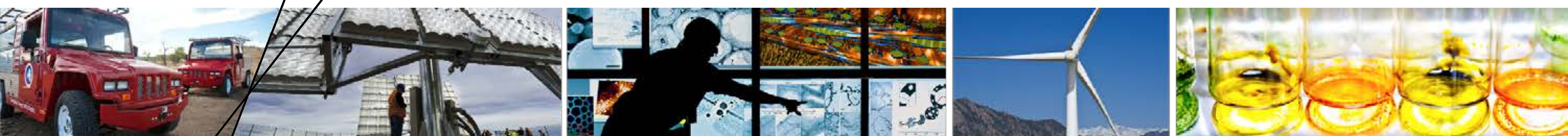
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Sustainability Analysis

Sustainability analysis of hydrogen supply and stationary fuel cell systems using the *Hydrogen Regional Sustainability* (HyReS) framework



Marc Melaina, Brian Bush, Michael Penev, Dana Stright, Darlene Steward, Joshua Sperling.
National Renewable Energy Laboratory

With support from Michael Wang and Amgad Elgowainy
Argonne National Laboratory

DOE Hydrogen and Fuel Cells Program
2016 Annual Merit Review and Peer Evaluation Meeting

June 8, 2016, Washington DC

Project ID
SA059

Overview

Timeline

Start: Sept, 2015
End: Sept, 2018
Percent complete: 15%

Barriers

4.5 A. Future Market Behavior
- Consumer preferences for green hydrogen

4.5 B. Stove-piped/Siloed Analytical Capability
- Integration of metrics from internal (DOE) and external models

4.5 D. Insufficient Suite of Models and Tools
- Lacking more complete analytics across all aspects of sustainability

Budget

Total project funding: $600k
- FY15: $200k
- FY16: $200k
- FY17: $200k

Partners

- **Argonne National Laboratory (GREET)**
- **Project Steering Team**
  - Institute for Sustainable Infrastructure (ISI)
  - Louis Berger
  - Toyota Motor Corporation

Relevance (1)
FCTO Systems Analysis Framework

- Expansion of existing systems analysis models that address costs and environmental impacts
- Additional sustainability metrics and a general regionalization of all inputs and results, given available data.

- Sustainability science and green business communities
- Other frameworks

- Fuel Cell Technologies Office
- Sustainable energy analysis community

Analysis Framework
- Cost estimation
- Supply chain efficiencies
- Energy resource and water utilization
- GHG and criteria emissions

Models & Tools
- H2A production and delivery models
- GREET
- H2FAST
- SERA

Studies & Analysis
- Sustainability metrics
- Framework implementation

Outputs & Deliverables
- Reports
- Workshops
- Public Framework

- FCTO and VTO Program Targets
- BETO Sustainability Framework

<u>Acronyms</u>

BETO: Bioenergy Technologies Office
GHG: Greenhouse gas
GREET: Greenhouse Gasses, Regulated Emissions, and Energy Use in Transportation model
H2FAST: Hydrogen Financial Analysis Scenario Tool
SERA: Scenario Evaluation and Regionalization Analysis models

Relevance (2)

Scope of Sustainable Development

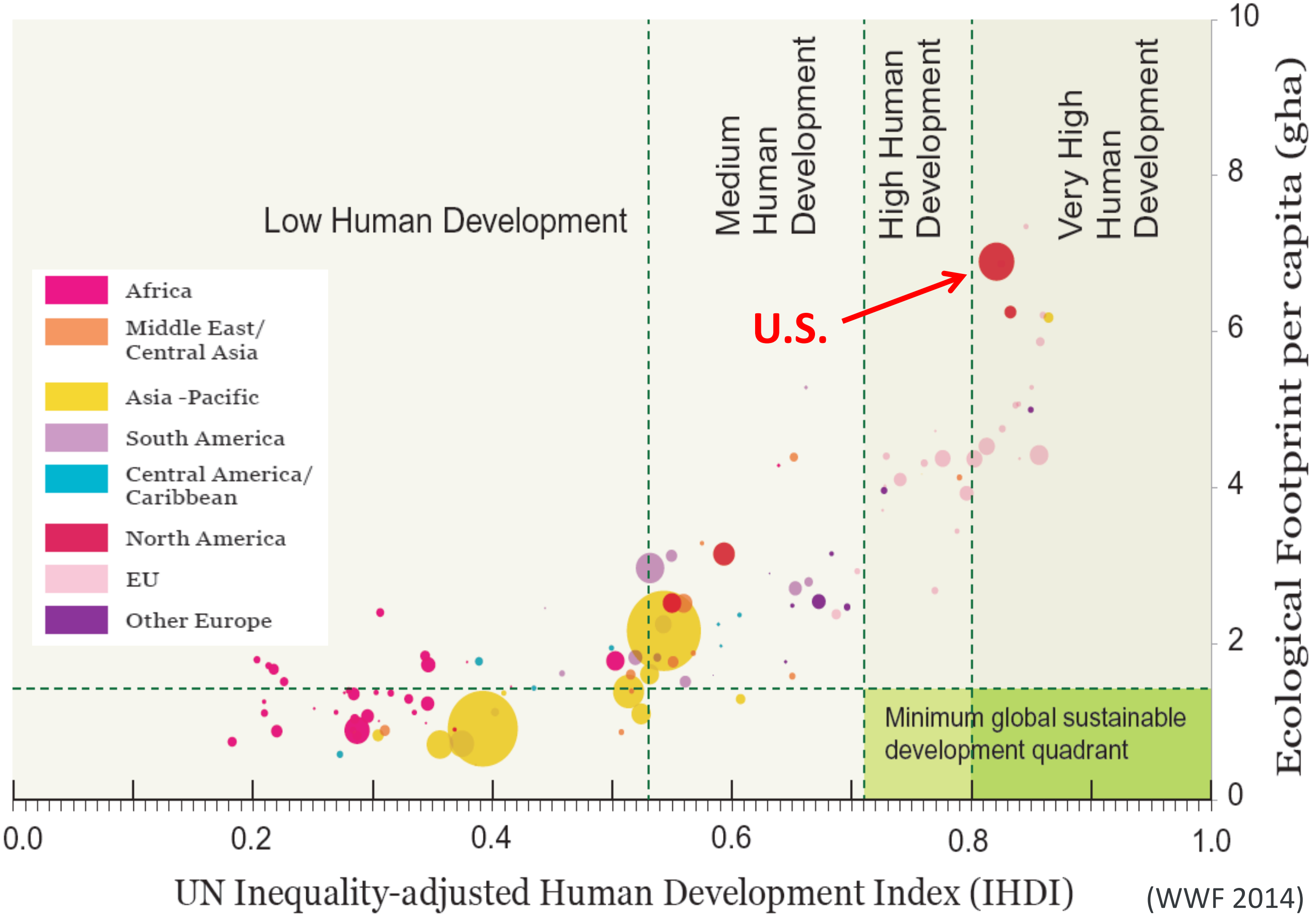
Sustainable development is **"development that meets the needs of the present without compromising the ability of future generations to meet their own needs." –** *Brundtland report, 1987*

