U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Systems Analysis Overview

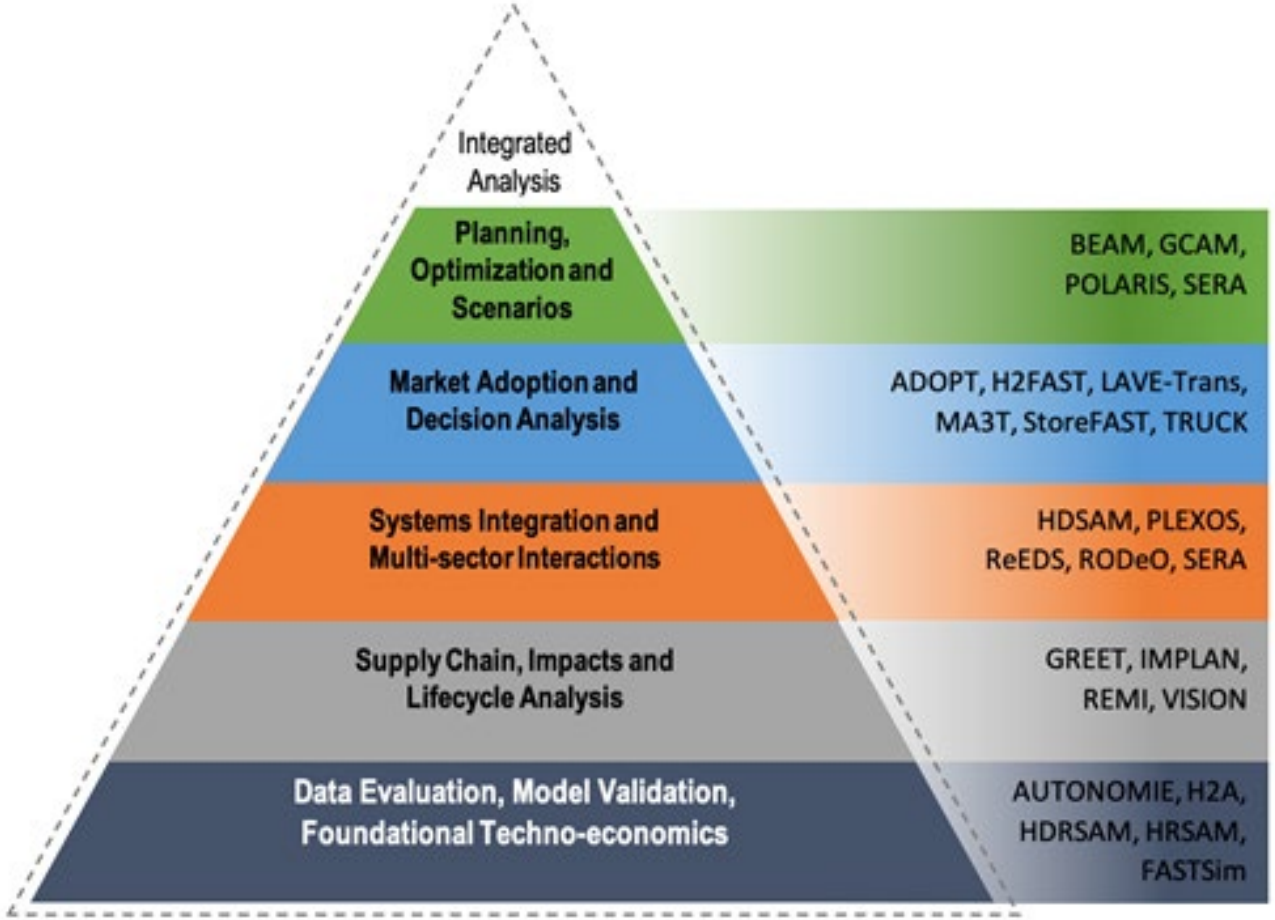
Neha Rustagi, HFTO - Systems Analysis Lead

2021 Annual Merit Review and Peer Evaluation Meeting

June 7, 2021 – Washington, D.C.

Systems Analysis Overview

Systems Analysis conducts cross-cutting analyses in collaboration with other HFTO sub-programs, DOE Offices and external stakeholders to inform RD&D priorities



Inform Program strategy and guide RD&D

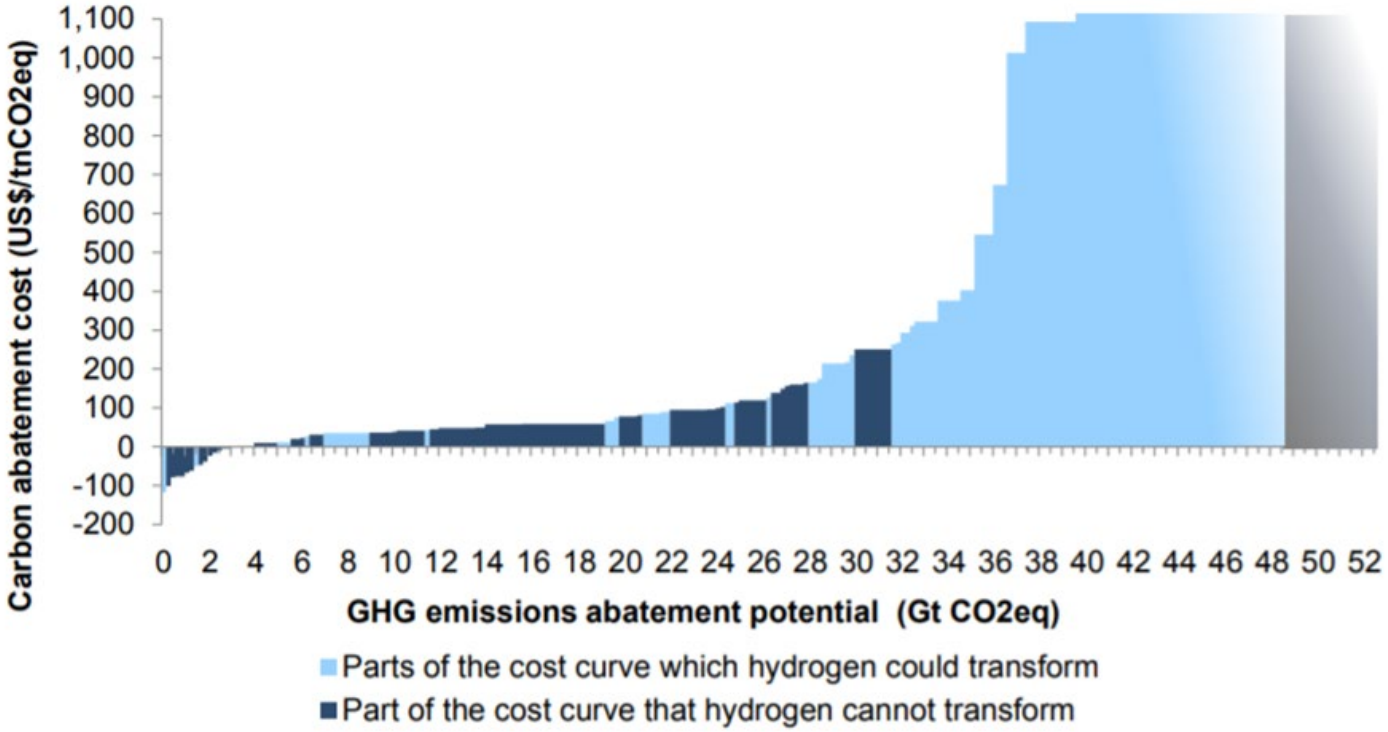
Integrate data from existing projects and updated market trends

Update projections of supply chain dynamics, and consumer behavior

Technology cost and performance estimates and validate models

Systems Analysis Focus Areas

Analyses in FY20-21 have focused on identifying the role of hydrogen in hard-to-decarbonize sectors



Cost of decarbonization increases significantly after 50%.[1]

Recent and ongoing analyses are characterizing:

