U.S. DEPARTMENT OF
ENERGY

Office of
ENERGY EFFICIENCY &
RENEWABLE ENERGY

Systems Analysis Overview

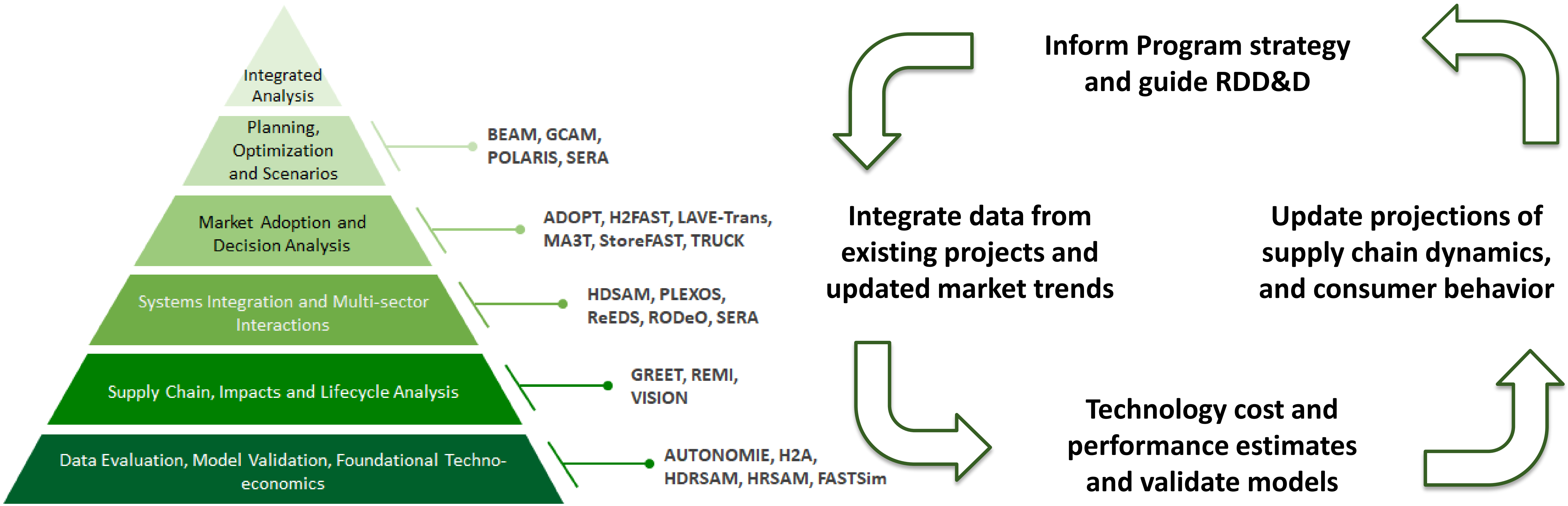
Neha Rustagi, HFTO - Systems Analysis Lead

2022 Annual Merit Review and Peer Evaluation Meeting

June 6, 2022 – Washington, D.C.

Systems Analysis Overview

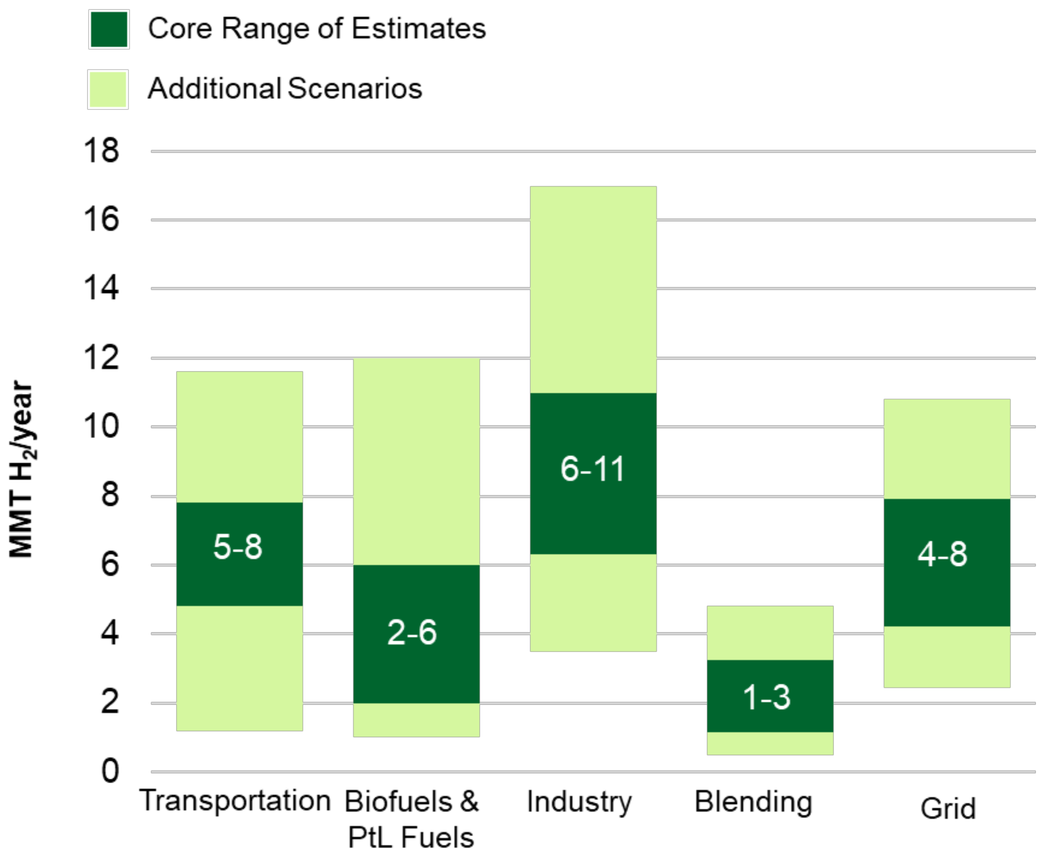
Systems Analysis conducts cross-cutting analyses in collaboration with other HFTO sub-programs, DOE Offices, and external stakeholders to inform RDD&D priorities



