IX.11 Resource Availability for Hydrogen Production

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Project Start Date: October 2016
Project End Date: Project continuation and direction determined annually by DOE.

Overall Objectives

- Estimate hydrogen production required for potential future fuel cell electric vehicle (FCEV) demand.
- Provide updated estimates of hydrogen production potential from a wide range of energy resources: natural gas, coal, uranium, biomass, wind, solar.
- Compare resource requirements for hydrogen to projected consumption in a future without significant FCEV market growth (from the U.S. Energy Information Administration's [EIA's] *Annual Energy Outlook* [AEO]) and with significant market growth (e.g., 50 million FCEVs deployed by 2040).
- Determine resource availability spatially and on a per-kilogram-of-hydrogen basis.

Fiscal Year (FY) 2017 Objectives

- Begin updating hydrogen production potential for natural gas, coal (with carbon capture and sequestration), nuclear, biomass (solid and gaseous), wind, and solar resources.
- Compare results with future 2040 consumption with and without significant growth in FCEV markets.
- Prepare results to be captured in final report and made available through HyDRA tool.

Technical Barriers

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

(A) Future Market Behavior

(E) Unplanned Studies and Analysis

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 Fuel Cell Technologies Office 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)

FY 2017 Accomplishments

- Began updating hydrogen production potential for natural gas, coal (with carbon capture and sequestration), nuclear, biomass (solid and gaseous), wind, and solar resources.
- Compared results with future 2040 consumption with and without significant growth in FCEV markets.
- Prepared results to be captured in final report and made available through HyDRA tool.

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INTRODUCTION

A successful, long-term strategy for FCEV deployment is to use hydrogen produced from a diverse array of low-carbon domestic energy resources, such as coal (with carbon capture and storage), nuclear, biomass, wind, and solar energy. Natural gas is considered a transitional energy feedstock, as well as a long-term, domestic, low-carbon option if converted to hydrogen in a large central plant with carbon capture and storage. Understanding the potential of multiple domestic, low-carbon energy resources to produce hydrogen is important for analyzing long-term scenarios with high FCEV deployment and a hydrogen infrastructure system that is robust, resilient, and economically competitive. To estimate these resource potentials, this study builds directly upon previous work [1], which in turn was based on previous estimates for hydrogen production potentials for wind, solar, and biomass [2] and for coal, natural gas, nuclear, and hydro power [3]. These renewable resource potentials are based upon an updated and consistent calculation of technical potential, part of the National Renewable Energy Laboratory's (NREL's) ongoing work to compare technical potential consistently across renewable energy technologies [4].

APPROACH

A framework is established to draw comparisons across different resource estimate types. The approach relies upon the same basic analytic methods used in Melaine et al. [1]. Updates are made to key input parameters where new information or improved assumptions are available. Comparisons to projected consumption depend upon new EIA AEO cases [5]. Production efficiencies—the amount of resource required to produce a kilogram of hydrogen—are key input assumptions for estimating future resource requirements; improved future conversion rates would reduce reliance on any particular resource. Most values are based upon H2A production model conversion efficiencies. The uranium conversion rate is being updated in coordination with the H2@Scale team. The resource requirements are estimated through simple energy-balance calculations and do not account for future policies or market competition. A clear and consistent approach is used to characterize and compare different estimates of the availability of fossil and renewable energy resources. The economic potential estimates for renewables from Lopez et al. [4] will be updated to reflect improved resource potentials for biomass, wind, and solar. This analytical framework is used to estimate total potential to produce hydrogen from major energy resources. Each major resource is tested for its potential to supply 4–10 million metric tons of hydrogen per year, and these results are compared with expected consumption in 2040 without significant FCEV market share.

RESULTS

The updated total resources and hydrogen production potentials for fossil and nuclear fuels are shown in Table 1. These account for significantly increased proved and unproved reserves of natural gas as well as lower estimates for uranium resources and coal estimates, which have continued a downward trend over time. The conversion efficiency of coal-to-hydrogen has been updated [5] such that, despite a lower physical coal resource, the hydrogen production potential from coal has increased by about 50%. Table 2 shows the total resources and hydrogen production potentials for renewables. The technically recoverable resources (TRRs) for solar and biomass (high) have been

TABLE 1. Fossil and Nuclear Resource and Hydrogen Production Potentials

Resource	Resource Potential		Hydrogen Production Potential	
Fossil and Nuclear	Physical Resource	Quads	Hydrogen Potential (MMT)	Quads of Hydrogen
Natural Gas (EP)	340 trillion cubic feet	350	2,030	270
Natural Gas (TRR)	2,500 trillion cubic feet	2,500	14,700	2,000
Coal (EP)	250 billion short tons	5,100	29,500	4,000
Coal (TRR)	480 billion short tons	9,500	55,100	7,400
Uranium (EP)	200 million lb U_3O_8	300	900	100
Uranium (TRR)	400 million lb U_3O_8	600	2,100	300