- Action towards sustainable development requires normative judgments about valuing natural systems, human quality of life, and economic growth.
- These judgments about development priorities can be better understood through quantification of costs "external" to our economic system.

The 17 UN sustainable development goals cover a broad spectrum of topics, including on natural systems, quality of life, and economic growth

Relevance (3)
Quantitative methods for sustainability science

- Science-based methods exist to assess sustainability goals
- Impacts relative to "Planetary Boundaries" can be measured (Steffen et al. 2015).
- Figure compares a country's ecological footprint human vs. development index.



(WWF 2014)

No single country currently meets criteria to satisfy thresholds for both <u>Human Development</u> and <u>Ecological Footprint</u>

Minimum global sustainable development quadrant

Approach (1)
Sustainability Indicators, Metrics and Frameworks

Indicator: a measurable aspect of environmental, economic, or social systems that is useful for monitoring changes in system characteristic.

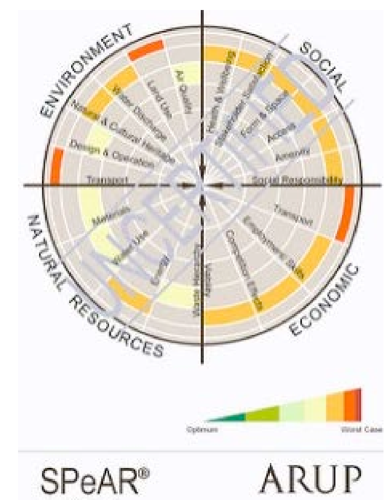
Metric: measured values used to assess specific indicators.

A **Framework** or **Index** is a quantitative aggregation of many indicators that provides a simplified, coherent, multidimensional view of a system. *(Fiksel et al. 2012)*

- Many sustainability frameworks have been developed to inform different stakeholders at different scales within different sectors.
- Because many frameworks use similar types of inputs, developing HyReS to satisfy a few different frameworks will ultimately satisfy a broad range of frameworks (and stakeholders).

ENVISION™

HyReS



The Hydrogen Regional Sustainability (HyReS) framework will function as an information warehouse designed to <u>interface with</u> and <u>feed into</u> other existing frameworks used to guide specific decision makers.

Approach (2)
Project Plan and Target Audiences

Project Plan

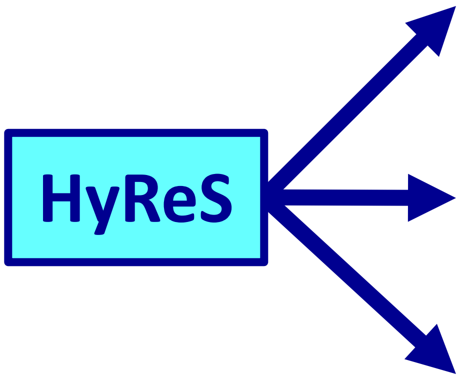
Year One
- Subject Review ☑
- Steering Team ☑
- Expanded Framework ☐

Year Two
- Additional Expansion ☐
- Framework Application ☐
- Corporate-Level Alignment ☐
- Beta Version ☐

Year Three
- Reviewer Feedback ☐
- Refine Framework ☐
- Implement Framework ☐

A major project goal in year one is to confirm with the Steering Team that the approach is sufficient for the target audience