Systems Analysis Focus Areas

Analyses in FY22 are identifying priority sectors for hydrogen deployments

Potential Hydrogen Demands in 2050



Source: Draft DOE National Clean Hydrogen Strategy and Roadmap

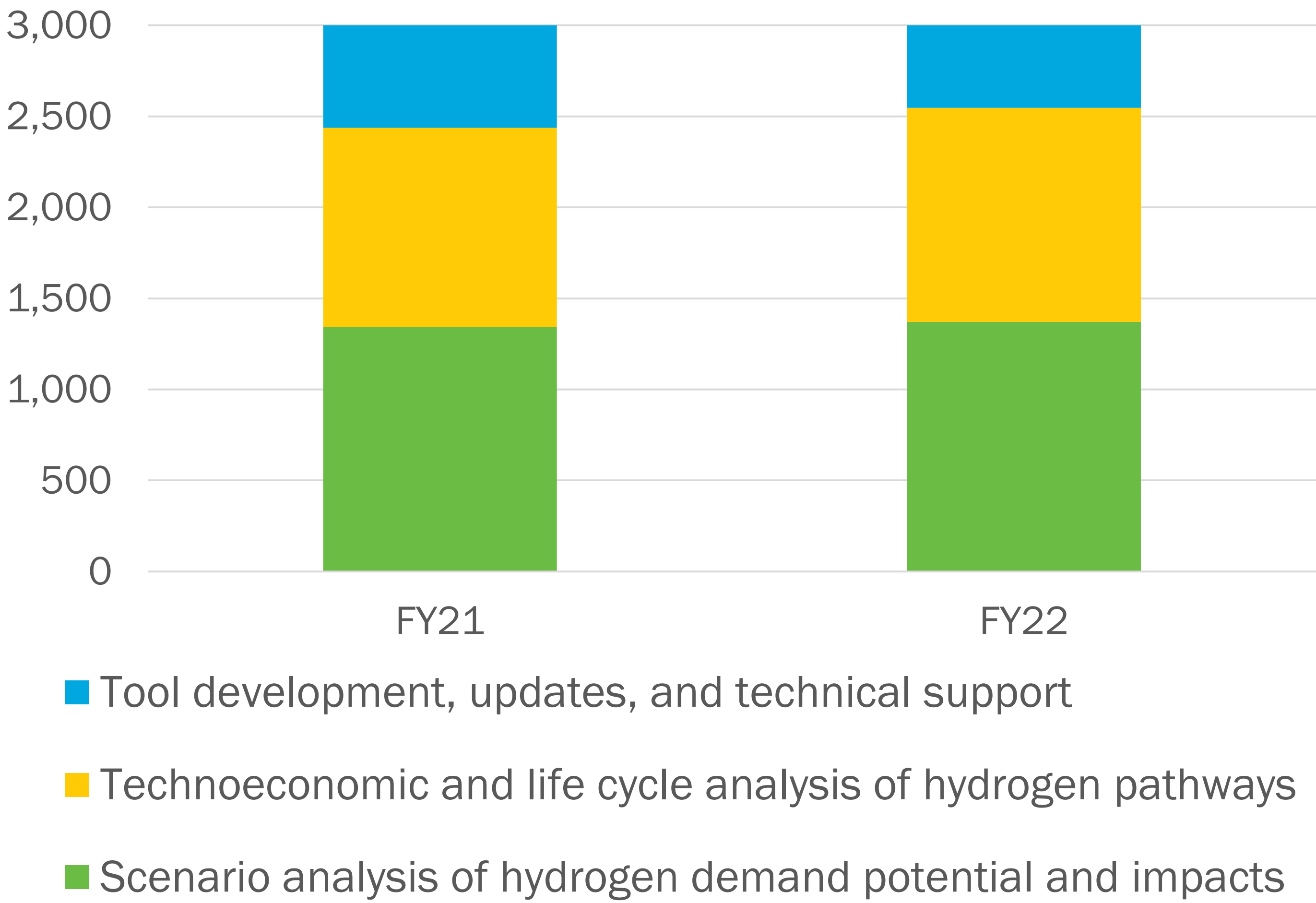
Recent and ongoing projects are focused on:

