IX.7 Sustainability Analysis of Hydrogen Supply and Stationary Fuel Cell Systems Using the Hydrogen Regional Sustainability (HyReS) Framework

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Overall Objectives

- Develop a regional hydrogen sustainability analysis assessment framework (HyReS) that can be applied to hydrogen supply and fuel cell systems and is consistent with a broad range of existing sustainability assessment tools used by relevant stakeholders.
- Apply the framework as an enhancement to the existing suite of hydrogen systems analysis models developed for the Fuel Cell Technology Office (FCTO).
- Refine the framework to incorporate the latest developments in the field of sustainable development assessment, including recent data and analytic approaches, and to capture current issues relevant to key stakeholders.
- Implement the framework through a user interface that is accessible to target audiences, including private sector sustainability managers, industry stakeholders, government and non-government agencies, and potential investors.

Fiscal Year (FY) 2016 Objectives

- Review existing sustainable development frameworks and tools to identify the most relevant and applicable metrics and approaches for hydrogen supply and fuel cell systems.
- Engage with leaders in the field of sustainable development assessment through a Project Advisory Committee.
- Develop an expanded systems analysis assessment framework to account for a broader range of sustainability metrics, focusing on environmental criteria.

Technical Barriers

This project addresses the following technical barriers from the Systems Analysis section of the FCTO Multi-Year Research, Development, and Demonstration Plan.

(A) Future Market Behavior

(B) Stove-piped/Siloed Analytical Capability

(D) Insufficient Suite of Models and Tools

Contribution to Achievement of DOE Systems Analysis Milestones

This project will contribute to achievement of the following DOE milestones from the Systems Analysis section of the FCTO Multi-Year Research, Development, and Demonstration Plan.

- Milestone 1.19: Complete analysis of the potential for hydrogen, stationary fuel cells, fuel cell vehicles, and other fuel cell applications such as material handling equipment including resources, infrastructure and system effects resulting from the growth in hydrogen market shares in various economic sectors. (4Q, 2020)
- Milestone 2.2: Annual model update and validation. (4Q, 2011 through 4Q, 2020)

FY 2016 Accomplishments

- Planned and executed an expert roundtable event, held on April 12–13, 2016, on the National Renewable Energy Laboratory campus in Golden, Colorado, to brainstorm and discuss framework scope and prioritize action items and areas of focus.
- Collected and prioritized stakeholder feedback on key questions related to future framework users, use characteristics, framework outputs and inputs, and framework maintenance and evolution considerations.
- Developed and proposed an indicator classification system for regional supply systems, which includes integrating spatial sustainability data with the Scenario Evaluation and Regionalization Analysis model.

- Identified existing frameworks to use as a reference for HyReS development, including ENVISION and metrics from the Natural Capital Coalition.

INTRODUCTION

Analytic methods for hydrogen systems developed to date include a broad range of relevant metrics, including technical specifications, costs, finances, and lifecycle greenhouse gas emissions. This project will enhance the existing set of FCTO analysis tools to include additional regional sustainability metrics across three pillars: environmental, economics and equity. The resulting HyReS framework will serve as an information warehouse, providing information of use to existing sustainability assessment frameworks.

APPROACH

The HyReS project is a three-year project with distinct tasks in each year. The first year involves a review of the literature on sustainability assessment methods, establishment of a project steering team, and development of a general framework structure with a select number of case study applications. Year 2 involves additional expansions to the framework, application of the framework to a broader set of regional hydrogen pathways, alignment of the framework with corporate-level sustainability assessment tools, and release of a beta version of the tool. Year 3 involves refinement of the tool in response to feedback on the beta tool and implementation of the final HyReS framework.

The key target audiences for the HyReS framework include the general public and consumer advocacy groups, engineering firms and funding agencies assessing specific projects, and impact investor or green fund managers. Case study pathways proposed for application of the framework in year one include central steam methane reforming with gaseous truck delivery and remote wind production with pipeline delivery.

RESULTS

Definitions of sustainability vary significantly depending upon context and subject area. A general and widely quoted definition from the Brundtland Report is "…development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [1]. More recent developments emphasize the importance of transitions and transformations across complex interactions of social, ecological, and infrastructural systems [5]. Of particular interest for regional hydrogen supply systems is the ability to design resilient civil infrastructure systems through an adaptive management approach to account for future shifts away from business-as-usual conditions, such as increased prevalence of droughts, floods, or other systems stresses [2,6]. Resilience, a complementary concept to sustainability, is highly relevant to both the design and social value of future regional hydrogen infrastructures, and has been defined in terms of adaptive capacities that support system functionality in times of crisis or stress [4].

