

February 19, 2025

Demo for Hydrogen in R&D GREET[®]

3:00-4:00 p.m. CT

Instructors

Gabrielle Olson, Great Plains Institute

Branden Leonhardt, Department of Energy

Argonne National Laboratory Subject Matter Experts

Amgad Elgowainy, Pradeep Vyawahare, Clarence Ng



**GREAT PLAINS
INSTITUTE**

Argonne
NATIONAL LABORATORY

U.S. Department of
ENERGY

R&D GREET disclaimer

The R&D GREET effort at Argonne National Laboratory is supported by the Office of Energy Efficiency and Renewable Energy, the Office of Fossil Energy and Carbon Management, the Office of Clean Energy Demonstration, the Office of Technology Transitions, the Office of Nuclear Energy, and ARPA-E of the US Department of Energy (DOE) under contract DE-AC02-06CH11357. The views and opinions expressed herein do not necessarily state or reflect those of the US government or any agency thereof. Neither the US government nor any agency thereof, nor any of their employees, makes any warranty, expressed or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights.

Argonne's R&D GREET is to inform the life cycle analysis of technical community. Not all pathways and data in R&D GREET are appropriate for use in circumstances where a high level of quantitative certainty or precision is required. GREET is referenced in numerous independent state and federal compliance and incentive programs (including solicitations, rulemakings, and tax incentives), but it is important to note that R&D GREET is not the version used by any of these specific programs. Argonne does not warrant that use of R&D GREET is consistent with the requirements of any particular regulatory or incentive program.



**GREAT PLAINS
INSTITUTE**

Argonne
NATIONAL LABORATORY

U.S. Department of
ENERGY

GREET end-user licensing terms and conditions

Commercial use:

For commercial use, please contact www.anl.gov/partners.

Non-commercial use:

This license is based on the Creative Commons Attribution-Non Commercial 4.0 International Public License, with the following modified definition. Non-Commercial means internal use (including use for internal business or operational purposes by for-profit entities), use by non-profit entities, or use for United States federal, state, or local government purposes. Government purposes include work performed pursuant to a United States federal, state, or local government funding agreement, and work performed by or on behalf of the United States federal, state, or local government. For purposes of this Public License, the exchange of the Licensed Material for other material subject to Copyright and Similar Rights by digital file-sharing or similar means is Non-Commercial provided there is no payment of monetary compensation in connection with the exchange.

Redistribution and use of the GREET software are permitted for non-commercial uses and provided that the following conditions are met:

1. Redistributions of the GREET software must retain the above copyright notice, this list of conditions, and the following disclaimer. Modification or reverse compilation of the source code is not permitted.
2. Neither the names of UChicago Argonne, LLC or the Department of Energy nor the names of its contributors may be used to endorse or promote products derived from this software without prior written permission.
3. The software redistribution, if any, must include the following acknowledgment: "This product includes software produced by UChicago Argonne, LLC under Contract No. DE-AC02-06CH11357 with the Department of Energy."
4. Any published results should indicate that the GREET software was developed by Argonne National Laboratory. If you publish results generated using GREET you should identify the GREET software version number. If you publish results generated using input data other than the input data supplied with the GREET software you must indicate that these results relied upon changed input data.



**GREAT PLAINS
INSTITUTE**



Table of contents

1. Outline Steps for Hydrogen Scenarios
2. Hydrogen Scenarios
 - a. Determine WTG Emissions from Gaseous SMR Hydrogen
 - b. Determine WTG Emissions from Gaseous PEM Electrolysis Hydrogen
 - c. Determine WTG Emissions from Nuclear-Powered PEM Electrolysis
 - d. Determine CO₂ Emissions from Ammonia Production
 - e. Model an FCV Using Gaseous Hydrogen from SMR and PEM Electrolysis



Outline Steps for Hydrogen Scenarios



**GREAT PLAINS
INSTITUTE**



Argonne
NATIONAL LABORATORY



U.S. Department of
ENERGY

Main Outputs for SI-ICE LDVs and FCV LDVs



GREAT PLAINS
INSTITUTE

Argonne
NATIONAL LABORATORY

U.S. Department of
ENERGY

File Home Insert Draw Page Layout Formulas Data Review View Automate Help

Clipboard Font Alignment Number Styles Cells Editing Sensitivity Add-ins Analyze Data

RSELSICEV Select Fuels

Home Inputs Back to Top WTP Results WTP Changes

WTW Results Menu Select a vehicle type from a pink drop down menu, then press "Go"

SI ICE Vehicles Select Fuels Go

SI - LPG Vehicle Go

SI - Dedi. MeOH Vehicle Go

SI - Dedi. EtOH Vehicle Go

SI - Gaseous H2

SI - Liquid H2

SI - RG from Bio Oil

SI - RG from Pyrolysis

SI - RG from IDL

SI - RG via CFP

SI - High Octane Fuel (E10)

SI - High Octane Fuel (E25)

SI - High Octane Fuel (E40)

SI Hybrid Vehicles (HEV) Select Fuels Go

CIDI Hybrid Vehicles (HEV) Select Fuels Go

BEV and FCV Select Fuels Go

SI Plug-in Hybrids (PHEV) Select Fuels Go

CIDI Plug-in Hybrids (PHEV) Select Fuels Go

N/A

GCI ICE Vehicles Select Fuels Go

Performance-enhancing Fuels Select Fuels

Select units from a pink drop down menu for the Results

Per Energy in Fuels

emission Unit: g Energy Unit: Btu Emission Unit: g

Functional Unit: mile Energy Functional Unit: mmBtu

1. Well-to-Pump Energy Consumption and Emissions: Btu or Gallon or g per mmBtu of Fuel Available at Fuel Station Pumps

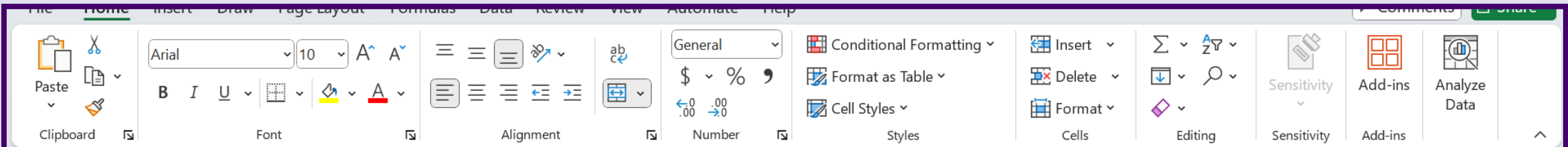
	Baseline Gasoline	CA Gasoline	Low-Level EtOH Blend with Gasoline (E10, Corn)	Baseline Conventional and LS Diesel	Compressed Natural Gas, NA NG	Liquefied Natural Gas, NA NG	Liquefied Petroleum Gas, Crude and NG Mix	NA NG	MeOH FFV, NA NG	Dedi. MeOH Vehicles,	FCV: NA NG	FFV, Corn	FFV: BtOH100, Corn	Dedi. EtOH Vehicle,
14 Total Energy	270,595	259,720	270,595	180,772	161,390	198,604	138,370	75						
15 WTP Efficiency	78.7%	79.4%	78.7%	84.7%	86.1%	83.4%	87.8%	5						
16 Fossil Fuels	242,287	232,533	242,287	174,811	150,628	197,299	135,738	77						
17 Coal	11,391	10,031	11,391	8,275	14,686	1,869	3,735	-3						
18 Natural Gas	159,788	163,719	159,788	120,844	135,051	189,133	119,478	807,950	367,460	414,364	470,460	360,330	666,643	360,336
19 Petroleum	74,400	59,700	74,400	45,000	0	0	40,500	0	0	0	0	0	0	0

Overview Inputs Results Petroleum Co_processing NG MeOH_FTD EtOH Electric Generation_mixes Bio

Ready Calculate Accessibility: Investigate Display Settings 85%

Note: press F9 to ensure the results of R&D GREET are up to date





RSELBEVFCV Select Fuels

Home | Inputs | Back to Top | WTP Results | WTP Changes

WTW Results Menu Select a vehicle type from a pink drop down menu, then press "Go"

SI ICE Vehicles Select Fuels	Go	SI Hybrid Vehicles (HEV) Select Fuels	Go	SI Plug-in Hybrids (PHEV) Select Fuels	Go	Performance-enhancing Fuels Select Fuels
SIDI ICE Vehicles Select Fuels	Go	CIDI Hybrid Vehicles (HEV) Select Fuels	Go	CIDI Plug-in Hybrids (PHEV) N/A	Go	
CIDI ICE Vehicles Select Fuels	Go	BEV and FCV Select Fuels	Go	GCI ICE Vehicles Select Fuels	Go	

Unit Selection Select units from a pink drop down menu

Per Vehicle Distance Travelled

Energy Unit: Btu Emission Unit: g
Service Functional Unit: mile

1. Well-to-Pump Energy Consumption, Water Consumption and Emissions per mmBtu of Fuel Available at Fuel Station Pumps

	Baseline Gasoline	CA Gasoline	Low-Level EtOH Blend with Gasoline (E10, Corn)	Baseline Conventional and LS Diesel	Compressed Natural Gas, NA NG	Liquefied Natural Gas, NA NG	Liquefied Petroleum Gas, Crude and NG Mix	NA NG	eOH FFV, NA NG	edi. MeOH Vehicles,	FCV: NA NG	FFV, Corn	FFV: BtOH100, Corn	EtOH Vehicle, Corn
Total Energy	270,595	259,720	270,595	180,772	161,390	198,604	138,370	75,000	387,480	414,384	476,488	380,536	606,643	380,536
WTP Efficiency	78.7%	79.4%	78.7%	84.7%	86.1%	83.4%	87.8%	80.0%	80.0%	80.0%	80.0%	80.0%	80.0%	80.0%
Fossil Fuels	242,287	232,533	242,287	174,811	150,628	197,299	135,738	77,000	387,480	414,384	476,488	380,536	606,643	380,536
Coal	11,391	10,031	11,391	8,275	14,686	1,869	3,735	-34,000	0	0	0	0	0	0
Natural Gas	159,788	163,719	159,788	120,844	135,051	189,133	119,478	807,936	387,480	414,384	476,488	380,536	606,643	380,536

Note: press F9 to ensure the results of R&D GREET are up to date

Overview | **Inputs** | Results | Petroleum | Co_processing | NG | MeOH_FTD | EtOH | Electric | Generation_mixes | Bio

Hydrogen Overview



**GREAT PLAINS
INSTITUTE**



Argonne
NATIONAL LABORATORY



U.S. Department of
ENERGY

General Settings to Alter a Hydrogen Pathway



**GREAT PLAINS
INSTITUTE**

Argonne 
NATIONAL LABORATORY

U.S. Department of
ENERGY

File Home Insert Draw Page Layout Formulas Data Review View Automate Help

Clipboard Font Alignment Number Styles Cells Editing Sensitivity Add-ins Analyze Data

N15

Home Results Petroleum MeOH & Ethanol Electric Vehicles Car_TS Tab LDV1_TS Tab LDV2_TS Tab
 Natural Gas Hydrogen Bio Oil Pyrolysis WTP Vehicles Tab HDV_TS Tab HDV_WTW Tab
 Fuel Economy

Scenario Control Variables and Input Assumptions

1. Key Options for Simulation

1.1) Target Year for Simulation: 2022

1.2) Point-Estimation or Probability-Estimation Option: Load Stochastic Toolkit

Link with GREET2: Reactivate GREET2 Links, Deactivate GREET2 Links

Load Stochastic Toolkit ... To load the stochastic toolkit
 Unload Stochastic Toolkit ... To unload the stochastic toolkit

2. Vehicle Types for Simulation

1 -- Passenger Cars; 2 -- Light-Duty Trucks 1 (LDT1) (Sports utility vehicles [SUV]); 3 -- Light-Duty Trucks 2 (LDT2) (Pickup Truck [PUT])

3. Petroleum-Based Fuels

3.1) Petroleum Recovery Options

3.1.a) Share of crude oil sources

1 -- Basis of share of crude oil sources: 1 -- EIA projection, 2 -- User defined

	U.S. Domestic	Canada (Oil Sands)	Canada (Conv. Crude)	Mexico	Middle East	Lat
EIA projection	80.8%	6.6%	5.0%	1.9%	2.3%	
User defined	0.0%	100.0%	0.0%	0.0%	2.3%	
Used in calculation	80.8%	6.6%	5.0%	1.9%	2.3%	
API gravity	34.0	18.1	26.5	26.5	31.8	
S Content (wt %)	1.4	2.9	1.9	2.2	2.3	
Average transportation distances (mi)	See T&D, Flowcharts tab	1,708	1,708	797	14,596	

U.S. Domestic crude	Shale Oil (Bakken)	Shale Oil (Eagle Ford)	Rest of U.S. domestic crude
API gravity	42	48	32.0
Vol. Share (%)	8.7%	8.0%	83.3%

Overview Inputs Results Petroleum Co-processing NG MeOH FTD EtOH Electric Generation mixes Bio



File Home Insert Draw Page Layout Formulas Data Review View Automate Help

Clipboard Font Alignment Number Styles Cells Editing Sensitivity Add-ins Analyze Data

Y220

6. Hydrogen Production

6.1) Basis of H2 Production Assumptions from Different Technology Pathways

1 -- GREET Default, 2 -- User defined

6.1.a) Scenarios for H2A Model Cases

1 -- Current, 2 -- Future

6.2) Share of H2 Production by Location

	Gaseous H2	Liquid H2
Central Plants	100.0%	100.0%
Refueling Stations	0.0%	0.0%

6.3) Share of H2 Feedstock Sources in Central Plants

	Gaseous H2	Liquid H2
NG	100.0%	100.0%
PEM Electrolysis	0.0%	0.0%
Nuclear (LWR) High Temperature Electrolysis with SOEC	0.0%	0.0%
Nuclear (Thermo-Chemical Cracking of Water)	0.0%	0.0%
High Temperature Electrolysis (Nuclear HTGR or NG)	0.0%	0.0%
Coal	0.0%	0.0%
Biomass	0.0%	0.0%
Integrated fermentation	0.0%	0.0%
Coke Oven Gas	0.0%	0.0%
Byproduct from chlorine plants	0.0%	0.0%
By-product from NGL steam cracker plants	0.0%	0.0%
Pet Coke	0.0%	0.0%
RNG SMR	0.0%	0.0%
NG Autothermal Reforming	0.0%	0.0%
RNG Autothermal Reforming	0.0%	0.0%
Methane Pyrolysis (Using NG)	0.0%	0.0%

Overview Inputs Results Petroleum Co processing NG MeOH FTD EtOH Electric Generation mixes Bio

File Home Insert Draw Page Layout Formulas Data Review View Automate Help

Comments Share

Paste Clipboard Font Alignment Number Styles Cells Editing Sensitivity Add-ins Analyze Data

Y220

6.5) NG Feedstock Options for H2 Production via SMR			
	Gaseous H2	Liquid H2	Note:
Central Plants	1	1	1 -- North American NG, 4 -- Renewable Natural Gas
Distributed Production at Refueling Stations	1	1	

6.6) CO2 Sequestration Options for Central Plant H2 Production			
	Gaseous H2	Liquid H2	Note:
NG-Based SMR H2 Plants	1	1	1 -- Without CO2 sequestration 2 -- With CO2 sequestration
Coal-Based H2 Plants	2	2	
Biomass-Based H2 Plants	1	1	
Pet Coke-to-H2 Plant	1		
ATR H2 Plants	2	2	

6.7) Selection of H2 Plant Design Types				
	NG/RNG	Coal	Biomass	Petcoke
Central Plant G.H2	1	0	0	0
Refueling Station G.H2	0			
Central Plant L.H2	1	0	0	
Refueling Station L.H2	0			

6.8) Selection of Method for Estimating Credits of Co-Products for NG Based Fuel Pathways (Co-products are defined in Section 6.7)				
	NG/RNG	Coal	Biomass	Petcoke
Central Plant G.H2	1	1	1	1
Refueling Station G.H2	1			
Central Plant L.H2	1	1	1	
Refueling Station L.H2	1			

6.9) Electric Generation Source for H2 Production via PEM Electrolysis		
	Gaseous H2	Liquid H2
	1	1

1 -- Solar, 2 -- Wind, 3 -- Hydro, 4 -- Nuclear (LWR), 5-- Mix for transportation use (see 10.2.a)

Overview Inputs Results Petroleum Co_processing NG MeOH_FTD EtOH Electric Generation mixes Bio



