February 10, 2025

Demo for Electricity and Electric Infrastructure 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

Zifeng Lu, Taemin Kim

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General Settings for Altering the Electric Generation Mix

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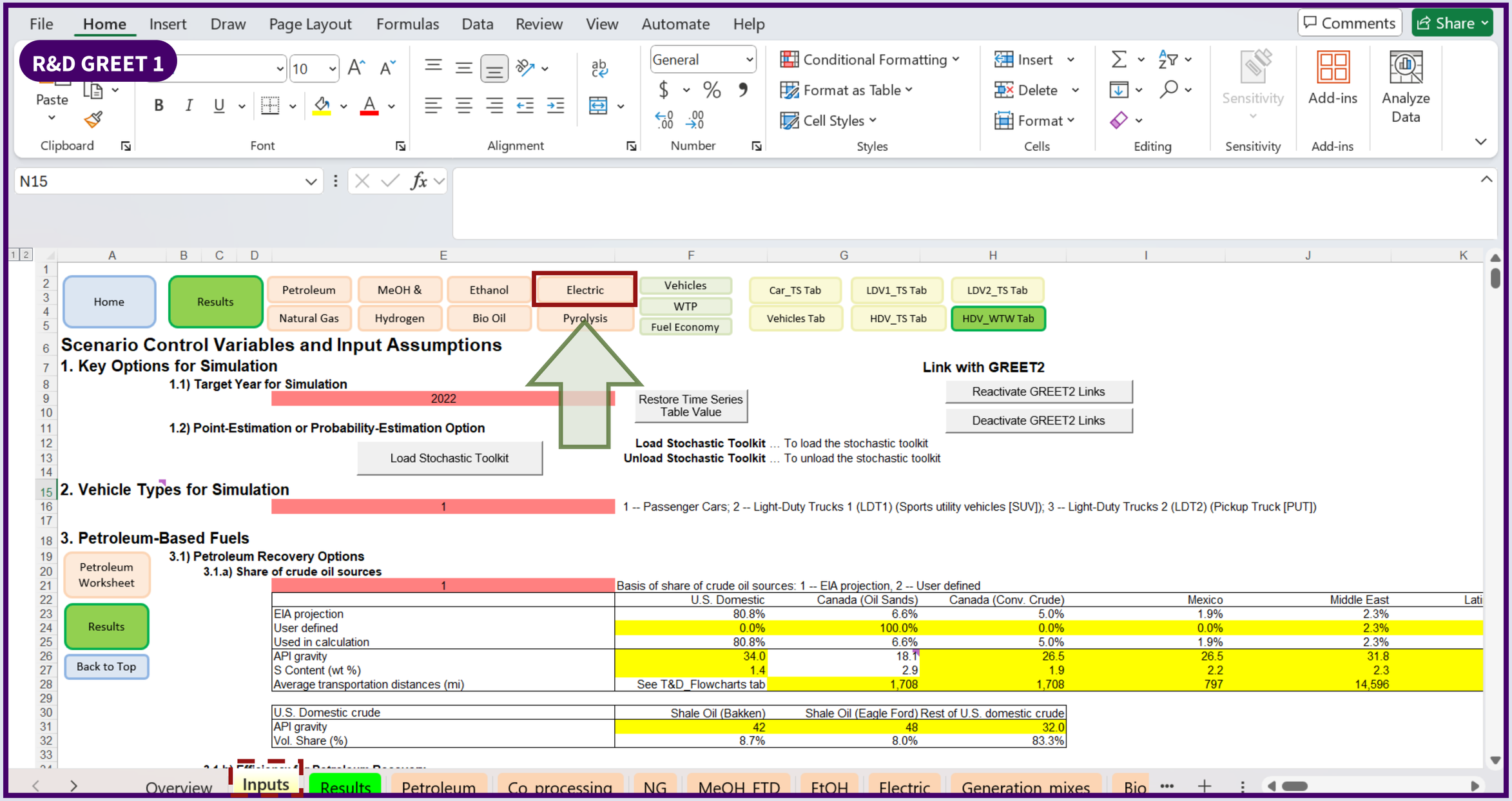

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10. Electric Generation

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

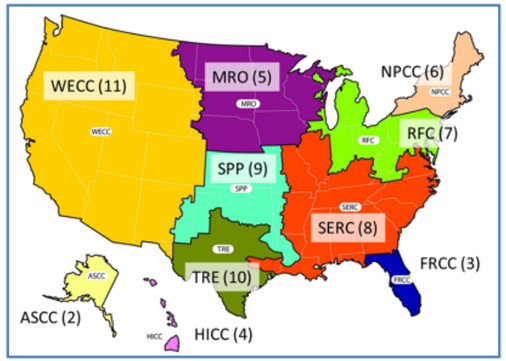
2

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



(U.S. EPA)

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
Residual oil	0.3%	0.3%	13.7%	13.7%	0.2%
Natural gas	38.5%	38.5%	46.7%	46.7%	71.3%
Coal	20.6%	20.6%	11.4%	11.4%	10.4%
Nuclear power	18.9%	18.9%	0.0%	0.0%	12.5%
Biomass	0.3%	0.3%	0.6%	0.6%	0.2%
Others	21.5%	21.5%	27.6%	27.6%	5.5%

10.2.c) Electric Generation Mixes for GREET Simulations

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

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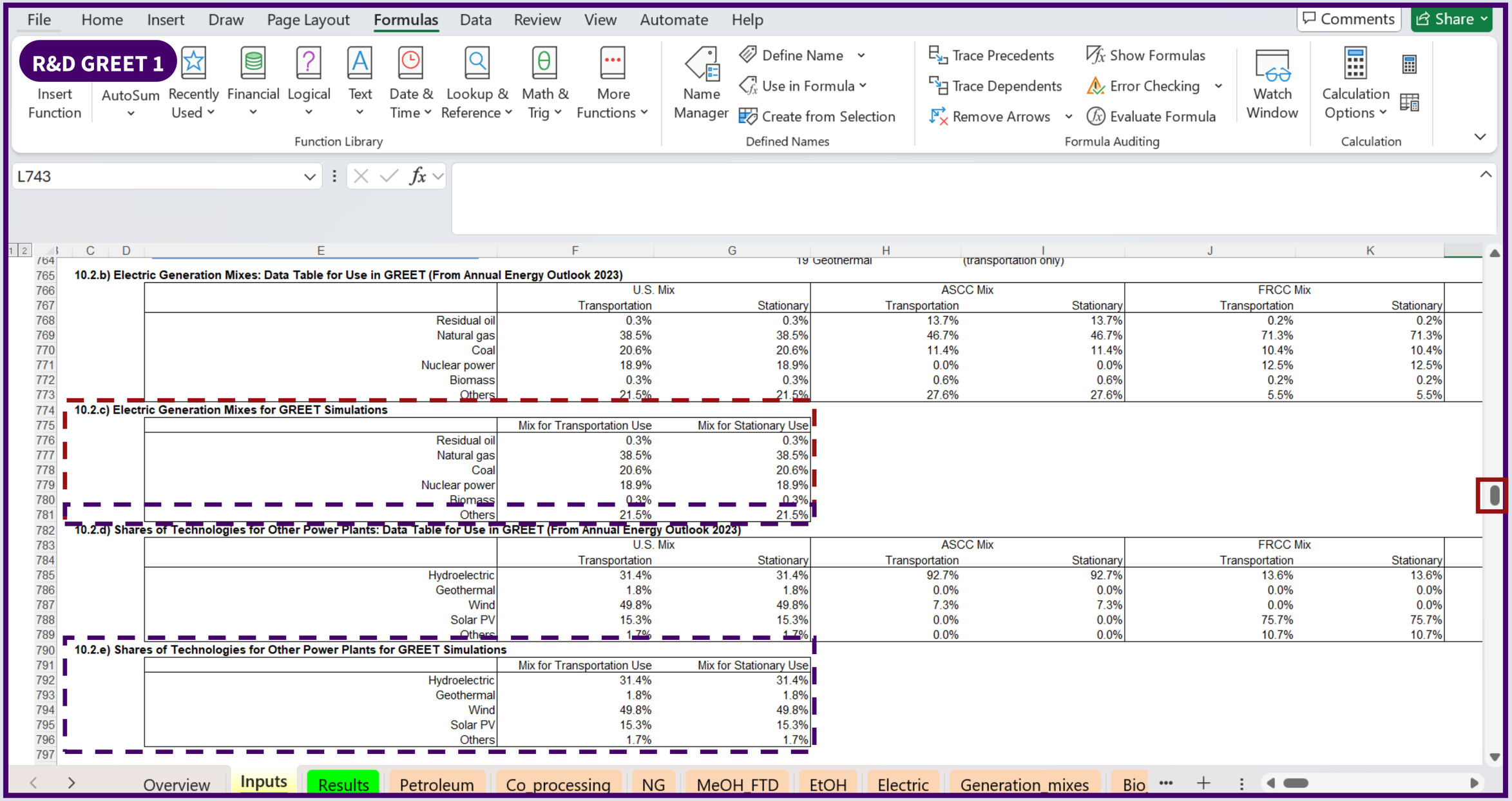

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Further Explore the Electric Generation Mix in a Pathway

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Electricity tabs in R&D GREET 1

Primary

Electric

Generation_mixes

Bioelectricity

Some Secondary

Inputs

Results

Petroleum

NG

RNG

BioOil

Fuel_Specs

Vehicles

T&D

T&D Flowcharts

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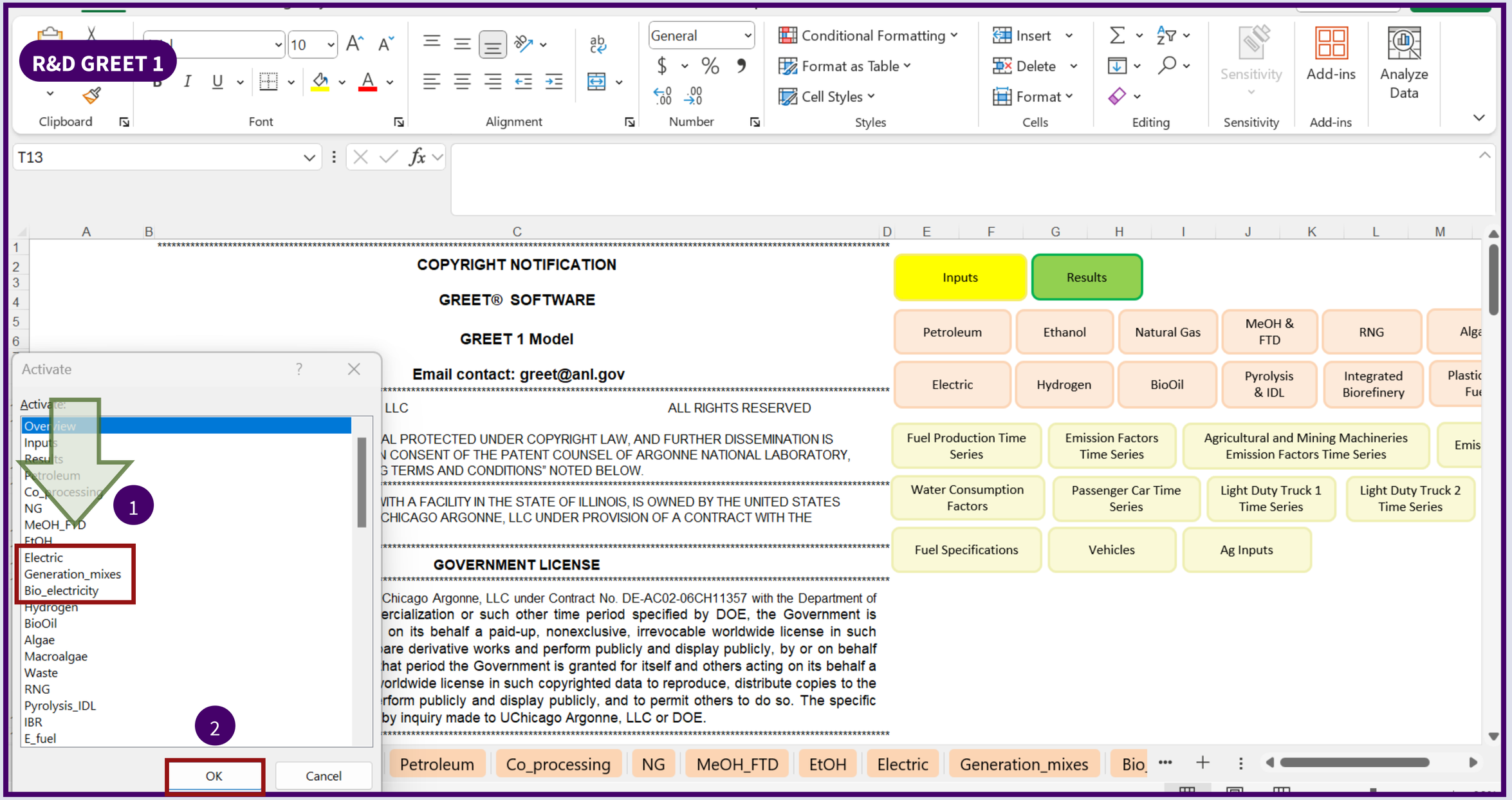

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Electricity Infrastructure

General Settings for Including the Construction of Electric Infrastructure Within the System Boundary

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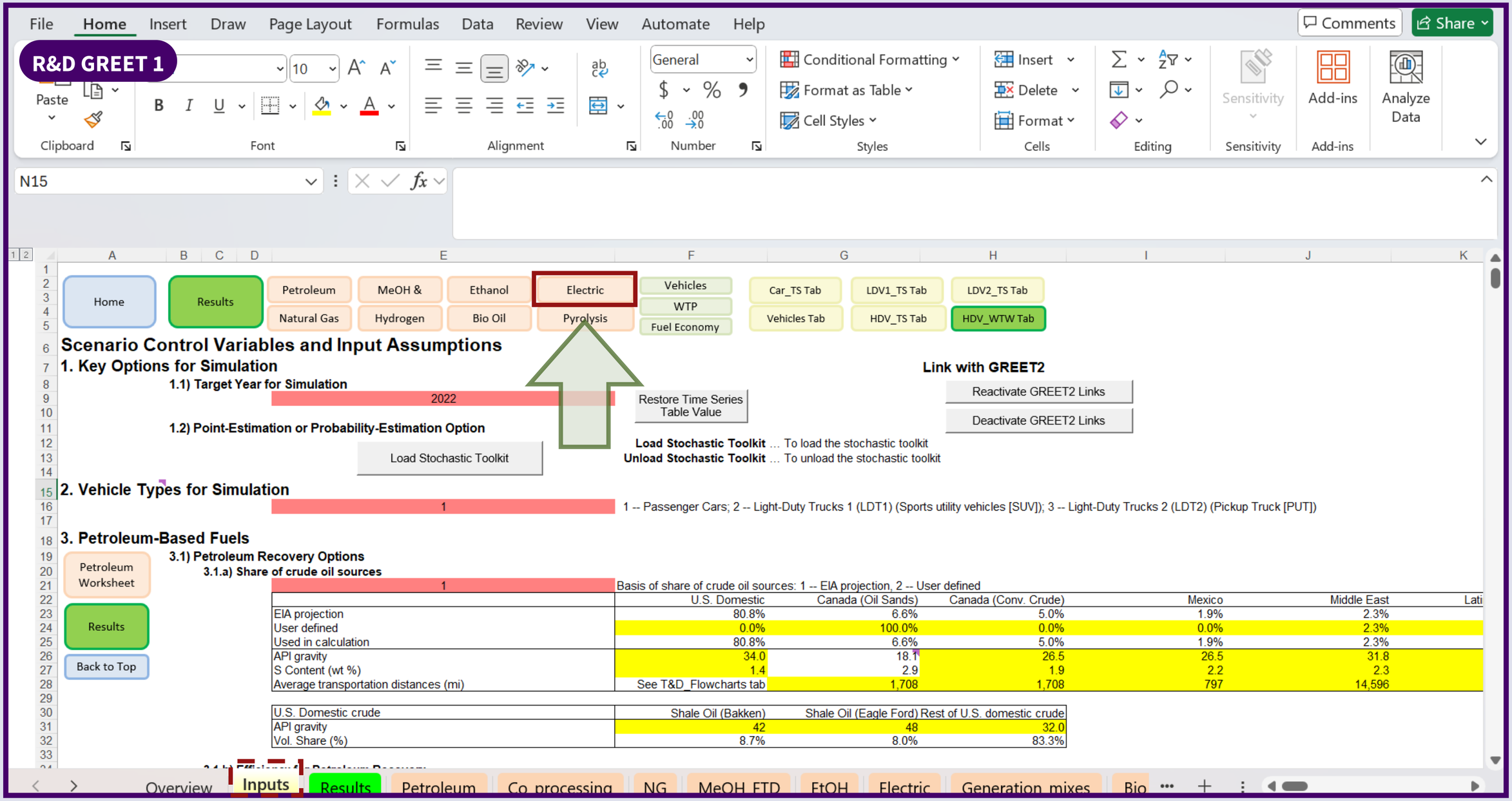

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10. Electric Generation

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

Electric

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10.2) Electricity Generation Mix

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

Results

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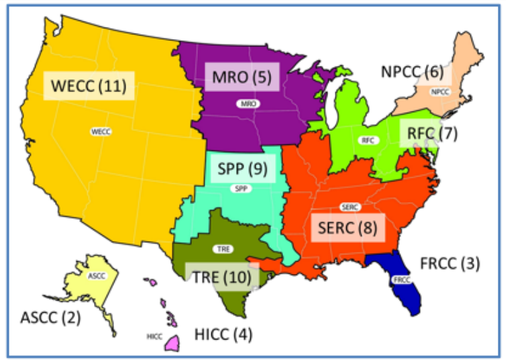
Mix for transportation use	1
Mix for stationary use	1



(U.S. EPA)

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Residual oil	0.3%	0.3%	13.7%	13.7%	0.2%
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Coal	20.6%	20.6%	11.4%	11.4%	10.4%
Nuclear power	18.9%	18.9%	0.0%	0.0%	12.5%
Biomass	0.3%	0.3%	0.6%	0.6%	0.2%
Others	21.5%	21.5%	27.6%	27.6%	5.5%

10.2.c) Electric Generation Mixes for GREET Simulations

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

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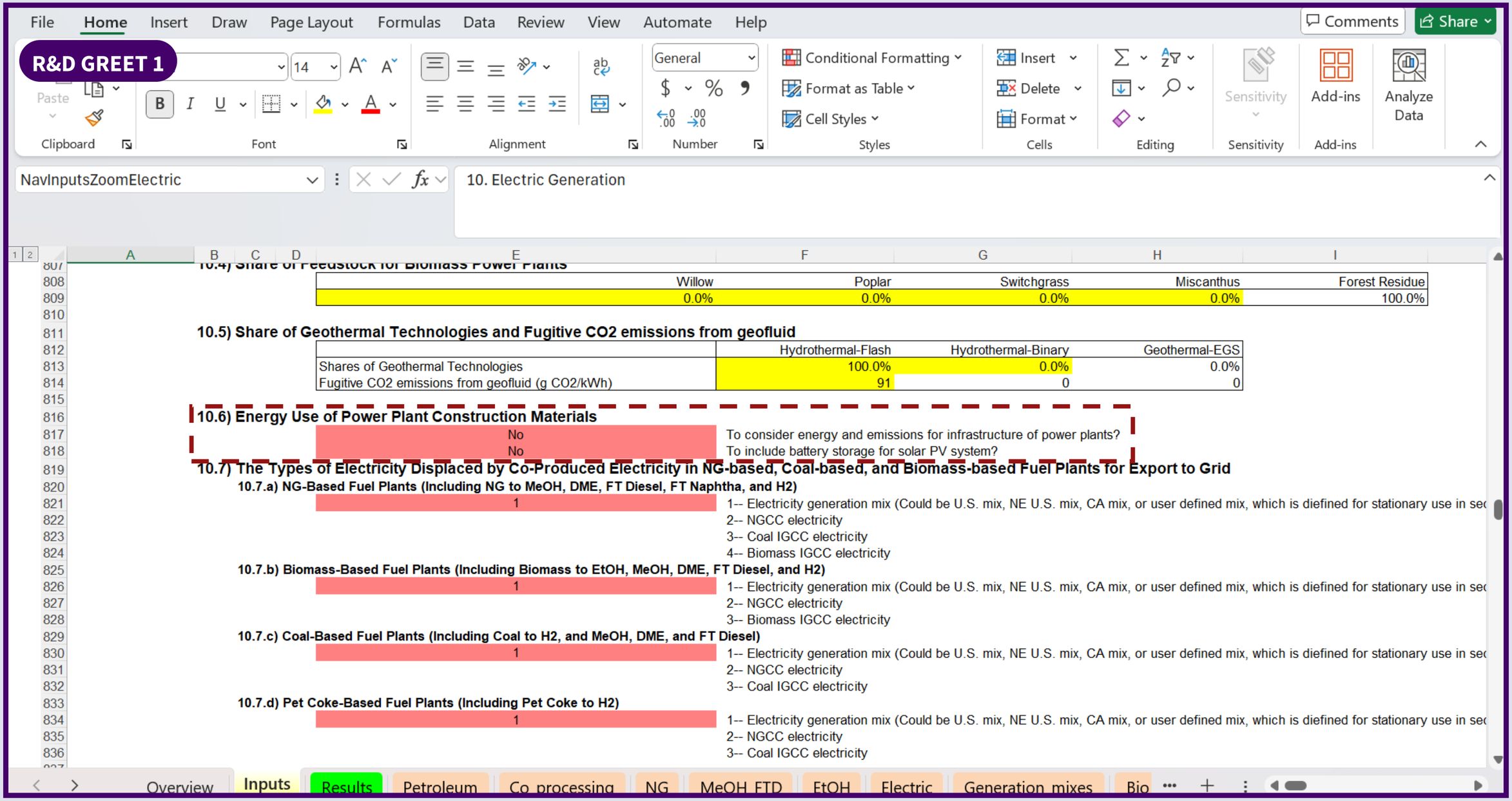

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Further Explore the Electric Infrastructure in a Pathway

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Electric infrastructure tabs in R&D GREET 1

Primary

Electric

ElecInfra

OilGasCoalInfra

Some Secondary

Inputs

Results

Fuel_Specs

EF

T&D

T&D Flowcharts

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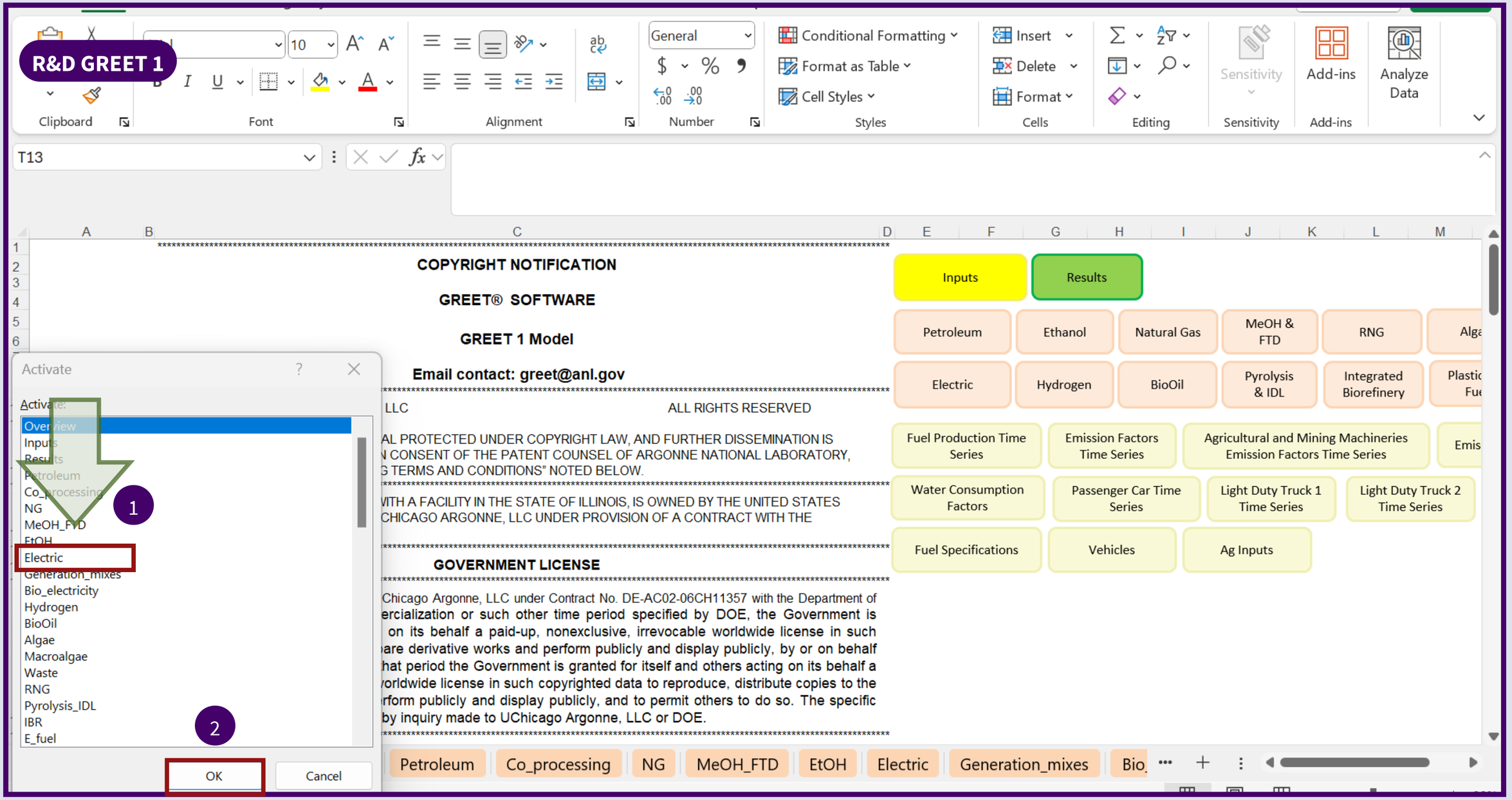

