III.12 Updated Well-to-Wheel Analysis of Energy and Emission Impacts of Fuel-Cell Vehicles

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End Date: Ongoing annual effort for DOE to update WTW results

Objectives

- Develop and update the *G*reenhouse gases, *R*egulated *E*missions, and *E*nergy use in *T*ransportation (GREET) model as part of the Model and Analysis Tool Development task under Systems Analysis in the Hydrogen, Fuel Cells and Infrastructure Technologies Multi-Year Research, Development and Demonstration (RD&D) Plan
- Conduct well-to-wheel (WTW) analyses for hydrogen (H_2) fuel cell vehicles (FCVs) by using the GREET model
- Review and evaluate WTW studies conducted by others

Technical Barriers

This project addresses the following technical barriers from the Systems Analysis section of the Hydrogen, Fuel Cells and Infrastructure Technologies Multi-Year RD&D Plan:

- A. Lack of Prioritized List of Analyses for Appropriate and Timely Recommendations
- B. Lack of Consistent Data, Assumptions, and Guidelines
- D. Stove-Piped/Siloed Analytical Capabilities

Approach

The GREET model has been updated and applied to analyze the WTW energy and emission effects of H_2 FCVs compared with conventional and other advanced vehicle technologies. The GREET model provides a consistent modeling methodology to allow comparison of the WTW energy and emission effects associated with various vehicle/fuel options. In developing key assumptions, Argonne conducts extensive research — investigating open literature; contacting industry representatives and stakeholders; and collaborating with industry partners, other national laboratories, and members of other DOE programs. More than 2,000 registered users have downloaded the GREET model to date.

For a given vehicle/fuel option, the GREET model separately calculates the following (on a WTW basis): (1) energy consumption for three energy categories (total energy, fossil fuels, and petroleum); (2) emissions of three greenhouse gases (CO_2, CH_4, N_2O); and (3) emissions of five criteria pollutants (total and urban emissions, volatile organic compounds, CO, NO_x, PM_{10}, and SO_x). Figure 1 shows the stages covered in GREET simulations. A WTW analysis includes the feedstock, fuel, and vehicle operation stages. The feedstock and fuel stages together are called well-to-pump (WTP) stages, and the vehicle operation stage is called the pump to-wheel (PTW) stage. In GREET, WTW energy and emission results are presented separately for each of the three stages.

GREET includes a variety of vehicle propulsion technologies and transportation fuels, of which H_2 FCVs are a subset. Figure 2 lists various H_2 production pathways simulated in the GREET model. The model can simulate multiple options for a given pathway. For example, the most recent GREET version (version 1.7 — to be released in fall 2005) includes over 50 options for compressed H_2 and liquid H_2 pathways. Besides H_2, many hydrocarbon fuels are being considered as intermediate fuel-cell fuels. For example, H_2 production from ethanol and methanol at refueling stations is included in GREET.

