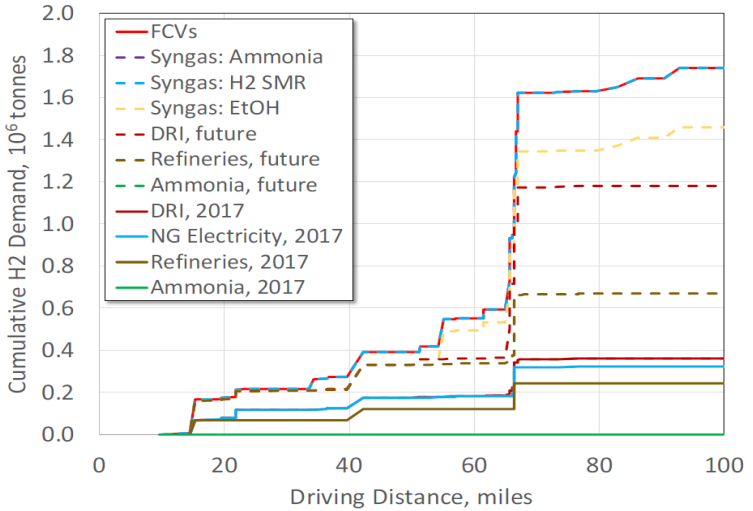
Preliminary result: Hydrogen demand

Hydrogen Demand near a nuclear site



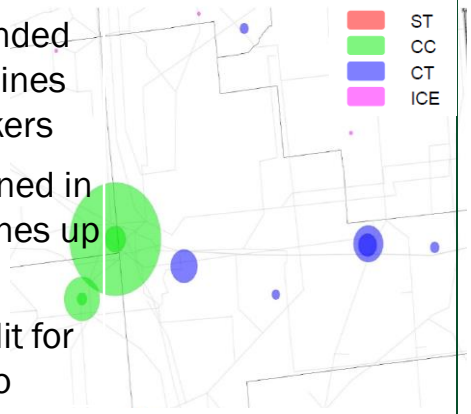
*Analysis from Argonne national lab

~1 MW electrolyzer

- 300 kg/day H2 for 8 hydrogen buses at a university campus
- Consistent with 1 MW electrolyzer @ 75% capacity factor
- ~100 miles tube trailer delivery

~10 MW electrolyzer

- Hydrogen can be blended into natural gas pipelines and sold to NG offtakers
- Hydrogen can be burned in NG combustion turbines up to 5% by volume
- Need significant credit for the green-hydrogen to make it economical



Large-scale (~100MW electrolyzer)

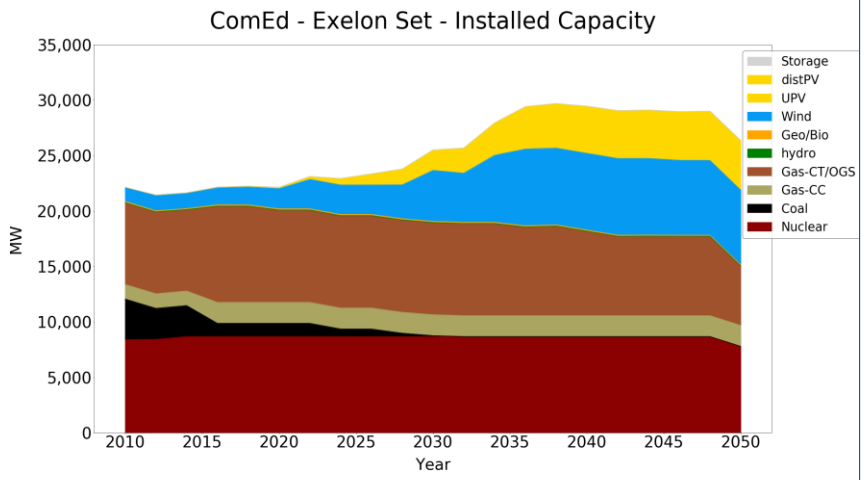
- ~50 MT/day additional hydrogen demand expected at a Refinery
- Consistent with ~100 MW electrolyzer @ 100% capacity factor