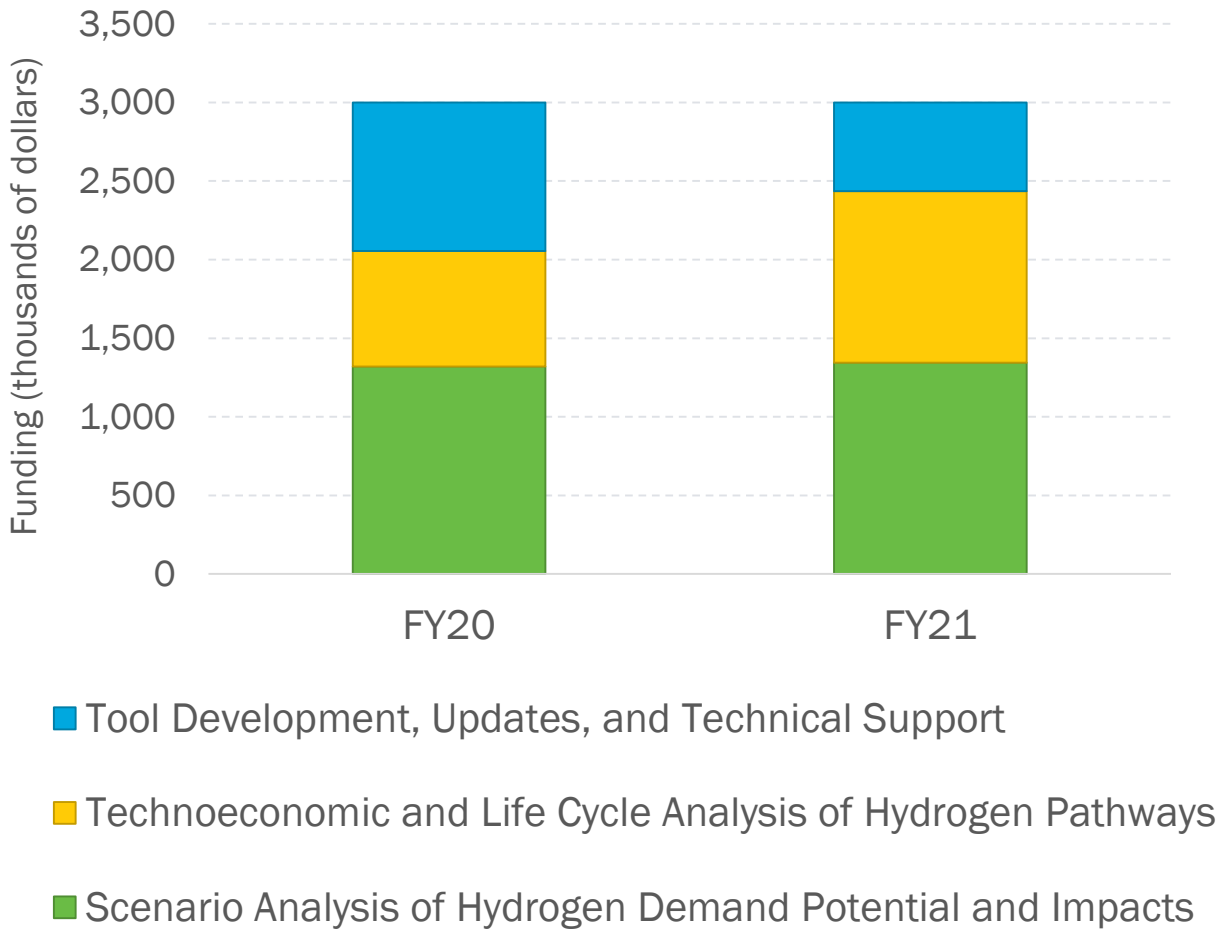
- Role of hydrogen in long duration energy storage
- Impact of hydrogen use on life cycle emissions of industrial applications
- Market segmentation in medium/heavy-duty transportation
- Supply and demand potential for hydrogen
- Impact of growth in hydrogen and fuel cells on global sustainability

1. Source: Goldman Sachs, https://www.goldmansachs.com/insights/pages/gs-research/carbonomics-the-rise-of-clean-hydrogen/report.pdf

Systems Analysis Budget

FY20 Appropriations
$3 million

FY21 Appropriations
$3 million



Program Direction

Scenario Analysis of H_2 Demand and Impacts

- Sustainability and environmental justice metrics
- Hydrogen market sizes in energy system scenarios (e.g., net zero by 2050)
- Value proposition of hydrogen energy storage

Technoeconomic and Life Cycle Analysis

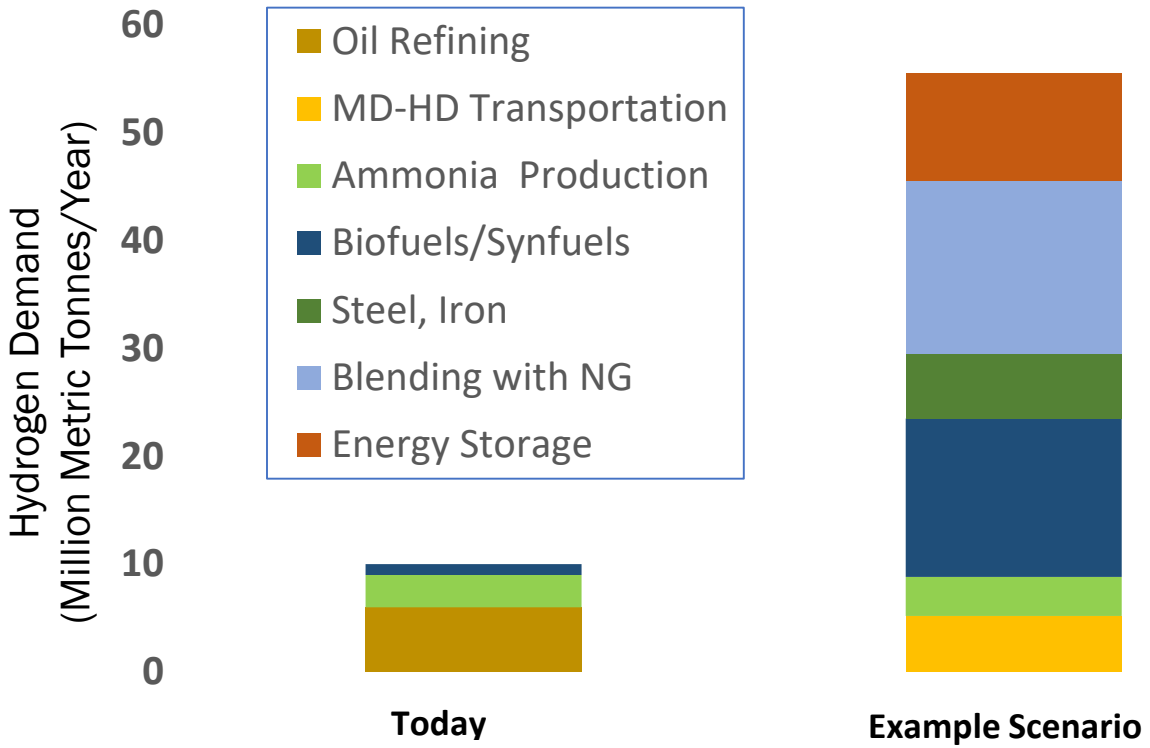
- Industrial Applications
- Synthetic fuels and biofuels
- Medium- and heavy-duty transportation

Tool Development, Updates, and Support

- Annual updates (e.g., to GREET, H2FAST)
- New tools to characterize value proposition of hydrogen and fuel cells (e.g., StoreFAST)

Key Reports Released in 2020

Comprehensive multi-lab analysis determined potential for growth in U.S. hydrogen demand of at least 2-5 x current consumption



Preliminary demand scenario based on published H2@Scale analysis and additional ongoing TEA

- **Resource Assessment for Hydrogen Production**[1]
  Determined technical potential of hydrogen supply
- **Assessment of Potential for Future Demands for Hydrogen in the United States**[2]
  Assessed price points and market potential for hydrogen in 8 sectors.
- **The Technical and Economic Potential of the H2@Scale Concept within the United States**[3]
  Assessed growth potential for hydrogen supply and demand in 5 scenarios

1. https://www.nrel.gov/docs/fy20osti/77198.pdf
2. https://greet.es.anl.gov/publication-us_future_h2
3. https://www.nrel.gov/docs/fy21osti/77610.pdf