- Analysis of cost and emissions benefits of hydrogen relative to other decarbonization solutions, in collaboration with offices across DOE
  - Analyses informed DOE National Clean Hydrogen Strategy and Roadmap
- Development of user-friendly analysis tools to characterize cost and emissions of deployments
- Coordination and collaboration internationally to harmonize methods of life cycle analysis, and identify priority knowledge gaps

Systems Analysis Budget

FY21 Appropriations $3 million

FY22 Appropriations $3 million



Program Direction

Scenario Analysis of H_2 Demand & Impacts

- H_2 demand scenarios in strategic sectors to enable net zero by 2050
- Cross-EERE updates to market and sustainability models
- Cross-office modeling to estimate role of H_2 in trucking sector

Technoeconomic & Life Cycle Analysis

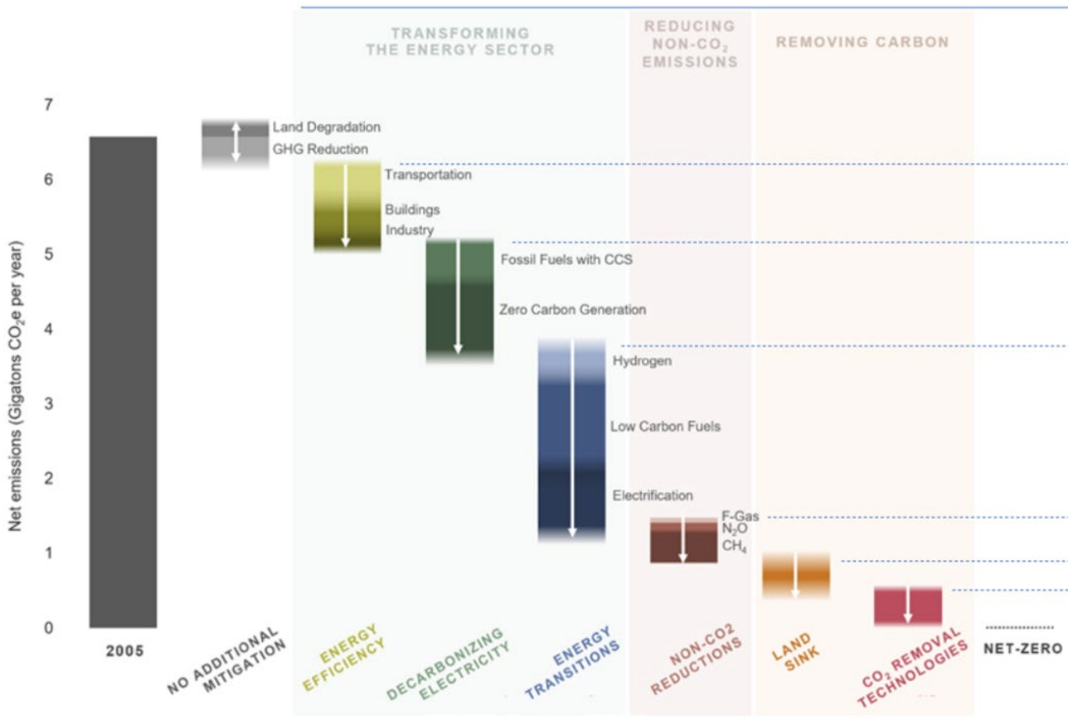
- Assessment of clean H_2 production pathways
- Harmonization with international community
- Climate impacts of H_2

Tool Development, Updates, & Support

- Development of user-friendly H2A and GREET tools for cost and emissions analysis
- Globalization of GREET LCA platform

Decarbonization Potential of Hydrogen Across Sectors

REPRESENTATIVE PATHWAY TO 2050 NET-ZERO



Example pathways to net zero in 2050, within the White House Long Term Strategy.[1] Inclusion of H_2 pathways in sustainability tools, such as GCAM and NEMS, can identify priority markets for deployment.