EP = economic potential, MMT = million metric tons, TRR = technically recoverable resource

TABLE 2. Renewable Resource and Hydrogen Production Potentials

Resource	Resource Potential		Hydrogen Production Potential	
Renewable	Physical Resource	Quads/yr	Hydrogen Potential (MMT/yr)	Quads of Hydrogen/yr
Biomass (EP)	900 million tons eq.	15	60	8
Biomass (moderate)	400 million tons eq.	7	30	4
Biomass (high)	1,200 million tons eq.	19	80	10
Wind (EP)	2,000 TWh electricity	20	40	6
Wind (TRR)	50,000 TWh electricity	500	1,100	150
Solar (EP)	1,000 TWh electricity	10	20	3
Solar (TRR)	180,000 TWh electricity	1,800	4,000	500

EP = economic potential, MMT = million metric tons, TRR = technically recoverable resource. Biomass TRR is shown as a moderate to high range. Conversions to quads are on a higher-heating basis; EIA thermal equivalent of 9,760 Btu/kWh is used for wind and solar. Sums are rounded.

updated, while other values are the same as reported in previous work [1].

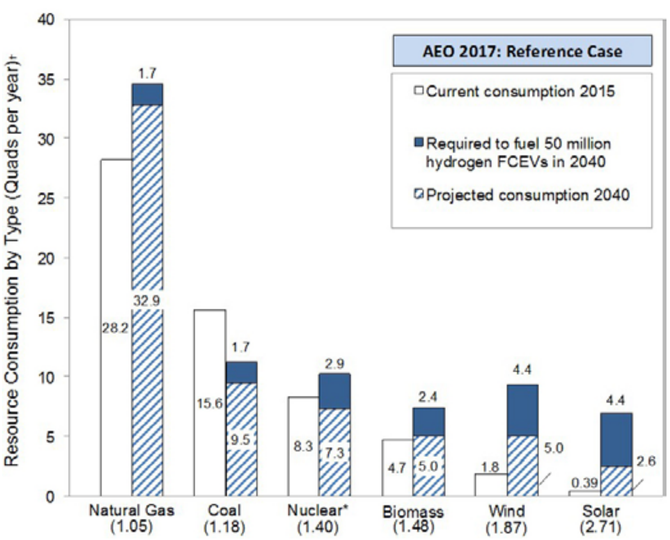
Figure 1 shows the updated comparison to current (2015) and future (2040) consumption for the AEO 2017 Reference Case [6]. The ratio of projected 2040 consumption and additional resource needed to supply 50 million FCEVs is shown as a factor in parenthesis below each resource label. The percentage increases are relatively low for natural gas (5%) and coal (18%), higher for nuclear (40%) and biomass (48%), and highest for wind (87%) and solar (171%). However, the updated increases for wind and solar are much lower than the 2013 results for wind (183%) and solar (780%) [1].

Figure 2 shows the updated comparison to current (2015) and future (2040) consumption for the AEO Low Oil and Gas Case [6]. This case includes limited domestic fossil resources and future consumption, resulting in greater reliance on nuclear, biomass, wind, and solar resources. The differences between these results and those from the Reference Case (Figure 1) suggest hydrogen production would likely be more diversified under the Low Oil and Gas Case market conditions. For example, the higher projected market success of wind and solar suggest increased viability of those sources for hydrogen production. At the same time, a larger increase in natural gas (7%) and coal (62%) resources is required to satisfy the demand from 50 million FCEVs, compared with the Reference Case.

Updated final resource assessment results will be provided in a final report and made available through HyDRA (https://maps.nrel.gov/hydra/). HyDRA is an online data-sharing and visualization tool, providing access to spatial data from a variety of studies. Figure 3 shows a screenshot of the enhanced HyDRA tool to be released later in FY 2017. The update includes new resource assessment data and enhanced end-user capabilities.

CONCLUSIONS AND UPCOMING ACTIVITIES

An improved understanding of U.S. resource potential for hydrogen production will help in analyzing long-term FCEV deployment scenarios. The forthcoming resource report is the main project deliverable. Subject to funding received, upcoming activities will include updating all renewable economic and technical potentials. Activities may also include using resource potential estimates as inputs to the Scenario Evaluation and Regionalization Analysis cost-optimization routine. Including spatial resource availability constraints will improve the realism of hydrogen supply chain cost estimates by generating more realistic depictions of production facility scales and locations as well as delivery distances between production facilities and demand centers (urban areas).