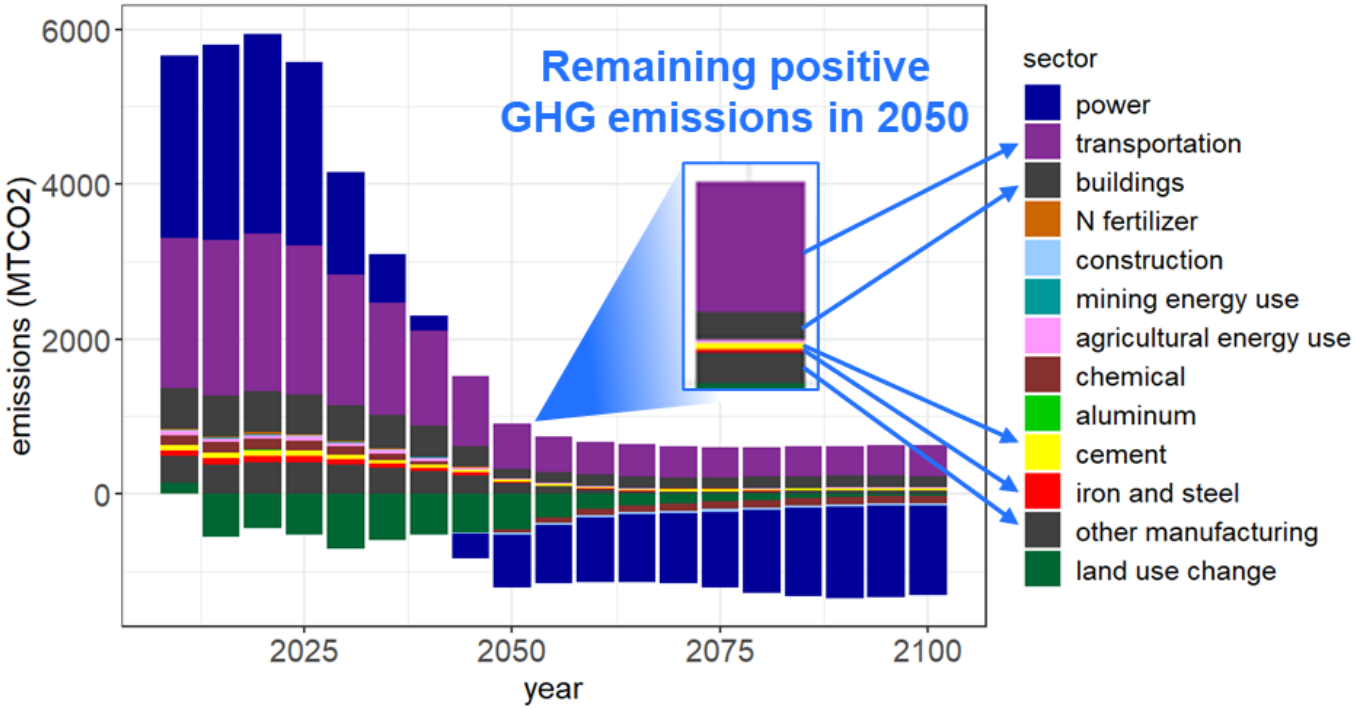
Hydrogen Energy Integrated Assessment: Updating H_2 in GCAM

GCAM: Global Change Analysis Model

GCAM represents linkages between five systems: energy, water, land, economic, and climate systems, at local, regional, and global scales

Current estimates of cost and performance of H_2 and fuel cell technologies will be incorporated into GCAM across all relevant pathways in industry and transportation

Example GCAM scenario before hydrogen updates



Anticipated GCAM Results

- Market shares and energy prices by sector
- GHG and criteria emission reductions
- GHG abatement costs compared to other options
- Land use, water use and other sustainability metrics

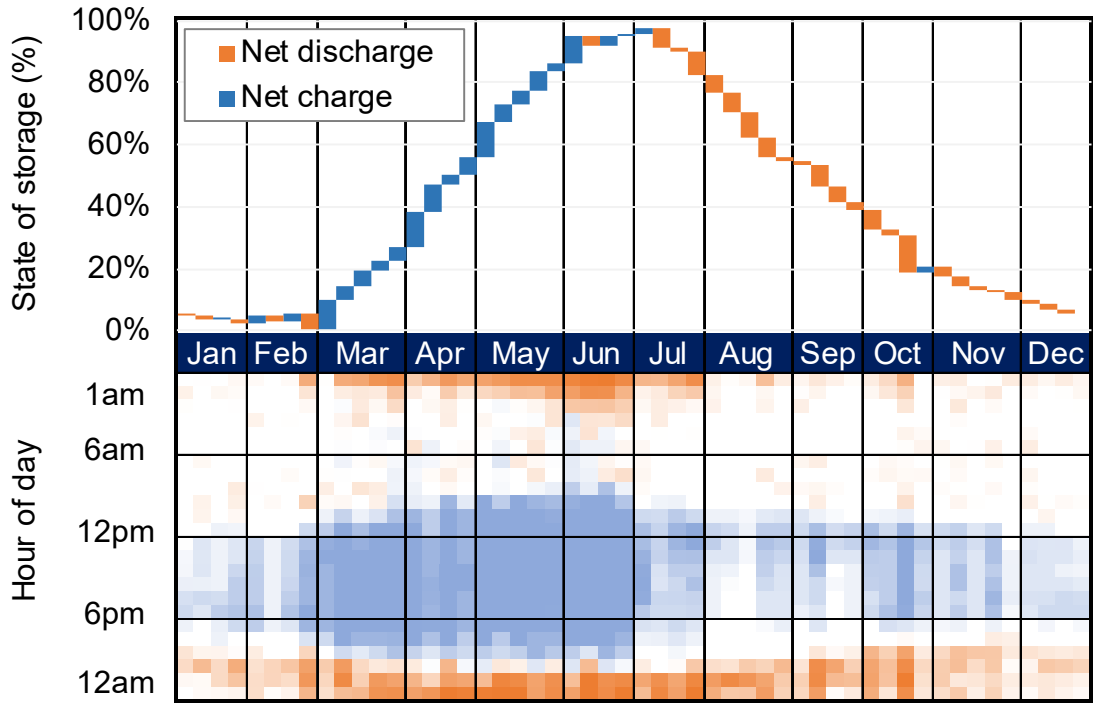
GCAM identifies which sectors are economically difficult to decarbonize to reach Net Zero GHGs

For more information, please see poster SA181

Competitiveness of Long Duration Energy Storage

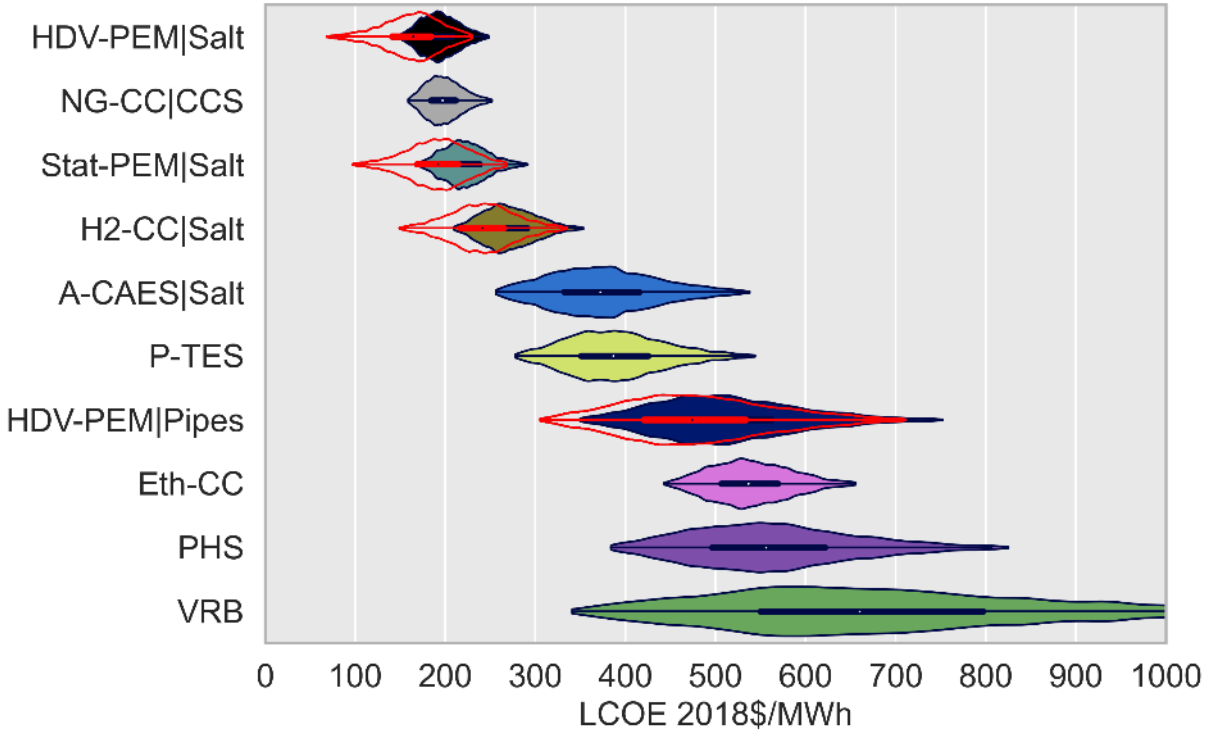
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Modeling of 85% renewable grid in Western Interconnect to inform energy storage capacity factors