File Home Insert Draw Page Layout Formulas Data Review View Automate Help

Clipboard Font Alignment Number Styles Cells Editing Sensitivity Add-ins Analyze Data

Y220

275

276 **6.10) Electric Generation Source for H2 Production via Electrolysis at Refueling Stations**

277

Gaseous H2	Liquid H2	
1	1	1 -- Solar, 2 -- Wind, 3 -- Hydro, 4 -- Nuclear (LWR), 5-- Mix for transportation use (see 10.2.a)

278

279

280 **6.11) Shares of Willow, Poplar, Switchgrass, Corn Stover, Forest Residue, and Miscanthus for H2 production in central plants**

	Willow	Poplar	Switchgrass	Corn Stover
Gaseous H2	0.0%	100.0%	0.0%	0.0%
Liquid H2	0.0%	100.0%	0.0%	0.0%

281

282

283

284

285 **6.12) Simulation Options of Treating H2 produced from Coke Oven Gas (COG)**

Gaseous H2	Liquid H2	
3	3	1 -- Scenario 1: COG is treated as a co-product 2 -- Scenario 2: COG is treated as a byproduct 3 -- Scenario 3: Supplemental NG and electricity use to makeup for BTU withdrawal from separated H2

286

287

288

289 **6.13) Selection of Electricity Generation Mix for H2 liquifaction in Central Plants**

H2 Plant Type	Electricity Mix	
NG-Based Plant	2	1 -- NGCC; 2 -- Mix for stationary use (see 10.2.a)
Solar Energy-Based Plant	2	1 -- Solar; 2 -- Mix for stationary use (see 10.2.a)
Nuclear Plant (HTGR water cracking)	1	1 -- Nuclear; 2 -- Mix for stationary use (see 10.2.a)
Coal-Based Plant	2	1 -- Coal IGCC; 2 -- Mix for stationary use (see 10.2.a)
Biomass-Based Plant	2	1 -- Biomass IGCC; 2 -- Mix for stationary use (see 10.2.a)
COG-Based Plant	2	1 -- Coal IGCC; 2 -- Mix for stationary use (see 10.2.a)

290

291

292

293

294

295

296

297

298 **6.14) Electricity Source for High Temperature Electrolysis with SOEC**

Gaseous H2	Liquid H2	
6	6	1 -- Oil Power Plants, 2 -- NG Power Plants, 3 -- Coal Power Plants, 4 -- Nuclear Power Plants 5 -- Other Renewable Power Plants, 6 -- Mix for transportation use (see 10.2.a), 7 -- NGCC Turbine

299

300

301

302 **6.15) Integrated Fermentation Plant Type**

1	1 -- w/ H2 Recovery, 2 -- w/ Energy Recovery
---	--

303

304

Overview Inputs Results Petroleum Co-processing NG MeOH ETD EtOH Electric Generation mixes Bio



File Home Insert Draw Page Layout Formulas Data Review View Automate Help

Clipboard Font Alignment Number Styles Cells Editing Sensitivity Add-ins Analyze Data

Z1109

13. GREET Default Key Assumptions for Well-to-Pump Activities			
13.18) Hydrogen Production Efficiencies			
13.18.a) Central Plant H2 Production Efficiencies			
		Source	User D
		Gaseous H2	H2 Production for L.H2
		NETL Model	
1100	NA NG feedstock		
1103	Without steam or electricity export	71.8%	71.8%
1104	With steam or electricity export (excluding energy in co-products)	71.8%	71.8%
1105	With steam or electricity export: net steam export credit: Btu of steam per mmBtu of H2 produced	0	213,343
1106	With steam or electricity export: net electricity export credit: kWh per mmBtu of H2 produced		14.01
1107	Feedstock share	69.3%	69.3%
1108	NG share	99.1%	99.1%
1109	Electricity share	0.9%	0.9%
1110	NNA NG feedstock		
1111	Without steam or electricity export	72.1%	72.1%
1112	With steam or electricity export (excluding energy in co-products)		
1113	With steam or electricity export: net steam export credit: Btu of steam per mmBtu of H2 produced		
1114	With steam or electricity export: net electricity export credit: kWh per mmBtu of H2 produced		0.00
1115	NNA FG feedstock		
1116	Without steam or electricity export	72.1%	72.1%
1117	With steam or electricity export (excluding energy in co-products)		
1118	With steam or electricity export: net steam export credit: Btu of steam per mmBtu of H2 produced		
1119	With steam or electricity export: net electricity export credit: kWh per mmBtu of H2 produced		0.00
1120	Coal feedstock		
1121	Gasification in central plants: without steam or electricity co-generation	58.9%	58.9%
1122	Gasification in central plants: without steam or electricity co-generation (CCS)	58.4%	58.4%
1123	Synthesis process for H2 production in central plants: without steam or electricity co-generation		100.0%
1124	Gasification for H2 production in central plants: with steam or electricity co-generation (without accounting Btu in steam or electricity)	44.3%	44.3%
1125	Synthesis process for H2 production in central plants, with steam or electricity co-generation (without accounting Btu in steam or electricity)		100.0%
1126	Net Steam export credit: Btu of steam per mmBtu of H2 produced		0
1127	Net electricity export credit: kWh per mmBtu of H2 produced	0.00	0.00
1128	Biomass feedstock		

Inputs Results Petroleum Co_processing NG MeOH_FTD EtOH Electric Generation_mixes Bio_electricity

File Home Insert Draw Page Layout Formulas Data Review View Automate Help

Clipboard Font Alignment Number Styles Cells Editing Sensitivity Add-ins Analyze Data

Y220

SMR and SMR-CCS Parameters		NETL Model			
		current w/o ccs	current w/ccs	future w/o ccs	future w/ccs
Efficiency		71.8%	65.7%	71.8%	65.7%
Feedstock share		69.3%	66.9%	69.3%	66.9%
NG share		99.08%	91.5%	99.1%	91.5%
Electricity share		0.9%	8.5%	0.9%	8.5%

SMR for Industries Parameters	
Conditions	current w/o ccs
Efficiency	71.8%
Feedstock share	69.3%
NG share	99.1%
Electricity share	0.9%
Steam Export, Btu	213,343

ATR Parameters	wCCS	Units
Efficiency	66.0%	
Feedstock Share	100%	
Electricity	106,596	Btu/mmBtu
Intermediate Fuel	95,562	Btu/mmBtu
Capture Rate	94.5%	

Methane Pyrolysis Parameters	Components	Value	Units (per mmBtu H2)
Inputs	NG	1.733	mmBtu
	Electricity	1.120	mmBtu
	Miscellaneous	0.257	mmBtu
Outputs	Water	26,243	gal
	Steam	274,877	Btu
	Carbon Black	0.0336	ton
	Coke	0.0011	ton
Efficiency	H2 output basis	35.04%	

Coal Gasification Parameters	Fuel share	
	Coal Share	Electricity Share
w/o CCS	97.7%	2.3%
CCS	95.7%	4.3%

Biomass Gasification	Efficiency	Biomass		NG Share	Electricity Share
		Feedstock	Fuel		

Further Explore Hydrogen Scenarios



**GREAT PLAINS
INSTITUTE**



Argonne
NATIONAL LABORATORY



Hydrogen tabs in R&D GREET 1

Primary
Hydrogen

Some Secondary

Ag_Inputs
Petroleum
EtOH
MeOH
E-fuels
Algae
PUP Conversion
Plastics

Inputs
Results
Fuel_Prod_TS
Fuel_Specs
Electricity
Car_TS
Vehicles
Tractor WTW
Rail PTW
EF
T&D
T&D Flowcharts



GREAT PLAINS
INSTITUTE



Hydrogen tabs in R&D GREET 2

Primary

Silicon
Rare Earth
Steel
Nickel

Some Secondary

TEC_Results
MHDV_TEC_Results



**GREAT PLAINS
INSTITUTE**

Argonne
NATIONAL LABORATORY

U.S. Department of
ENERGY

Microsoft Excel ribbon: Home, Insert, Draw, Page Layout, Formulas, Data, Review, View, Automate, Help. Ribbon groups: Clipboard, Font, Alignment, Number, Styles, Conditional Formatting, Format as Table, Cell Styles, Insert, Delete, Format, Cells, Editing, Sensitivity, Add-ins, Analyze Data.

Formula bar: P13

Worksheet: Hydrogen Production Pathways: from NG, Electrolysis, Solar Photovoltaics, Nuclear Energy, Coal, Biomass, Coke Oven Gas, Ethanol, and Methanol

Navigation buttons: Home, Inputs, Results

Section 1: Scenario Control and Key Input Parameters (from the Inputs sheet)

Transportation Fuel Application

	Central Plant: NG	Central Plant: Solar Energy	Central Plant: Nuclear (water cracking)	Central Plant: Electrolysis (HTGR)	Central Plant: Coal	Central Plant: Biomass	Central Plant: Intergrated Fermentation	Central Plant: Temperature Electrolysis with SOFC	Central Plant: Coke oven gas	Central Plant: Byproduct from Chlorine Plants	Central Plant: from NGL Cracker Plants	Central Plant: Pet Coke
Hydrogen Production Facility												
Share of H2 Production: G.H2	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0%	0%	0.0%
Share of H2 Production: L.H2	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0%	0%	

CO2 Sequestration in Central H2 Plants: Percentage of CO2 to Be Captured

	G.H2	L.H2
NG-to-H2 Plant	96.2%	0.0%
Coal-to-H2 Plant	92.5%	92.5%
Biomass-to-H2 Plant	0.0%	0.0%
Pet Coke-to-H2 Plant	0.0%	
ATR-to-H2 Plant	94.5%	94.5%

Conversion factor for HTGR (MWh of electricity or H2 per gram of U-235): 8.7

Conversion factor for High Temperature Electrolysis with SOEC (MWh of H2 per gram of U-235): 14.2

Selection of Method for Estimating Credits of Co-Products for H2 Pathways

Feedstock	NG	Coal	Biomass	Pet Coke	ATR	Methane Pyrolysis
Central Plant G.H2	1	1	1	1	1	1
Refueling Station G.H2	1					

1 -- Displacement method
2 -- Btu-based Allocation

Navigation tabs: Petroleum, Co_processing, NG, MeOH_FTD, EtOH, Electric, Generation_mixes, Bio_electricity, Hydrogen, BioOil



Microsoft Excel ribbon: Home, Insert, Draw, Page Layout, Formulas, Data, Review, View, Automate, Help. Ribbon groups: Clipboard, Font, Alignment, Number, Styles, Cells, Editing, Sensitivity, Add-ins, Analyze Data.

Formula bar: S3, fx

61 Selection of Electricity Generation Mix for H2 production pathways			
62	1	1--U.S. Mix, 2--ASCC Mix, 3--FRCC Mix, 4--HICC Mix, 5--MRO Mix, 6--NPCC Mix, 7--RFC Mix, 8--SERC Mix, 9--SPP Mix, 10--TRE Mix, 11--WECC Mix, 12--CA Mix, 13--User Defined Mix	
64	Share for NGCC wCCS technology (Only for User Defined Mix selection)		0.0% 0.0%
66 Selection of Electricity Generation Mix for H2 liquifaction in Central Plants			
67	H2 Plant Type		
68	NG-Based Plant	2	1 -- NGCC; 2 -- Mix for stationary use (see 10.2.a in the Inputs tab)
69	Solar Energy-Based Plant	2	1 -- Solar; 2 -- Mix for stationary use (see 10.2.a in the Inputs tab)
70	Nuclear Plant (LWR/HTGR water cracking)	1	1 -- Nuclear; 2 -- Mix for stationary use (see 10.2.a in the Inputs tab)
71	Coal-Based Plant	2	1 -- Coal IGCC; 2 -- Mix for stationary use (see 10.2.a in the Inputs tab)
72	Biomass-Based Plant	2	1 -- Biomass IGCC; 2 -- Mix for stationary use (see 10.2.a in the Inputs tab)
73	COG-Based Plant	2	1 -- Coal IGCC; 2 -- Mix for stationary use (see 10.2.a in the Inputs tab)
75 G.H2 Production: Non-Combustion Emissions			
		g/mmBtu of H2 output	g/mmBtu of NG inptus
77	VOC	0.965	0.693
78	CO	1.261	0.906
79	NOx	1.645	1.182
80	PM10	1.207	0.867
81	PM 2.5	1.164	0.836
82	SOx	0.027	0.019
84 Yeast and Enzyme Use in Intergrated Fermentation			
		Gaseous H2	Liquid H2
86	Ammonia (kg/ mmbtu H2)	0.894	0.894
87	NaOH (kg/ mmbtu H2)	3.414	3.414
88	H2SO4 (kg/ mmbtu H2)	1.821	1.821
89	Glucose (kg/ mmbtu H2)	2.945	2.945

Worksheet tabs: Bio_electricity, Hydrogen, BioOil, Algae, Macroalgae, Waste, RNG, Pyrolysis_IDL, IBR, E_fuel, Fuel_Prod_TS



File Home Insert Draw Page Layout Formulas Data Review View Automate Help

Paste Font Alignment Number Styles Cells Editing Sensitivity Add-ins Analyze Data

S3

93	Electrolysis Pathways			
94	Share of co-product O2 exported	100%		
95	O2 Byproduct (ton/mmBtu H2)	0.077		
96	0	0--No co-product credit, 1--With O2 co-product credit		
97				
98	Biogenic CH4 in RNG (g/mmBtu)	390		
99				
100	ATR Pathways: By Product			
101	Share of by-product N2 exported	100%		
102	N2 Byproduct (ton/mmBtu H2)	0.142		
103	0	N2 Byproduct option (0: No by-product credit, 1:		
104				
105	1.1) H2 production from chloralkali process			
106	H2 handling method	3	<ul style="list-style-type: none"> 1 -- H2 diverted from vented emissions (carrying no energy/emissions burdens) 2 -- H2 diverted from internal combustion (NG substituting H2) 3 -- H2 as co-products allocated by mass 4 -- H2 as coproducts allocated by market value 	
107				
108				
109				
110				
111		Cl2	NaOH	H2
112	Co-products (kg/kg H2)	35.1	39.6	1
113	Market Values (\$/kg)	0.255	0.441	1
114	Mass share	46.3%	52.4%	1.3%
115	Market value share	32.6%	63.7%	3.6%
116				
117	Energy use before allocation			
118		Diaphragm		Membrane
119	Capacity Share	55%		45%
120	Water consumption (gal/kg H2)	21.4		21.4
121	Energy use (mmBtu/ka H2)	Electricity	Heat (as NG use)	Electricity

Bio_electricity Hydrogen BioOil Algae Macroalgae Waste RNG Pyrolysis_IDL IBR E_fuel Fuel_Prod_TS



File Home Insert Draw Page Layout Formulas Data Review View Automate Help

Paste Clipboard Font Alignment Number Styles Cells Editing Sensitivity Add-ins Analyze Data