Electric power scenario modeling

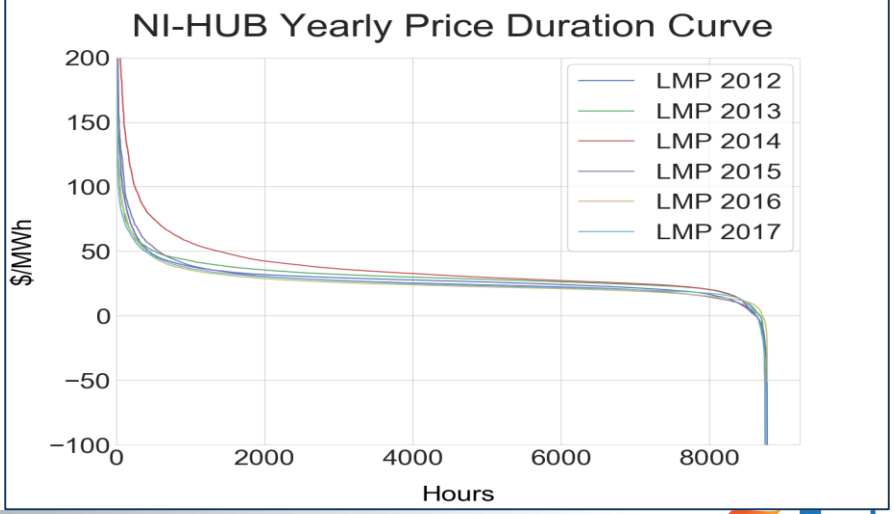
Future scenario assumptions

- **Low NG + Low RE** – AEO 2018 High Oil & Gas Resource and Technology & 2018 ATB Renewable Low-Case Projections (no increase in NG prices from 2018-2050)
- **80 Year Nuclear Lifetime** – All nuclear plants have an 80-year lifetime
- **Low Demand Growth** – AEO 2018 Low Economic Growth Rate (approximately 19% increase in U.S electricity demand from 2018 to 2050)
- **Vehicle Electrification** - Adoption of plug-in electric vehicles and plug-in hybrid electric vehicles reaches 40% of sales by 2050; 45% of charging utility-controlled, 55% opportunistic