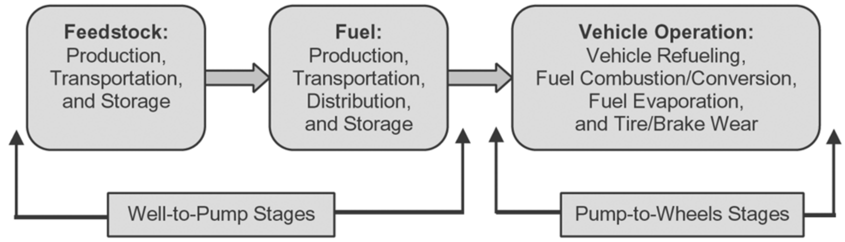

Figure 1. Stages Covered in GREET Well-to-Wheels Analysis

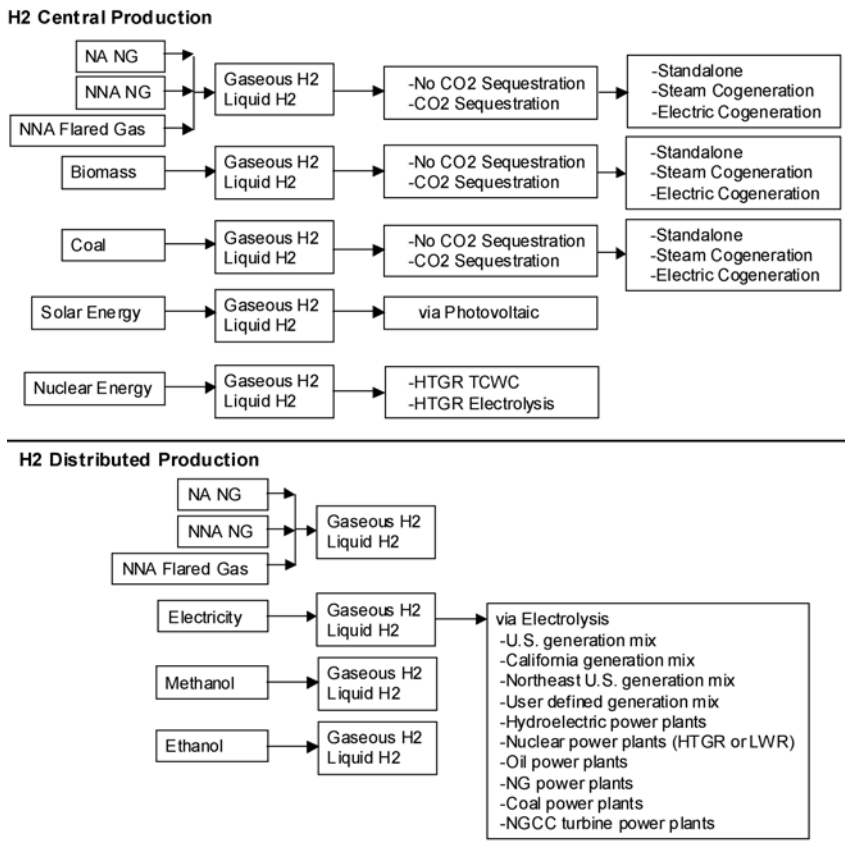

Figure 2. H_2 Production Pathways in GREET

Accomplishments

Argonne applied the GREET model to estimate the WTW energy and emission impacts of FCVs powered with H_2 produced from several energy feedstocks. Many H_2 production pathways and intermediate fuel cell fuels have been added to the GREET model. A new GREET version will be released in fall 2005. A significant effort was made in the past year to address the uncertainties associated with key input parameters regarding H_2 production and FCV fuel economy. Figures 3 through 6 provide updated results for WTW total energy use, fossil energy use, petroleum use, and CO_2-equivalent greenhouse gas (GHG) emissions for the following selected H_2 production pathways: (1) distributed production of gaseous hydrogen (GH_2) from North American natural gas; and (2) distributed production of GH_2 from renewable electricity via electrolysis; and (3) distributed production of GH_2 from cellulosic ethanol. To allow comparison of these H_2 FCV options with other vehicle technologies, we also present WTW results for conventional gasoline vehicles, diesel vehicles, gasoline hybrids, and diesel hybrids.

Although the use of H_2 produced from cellulosic ethanol may increase total energy use (Figure 3), the other two H_2 pathways show significant reductions in total energy use. When one considers fossil energy use (petroleum, natural gas, and coal; Figure 4), H_2 from both cellulosic ethanol and renewable electricity is far superior to any other fossil-fuel-based vehicle/fuel option. All of the three H_2 FCV options almost eliminate petroleum use (Figure 5).

All three H_2 FCV options achieve huge GHG emission reduction benefits compared to current gasoline vehicles (Figure 6). Reductions in GHG emissions by the FCV options are remarkable — even compared to those of gasoline and diesel hybrids.