S3

4) Summary of Energy Consumption, Water Consumption, and Emissions: Btu or Gallons or Grams per mmBtu of H2 Throughput at Each Stage													
4.1) Energy Use, Water Consumption, and Total Emissions													
	Central Plants: NG to Gaseous Hydrogen		Central Plants: PEM electrolysis to Gaseous Hydrogen via Solar		Central Plants: Nuclear Energy to Gaseous Hydrogen (Thermo-Chemical Cracking of Water)		Central Plants: Electrolysis (HTGR) to Gaseous Hydrogen		Central Plants: Coal to Gaseous Hydrogen with CCS		Central Plants: Biomass to Gaseous Hydrogen		
	Feedstock	Fuel	Feedstock	Fuel	Feedstock	Fuel	Feedstock	Fuel	Feedstock	Fuel	Feedstock	Fuel	
325	Loss factor		0.961		1.000		1.000		1.000		1.000		1.000
326	Total energy	112,046	373,715	1,750,297	226,234	1,009,396	226,234	1,209,143	168,148	20,047	983,539	38,325	1,554,825
327	Fossil fuels	111,403	330,332	0	184,686	7,822	184,686	9,370	94,489	19,144	927,837	37,895	308,872
328	Coal	923	62,176	0	59,546	1,821	59,546	2,181	23,761	1,926	761,366	615	68,699
329	Natural gas	110,020	235,078	0	92,213	4,066	92,213	4,871	38,810	3,418	123,540	10,236	174,563
330	Petroleum	460	33,078	0	32,927	1,935	32,927	2,318	31,918	13,800	42,931	27,043	65,610
331	Water consumption	3.457	54.691	87.055	16.796	163.219	16.796	188.383	14.307	3.863	79.680	1.537	51.426
332	VOC	11.107	4.866	0.000	1.798	0.100	1.798	0.120	0.972	7.322	9.990	1.747	4.794
333	CO	35.006	12.957	0.000	10.873	0.490	10.873	0.587	7.942	1.754	18.735	7.552	23.578
334	NOx	41.190	15.953	0.000	12.729	0.818	12.729	0.979	7.535	4.847	18.863	10.995	34.148
335	PM10	0.406	3.172	0.000	1.480	0.086	1.480	0.103	0.727	8.507	7.684	0.789	2.805
336	PM2.5	0.384	2.393	0.000	0.772	0.052	0.772	0.063	0.347	1.184	1.810	0.688	1.898
337	SOx	11.211	9.495	0.000	7.401	0.471	7.401	0.564	3.041	6.799	27.179	1.172	26.823
338	BC	0.077	0.150	0.000	0.044	0.010	0.044	0.013	0.021	0.035	0.080	0.386	0.545
339	OC	0.162	0.482	0.000	0.208	0.013	0.208	0.016	0.089	0.071	0.321	0.134	0.483
340	CH4	210.790	62.082	0.000	27.165	1.156	27.165	1.385	12.777	147.657	135.939	4.225	46.586
341	N2O	1.417	0.594	0.000	0.237	0.045	0.237	0.054	0.103	0.030	0.332	2.956	3.923
342	CO2	6,624	82,223	0	14,052	563	14,052	675	7,210	1,490	30,116	3,133	22,831
343	CO2 (w/ C in VOC & CO)	6,714	82,259	0	14,075	564	14,075	676	7,225	1,516	30,177	3,150	22,883
344	GHGs	13,382	84,271	0	14,949	611	14,949	732	7,634	5,924	34,319	4,083	25,342
345	4.2) Urban Emissions: Grams per mmBtu of H2 Throughput at Each Stage												
346	Loss factor												
347	VOC	0.594	0.720	0.000	0.314	0.008	0.314	0.010	0.258	0.041	0.372	0.082	0.456

WTG: Energy Consumption, Water Consumption, and Emissions of Hydrogen Pathways for H2 Module													
	Units	Central: NG SMR	Central: Low Temperature Electrolysis PEM using Solar	Central: Coal Gasification with CCS	Central: Biomass Gasification	Central: High Temperature Electrolysis with SOEC using Nuclear LWR	Central: By-product H2 from Chlorine Plants	Central: By-product H2 from NGL Steam Cracker Plants	Distributed: NG SMR	Distributed: Low Temperature Electrolysis PEM using Solar	Central: RNG SMR	Distributed: RNG SMR	
389	Total energy	Btu/mmBtu	551,766	1,750,297	777,351	1,366,916	1,342,922	201,833	1,142,460	634,975	1,760,678	-1,201,714	-991,276
390	Fossil fuels	Btu/mmBtu	549,140	0	762,295	162,082	13,116	162,529	1,135,234	599,813	0	180,330	294,251
391	Coal	Btu/mmBtu	3,763	0	703,746	9,768	2,992	56,335	10,358	50,400	0	54,955	99,227
392	Natural gas	Btu/mmBtu	544,661	0	34,745	92,586	6,797	101,429	1,124,121	547,268	0	123,645	191,912
393	Petroleum	Btu/mmBtu	716	0	23,804	59,727	3,326	4,765	754	2,144	0	1,730	3,112
394	Water consumption	gal/mmBtu	42.141	87.055	66.746	36.167	191.238	17.885	6.020	39.927	87.420	51.711	49.054
395	VOC	g/mmBtu	17.386	0.000	15.513	4.742	0.170	1.542	13.866	17.607	0.000	-25.025	-22.844
396	CO	g/mmBtu	50.998	0.000	9.617	20.257	0.833	5.835	57.994	56.970	0.000	-24.428	-14.971
397	NOx	g/mmBtu	63.517	0.000	10.982	32.414	1.379	9.864	55.864	70.833	0.000	23.712	32.868
398	PM10	g/mmBtu	3.126	0.000	14.712	2.113	0.144	1.313	3.820	3.164	0.000	-3.430	-3.089
399	PM2.5	g/mmBtu	3.028	0.000	2.223	1.814	0.088	0.763	3.712	2.638	0.000	-3.980	-4.046
400	SOx	g/mmBtu	15.934	0.000	26.578	20.594	0.785	7.281	12.685	20.951	0.000	6.828	12.265
401	BC	g/mmBtu	0.356	0.000	0.071	0.887	0.018	0.048	0.614	0.195	0.000	-6.508	-6.352
402	OC	g/mmBtu	0.874	0.000	0.183	0.409	0.022	0.215	1.569	0.537	0.000	0.491	0.172
403	CH4	g/mmBtu	294.075	0.000	256.431	23.646	1.935	26.228	215.650	335.106	0.000	680.982	704.135
404	N2O	g/mmBtu	2.297	0.000	0.124	6.642	0.078	0.250	1.854	2.287	0.000	0.893	0.949
405	CO2	g/mmBtu	92,139	0	17,555	11,912	942	12,064	67,799	96,980	0	13,194	21,779
406	CO2 (w/ C in VOC & CO)	g/mmBtu	92,273	0	17,618	11,958	944	12,078	67,933	97,124	0	13,078	21,684
407	GHGs	gCO2e/mmBtu	101,664	0	25,294	14,476	1,023	12,928	74,866	107,735	0	31,877	41,177
408	VOC: Urban	g/mmBtu	1.305	0.000	0.099	0.224	0.014	0.107	2.387	1.799	0.000	-15.523	-14.252



File Home Insert Draw Page Layout Formulas Data Review View Automate Help

Clipboard Font Alignment Number Styles Cells Editing Sensitivity Add-ins Analyze Data

A1

Navigation Menu: Select the desired pathway from the following drop down lists (highlighted yellow) and click "Go"

Home	Petroleum & Petroleum Products	Go	Natural Gas & Fossil Fuels	Go
Inputs	Conventional Crude Oil for Use in US Refinery		Natural Gas (NG)	
Results	Alternative Fuels	Go	Crops and Feedstocks	Go
Back to Top	Gaseous Hydrogen (G. H2)		Used Cooking Oil	
	Agricultural Products and Chemicals	Go		
	Ammonia as a Final Fertilizer			

Flowcharts for Transportation and Distribution of Transportation Fuels and Feedstocks

ILLUSTRATION:

```

graph LR
    A((Source or Origin)) -- Market Share --> B[Transportation Mode]
    B -- "Transportation Mode Share  
Transportation Distance (miles)" --> C((Port or Destination 47))
  
```

1. Conventional Crude Oil for Use in US Refinery

LDT1_TS LDT2_TS Vehicles Urban_Shares Compression Coal T&D_Flowcharts T&D Uranium ASU Ag_Inp



Microsoft Excel ribbon showing tabs: File, Home, Insert, Draw, Page Layout, Formulas, Data, Review, View, Automate, Help. The Home tab is active, displaying options for Clipboard, Font, Alignment, Number, Styles, Cells, Editing, Sensitivity, Add-ins, and Analyze Data.

AN12

Specifications of Fuels, Global Warming Potentials of Greenhouse Gases, and Carbon and Sulfur Ratios of Pollutants								
1) Specifications of Fuels and Other Substances								
Fuel	Heating Value			Density	C ratio	S ratio	S ratio	LHV/HHV
	Calculation:	LHV	HHV					
Use LHV or HHV in calculations?	1	1 -- LHV; 2 -- HHV		(% by wt)	(ppm by wt)	by wt		
Liquid Fuels:	Btu/gal	Btu/gal	Btu/gal	grams/gal				
Crude oil	129,670	129,670	138,350	3,205	85.3%	16,000	0.016000	0.937
Synthetic crude oil (SCO)	135,085	135,085	144,476	3,266	85.6%	1,800	0.001800	0.935
Bitumen	152,371	152,371	162,964	3,840	83.0%	48,000	0.048000	0.935
Dilbit (After Recovery)	152,371	152,371	162,964	3,840	83.0%	48,000	0.048000	0.935
Dilbit (Before Recovery)	145,194	145,194	155,288	3,500	83.2%	37,227	0.037227	0.935
Diluent	128,449	128,449	137,378	2,709	84.1%	1,600	0.001600	0.935
Shale Oil (Bakken)	125,601	125,601	134,009	3,087	0.853	16000	0.016000	0.937
Shale Oil (Eagle Ford)	122,493	122,493	130,692	2,984	0.853	16000	0.016000	0.937
Gasoline blendstock	116,090	116,090	124,340	2,819	86.3%	10	0.000010	0.934
Gasoline	112,194	112,194	120,439	2,836	82.8%	9	0.000009	0.932
CA gasoline	112,194	112,194	120,439	2,836	82.8%	9	0.000009	0.932
High Octane Fuel (E25)	106,150	106,150	114,388	2,861	77.8%	8	0.000008	0.928
High Octane Fuel (E40)	100,186	100,186	108,416	2,887	72.7%	6	0.000006	0.924
U.S. conventional diesel	128,450	128,450	137,380	3,167	86.5%	200	0.000200	0.935
CA diesel	129,488	129,488	138,490	3,206	87.1%	11	0.000011	
Diesel for non-road engines	128,450	128,450	137,380	3,167	86.5%	11	0.000011	0.935
Low-sulfur diesel	129,488	129,488	138,490	3,206	87.1%	11	0.000011	0.935
Petroleum naphtha	116,920	116,920	125,080	2,745	85.0%	1	0.000001	0.935
Low Octane Gasoline-Like Fuel (LOF)	118,237	118,237	126,586	2,834	85.3%	10	0.000010	0.934
Conventional Jet Fuel	124,307	124,307	132,949	3,036	86.2%	700	0.000700	0.935
ULS Jet Fuel	123,041	123,041	131,595	2,998	86.0%	11	0.000011	0.935
NG-based FT naphtha	111,520	111,520	119,740	2,651	84.2%	0	0.000000	0.931
Residual oil	140,353	140,353	150,110	3,752	86.8%	5,000	0.005000	0.935

Navigation buttons: Home (blue), Inputs (yellow), Results (green).

Excel taskbar showing tabs: AgMining_EF_TS, EF, WCF, Fuel_Specs (active), Car_TS, LDT1_TS, LDT2_TS, Vehicles, Urban_Shares, Compression, Coa.

Hydrogen Scenarios



**GREAT PLAINS
INSTITUTE**



Argonne
NATIONAL LABORATORY



U.S. Department of
ENERGY

G. H₂ SMR

Determine the WTG GHG Emissions of Gaseous H₂
Produced from Steam Methane Reforming (SMR)
with 95% Carbon Capture and Sequestration (CCS)
and Steam Export of 0.15 mmBtu/mmBtu H₂



GREAT PLAINS
INSTITUTE

Argonne
NATIONAL LABORATORY

U.S. Department of
ENERGY

File Home Insert Draw Page Layout Formulas Data Review View Automate Help

Clipboard Font Alignment Number Styles Cells Editing Sensitivity Add-ins Analyze Data

Y220

6.5) NG Feedstock Options for H2 Production via SMR				
		Gaseous H2	Liquid H2	Note:
Central Plants		1	1	1 -- North American NG, 4 -- Renewable Natural Gas
Distributed Production at Refueling Stations		1	1	

6.6) CO2 Sequestration Options for Central Plant H2 Production				
		Gaseous H2	Liquid H2	Note:
NG-Based SMR H2 Plants		1	1	1 -- Without CO2 sequestration 2 -- With CO2 sequestration
Coal-based H2 Plants		2	2	
Biomass-Based H2 Plants		1	1	
Pet Coke-to-H2 Plant		1		
ATR H2 Plants		2	2	

6.7) Selection of H2 Plant Design Types					
		NG/RNG	Coal	Biomass	Petcoke
Central Plant G.H2		1	0	0	0
Refueling Station G.H2		0			
Central Plant L.H2		1	0	0	
Refueling Station L.H2		0			

6.8) Selection of Method for Estimating Credits of Co-Products for NG Based Fuel Pathways (Co-products are defined in Section 6.7)					
		NG/RNG	Coal	Biomass	Petcoke
Central Plant G.H2		1	1	1	1
Refueling Station G.H2		1			
Central Plant L.H2		1	1	1	
Refueling Station L.H2		1			

6.9) Electric Generation Source for H2 Production via PEM Electrolysis		
	Gaseous H2	Liquid H2
	1	1

1 -- Solar, 2 -- Wind

Note: CCS is disabled by default

Overview Inputs Results Petroleum Co_processing NG MeOH_FTD EtOH Electric Generation mixes Bio



File Home Insert Draw Page Layout Formulas Data Review View Automate Help

Clipboard Font Alignment Number Styles Cells Editing Sensitivity Add-ins Analyze Data

NG_GH2_CO2_Sequestration 1

6.5) NG Feedstock Options for H2 Production via SMR				
		Gaseous H2	Liquid H2	Note:
Central Plants		1	1	1 -- North American NG, 4 -- Renewable Natural Gas
Distributed Production at Refueling Stations		1	1	

6.6) CO2 Sequestration Options for Central Plant H2 Production				
		Gaseous H2	Liquid H2	Note:
NG-Based SMR H2 Plants		1	1	1 -- Without CO2 sequestration 2 -- With CO2 sequestration
Coal-Based H2 Plants	1		2	
Biomass-Based H2 Plants	2		1	
Pet Coke-to-H2 Plant				
ATR H2 Plants			2	

6.7) Selection of H2 Plant Design Types				
	NG/RNG	Coal	Biomass	Petcoke
Central Plant G.H2	1	0	0	0
Refueling Station G.H2	0			
Central Plant L.H2	1	0	0	
Refueling Station L.H2	0			

6.8) Selection of Method for Estimating Credits of Co-Products for NG Based Fuel Pathways (Co-products are defined in Section 6.7)				
	NG/RNG	Coal	Biomass	Petcoke
Central Plant G.H2	1	1	1	1
Refueling Station G.H2	1			
Central Plant L.H2	1	1	1	
Refueling Station L.H2	1			

6.9) Electric Generation Source for H2 Production via PEM Electrolysis		
	Gaseous H2	Liquid H2
	1	1

1 -- Solar, 2 -- Wind, 3 -- Hydro, 4 --Nuclear (LWR), 5-- Mix for transportation use (see 10.2.a)

Inputs Results Petroleum Co processing NG MeOH FTD EtOH Electric Generation mixes Bio electricity



File Home Insert Draw Page Layout Formulas Data Review View Automate Help

Clipboard Font Alignment Number Styles Cells Editing Sensitivity Add-ins Analyze Data

Z1109

13. GREET Default Key Assumptions for Well-to-Pump Activities

13.18) Hydrogen Production Efficiencies

13.18.a) Central Plant H2 Production Efficiencies

	Source		User D
	Gaseous H2	H2 Production for L.H2	
NETL Model			
NA NG feedstock			
Without steam or electricity export	71.8%	71.8%	71.8%
With steam or electricity export (excluding energy in co-products)	71.8%	71.8%	71.8%
With steam or electricity export: net steam export credit: Btu of steam per mmBtu of H2 produced	0	213,343	213,343
With steam or electricity export: net electricity export credit: kWh per mmBtu of H2 produced			14.01
Feedstock share			
	69.3%	69.3%	69.3%
NG share			
	99.1%	99.1%	99.1%
Electricity share			
	0.9%	0.9%	0.9%
NNA NG feedstock			
Without steam or electricity export	72.1%	72.1%	72.1%
With steam or electricity export (excluding energy in co-products)			
With steam or electricity export: net steam export credit: Btu of steam per mmBtu of H2 produced			
With steam or electricity export: net electricity export credit: kWh per mmBtu of H2 produced			0.00
NNA FG feedstock			
Without steam or electricity export	72.1%	72.1%	72.1%
With steam or electricity export (excluding energy in co-products)			
With steam or electricity export: net steam export credit: Btu of steam per mmBtu of H2 produced			
With steam or electricity export: net electricity export credit: kWh per mmBtu of H2 produced			0.00
Coal feedstock			
NETL Model			
Gasification in central plants: without steam or electricity co-generation			8.9%
Gasification in central plants: without steam or electricity co-generation (CCS)			4%
Gasification for H2 production in central plants: without steam or electricity co-generation			0%
Gasification for H2 production in central plants: with steam or electricity co-generation (without accounting Btu in steam or electricity)			9%
Synthesis process for H2 production in central plants, with steam or electricity co-generation (without accounting Btu in steam or electricity)			0%
Net Steam export credit: Btu of steam per mmBtu of H2 produced			0
Net electricity export credit: kWh per mmBtu of H2 produced			0.00
Biomass feedstock			