1. https://www.whitehouse.gov/wp-content/uploads/2021/10/US-Long-Term-Strategy.pdf
2. In collaboration with EERE Offices and DOE Office of Fossil Energy and Carbon Management

- **Cross-EERE studies and roadmaps** are identifying **optimal pathways to decarbonize industry, transportation, and the grid** through clean fuels and electrification. Focus areas include:
  - Transition pathways
  - Cost of decarbonization ($/$CO_2$e avoided)
  - Regional potential of biofuel production, given hydrogen and biomass resources
- **Updates to market and sustainability models**, such as PNNL's **Global Change Analysis Model** (**GCAM)** and the **National Energy Modeling System** will inform decarbonization scenarios[2]
  - Modeling structures updated to represent **H_2 production from renewables, nuclear, and fossil resources;** and **multiple end-uses of H_2** in industry, power buildings, and transportation
  - **Underlying cost and emission estimates**, to be updated and incorporated by end of FY22

Life Cycle Analysis of Hydrogen Applications

Life cycle analyses of hydrogen supply chain and incumbent fuels inform estimates of decarbonization potential

Recent analyses have identified that use of clean H_2 can enable:

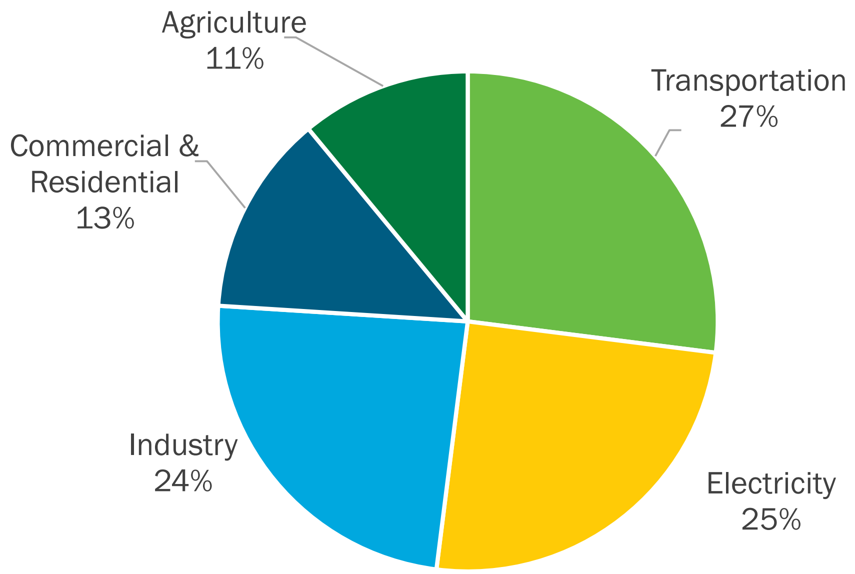
- ~12% lower GHGs from petroleum refining[1]
- 40-70% lower GHGs for iron refining[2]
- Up to 90% lower GHGs from ammonia and methanol[3,4]
- Up to 90% lower GHGs from trucks[5]

Future analysis will develop estimates for:

- Hydrogen blending
- Energy storage
- Additional emerging applications, such as plastics and specialty chemicals

Use of clean H_2 can reduce emissions in numerous strategic applications with limited options for decarbonization

U.S. GHG Emissions by Sector in 2020[6]