Example capacity factor for technology with 40% round-trip efficiency

Analysis of current and future costs for long duration energy storage



Monte Carlo analysis of future costs

Hydrogen technologies are among the lowest cost pathways for multi-day energy storage

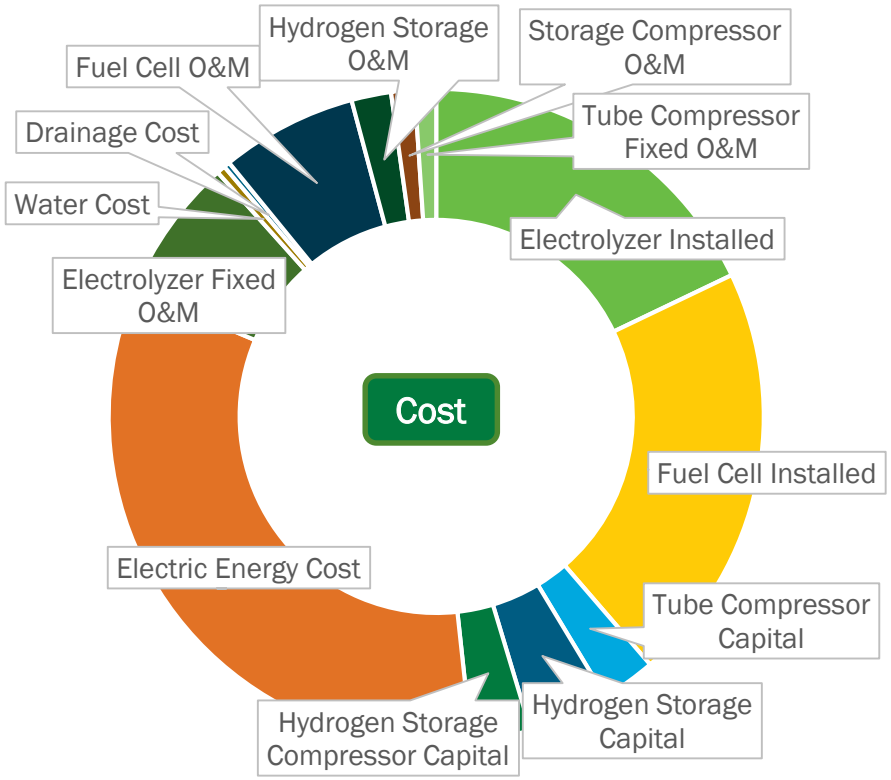
Analysis led by DOE-Strategic Analysis and co-funded with Solar Energy Technologies Office and Wind Energy Technologies Office.
Grid modeling informed by EPRI and five member utilities

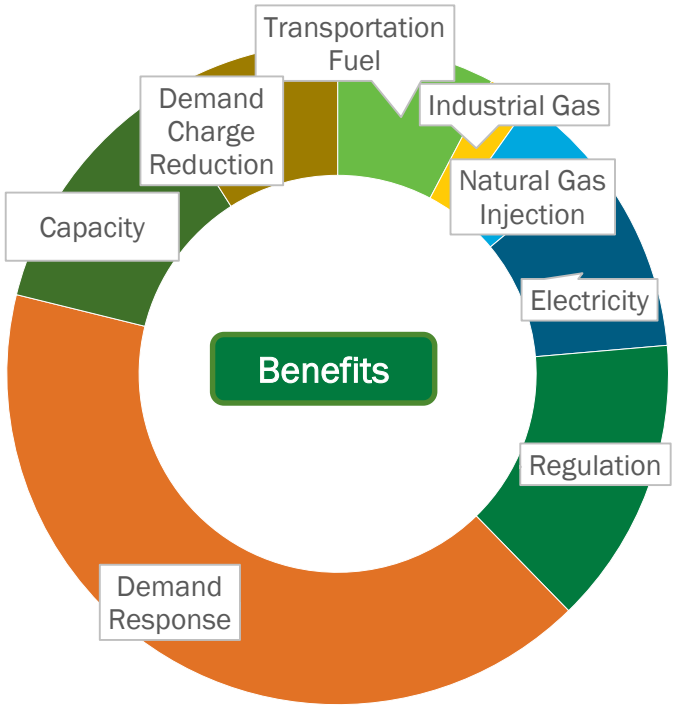
Hydrogen Energy Storage Techno-economic Assessment Model

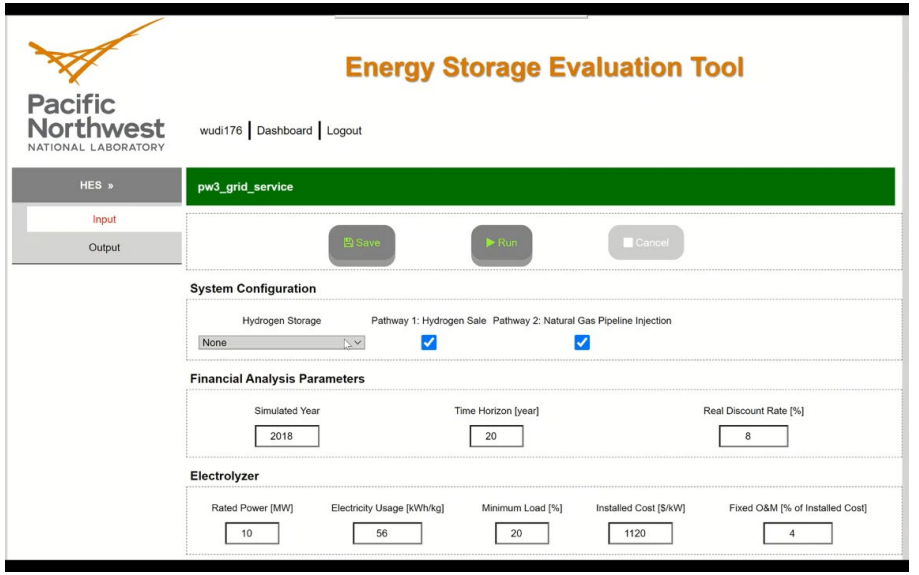
New tool for hydrogen energy storage valuation toward multiple energy delivery pathways and grid services

Key Inputs: Price of electricity and various grid services, price point of regional demands for hydrogen

Key Outputs: Financial analysis of costs and net profit over life of system, from all revenue streams considered







HESET models the operation of a user-defined energy storage system, to allow users to optimize component size and revenue streams

Co-funded with DOE Office of Electricity | Now in beta testing at: https://eset.pnnl.gov

Hybridized Nuclear Plants Producing Hydrogen

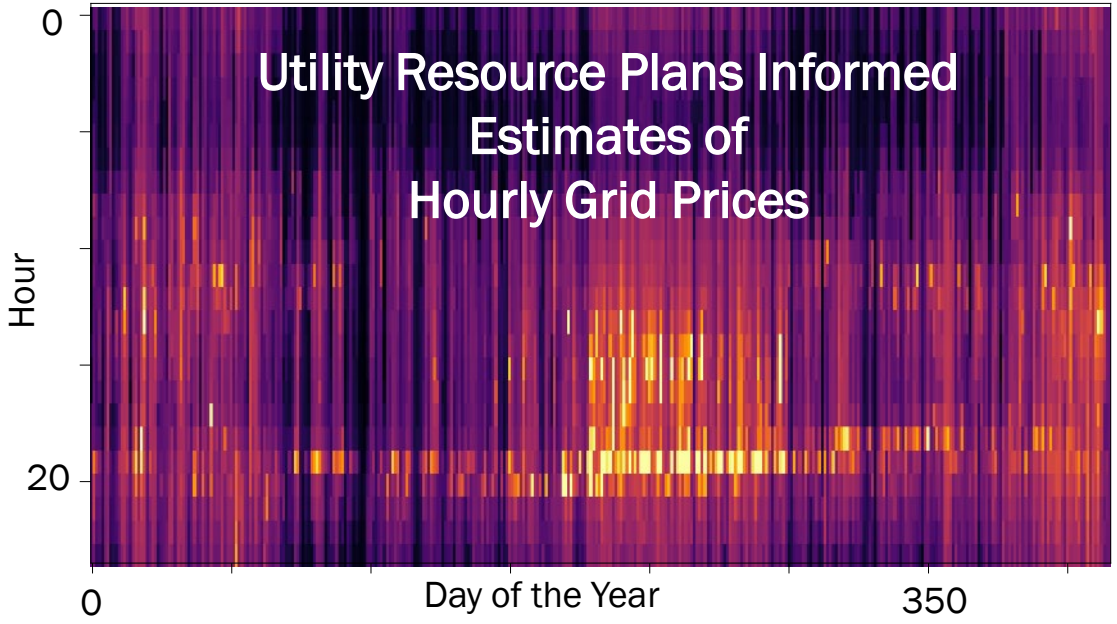
Used state-of-the art analysis tools to estimate the value of integrating hydrogen production at two Xcel Energy nuclear power plants