Key Target Audiences



General Public
- FCTO Communication
- Consumer advocacy groups

Project Execution
- Engineering firms
- Funding agencies (and their requirements)

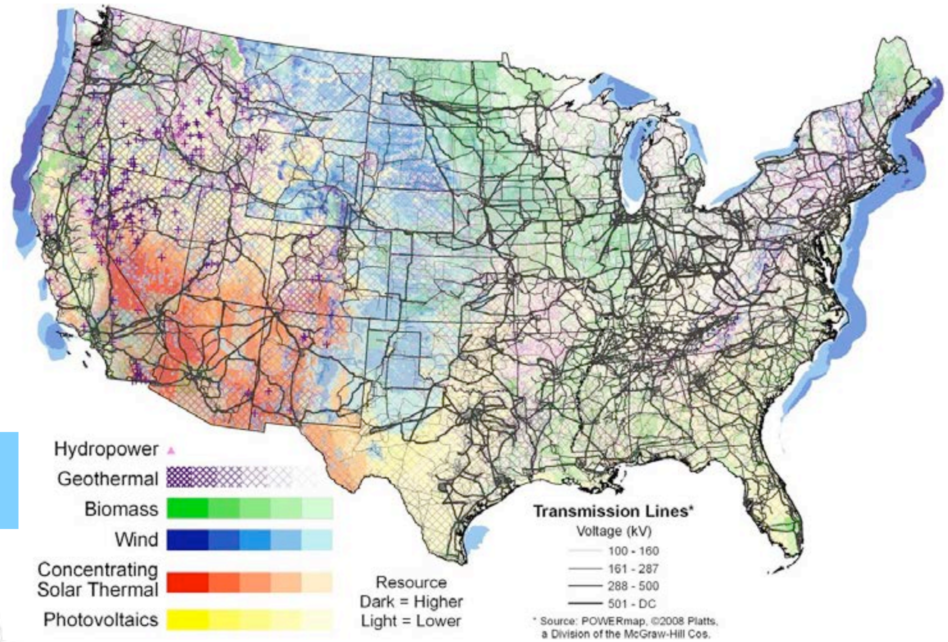
Green Investors
- Impact Investing
- Green Funds

Remaining task in FY16 is to demonstrate the expanded framework for two pathways: (1) Central SMR with gaseous truck delivery, (2) Remote wind with pipeline delivery

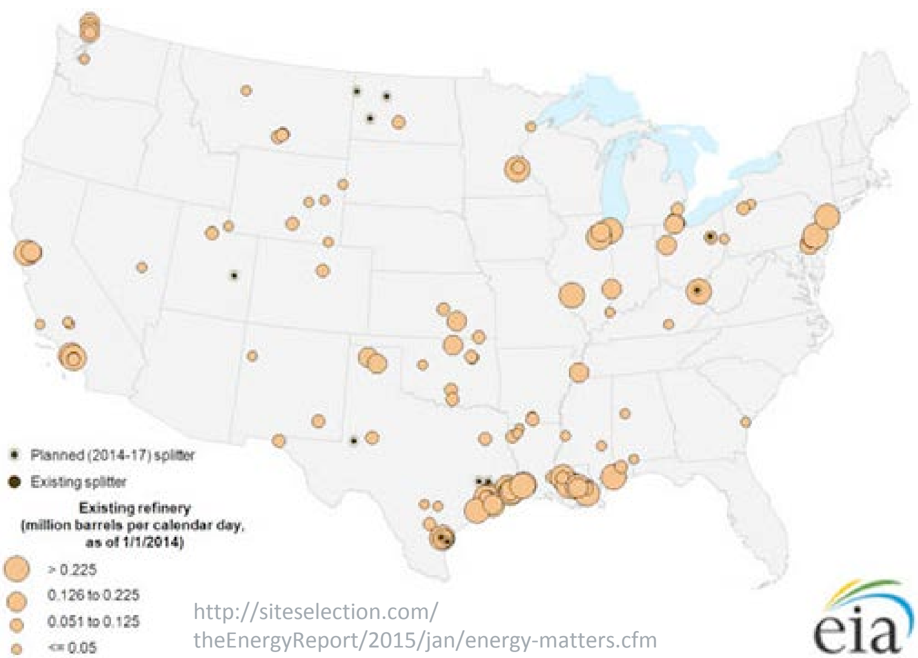
Approach (3) Dimensions of Regional Analysis

Development of a regional sustainability framework for hydrogen and stationary fuel cell systems involves many analytic and data management challenges.

Renewable Resources and Existing Transmission Lines



Existing Refinery Locations



http://siteselection.com/theEnergyReport/2015/jan/energy-matters.cfm

Energy Resources - Existing Infrastructure Biological Systems - Water System Social Systems

Development of an analytical approach for a detailed regional framework has been a major focus in year one

Accomplishments and Progress (1)
HyReS Roundtable: NREL Campus, April 12–13, 2016

Convened sustainability and hydrogen/fuel cell experts to provide feedback on the development of a regional sustainability framework.

Round Table Agenda

Day 1
- Sustainability Overview
- Hydrogen and Fuel Cells Overview
- Sustainability Assessment Tools and Stakeholders
- *Breakout Session #1*

Day 2
- Sustainability Assessment Methods
- *Breakout Session #2*
- Group Discussion: Future use of the HYRES Framework
  - How would you like to stay involved? How should we involve others?

