Estimating Greenhouse Gas Emissions of the Production and Use of Alternative Transportation Fuels for EPAct Petitions

Sec. 301(2) of the Energy Policy Act of 1992 (EPAct) provides the U.S. Department of Energy (DOE) with the authority to designate additional fuels as "alternative" if DOE finds the fuel to be "substantially not petroleum and yields substantial energy security benefits and substantial environmental benefits." In determining environmental benefits of a given fuel, DOE takes into account emissions of greenhouse gases (GHG) from its production and use.

One of the primary environmental benefits envisioned from EPAct provisions is reducing greenhouse gases. There is also potential for production and use of some nonpetroleum fuels to cause increases in GHG emissions relative to petroleum gasoline and diesel. Production of nonpetroleum fuels is subject to activities considerably different from those of petroleum gasoline and diesel, which alternative fuels are intended to replace. These differences can result in different energy conversion efficiencies and GHG emissions in fuel production and distribution. To estimate GHG reductions or increases, DOE uses fuel-cycle analysis, or well-to-wheels (WTW) analysis, to determine potential the GHG emission effects of transportation fuels (see "Guidelines for Submission of Petitions for Designation of Alternative Fuels Under EPAct Sec. 301(2)" at www.eere.energy.gov/vehiclesandfuels/epact/pdfs/pseries_guidelines.pdf).

This document provides general guidelines on how to conduct analysis of GHG emissions of alternative fuels in preparing alternative fuel petitions for DOE's consideration.

Coverage and Methodology of Well-to-Wheels Analysis

A WTW analysis includes the feedstock, fuel, and vehicle operation stages (see Figure 1). The feedstock and fuel stages are called the "well-to-pump" (WTP) or "upstream" stages; the vehicle operation stage is called the "pump-to-wheels" (PTW) or "downstream" stage. Since differences occur in both WTP and PTW stages for candidate fuels versus petroleum gasoline and diesel, a complete evaluation of GHG emission effects of candidate fuels requires a WTW analysis of alternative fuels, petroleum gasoline, and petroleum diesel.

In particular, a WTW analysis for alternative fuels includes:

- Production of feedstocks (natural gas, coal, biomass, etc., for feedstock production. Input parameters with significant amounts, such as fertilizer for biomass growth, should be taken into account.)
- Transportation of feedstocks from production sites to fuel production plants
- Fuel production in plants
- Transportation and distribution of alternative fuels
- Vehicle operation with alternative fuels

Similarly, a WTW analysis for petroleum gasoline and diesel includes:

- Petroleum recovery
- Petroleum transportation from oil fields to petroleum refineries
- Petroleum refining at refineries
- Gasoline and diesel transportation and distribution
- Vehicle operation with gasoline and diesel

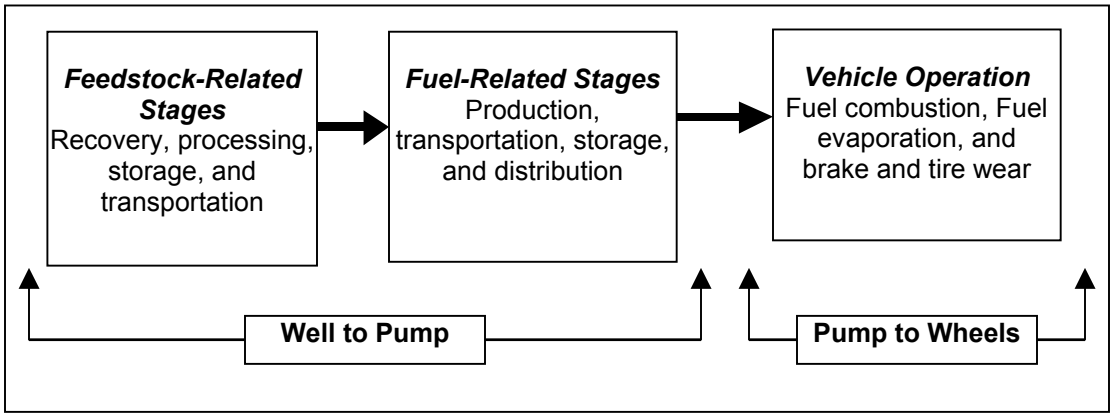
GHG emissions for each type of WTW analysis can be estimated with the amount of process fuels consumed for the activity and GHG emissions per unit of process fuels used. For carbon dioxide (CO_2) emissions, the carbon balance method should be used. This method estimates CO_2 emissions by taking

carbon in process fuel minus carbon in emissions of hydrocarbon (including methane) and carbon monoxide during fuel combustion. The remaining volume of carbon atoms is assumed to form CO_2.

GHG emissions should include emissions of CO_2, methane (CH_4), and nitrous oxide (N_2O)—the three major GHGs included in the assessments of the Intergovernmental Panel on Climate Change (IPCC). Furthermore, the three GHGs should be combined with their global warming potentials (1, 23, 296 for CO_2, CH_4, and N_2O, respectively) recommended by IPCC to derive CO_2-equivalent GHG emissions.

Besides emissions from combustion of process fuels, emissions from noncombustion sources in significant amounts (such as CO_2 and CH_4 emissions from petroleum recovery and natural gas processing) and N_2O emissions from nitrification and denitrification in soil (for biofuel production) should be taken into account to the extent possible.