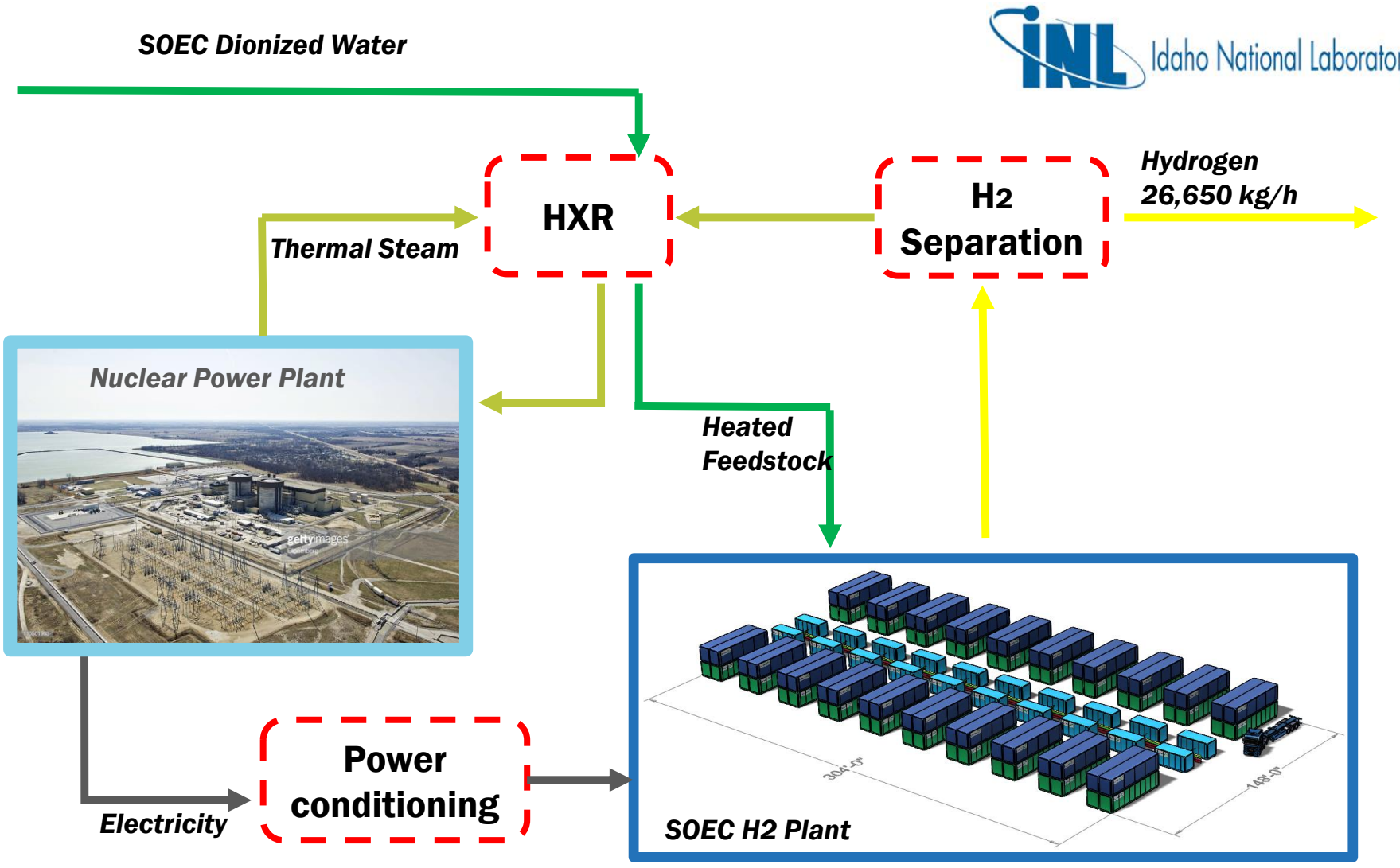
Capacity buildout projections



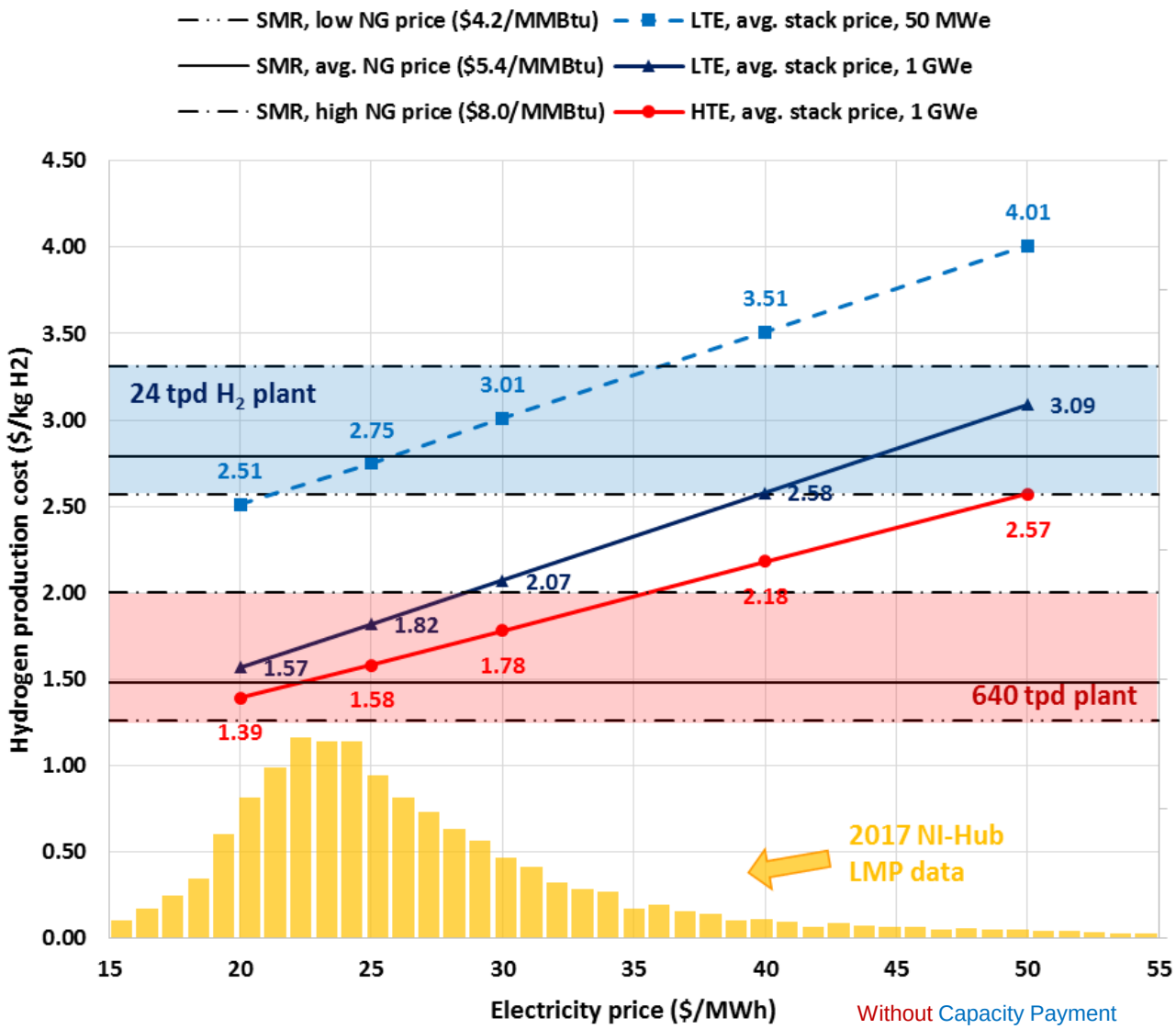
Price duration curves



Preliminary result: Nuclear-integrated Electrolyzer Plant System Architecture



H_2 Production Cost Results Summary- Steady State (2019$)