- Estimated grid prices with and without hydrogen integration
- Optimized operating strategy for hybrid energy system
- Assessed size of regional hydrogen market

Next Steps

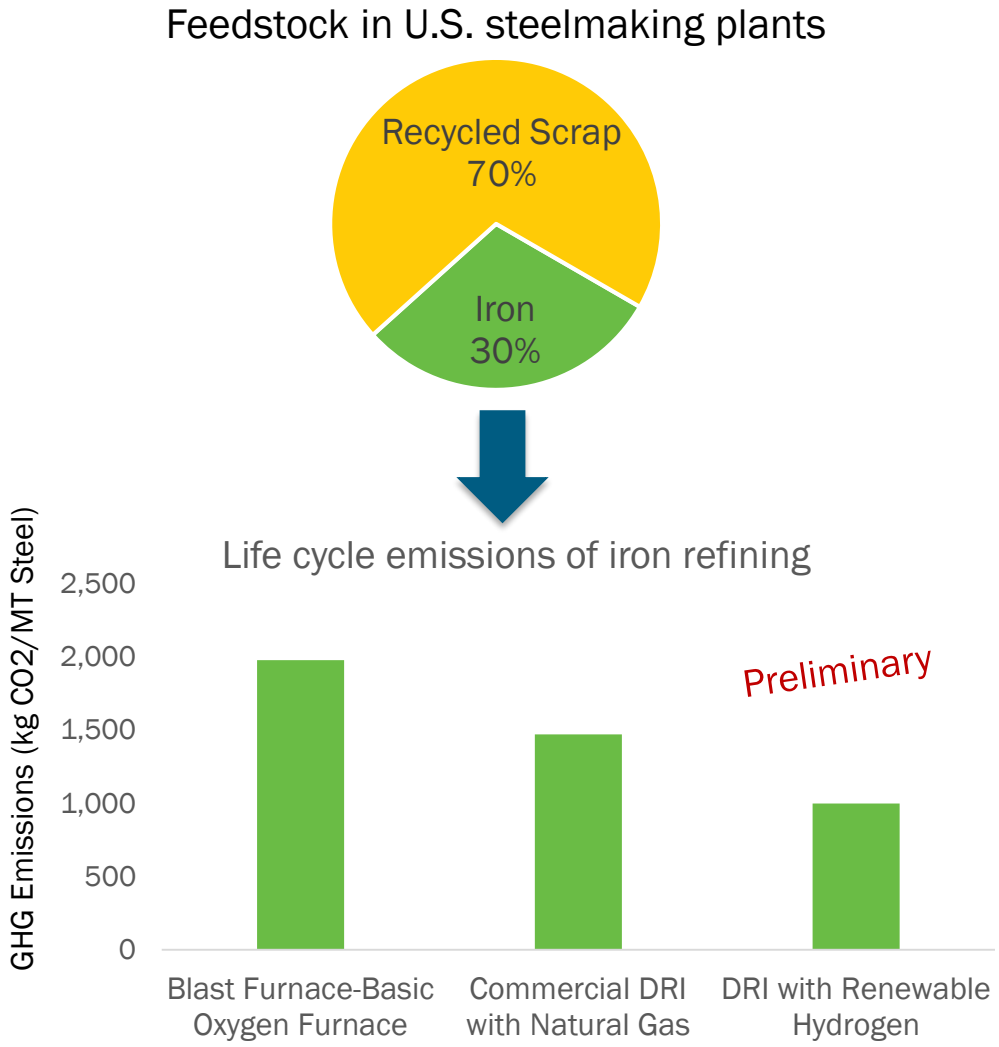
- Identifying parameters necessary for profitability, including:
  - Technology cost
  - Hydrogen market size
  - Decarbonization drivers

Collaboration with Office of Nuclear Energy |SA175

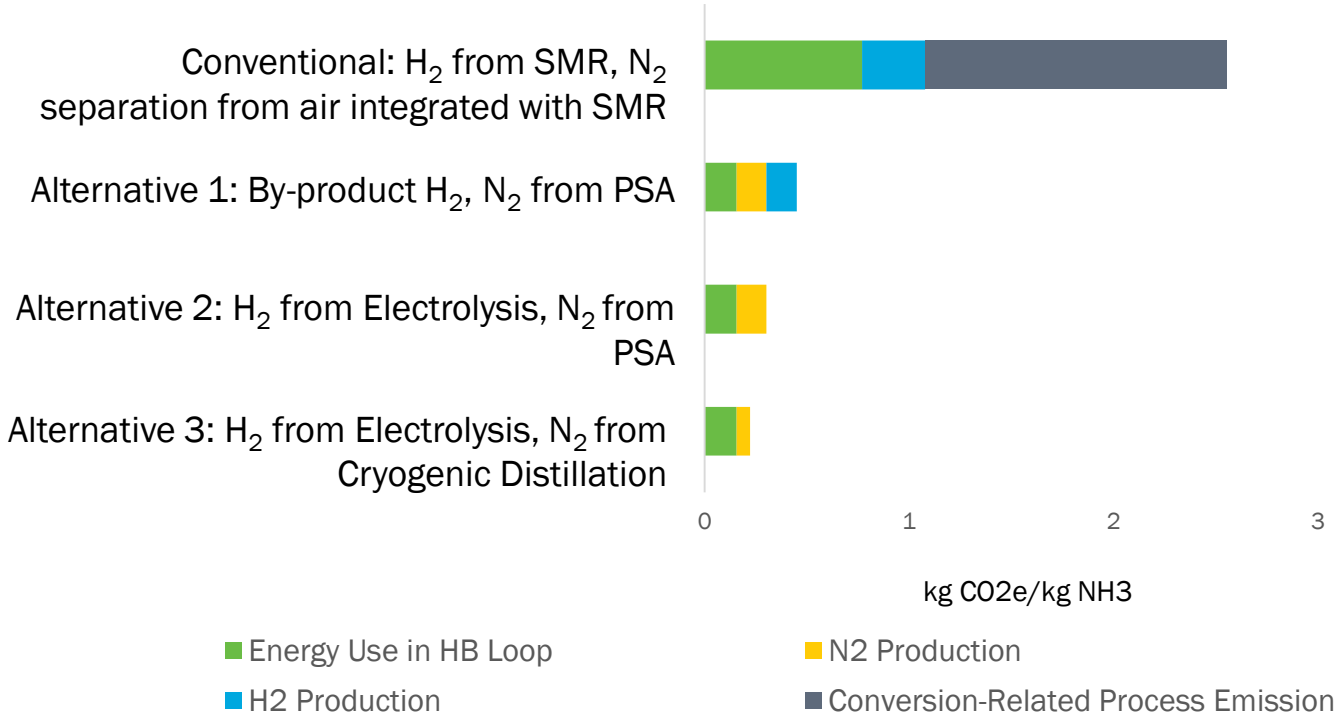


Industrial Applications for Hydrogen: Life Cycle Analysis

Hydrogen use in iron refining can reduce life cycle emissions by 30-50%[1]



Clean hydrogen use in ammonia production can reduce life cycle emissions by over 80%[2]



Steam methane reforming is largest contributor to life cycle emissions of conventional ammonia production

1. *In collaboration with DOE- Strategic Analysis and Advanced Manufacturing Office. For more information, please see SA 174*