Figure 1. Activities Covered in a Well-to-Wheels Analysis for Transportation Fuels



Key Data for WTW Analysis

It is crucial that the WTW analysis in a fuel petition is transparent so DOE (and other reviewers) can conduct independent analyses to verify the results presented in a petition. For the purpose of transparency, key input data in a WTW analysis need to be presented explicitly.

The following is a list of key input parameters for which data need to be presented for analysis.

- **Type of feedstocks for fuel production:** A petition must explain whether natural gas, coal, biomass, or other feedstock will be used for fuel production. This information is especially important for fuels that can be produced from multiple feedstock sources.
- **General locations of fuel production:** This information will help DOE determine the transportation logistics for alternative fuels in its independent analysis. It will also shed light on whether a production option offers geographic diversity in supplying a given fuel.
- **Energy and carbon efficiencies of key well-to-pump stages:** These could be the most important factors in determining WTW GHG emissions. Energy and carbon efficiencies could differ among potential production technologies. Production processes should be defined in enough detail to differentiate them from other potential processes in producing similar fuels. Energy and carbon efficiencies of fuel production facilities should include energy use in and carbon emissions from all necessary units, including preproduction and final fuel processing.
- **Fuel properties:** These include heat (in both lower and higher heating values), carbon, and sulfur contents.
- **Fuel consumption differences:** This is a comparison of candidate fuels, petroleum gasoline, and petroleum diesel for use in motor vehicles. The types of vehicles used (such as passenger cars, buses,

trucks) for determining fuel consumption differences must be specified. Data verifying how the parameters were determined should also be included.

- **Emission performance:** This covers the emissions performance of vehicles fueled with candidate fuels, petroleum gasoline, and petroleum diesel. This information may be used for estimating the GHG emissions of vehicle operation.

Dealing with Joint Products from Alternative Fuel Production Plants

Some fuel production plants produce multiple products. For example, Fischer-Tropsch diesel plants produce diesel, naphtha, wax, and other products. In a WTW analysis, conceptually, either a system boundary expansion or allocation approach could be used with multiple products.

With the allocation approach, energy use and emissions from a candidate fuel plant are allocated to products from the plant based on their energy output shares. Similarly, energy use and emissions from the petroleum refinery are allocated to petroleum products. The allocated energy use and emissions of alternative fuels, petroleum gasoline, and petroleum diesel are compared with each other on a WTW basis. The allocation approach is a well-accepted method for analyzing transportation fuels. The method is well understood and clearly allocates benefits and costs to different products (and consequently to different economic sectors).

With the system boundary expansion (SBE) approach, a nonpetroleum fuel plant system is compared with a petroleum refinery system, each potentially including a variety of products and markets. The systems are defined for comparison with each other to include whatever additional facilities and activities are necessary to match the functions of the two systems. While the SBE approach may be conceptually a more appealing method, it has two major issues that need to be addressed further. First, its application involves considerable uncertainty as to how the same functions would be served in two competing systems, particularly since price and substitution interactions are likely between the two "systems." Some of this can be addressed with sensitivity cases of how different functions are served with each system. But DOE believes that in many cases the multiplicity of potential secondary impacts and their high complexity will often make meaningful use of SEB impractical.

The second issue with the SBE approach is the attribution of all energy and emission benefits from a multifunction system to the transportation fuel. The petition for EPAct designation should focus on results (benefits) that can be clearly, directly, and causally attributed to the transportation fuel. Governmental policy and programs generally must be extremely careful to avoid providing multiple environmental credits for the same benefits, which is likely to occur when programs give credit broadly for benefits occurring outside their own program area.

These same benefits could be claimed as credits in setting policy in a separate program. Moreover, where benefits are attributed to transportation fuel for results of other products (or absence of other products), the lower the percentage of a plant's production that is transportation fuel, the higher will be the funneling of such benefits to the transportation fuel on a volumetric basis. This suggests obvious potential anomalies and inequities. For these reasons, petitioners should be aware of methodological problems, which DOE believes remain to be resolved.

Available Resources for WTW Analyses

DOE supports WTW modeling of advanced vehicle technologies and new transportation fuels at Argonne National Laboratory. Argonne developed the GREET model (which stands for Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation) to provide a tool for practitioners to use to evaluate transportation fuels, including a variety of alternative fuels. The GREET model is available to the public and can be downloaded from www.transportation.anl.gov/software/GREET/index.html.

Argonne conducted a WTW analysis of Fischer-Tropsch diesel for DOE's Fischer-Tropsch diesel rulemaking (see "Assessment of Well-to-Wheels Energy Use and Greenhouse Gas Emissions of Fischer-Tropsch Diesel" at www.eere.energy.gov/vehiclesandfuels/epact/pdfs/ftd_docket/greenhouse_gas.pdf).

Potential fuel petitioners are encouraged to input their own data into the GREET model to assess GHG effects of alternative fuels. Other modeling tools can be used as long as input data and methodologies are well documented. Petitioners should keep in mind that DOE has a duty to carefully evaluate the validity of such methodologies and that the public must also be given opportunity to do so. DOE is also likely to perform its own analysis using the GREET model.

For more information on the Alternative Fuel Designation Authority, e-mail fuel_petitions@afdc.nrel.gov.