Inputs Results Petroleum Co_processing NG MeOH_FTD EtOH Electric Generation_mixes Bio_electricity

Note: steam export is 0 mmBtu by default

File Home Insert Draw Page Layout Formulas Data Review View Automate Help

Clipboard Font Alignment Number Styles Cells Editing Sensitivity Add-ins Analyze Data

Z1109

13. GREET Default Key Assumptions for Well-to-Pump Activities

13.18) Hydrogen Production Efficiencies

13.18.a) Central Plant H2 Production Efficiencies

	Source		User D
	Gaseous H2	H2 Production for L.H2	Gaseous H2
NETL Model			
NA NG feedstock			
Without steam or electricity export	71.8%	71.8%	71.8%
With steam or electricity export (excluding energy in co-products)	71.8%	71.8%	71.8%
With steam or electricity export: net steam export credit: Btu of steam per mmBtu of H2 produced	0	213,343	213,343
With steam or electricity export: net electricity export credit: kWh per mmBtu of H2 produced			14.01
Feedstock share			
NG share	69.3%		69.3%
Electricity share	99.1%		99.1%
	0.9%		0.9%
NNA NG feedstock			
Without steam or electricity export	72.1%		72.1%
With steam or electricity export (excluding energy in co-products)			
With steam or electricity export: net steam export credit: Btu of steam per mmBtu of H2 produced			
With steam or electricity export: net electricity export credit: kWh per mmBtu of H2 produced			0.00
NNA FG feedstock			
Without steam or electricity export	72.1%	72.1%	72.1%
With steam or electricity export (excluding energy in co-products)			
With steam or electricity export: net steam export credit: Btu of steam per mmBtu of H2 produced			
With steam or electricity export: net electricity export credit: kWh per mmBtu of H2 produced			0.00
Coal feedstock			
NETL Model			
Gasification in central plants: without steam or electricity co-generation	58.9%	58.9%	58.9%
Gasification in central plants: without steam or electricity co-generation (CCS)	58.4%	58.4%	58.4%
Synthesis process for H2 production in central plants: without steam or electricity co-generation			
Gasification for H2 production in central plants: with steam or electricity co-generation (without accounting Btu in steam or electricity)	44.3%	44.3%	56.9%
Synthesis process for H2 production in central plants, with steam or electricity co-generation (without accounting Btu in steam or electricity)			100.0%
Net Steam export credit: Btu of steam per mmBtu of H2 produced			0
Net electricity export credit: kWh per mmBtu of H2 produced	0.00	0.00	0.00
Biomass feedstock			

Inputs Results Petroleum Co_processing NG MeOH_FTD EtOH Electric Generation_mixes Bio_electricity

Type 150,000

Percentage of Carbon Sequestered by Default in Central NG-to-H₂ Plants



**GREAT PLAINS
INSTITUTE**

Argonne
NATIONAL LABORATORY

U.S. Department of
ENERGY

Microsoft Excel ribbon: Home, Insert, Draw, Page Layout, Formulas, Data, Review, View, Automate, Help. Ribbon groups: Clipboard, Font, Alignment, Number, Styles, Conditional Formatting, Format as Table, Cell Styles, Insert, Delete, Format, Cells, Editing, Sensitivity, Add-ins, Analyze Data.

Formula bar: P13

Worksheet Title: Hydrogen Production Pathways: from NG, Electrolysis, Solar Photovoltaics, Nuclear Energy, Coal, Biomass, Coke Oven Gas, Ethanol, and Methanol

Navigation buttons: Home, Inputs, Results

Section 1: 1) Scenario Control and Key Input Parameters (from the *Inputs* sheet)

Table: Transportation Fuel Application

	Central Plant: NG	Central Plant: Solar Energy	Central Plant: Nuclear (water cracking)	Central Plant: Electrolysis (HTGR)	Central Plant: Coal	Central Plant: Biomass	Central Plant: Intergrated Fermentation	Central Plant: Temperature Electrolysis with SOFC	Central Plant: Coke oven gas	Central Plant: Byproduct from Chlorine Plants	Central Plant: from NGL Cracker Plants	Central Plant: Pet Coke
6 Hydrogen Production Facility												
7 Share of H2 Production: G.H2	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0%	0%	0.0%
8 Share of H2 Production: L.H2	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0%	0%	0.0%

Section 9: CO2 Sequestration - Central H2 Plants: Percentage of CO2 to Be Captured

	G.H2	L.H2
10		
11 NG-to-H2 Plant	96.2%	0.0%
12 Coal-to-H2 Plant	92.5%	92.5%
13 Biomass-to-H2 Plant	0.0%	0.0%
14 Pet Coke-to-H2 Plant	0.0%	0.0%
15 ATR-to-H2 Plant	94.5%	94.5%

Section 16: Conversion factor for HTGR (MWh of electricity or H2 per gram of U-235) = 8.7

Section 17: Conversion factor for High Temperature Electrolysis with SOEC (MWh of H2 per gram of U-235) = 14.2

Section 19: Selection of Method for Estimating Credits of Co-Products for H2 Pathways

Feedstock	NG	Coal	Biomass	Pet Coke	ATR	Methane Pyrolysis
20						
21 Central Plant G.H2	1	1	1	1	1	1
22 Refueling Station G.H2	1					

Navigation tabs: Petroleum, Co_processing, NG, MeOH_FTD, EtOH, Electric, Generation_mixes, Bio_electricity, Hydrogen, BioOil

Annotations: 1 - Type 95% (pointing to cell B11); 2 - Press F9 (pointing to cell B11)



Well-to-Gate (WTG) GHG Emissions



**GREAT PLAINS
INSTITUTE**

Argonne
NATIONAL LABORATORY

U.S. Department of
ENERGY

WTG: Energy Consumption, Water Consumption, and Emissions of Hydrogen Pathways for H2 Module													
	Units	Central: NG SMR with CCS	Central: Low Temperature Electrolysis PEM using Solar	Central: Coal Gasification with CCS	Central: Biomass Gasification	Central: High Temperature Electrolysis with SOEC using Nuclear LWR	Central: By-product H2 from Chlorine Plants	Central: By-product H2 from NGL Steam Cracker Plants	Distributed: NG SMR	Distributed: Low Temperature Electrolysis PEM using Solar	Central: RNG SMR with CCS	Distributed: RNG SMR	
388													
389	Total energy	Btu/mmBtu	524,891	1,750,297	777,351	1,366,916	1,342,922	201,833	1,142,460	634,975	1,760,678	-1,403,370	-991,276
390	Fossil fuels	Btu/mmBtu	504,226	0	762,295	162,082	13,116	162,529	1,135,234	599,813	0	48,529	294,251
391	Coal	Btu/mmBtu	29,620	0	703,746	9,768	2,992	56,335	10,358	50,400	0	84,062	99,227
392	Natural gas	Btu/mmBtu	473,126	0	34,745	92,586	6,797	101,429	1,124,121	547,268	0	-38,091	191,912
393	Petroleum	Btu/mmBtu	1,480	0	23,804	59,727	3,326	4,765	754	2,144	0	2,558	3,112
394	Water consumption	gal/mmBtu	68.452	87.055	66.746	36.167	191.238	17.885	6.020	39.927	87.420	78.629	49.054
395	VOC	g/mmBtu	16.544	0.000	15.513	4.742	0.170	1.542	13.866	17.524	0.000	-28.559	-22.927
396	CO	g/mmBtu	45.629	0.000	9.617	20.257	0.833	5.835	57.994	56.862	0.000	-34.584	-15.079
397	NOx	g/mmBtu	57.015	0.000	10.982	32.414	1.379	9.864	55.864	70.693	0.000	14.683	32.727
398	PM10	g/mmBtu	3.165	0.000	14.712	2.113	0.144	1.313	3.820	3.060	0.000	-3.807	-3.193
399	PM2.5				2.223	1.814	0.088	0.763					146
400	SOx				26.578	20.594	0.785	7.281					63
401	BC				0.071	0.887	0.018	0.048					52
402	OC				0.183	0.409	0.022	0.215					72
403	CH4				256.431	23.646	1.935	26.228					35
404	N2O				0.124	6.642	0.078	0.250					49
405	CO2				17,555	11,912	942	12,064					79
406	CO2 (w/ C in VOC & CO)	g/mmBtu	7,350	0	17,618	11,958	944	12,078					84
407	GHGs	gCO2e/mmBtu	16,386	0	25,294	14,476	1,023	12,928					177
408	VOC: Urban	g/mmBtu	1.202	0.000	0.099	0.224	0.014	0.107	2.387	1.741	0.000	-16.695	-14.310

WTG GHG emissions
16,386 g CO₂e/mmBtu

Gaseous hydrogen from SMR with CCS and steam export



GREAT PLAINS INSTITUTE



G. H₂ PEM Electrolysis

Determine the WTG GHG Emissions of Gaseous H₂
Produced from PEM Electrolysis Using the U.S.
Average Electricity Grid Mix While Exporting all
Oxygen Produced



GREAT PLAINS
INSTITUTE

Argonne
NATIONAL LABORATORY

U.S. Department of
ENERGY

Microsoft Excel ribbon: Formulas, Data, Review, View, Automate, Help. Sub-ribbons include: Function Library (AutoSum, Logical, Text, Date & Time, More Functions), Python (Reset, Diagnostics, Initialization), Name Manager (Define Name, Use in Formula, Create from Selection), Formula Auditing (Trace Precedents, Trace Dependents, Remove Arrows), Watch Window, Calculation Options.

Address bar: L218

Worksheet tabs: Inputs, Results, Petroleum, Co_processing, NG, MeOH_FTD, EtOH, Electric, Generation_mixes, Bio_electricity

6. Hydrogen Production

206 **6.1) Basis of H2 Production Assumptions from Different Technology Pathways**

207 Hydrogen Worksheet

208 1 -- GREET Default, 2 -- User defined

209 6.1.a) Scenarios for H2A Model Cases

210 2 1 -- Current, 2 -- Future

211 Results

212 **6.2) Share of H2 Production by Location**

	Gaseous H2	Liquid H2
Central Plants	100.0%	100.0%
Refueling Stations	0.0%	0.0%

213

214 Back to Top

215

216

217 **6.3) Share of H2 Feedstock Sources in Central Plants**

	Gaseous H2	Liquid H2
NG	100.0%	
PEM Electrolysis	0.0%	
Nuclear (LWR) High Temperature Electrolysis with SOEC	0.0%	
Nuclear (Thermo-Chemical Cracking of Water)	0.0%	
High Temperature Electrolysis (Nuclear HTGR or NG)	0.0%	
Coal	0.0%	0.0%
Biomass	0.0%	0.0%
Integrated fermentation	0.0%	0.0%
Coke Oven Gas	0.0%	0.0%
Byproduct from chlorine plants	0.0%	0.0%
By-product from NGL steam cracker plants	0.0%	0.0%
Pet Coke	0.0%	0.0%
RNG SMR	0.0%	
NG Autothermal Reforming	0.0%	
RNG Autothermal Reforming	0.0%	
Methane Pyrolysis (Using NG)	0.0%	
Methane Pyrolysis (Using RNG)	0.0%	

218

219

220

221

222

223

224

225

226

227

228

229

230

231

232

233

234

235

Callouts:

- 1: Callout pointing to the 0.0% value for NG in the 6.3 table.
- 2: Callout pointing to the scrollbar on the right side of the worksheet.

Annotation: Type 0% for NG and 100% for PEM electrolysis



Default Electricity Source for Hydrogen Production via PEM Electrolysis



**GREAT PLAINS
INSTITUTE**

Argonne
NATIONAL LABORATORY

U.S. Department of
ENERGY

File Home Insert Draw Page Layout Formulas Data Review View Automate Help

Comments Share

Paste Clipboard Font Alignment Number Styles Cells Editing Sensitivity Add-ins Analyze Data

Y220

6.5) NG Feedstock Options for H2 Production via SMR			
	Gaseous H2	Liquid H2	Note:
Central Plants	1	1	1 -- North American NG, 4 -- Renewable Natural Gas
Distributed Production at Refueling Stations	1	1	

6.6) CO2 Sequestration Options for Central Plant H2 Production			
	Gaseous H2	Liquid H2	Note:
NG-Based SMR H2 Plants	1	1	1 -- Without CO2 sequestration 2 -- With CO2 sequestration
Coal-Based H2 Plants	2	2	
Biomass-Based H2 Plants	1	1	
Pet Coke-to-H2 Plant	1		
ATR H2 Plants	2	2	

6.7) Selection of H2 Plant Design Types				
	NG/RNG	Coal	Biomass	Petcoke
Central Plant G.H2	1	0	0	0
Refueling Station G.H2	0			
Central Plant L.H2	1	0	0	
Refueling Station L.H2	0			

6.8) Selection of Method for Estimating Credits of Co-Products for NG Based Fuel Pathways (Co-products are defined in Section 6.7)				
	NG/RNG	Coal	Biomass	Petcoke
Central Plant G.H2	1	1	1	1
Refueling Station G.H2	1			
Central Plant L.H2	1	1	1	
Refueling Station L.H2	1			

6.9) Electric Generation Source for H2 Production via PEM Electrolysis		
	Gaseous H2	Liquid H2
	1	1

1 -- Solar, 2 -- Wind, 3 -- Hydro, 4 -- Nuclear (LWR), 5-- Mix for transportation use (see 10.2.a)

Overview Inputs Results Petroleum Co_processing NG MeOH_FTD EtOH Electric Generation mixes Bio



File Home Insert Draw Page Layout Formulas Data Review View Automate Help

Paste Clipboard Font Alignment Number Styles Cells Editing Sensitivity Add-ins Analyze Data

NG_GH2_Electrolysis_PowerPlant

6.9) Electric Generation Source for H2 Production via PEM Electrolysis

	Gaseous H2	Liquid H2	1 -- Solar, 2 -- Wind, 3 -- Hydro, 4 -- Nuclear (LWR), 5 -- Mix for transportation use (see 10.2.a)
1	1	1	

6.10) Electric Generation Stations

1	Liquid H2	1 -- Solar, 2 -- Wind, 3 -- Hydro, 4 -- Nuclear (LWR), 5 -- Mix for transportation use (see 10.2.a)
2		
3	1	

6.11) Shares of Willows for H2 production in central plants

	Willow	Poplar	Switchgrass	Corn Stover	Forest Residue	Miscanthus
Gaseous H2	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%
Liquid H2	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%

6.12) Simulation Options of Treating CO2 produced from Coke Oven Gas (COG)

	Gaseous H2	Liquid H2	1 -- Scenario 1: COG is treated as a co-product 2 -- Scenario 2: COG is treated as a byproduct 3 -- Scenario 3: Supplemental NG and electricity use to makeup for BTU withdrawal from separated H2 for the whole system
3	3	3	

6.13) Selection of Electricity Generation Mix for H2 Liquefaction in Central Plants

H2 Plant Type	Electricity Mix	
NG-Based Plant	2	1 -- NGCC; 2 -- Mix for stationary use (see 10.2.a)
Solar Energy-Based Plant	2	1 -- Solar; 2 -- Mix for stationary use (see 10.2.a)
Nuclear Plant (HTGR water cracking)	1	1 -- Nuclear; 2 -- Mix for stationary use (see 10.2.a)
Coal-Based Plant	2	1 -- Coal IGCC; 2 -- Mix for stationary use (see 10.2.a)
Biomass-Based Plant	2	1 -- Biomass IGCC; 2 -- Mix for stationary use (see 10.2.a)
COG-Based Plant	2	1 -- Coal IGCC; 2 -- Mix for stationary use (see 10.2.a)

6.14) Electricity Source for High Temperature Electrolysis with SOEC

	Gaseous H2	Liquid H2	1 -- Oil Power Plants, 2 -- NG Power Plants, 3 -- Coal Power Plants, 4 -- Nuclear Power Plants 5 -- Other Renewable Power Plants, 6 -- Mix for transportation use (see 10.2.a), 7 -- NGCC Turbine
6	6	6	

6.15) Integrated Fermentation Plant Type

1	1 -- w/ H2 Recovery, 2 -- w/ Energy Recovery
---	--

6.16) Biomass-derived Liquid Reforming

Plant Design	1	1 -- Once-through; 2 -- Recycled
--------------	---	----------------------------------

Inputs Results Petroleum Co_processing NG MeOH_FTD EtOH Electric Generation_mixes Bio_electricity



File Home Insert Draw Page Layout Formulas Data Review View Automate Help

Paste Font Alignment Number Styles Cells Editing Sensitivity Add-ins Analyze Data