NOTE: Wind and solar resource requirements are calculated using a thermal equivalent value of 9,510 Btu per kWh, following the convention used by EIA (see [6], Table A17)

FIGURE 1. Updated comparison to current (2015) and future (2040) consumption for the AEO 2017 Reference Case (ratio of projected 2040 consumption and additional resource needed to supply 50 million FCEVs shown as a factor in parenthesis below each resource label), *nuclear values are for high-temperature electrolysis

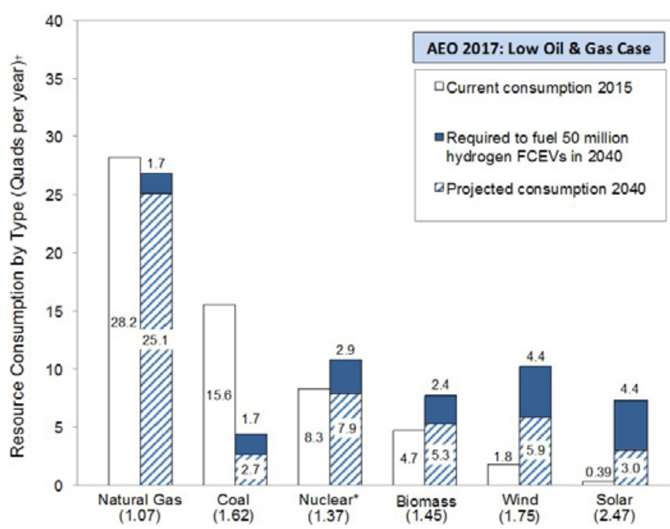


FIGURE 2. Updated comparison to current (2015) and future (2040) consumption for the AEO Low Oil and Gas Case (ratio of projected 2040 consumption and additional resource needed to supply 50 million FCEVs shown as a factor in parenthesis below each resource label), *nuclear values are for high-temperature electrolysis

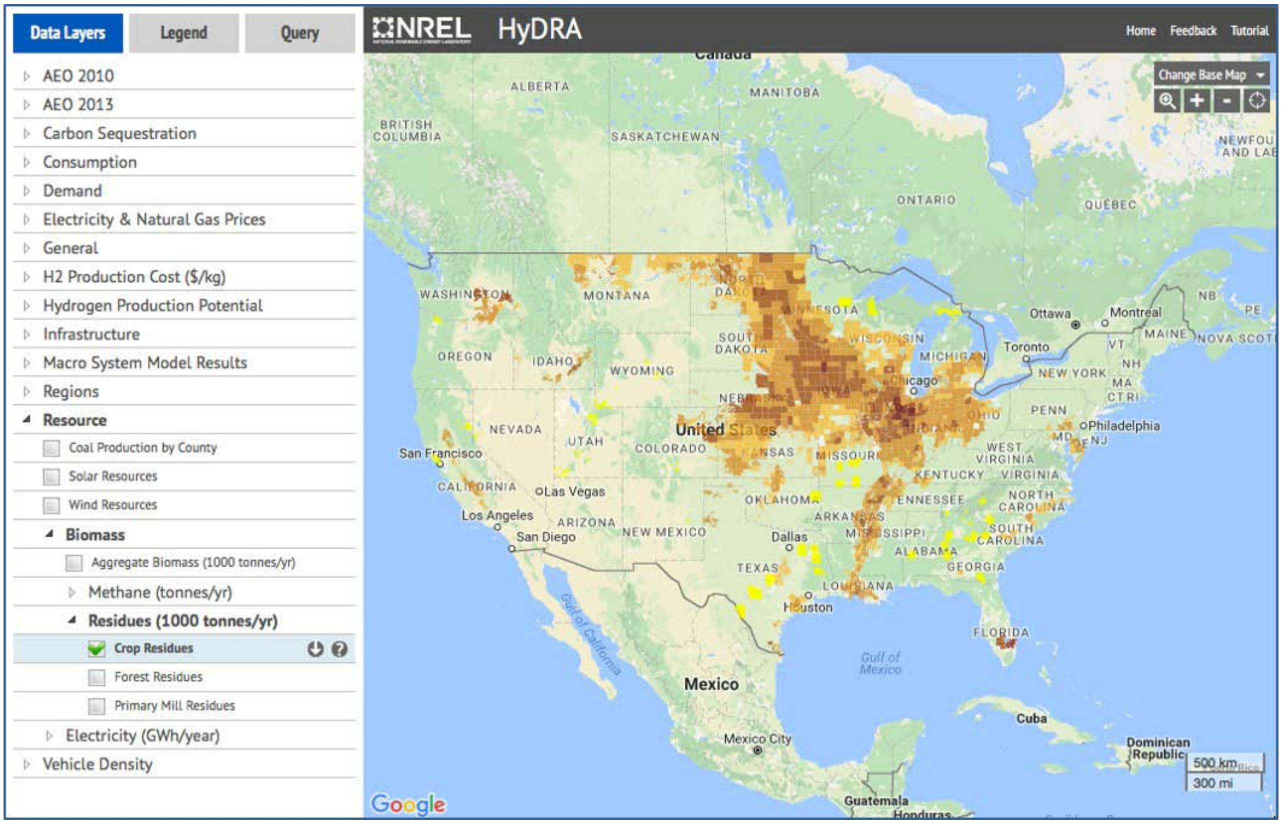


FIGURE 3. Screenshot of the enhanced HyDRA tool to be released later in FY 2017

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