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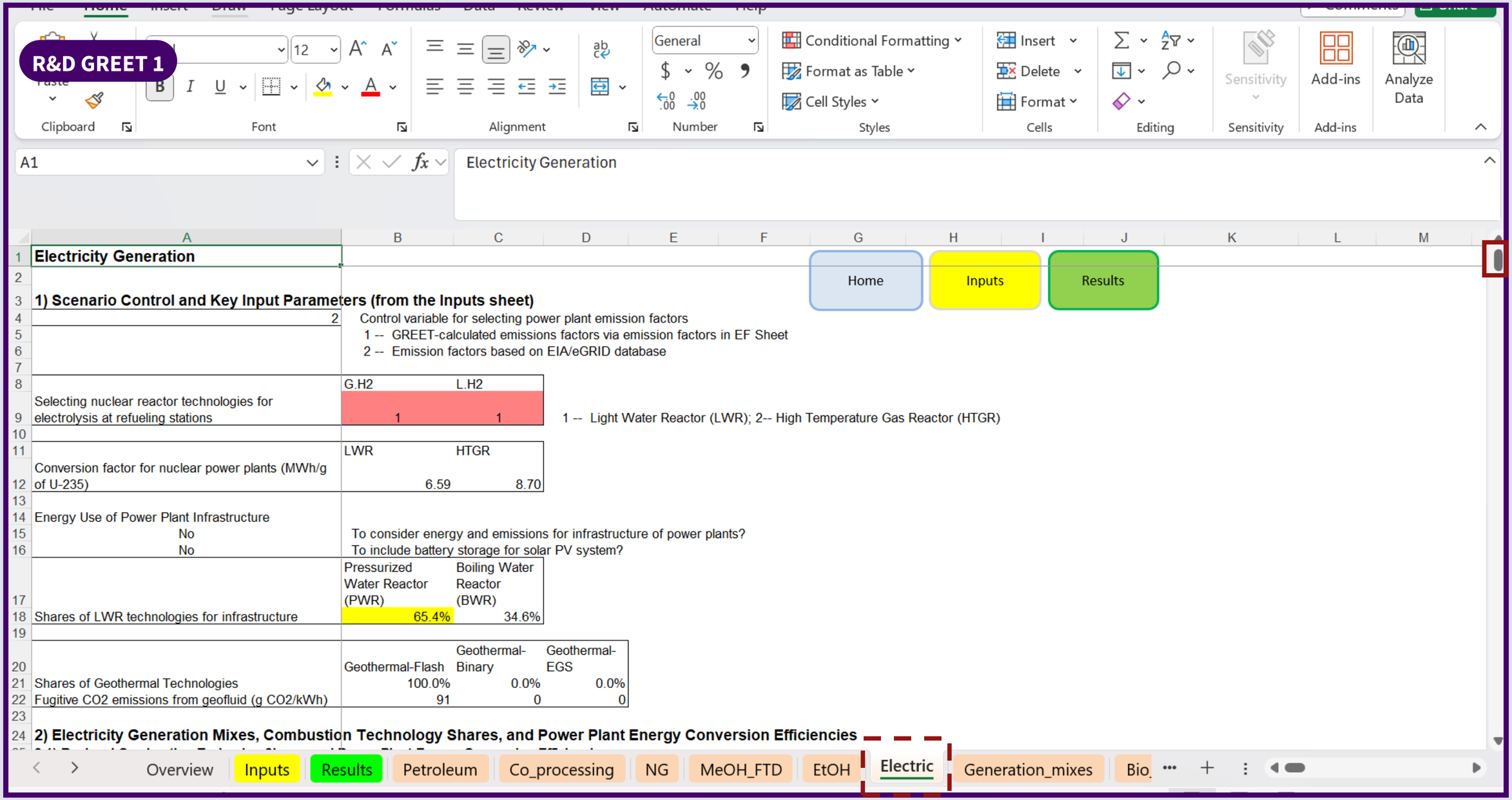

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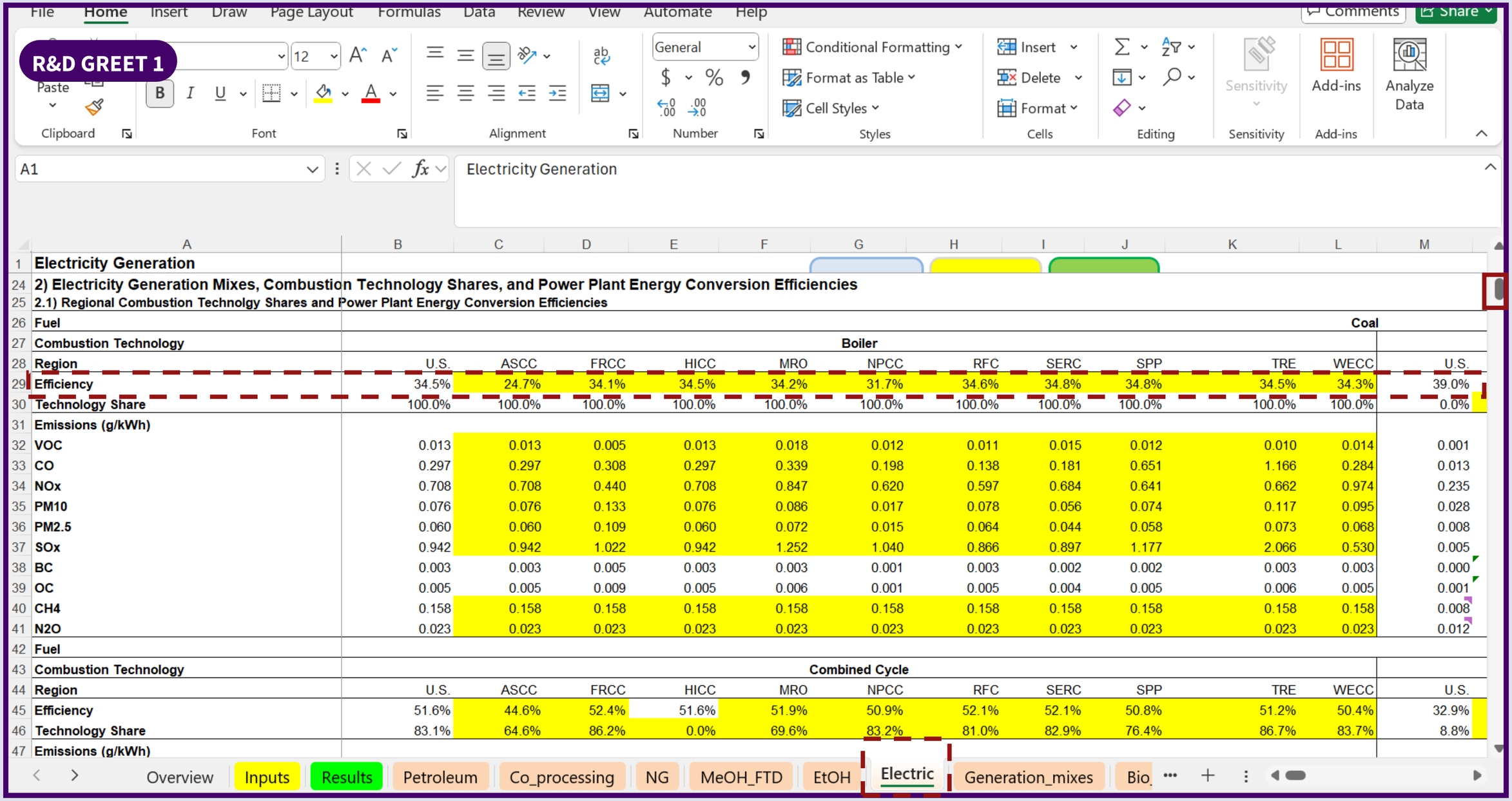

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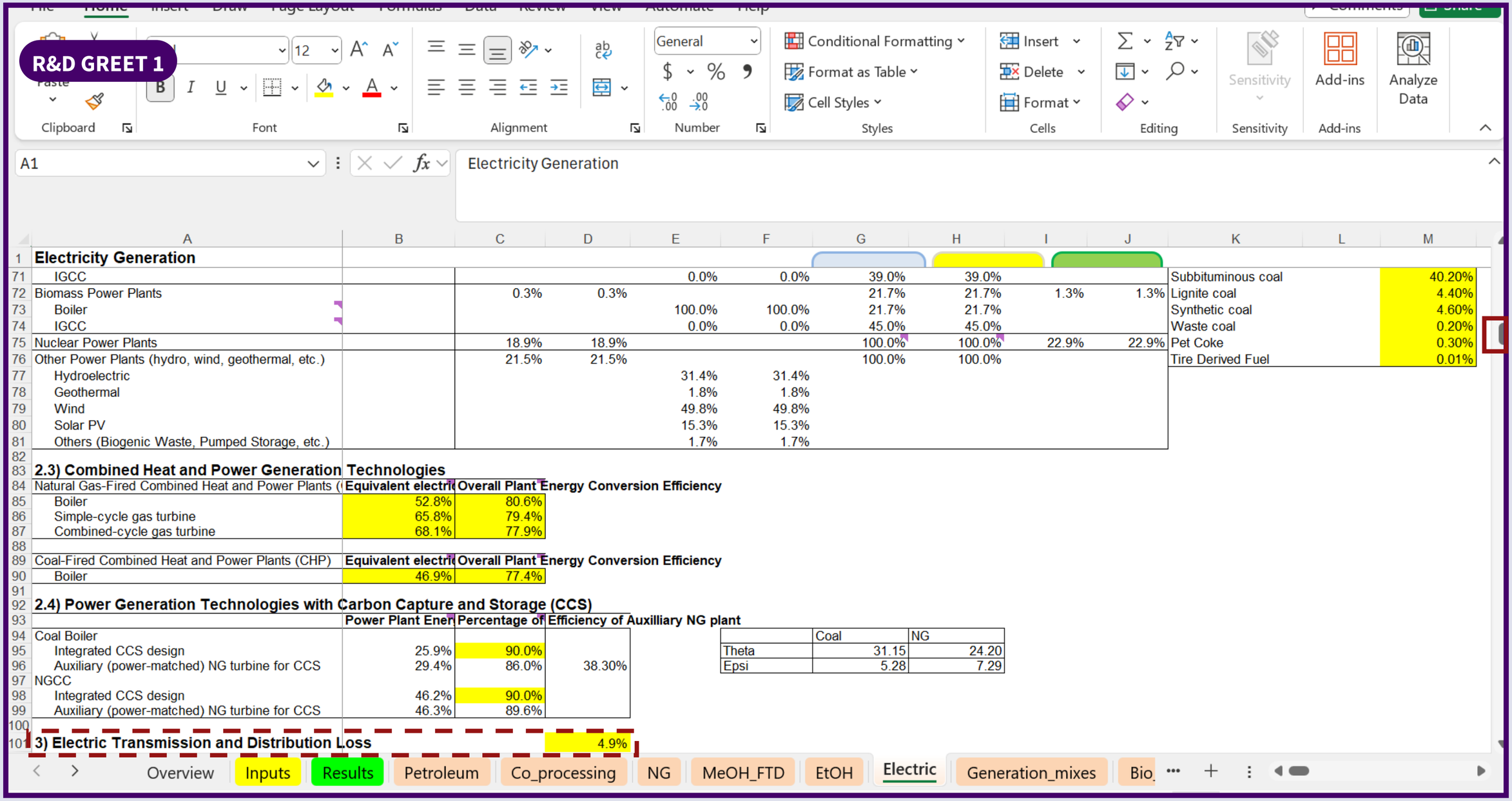

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	**Electricity Generation**												
71	IGCC				0.0%	0.0%	39.0%	39.0%			Subbituminous coal		40.20%
72	Biomass Power Plants		0.3%	0.3%			21.7%	21.7%	1.3%	1.3%	Lignite coal		4.40%
73	Boiler				100.0%	100.0%	21.7%	21.7%			Synthetic coal		4.60%
74	IGCC				0.0%	0.0%	45.0%	45.0%			Waste coal		0.20%
75	Nuclear Power Plants		18.9%	18.9%			100.0%	100.0%	22.9%	22.9%	Pet Coke		0.30%
76	Other Power Plants (hydro, wind, geothermal, etc.)		21.5%	21.5%			100.0%	100.0%			Tire Derived Fuel		0.01%
77	Hydroelectric				31.4%	31.4%							
78	Geothermal				1.8%	1.8%							
79	Wind				49.8%	49.8%							
80	Solar PV				15.3%	15.3%							
81	Others (Biogenic Waste, Pumped Storage, etc.)				1.7%	1.7%							
82													
83	**2.3) Combined Heat and Power Generation Technologies**												
84	Natural Gas-Fired Combined Heat and Power Plants (	**Equivalent electri**	**Overall Plant Energy Conversion Efficiency**										
85	Boiler	52.8%	80.6%										
86	Simple-cycle gas turbine	65.8%	79.4%										
87	Combined-cycle gas turbine	68.1%	77.9%										
88													
89	Coal-Fired Combined Heat and Power Plants (CHP)	**Equivalent electri**	**Overall Plant Energy Conversion Efficiency**										
90	Boiler	46.9%	77.4%										
91													
92	**2.4) Power Generation Technologies with Carbon Capture and Storage (CCS)**												
93		**Power Plant Ener**	**Percentage of**	**Efficiency of Auxilliary NG plant**									
94	Coal Boiler												
95	Integrated CCS design	25.9%	90.0%										
96	Auxiliary (power-matched) NG turbine for CCS	29.4%	86.0%	38.30%									
97	NGCC												
98	Integrated CCS design	46.2%	90.0%										
99	Auxiliary (power-matched) NG turbine for CCS	46.3%	89.6%										
100													
101	**3) Electric Transmission and Distribution Loss**			4.9%									

	Coal	NG
Theta	31.15	24.20
Epsi	5.28	7.29

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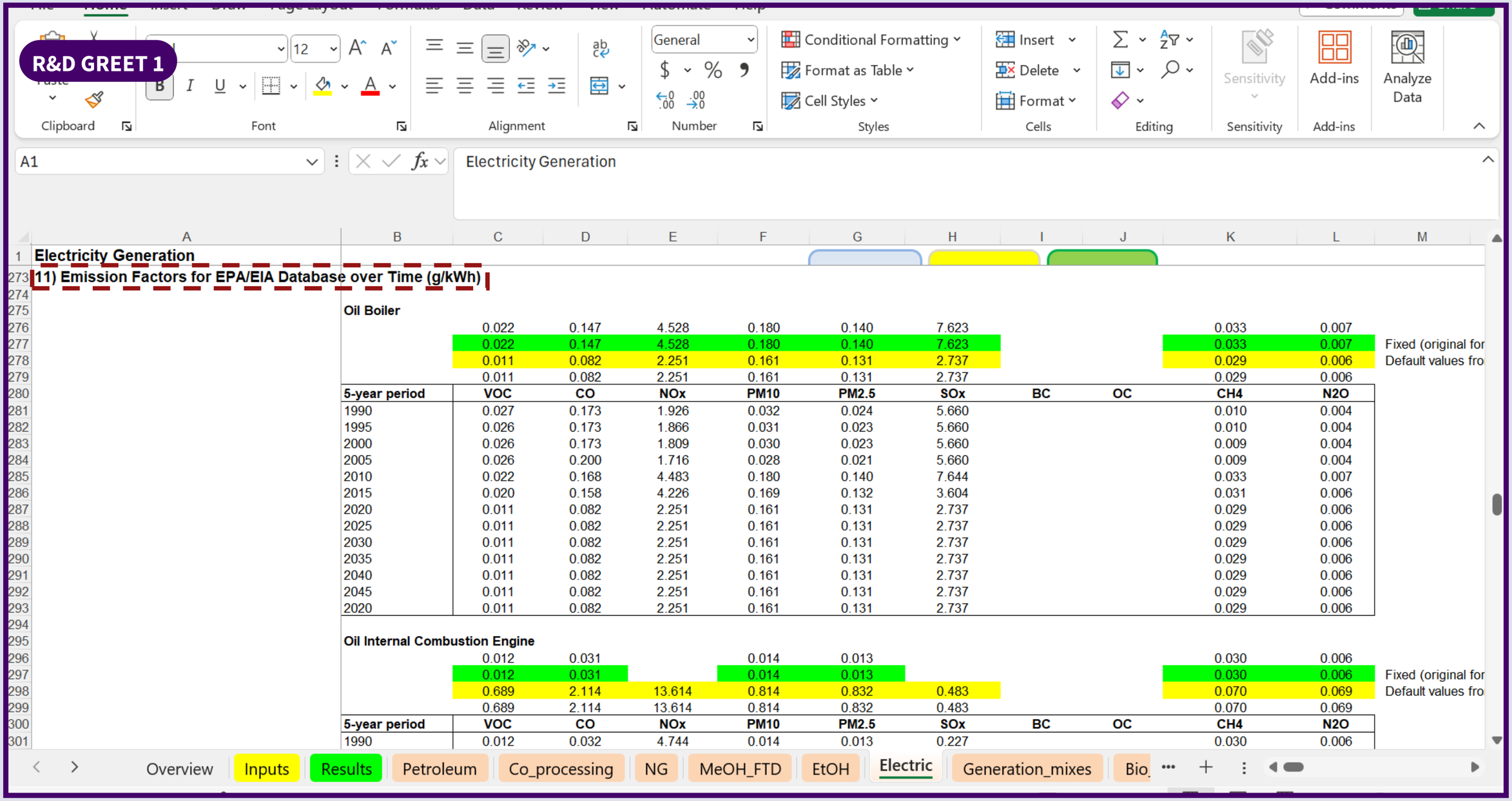

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Electric infrastructure tabs in R&D GREET 2

Primary

Wind_Turbine

Solar_PV

Hydropower

Nuclear_Power

Some Secondary

TEC_Results

MHDV_TEC_Results

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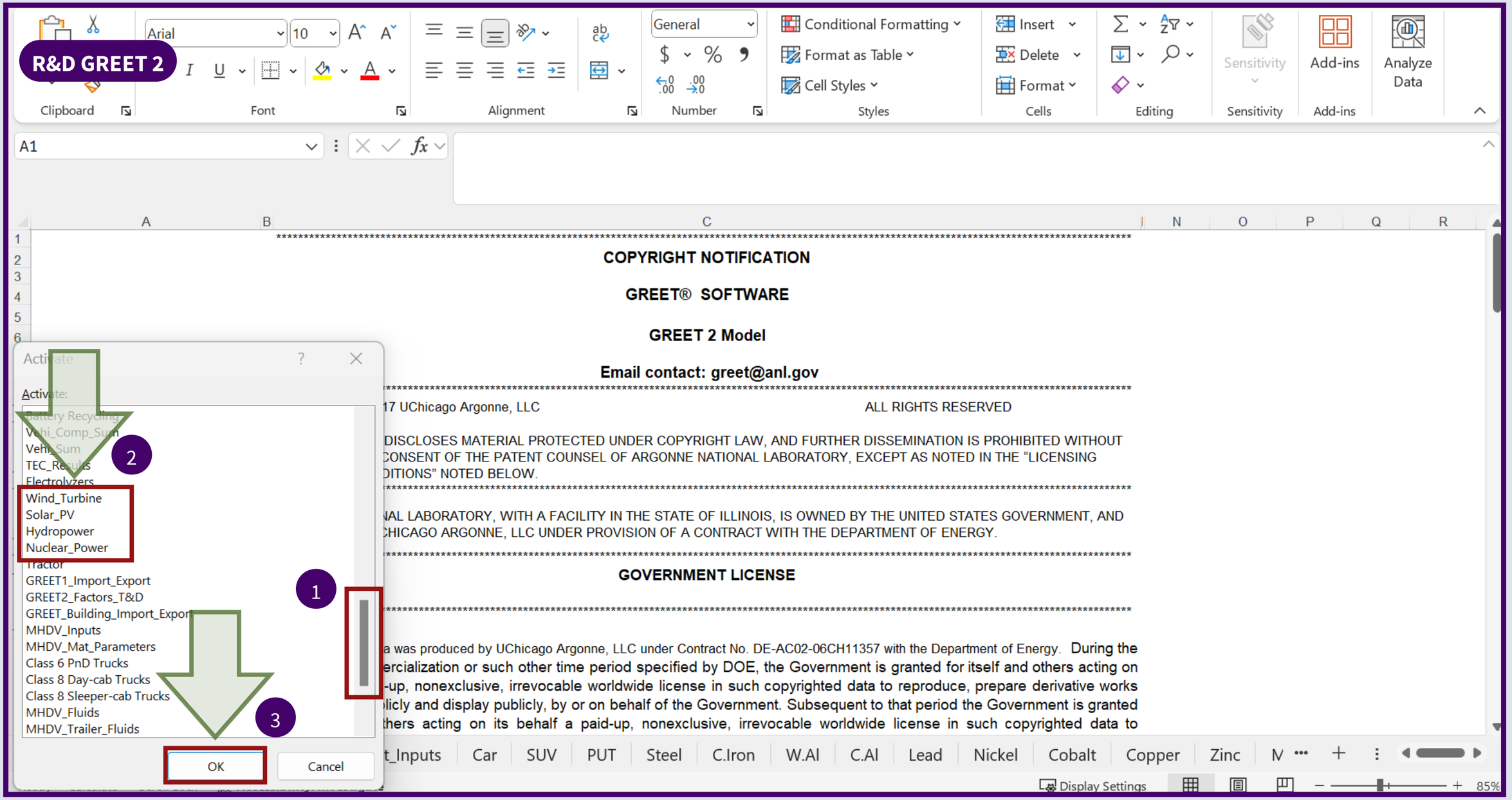

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Electric Generation Mix Scenarios

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CIDI RD from BioOil

Model a Compression Ignition Direct Injection (CIDI) Internal Combustion Engine Passenger Car Using Renewable Diesel from Biooil

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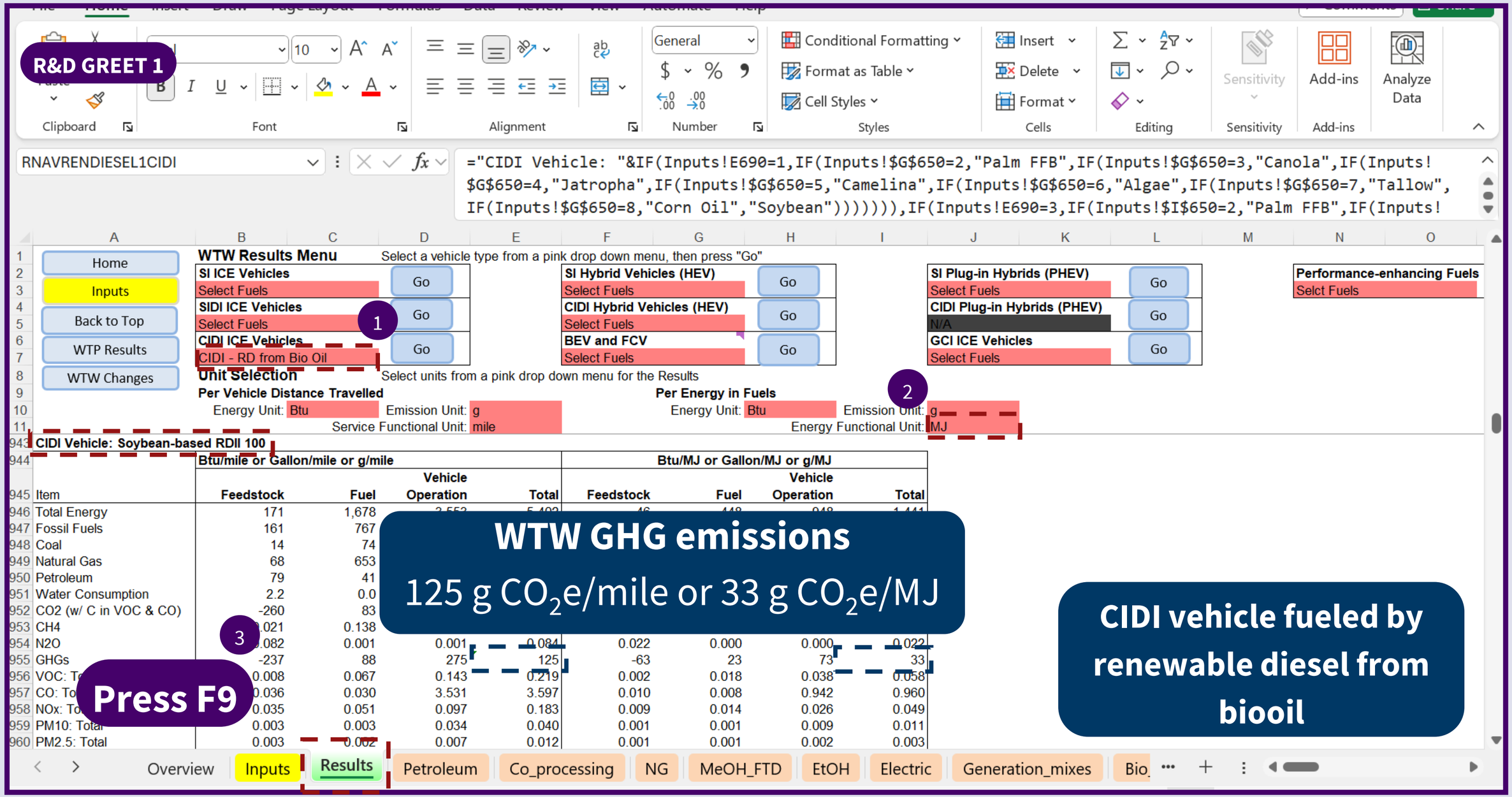
Well-to-Wheel (WTW) GHG Emissions