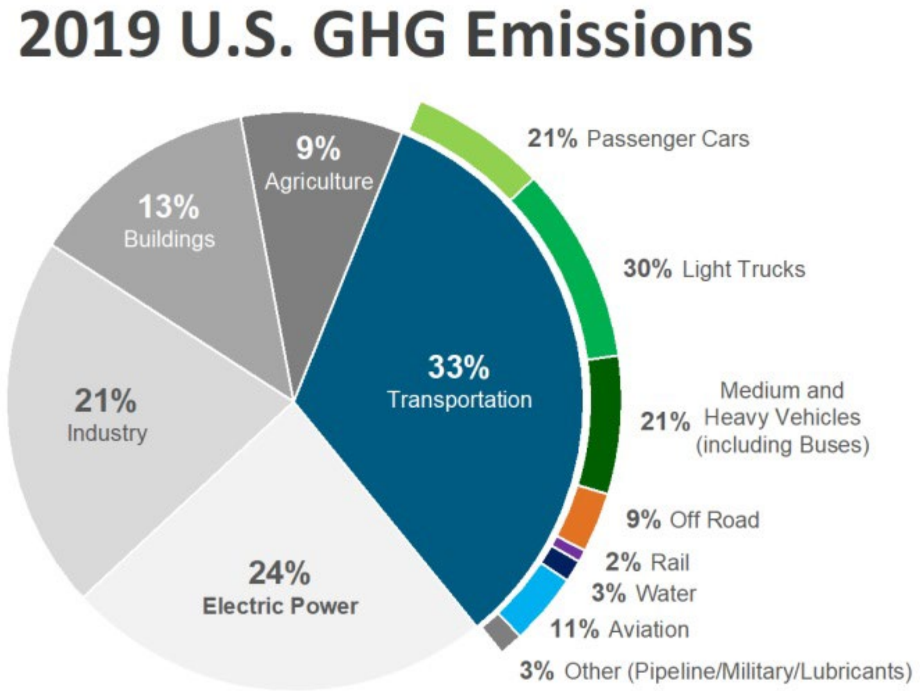


Sources:

1. ANL 2021, Preliminary Analysis, Under Review
2. ANL, 2021, Preliminary Analysis, Under Review
3. ANL, 2020, https://pubs.rsc.org/en/content/articlelanding/2020/gc/d0gc02301a
4. ANL, 2021, https://pubs.acs.org/doi/10.1021/acs.est.0c08237
5. GREET, Argonne GREET Model (anl.gov)
6. U.S. EPA 2020

Cross-Office Modeling of Transportation

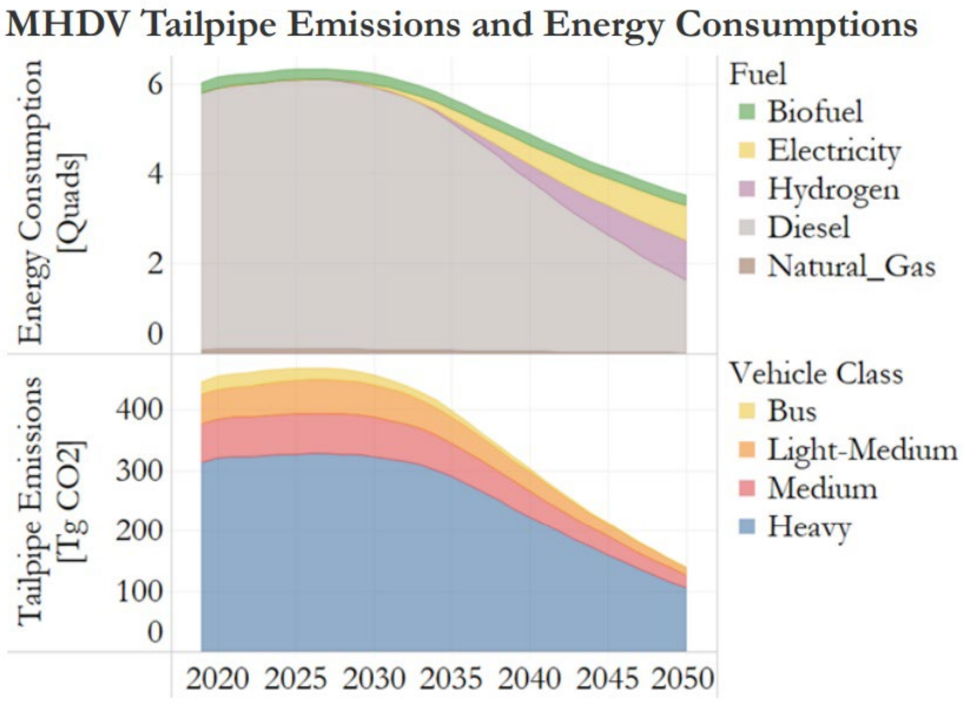
Medium and heavy vehicles account for 21% of emissions from transportation[1,3]



Previous TCO analysis shows the core value proposition of hydrogen and fuel cells in fleets with long range, heavy-duty class vehicles and/or multi-shift operation.[2]

Sources:
1. U.S. EPA, 2019
2. https://www.nrel.gov/docs/fy21osti/71796.pdf

Vehicle choice modeling estimated that 10-14% of trucks in 2050 could use hydrogen if DOE targets are met[3]



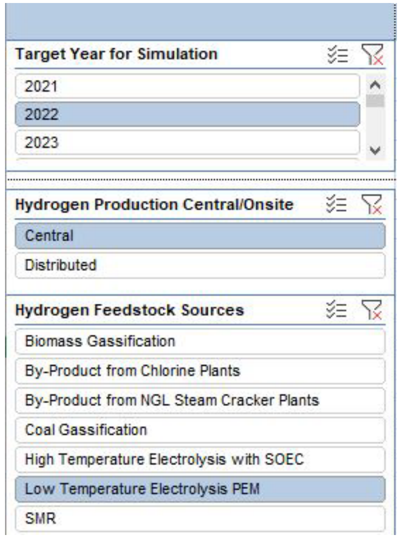
Additional ongoing analyses are evaluating cradle-to-grave emissions of MHDVs, in collaboration with U.S. DRIVE Integrated Systems Analysis Tech Team, and impact of autonomous capabilities on cost and emissions of fuel cell fleets for parcel delivery