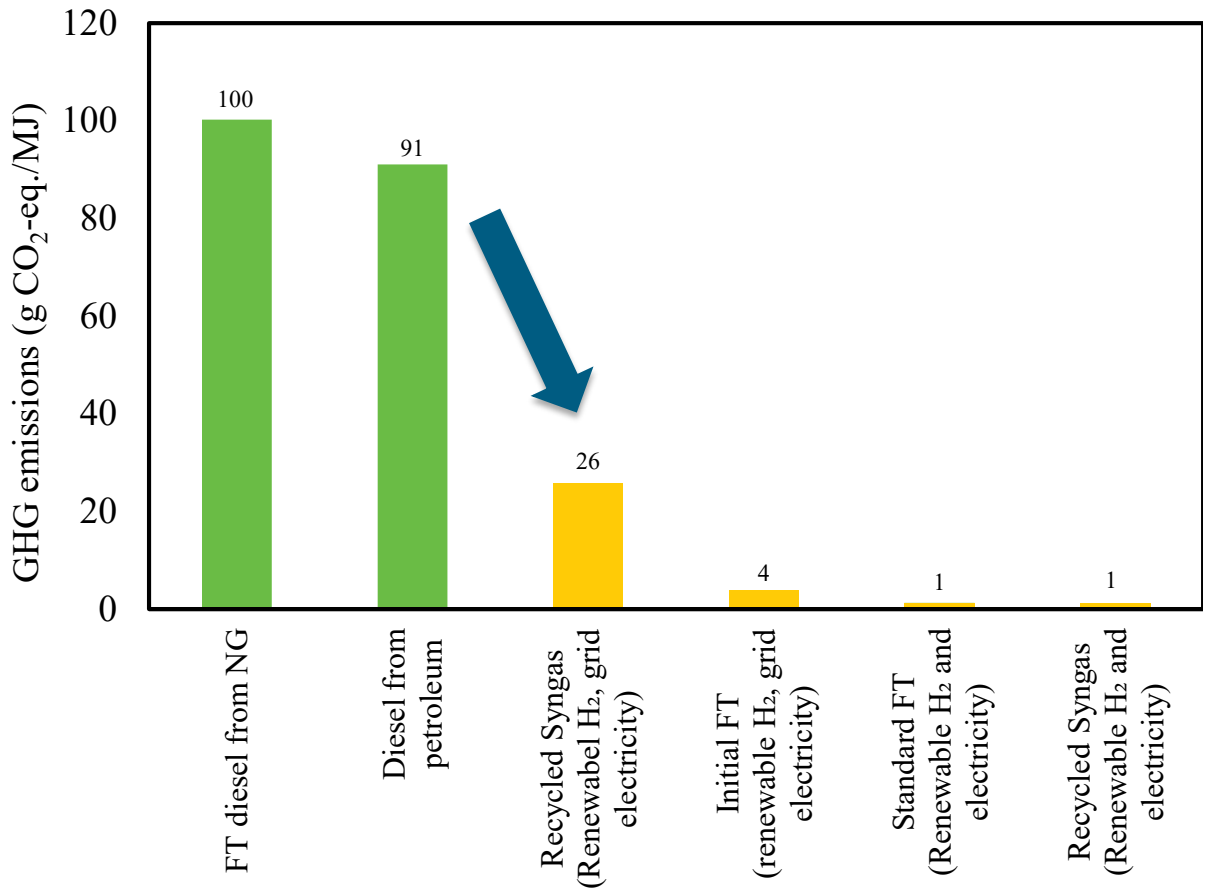
2. *Source: https://pubs.rsc.org/en/content/articlelanding/2020/gc/d0gc02301a#!divAbstract*

Analysis funded by DOE Advanced Research Projects Agency- Energy

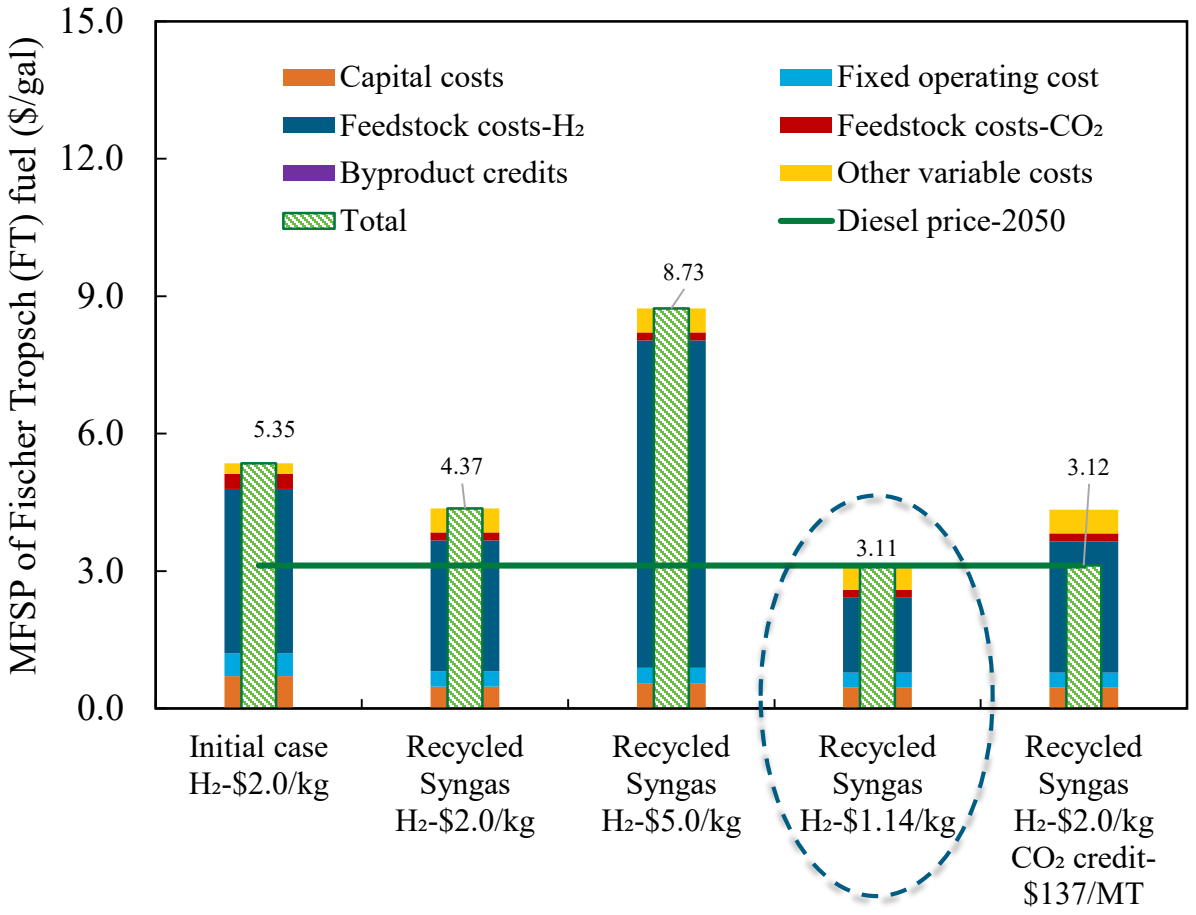
Industrial Applications for Hydrogen: Synthetic Fuels

Argonne NATIONAL LABORATORY

Fuels synthesized from hydrogen and concentrated CO_2 can achieve >70% lower emissions than conventional diesel



Hydrogen cost of ~$1/kg needed to enable competitive production



Conducted in coordination with DOE-EERE Bioenergy Technologies Office, in support of Net Zero Carbon Tech Team