P749

1 2 A B C D E F G H I J K

10. Electric Generation

Electric Worksheet

Results

Back to Top

10.1) GREET-Calculated or User-Inputted Emission Factors for Power Plants

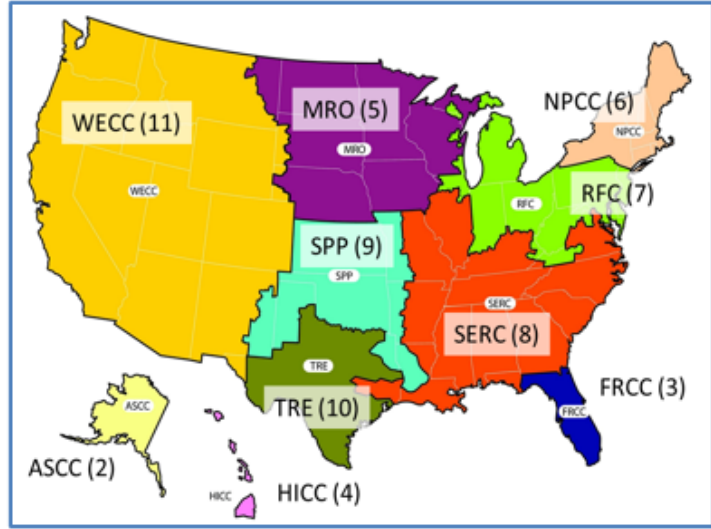
2

1 -- GREET-calculated emissions factors via emission factors in EF Sheet
 2 -- Emission factors based on EPA and EIA database in g/kWh

10.2) Electricity Generation Mix

10.2.a) Selection of Electricity Generation Mix for Transportation Use

Mix for transportation use 1
 Mix for stationary use 1



- 1 U.S. Mix
- 2 ASCC Mix
- 3 FRCC Mix
- 4 HICC Mix
- 5 MISO (former MRO) Mix
- 6 NPCC Mix
- 7 PJM (former RFC) Mix
- 8 SERC Mix
- 9 SPP Mix
- 10 TRE Mix
- 11 WECC Mix
- 12 CA Mix
- 13 User Defined Mix
- 14 NG Power Plants (transportation only)
- 15 Coal Power Plants (transportation only)
- 16 Nuclear Power Plants (transportation only)
- 17 Hydro Power Plants (transportation only)
- 18 NGCC Turbine (transportation only)
- 19 Geothermal (transportation only)

10.2.b) Electric Generation Mixes: Data Table for Use in GREET (From Annual Energy Outlook 2023)

	U.S. Mix		ASCC Mix		FRCC Mix	
	Transportation	Stationary	Transportation	Stationary	Transportation	Stationary
Residual oil	0.3%	0.3%	13.7%	13.7%	0.2%	0.2%
Natural gas	38.5%	38.5%	46.7%	46.7%	71.3%	71.3%
Coal	20.6%	20.6%	11.4%	11.4%	10.4%	10.4%
Nuclear power	18.9%	18.9%	0.0%	0.0%	12.5%	12.5%
Biomass	0.3%	0.3%	0.6%	0.6%	0.2%	0.2%
Others	21.5%	21.5%	27.6%	27.6%	5.5%	5.5%

10.2.c) Electric Generation Mixes for GREET Simulations

Inputs Results Petroleum Co_processing NG MeOH_FTD EtOH Electric Generation_mixes Bio_electricity

File Home Insert Draw Page Layout Formulas Data Review View Automate Help

Clipboard Font Alignment Number Styles Cells Editing Sensitivity Add-ins Analyze Data

O2_CoProduct_Electrolysis 0

1 2 A B C D E F G H I J K L M

93 **Electrolysis Pathways**

94 Share of co-product O2 exported 100%

95 O2 Byproduct (ton/mmBtu H2) 0.077

96 0 No co-product credit, 1--With O2 co-product credit

97 0

98 1 390

99

100 **ATR Pathways: Byproduct**

101 Share of by-product exported 100%

102 N2 Byproduct (ton/mmBtu H2) 0.142

103 0 N2 Byproduct option (0: No by-product credit, 1:

104

105 **1.1) H2 production from chloralkali process**

106 H2 handling method 3

107 1 -- H2 diverted from vented emissions (carrying no energy/emissions burdens)

108 2 -- H2 diverted from internal combustion (NG substituting H2)

109 3 -- H2 as co-products allocated by mass

110 4 -- H2 as coproducts allocated by market value

111

	Cl2	NaOH	H2
112 Co-products (kg/kg H2)	35.1	39.6	1
113 Market Values (\$/kg)	0.255	0.441	1
114 Mass share	46.3%	52.4%	1.3%
115 Market value share	32.6%	63.7%	3.6%

116

117 **Energy use before allocation**

	Diaphragm		Membrane		Capacity Weighted	
118						
119 Capacity Share		55%		45%		
120 Water consumption (gal/kg H2)		21.4		21.4		21.4
121 Energy use (mmBtu/kg H2)						
	Electricity	Heat (as NG use)	Electricity	Heat (as NG use)	Electricity	Heat (as NG use)

122

Petroleum Co_processing NG MeOH_FTD EtOH Electric Generation_mixes Hydrogen BioOil

3 Press F9

4



Well-to-Gate (WTG) GHG Emissions



**GREAT PLAINS
INSTITUTE**

Argonne
NATIONAL LABORATORY

U.S. Department of
ENERGY

WTG: Energy Consumption, Water Consumption, and Emissions of Hydrogen Pathways for H2 Module													
	Units	Central: NG SMR	Central: Low Temperature Electrolysis PEM using Mix for transportation use	Central: Coal Gasification with CCS	Central: Biomass Gasification	Central: High Temperature Electrolysis with SOEC using Nuclear LWR	Central: By-product H2 from Chlorine Plants	Central: By-product H2 from NGL Steam Cracker Plants	Distributed: NG SMR	Distributed: Low Temperature Electrolysis PEM using Solar	Central: RNG SMR	Distributed: RNG SMR	
389	Total energy	Btu/mmBtu	551,766	3,344,108	777,351	1,366,916	1,311,114	201,833	1,142,460	634,975	1,728,869	-1,201,714	-991,276
390	Fossil fuels	Btu/mmBtu	549,140	2,620,299	762,295	162,082	-11,808	162,529	1,135,234	599,813	-24,924	180,330	294,251
391	Coal	Btu/mmBtu	3,763	1,037,475	703,746	9,768	-6,876	56,335	10,358	50,400	-9,868	54,955	99,227
392	Natural gas	Btu/mmBtu	544,661	1,550,468	34,745	92,586	-7,951	101,429	1,124,121	547,268	-14,748	123,645	191,912
393	Petroleum	Btu/mmBtu	716	32,356	23,804	59,727	3,019	4,765	754	2,144	-308	1,730	3,112
394	Water consumption	gal/mmBtu	42.141	307.227	66.746	36.167	188.558	17.885	6.020	39.927	84.741	51.711	49.054
395	VOC	g/mmBtu	17.386	24.046	15.513	4.742	-0.059	1.542	13.866	17.607	-0.229	-25.025	-22.844
396	CO	g/mmBtu	50.998	85.526	9.617	20.257	0.020	5.835	57.994	56.970	-0.814	-24.428	-14.971
397	NOx	g/mmBtu	63.517	151.480	10.982	32.414	-0.062	9.864	55.864	70.833	-1.441	23.712	32.868
398	PM10	g/mmBtu	3.126	21.920	14.712	2.113	-0.064						3.089
399	PM2.5	g/mmBtu	3.028	12.381	2.223	1.814	-0.030						0.46
400	SOx	g/mmBtu				20.594	-0.421						0.265
401	BC	g/mmBtu				0.887	0.012						0.352
402	OC	g/mmBtu				0.409	-0.010						0.72
403	CH4	g/mmBtu				23.646	-2.039						0.35
404	N2O	g/mmBtu				6.642	0.041						0.49
405	CO2	g/mmBtu				11,912	-948						0.79
406	CO2 (w/ C in VOC & CO)	g/mmBtu	92,273	198,928	17,618	11,958	-948						0.84
407	GHGs	gCO2e/mmBtu	101,664	212,462	25,294	14,476	-998						1,177
408	VOC: Urban	g/mmBtu	1.305	1.625	0.099	0.224	-0.001	0.107	2.387	1.799	-0.015	-15.523	-14.252

WTG GHG emissions
212,462 g CO₂e/mmBtu

Gaseous hydrogen from PEM electrolysis exporting all oxygen produced

Nuclear-Powered PEM

Determine the WTP GHG Emissions of Liquified H₂
Produced from PEM Electrolysis Using Nuclear
Energy Transported 200 miles via Tube Truck



GREAT PLAINS
INSTITUTE

Argonne
NATIONAL LABORATORY

U.S. Department of
ENERGY

Microsoft Excel interface showing the 'Formulas' ribbon and a spreadsheet with the following content:

6. Hydrogen Production

6.1) Basis of H2 Production Assumptions from Different Technology Pathways

1 -- GREET Default, 2 -- User defined

6.1.a) Scenarios for H2A Model Cases

2 1 -- Current, 2 -- Future

6.2) Share of H2 Production by Location

	Gaseous H2	Liquid H2
Central Plants	100.0%	100.0%
Refueling Stations	0.0%	0.0%

6.3) Share of H2 Feedstock Sources in Central Plants

	Gaseous H2	Liquid H2
NG	100.0%	100.0%
PEM Electrolysis	0.0%	0.0%
Nuclear (LWR) High Temperature Electrolysis with SOEC	0.0%	0.0%
Nuclear (Thermo-Chemical Cracking of Water)	0.0%	0.0%
High Temperature Electrolysis (Nuclear HTGR or NG)	0.0%	0.0%
Coal	0.0%	0.0%
Biomass	0.0%	0.0%
Integrated fermentation	0.0%	0.0%
Coke Oven Gas	0.0%	0.0%
Byproduct from chlorine plants	0.0%	0.0%
By-product from NGL steam cracker plants	0.0%	0.0%
Pet Coke	0.0%	0.0%
RNG SMR	0.0%	0.0%
NG Autothermal Reforming	0.0%	0.0%
RNG Autothermal Reforming	0.0%	0.0%
Methane Pyrolysis (Using NG)	0.0%	0.0%

Navigation buttons: Hydrogen Worksheet, Results, Back to Top

Worksheet tabs: Inputs, Results, Petroleum, Co_processing, NG, MeOH_FTD, EtOH, Electric, Generation_mixes, Bio_electricity

Type 0% for NG and 100% for PEM electrolysis

File Home Insert Draw Page Layout Formulas Data Review View Automate Help

Clipboard Font Alignment Number Styles Cells Editing Sensitivity Add-ins Analyze Data

Y220

246 **6.5) NG Feedstock Options for H2 Production via SMR**

	Gaseous H2	Liquid H2	Note:
	1	1	1 -- North American NG, 4 -- Renewable Natural Gas
	1	1	

247

Note: default electric generation source for hydrogen production via PEM electrolysis is solar

	Gaseous H2	Liquid H2	Note:
	1	1	1 -- Without CO2 sequestration 2 -- With CO2 sequestration
	2	2	
	1	1	
ATR H2 Plants	2	2	

257

258 **6.7) Selection of H2 Plant Design Types**

	NG/RNG	Coal	Biomass	Petcoke
Central Plant G.H2	1	0	0	0
Refueling Station G.H2	0			
Central Plant L.H2	1	0	0	
Refueling Station L.H2	0			

260

261

262

263

264

265 **6.8) Selection of Method for Estimating Credits of Co-Products for NG Based Fuel Pathways (Co-products are defined in Section 6.7)**

	NG/RNG	Coal	Biomass	Petcoke
Central Plant G.H2	1	1	1	1
Refueling Station G.H2	1			
Central Plant L.H2	1	1	1	
Refueling Station L.H2	1			

266

267

268

269

270

271

272 **6.9) Electric Generation Source for H2 Production via PEM Electrolysis**

	Gaseous H2	Liquid H2	Note:
	1	1	1 -- Solar, 2 -- Wind, 3 -- Hydro, 4 -- Nuclear (LWR), 5-- Mix for transportation use (see 10.2.a)

273

274

275

Overview Inputs Results Petroleum Co_processing NG MeOH_FTD EtOH Electric Generation mixes Bio



Microsoft Excel ribbon showing various toolbars: Clipboard, Font (Arial, 10), Alignment, Number, Styles (General, Conditional Formatting, Format as Table, Cell Styles), Cells (Insert, Delete, Format), Editing, Sensitivity, Add-ins, and Analyze Data.

Workbook name: NG_LH2_Electrolysis_PowerPlant
 Formula bar: 1

	A	B	C	D	E	F	G	H	I	
246	6.5) NG Feedstock Options for H2 Production via SMR									
247						Gaseous H2	Liquid H2	Note:		
248					Central Plants	1	1	1 -- North American NG, 4 -- Renewable Natural Gas		
249					Distributed Production at Refueling Stations	1	1			
250	6.6) CO2 Sequestration Options for Central Plant H2 Production									
251						Gaseous H2	Liquid H2	Note:		
252					NG-Based SMR H2 Plants	1	1	1 -- Without CO2 sequestration		
253					Coal-Based H2 Plants	2	2	2 -- With CO2 sequestration		
254					Biomass-Based H2 Plants	1	1			
255					Pet Coke-to-H2 Plant	1				
256					ATR H2 Plants	2	2			
257	6.7) Selection of H2 Plant Design Types									
258						NG/RNG	Coal	Biomass	Petcoke	
259					Central Plant G.H2	1	0	0	0	
260					Refueling Station G.H2	0				
261					Central Plant L.H2	1	0	0		
262					Refueling Station L.H2	0				
263	6.8) Selection of Method for Estimating Credits of Co-Products for NG Based Fuel Pathways (Co-products are defined in Section 6.7)									
264						NG/RNG	Coal	Biomass	Petcoke	
265					Central Plant G.H2	1	1	1	1	
266					Refueling Station G.H2	1				
267					Central Plant L.H2	2	1	1		
268					Refueling Station L.H2	3				
269	6.9) Electric Generation Source for H2 Production via PEM Electrolysis									
270										
271					Gaseous H2	5	1	1 -- Solar, 2 -- Wind, 3 -- Hydro, 4 -- Nuclear (LWR), 5 -- Mix for transportation use (see 10.2.a)		
272						1	1			

Excel navigation bar showing tabs: Inputs, Results, Petroleum, Co_processing, NG, MeOH_FTD, EtOH, Electric, General, Bio_electricity. Status bar: Ready, Calculate, Accessibility: Investigate, Display Settings, 85% zoom.

Microsoft Excel ribbon: Home, Insert, Draw, Page Layout, Formulas, Data, Review, View, Automate, Help. Ribbon groups: Clipboard, Font, Alignment, Number, Styles, Conditional Formatting, Format as Table, Cell Styles, Insert, Delete, Format, Cells, Editing, Sensitivity, Add-ins, Analyze Data.

Formula bar: TDSELALTFUELS, fx, Gaseous Hydrogen (G. H2)

Worksheet content:

Row 1: Navigation Menu: Select the desired pathway from the following drop down lists (highlighted yellow) and click "Go"

Row 2: Home (button)

Row 3: Inputs (button)

Row 4: Results (button)

Row 5: Back to Top (button)

Row 2: Petroleum & Petroleum Products

Row 3: Conventional Crude Oil for Use in US Refinery (highlighted yellow) [Go]

Row 4: Alternative Fuel

Row 5: Gaseous Hydrogen (G. H2) (highlighted yellow) [Go]

Row 6: Ethanol

Row 7: Gaseous Hydrogen (G. H2)

Row 8: Liquefied Hydrogen (LH2)

Row 9: Biodiesel

Row 10: Renewable Diesel

Row 11: Hydroprocessed Renewable Jet (HRJ)

Row 12: Renewable Gasoline

Row 13: EtOH-Diesel Additive

Row 14: Uranium

Row 10: Natural Gas & Fossil Fuels

Row 11: Natural Gas (NG) (highlighted yellow) [Go]

Row 12: Crops and Feedstocks

Row 13: Used Cooking Oil (highlighted yellow) [Go]

Row 9: Flowcharts for Transportation Modes and Feedstocks

Diagram components:

- Source or Origin (purple circle)
- Market Share (input field)
- Transportation Mode (blue box)
- Transportation Mode Share (input field)
- Transportation Distance (miles) (input field)
- Port or Destination 47 (blue circle)

Row 20: 1. Conventional Crude Oil for Use in US Refinery

Taskbar: WCF, Fuel_Specs, Car_TS, LDT1_TS, LDT2_TS, Vehicles, Urban_Shares, Compression, Coal, T&D_Flowcharts, T&D



Default Transportation Mode for Liquefied Hydrogen to the Refueling Station



**GREAT PLAINS
INSTITUTE**



Argonne
NATIONAL LABORATORY



U.S. Department of
ENERGY

Microsoft Excel interface showing a navigation menu and flowcharts.