Breakout Session #1:
Stakeholders and Use of the HYRES framework
- Who will find this framework useful and why?
- In what ways might the framework be made most useful to stakeholders?

Breakout Session #2:
Drill Down Into Assessment Methods
- What are the key output indicators and metrics that should be reported?
- What input data, models, and information resources can be drawn on and incorporated into an enhanced framework?

Attendees voted to prioritize feedback collected during breakout groups

Accomplishments and Progress (2)
HyReS Roundtable: Speakers and Attendees

Attendees noted value of assembling technical and sustainability experts—each group learned from the other, and the groups generated ideas collaboratively.

Speakers

Organization	Topic
Wallace Futures Group	Sustainability (civil engineering)
DOE Fuel Cell Technologies Office	Hydrogen and Fuel Cell Technologies
DOE Bioenergy Technologies Office	Bioenergy Technologies
Inst. for Sustainable Infrastructure	Sustainability (civil engineering)
IO Sustainability	Sustainability (ROI Report)
Toyota	Fuel Cell Vehicles
Trucost	Sustainability (business metrics)
Argonne National Lab	Lifecycle Analysis (GREET)

Other Attending Organizations

Colorado Cleantech Industries Association
ITM Power
Lawrence Berkeley National Lab
Louis Berger
National Institute of Standards and Technology
Pacific Northwest National Lab
SoCalGas

NREL Presentations

HYRES Overview
SERA Model Overview

Accomplishments and Progress (3)

Breakout Results: HyReS Users and Use Characteristics

Breakout groups identified and ranked the most important framework users and use characteristics.

Top 5 Framework Users

1. Governments/policymakers (federal, state, local)
2. Investors (infrastructure owners, R&D funders, venture capital, foundations, lenders)
3. Original equipment manufacturers (vehicles, supply chain, fueling infrastructure)
4. Consumers/drivers
5. NGOs (alternative energy/sustainable community advocates, framework developers)

Top 5 Framework Use Characteristics

1. Enable comparisons of various technologies and policies with regard to sustainability outcomes
2. Provide flexibility to serve different users, with capabilities from simple to advanced
3. Enable identification of gaps to improve sustainability, ranking, SWOT analysis, time series analysis
4. Provide credibility and transparency, with annual data updates
5. Facilitate creation of business cases and justification for incentives

Accomplishments and Progress (4)

Breakout Results: HYRES Outputs, Inputs & Maintenance

Breakout groups identified and ranked the most important framework output, input, and maintenance/evolution considerations.

Top 5 Framework Outputs (last 2 tied)

1. Carbon intensity
2. Investor metrics such as return on investment
3. Ecological impacts
4. Regionalized results
5. Water impacts
6. Monetized value of natural capital required per vehicle-mile driven

Top 5 Framework Inputs

1. Data sets from regulatory programs and agencies
2. Feedback from industry users
3. Future climate data
4. Regulations and incentives
5. Customer-driven metrics (like *Consumer Reports* ratings)

Top 5 Framework Maintenance/Evolution Considerations

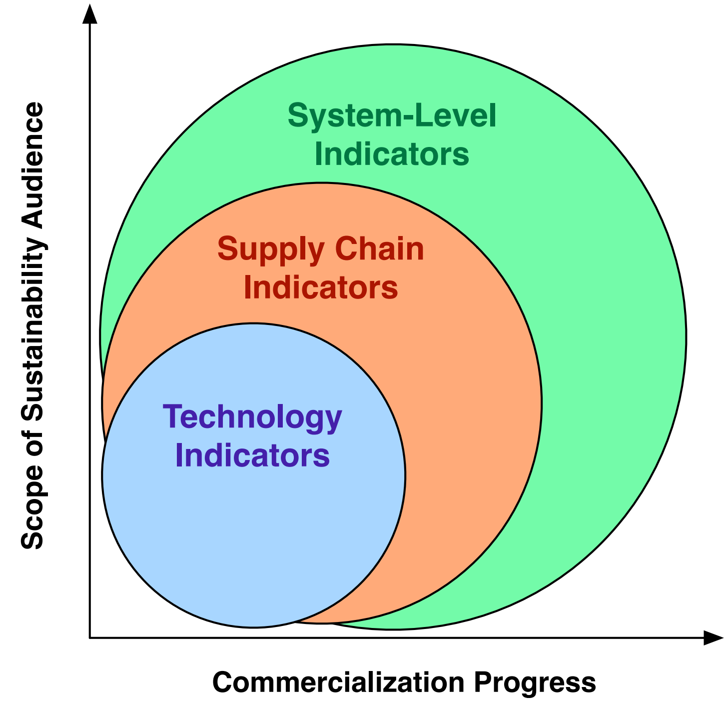
1. Start with outputs that can be measured well
2. Start by serving subject-matter experts and then serve stakeholders/customers – consider a framework like H2FAST's (simple to advanced versions)
3. Establish a formal feedback and revision process
4. Add ability for users to analyze specific scenarios tailored to their projects
5. Secure upfront public and private funding to support framework maintenance – create self-sustaining business model for framework