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50% Coal/50% NG Electricity

Model a Compression Ignition Direct Injection (CIDI) Internal Combustion Engine Passenger Car Using Renewable Diesel from Biooil Produced with a 50% Coal/50% Natural Gas Electricity Generation Mix

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Default Electricity Generation Mix

R&D GREET 1

10. Electric Generation

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

Electric

Results

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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
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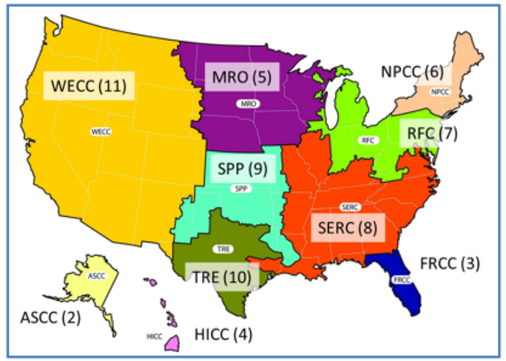

(U.S. EPA)

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Transportation compared to stationary electricity generation

Transportation Mix

Users to switch the electricity generation mix for the vehicle-use phase of the life cycle assessment

Stationary Mix

Users to switch the electricity generation mix for the phases of the life cycle assessment outside of the vehicle-use (i.e., electricity for coal production)

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R&D GREET 1

Electric_Averagemix_FacilityUse | 13

10. Electric Generation

Electric Worksheet | Results | Back to Top

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

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10.2) Electricity Generation Mix

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Mix for transportation use	1
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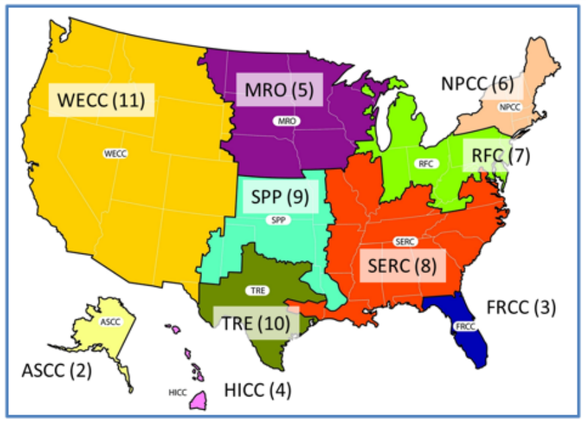

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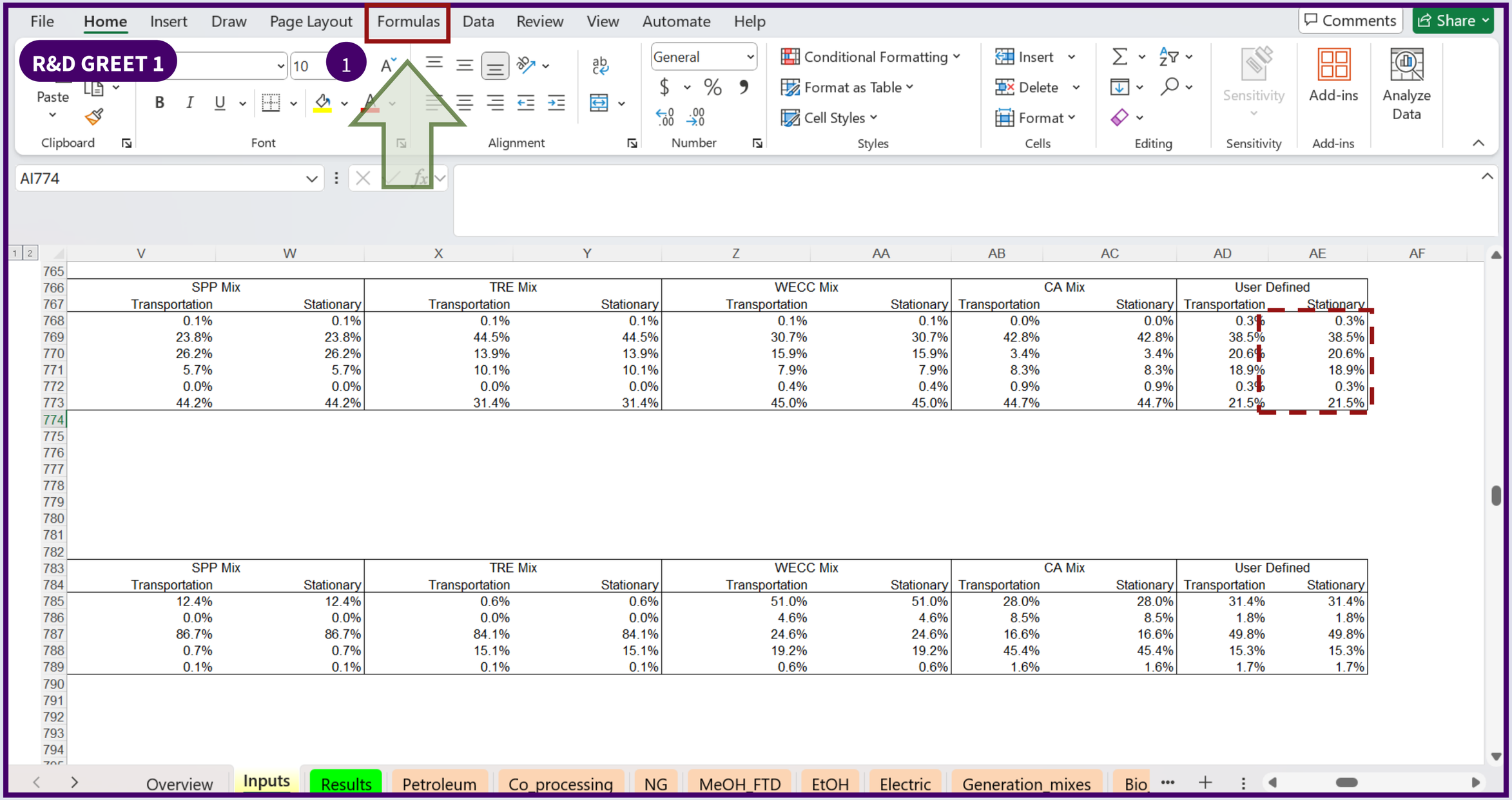

	SPP Mix		TRE Mix		WECC Mix		CA Mix		User Defined	
	Transportation	Stationary	Transportation	Stationary	Transportation	Stationary	Transportation	Stationary	Transportation	Stationary
	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.0%	0.0%	0.3%	0.3%
	23.8%	23.8%	44.5%	44.5%	30.7%	30.7%	42.8%	42.8%	38.5%	38.5%
	26.2%	26.2%	13.9%	13.9%	15.9%	15.9%	3.4%	3.4%	20.6%	20.6%
	5.7%	5.7%	10.1%	10.1%	7.9%	7.9%	8.3%	8.3%	18.9%	18.9%
	0.0%	0.0%	0.0%	0.0%	0.4%	0.4%	0.9%	0.9%	0.3%	0.3%
	44.2%	44.2%	31.4%	31.4%	45.0%	45.0%	44.7%	44.7%	21.5%	21.5%

	SPP Mix		TRE Mix		WECC Mix		CA Mix		User Defined	
	Transportation	Stationary	Transportation	Stationary	Transportation	Stationary	Transportation	Stationary	Transportation	Stationary
	12.4%	12.4%	0.6%	0.6%	51.0%	51.0%	28.0%	28.0%	31.4%	31.4%
	0.0%	0.0%	0.0%	0.0%	4.6%	4.6%	8.5%	8.5%	1.8%	1.8%
	86.7%	86.7%	84.1%	84.1%	24.6%	24.6%	16.6%	16.6%	49.8%	49.8%
	0.7%	0.7%	15.1%	15.1%	19.2%	19.2%	45.4%	45.4%	15.3%	15.3%
	0.1%	0.1%	0.1%	0.1%	0.6%	0.6%	1.6%	1.6%	1.7%	1.7%

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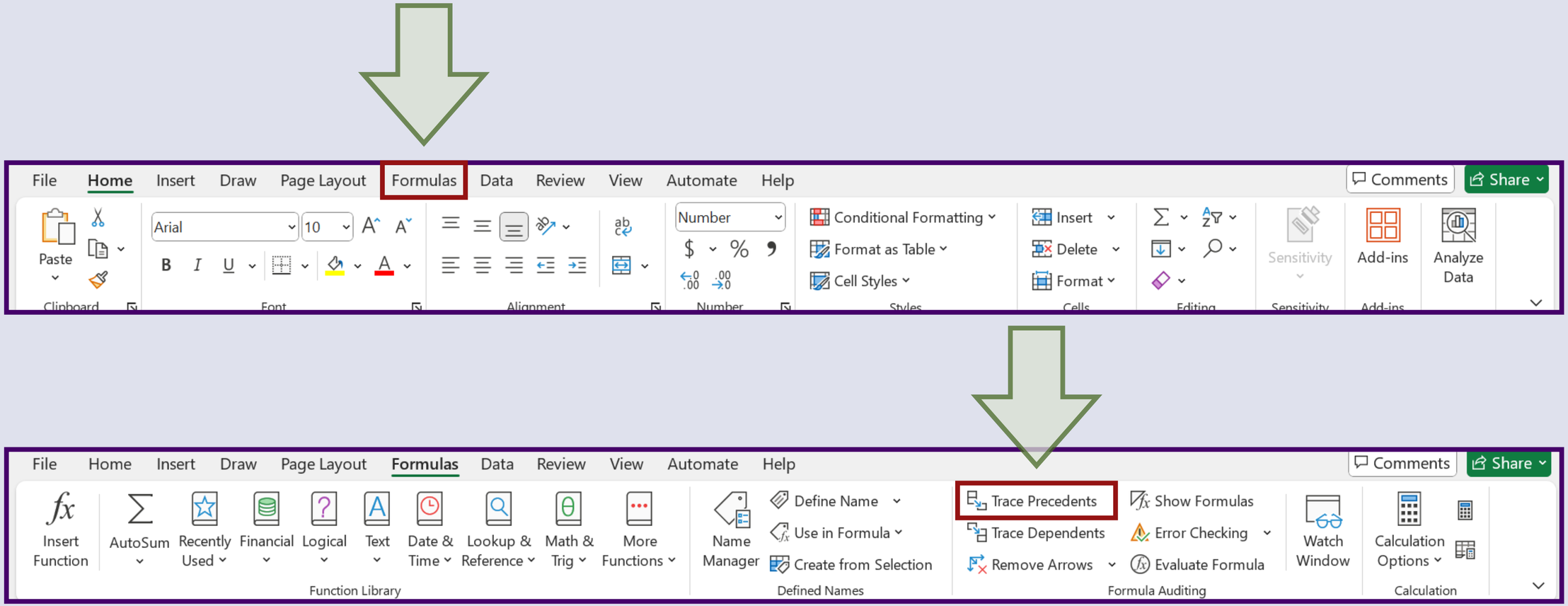
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Lookup & Reference
Math & Trig
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Function Library
Name Manager
Define Name
Use in Formula
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Trace Precedents
Trace Dependents
Remove Arrows
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Error Checking
Evaluate Formula
Formula Auditing
Watch Window
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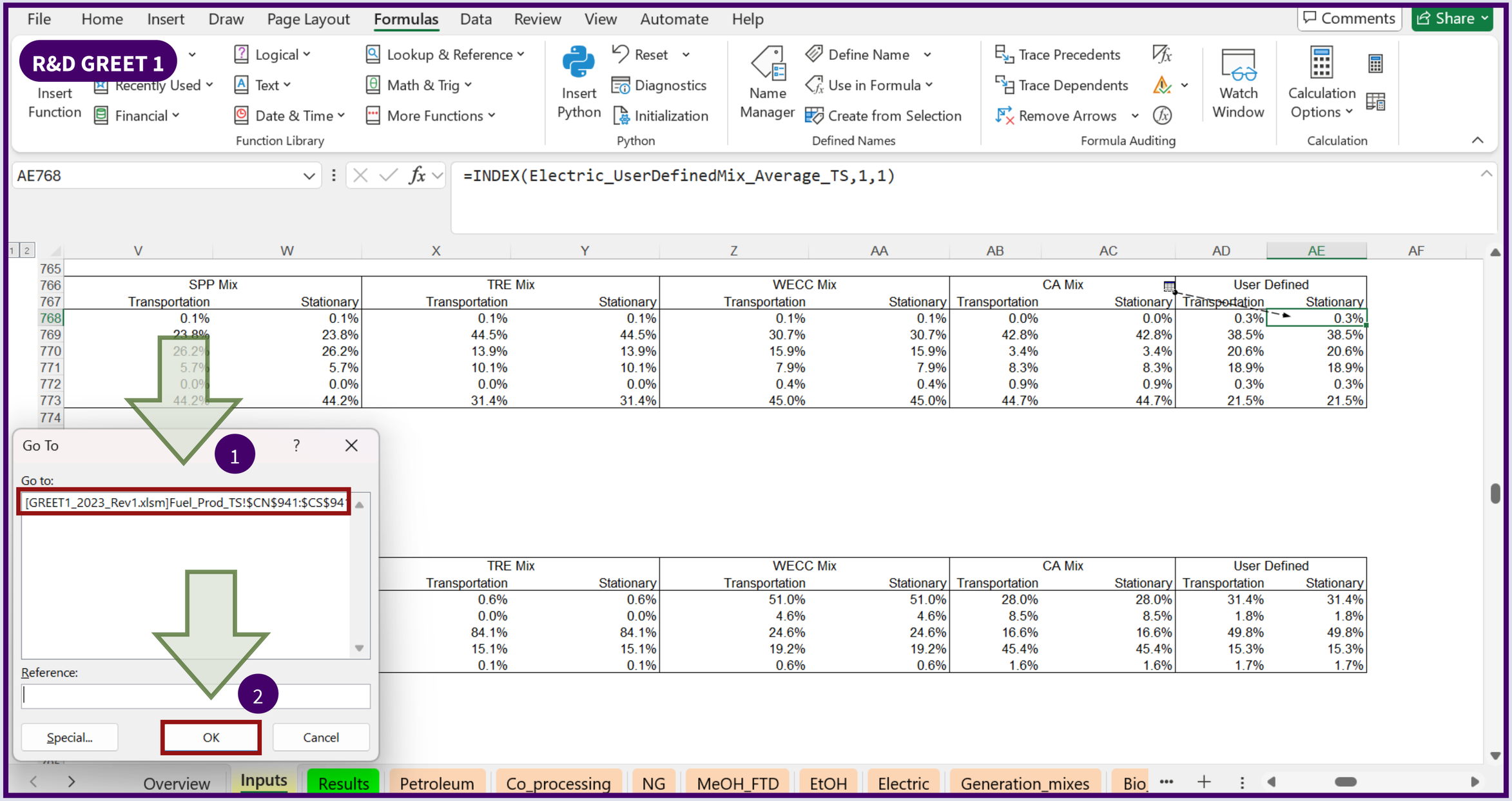

	SPP Mix		TRE Mix		WECC Mix		CA Mix		User Defined	
766	Transportation	Stationary	Transportation	Stationary	Transportation	Stationary	Transportation	Stationary	Transportation	Stationary
768	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.0%	0.0%	0.3%	0.3%
769	23.8%	23.8%	44.5%	44.5%	30.7%	30.7%	42.8%	42.8%	38.5%	38.5%
770	26.2%	26.2%	13.9%	13.9%	15.9%	15.9%	3.4%	3.4%	20.6%	20.6%
771	5.7%	5.7%	10.1%	10.1%	7.9%	7.9%	8.3%	8.3%	18.9%	18.9%
772	0.0%	0.0%	0.0%	0.0%	0.4%	0.4%	0.9%	0.9%	0.3%	0.3%
773	44.2%	44.2%	31.4%	31.4%	45.0%	45.0%	44.7%	44.7%	21.5%	21.5%

	TRE Mix		WECC Mix		CA Mix		User Defined	
	Transportation	Stationary	Transportation	Stationary	Transportation	Stationary	Transportation	Stationary
	0.6%	0.6%	51.0%	51.0%	28.0%	28.0%	31.4%	31.4%
	0.0%	0.0%	4.6%	4.6%	8.5%	8.5%	1.8%	1.8%
	84.1%	84.1%	24.6%	24.6%	16.6%	16.6%	49.8%	49.8%
	15.1%	15.1%	19.2%	19.2%	45.4%	45.4%	15.3%	15.3%
	0.1%	0.1%	0.6%	0.6%	1.6%	1.6%	1.7%	1.7%

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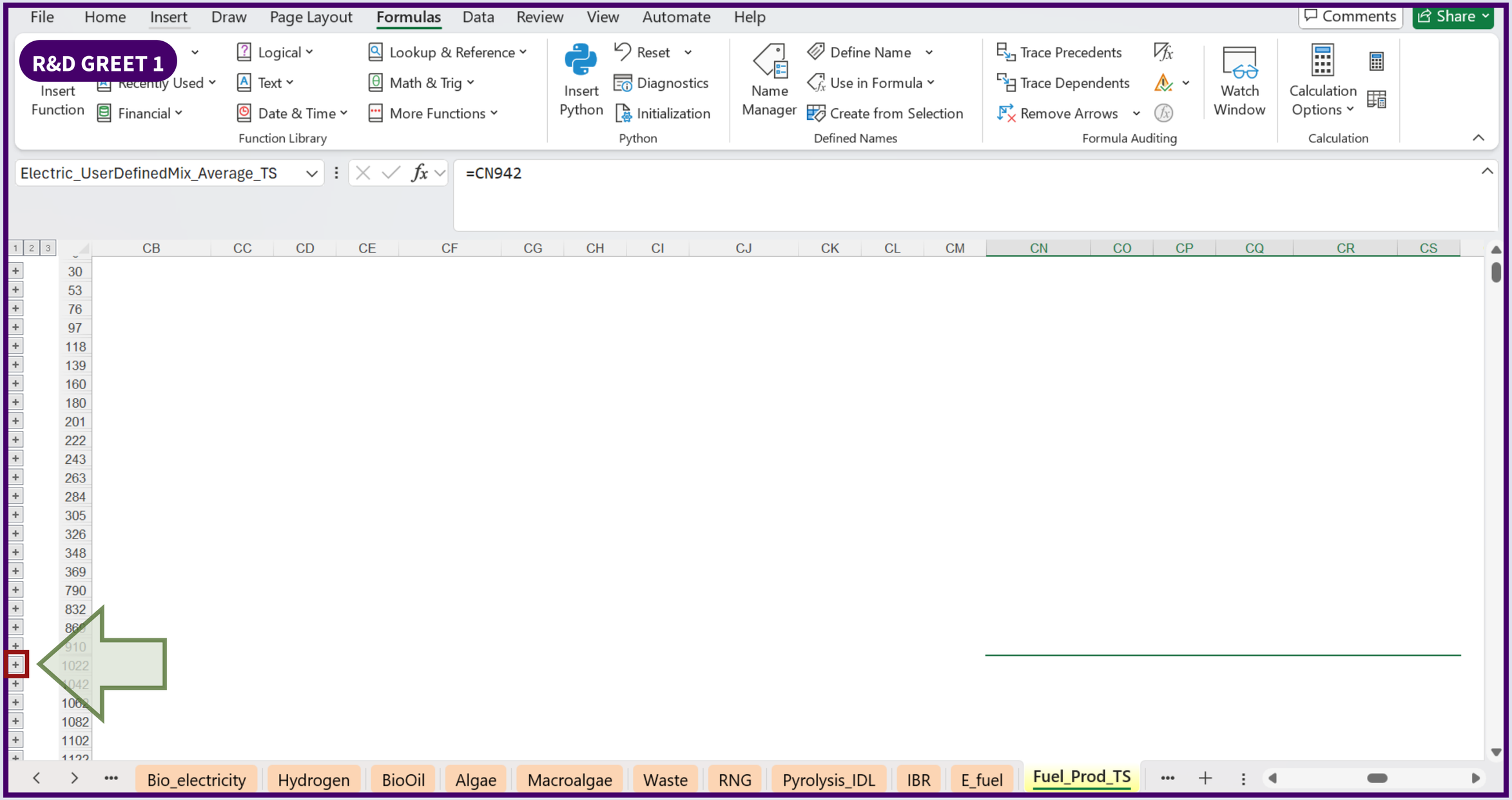

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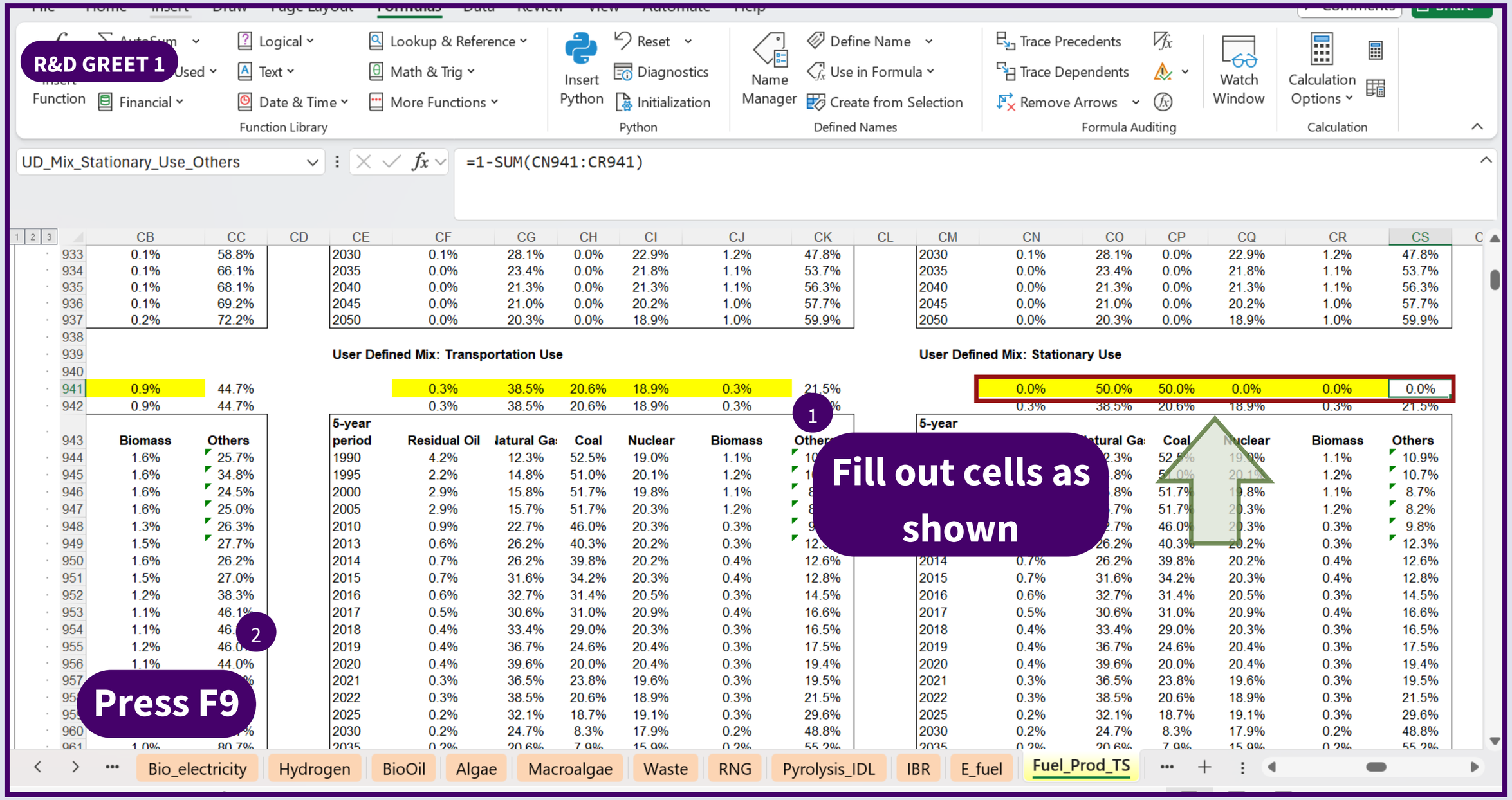