Navigation Menu: Select the desired pathway from the following drop down lists (highlighted yellow) and click "Go"

Home	Petroleum & Petroleum Products	Go	Natural Gas & Fossil Fuels	Go
Inputs	Conventional Crude Oil for Use in US Refinery	Go	Natural Gas (NG)	Go
Results	Alternative Fuels	Go	Crops and Feedstocks	Go
Back to Top	Liquefied Hydrogen (L.H2)	Go	Used Cooking Oil	Go
	Agricultural Products and Chemicals	Go		
	Ammonia as a Final Fertilizer			

27.4. Produced from Solar Energy

```

graph LR
    L[H2 Plant] --> B[Barge]
    L --> R[Rail]
    B --> T[Bulk Terminal]
    R --> T
    T --> TR[Truck HHDDT]
    TR --> RS[Refueling Station]
  
```

27.5. Produced from Nuclear (Water Cracking)

Navigation bar: WCF, Fuel_Specs, Car_TS, LDT1_TS, LDT2_TS, Vehicles, Urban_Shares, Compression, Coal, T&D_Flowcharts, T&



Microsoft Excel interface showing a navigation menu and a flowchart for hydrogen production and distribution.

Navigation Menu: Select the desired pathway from the following drop down lists (highlighted yellow) and click "Go"

Petroleum & Petroleum Products	<input type="button" value="Go"/>
Conventional Crude Oil for Use in US Refinery	
Alternative Fuels	<input type="button" value="Go"/>
Liquefied Hydrogen (L.H2)	
Agricultural Products and Chemicals	<input type="button" value="Go"/>
Ammonia as a Final Fertilizer	

Natural Gas & Fossil Fuels	<input type="button" value="Go"/>
Natural Gas (NG)	
Crops and Feedstocks	<input type="button" value="Go"/>
Used Cooking Oil	

27.4. Produced from Solar Energy

Press F9

Worksheet tabs: WCF, Fuel_Specs, Car_TS, LDT1_TS, LDT2_TS, Vehicles, Urban_Shares, Compression, Coal, T&D_Flowcharts, T&D...



Well-to-Pump (WTP) GHG Emissions



**GREAT PLAINS
INSTITUTE**

Argonne
NATIONAL LABORATORY

U.S. Department of
ENERGY

WTP emissions

$$\text{WTP} = (\text{feedstock} \times \text{loss factor}) + \text{fuel}$$



GREAT PLAINS
INSTITUTE

Argonne
NATIONAL LABORATORY

U.S. Department of
ENERGY

File Home Insert Draw Page Layout Formulas Data Review View Automate Help

Clipboard Font Alignment Number Styles Cells Editing Sensitivity Add-ins Analyze Data

G98

4) Summary of Energy Consumption, Water Consumption, and Emissions: Btu or Gallons or Grams per mmBtu of H2 Throughput at Each Stage

4.1) Energy Use, Water Consumption, and Total Emissions

	Central Plants: NG to Gaseous Hydrogen		Central Plants: PEM electrolysis to Gaseous Hydrogen via Solar		Central Plants: Nuclear Energy to Gaseous Hydrogen (Thermo-Chemical Cracking of Water)		Central Plants: Electrolysis (HTGR) to Gaseous Hydrogen		Central Plants: Coal to Gaseous Hydrogen with CCS		Central Plants: Biomass to Gaseous Hydrogen	
	Feedstock	Fuel	Feedstock	Fuel	Feedstock	Fuel	Feedstock	Fuel	Feedstock	Fuel	Feedstock	Fuel
Loss factor		0.961		1.000		1.000		1.000		1.000		1.000
Total energy	112,046	670,274	1,750,297	226,234	1,009,396	226,234	1,209,143	168,148	20,047	983,539	38,325	1,554,825
Fossil fuels	111,403	626,719	0	184,686	7,822	184,686	9,370	94,489	19,144	927,837	37,895	308,872
Coal	923	62,422	0	59,546	1,821	59,546	2,181	23,761	1,926	761,366	615	68,699
Natural gas	110,020	531,097	0	92,213	4,066	92,213	4,871	38,810	3,418	123,540	10,236	174,563
Petroleum	460	33,201	0	32,927	1,935	32,927	2,318	31,918	13,800	42,931	27,043	65,610
Water consumption	3.457	55.613	87.055	16.796	163.219	16.796	188.383	14.307	3.863	79.680	1.537	51.426
VOC	11.107	8.505	0.000	1.798	0.100	1.798	0.120	0.972	7.322	9.990	1.747	4.794
CO	35.006	28.215	0.000	10.873	0.490	10.873	0.587	7.942	1.754	18.735	7.552	23.578
NOx	41.190	36.645	0.000	12.729	0.818	12.729	0.979	7.535	4.847	18.863	10.995	34.148
PM10	0.406	4.215	0.000	1.480	0.086	1.480	0.103	0.727	8.507	7.684	0.789	2.805
PM2.5	0.384	3.431	0.000	0.772	0.052	0.772	0.063	0.347	1.184	1.810	0.688	1.898
SOx	11.211	12.556	0.000	7.401	0.471	7.401	0.564	3.041	6.799	27.179	1.172	26.823
BC	0.077	0.325	0.000	0.044	0.010	0.044	0.013	0.021	0.035	0.080	0.386	0.545
OC	0.162	0.926	0.000	0.208	0.013	0.208	0.016	0.089	0.071	0.321	0.134	0.483
CH4	210.790	118.578	0.000	27.165	1.156	27.165	1.385	12.777	147.657	135.939	4.225	46.586
N2O	1.417	1.172	0.000	0.237	0.045	0.237	0.054	0.103	0.030	0.332	2.956	3.923
CO2	6,624	99,822	0	14,052	563	14,052	675	7,210	1,490	30,116	3,133	22,831
CO2 (w/ C in VOC & CO)	6,714	99,893	0	14,075	564	14,075	676	7,225	1,516	30,177	3,150	22,883
GHGs	13,382	103,746	0	14,949	611	14,949	732	7,634	5,924	34,319	4,083	25,342
4.2) Urban Emissions: Grams per mmBtu of H2 Throughput at Each Stage												
Loss factor												
VOC	0.594	1.048	0.000	0.314	0.008	0.314	0.010	0.258	0.041	0.372	0.082	0.456

Petroleum Co_processing NG MeOH_FTD EtOH Electric Generation_mixes Bio_electricity **Hydrogen** BioOil

Ready Calculate Accessibility: Investigate Display Settings 85%



File Home Insert Draw Page Layout Formulas Data Review View Automate Help

Clipboard Font Alignment Number Styles Cells Editing Sensitivity Add-ins

SUM fx **=AP344*AQ325+AQ344**

1 Type the equation to the left into an empty cell

		Gaseous Hydrogen: Combined		Gaseous Hydrogen: Combined (for MHDVs)		Central Plants: NG or FG to Liquid Hydrogen		Central Plants: PEM Electrolysis to Liquid Hydrogen		Central Plants: Nuclear Energy to Liquid Hydrogen (Thermo-Chemical Cracking of Water)		Central Plants: Electrolysis (HTGR) to Liquid Hydrogen			
		Fuel	Feedstock	Fuel	Feedstock	Fuel	Feedstock	Fuel	Feedstock	Fuel	Feedstock	Fuel	Feedstock	Fuel	
325	Loss factor	1.000		1.000		1.000		1.039		1.080		1.080		1.080	
326	Total energy	779,685	107,725	670,274	107,725	670,274	112,046	1,014,579	1,770,903	429,126	1,009,396	399,774	1,209,143	399,774	
327	Fossil fuels	697,300	107,106	626,719	107,106	626,719	111,403	846,874	17,295	37,005	7,822	26,691	9,370	26,691	
328	Coal	118,086	887	62,422	887	62,422	923	240,378	3,946	6,720	1,821	6,452	2,181	6,452	
329	Natural gas	572,690	105,777	531,097	105,777	531,097	110,020	590,583	8,963	12,452	4,066	11,003	4,871	11,003	
330	Petroleum	6,524	442	33,201	442	33,201	460	15,913	4,386	17,832	1,935	9,235	2,318	9,235	
331	Water consumption	33.266	3.324	55.613	3.324	55.613	3.457	106	253.182	52	163.219	49	188.383	49	
332	VOC	10.313	10.679	8.505	10.679	8.505	11.107	8.931	0.224	0.410	0.100	0.283	0.120	0.283	
333	CO	17.511	33.656	28.215	33.656	28.215	35.006	23.434	1.099	3.927	0.490	2.258	0.587	2.258	
334	NOx						36.645	41.190	39.251	1.818	3.424	0.818	2.230	0.979	2.230
335	PM10						4.215	0.406	6.906	0.190	0.285	0.086	0.213	0.103	0.213
336	PM2.5						3.431	0.384	4.603	0.116	0.128	0.052	0.105	0.063	0.105
337	SOx						12.556	11.211	31.325	1.035	1.010	0.471	0.913	0.564	0.913
338	BC						0.325	0.077	0.268	0.024	0.012	0.010	0.009	0.013	0.009
339	OC						0.926	0.162	1.090	0.030	0.031	0.013	0.027	0.016	0.027
340	CH4						118.578	210.790	134.240	2.552	4.629	1.156	3.609	1.385	3.609
341	N2O						1.172	1.417	1.296	0.103	0.056	0.045	0.041	0.054	0.041
342	CO2						99,822	6,624	119,857	1,242	2,316	563	2,025	675	2,025
343	CO2 (w/ C in VOC & CO)						99,893	6,714	119,922	1,245	2,823	564	2,030	676	2,030
344	GHGs	121,781	12,866	103,746	12,866	103,746	13,382	124,276	1,349	2,975	611	2,149	732	2,149	
345	4.2) Urban Emissions: Grams per mmBtu of H2 Through														
346	Loss factor			1.000		1.000									

2 Gaseous hydrogen from PEM electrolysis using nuclear energy

AQ344

WTP GHG emissions
4,431 g CO₂e/mmBtu

4,431.81

Ammonia Production

Determine the Emissions of CO₂ Associated with Ammonia Production Utilizing H₂ Production Produced from PEM Electrolysis with an Operating Efficiency for the Electrolyzer at 60 kWh/kg H₂ and a Hydropower Power Source



GREAT PLAINS
INSTITUTE

Argonne
NATIONAL LABORATORY

U.S. Department of
ENERGY

Microsoft Excel interface showing the 'Formulas' ribbon and a worksheet titled 'Hydrogen Production'.

6. Hydrogen Production

6.1) Basis of H2 Production Assumptions from Different Technology Pathways

1 -- GREET Default, 2 -- User defined

6.1.a) Scenarios for H2A Model Cases

1 -- Current, 2 -- Future

6.2) Share of H2 Production by Location

	Gaseous H2	Liquid H2
Central Plants	100.0%	100.0%
Refueling Stations	0.0%	0.0%

6.3) Share of H2 Feedstock Sources in Central Plants

	Gaseous H2	Liquid H2
NG	100.0%	
PEM Electrolysis	0.0%	
Nuclear (LWR) High Temperature Electrolysis with SOEC	0.0%	
Nuclear (Thermo-Chemical Cracking of Water)	0.0%	
High Temperature Electrolysis (Nuclear HTGR or NG)	0.0%	
Coal	0.0%	0.0%
Biomass	0.0%	0.0%
Integrated fermentation	0.0%	0.0%
Coke Oven Gas	0.0%	0.0%
Byproduct from chlorine plants	0.0%	0.0%
By-product from NGL steam cracker plants	0.0%	0.0%
Pet Coke	0.0%	0.0%
RNG SMR	0.0%	
NG Autothermal Reforming	0.0%	
RNG Autothermal Reforming	0.0%	
Methane Pyrolysis (Using NG)	0.0%	
Methane Pyrolysis (Using RNG)	0.0%	

Callout: Type 0% for NG and 100% for PEM electrolysis

Worksheet tabs: Inputs, Results, Petroleum, Co_processing, NG, MeOH_FTD, EtOH, Electric, Generation_mixes, Bio_electricity



File Home Insert Draw Page Layout Formulas Data Review View Automate Help

Paste Clipboard Font Alignment Number Styles Cells Editing Sensitivity Add-ins Analyze Data

NG_GH2_Electrolysis_PowerPlant

6.9) Electric Generation Source for H2 Production via PEM Electrolysis

	Gaseous H2	Liquid H2	1 -- Solar, 2 -- Wind, 3 -- Hydro, 4 -- Nuclear (LWR), 5 -- Mix for transportation use (see 10.2.a)
	1	1	

6.10) Electric Generation Stations

	Liquid H2	1 -- Solar, 2 -- Wind, 3 -- Hydro, 4 -- Nuclear (LWR), 5 -- Mix for transportation use (see 10.2.a)
	3	1

6.11) Shares of Willows for H2 production in central plants

	Willow	Poplar	Switchgrass	Corn Stover	Forest Residue	Miscanthus
Gaseous H2	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%
Liquid H2	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%

6.12) Simulation Options of Treating H2 produced from Coke Oven Gas (COG)

	Gaseous H2	Liquid H2	1 -- Scenario 1: COG is treated as a co-product 2 -- Scenario 2: COG is treated as a byproduct 3 -- Scenario 3: Supplemental NG and electricity use to makeup for BTU withdrawal from separated H2 for the whole system
	3	3	

6.13) Selection of Electricity Generation Mix for H2 liquification in Central Plants

H2 Plant Type	Electricity Mix
NG-Based Plant	2
Solar Energy-Based Plant	2
Nuclear Plant (HTGR water cracking)	1
Coal-Based Plant	2
Biomass-Based Plant	2
COG-Based Plant	2

6.14) Electricity Source for High Temperature Electrolysis with SOEC

	Gaseous H2	Liquid H2	1 -- Oil Power Plants, 2 -- NG Power Plants, 3 -- Coal Power Plants, 4 -- Nuclear Power Plants 5 -- Other Renewable Power Plants, 6 -- Mix for transportation use (see 10.2.a), 7 -- NGCC Turbine
	6	6	

6.15) Integrated Fermentation Plant Type

	1	1 -- w/ H2 Recovery, 2 -- w/ Energy Recovery
--	---	--

6.16) Biomass-derived Liquid Reforming

Plant Design	1	1 -- Once-through; 2 -- Recycled
--------------	---	----------------------------------

Inputs Results Petroleum Co_processing NG MeOH_FTD EtOH Electric Generation_mixes Bio_electricity



Efficiency of the Electrolysis Unit



**GREAT PLAINS
INSTITUTE**



Argonne
NATIONAL LABORATORY



U.S. Department of
ENERGY

Calculating the efficiency of the electrolysis unit

Hydrogen LHV (in Btu/kg)

$G. \text{ LHV (Btu/ft}^3) / \text{Density of G. Hydrogen (g/ft}^3)$
Convert from g to kg

Direct Unit Conversion

60 kWh/kg to Btu/kg

Efficiency

$\text{LHV (Btu/kg) / Efficiency (Btu/kg)}$



GREAT PLAINS
INSTITUTE

Argonne
NATIONAL LABORATORY

U.S. Department of
ENERGY

File Home Insert Draw Page Layout Formulas Data Review View Automate Help

Clipboard Font Alignment Number Styles Cells Editing Sensitivity Add-ins Analyze Data