Accomplishments and Progress (5)
Proposed Indicator Classification

Figure shows three categories spanning two dimensions of a sustainability framework:

- Scope of Sustainability Audience
- Commercialization progress

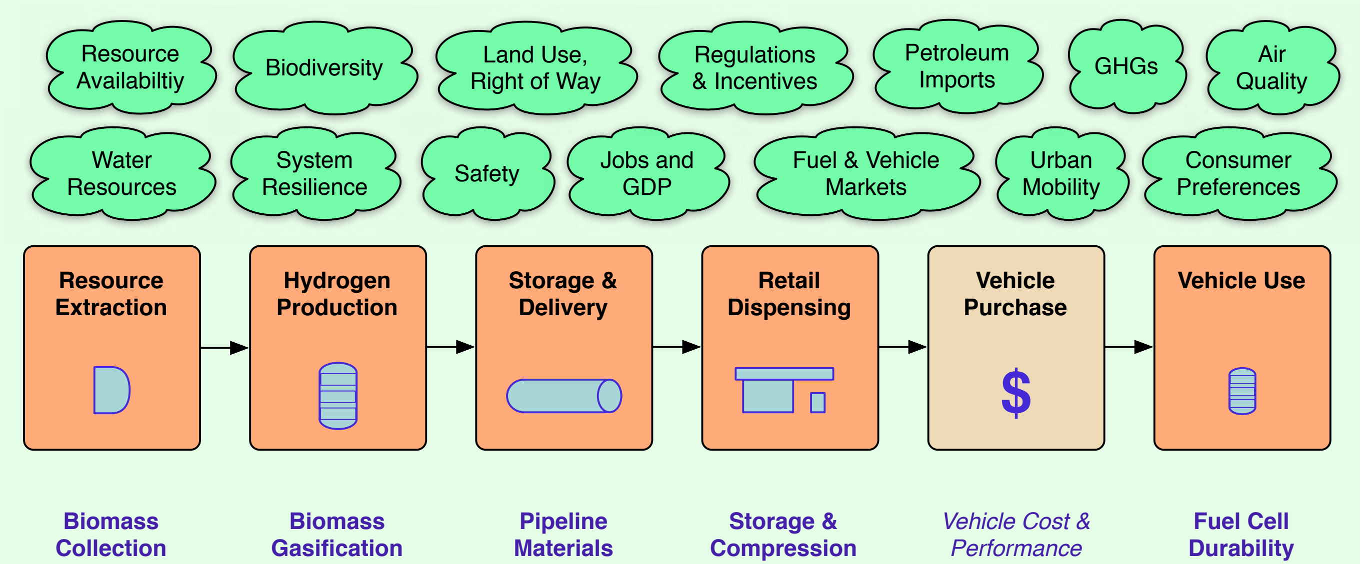
Broadest audience is concerned with system-level indicators of a fully commercialized hydrogen system. For example, the GHGs for a future with 50% LDV market share by 2050.