	CB	CC	CD	CE	CF	CG	CH	CI	CJ	CK	CL	CM	CN	CO	CP	CQ	CR	CS
933	0.1%	58.8%		2030	0.1%	28.1%	0.0%	22.9%	1.2%	47.8%		2030	0.1%	28.1%	0.0%	22.9%	1.2%	47.8%
934	0.1%	66.1%		2035	0.0%	23.4%	0.0%	21.8%	1.1%	53.7%		2035	0.0%	23.4%	0.0%	21.8%	1.1%	53.7%
935	0.1%	68.1%		2040	0.0%	21.3%	0.0%	21.3%	1.1%	56.3%		2040	0.0%	21.3%	0.0%	21.3%	1.1%	56.3%
936	0.1%	69.2%		2045	0.0%	21.0%	0.0%	20.2%	1.0%	57.7%		2045	0.0%	21.0%	0.0%	20.2%	1.0%	57.7%
937	0.2%	72.2%		2050	0.0%	20.3%	0.0%	18.9%	1.0%	59.9%		2050	0.0%	20.3%	0.0%	18.9%	1.0%	59.9%
938																		
939																		
940																		
941	0.9%	44.7%			0.3%	38.5%	20.6%	18.9%	0.3%	21.5%			0.0%	50.0%	50.0%	0.0%	0.0%	0.0%
942	0.9%	44.7%			0.3%	38.5%	20.6%	18.9%	0.3%					0.3%	38.5%	20.6%	18.9%	0.3%	21.5%
943	Biomass	Others		5-year period	Residual Oil	Natural Gas	Coal	Nuclear	Biomass	Others		5-year		Natural Gas	Coal	Nuclear	Biomass	Others
944	1.6%	25.7%		1990	4.2%	12.3%	52.5%	19.0%	1.1%	10				12.3%	52.5%	19.0%	1.1%	10.9%
945	1.6%	34.8%		1995	2.2%	14.8%	51.0%	20.1%	1.2%	1				14.8%	51.0%	20.1%	1.2%	10.7%
946	1.6%	24.5%		2000	2.9%	15.8%	51.7%	19.8%	1.1%	8				15.8%	51.7%	19.8%	1.1%	8.7%
947	1.6%	25.0%		2005	2.9%	15.7%	51.7%	20.3%	1.2%	8				15.7%	51.7%	20.3%	1.2%	8.2%
948	1.3%	26.3%		2010	0.9%	22.7%	46.0%	20.3%	0.3%	9				22.7%	46.0%	20.3%	0.3%	9.8%
949	1.5%	27.7%		2013	0.6%	26.2%	40.3%	20.2%	0.3%	12				26.2%	40.3%	20.2%	0.3%	12.3%
950	1.6%	26.2%		2014	0.7%	26.2%	39.8%	20.2%	0.4%	12.6%		2014	0.7%	26.2%	39.8%	20.2%	0.4%	12.6%
951	1.5%	27.0%		2015	0.7%	31.6%	34.2%	20.3%	0.4%	12.8%		2015	0.7%	31.6%	34.2%	20.3%	0.4%	12.8%
952	1.2%	38.3%		2016	0.6%	32.7%	31.4%	20.5%	0.3%	14.5%		2016	0.6%	32.7%	31.4%	20.5%	0.3%	14.5%
953	1.1%	46.1%		2017	0.5%	30.6%	31.0%	20.9%	0.4%	16.6%		2017	0.5%	30.6%	31.0%	20.9%	0.4%	16.6%
954	1.1%	46.		2018	0.4%	33.4%	29.0%	20.3%	0.3%	16.5%		2018	0.4%	33.4%	29.0%	20.3%	0.3%	16.5%
955	1.2%	46.0		2019	0.4%	36.7%	24.6%	20.4%	0.3%	17.5%		2019	0.4%	36.7%	24.6%	20.4%	0.3%	17.5%
956	1.1%	44.0%		2020	0.4%	39.6%	20.0%	20.4%	0.3%	19.4%		2020	0.4%	39.6%	20.0%	20.4%	0.3%	19.4%
957		%		2021	0.3%	36.5%	23.8%	19.6%	0.3%	19.5%		2021	0.3%	36.5%	23.8%	19.6%	0.3%	19.5%
95				2022	0.3%	38.5%	20.6%	18.9%	0.3%	21.5%		2022	0.3%	38.5%	20.6%	18.9%	0.3%	21.5%
95				2025	0.2%	32.1%	18.7%	19.1%	0.3%	29.6%		2025	0.2%	32.1%	18.7%	19.1%	0.3%	29.6%
960		%		2030	0.2%	24.7%	8.3%	17.9%	0.2%	48.8%		2030	0.2%	24.7%	8.3%	17.9%	0.2%	48.8%
961	1.0%	80.7%		2035	0.2%	20.6%	7.9%	15.9%	0.2%	55.2%		2035	0.2%	20.6%	7.9%	15.9%	0.2%	55.2%

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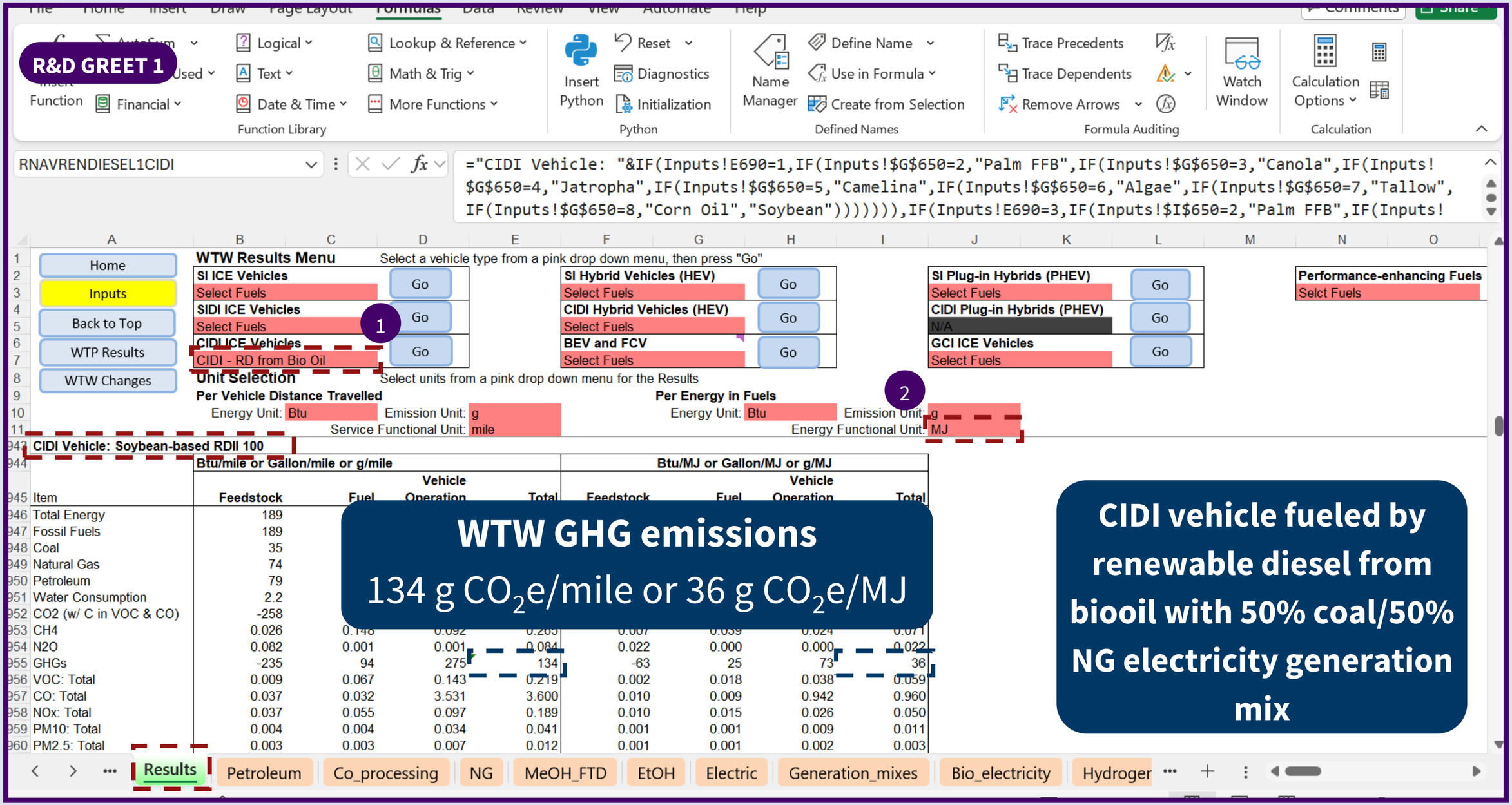
Well-to-Wheel (WTW) GHG Emissions



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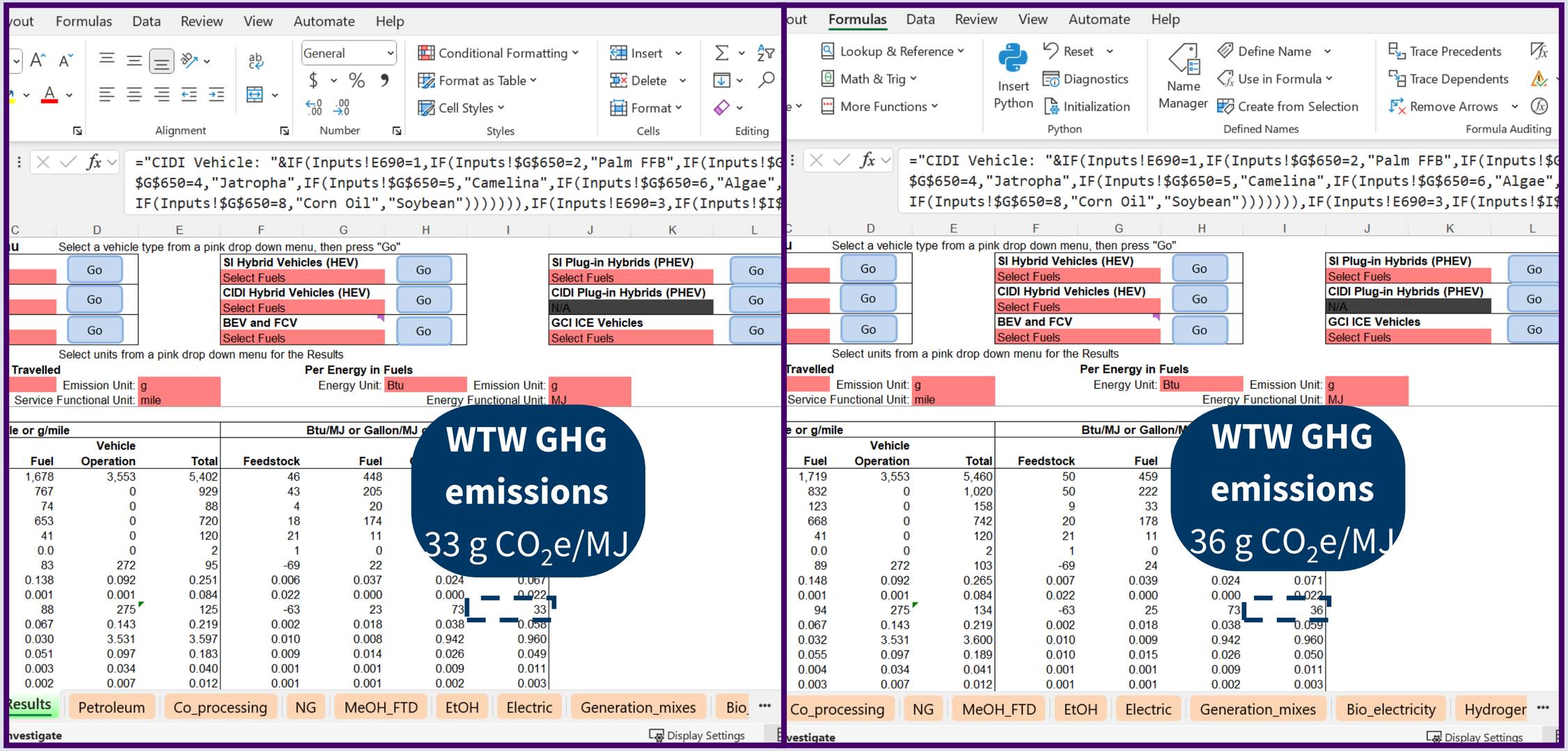
Default electricity generation mix

50% coal/50% NG electricity generation mix



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FCV in Florida

Model a Fuel Cell Electric Vehicle (FCV) Using Gaseous Hydrogen Produced with a Florida-specific Electricity Grid (EIA Form-923) Electricity Generation Mix

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R&D GREET 1

Electric_Averagemix_FacilityUse | 13

10. Electric Generation

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

Electric Worksheet

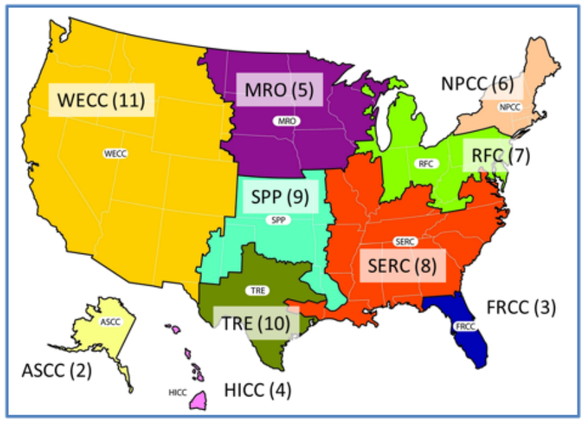
Results

Back to Top

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	13



1
2

(U.S. EPA)

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	
	Transportation	Stationary	Transportation	Stationary
Residual oil	0.3%	0.3%	13.7%	13.7%
Natural gas	38.5%	38.5%	46.7%	46.7%

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

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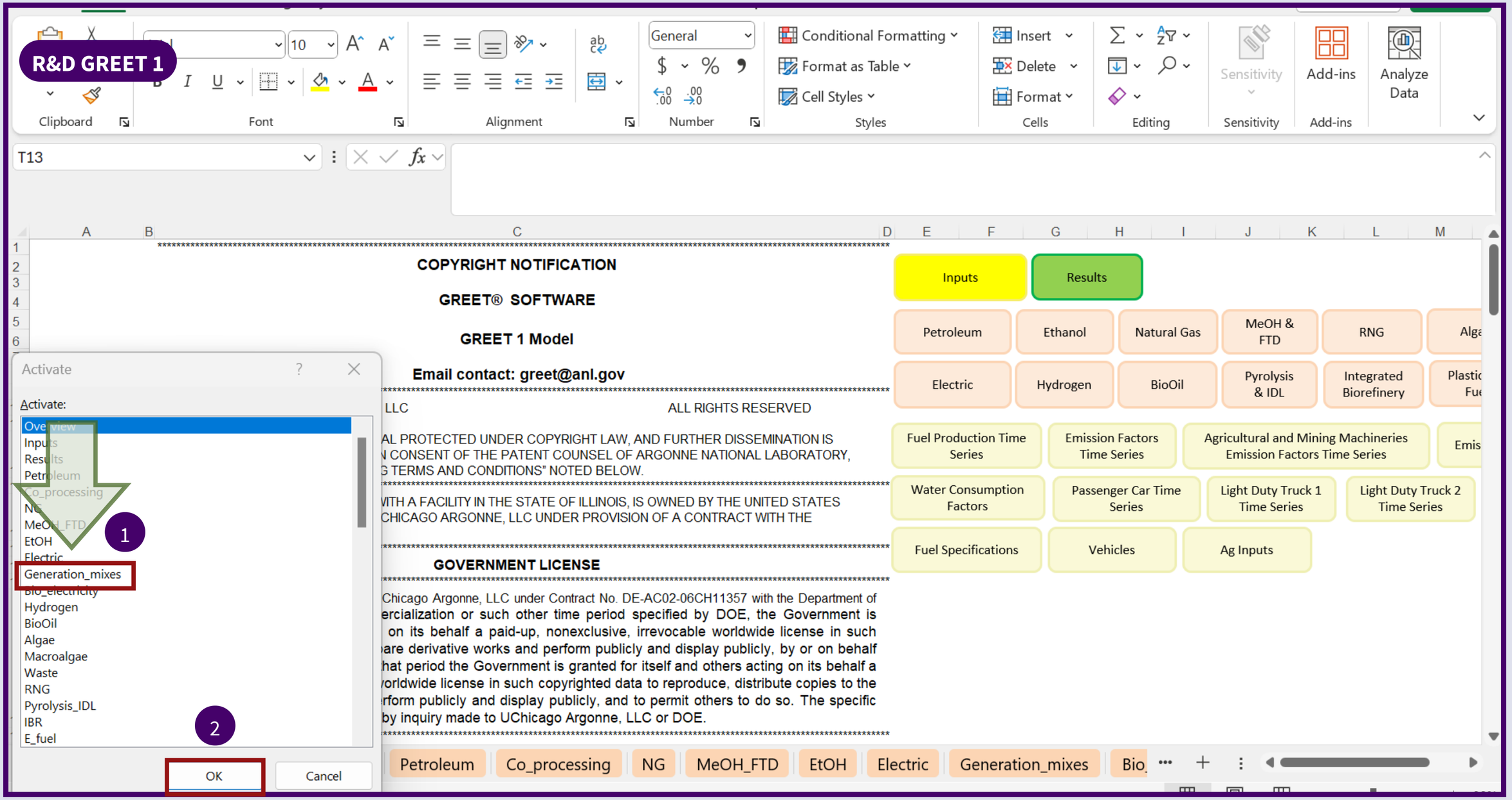

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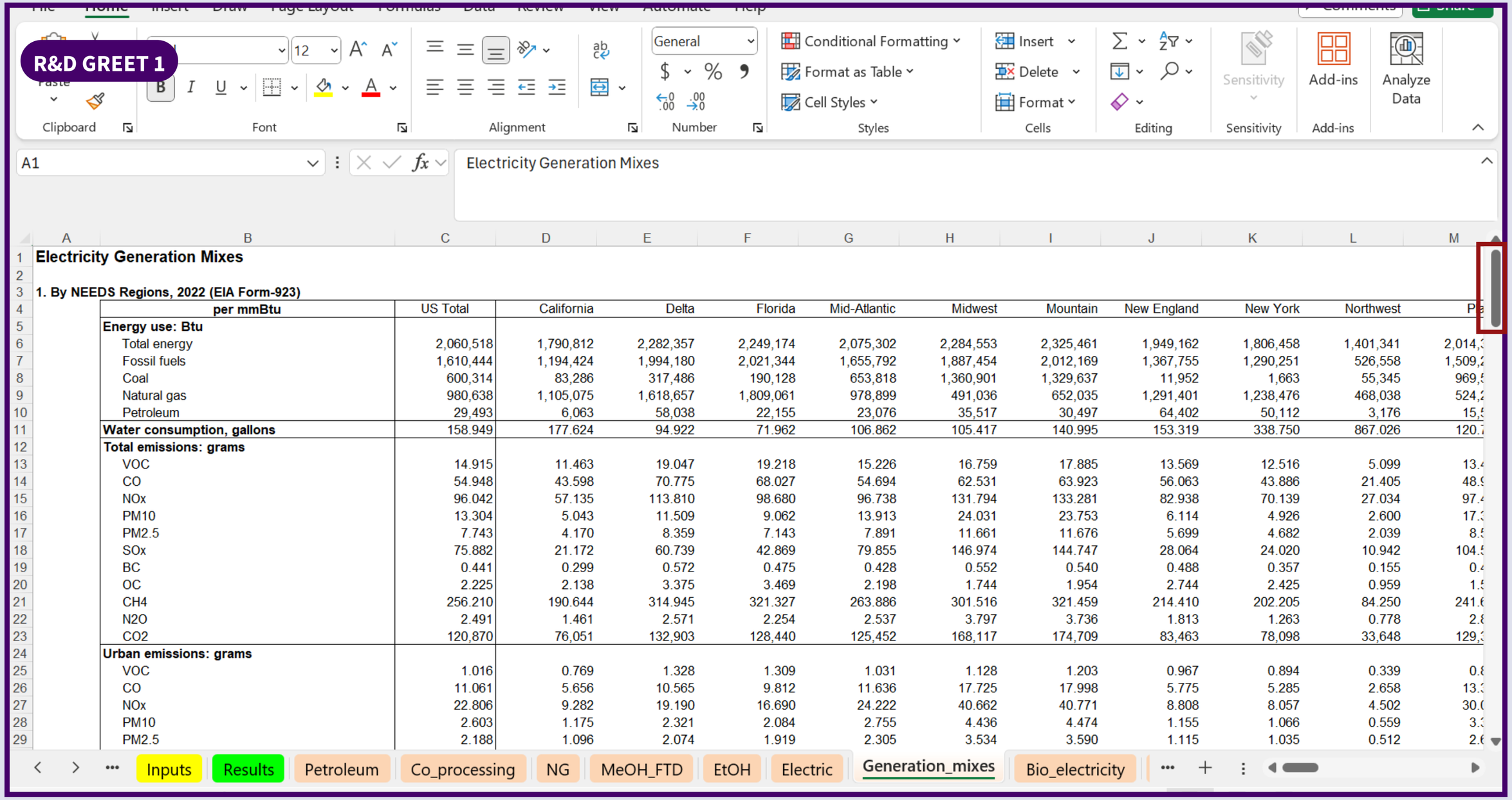

Electricity Generation Mixes

1. By NEEDS Regions, 2022 (EIA Form-923)

per mmBtu	US Total	California	Delta	Florida	Mid-Atlantic	Midwest	Mountain	New England	New York	Northwest	P
Energy use: Btu											
Total energy	2,060,518	1,790,812	2,282,357	2,249,174	2,075,302	2,284,553	2,325,461	1,949,162	1,806,458	1,401,341	2,014,
Fossil fuels	1,610,444	1,194,424	1,994,180	2,021,344	1,655,792	1,887,454	2,012,169	1,367,755	1,290,251	526,558	1,509,
Coal	600,314	83,286	317,486	190,128	653,818	1,360,901	1,329,637	11,952	1,663	55,345	969,
Natural gas	980,638	1,105,075	1,618,657	1,809,061	978,899	491,036	652,035	1,291,401	1,238,476	468,038	524,
Petroleum	29,493	6,063	58,038	22,155	23,076	35,517	30,497	64,402	50,112	3,176	15,
Water consumption, gallons	158.949	177.624	94.922	71.962	106.862	105.417	140.995	153.319	338.750	867.026	120.
Total emissions: grams											
VOC	14.915	11.463	19.047	19.218	15.226	16.759	17.885	13.569	12.516	5.099	13.
CO	54.948	43.598	70.775	68.027	54.694	62.531	63.923	56.063	43.886	21.405	48.
NOx	96.042	57.135	113.810	98.680	96.738	131.794	133.281	82.938	70.139	27.034	97.
PM10	13.304	5.043	11.509	9.062	13.913	24.031	23.753	6.114	4.926	2.600	17.
PM2.5	7.743	4.170	8.359	7.143	7.891	11.661	11.676	5.699	4.682	2.039	8.
SOx	75.882	21.172	60.739	42.869	79.855	146.974	144.747	28.064	24.020	10.942	104.
BC	0.441	0.299	0.572	0.475	0.428	0.552	0.540	0.488	0.357	0.155	0.
OC	2.225	2.138	3.375	3.469	2.198	1.744	1.954	2.744	2.425	0.959	1.
CH4	256.210	190.644	314.945	321.327	263.886	301.516	321.459	214.410	202.205	84.250	241.
N2O	2.491	1.461	2.571	2.254	2.537	3.797	3.736	1.813	1.263	0.778	2.
CO2	120,870	76,051	132,903	128,440	125,452	168,117	174,709	83,463	78,098	33,648	129,
Urban emissions: grams											
VOC	1.016	0.769	1.328	1.309	1.031	1.128	1.203	0.967	0.894	0.339	0.
CO	11.061	5.656	10.565	9.812	11.636	17.725	17.998	5.775	5.285	2.658	13.
NOx	22.806	9.282	19.190	16.690	24.222	40.662	40.771	8.808	8.057	4.502	30.
PM10	2.603	1.175	2.321	2.084	2.755	4.436	4.474	1.155	1.066	0.559	3.
PM2.5	2.188	1.096	2.074	1.919	2.305	3.534	3.590	1.115	1.035	0.512	2.