SUM $=(\text{GH2_Heating_Value}/\text{GH2_Density_g_per_cuft})/\text{g2kg}$

	Btu/ft3	Btu/ft3	Btu/ft3	gms/ft3			LHV/HHV
74 Pyrolysis diesel	123,329	123,329		3,151	86.5%		
75 FT-Gasoline-Nuclear	108,327	108,327	116,964	2,599	83.1%		
76 FT-Jet-Nuclear	117,300	117,300	126,125	2,805	84.6%		
77 FT-Diesel-Nuclear	121,166	121,166	130,269	2,909	84.9%		
78 FT-Fuel Mix-Nuclear	111,313	111,313	119,859	2,668	84.2%		
79 Ammonia	40,571	40,571	40,571	2,282	0.0%	0	0.000000 1.000
80 Gaseous Fuels (at 32F and 1atm):	Btu/ft3	Btu/ft3	Btu/ft3	gms/ft3			LHV/HHV
81 Natural gas	983	983	1,089	22.0	72.4%	6	0.000006 0.903
82 Renewable Natural Gas	983	983	1,089	22.0	72.4%	6	0.000006 0.903
83 Synthetic NG (SNG)	959	959	1,065	20.3	74.7%	0	0.000000 0.901
84 Pure Methane	962	962	1,068	20.3	75.0%	0	0.000000 0.901
85 Gaseous hydrogen	290	290	343	2.6	0.0%	0	0.000000 0.845
86 Carbon Dioxide				56.0	27.3%	0	0.000000
87 Still gas (in refineries)	1,159	1,159	1,280	25.0	77.0%	6	0.000006 0.906
88 Fuel gas (ATR)	288	288	336	17.0	6.0%	0	0.000000 0.856
89 Solid Fuels:	Btu/ton	Btu/ton	Btu/ton				LHV/HHV
90 Coal Mix for Electricity Generation	19,474,169	19,474,169	20,673,610		58.6%	10,456	0.010456
91 Bituminous coal	22,639,320	22,639,320	23,633,493		61.2%	15,352	0.015352 0.958
92 Subbituminous coal	16,085,444	16,085,444	17,449,320		53.7%	3,568	0.003568 0.922
93 Lignite coal	10,805,183	10,805,183	12,992,302		49.1%	9,064	0.009064 0.832
94 Synthetic coal	22,639,320	22,639,320	23,633,493		80.6%	16,143	0.016143 0.958
95 Waste coal	9,945,646	9,945,646	11,958,783		32.6%	9,064	0.009064 0.832
96 Pet Coke	26,949,429	26,949,429	28,595,925		86.7%	45,138	0.045138 0.942
97 Tire Derived Fuel	26,664,354	26,664,354	28,293,434		48.8%	45,138	0.045138 0.942
98 Coking coal	24,599,422	24,599,422	25,679,670		74.7%	11,800	0.011800 0.958
99 Catalyst Coke	28,385,750	28,385,750	30,120,000		86.4%	45,138	0.045138 0.942
00 Willow	15,396,000	15,396,000	16,524,000		48.7%	500	0.000500 0.932
01 Poplar	15,929,000	15,929,000	17,062,000		50.1%	200	0.000200 0.934
02 Switchgrass	14,447,000	14,447,000	15,583,000		46.6%	1,100	0.001100 0.927
03 Miscanthus	15,342,000	15,342,000	16,377,000		47.6%	800	0.000800 0.937
04 Corn stover	14,716,000	14,716,000	15,774,000		46.7%	1,000	0.001000 0.933
05 Forest residue	17,289,000	17,289,000	17,906,000		50.3%	400	0.000400 0.966
06 Clean Pine	15,929,000	15,929,000	17,062,000		50.1%	200	0.000200 0.934

LHV (Btu/kg)
er_cuft)/g2kg

IBR E_fuel Fuel_Prod_TS EF_TS AgMining_EF_TS EF WCF Fuel_Specs Car_TS LDT1_TS LDT2_TS Vehicle

Accessibility: Investigate 85%

Type the equation to the left into an empty cell

LHV in Btu/kg

113725.4902



GREAT PLAINS INSTITUTE



LHV in Btu/kg

113725.4902

File Home Insert Draw Page Layout Formulas Data Review View Automate Help

Clipboard Font Alignment Number Styles Cells Editing Sensitivity Add-ins Analyze Data

SUM $=60 * kWh2BTU$

Type the equation to the left into an empty cell

	Btu/ft3	Btu/ft3	Btu/ft3	gms/ft3			LHV/HHV
80 Gaseous Fuels (at 32F and 1atm):							
81 Natural gas	983	983	1,089	22.0	72.4%	6	0.000006 0.903
82 Renewable Natural Gas	983	983	1,089	22.0	72.4%	6	0.000006 0.903
83 Synthetic NG (SNG)	959	959	1,065	20.3	74.7%	0	0.000000 0.901
84 Pure Methane	962	962	1,068	20.3	75.0%	0	0.000000 0.901
85 Gaseous hydrogen	290	290	343	2.6	0.0%	0	0.000000 0.845
86 Carbon Dioxide				56.0	27.3%	0	0.000000
87 Still gas (in refineries)	1,159	1,159	1,280	25.0	77.0%	6	0.000006 0.906
88 Fuel gas (ATR)	288	288	336	17.0	6.0%	0	0.000000 0.856
89 Solid Fuels:							
90 Coal Mix for Electricity Generation	19,474,169	19,474,169	20,673,610		58.6%	10,456	0.010456
91 Bituminous coal	22,639,320	22,639,320	23,633,493		61.2%	15,352	0.015352 0.958
92 Subbituminous coal	16,085,444	16,085,444	17,449,320		53.7%	3,568	0.003568 0.922
93 Lignite coal	10,805,183	10,805,183	12,992,302		49.1%	9,064	0.009064 0.832
94 Synthetic coal	22,639,320	22,639,320	23,633,493		80.6%	16,143	0.016143 0.958
95 Waste coal	9,945,646	9,945,646	11,958,783		32.6%	9,064	0.009064 0.832
96 Pet Coke	26,949,429	26,949,429	28,595,925		86.7%	45,138	0.045138 0.942
97 Tire Derived Fuel	26,664,354	26,664,354	28,293,434		48.8%	45,138	0.045138 0.942
98 Coking coal	24,599,422	24,599,422	25,679,670		74.7%	11,800	0.011800 0.958

LHV (Btu/kg) Power (Btu/kg)
113725.4902 kWh2BTU

Waste RNG Pyrolysis_IDL IBR E_fuel Fuel_Prod_TS EF_TS AgMining_EF_TS EF WCF Fuel_Specs Car_TS

Accessibility: Investigate Display Settings 85%



File Home Insert Draw Page Layout Formulas Data Review View Automate Help

Clipboard Font Alignment Number Styles Cells Editing Sensitivity Add-ins Analyze Data

SUM $=K85/L85$

Type the equation to the left into an empty cell

	Btu/ft3	Btu/ft3	Btu/ft3	gms/ft3			LHV/HHV
80 Gaseous Fuels (at 32F and 1atm):							
81 Natural gas	983	983	1,089	22.0	72.4%	6	0.000006 0.903
82 Renewable Natural Gas	983	983	1,089	22.0	72.4%	6	0.000006 0.903
83 Synthetic NG (SNG)	959	959	1,065	20.3	74.7%	0	0.000000 0.901
84 Pure Methane	962	962	1,068	20.3	75.0%	0	0.000000 0.901
85 Gaseous hydrogen	290	290	343	2.6	0.0%	0	0.000000 0.845
86 Carbon Dioxide				56.0	27.3%	0	0.000000
87 Still gas (in refineries)	1,159	1,159	1,280	25.0	77.0%	6	0.000006 0.906
88 Fuel gas (ATR)	288	288	336	17.0	6.0%	0	0.000000 0.856
89 Solid Fuels:							
90 Coal Mix for Electricity Generation	19,474,169	19,474,169	20,673,610		58.6%	10,456	0.010456
91 Bituminous coal	22,639,320	22,639,320	23,633,493		61.2%	15,352	0.015352 0.958
92 Subbituminous coal	16,085,444	16,085,444	17,449,320		53.7%	3,568	0.003568 0.922
93 Lignite coal	10,805,183	10,805,183	12,992,302		49.1%	9,064	0.009064 0.832
94 Synthetic coal	22,639,320	22,639,320	23,633,493		80.6%	16,143	0.016143 0.958
95 Waste coal	9,945,646	9,945,646	11,958,783		32.6%	9,064	0.009064 0.832
96 Pet Coke	26,949,429	26,949,429	28,595,925		86.7%	45,138	0.045138 0.942
97 Tire Derived Fuel	26,664,354	26,664,354	28,293,434		48.8%	45,138	0.045138 0.942
98 Coking coal	24,599,422	24,599,422	25,679,670		74.7%	11,800	0.011800 0.958

LHV (Btu/kg) Power (Btu/kg) Efficiency (%)
 113725.4902 204728.4985 =K85/L85

IBR E_fuel Fuel_Prod_TS EF_TS AgMining_EF_TS EF WCF Fuel_Specs Car_TS LDT1_TS LDT2_TS Vehicle

Accessibility: Investigate Display Settings 85%



GREAT PLAINS INSTITUTE



Efficiency in %

55.55%

File Home Insert Draw Page Layout Formulas Data Review View Automate Help

Clipboard Font Alignment Number Styles Cells Editing Sensitivity Add-ins Analyze Data

Z1109

13. GREET Default Key Assumptions for Well-to-Pump Activities
 13.18) Hydrogen Production Efficiencies
 13.18.a) Central Plant H2 Production Efficiencies

	Source		User D
	Gaseous H2	H2 Production for L.H2	
NETL Model			
NA NG feedstock			
Without steam or electricity export	71.8%	71.8%	71.8%
With steam or electricity export (excluding energy in co-products)	71.8%	71.8%	71.8%
With steam or electricity export: net steam export credit: Btu of steam per mmBtu of H2 produced	0	213,343	213,343
With steam or electricity export: net electricity export credit: kWh per mmBtu of H2 produced			14.01
Feedstock share	69.3%	69.3%	69.3%
NG share	99.1%	99.1%	99.1%
Electricity share	0.9%	0.9%	0.9%
NNA NG feedstock			
Without steam or electricity export	72.1%	72.1%	72.1%
With steam or electricity export (excluding energy in co-products)			
With steam or electricity export: net steam export credit: Btu of steam per mmBtu of H2 produced			
With steam or electricity export: net electricity export credit: kWh per mmBtu of H2 produced			0.00
NNA FG feedstock			
Without steam or electricity export	72.1%	72.1%	72.1%
With steam or electricity export (excluding energy in co-products)			
With steam or electricity export: net steam export credit: Btu of steam per mmBtu of H2 produced			
With steam or electricity export: net electricity export credit: kWh per mmBtu of H2 produced			0.00
Coal feedstock			
NETL Model			
Gasification in central plants: without steam or electricity co-generation	58.9%	58.9%	58.9%
Gasification in central plants: without steam or electricity co-generation (CCS)	58.4%	58.4%	58.4%
Gasification for H2 production in central plants: with steam or electricity co-generation (without accounting Btu in steam or electricity)	44.3%	44.3%	56.9%
Synthesis process for H2 production in central plants, with steam or electricity co-generation (without accounting Btu in steam or electricity)			100.0%
Net Steam export credit: Btu of steam per mmBtu of H2 produced			0
Net electricity export credit: kWh per mmBtu of H2 produced	0.00	0.00	0.00
Biomass feedstock			

Inputs Results Petroleum Co_processing NG MeOH_FTD EtOH Electric Generation_mixes Bio_electricity



Excel ribbon: Formulas, Data, Review, View, Automate, Help. Function Library: AutoSum, Logical, Lookup & Reference, Text, Math & Trig, Date & Time, More Functions. Python: Insert Python, Diagnostics, Initialization. Defined Names: Name Manager, Define Name, Use in Formula, Create from Selection. Formula Auditing: Trace Precedents, Trace Dependents, Remove Arrows, Watch Window. Calculation: Calculation Options.

Formula Bar: O1152

	D	E	F	G	H	I	J
1125		Synthesis process for H2 production in central plants, with steam or electricity co-generation (without accounting Btu in steam or electricity)					
1126							
1127							
1128		Biomass feedstock					
1129							
1130		Gasification in central plants: without steam or electricity co-generation				44.2%	44.2%
1131		Synthesis process for H2 production in central plants: without steam or electricity co-generation					
1132		Gasification for H2 production in central plants: with steam or electricity co-generation (without accounting Btu in steam or electricity)					
1133		Synthesis process for H2 production in central plants, with steam or electricity co-generation (without accounting Btu in steam or electricity)					
1134							
1135		Coke Oven Gas feedstock					
1136							
1137							
1138							
1139		Pet Coke feedstock					
1140							
1141		Gasification in central plants: without steam or electricity co-generation					
1142		Synthesis process for H2 production in central plants: without steam or electricity co-generation					
1143		Gasification for H2 production in central plants: with steam or electricity co-generation (without accounting Btu in steam or electricity)					
1144		Synthesis process for H2 production in central plants, with steam or electricity co-generation (without accounting Btu in steam or electricity)					
1145							
1146		Nuclear energy					
1147							
1148							
1149							
1150							
1151							
1152							
1153							
1154							
1155		b) Energy Use for Carbon Capture in H2 Central Plants: kWh per ton of C captured					

Navigation: Inputs, Results, Petroleum, Co_processing, NG, MeOH_FTD, EtOH, Electric, Generation_mixes, Bio_electricity



Type 55.55%

$$=NG_GH2_Cntrl_Prod_Eff_PEM_Electrolysis_TS*0+55.55\%$$

File Home Insert Draw Page Layout Formulas Data Review View Automate Help

fx Insert Function Recently Used Financial Logical Text Date & Time More Functions Math & Trig Lookup & Reference Python Initialization Python Name Manager Define Name Use in Formula Create from Selection Trace Precedents Trace Dependents Remove Arrows Watch Window Calculation Options Calculation

A1 Production and Transportation of Fertilizers, Herbicides, and Insecticides

1 Production and Transportation of Fertilizers, Herbicides, and Insecticides

2

3

4 1) Scenario Control and Key Input Parameters

5 1.1) Ammonia Production

	Conventional	Green	Carbon Capturing (Blue)
Share of conventional, green, and blue ammonia	100%	0%	0%
Ammonia Heating Value (MJ/kg)	18.8		

6

7

8

9 1.2) Green Ammonia Production

	1	2	3	4
Electricity source for N2 production	1	1--US mix, 2--Wind electricity	3--Nuclear electricity	
Electricity source for HB	1	1--US mix, 2--Wind electricity, 3--Nuclear electricity		
Use of electricity generated using steam from HB	1	1--Use for N2 production, 2--Export to grid		
H2 production	1	1--Low-temperature electrolysis, 2--Water electrolysis, 3--Chlorine alkaline, 4--Steam cracker		
N2 production	1	1--Cryogenic distillation, 2--Pressure swing adsorption		

10

11

12

13

14

15 1.3) Carbon Capturing Blue Ammonia Production

CO2 source for carbon capture	1	1--Process emissions only, 2--Pre-combustion emissions
-------------------------------	---	--

16

17 1.4) RNG Source for Ammonia Production

Select feedstock for RNG Production	2	1--Sludge, 2--Manure, 3--Food Waste, 4--FOG (Fats, oil, and grease)
-------------------------------------	---	---

18

19 2) Shares of Combustion Processes for Each Stage

Home Inputs Results

Urban_Shares Compression Coal T&D_Flowcharts T&D Uranium ASU Ag_Inputs Enzymes_Yeast Pretreatment



Carbon Dioxide Emitted from the Ammonia Production



**GREAT PLAINS
INSTITUTE**



Argonne
NATIONAL LABORATORY



U.S. Department of

ENERGY

File Home Insert Draw Page Layout Formulas Data Review View Automate Help

Clipboard Font Alignment Number Styles Cells Editing Sensitivity Add-ins Analyze Data

C8

96

97 **4) Calculation of Energy Use, Water Consumption, and Emissions of Fertilizer Production: Production Processes and Feedstock-Related Activities**

98

	Ammonia	Ammonia Urea from RNG	Ammonia from Hydrogen from Coal Gasification	Ammonia from Hydrogen from Poplar	Ammonium Nitrate	Urea-Ammonium Nitrate Sulfuric Acid	Phosphoric Acid (per ton of P2O5)	Potash
99								
100	Ratio of Nutrient to Product for Fertilizer							
101	Mass share between N and P							
102	Shares of Nitrogen Fertilizer Types for Use							
103	Energy Use: mmBtu/ton							
104	Total Energy	39.627	28.307	47.59	41.86	33.57	19.464	
105	Fossil fuels	0.943	6.168	9.50	40.51	7.72	2.337	
106	Coal	0.244	0.432	3.28	36.17	1.69	0.262	
107	Natural gas	0.394	5.112	5.30	3.02	3.96	1.172	
108	Petroleum	0.30491	0.625	0.93	1.33	2.06	0.903	
109	Water consumption: gallon/ton							
110	Total Emissions: grams/ton							
111	VOC	14.110	94.075	4,416.58	362.38	108.86	62.732	
112	CO			311.27	464.92	646.81	191.823	
113	NOx			7.11	573.45	1,000.06	1,706.328	
114	PM10			0.79	337.03	80.36	1,148.853	
115	PM2.5			0.28	65.37	56.82	926.963	
116	SOx			0.87	726.30	602.19	669.150	
117	BC			0.73	2.64	19.21	11.683	
118	OC			0.03	9.44	13.92	31.495	
119	CH4			0.99	5,901.41	1,122.35	331.221	
120	N2O	1.200	10.382	-1,408.12	8.61	141.00	3,402.364	
121	CO2	72,245	-267,528	1,183,274	710,740.27	581,762.40	170,155	168,418 38,736 1,263,766 411,034
122	Biogenic CH4							
123	Urban Emissions: grams/ton							

123

Ready Calculate Accessibility: Investigate

LDT2_TS Vehicles Urban_Shares Compression Coal T&D_Flowcharts T&D Uranium ASU Ag_Inputs Enzyr

CO₂ emissions
72,245 g CO₂/ton

Gaseous hydrogen from PEM electrolysis with an operating efficiency of the electrolyzer of 60 kWh/kg hydrogen and a hydropower power source

FCV Using SMR and PEM

Model a Fuel-Cell Electric Vehicle (FCV) Fueled Equally Using Gaseous Hydrogen from SMR (w/ 95% CCS) and Wind-powered PEM Electrolysis Transported 200 Miles Via Tube Truck



GREAT PLAINS
INSTITUTE

Argonne
NATIONAL LABORATORY

U.S. Department of
ENERGY

Microsoft Excel ribbon: Formulas, Data, Review, View, Automate, Help. Sub-ribbons include: Function Library (AutoSum, Logical, Text, Date & Time, More Functions), Python (Reset, Diagnostics, Initialization), Name Manager (Define Name, Use in Formula, Create from Selection), Formula Auditing (Trace Precedents, Trace Dependents, Remove Arrows), Watch Window, Calculation Options.