System-Level: General audience; high or full market potential

Supply Chain: H2FC Industry; current market transformation activities & planning

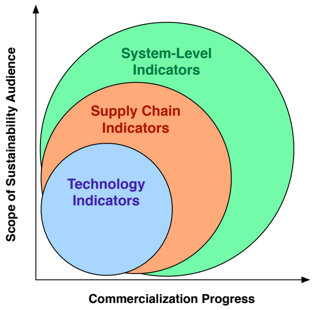
Technology: Current R&D management

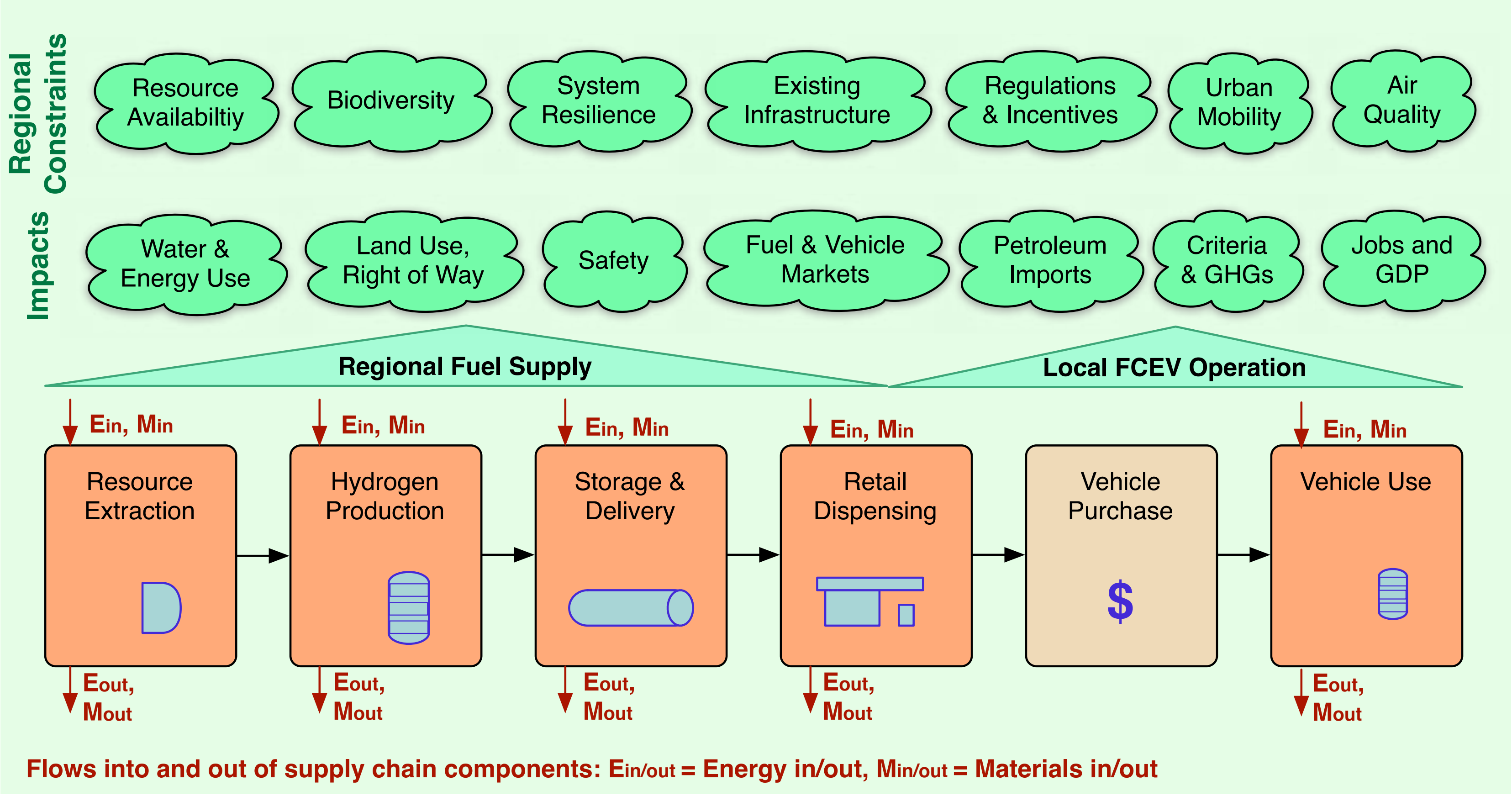


Example for biomass gasification supply chain

Accomplishments and Progress (6)
Regional Supply Chain Sustainability Assessment

- **Ongoing FCTO activities track technology cost and performance**
- **Argonne's GREET model captures national average trends in energy (E) and material (M) flows across supply chain phases**
- **HyReS focus is regional hydrogen fuel supply chains**





Accomplishments and Progress (7)
Geographic Variability Example

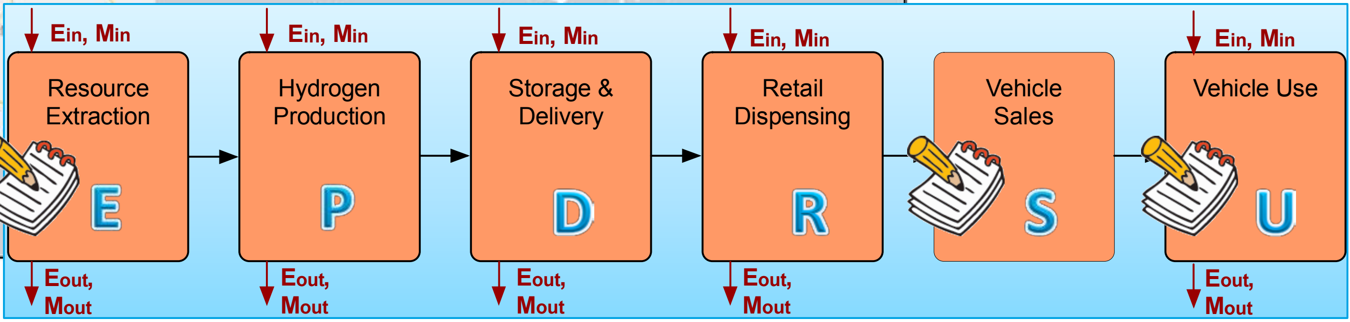
Energy Resources, Environment, Infrastructure, Demand, Impacts

Spatial accounting & optimization:

- Wind
- Solar
- Solid biomass
- Biogas
- Water
- Sequestration
- Pipelines
- Electric grid

Sum of Impacts:

- GHG emissions
- Criteria emissions
- Resource use
- Habitat impact



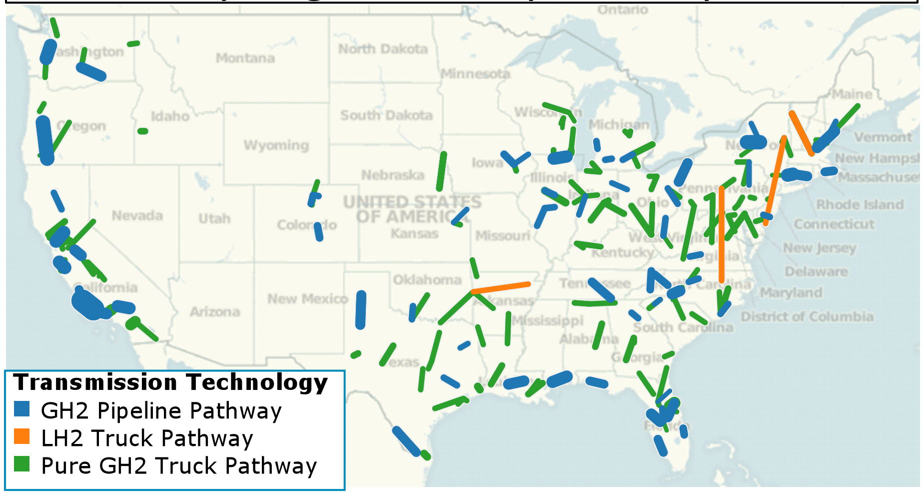
Accomplishments and Progress (8)