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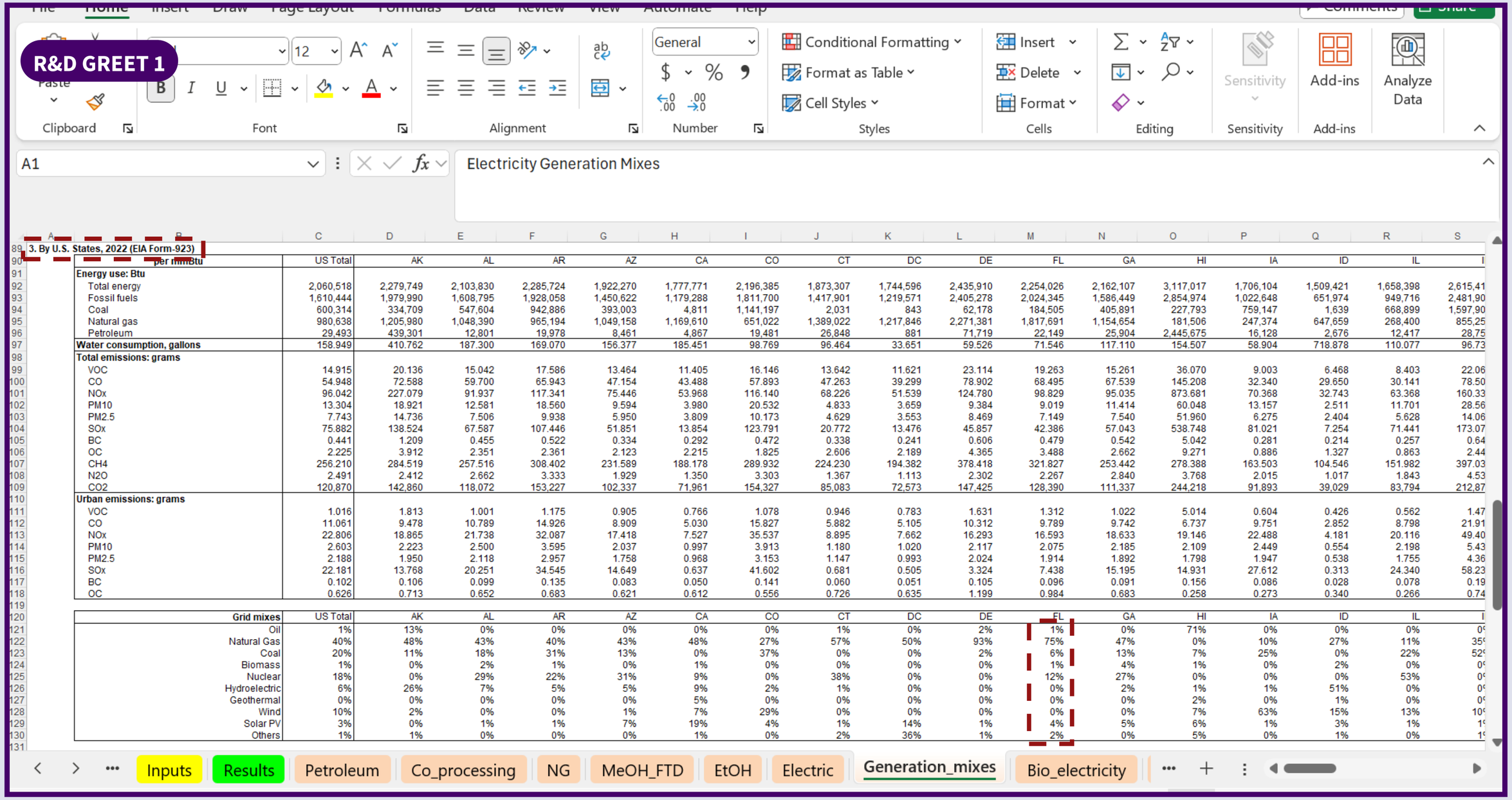
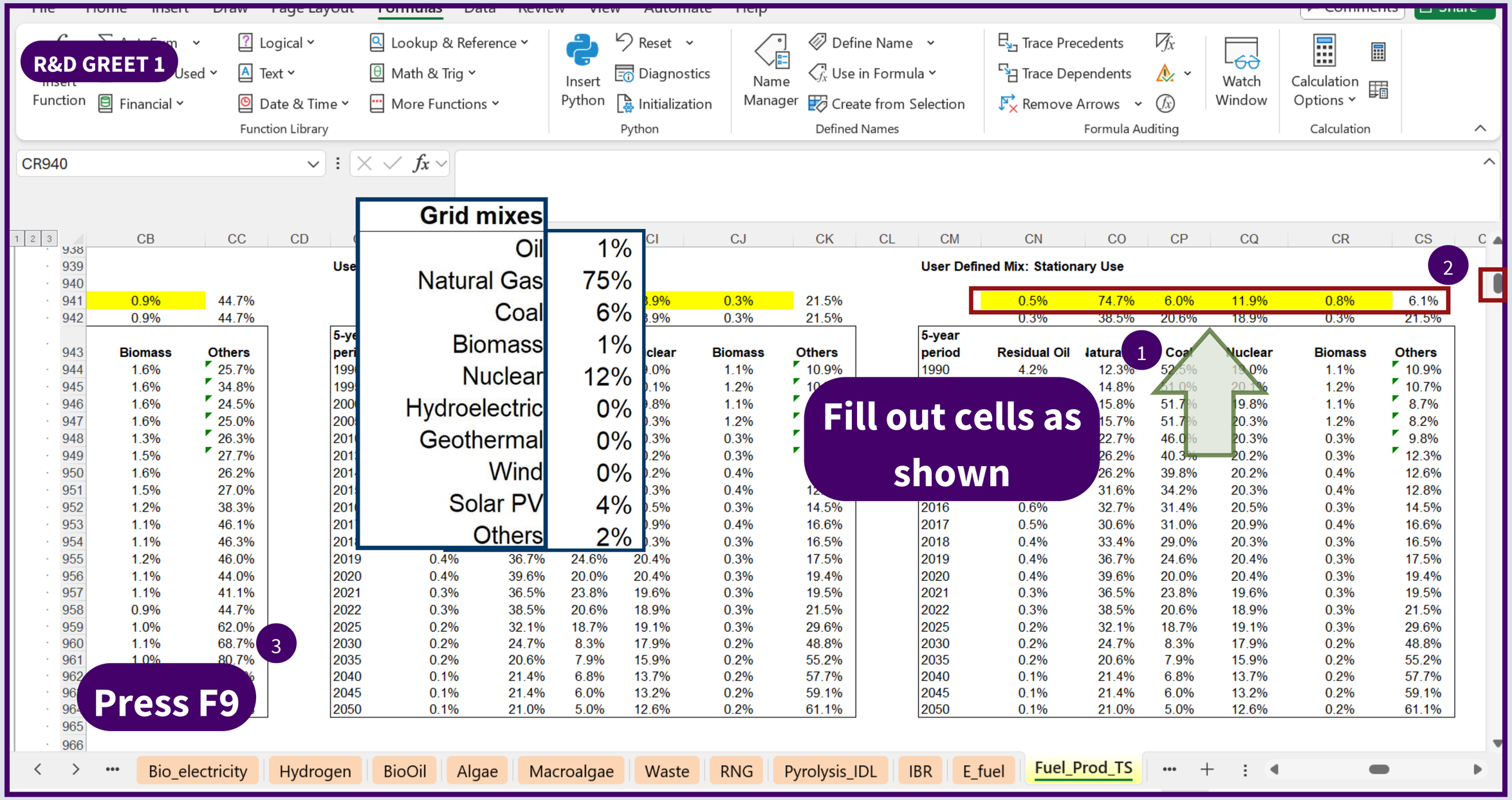


per mmBtu	US Total	AK	AL	AR	AZ	CA	CO	CT	DC	DE	FL	GA	HI	IA	ID	IL	I
Energy use: Btu																	
Total energy	2,060,518	2,279,749	2,103,830	2,285,724	1,922,270	1,777,771	2,196,385	1,873,307	1,744,596	2,435,910	2,254,026	2,162,107	3,117,017	1,706,104	1,509,421	1,658,398	2,615,41
Fossil fuels	1,610,444	1,979,990	1,608,795	1,928,058	1,450,622	1,179,288	1,811,700	1,417,901	1,219,571	2,405,278	2,024,345	1,586,449	2,854,974	1,022,648	651,974	949,716	2,481,90
Coal	600,314	334,709	547,604	942,886	393,003	4,811	1,141,197	2,031	843	62,178	184,505	405,891	227,793	759,147	1,639	668,899	1,597,90
Natural gas	980,638	1,205,980	1,048,390	965,194	1,049,158	1,169,610	651,022	1,389,022	1,217,846	2,271,381	1,817,691	1,154,654	181,506	247,374	647,659	268,400	855,25
Petroleum	29,493	439,301	12,801	19,978	8,461	4,867	19,481	26,848	881	71,719	22,149	25,904	2,445,675	16,128	2,676	12,417	28,75
Water consumption, gallons	158.949	410.762	187.300	169.070	156.377	185.451	98.769	96.464	33.651	59.526	71.546	117.110	154.507	58.904	718.878	110.077	96.73
Total emissions: grams																	
VOC	14.915	20.136	15.042	17.586	13.464	11.405	16.146	13.642	11.621	23.114	19.263	15.261	36.070	9.003	6.468	8.403	22.06
CO	54.948	72.588	59.700	65.943	47.154	43.488	57.893	47.263	39.299	78.902	68.495	67.539	145.208	32.340	29.650	30.141	78.50
NOx	96.042	227.079	91.937	117.341	75.446	53.968	116.140	68.226	51.539	124.780	98.829	95.035	873.681	70.368	32.743	63.368	160.33
PM10	13.304	18.921	12.581	18.560	9.594	3.980	20.532	4.833	3.659	9.384	9.019	11.414	60.048	13.157	2.511	11.701	28.56
PM2.5	7.743	14.736	7.506	9.938	5.950	3.809	10.173	4.629	3.553	8.469	7.149	7.540	51.960	6.275	2.404	5.628	14.06
SOx	75.882	138.524	67.587	107.446	51.851	13.854	123.791	20.772	13.476	45.857	42.386	57.043	538.748	81.021	7.254	71.441	173.07
BC	0.441	1.209	0.455	0.522	0.334	0.292	0.472	0.338	0.241	0.606	0.479	0.542	5.042	0.281	0.214	0.257	0.64
OC	2.225	3.912	2.351	2.361	2.123	2.215	1.825	2.606	2.189	4.365	3.488	2.662	9.271	0.886	1.327	0.863	2.44
CH4	256.210	284.519	257.516	308.402	231.589	188.178	289.932	224.230	194.382	378.418	321.827	253.442	278.388	163.503	104.546	151.982	397.03
N2O	2.491	2.412	2.662	3.333	1.929	1.350	3.303	1.367	1.113	2.302	2.267	2.840	3.768	2.015	1.017	1.843	4.53
CO2	120,870	142,860	118,072	153,227	102,337	71,961	154,327	85,083	72,573	147,425	128,390	111,337	244,218	91,893	39,029	83,794	212,87
Urban emissions: grams																	
VOC	1.016	1.813	1.001	1.175	0.905	0.766	1.078	0.946	0.783	1.631	1.312	1.022	5.014	0.604	0.426	0.562	1.47
CO	11.061	9.478	10.789	14.926	8.909	5.030	15.827	5.882	5.105	10.312	9.789	9.742	6.737	9.751	2.852	8.798	21.91
NOx	22.806	18.865	21.738	32.087	17.418	7.527	35.537	8.895	7.662	16.293	16.593	18.633	19.146	22.488	4.181	20.116	49.40
PM10	2.603	2.223	2.500	3.595	2.037	0.997	3.913	1.180	1.020	2.117	2.075	2.185	2.109	2.449	0.554	2.198	5.43
PM2.5	2.188	1.950	2.118	2.957	1.758	0.968	3.153	1.147	0.993	2.024	1.914	1.892	1.798	1.947	0.538	1.755	4.36
SOx	22.181	13.768	20.251	34.545	14.649	0.637	41.602	0.681	0.505	3.324	7.438	15.195	14.931	27.612	0.313	24.340	58.23
BC	0.102	0.106	0.099	0.135	0.083	0.050	0.141	0.060	0.051	0.105	0.096	0.091	0.156	0.086	0.028	0.078	0.19
OC	0.626	0.713	0.652	0.683	0.621	0.612	0.556	0.726	0.635	1.199	0.984	0.683	0.258	0.273	0.340	0.266	0.74

Grid mixes	US Total	AK	AL	AR	AZ	CA	CO	CT	DC	DE	FL	GA	HI	IA	ID	IL	I
Oil	1%	13%	0%	0%	0%	0%	0%	1%	0%	2%	1%	0%	71%	0%	0%	0%	0
Natural Gas	40%	48%	43%	40%	43%	48%	27%	57%	50%	93%	75%	47%	0%	10%	27%	11%	35
Coal	20%	11%	18%	31%	13%	0%	37%	0%	0%	2%	6%	13%	7%	25%	0%	22%	52
Biomass	1%	0%	2%	1%	0%	1%	0%	0%	0%	0%	1%	4%	1%	0%	2%	0%	0
Nuclear	18%	0%	29%	22%	31%	9%	0%	38%	0%	0%	12%	27%	0%	0%	0%	53%	0
Hydroelectric	6%	26%	7%	5%	5%	9%	2%	1%	0%	0%	0%	2%	1%	1%	51%	0%	0
Geothermal	0%	0%	0%	0%	0%	5%	0%	0%	0%	0%	0%	0%	2%	0%	1%	0%	0
Wind	10%	2%	0%	0%	1%	7%	29%	0%	0%	0%	0%	0%	7%	63%	15%	13%	10
Solar PV	3%	0%	1%	1%	7%	19%	4%	1%	14%	1%	4%	5%	6%	1%	3%	1%	1
Others	1%	1%	0%	0%	0%	1%	0%	2%	36%	1%	2%	0%	5%	0%	1%	0%	1



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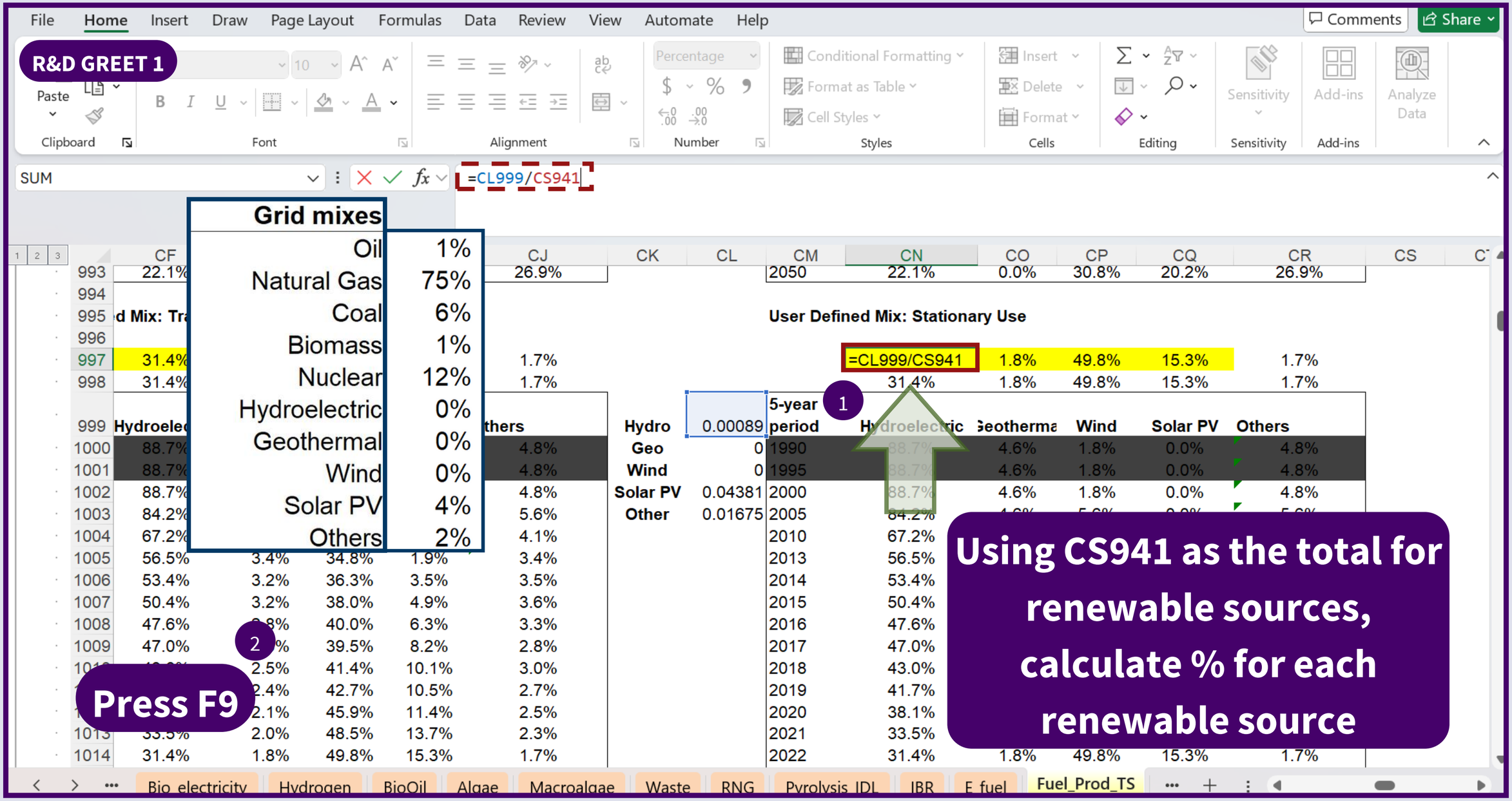

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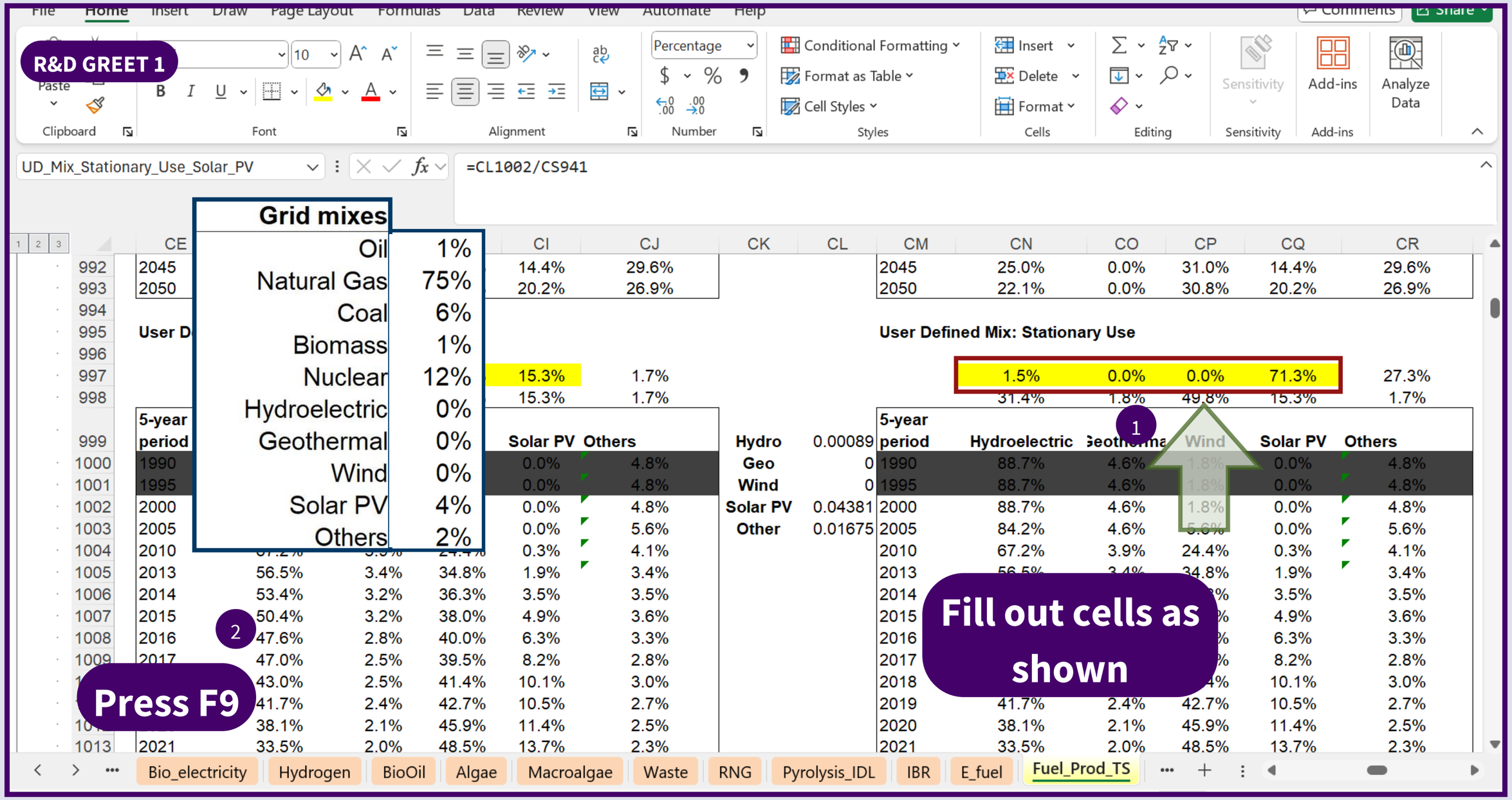

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Conversion Factor for Light Water Reactor (LWR) Nuclear Power Plants

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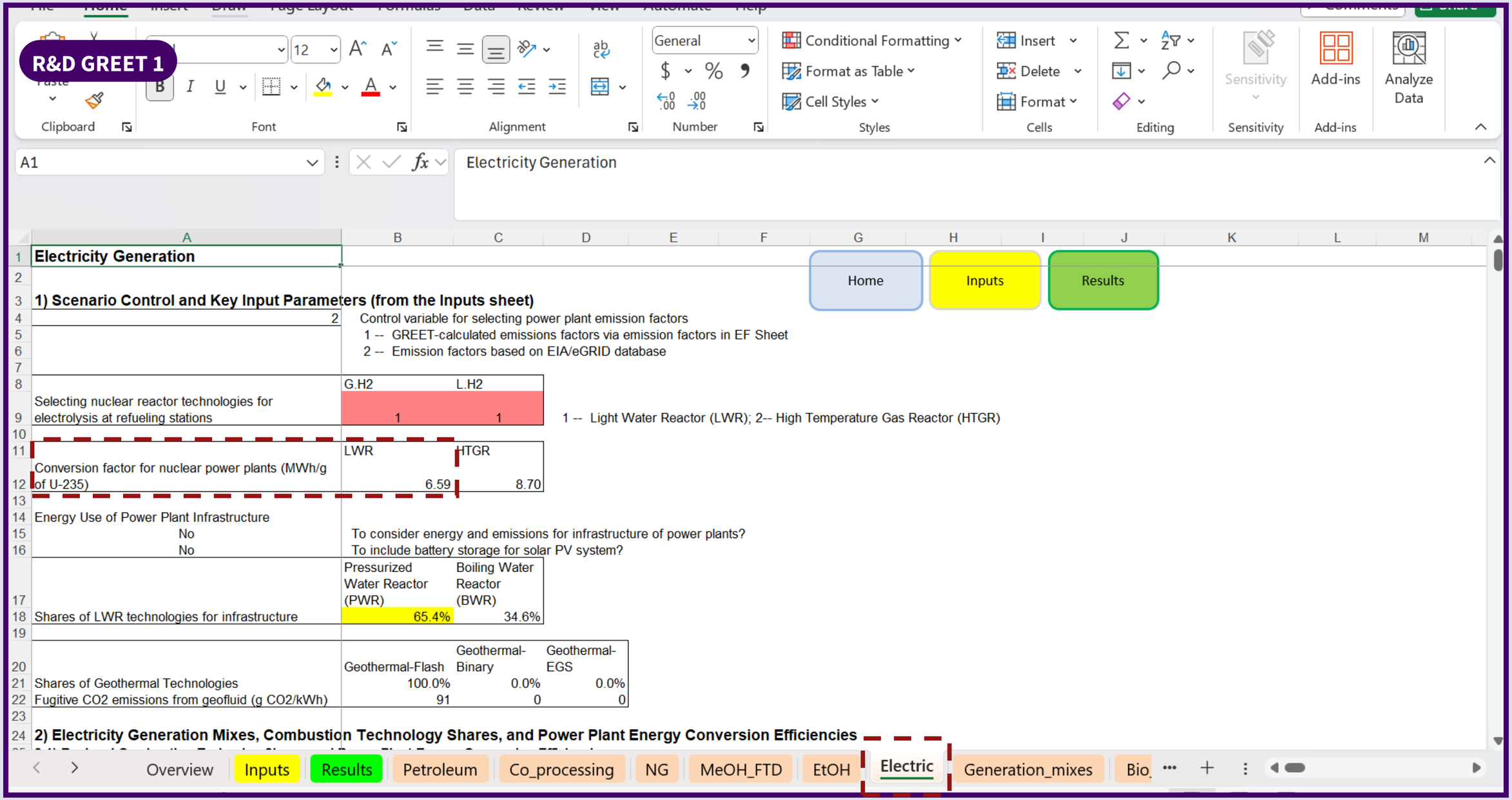

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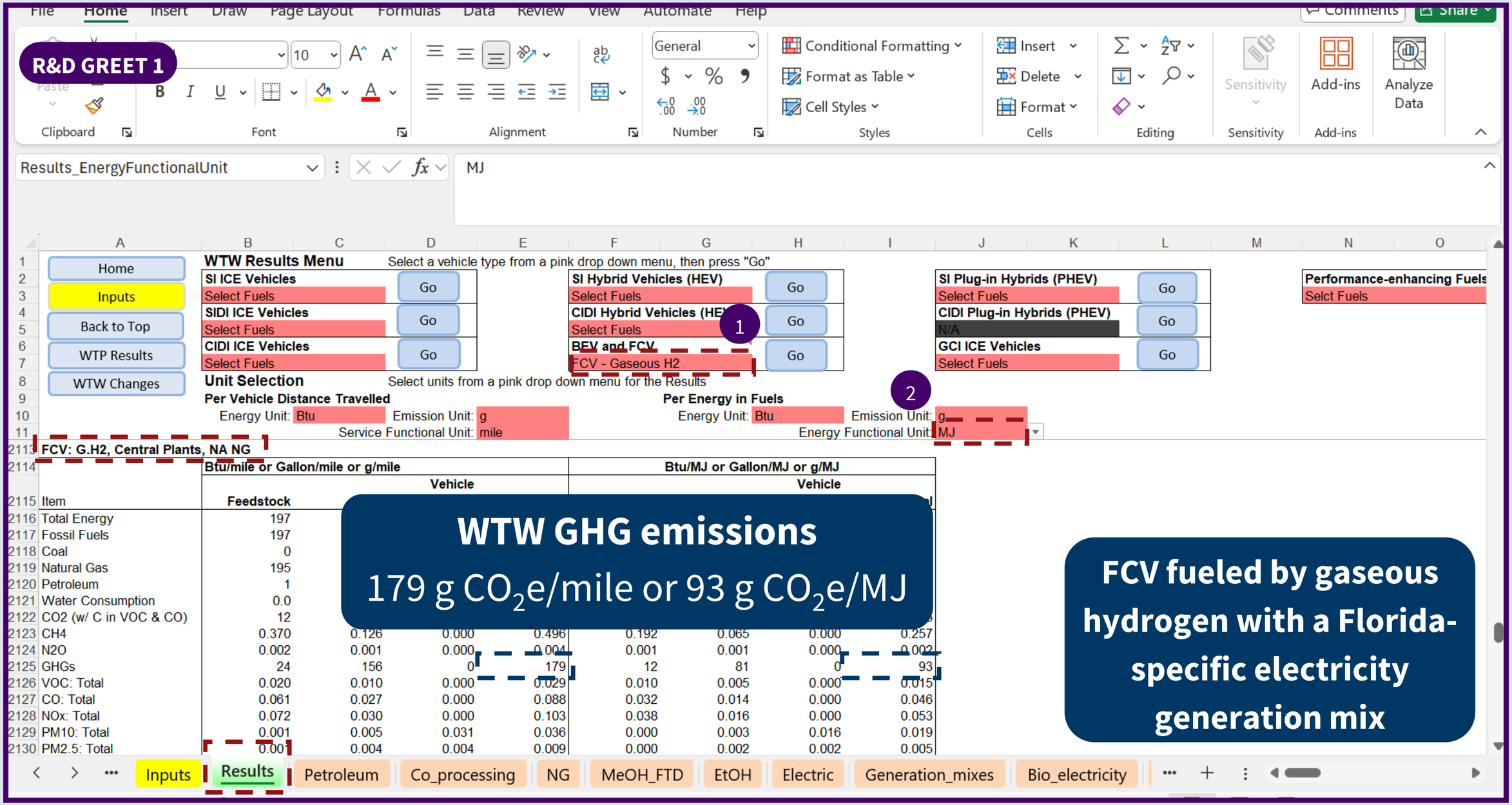
Well-to-Wheel (WTW) GHG Emissions