Without Capacity Payment

Modular construction with 95% experience curve for HTSE (5% cost reduction as installations double)

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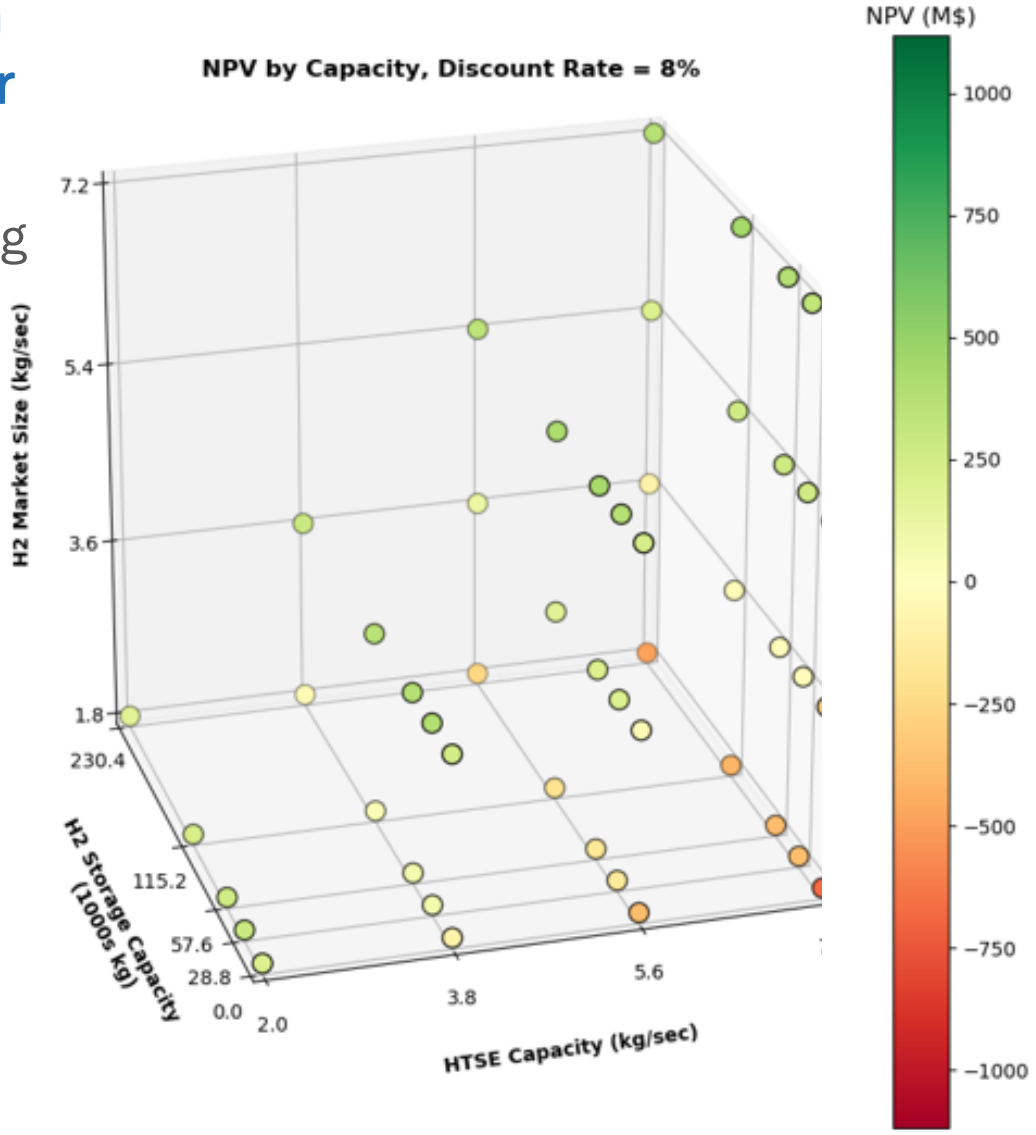
Dynamic HTSE operation results- Preliminary

