Systems Analysis Overview

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2022 Annual Merit Review and Peer Evaluation Meeting

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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.
Analyses in FY22 are identifying priority sectors for hydrogen deployments

Potential Hydrogen Demands in 2050

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

Source: Draft DOE National Clean Hydrogen Strategy and Roadmap
Systems Analysis Budget

**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

**Chart**

- Tool development, updates, and technical support
- Technoeconomic and life cycle analysis of hydrogen pathways
- Scenario analysis of hydrogen demand potential and impacts
Decarbonization Potential of Hydrogen Across Sectors

- 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 ($/CO₂e 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.
  - Modeling structures updated to represent H₂ production from renewables, nuclear, and fossil resources; and multiple end-uses of H₂ in industry, power buildings, and transportation
  - Underlying cost and emission estimates, to be updated and incorporated by end of FY22

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2. In collaboration with EERE Offices and DOE Office of Fossil Energy and Carbon Management
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)
Cross-Office Modeling of Transportation

Medium and heavy vehicles account for 21% of emissions from transportation\(^1,3\)

**2019 U.S. GHG Emissions**

- 21% Industry
- 9% Agriculture
- 24% Electric Power
- 13% Buildings
- 30% Light Trucks
- 33% Transportation
- 21% Passenger Cars
- 9% Off Road
- 2% Rail
- 3% Water
- 11% Aviation
- 3% Other (Pipeline/Military/Lubricants)

Vehicle choice modeling estimated that 10-14% of trucks in 2050 could use hydrogen if DOE targets are met\(^3\)

Sources:
1. U.S. EPA, 2019
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

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
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

➢ 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

Presenting on June 8!
Key Collaborations to Inform Future Hydrogen Markets


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

**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

**Tools developed through Systems Analysis projects inform RDD&D strategy**

**RDD&D Roadmaps**
are developed through collaboration across DOE, with feedback from external stakeholders

**IPHE H₂ 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 projects are coordinated and informed by the stakeholder community**
Systems Analysis Collaboration Network

Fostering technical excellence, economic growth and environmental justice

**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)*

**5 National Labs**

**2 Universities**

**CRADAs to enable collaborations with industry**

**Engagement with public-private partnerships to inform analysis (e.g. 21CTP)**
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<th>FY2021</th>
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<tr>
<td><strong>Release of Patents and Commercial Pathways Report</strong></td>
<td><strong>Completion of analysis to inform National Clean Hydrogen Strategy and Roadmap</strong></td>
<td><strong>Completion of updates to GCAM and NEMS market models in coordination with other EERE offices to inform future decarbonization scenarios</strong></td>
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<td>Completed cross-office analysis of the total cost of ownership of fuel cells in MDHD vehicles, with varying ranges and operating conditions</td>
<td>Completed cross-office vehicle choice modeling to estimate market potential of fuel cell vehicles in trucks</td>
<td>Cross-office analysis to quantify hydrogen requirements in liquid fuels, such as biofuels and synfuels</td>
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<td>Supported development of internationally agreed upon methods of LCA, within IPHE’s Hydrogen Production Analysis (H2PA) Task Force</td>
<td>Led development of LCA methods to characterize emissions of hydrogen carriers and conditioning within IPHE H2PA</td>
<td>Assessment of sustainability impacts of hydrogen, including water use</td>
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<td>Launch of cross-office updates to Global Change Assessment Model to inform decarbonization strategy</td>
<td>Launch of user-friendly GREET and H2A tools, and globalization of GREET in collaboration with IEA</td>
<td>In collaboration with other agencies, quantify climate impacts of hydrogen and emissions associated with component manufacturing</td>
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The Systems Analysis Dream Team!

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