The HyReS framework goals, as presented to attendees at the roundtable event on April 12–13, 2016, include the following:

- R&D Needs: Inform hydrogen fuel cell production goals and priorities.
- Sector Assessment: Support market transformation efforts by multiple stakeholders within formal and informal public-private partnership consortiums.
- Public Outreach: Engage with and contribute to public dialogue on progress and options towards achieving sustainable development goals.

The categorization of sustainability indicators that follows from these goals is presented in Figure 1, and involves three overlapping spheres across two dimensions: (1) scope of sustainability audience and (2) commercialization progress. R&D needs fall within the first sphere of technology indicators, relevant to pre- or early-commercial status technologies and of interest to a relatively limited audience. Sector-wide assessments are addressed through supply chain indicators, and broader

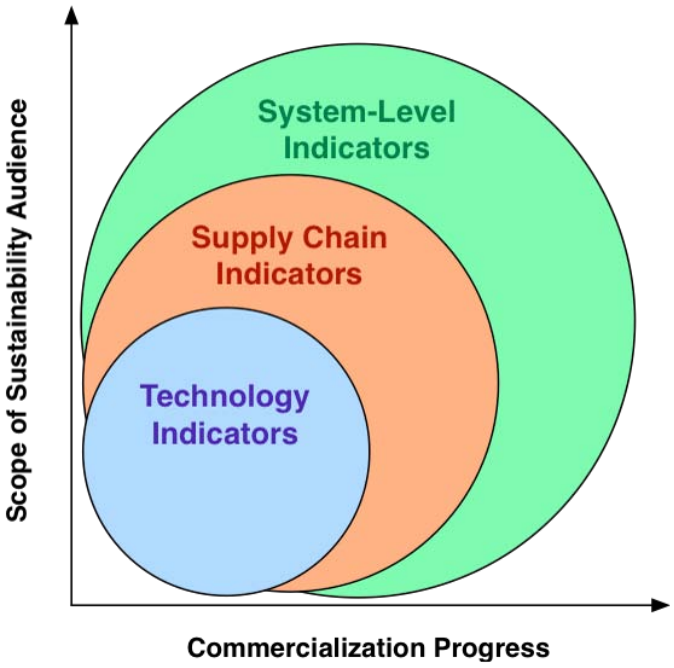

FIGURE 1. Categorization of HyReS indicators

general audiences concerned with full commercialization of regional hydrogen systems are addressed through system-level indicators. For example, improvements in electrolysis efficiency would fall under technology indicators, while total greenhouse gas emissions from hydrogen produced from future wind farms would fall under system-level indicators.

One of the key challenges of the HyReS project will be integration of multiple levels and types of sustainability data into a consistent geographic framework that both extends into the future and is relevant to project-specific assessments. The geographically detailed Scenario Evaluation and Regionalization Analysis model will serve as as the means of reconciling any data inconsistencies, and can also be used as an optimization tool or for multi-criteria assessment comparisons. One of the proposed analytic approaches to achieving consistency with quantitative assessment methods used in the broader corporate sustainability community is alignment with the framework and valuation assumptions contained within the Protocol developed through the Natural Capital Coalition [3]. Some additional high-priority items resulting from the expert roundtable include the following:

- Design HyReS with government agencies, policy makers, investors and original equipment manufacturers (autos and fuel equipment) as key framework users.
- The framework should enable comparisons of various technologies and policies with regard to sustainability outcomes, provide flexibility to serve different types of users, and identify gaps to improve assessment results.
- Key HyReS outputs should include carbon intensity, investments metrics (e.g., return on investment), ecological inputs, regional results, water impacts, and monetized natural capital value per vehicle-mile driven.
- Key HyReS inputs should include data from regulatory programs and agencies, feedback from industry users, future climate data, and regulations and incentives.
- Maintenance and evolution considerations include use of measurable outputs, focusing on subject matter experts first and then other stakeholders, establishment of a formal feedback and revision process, ability for users to tailor results, and creation of a self-sustaining business model to support for the framework over the long term.

CONCLUSIONS AND FUTURE DIRECTIONS

This three-year project began in FY 2016 with initial scoping and development of a preliminary framework structure, which was presented along with key framework development questions at an expert roundtable event held April 12–13, at National Renewable Energy Laboratory in Golden, Colorado. Next steps and key attributes for the HyReS framework were prioritized by roundtable attendees. Proceedings from the roundtable will be published as a technical report, as well as a select number of case studies applying the framework to specific regional hydrogen pathways.

FY 2016 PUBLICATIONS/PRESENTATIONS

1. Marc Melaina, Brian Bush, Michael Penev, Dana Stright, Darlene Steward, Joshua Sperling, "Sustainability Analysis: Sustainability analysis of hydrogen supply and stationary fuel cell systems using the Hydrogen Regional Sustainability (HyReS) framework." Presented at the DOE Hydrogen and Fuel Cells Program Annual Merit Review and Peer Evaluation Meeting, Washington, D.C., June 6–10, 2016.

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