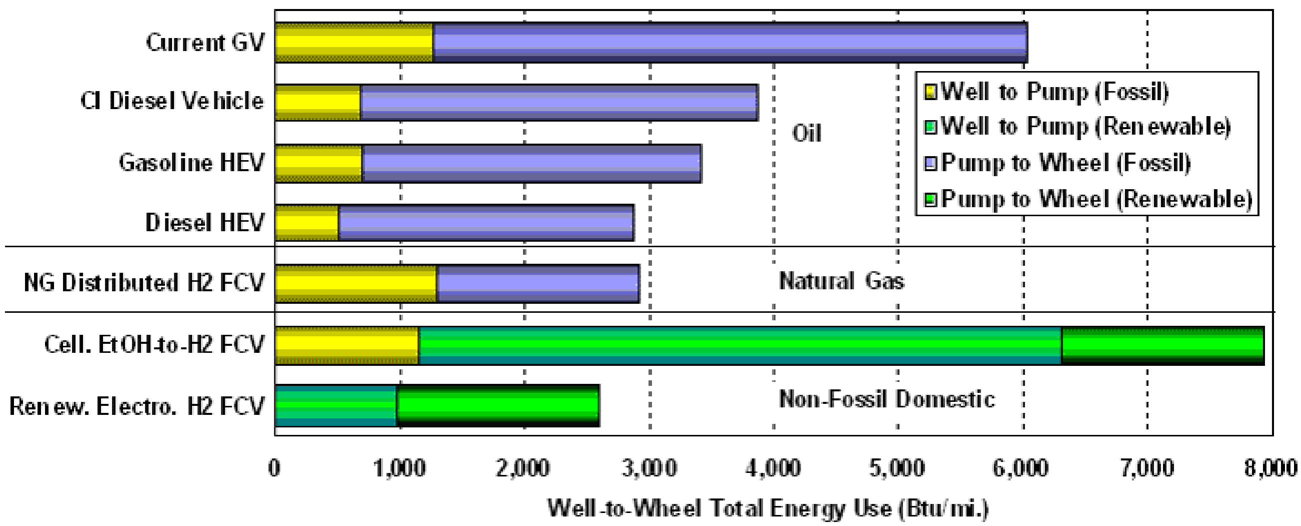

Figure 3. WTW Total Energy Use of Selected Vehicle/Fuel Systems

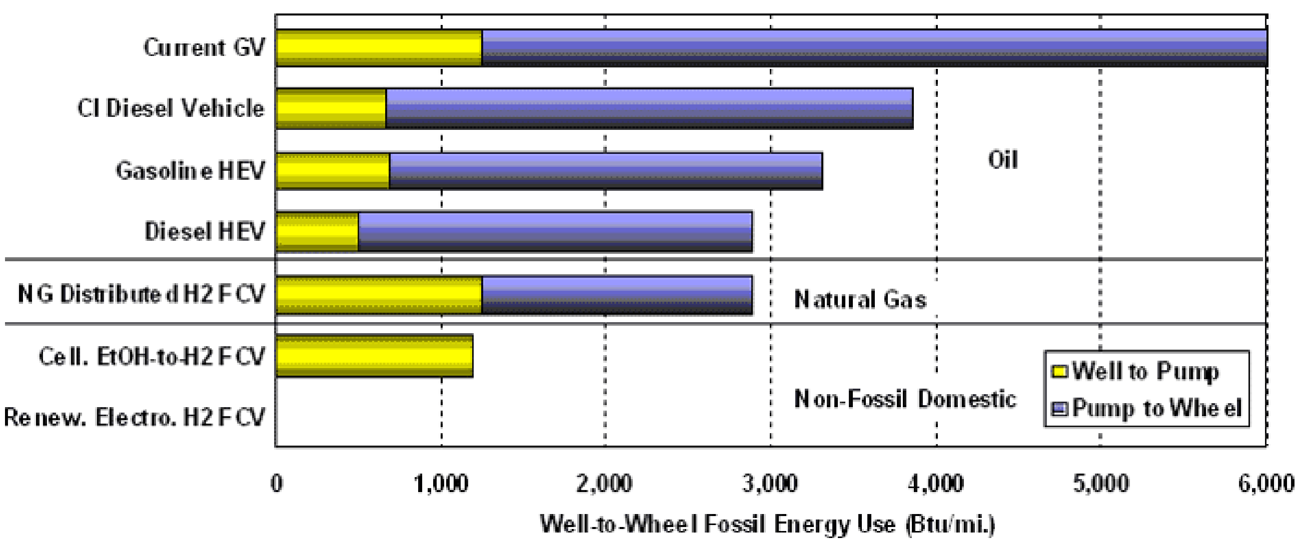

Figure 4. WTW Fossil Energy Use of Selected Vehicle/Fuel Systems