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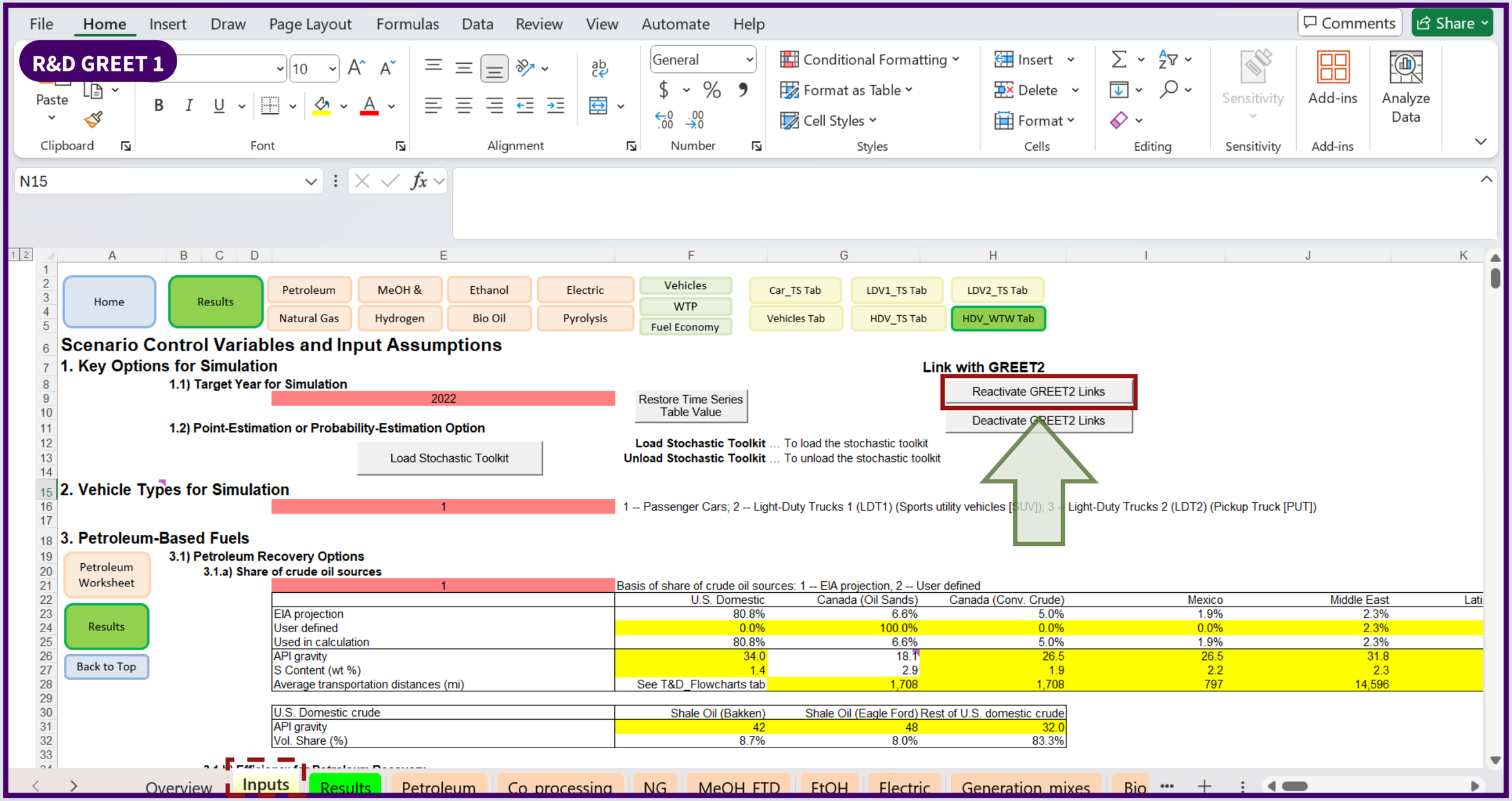
Cradle-to-Grave (C2G) GHG Emissions



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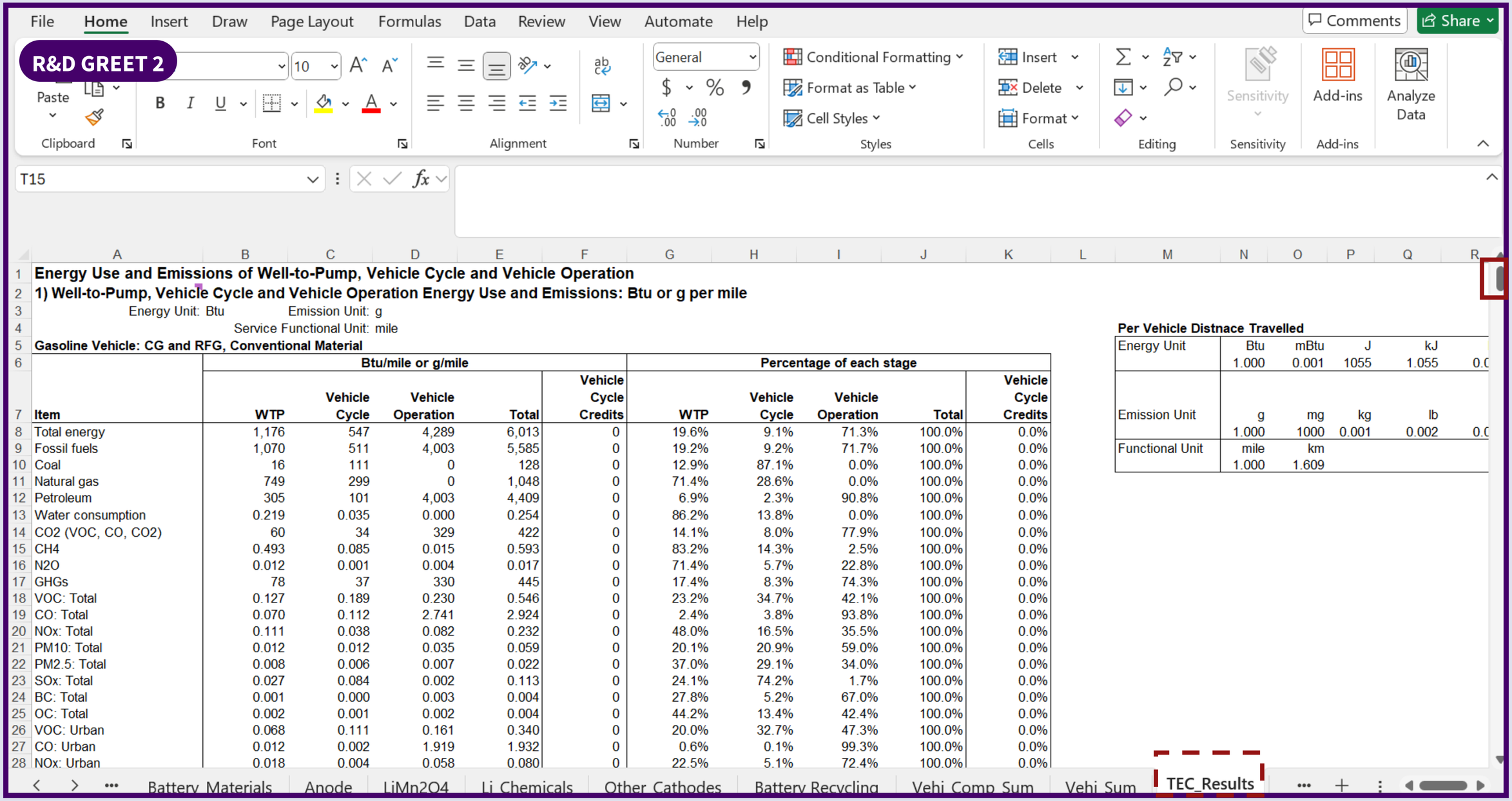

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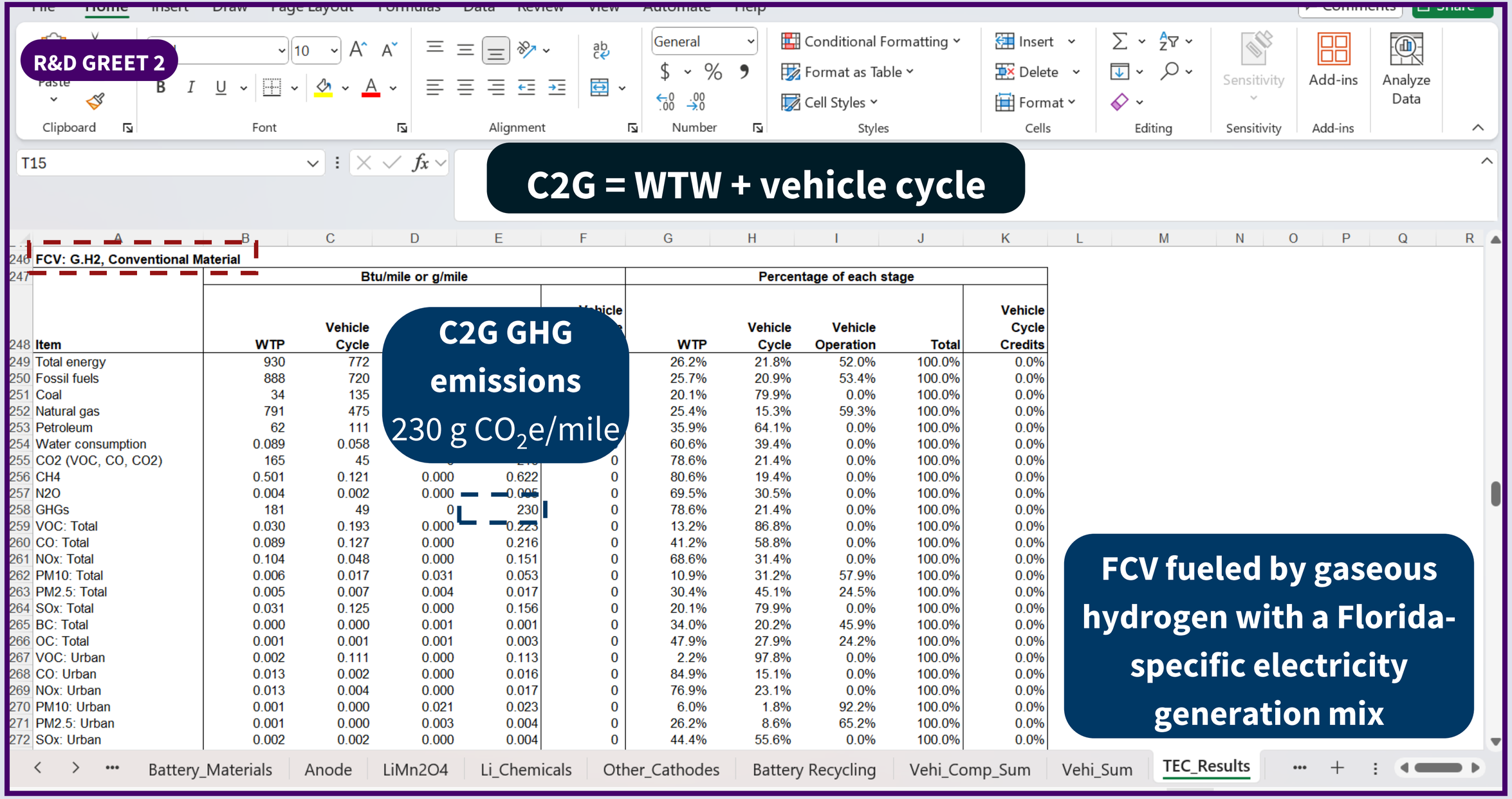
R&D GREET 2

C2G = WTW + vehicle cycle



FCV: G.H2, Conventional Material

Item	Btu/mile or g/mile					Percentage of each stage				
	WTP	Vehicle Cycle			Vehicle	WTP	Vehicle Cycle	Vehicle Operation	Total	Vehicle Cycle Credits
Total energy	930	772				26.2%	21.8%	52.0%	100.0%	0.0%
Fossil fuels	888	720				25.7%	20.9%	53.4%	100.0%	0.0%
Coal	34	135				20.1%	79.9%	0.0%	100.0%	0.0%
Natural gas	791	475				25.4%	15.3%	59.3%	100.0%	0.0%
Petroleum	62	111				35.9%	64.1%	0.0%	100.0%	0.0%
Water consumption	0.089	0.058				60.6%	39.4%	0.0%	100.0%	0.0%
CO2 (VOC, CO, CO2)	165	45			0	78.6%	21.4%	0.0%	100.0%	0.0%
CH4	0.501	0.121	0.000	0.622	0	80.6%	19.4%	0.0%	100.0%	0.0%
N2O	0.004	0.002	0.000	0.005	0	69.5%	30.5%	0.0%	100.0%	0.0%
GHGs	181	49	0	230	0	78.6%	21.4%	0.0%	100.0%	0.0%
VOC: Total	0.030	0.193	0.000	0.223	0	13.2%	86.8%	0.0%	100.0%	0.0%
CO: Total	0.089	0.127	0.000	0.216	0	41.2%	58.8%	0.0%	100.0%	0.0%
NOx: Total	0.104	0.048	0.000	0.151	0	68.6%	31.4%	0.0%	100.0%	0.0%
PM10: Total	0.006	0.017	0.031	0.053	0	10.9%	31.2%	57.9%	100.0%	0.0%
PM2.5: Total	0.005	0.007	0.004	0.017	0	30.4%	45.1%	24.5%	100.0%	0.0%
SOx: Total	0.031	0.125	0.000	0.156	0	20.1%	79.9%	0.0%	100.0%	0.0%
BC: Total	0.000	0.000	0.001	0.001	0	34.0%	20.2%	45.9%	100.0%	0.0%
OC: Total	0.001	0.001	0.001	0.003	0	47.9%	27.9%	24.2%	100.0%	0.0%
VOC: Urban	0.002	0.111	0.000	0.113	0	2.2%	97.8%	0.0%	100.0%	0.0%
CO: Urban	0.013	0.002	0.000	0.016	0	84.9%	15.1%	0.0%	100.0%	0.0%
NOx: Urban	0.013	0.004	0.000	0.017	0	76.9%	23.1%	0.0%	100.0%	0.0%
PM10: Urban	0.001	0.000	0.021	0.023	0	6.0%	1.8%	92.2%	100.0%	0.0%
PM2.5: Urban	0.001	0.000	0.003	0.004	0	26.2%	8.6%	65.2%	100.0%	0.0%
SOx: Urban	0.002	0.002	0.000	0.004	0	44.4%	55.6%	0.0%	100.0%	0.0%

C2G GHG emissions

230 g CO_2e/mile

FCV fueled by gaseous hydrogen with a Florida-specific electricity generation mix

Battery_Materials | Anode | LiMn2O4 | Li_Chemicals | Other_Cathodes | Battery Recycling | Vehi_Comp_Sum | Vehi_Sum | TEC_Results

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How Does a Change in the Electric Grid Used to Charge EVs Affect Their WTW Emissions and C2G Emissions?

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SUV BEV Charged in WECC

Model a 2022 Sport Utility Vehicle (SUV) Battery Electric Vehicle (BEV) Using an NMC622 Battery Charged with a WECC Electricity Generation Mix

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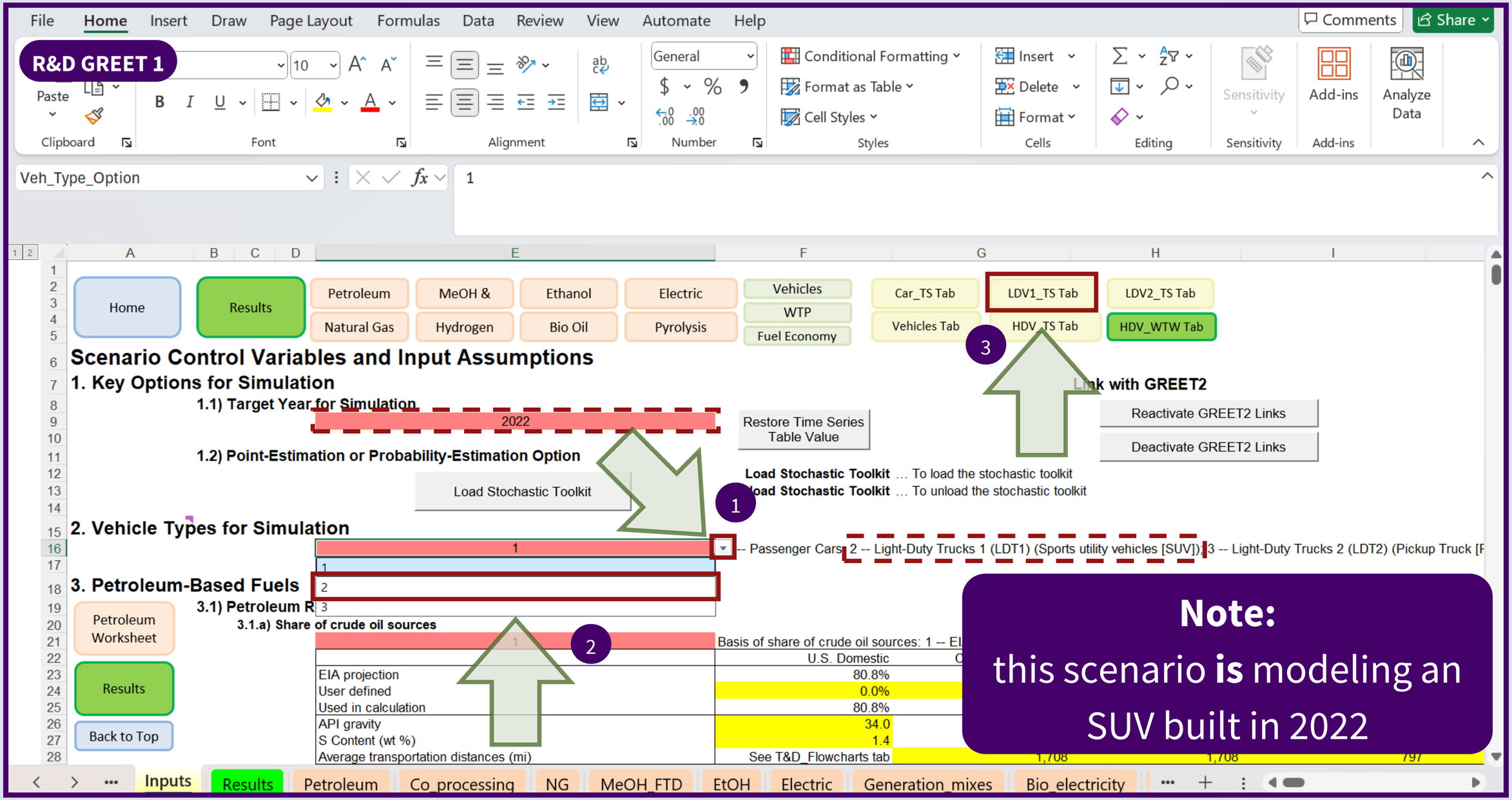

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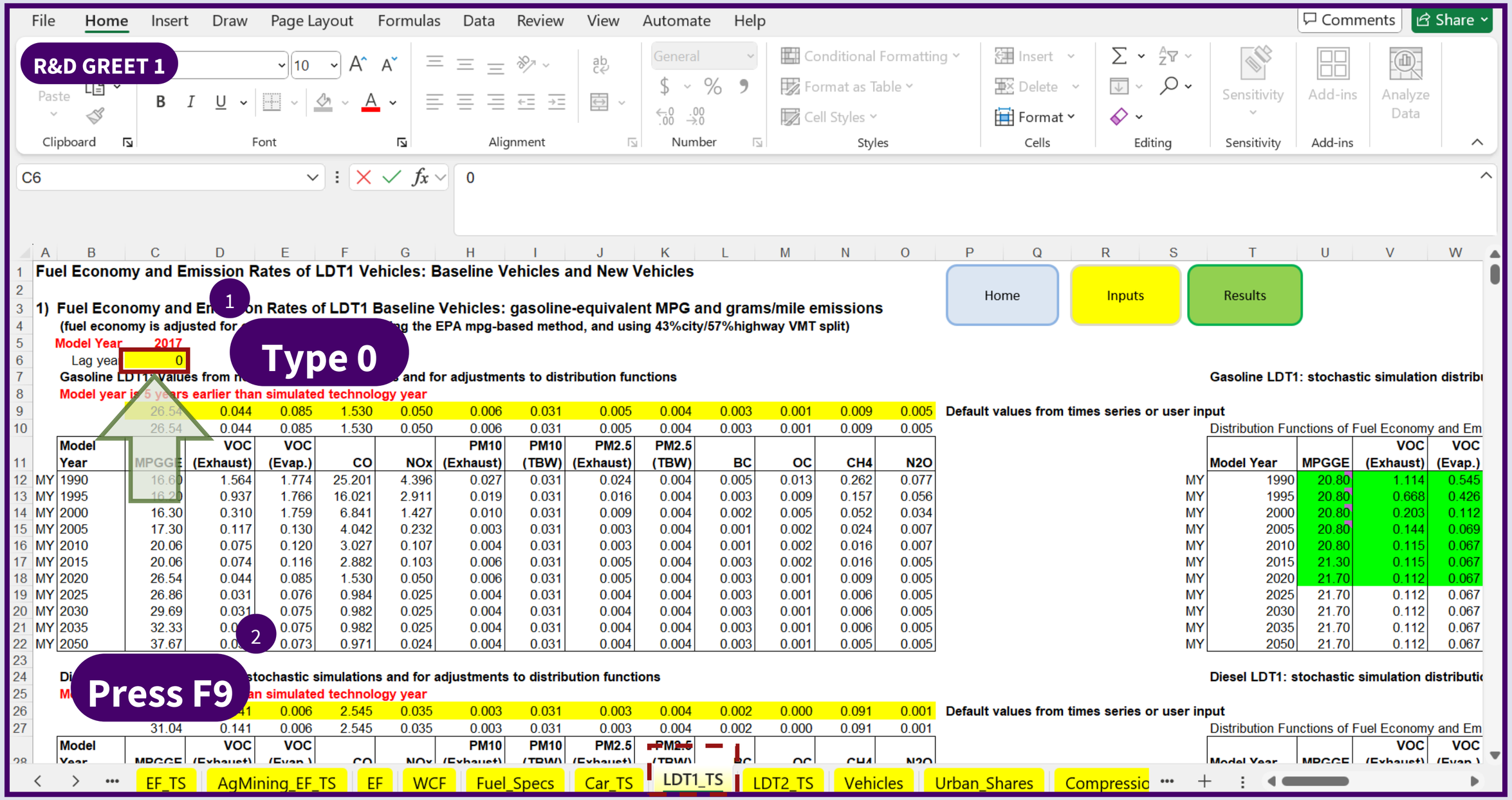

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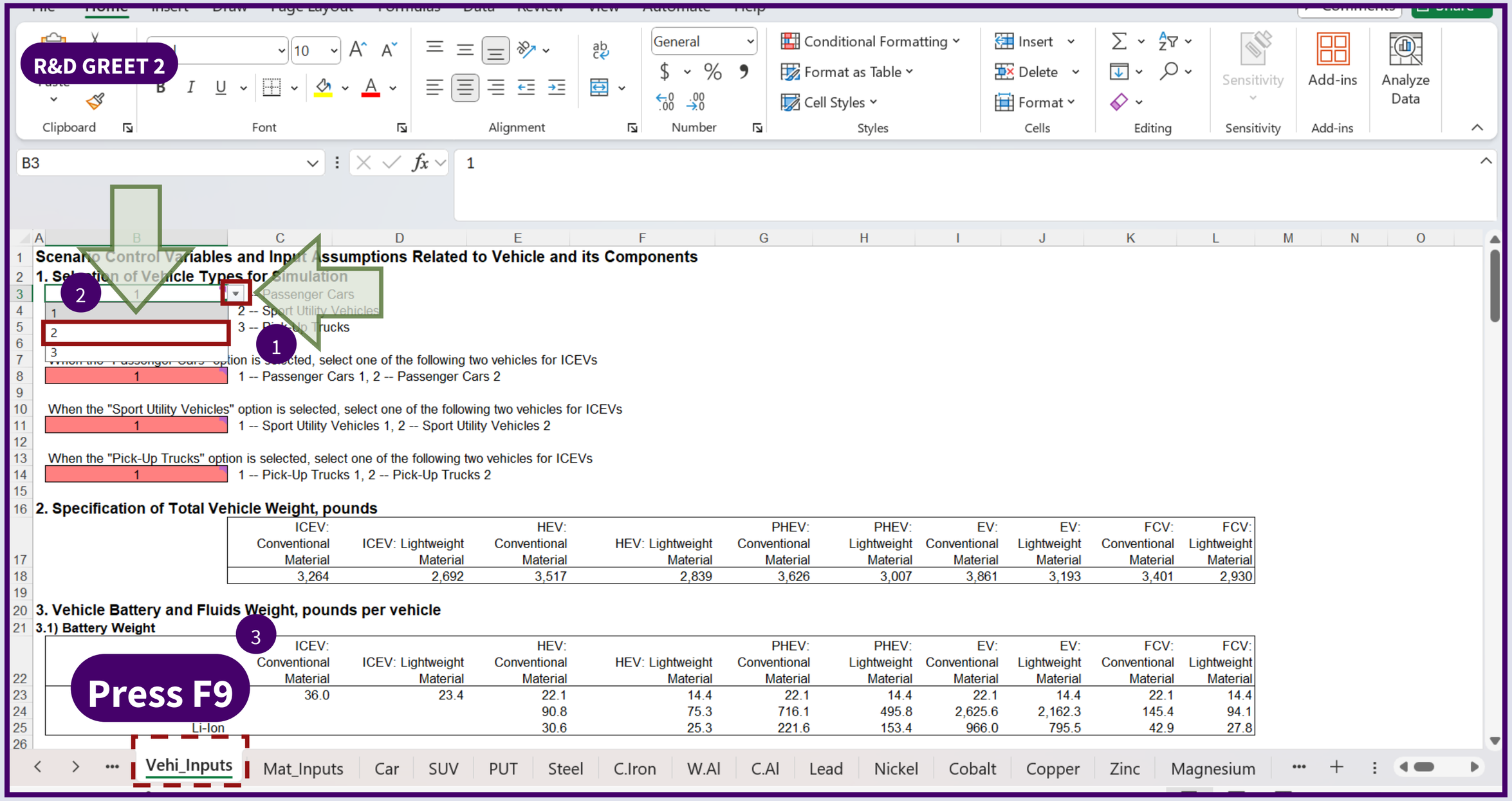

