Updates to Parameters of Hydrogen Production Pathways in GREET™

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1. Introduction

The Greenhouse gases, Regulated Emissions, and Energy use in Transportation (GREET™) model calculates well-to-wheels (WTW) energy use and emissions for various central and distributed hydrogen production pathways. In this memo, we document updates to the hydrogen production energy efficiency and process fuel shares in GREET based on the latest H2A production models[1] developed at National Renewable Energy Laboratory (NREL) with support from the DOE Fuel Cell Technologies Office (FCTO). These H2A estimates are added as GREET defaults for the various hydrogen pathway options while the original pathways options and estimates in GREET are maintained as user defined options. The updated central hydrogen production pathways based on H2A models include both current and future technology cases for natural gas steam methane reforming (SMR) with and without carbon capture and storage (CCS), coal gasification with and without CCS, biomass gasification, and nuclear high-temperature electrolysis. The updated H2A distributed (forecourt) hydrogen production pathways include both current and future technology cases for natural gas steam methane reforming (SMR), water electrolysis, and ethanol reformation. The original feedstock properties in GREET for coal, biomass and natural gas are maintained.

2. Central Hydrogen Production Pathways

2.1 Natural Gas SMR

The production efficiency of hydrogen via SMR of natural gas was updated based on H2A model version 3.0 for current and future case studies as shown in the following table for two scenarios: with and without CCS. The energy for CCS in the H2A models translates to 355 kWh/ton of carbon for both current and future cases.

[1] http://www.hydrogen.energy.gov/h2a_prod_studies.html

	H2A			
	Current w/o CCS	Future w/o CCS	Current w/ CCS	Future w/ CCS
Production efficiency	**72.0%**	**72.1%**	**70.8%***	**70.8%***
Production efficiency, **NOT** including energy for CCS (**GREET format**)	**72.0%**	**72.1%**	**72.2%**	**72.2%**
CCS Energy (kWhe/ton C)	**N/A**	**N/A**	**357**	**357**

*Adjusted the H2A model (V3.0) efficiency to correctly count the energy for CCS

2.2 Coal Gasification

The production efficiency of hydrogen via gasification of coal was updated based on H2A model version 2.1.1 for current and future case studies as shown in the following table for two scenarios: with and without CCS. The table shows also the energy intensity for CCS and the amount of electricity co-product exports.

	H2A			
	Current w/o CCS	Future w/o CCS	Current w/ CCS	Future w/ CCS
Production efficiency, including electricity coproduction and energy for CCS	**55.9%**	**64.2%**	**53.6%***	**60.7%***
Production efficiency, **NOT** including electricity coproduction or energy for CCS (**GREET format**)	**51.0%**	**44.3%**	**55.3%**	**44.3%**
Co-product Electricity Output (kWh/mmBtu H2)	**26.9**	**132**	**0**	**110**
CCS Energy (kWhe/ton C)	**N/A**	**N/A**	**357**	**357**

*Adjusted the H2A model (V2.1.1) efficiency to correctly count the electricity export and the energy for CCS

2.3 Biomass Gasification

The production efficiency of hydrogen via gasification of biomass and the process fuel shares were updated based on H2A model version 3.0 for current and future case studies as shown in the following table.

	H2A	
	Current	Future
Production efficiency	**46.1%**	**48.3%**
Process input share: Biomass	**93.1%**	**94.9%**
Process input share: Natural Gas	**4.4%**	**2.4%**
Process input share: Electricity	**2.5%**	**2.6%**

2.4 Central Electrolysis

The production efficiency of hydrogen via electrolysis was updated based on H2A model version 3.0 for current and future case studies as shown in the following table.

	H2A	
	Current	Future
Production efficiency	**66.8%**	**72.6%**

2.5 Nuclear High-Temperature Electrolysis

The production efficiency of hydrogen via nuclear high-temperature electrolysis was updated based on H2A model version 2.1.1 for current and future case studies as shown in the following table.

	H2A	
	Current	Future
Production efficiency	**83.4%**	**83.4%**

3. Distributed (Forecourt) Hydrogen Production Pathways

3.1 Natural Gas SMR

The production efficiency of hydrogen via distributed natural gas SMR and the process fuel shares were updated based on H2A model version 3.0 for current and future case studies as shown in the following table.

	H2A	
	Current	Future
Production efficiency*	**71.4%**	**74.2%**
Process input share: Natural Gas	**91.7%**	**80.5%**
Process input share: Electricity	**8.3%**	**19.5%**

* Adjusted the H2A model (V3.0) efficiency to discount the compression energy for dispensing, which is calculated separately in GREET

3.2 Water Electrolysis

The production efficiency of hydrogen via distributed water electrolysis was updated based on H2A model version 3.0 for current and future case studies as shown in the following table.

	H2A	
	Current	Future
Production efficiency*	**66.8%**	**72.6%**

* Adjusted the H2A model (V3.0) efficiency to discount the compression energy for dispensing, which is calculated separately in GREET

3.3 Ethanol Reformation

The production efficiency of hydrogen via distributed ethanol reformation and the process fuel shares were updated based on H2A model version 3.0 for current and future case studies as shown in the following table.

	H2A	
	Current	Future
Production efficiency	**67.1%**	**72.0%**
Process input share: Ethanol	**97.0%**	**84.8%**
Process input share: Electricity	**3.0%**	**15.2%**

* Adjusted the H2A model (V3.0) efficiency to discount the compression energy for dispensing, which is calculated separately in GREET

References

DOE, Office of Energy Efficiency and Renewable Energy (EERE), Hydrogen Production Analysis (H2A) models http://www.hydrogen.energy.gov/h2a_prod_studies.html.