Integration of spatial sustainability data within the SERA model

The SERA model has been developed for spatiotemporal optimization using highly detailed geographic data due to the sensitivity of hydrogen infrastructure costs to distance.

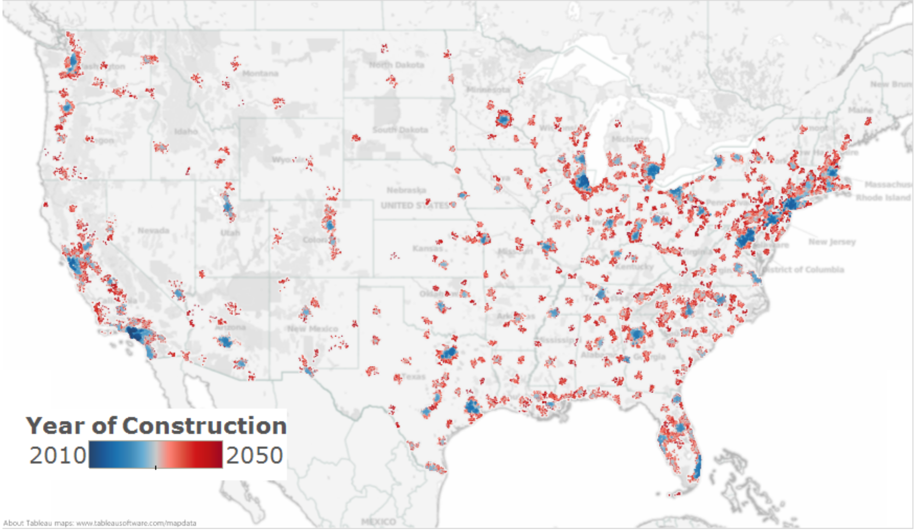
SERA will be relied upon for integrating HyReS data and optimizing metrics

Hydrogen Delivery Pathways



Water Systems

Hydrogen Demand and Stations



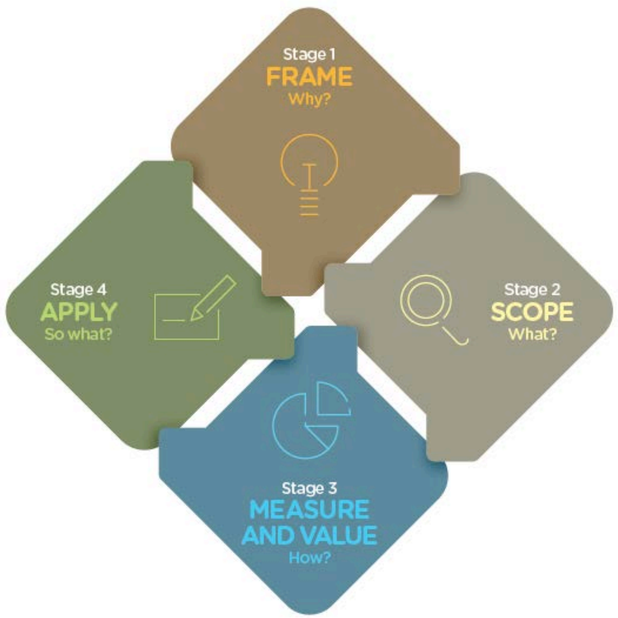
Accomplishments and Progress (9)

Commensurability with Business Community: Natural Capital Coalition

Ensuring that HyReS assessment methods are consistent with existing practices established within the business community will facilitate adoption and enhance the effectiveness and meaningfulness of results.

The Natural Capital Protocol may help ensure consistency of HyReS methods with needs of the business and investment communities

The Stages of the Natural Capital Protocol are all connected, meaning it is possible to retrace and repeat steps that will help with decision making.



Principles (Draft)

We suggest that the four following principles are followed when conducting a natural capital assessment:

NATURAL CAPITAL COALITION

Relevance	Rigor	Replicability	Consistency
Identify the natural capital impacts and/ or dependencies that are most important for a business and its stakeholders, to enable relevant and timely decisions.	Use technically correct (from a scientific and economic perspective) information, data and methods that are also fit for purpose.	Ensure that all assumptions, data, caveats and methods used are transparent, traceable, fully documented, and repeatable. This allows for eventual verification or audit, as required.	Ensure the data and methods used for an assessment are compatible with each other and with the scope of analysis, which depends on the overall objective and expected application.
Modified from original in CDSB, 2015; and WRI and WBCSD, 2004.		Adapted from GRI, 2013.	Adapted from WRI and WBCSD, 2004; and IIRC, 2013.