Fore more information, please see SA 174

Medium- and Heavy-duty Trucks Market Segmentation

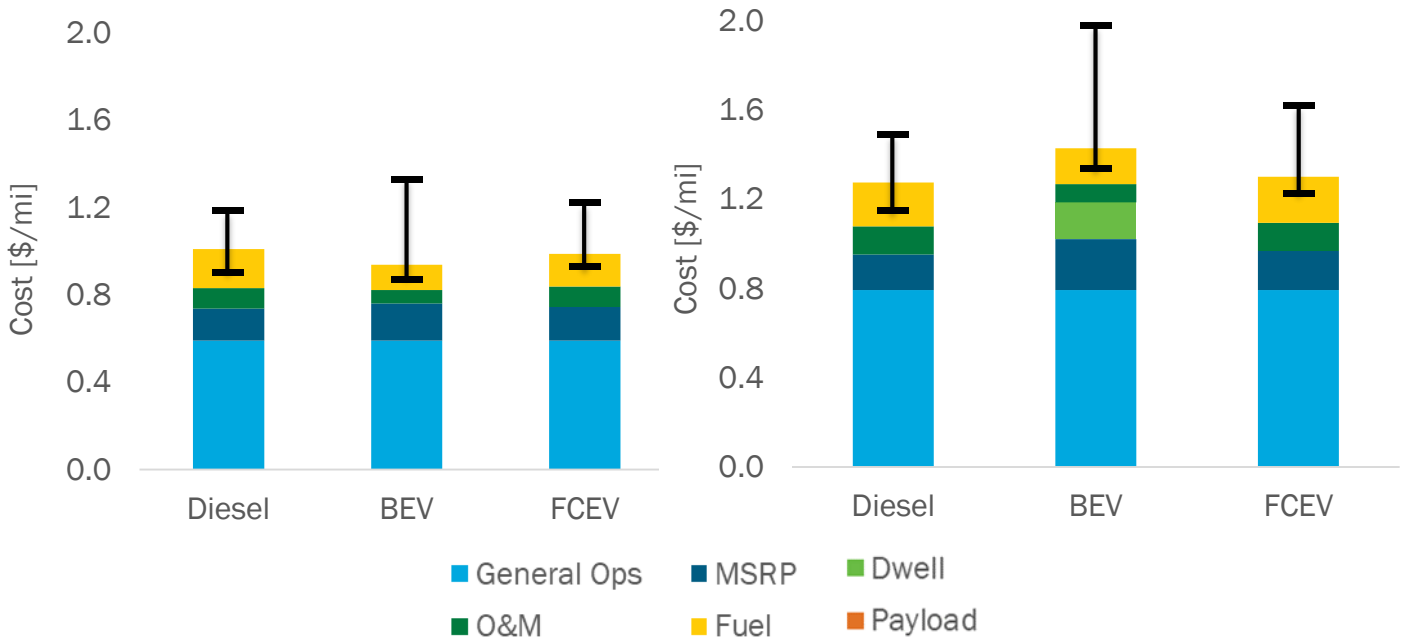
Total Cost of Ownership (TCO) of Class 4 and 8 fuel cell trucks achieves parity with diesel if HFTO targets are met

Class 8 (300-mile)

- Single-shift operations
- 60,000 mi/yr
- 16.7 years life

Class 8 (500-mile)

- Multi-shift operations
- 150,000 mi/yr
- 6.7 years life

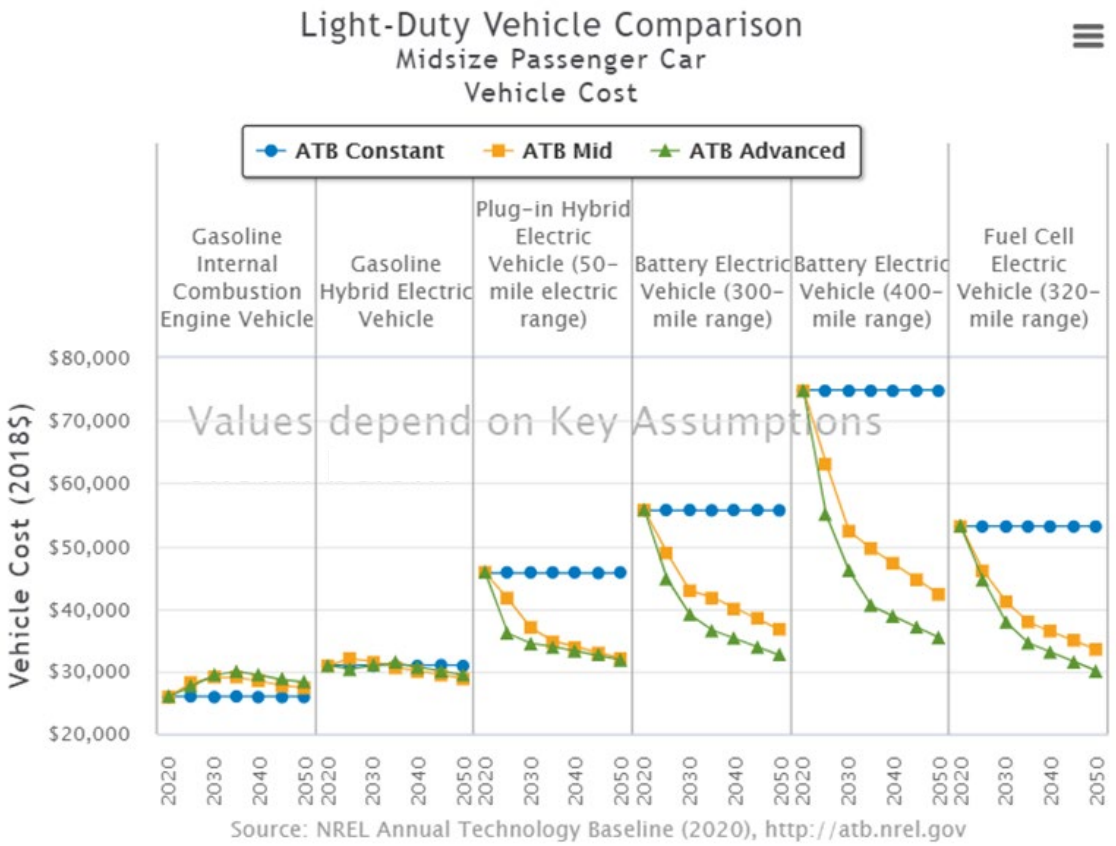


Error bars reflect uncertainty in fuel prices and O&M costs
For more information, please, see SA 169
Project completed in conjunction with DOE Vehicle Technologies Office
Report to be published in 2021

- **Key assumptions:**
  - Real-world drive cycles
  - Estimates of cost based on current technology and R&D success
- **Impact of payload and time constraints on TCO evaluated**
  - FCEVs are more attractive in scenarios with time constraints (e.g., multi-shift) or longer ranges
  - Vehicle classes with higher fuel economy had narrower gap in TCO between fuel cells and diesel
- **Range of TCO values reflects uncertainty in fuel prices and O&M cost**
  - Cost of fuel is largest driver of TCO
- **Future work: Analysis and data gathering to identify size of MDHD truck market segments and vocations and assess TCO in additional classes**

Annual Technology Baseline: Transportation

User-friendly, online platform hosting data regarding cost and emissions of vehicles, based on annual DOE analysis



Available at:
https://atb.nrel.gov/transportation/2020/about.html

- **Website launched in 2020 to share cost and emissions data regarding 10 different light-duty vehicle powertrains, under user-specified scenarios of technology progress and scale**
  - Scenarios based on DOE estimates of technology status and RD&D targets
  - Cost and emissions estimates based on modeling within Autonomie and GREET
- **2021 update will include expansion to medium- and heavy-duty vehicles and aviation**
- **Extensive peer review with experts across industry, academia, and government**

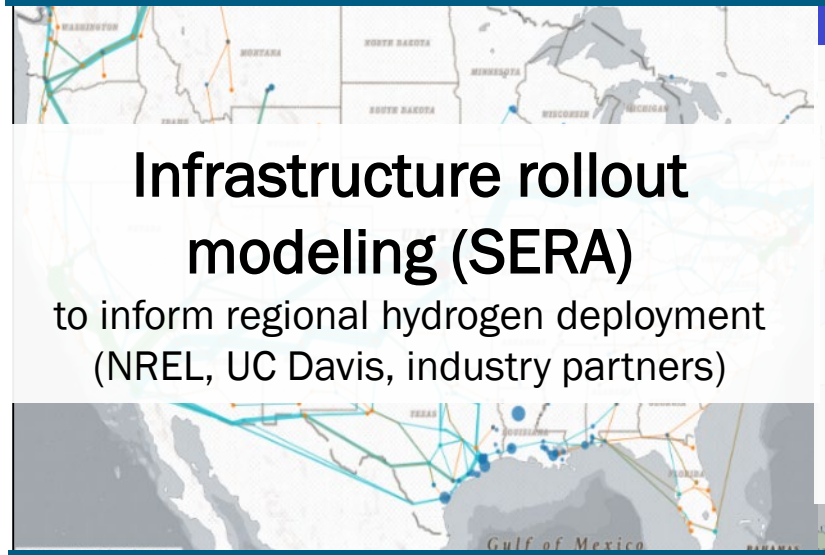
For more information, please see SA176

Project launch and annual updates led by DOE-Strategic Analysis, in collaboration with all three Transportation Offices (HFTO, VTO, BETO)