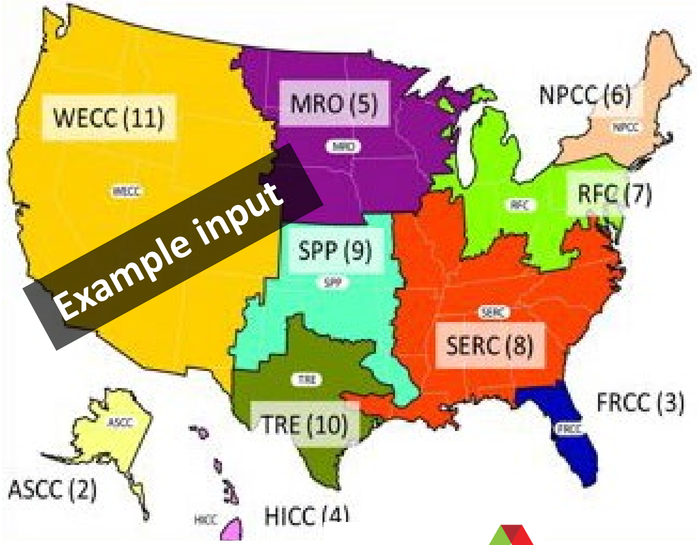
Source:
3. https://www.nrel.gov/docs/fy22osti/82081.pdf

User-friendly Analysis Tools Under Development

Greenhouse gases, Regulated Emissions, and Energy use in Technologies (GREET) model being updated to represent global pathways and simulate user-defined deployments

- User-friendly interface to specify assumptions for energy sources, technology performance, and more
- Pathways representative of other countries being incorporated in coordination with International Energy Agency

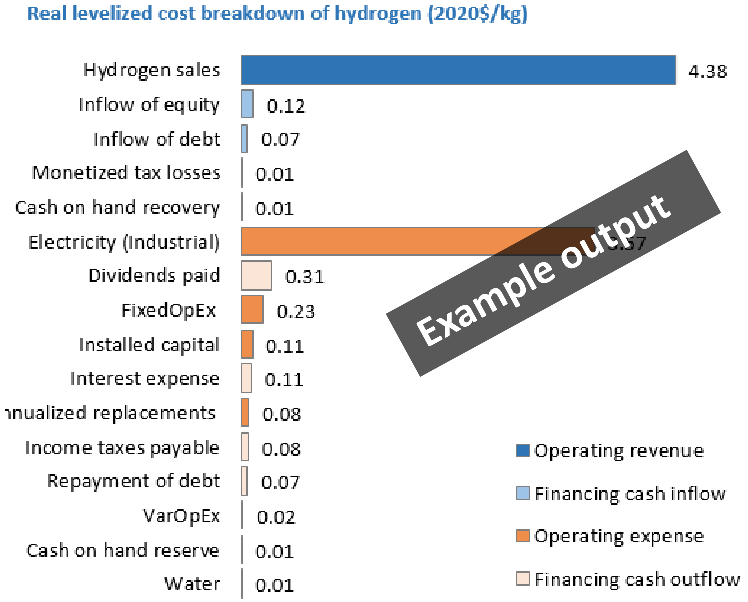




Argonne NATIONAL LABORATORY

H2A Lite will allow for levelized cost analysis of hydrogen production across 6 different pathways, based on process modeling within detailed H2A Case studies

- User-specified energy and capital costs, and technology performance metrics
- Complete discounted cash flow analysis results
- Default values based off AEO and regional energy sources



NREL NATIONAL RENEWABLE ENERGY LABORATORY

Hydrogen Business Case Prize

Competition to develop user-friendly computational tools that characterize regional value propositions for hydrogen in multiple applications, including opportunities to co-locate supply and demand

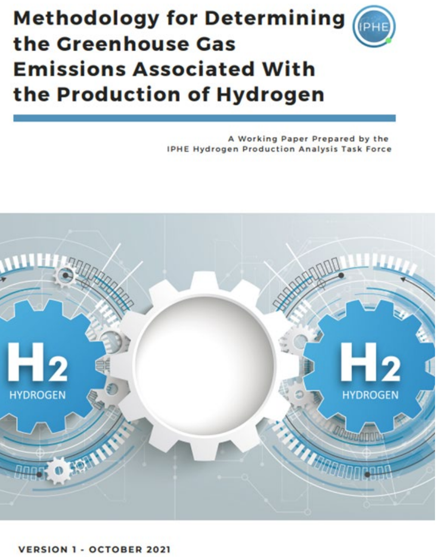
- ***1st place:*** Super Hydrogen Family – University of Southern California, University of South Florida, University of Central Florida
- ***2nd place:*** Bend Hydrogen – Oregon State University
- ***3rd place:*** Pure Hydrogen – University of California, Berkeley
- ***4th place:*** H24SCR – University of Oklahoma

Presenting on June 8!