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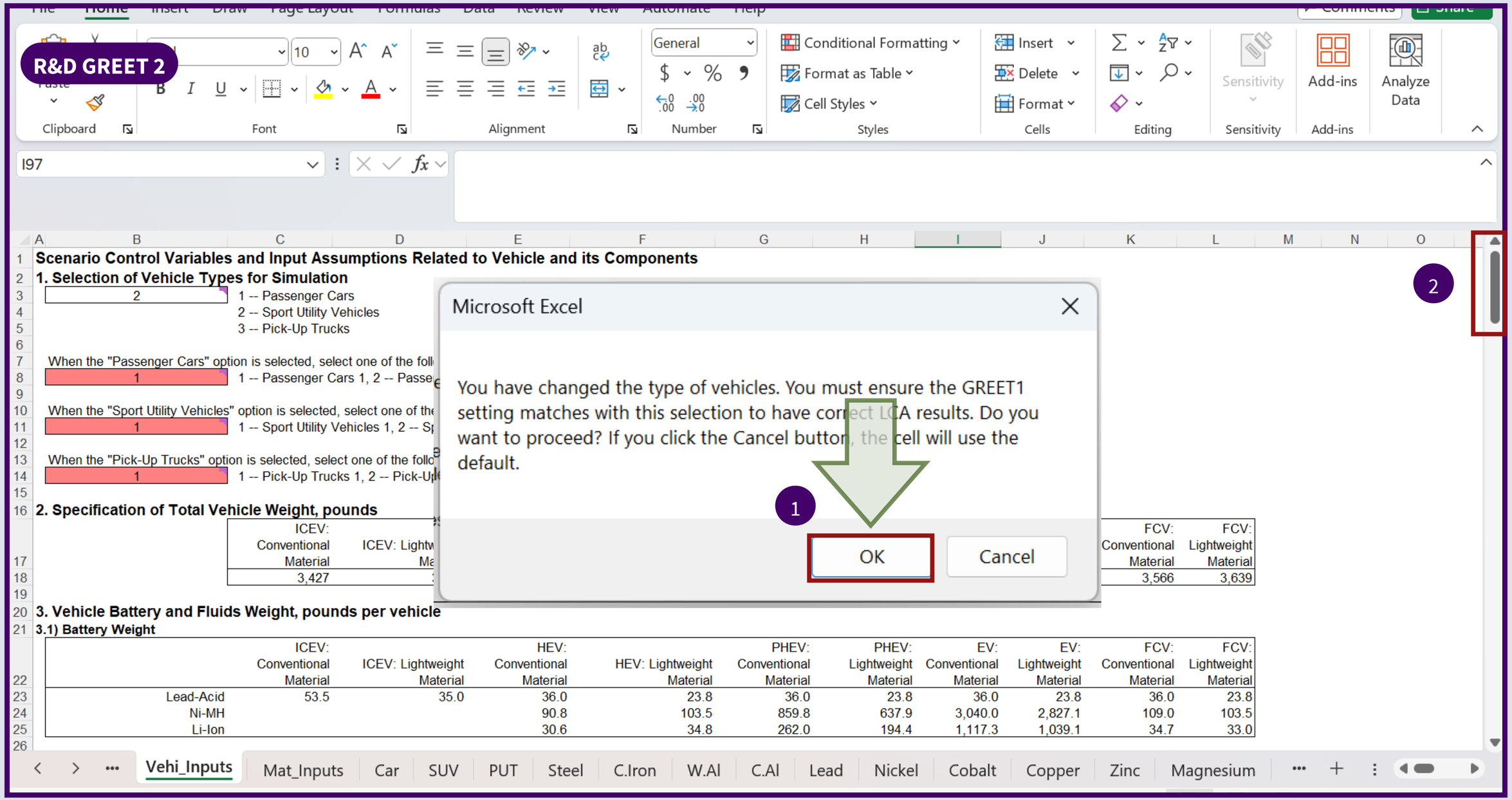

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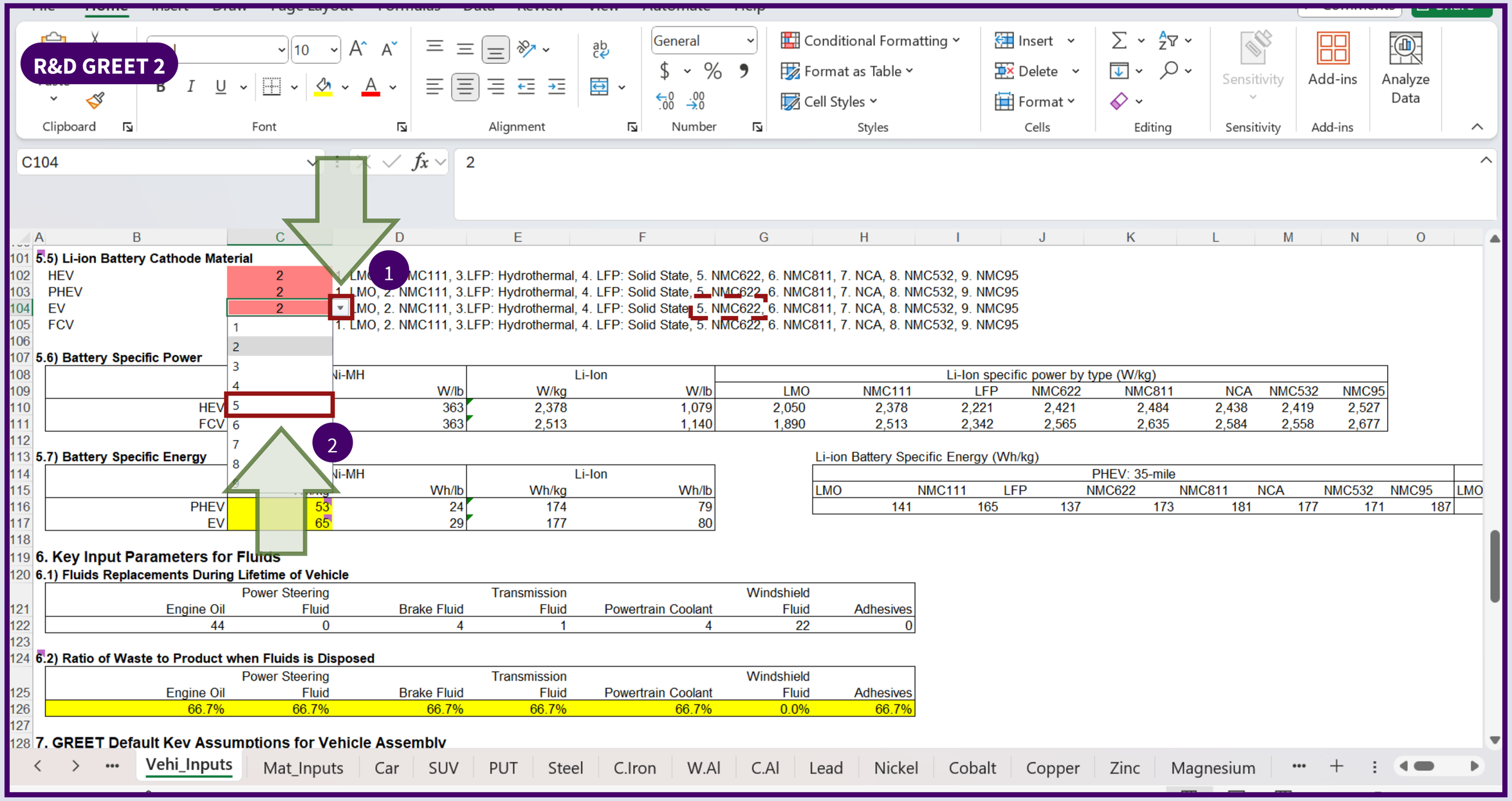

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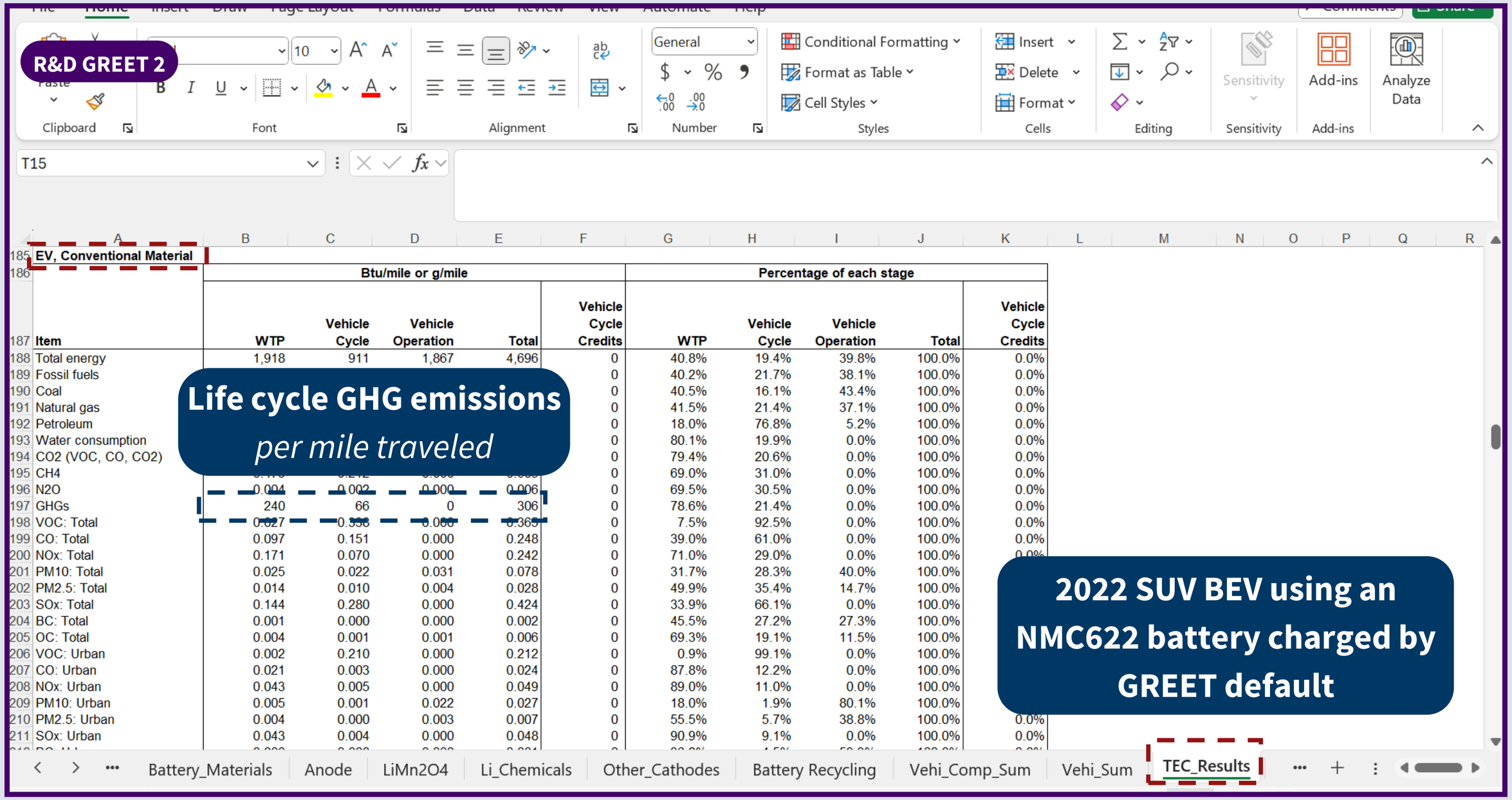

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R&D GREET 1

Note:
this scenario **is** modeling an SUV charged in the West

10. Electric Generation

Electric Worksheet | Results | Back to Top

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

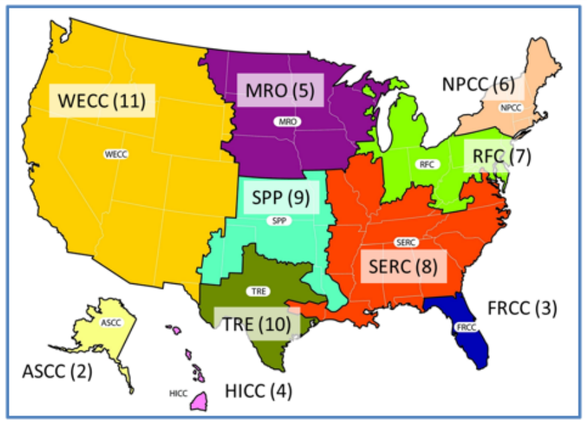
2

1 -- GREET-calculated emissions factors via
2 -- Emission factors based on EPA and EIA

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	



(U.S. EPA)

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	
	Transportation	Stationary	Transportation	Stationary
Residual oil	0.3%	0.3%	13.7%	13.7%
Natural gas	38.5%	38.5%	46.7%	46.7%

Inputs | Results | Petroleum | Co_processing | NG | MeOH_FTD | EtOH | Electric | Generation_mixes | Bio_electricity

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Well-to-Pump (WTP) and Well-to-Wheel (WTW) GHG Emissions

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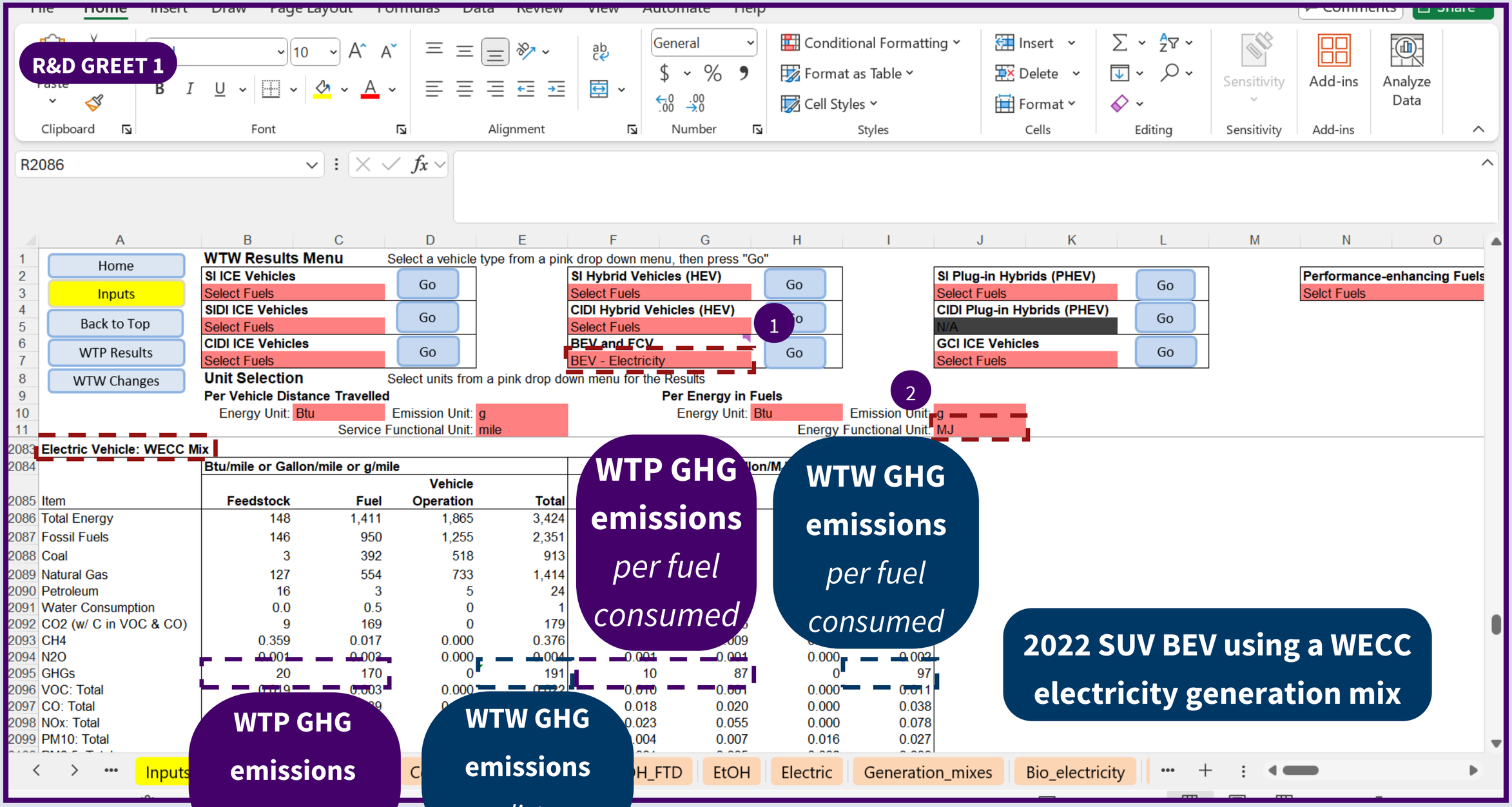

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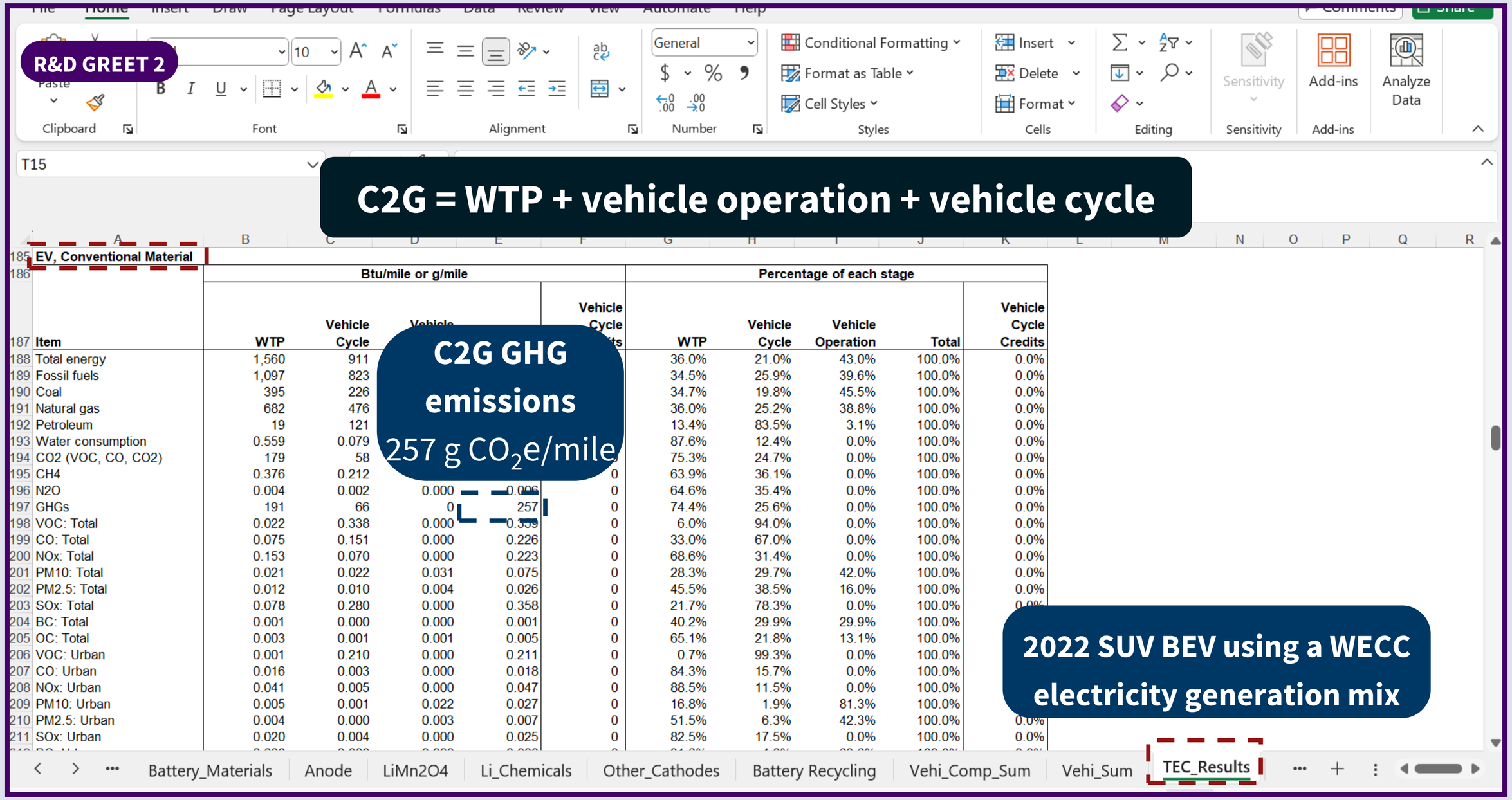
Cradle-to-Grave (C2G) GHG Emissions



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Phase of the Fuel Cycle Responsible for the Reduction of C2G GHG Emissions

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2022 SUV BEV charged by GREET default

2022 SUV BEV charged in West

Life cycle GHG emissions
per mile traveled

Life cycle GHG emissions
per mile traveled

Item	Btu/mile or g/mile WTP	Vehicle Cycle	Vehicle Operation	Total	Vehicle Cycle Credits	Percentage of each WTP	Vehicle Cycle	Vehicle Operation
EV, Conventional Material								
Total energy					0	40.8%	19.4%	39.8%
Fossil fuels					0	40.2%	21.7%	38.1%
Coal					0	40.5%	16.1%	43.4%
Natural gas					0	41.5%	21.4%	37.1%
Petroleum					0	18.0%	76.8%	5.2%
Water consumption					0	80.1%	19.9%	0.0%
CO2 (VOC, CO, CO2					0	79.4%	20.6%	0.0%
CH4					0	69.0%	31.0%	0.0%
N2O	0.004	0.002	0.000	0.006	0	69.5%	30.5%	0.0%
GHGs	240	66	0	306	0	78.6%	21.4%	0.0%
VOC: Total	0.027	0.338	0.000	0.365	0	7.5%	92.5%	0.0%
CO: Total	0.097	0.151	0.000	0.248	0	39.0%	61.0%	0.0%
NOx: Total	0.171	0.070	0.000	0.242	0	71.0%	29.0%	0.0%
PM10: Total	0.025	0.022	0.031	0.078	0	31.7%	28.3%	40.0%
PM2.5: Total	0.014	0.010	0.004	0.028	0	49.9%	35.4%	14.7%
SOx: Total	0.144	0.280	0.000	0.424	0	33.9%	66.1%	0.0%
BC: Total	0.001	0.000	0.000	0.002	0	45.5%	27.2%	27.3%
OC: Total	0.004	0.001	0.001	0.006	0	69.3%	19.1%	11.5%
VOC: Urban	0.002	0.210	0.000	0.212	0	0.9%	99.1%	0.0%
CO: Urban	0.021	0.003	0.000	0.024	0	87.8%	12.2%	0.0%
NOx: Urban	0.043	0.005	0.000	0.049	0	89.0%	11.0%	0.0%
PM10: Urban	0.005	0.001	0.022	0.027	0	18.0%	1.9%	80.1%
PM2.5: Urban	0.004	0.000	0.003	0.007	0	55.5%	5.7%	38.8%
SOx: Urban	0.043	0.004	0.000	0.048	0	90.9%	9.1%	0.0%

Item	Btu/mile or g/mile WTP	Vehicle Cycle	Vehicle Operation	Total	Vehicle Cycle Credits	Percentage of each WTP	Vehicle Cycle	Vehicle Operation
EV, Conventional Material								
Total energy					0	36.0%	21.0%	43.0%
Fossil fuels					0	34.5%	25.9%	39.6%
Coal					0	34.7%	19.8%	45.5%
Natural gas					0	36.0%	25.2%	38.8%
Petroleum					0	13.4%	83.5%	3.1%
Water consumptio					0	87.6%	12.4%	0.0%
CO2 (VOC, CO, C					0	75.3%	24.7%	0.0%
CH4					0	63.9%	36.1%	0.0%
N2O	0.004	0.002	0.000	0.006	0	64.6%	35.4%	0.0%
GHGs	191	66	0	257	0	74.4%	25.6%	0.0%
VOC: Total	0.022	0.338	0.000	0.359	0	6.0%	94.0%	0.0%
CO: Total	0.075	0.151	0.000	0.226	0	33.0%	67.0%	0.0%
NOx: Total	0.153	0.070	0.000	0.223	0	68.6%	31.4%	0.0%
PM10: Total	0.021	0.022	0.031	0.075	0	28.3%	29.7%	42.0%
PM2.5: Total	0.012	0.010	0.004	0.026	0	45.5%	38.5%	16.0%
SOx: Total	0.078	0.280	0.000	0.358	0	21.7%	78.3%	0.0%
BC: Total	0.001	0.000	0.000	0.001	0	40.2%	29.9%	29.9%
OC: Total	0.003	0.001	0.001	0.005	0	65.1%	21.8%	13.1%
VOC: Urban	0.001	0.210	0.000	0.211	0	0.7%	99.3%	0.0%
CO: Urban	0.016	0.003	0.000	0.018	0	84.3%	15.7%	0.0%
NOx: Urban	0.041	0.005	0.000	0.047	0	88.5%	11.5%	0.0%
PM10: Urban	0.005	0.001	0.022	0.027	0	16.8%	1.9%	81.3%
PM2.5: Urban	0.004	0.000	0.003	0.007	0	51.5%	6.3%	42.3%
SOx: Urban	0.020	0.004	0.000	0.025	0	82.5%	17.5%	0.0%

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Electric Infrastructure Scenarios

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Power-plant Construction

Model a 2022 Sport Utility Vehicle (SUV) Battery Electric Vehicle (BEV) Using an NMC622 Battery Charged with a WECC Electricity Generation Mix.