Collaborations Across Industry, Academia, and Government

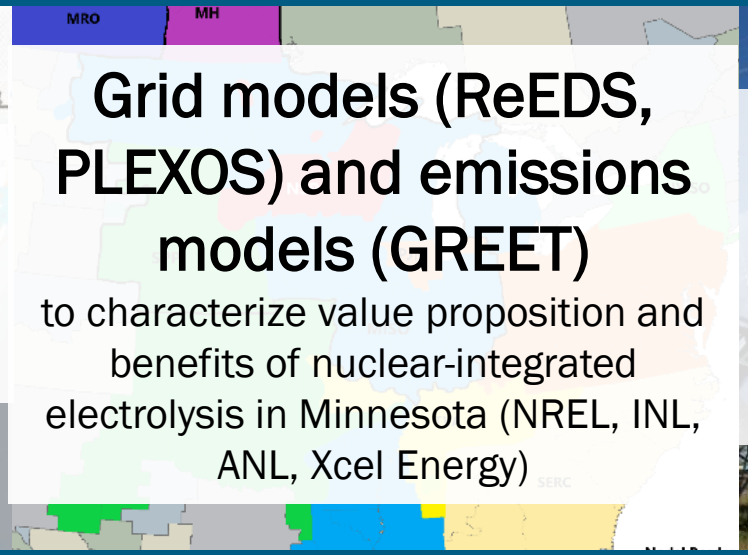
Tools developed through Systems Analysis projects inform real-world deployments and demonstrations

Examples



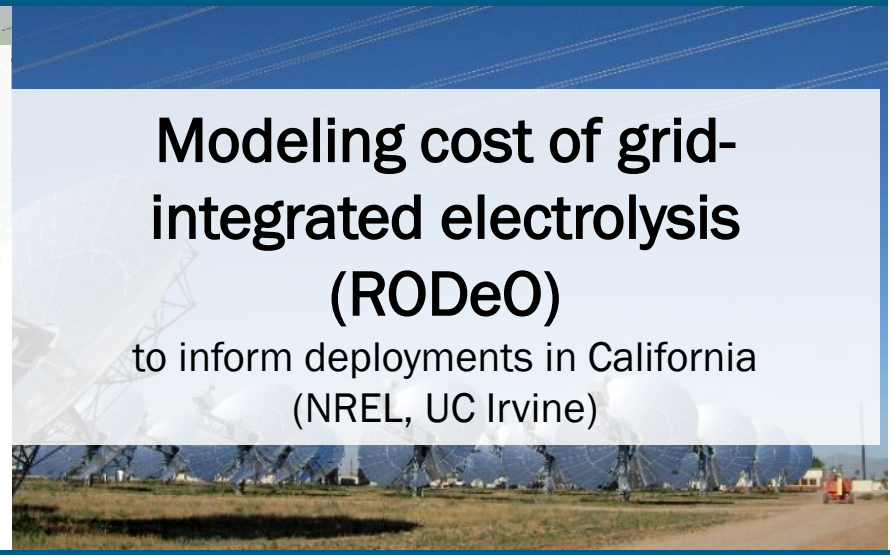
Infrastructure rollout modeling (SERA)

to inform regional hydrogen deployment (NREL, UC Davis, industry partners)



Grid models (ReEDS, PLEXOS) and emissions models (GREET)

to characterize value proposition and benefits of nuclear-integrated electrolysis in Minnesota (NREL, INL, ANL, Xcel Energy)

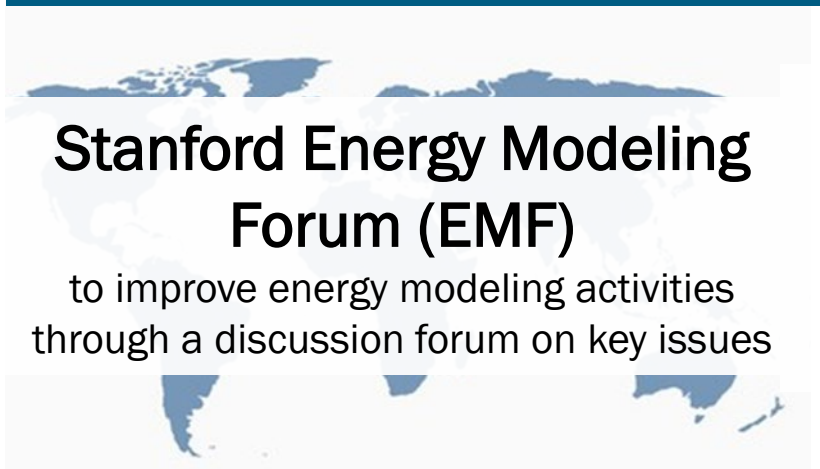


Modeling cost of grid-integrated electrolysis (RODeO)

to inform deployments in California (NREL, UC Irvine)

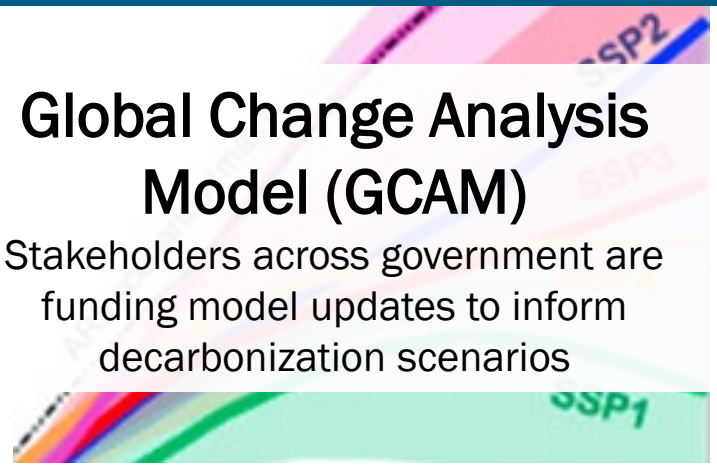
Systems Analysis projects are coordinated and informed by the stakeholder community

Examples



Stanford Energy Modeling Forum (EMF)

to improve energy modeling activities through a discussion forum on key issues



Global Change Analysis Model (GCAM)

Stakeholders across government are funding model updates to inform decarbonization scenarios

IPHE H_2 Production Task Force

Representatives from 13 countries and the European Commission developing standardized approaches to life cycle analysis to inform global trade

Systems Analysis Collaboration Network

Fostering technical excellence, economic growth and environmental justice

5 National Labs

2 Universities

Cross-Office work with 9 DOE Offices
(e.g., joint and coordinated analyses)

DOE Cross-Cutting Initiatives in Energy Storage and Decarbonization

Cross-Agency Collaborations
(e.g., U.S. EPA)

Regional and International Collaborations
(e.g., joint and coordinated U.S. and global analyses)

CRADAs to enable collaborations with industry

Engagement with public-private partnerships to inform analysis (e.g. 21CTP)

Systems Analysis Highlights Summary

FY2019	FY2020	FY2021	FY2022
Cost analysis of hydrogen fueling given advanced onboard hydrogen storage, in support of Hydrogen Interface task Force	*Released Resource Report characterizing supply potential of hydrogen in the US*	*Completed cross-office analysis of the total cost of ownership of fuel cells in MDHD vehicles, with varying ranges and operating conditions*	*Launch of new analysis to assess environmental justice impacts of hydrogen and fuel cells, such as job creation*
Launch of joint analysis project with NE to assess value proposition of hybrid energy systems integrating electrolysis with nuclear power plants	*Released Hydrogen Demand report characterizing willingness to pay for hydrogen in 9 demand sectors markets*	*Supporting development of internationally agreed upon methods of LCA, within IPHE's Hydrogen Production Analysis Task Force*	*Launch of new analysis to assess role of hydrogen energy storage in near-term grid scenarios*
Launch of cross-office modeling of the costs of long duration energy storage	*Released H2@Scale report characterizing technical and economic potential of hydrogen supply and demand*	*Launch of cross-office updates to Global Change Assessment Model to inform decarbonization strategy*	*Completion of analysis addressing role of hydrogen and fuel cells in autonomous fleets*
Completion of initial analysis assessing cost of fuel cells in medium- and heavy-duty transportation	*Launch of quadrennial, cross-office cradle-to-grave analysis of transportation technologies*	*Release of Patents and Commercial Pathways Report*	*Completion of cross-office analysis on market adoption of transportation technologies to support decarbonization goals*

The Systems Analysis Dream Team!

Neha Rustagi
Systems Analysis Lead
neha.rustagi@ee.doe.gov

Marc Melaina
HFTO Senior Analyst
marc.melaina@ee.doe.gov

Mariya Koleva
Analyst on Detail to HFTO
mariya.koleva@ee.doe.gov

More information on ongoing projects will be presented in the Systems Analysis track on June 8

Thank you!