- Prizes of $20-$50K for four winning teams, and paid internships for teams in first and second place
- Nine mentors across industry and national laboratories guided teams for six months
- Each team developed Excel-based modeling tools and a final report describing a regional business case for hydrogen

Key Collaborations to Inform Future Hydrogen Markets

Mutually Agreed Upon Methods of Life Cycle Analysis: International Partnership for Hydrogen in the Economy Hydrogen Production Analysis Task Force



https://www.iphe.net/iphe-working-paper-methodology-doc-oct-2021

Collaboration across countries within IPHE generated guidance to estimate life cycle emissions associated with electrolysis, SMR, and coal gasification. Guidance on other production pathways (e.g., autothermal reforming, biomass), carriers, and distribution currently underway.

Climate Impacts of Hydrogen

Atmospheric modeling of hydrogen underway at NOAA to understand climate impacts of hydrogen and incorporate into life cycle analyses and integrated assessment modeling. Joint workshop held with European Commission to identify gaps in existing models, and future work being planned to address modeling gaps through experimentation.

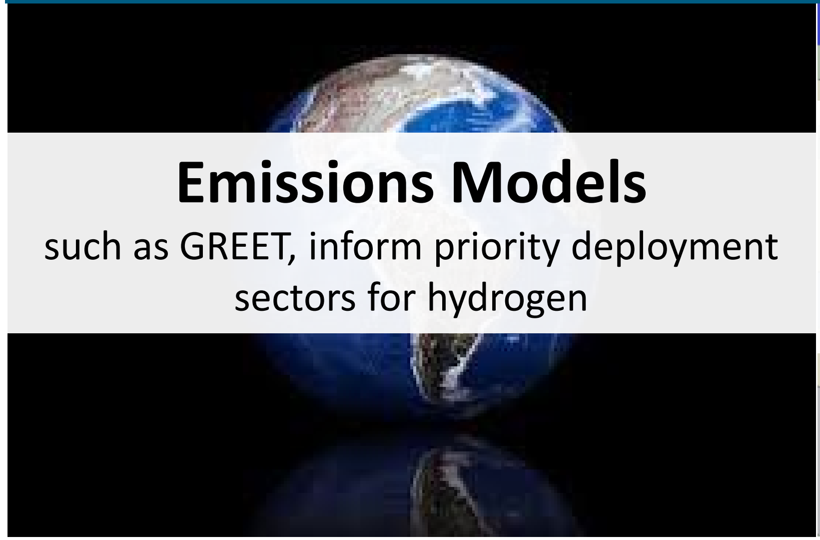
Cross-Office Initiatives

Energy storage analyses being conducted in support of the Long Duration Storage Shot and the Energy Storage Grand Challenge will identify future role of hydrogen in a clean grid, and develop modeling tools characterizing hydrogen integration with baseload nuclear plants