Address bar: L218

Worksheet: 6. Hydrogen Production

6.1) Basis of H2 Production Assumptions from Different Technology Pathways

6.1.a) Scenarios for H2A Model Cases

6.2) Share of H2 Production by Location

	Gaseous H2	Liquid H2
Central Plants	100.0%	100.0%
Refueling Stations	0.0%	0.0%

6.3) Share of H2 Feedstock Sources in Central Plants

	Gaseous H2	Liquid H2
NG	100.0%	
PEM Electrolysis	0.0%	
Nuclear (LWR) High Temperature Electrolysis with SOEC	0.0%	
Nuclear (Thermo-Chemical Cracking of Water)	0.0%	
High Temperature Electrolysis (Nuclear HTGR or NG)	0.0%	
Coal	0.0%	0.0%
Biomass	0.0%	0.0%
Integrated fermentation	0.0%	0.0%
Coke Oven Gas	0.0%	0.0%
Byproduct from chlorine plants	0.0%	0.0%
By-product from NGL steam cracker plants	0.0%	0.0%
Pet Coke	0.0%	0.0%
RNG SMR	0.0%	
NG Autothermal Reforming	0.0%	
RNG Autothermal Reforming	0.0%	
Methane Pyrolysis (Using NG)	0.0%	
Methane Pyrolysis (Using RNG)	0.0%	

Annotations: A red box highlights the 'NG' cell in the 6.3 table with a '1' in a purple circle. A purple callout bubble says 'Type 50% for both NG and PEM electrolysis'. A green arrow points to the 'NG' cell. A red box highlights the scrollbar on the right with a '2' in a purple circle.

Worksheet tabs: Inputs, Results, Petroleum, Co_processing, NG, MeOH_FTD, EtOH, Electric, Generation_mixes, Bio_electricity.



File Home Insert Draw Page Layout Formulas Data Review View Automate Help

Clipboard Font Alignment Number Styles Cells Editing Sensitivity Add-ins Analyze Data

NG_GH2_CO2_Sequestration 1

6.5) NG Feedstock Options for H2 Production via SMR				
		Gaseous H2	Liquid H2	Note:
Central Plants		1	1	1 -- North American NG, 4 -- Renewable Natural Gas
Distributed Production at Refueling Stations		1	1	

6.6) CO2 Sequestration Options for Central Plant H2 Production				
		Gaseous H2	Liquid H2	Note:
NG-Based SMR H2 Plants		1	1	1 -- Without CO2 sequestration 2 -- With CO2 sequestration
Coal-Based H2 Plants	1		2	
Biomass-Based H2 Plants	2		1	
Pet Coke-to-H2 Plant				
ATR H2 Plants			2	

6.7) Selection of H2 Plant Design Types				
	NG/RNG	Coal	Biomass	Petcoke
Central Plant G.H2	1	0	0	0
Refueling Station G.H2	0			
Central Plant L.H2	1	0	0	
Refueling Station L.H2	0			

6.8) Selection of Method for Estimating Credits of Co-Products for NG Based Fuel Pathways (Co-products are defined in Section 6.7)				
	NG/RNG	Coal	Biomass	Petcoke
Central Plant G.H2	1	1	1	1
Refueling Station G.H2	1			
Central Plant L.H2	1	1	1	
Refueling Station L.H2	1			

6.9) Electric Generation Source for H2 Production via PEM Electrolysis		
	Gaseous H2	Liquid H2
	1	1

1 -- Solar, 2 -- Wind, 3 -- Hydro, 4 --Nuclear (LWR), 5-- Mix for transportation use (see 10.2.a)

Inputs Results Petroleum Co processing NG MeOH FTD EtOH Electric Generation mixes Bio electricity



File Home Insert Draw Page Layout Formulas Data Review View Automate Help

Clipboard Font Alignment Number Styles Cells Editing Sensitivity Add-ins Analyze Data

NG_GH2_Electrolysis_PowerPlant

1 2 A B C D E G H I J K

272 **6.9) Electric Generation Source for H2 Production via PEM Electrolysis**

Gaseous H2	Liquid H2	1 -- Solar, 2 -- Wind, 3 -- Hydro, 4 -- Nuclear (LWR), 5 -- Mix for transportation use (see 10.2.a)
1	1	

274

275

276 **6.10) Electric Generation Stations**

Gaseous H2	Liquid H2	1 -- Solar, 2 -- Wind, 3 -- Hydro, 4 -- Nuclear (LWR), 5 -- Mix for transportation use (see 10.2.a)
1	1	

277

278

279

280 **6.11) Shares of Willows for H2 production in central plants**

	Willow	Poplar	Switchgrass	Corn Stover	Forest Residue	Miscanthus
Gaseous H2	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%
Liquid H2	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%

281

282

283

284

285 **6.12) Simulation Options of Treating H2 produced from Coke Oven Gas (COG)**

Gaseous H2	Liquid H2	1 -- Scenario 1: COG is treated as a co-product
3	3	2 -- Scenario 2: COG is treated as a byproduct
		3 -- Scenario 3: Supplemental NG and electricity use to makeup for BTU withdrawal from separated H2 for the whole system

286

287

288

289 **6.13) Selection of Electricity Generation Mix for H2 liquifaction in Central Plants**

H2 Plant Type	Electricity Mix	
NG-Based Plant	2	1 -- NGCC; 2 -- Mix for stationary use (see 10.2.a)
Solar Energy-Based Plant	2	1 -- Solar; 2 -- Mix for stationary use (see 10.2.a)
Nuclear Plant (HTGR water cracking)	1	1 -- Nuclear; 2 -- Mix for stationary use (see 10.2.a)
Coal-Based Plant	2	1 -- Coal IGCC; 2 -- Mix for stationary use (see 10.2.a)
Biomass-Based Plant	2	1 -- Biomass IGCC; 2 -- Mix for stationary use (see 10.2.a)
COG-Based Plant	2	1 -- Coal IGCC; 2 -- Mix for stationary use (see 10.2.a)

290

291

292

293

294

295

296

297

298 **6.14) Electricity Source for High Temperature Electrolysis with SOEC**

Gaseous H2	Liquid H2	1 -- Oil Power Plants, 2 -- NG Power Plants, 3 -- Coal Power Plants, 4 -- Nuclear Power Plants
6	6	5 -- Other Renewable Power Plants, 6 -- Mix for transportation use (see 10.2.a), 7 -- NGCC Turbine

299

300

301

302 **6.15) Integrated Fermentation Plant Type**

1	1 -- w/ H2 Recovery, 2 -- w/ Energy Recovery
---	--

303

304

305 **6.16) Biomass-derived Liquid Reforming**

Plant Design	1	1 -- Once-through; 2 -- Recycled
--------------	---	----------------------------------

306

Ready Calculate Accessibility: Investigate Display Settings 70%



Microsoft Excel ribbon: Home, Insert, Draw, Page Layout, Formulas, Data, Review, View, Automate, Help

Clipboard: Paste, Copy, Paste with Styles, Paste as Text Only, Paste as Plain Text and Merge Formatting

Font: Arial, 10, Bold, Italic, Underline, Paragraph, Text Color, Background Color

Alignment: Left, Center, Right, Indent, Decrease Indent, Increase Indent, Wrap Text, Merge & Center, Unmerge Cells

Number: General, Currency, Percentage, Decimals, Fractions, Text, Scientific, Custom

Styles: Conditional Formatting, Format as Table, Cell Styles

Cells: Insert, Delete, Format

Editing: Undo, Redo, Find, Replace, Fill, Sort, Filter, Hide Rows, Hide Columns, Show All Rows, Show All Columns

Sensitivity: Sensitivity

Add-ins: Add-ins

Analyze Data: Analyze Data

Formula Bar: P13, fx

Worksheet: Hydrogen Production Pathways: from NG, Electrolysis, Solar Photovoltaics, Nuclear Energy, Coal, Biomass, Coke Oven Gas, Ethanol, and Methanol

Navigation: Home, Inputs, Results

Section: 1) Scenario Control and Key Input Parameters (from the *Inputs* sheet)

Table: Transportation Fuel Application

	Central Plant: NG	Central Plant: Solar Energy	Central Plant: Nuclear (water cracking)	Central Plant: Electrolysis (HTGR)	Central Plant: Coal	Central Plant: Biomass	Central Plant: Intergrated Fermentation	Central Plant: Temperature Electrolysis with SOFC	Central Plant: Coke oven gas	Central Plant: Byproduct from Chlorine Plants	Central Plant: from NGL Cracker Plants	Central Plant: Pet Coke
Hydrogen Production Facility												
Share of H2 Production: G.H2	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0%	0%	0.0%
Share of H2 Production: L.H2	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0%	0%	

Section: CO2 Sequestration in Central H2 Plants: Percentage of CO2 to Be Captured

	G.H2	L.H2
NG-to-H2 Plant	96.2%	0.0%
Coal-to-H2 Plant	92.5%	92.5%
Biomass-to-H2 Plant	0.0%	0.0%
Pet Coke-to-H2 Plant	0.0%	
ATR-to-H2 Plant	94.5%	94.5%

Section: Selection of Method for Estimating Credits of Co-Products for H2 Pathways

Feedstock	NG	Coal	Biomass	Pet Coke	ATR	Methane Pyrolysis
Central Plant G.H2	1	1	1	1	1	1
Refueling Station G.H2	1					

Navigation: Petroleum, Co_processing, NG, MeOH_FTD, EtOH, Electric, Generation_mixes, Bio_electricity, Hydrogen, BioOil

Annotations: 1 Type 95%, 2 Press F9



File Home Insert Draw Page Layout Formulas Data Review View Automate Help

fx Insert Function Recently Used Financial Logical Text Date & Time Function Library Lookup & Reference Math & Trig More Functions Python Python Reset Diagnostics Initialization Name Manager Defined Names Define Name Use in Formula Create from Selection Trace Precedents Trace Dependents Remove Arrows Formula Auditing Watch Window Calculation Options Calculation

A1034

1	Home	Navigation Menu: Select the desired pathway from the following drop down lists (highlighted yellow) and click "Go"	
2	Inputs	Petroleum & Petroleum Products	Go
3	Results	Conventional Crude Oil for Use in US Refinery	Go
4	Back to Top	Alternative Fuels	Go
5		Gaseous Hydrogen (G. H ₂)	Go
6		Agricultural Products and Chemicals	Go
7		Ammonia as a Final Fertilizer	Go
8		Natural Gas & Fossil Fuels	Go
		Natural Gas (NG)	Go
		Crops and Feedstocks	Go
		Used Cooking Oil	Go

1033

1034 **26. Gaseous Hydrogen (G. H₂)**

1035

1036 **26.1. Produced in Central Plant from NG**

1037

1038

1039

1040

1041

1042

1043

1044

1045

1046

26.1. Produced in Central Plant from Solar Energy

WCF Fuel_Specs Car_TS LDT1_TS LDT2_TS Vehicles Urban_Shares Compression Coal T&D_Fl...



Well-to-Wheels (WTW) GHG Emissions



**GREAT PLAINS
INSTITUTE**

Argonne
NATIONAL LABORATORY

U.S. Department of
ENERGY

File Home Insert Draw Page Layout Formulas Data Review View Automate Help

fx Insert Function Recently Used Financial Logical Text Date & Time Math & Trig More Functions Function Library

Python Insert Python Diagnostics Initialization Reset Diagnostics Initialization

Name Manager Define Name Use in Formula Create from Selection

Trace Precedents Trace Dependents Remove Arrows Watch Windows Calculation Options

RNAVFCVGH2

```
= "FCV: G.H2"&IF(Inputs!F214=1, "Central Plants", "&IF(Inputs!F219=1, IF(Inputs!F248=1, "NA NG", IF(Inputs!F248=2, "Non-NA NG", IF(Inputs!F248=3, "FG", IF(RNG!E6=1, "LFG", IF(RNG!E7=1, "Manure-based AD Gas", IF(RNG!E8=1, "WWTP-based AD Gas", "RNG")))))),"")&IF(Inputs!F226=1,
```

WTW Results Menu

Select a vehicle type from a pink drop down menu, then press "Go"

- SI ICE Vehicles (Go)
- SIDI ICE Vehicles (Go)
- CIDI ICE Vehicles (Go)
- SI Hybrid Vehicles (HEV) (Go)
- CIDI Hybrid Vehicles (HEV) (Go)
- BEV and FCV (Go)
- FCV - Gaseous H2 (Go)
- SI Plug-in Hybrids (PHEV) (Go)
- CIDI Plug-in Hybrids (PHEV) (Go)
- GCI ICE Vehicles (Go)
- Performance-enhancing Fuels (Select Fuels)

Unit Selection

Select units from a pink drop down menu for the Results

Per Vehicle Distance Travelled

Energy Unit: Btu Emission Unit: g Service Functional Unit: mile

Per Energy in Fuels

Energy Unit: Btu Emission Unit: g Energy Functional Unit: MJ

FCV: G.H2, Central Plants, Mixed Sources

Item	Btu/mile or Gallon/mile or g/mile				Btu/MJ or Gallon/MJ or g/MJ			
	Feedstock	Fuel	Vehicle Operation	Total	Feedstock	Fuel	Vehicle Operation	Total
Total Energy	786	1,013						
Fossil Fuels	100	919						
Coal	1	135						
Natural Gas	99	694						
Petroleum	0	89						
Water Consumption	0.0	0.1						
CO2 (w/ C in VOC & CO)	6	40						
CH4	90	0.157						
N2O	001	0.002	0.000	0.009	0.001	0.001	0.000	0.001
GHGs	12	45	0	57	6	23	0	30
VOC: T	0.010	0.011	0.000	0.021	0.005	0.006	0.000	0.011
CO: T	0.032	0.045	0.000	0.077	0.016	0.023	0.000	0.040
NOx: T	0.037	0.055	0.000	0.092	0.019	0.029	0.000	0.048
PM10: T	0.000	0.006	0.031	0.037	0.000	0.003	0.016	0.019
PM2.5: Total	0.000	0.004	0.004	0.009	0.000	0.002	0.002	0.005

WTW GHG emissions
57 g CO₂e/mile or 30 g CO₂e/MJ

FCV fueled by gaseous hydrogen

Press F9

Results Petroleum Co_processing NG MeOH_FTD EtOH Electric Generation_mixes Bio_electricity Hydroger

Questions?

hcai@anl.gov

golson@gpisd.net

Visit <https://greet.anl.gov/>

Contributors

Gabrielle Olson, Branden Leonhardt, Pradeep Vyawahare, Clarence Ng, and Hao Cai



**GREAT PLAINS
INSTITUTE**



THANK YOU



**GREAT PLAINS
INSTITUTE**



Argonne
NATIONAL LABORATORY



U.S. Department of

ENERGY