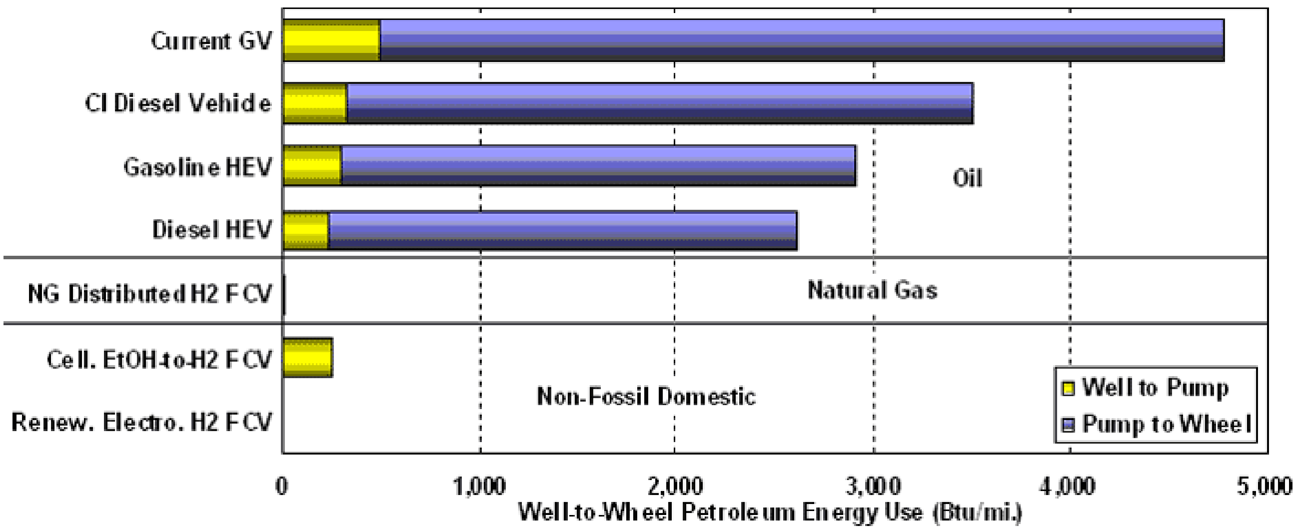

Figure 5. WTW Petroleum Use of Selected Vehicle/Fuel Systems

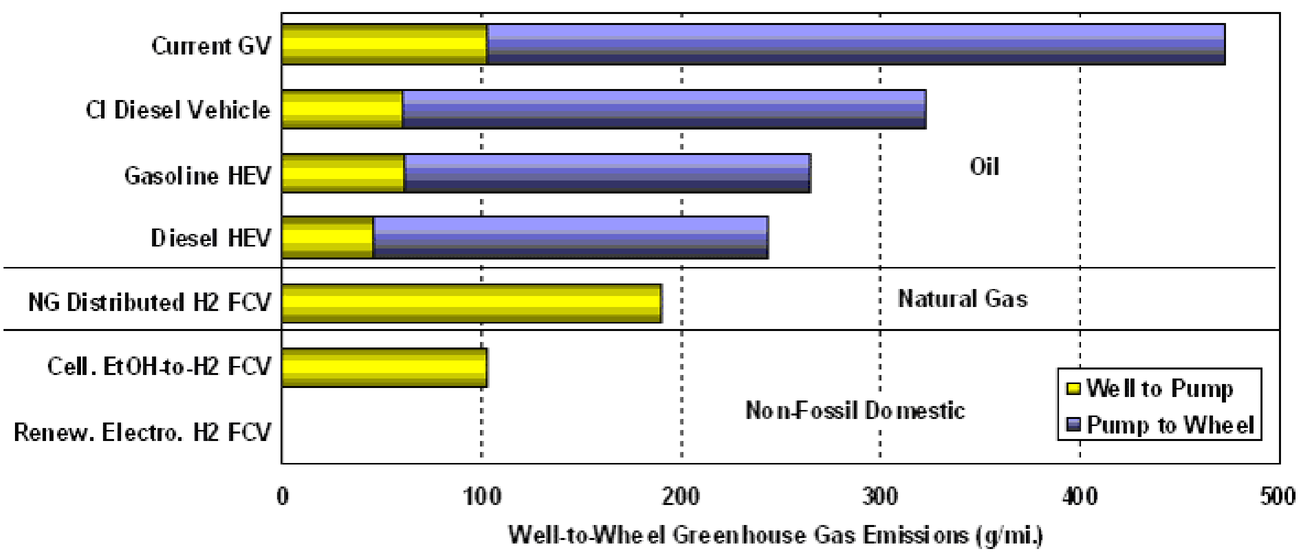

Figure 6. WTW Greenhouse Gas Emissions of Selected Vehicle/Fuel Systems