Collaborations Across Industry, Academia, and Government

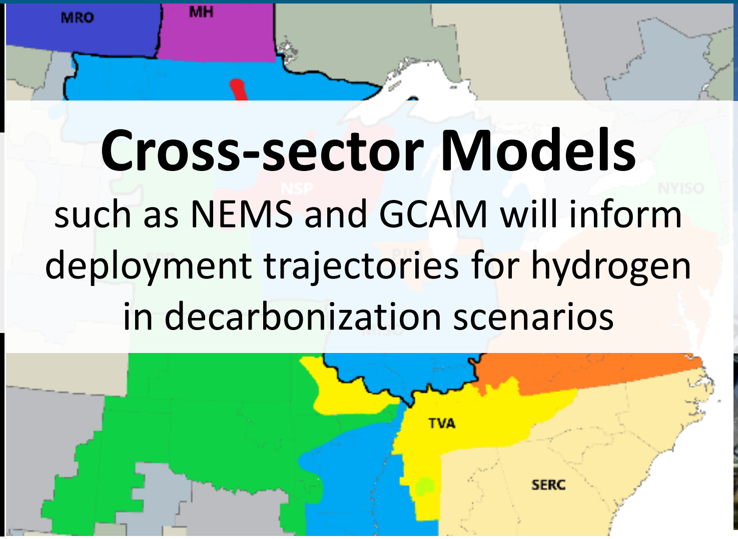
Examples

Tools developed through Systems Analysis projects inform RDD&D strategy



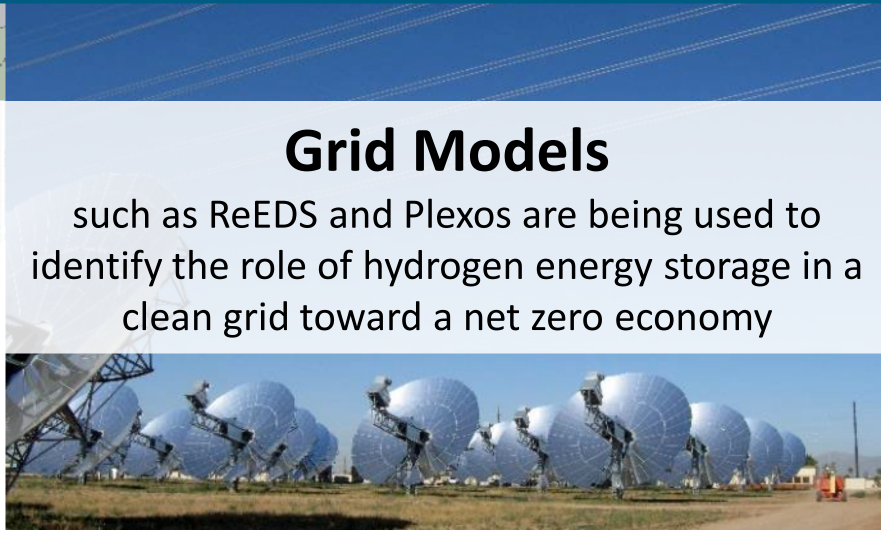
Emissions Models

such as GREET, inform priority deployment sectors for hydrogen



Cross-sector Models

such as NEMS and GCAM will inform deployment trajectories for hydrogen in decarbonization scenarios



Grid Models

such as ReEDS and Plexos are being used to identify the role of hydrogen energy storage in a clean grid toward a net zero economy

Examples

Systems Analysis projects are coordinated and informed by the stakeholder community

RDD&D Roadmaps

are developed through collaboration across DOE, with feedback from external stakeholders

IPHE H_2 Production Task Force

Representatives from 22 countries and the European Commission developing mutually agreed upon approaches to life cycle analysis to inform global trade

Stanford Energy Modeling Forum (EMF)

to improve energy modeling activities through discussions on key issues

Systems Analysis Collaboration Network

Fostering technical excellence, economic growth and environmental justice

5 National Labs

2 Universities

Cross-Office work across EERE, FECM, and NE

DOE Cross-Cutting Initiatives in Energy Storage and Industrial Decarbonization

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

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

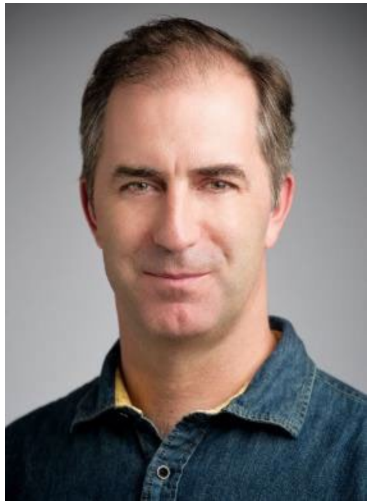
CRADAs to enable collaborations with industry

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

Systems Analysis Highlights Summary

FY2021	FY2022	FY2023
Release of Patents and Commercial Pathways Report	*Completion of analysis to inform National Clean Hydrogen Strategy and Roadmap*	*Completion of updates to GCAM and NEMS market models in coordination with other EERE offices to inform future decarbonization scenarios*
Completed cross-office analysis of the total cost of ownership of fuel cells in MDHD vehicles, with varying ranges and operating conditions	*Completed cross-office vehicle choice modeling to estimate market potential of fuel cell vehicles in trucks*	*Cross-office analysis to quantify hydrogen requirements in liquid fuels, such as biofuels and synfuels*
Supported development of internationally agreed upon methods of LCA, within IPHE's Hydrogen Production Analysis (H2PA) Task Force	*Led development of LCA methods to characterize emissions of hydrogen carriers and conditioning within IPHE H2PA*	*Assessment of sustainability impacts of hydrogen, including water use*
Launch of cross-office updates to Global Change Assessment Model to inform decarbonization strategy	*Launch of user-friendly GREET and H2A tools, and globalization of GREET in collaboration with IEA*	*In collaboration with other agencies, quantify climate impacts of hydrogen and emissions associated with component manufacturing*

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

Tomas Green
Systems Analysis Fellow
Tomas.green@ee.doe.gov

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

Thank you!