Differential NPV over seventeen years of a co-generating nuclear station in PJM

- Medium hydrogen market selling prices ($/kg-$H_2$)
- Discount Rate = 8%
- Corporate Tax Rate = 21%,
- Inflation = 2.2%
- No carbon tax credits
- No participation in ancillary services market
- Assumes building a pipeline for delivery
- No ability to thermally cycle the HTSE plant due to current thermal constraints



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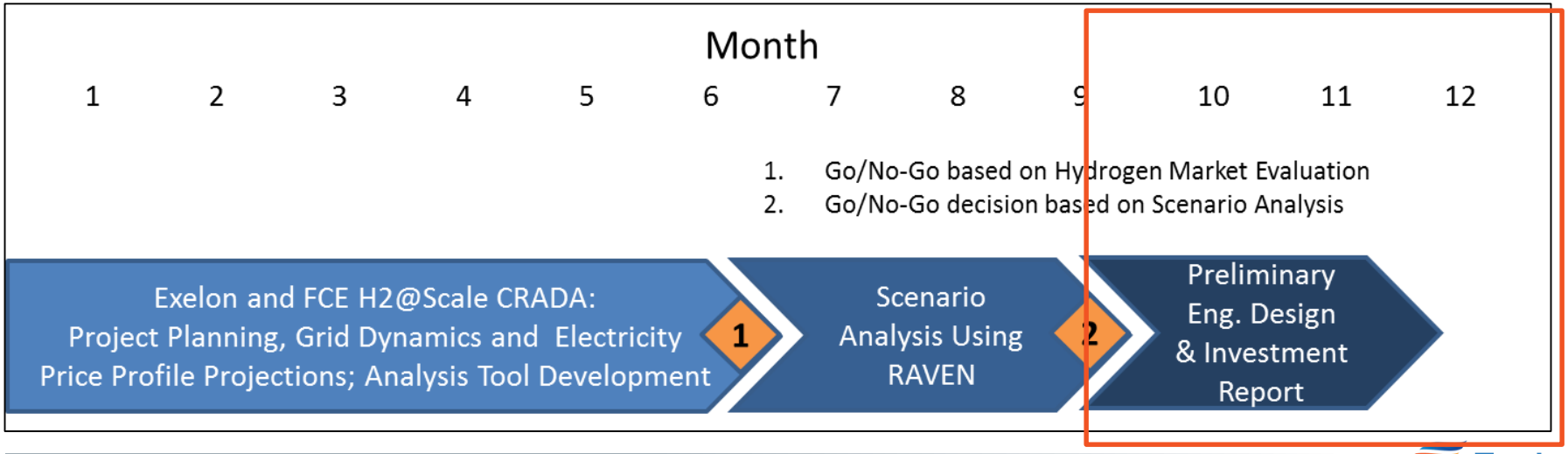
Next step

- Completing investor grade TEA report proprietary to Exelon
- Incorporates Exelon's plant location, hydrogen demand, proprietary cost estimates
- Financial assumptions include, Exelon's cost of capital, tax rate, capacity price in PJM, nuclear plant availability and capacity factor
- Performs a sensitivity study electric market prices, hydrogen selling price and dynamic operation



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