H2@Scale CRADA Kickoff

Region Specific Merchant Hydrogen Market Assessment and Techno-Economic Assessment of Electrolytic Hydrogen Generation

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Overview

Timeline and Budget

- Project Start Date: 09/01/2018
- Project End Date: 05/30/2019
- Total Project Budget: $350,000
  - Total Recipient Share: $200,000
  - Total Federal Share: $100,000
  - Total DOE Funds Spent*: $0

CRADA Partners

- Southern Company
- Exelon Corporation
- Xcel Energy (cash-in)
- Idaho National Laboratory
- National Renewable Energy Laboratory
- Argonne National Laboratory

Barriers

- Tools and methods for assessment of optimization of regional natural resources and energy production
- Detailed capital investment pro-forma and life-cycle assessments for hydrogen markets
- Market options for otherwise-curtailed electricity
- Understanding interfaces for connecting variable and baseload plants to industry in hybrid operation

DOE Sponsors

- EERE- Fuel Cell Technology Office
Relevance

This project will analyze regional hydrogen market opportunities (especially for low-CO$_2$ hydrogen). It will identify and characterize industrial demand for clean hydrogen in the service territories of SCS (Southeast U.S.), Exelon (Upper Midwest), and Xcel Energy (West-Central Plains States). Based on the projected industrial utilization markets, a cursory technical-economic assessment of large-scale, centralized hydrogen generation plant will be completed- considering existing nuclear plants and renewables in each region.

- Electricity markets vary by region
- Renewable energy growth varies by region
- Regional hydrogen markets depend on logistics of natural resources, transportation systems, and other infrastructure
Approach: 9 Month Activity

1st Quarter:
- Identify, validate, and rank regional hydrogen markets

2nd Quarter:
- Characterize power, load demand, and electricity price profiles
- Evaluate electrolysis plant options

3rd Quarter:
- Assess hydrogen storage needs

Technical Evaluation Report
Methods: Electricity Prices

• Collect historical grid price information relative to participating CRADA partners

• Assess regional grid markets for each Utility/CRADA Partner
  – Regulated vs Deregulated
  – Vertically integrated Utility vs Merchant nuclear plants
  – Renewable energy targets and trends

• Develop price duration curves pertinent to hydrogen production plant

• Determine nuclear plant energy production costs

• Establish geographic locations of renewable energy

Regional hydrogen markets depend on logistics of natural resources, transportation systems, and other infrastructure

Nuclear plants can be provide energy directly to H₂ plants
Methods: Hydrogen Demand

- Survey of existing industries using hydrogen
- Projections for hydrogen demand growth
  - Fuel Cell Vehicles
  - Near-term hydrogen customers; for example ammonia plants
  - Potential long-term hydrogen users; for example Synthetic fuels
- Develop geographical map of hydrogen use customers

- Leverage H2@Scale Analysis Team studies for county-by-county hydrogen demand opportunities
- Develop local demand curves vs price of hydrogen
Methods: Hydrogen Production

- Use H2A model for hydrogen production costs
- Large centralized H\(_2\) plants vs Distributed H\(_2\) plants
- Steam electrolysis based on Dominion Engineering design
- Aspen model for balance of plant to derive balance of plant capital and operative costs
- Compare to natural gas reforming relative to regional natural gas price projects
  - DOE-AEO Natural Gas Projection: Reference Case, High Cost, Low Cost
- Independent H2A cost calculations review

- Leverage H2A model development by DOE-NE program for high temperature steam electrolysis
- Develop hydrogen supply curve costs
The maximum LMP value reached 600 $/MWh.

Northern Illinois Hub 2017 Price Duration Curve
Progress: Grid LMP Profiles & Trends

$/MWh

(SPP-South PDC)

Aligning Xcel Energy Projected PDC with 2017 Volatility
Progress: Potential Hydrogen Demand, Future (2030)
Progress: $\text{H}_2$ Demand near the Farly Generating Station

- Syngas: EtOH
- Syngas: H2 SMR
- Syngas: Ammonia
- Refineries, 2030
- Ammonia, 2021
- Refineries, 2017
- Ammonia 2017

H$_2$ Demand, kilotonnes
Distance, miles
Progress: H₂ Production Cost Results

- **LTE (small scale)**
  - 50 MWe
  - 23.9 tons/day H₂
  - 97% OCF
  - $329/kWe (DC power input)
  - TCI of $15.3 M

- **LWR/LTE (large scale)**
  - 1191 MWe
  - 569 tons/day H₂
  - 90% OCF
  - $329/kWe (DC power input)
  - TCI of $365 M

- **LWR/HTE (large scale)**
  - 1191 MWe
  - 755 tons/day H₂
  - 84.7% OCF
  - $403/kWe (DC power input)
  - TCI of $434 M

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### Hydrogen Production Cost ($/kg H₂)

- **SMR, high NG price ($8.0/MMBtu)**
- **LTE, avg. stack price, 50MWe**
- **SMR, avg. NG price ($5.4/MMBtu)**
- **LTE, avg. stack price, 1191MWe**
- **SMR, low NG price ($4.2/MMBtu)**
- **HTE, avg. stack price, 1191MWe**

### Electricity price ($/MWh)

- 15
- 20
- 25
- 30
- 35
- 40
- 45
- 50
- 55

### Progress: H₂ Production Cost Results

- **2018 price data**
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Overview of Primary and Emerging H₂ Markets

Distributed Water Electrolysis Plants

Light-Water Reactor Power Plant

Wind Solar Hydro, Geo.

Central Hydrogen Plant

PEM AE, PEM

Steam Electrolysis

Clean Transportation Fleet

H₂

Synfuels

By-Product CO₂ Pipeline

Regional Ethanol Plants

Biodigester Plants

Central Clean Chemical & Fuels Synthesis

H₂

H₂

O₂

Refinery / Petrochemical Plant

Ammonia-Based Fertilizers Plant

Direct Reduced Iron / Electric Arc Mini Steel Plant
Summary

- This CRADA addresses hydrogen merchant markets in three different regions
- Electricity market price duration characteristics for the different regions have been obtained and are being used to calculate hydrogen costs
- Hydrogen markets have been evaluated for each Exelon
- H2A model revisions were completed to compare distributed and centralized hydrogen plants with steam methane reforming in the Upper Midwest

Future Work

1. Wrap up hydrogen market opportunities for Xcel Energy
2. Determine hydrogen production costs for Xcel Energy and Southern Company Services regions
3. Evaluate region-specific hydrogen storage needs and costs
4. Provide project report