http://www.naturalcapitalcoalition.org

Collaborations and Previous AMR Reviews

- **Scope of project reviewed with members of the Project Steering Team**
  - Institute for Sustainable Infrastructure (Fall 2015)
  - Louis Berger (Fall 2015)
  - Toyota Motor Company (Spring 2016)
- **HyReS Roundtable Discussion**
  - 30 attendees
  - Feedback from focused breakout groups

Responses to previous Annual Merit Review Comments

This is the first year the project has been reviewed at AMR

Remaining Challenges and Barriers

Regional inputs for the GREET model

- Consistent regional inputs: Many technical parameters (water use, efficiency, criteria emissions) will be identical at the component level, but resulting impacts will vary by region
- Allocation: Some allocation parameters in GREET may vary regionally
- Feedback to GREET: Some regional trends may be useful for GREET

Data sources and management

- Integration of best available data: May depend upon application or audience

Relevance to key stakeholders

- Steering Team: One or two additional members may be added over the course of the project.
- Outreach to (and feedback from) Sustainability Science community: Bringing hydrogen stakeholders to sustainability science venues (e.g. conferences) may be an important strategy for aligning HyReS with key stakeholders.

Proposed Future Work

Project Plan

Year One

- Subject Review ☑
- Steering Team ☑
- Expanded Framework ☐

Year Two

- Additional Expansion ☐
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Year Three

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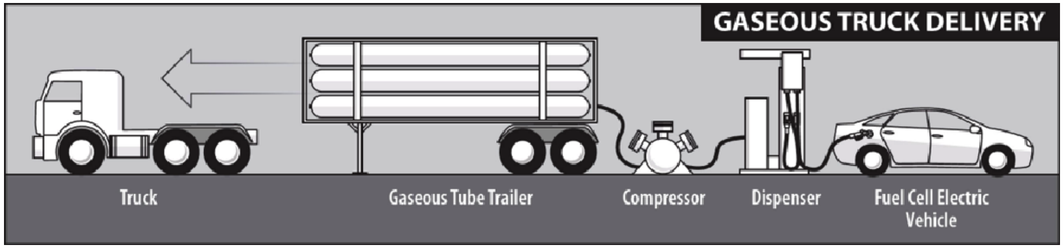
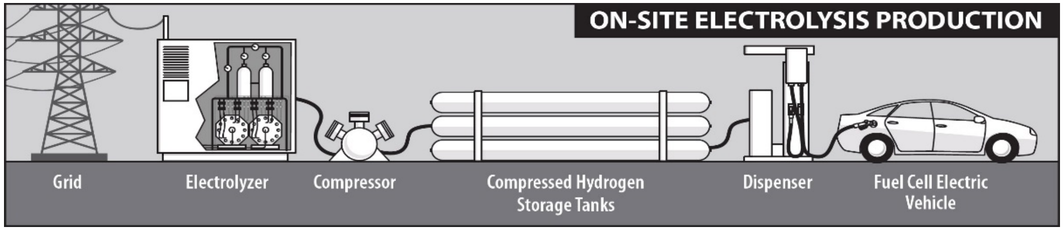
- Implement Framework ☐

Identify and characterize example pathways for initial application of HyReS in year one





- Project plan includes ongoing collection of feedback from stakeholders
- Expansion scope must ultimately be limited to high-priority focus topics.

Summary

Relevance

- Existing energy and industrial systems must adapt to evolving sustainability criteria
- Scientific methods around planetary limitations can inform adaptation options

Approach

- Development of regional metrics around upstream hydrogen supply chains
- Consistency with existing frameworks and tools used by engineering firms, sustainable business community, and green investors
- Leveraging GREET model with spatial detail of the SERA model
- Develop pathway cases, beta framework, then final public framework

Technical Accomplishments and Progress

- Formation of Steering Team and proposed HyReS scope
- HyReS Roundtable Discussion event at NREL (April 12-13, 2016) collected feedback from key stakeholder groups; priorities users, use and development options

Collaboration

- GREET model developers at Argonne; others TBD

Proposed Future Research

- Continue integration of regional data; development of example pathways cases

Questions?

Contact Information

Marc.Melaina@nrel.gov

Technical Back-Up Slides

Technical Backup (1)
References

Fiksel, J, T Eason, and H Frederickson. 2012. "A Framework for Sustainability Indicators at EPA." Edited by T Eason. U.S. EPA. https://www.epa.gov/sites/production/files/2014-10/documents/framework-for-sustainability-indicators-at-epa.pdf.

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Steffen, W, K Richardson, J Rockstrom, S E Cornell, I Fetzer, E M Bennett, R Biggs, et al. 2015. "Planetary Boundaries: Guiding Human Development on a Changing Planet." Science 347 (6223): 1259855–55. doi:10.1126/science.1259855.

WWF, 2014. *Living Planet Report 2014: Species and spaces, people and places*. World Wildlife Fund, available online: http://wwf.panda.org/about_our_earth/all_publications/living_planet_report/

Examples of existing sustainability frameworks include:

- Institute for Sustainable Infrastructure's ENVISION
- Yale's Environmental Performance Index (EPI)
- Sustainable Project Appraisal Routine (SPeAR)

Technical Backup (2)
Roundtable Feedback (SurveyMonkey)