Include Emissions Associated with Constructing the Power-plant from Raw Materials

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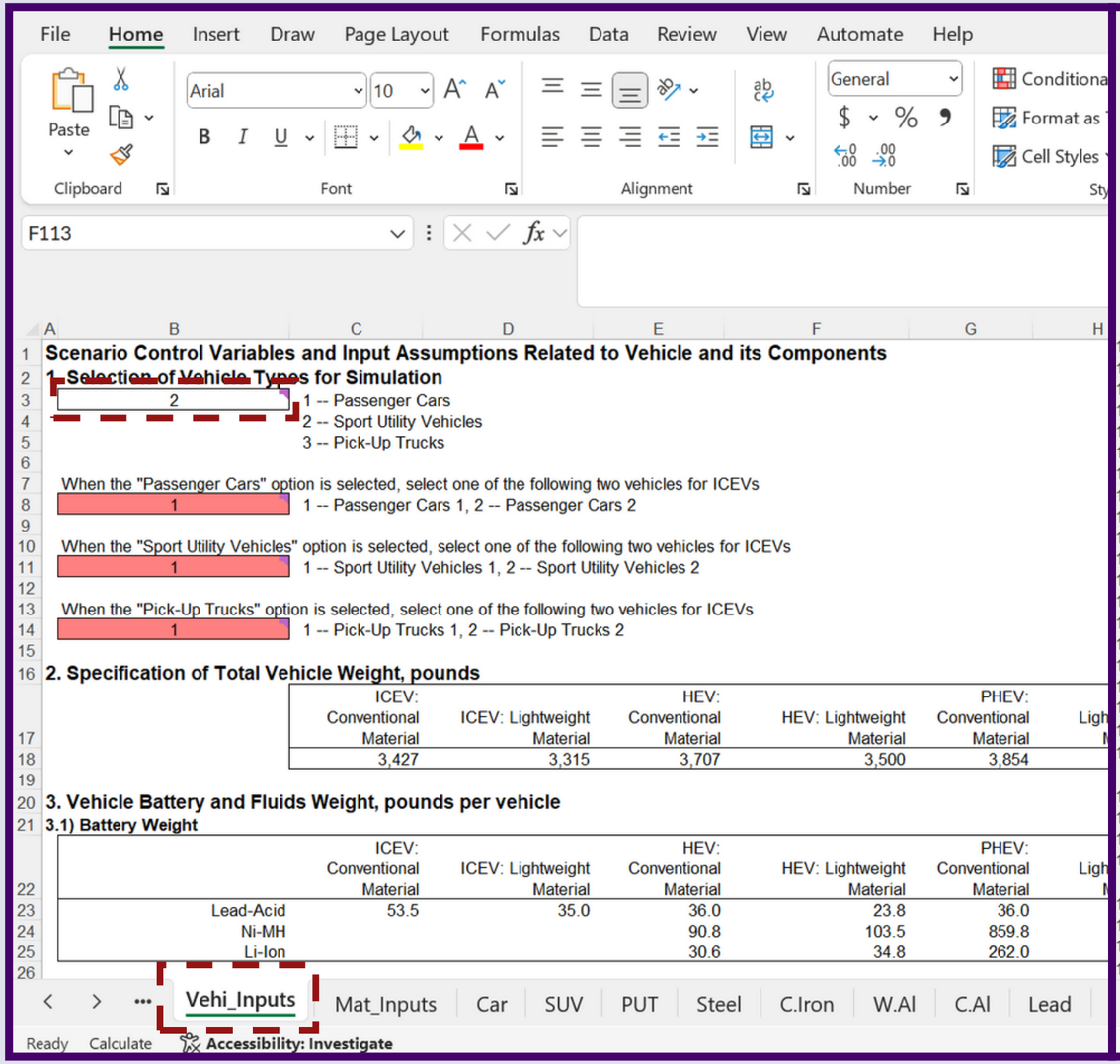
Ensure R&D GREET 2 also has the inputs from the previous example



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F113

Scenario Control Variables and Input Assumptions Related to Vehicle and its Components

1. Selection of Vehicle Types for Simulation

2

1 -- Passenger Cars
2 -- Sport Utility Vehicles
3 -- Pick-Up Trucks

When the "Passenger Cars" option is selected, select one of the following two vehicles for ICEVs
1
1 -- Passenger Cars 1, 2 -- Passenger Cars 2

When the "Sport Utility Vehicles" option is selected, select one of the following two vehicles for ICEVs
1
1 -- Sport Utility Vehicles 1, 2 -- Sport Utility Vehicles 2

When the "Pick-Up Trucks" option is selected, select one of the following two vehicles for ICEVs
1
1 -- Pick-Up Trucks 1, 2 -- Pick-Up Trucks 2

2. Specification of Total Vehicle Weight, pounds

ICEV: Conventional Material	ICEV: Lightweight Material	HEV: Conventional Material	HEV: Lightweight Material	PHEV: Conventional Material	Ligh
3,427	3,315	3,707	3,500	3,854	

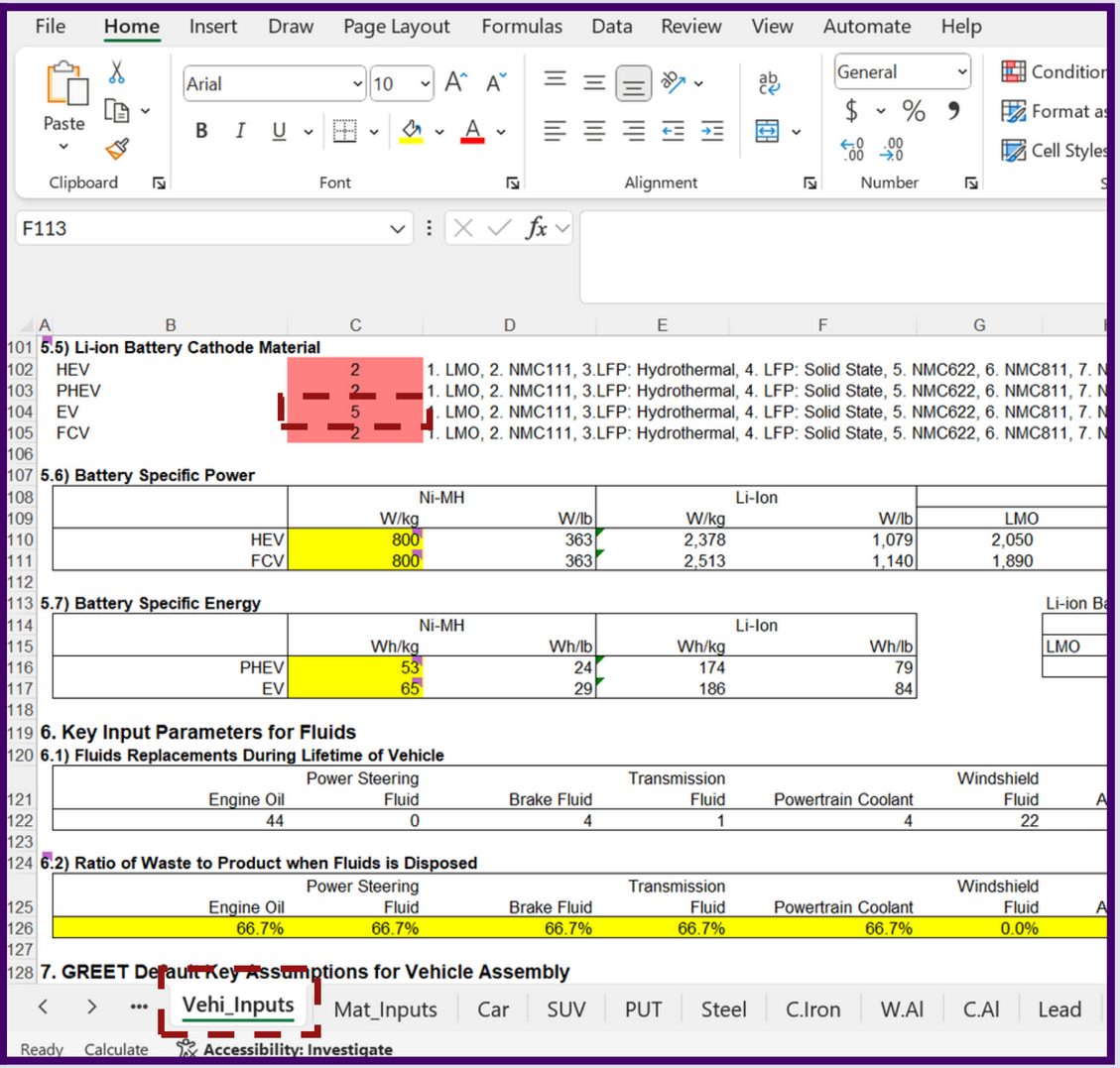
3. Vehicle Battery and Fluids Weight, pounds per vehicle

3.1) Battery Weight

	ICEV: Conventional Material	ICEV: Lightweight Material	HEV: Conventional Material	HEV: Lightweight Material	PHEV: Conventional Material	Ligh
Lead-Acid	53.5	35.0	36.0	23.8	36.0	
Ni-MH			90.8	103.5	859.8	
Li-Ion			30.6	34.8	262.0	

Vehi_Inputs Mat_Inputs Car SUV PUT Steel C.Iron W.Al C.Al Lead

Ready Calculate Accessibility: Investigate



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F113

5.5) Li-ion Battery Cathode Material

HEV	2	1. LMO, 2. NMC111, 3.LFP: Hydrothermal, 4. LFP: Solid State, 5. NMC622, 6. NMC811, 7. N
PHEV	2	1. LMO, 2. NMC111, 3.LFP: Hydrothermal, 4. LFP: Solid State, 5. NMC622, 6. NMC811, 7. N
EV	5	1. LMO, 2. NMC111, 3.LFP: Hydrothermal, 4. LFP: Solid State, 5. NMC622, 6. NMC811, 7. N
FCV	2	1. LMO, 2. NMC111, 3.LFP: Hydrothermal, 4. LFP: Solid State, 5. NMC622, 6. NMC811, 7. N

5.6) Battery Specific Power

	Ni-MH		Li-Ion		
	W/kg	W/lb	W/kg	W/lb	LMO
HEV	800	363	2,378	1,079	2,050
FCV	800	363	2,513	1,140	1,890

5.7) Battery Specific Energy

	Ni-MH		Li-Ion		Li-ion Ba
	Wh/kg	Wh/lb	Wh/kg	Wh/lb	LMO
PHEV	53	24	174	79	
EV	65	29	186	84	

6. Key Input Parameters for Fluids

6.1) Fluids Replacements During Lifetime of Vehicle

	Power Steering		Transmission		Windshield	
Engine Oil	Fluid	Brake Fluid	Fluid	Powertrain Coolant	Fluid	A
44	0	4	1	4	22	

6.2) Ratio of Waste to Product when Fluids is Disposed

	Power Steering		Transmission		Windshield	
Engine Oil	Fluid	Brake Fluid	Fluid	Powertrain Coolant	Fluid	A
66.7%	66.7%	66.7%	66.7%	66.7%	0.0%	

7. GREET Default Key Assumptions for Vehicle Assembly

Vehi_Inputs Mat_Inputs Car SUV PUT Steel C.Iron W.Al C.Al Lead

Ready Calculate Accessibility: Investigate

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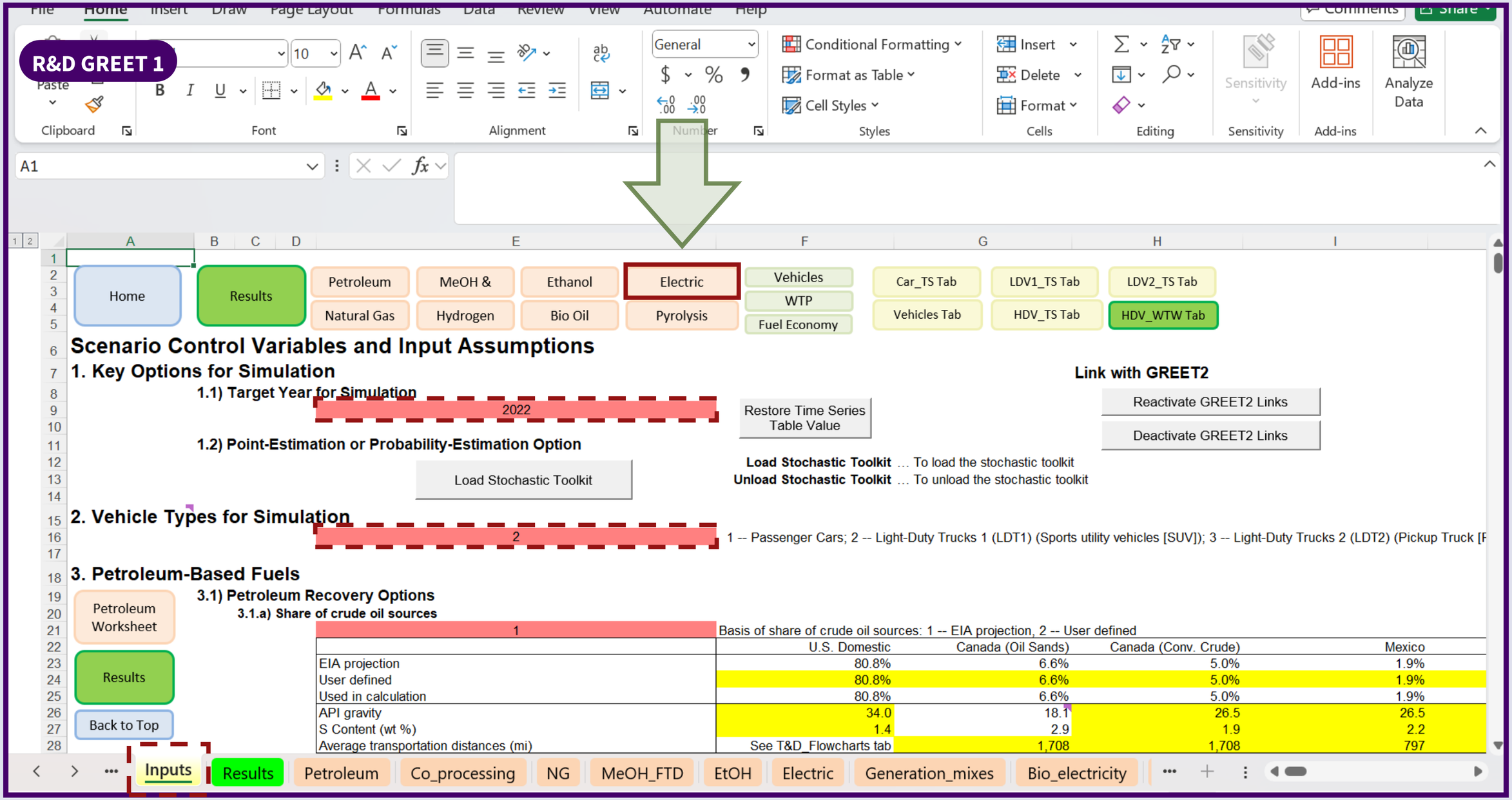

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R&D GREET 1

NavInputsZoomElectric

10. Electric Generation

10. Electric Generation

Electric Worksheet

Results

Back to Top

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

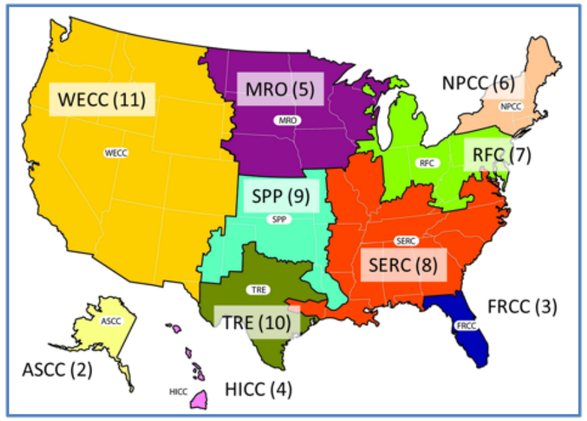
2

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	11
Mix for stationary use	1



(U.S. EPA)

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	
	Transportation	Stationary	Transportation	Stationary
Residual oil	0.3%	0.3%	13.7%	13.7%
Natural gas	38.5%	38.5%	46.7%	46.7%

Inputs | Results | Petroleum | Co_processing | NG | MeOH_FTD | EtOH | Electric | Generation_mixes | Bio_electricity

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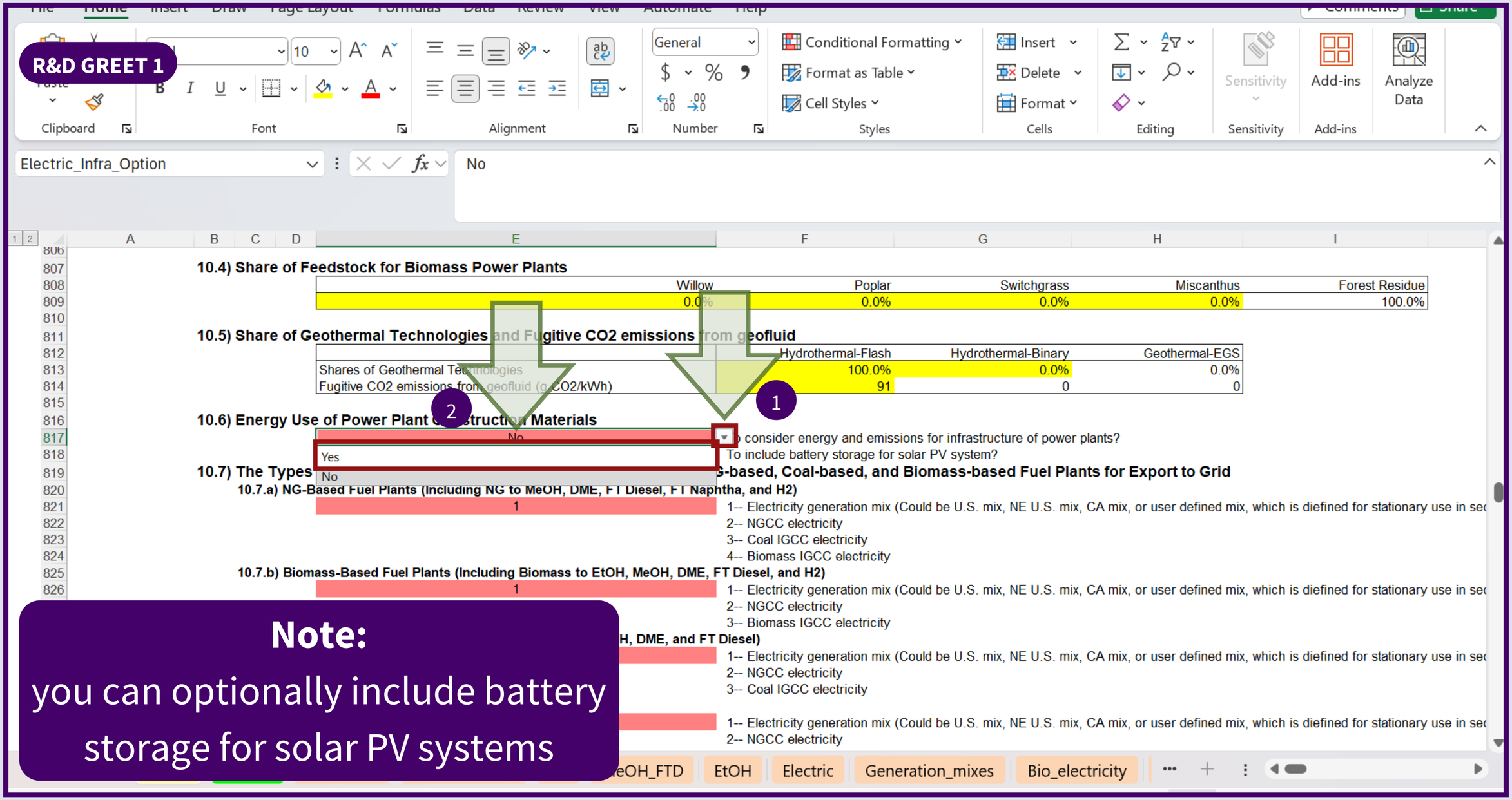

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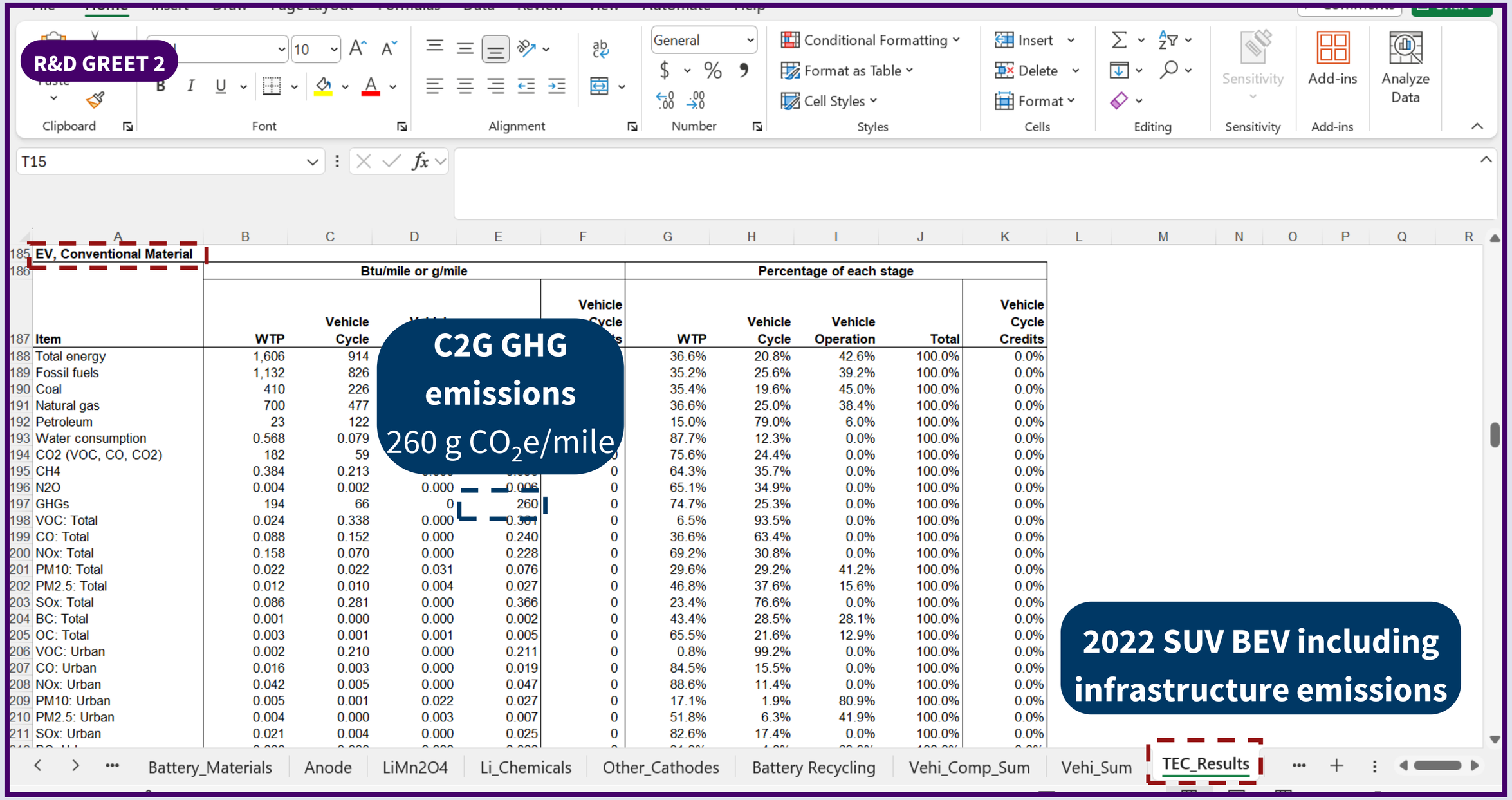
Cradle-to-Grave (C2G) GHG Emissions

R&D GREET 2



EV, Conventional Material

Item	Btu/mile or g/mile: WTP	Vehicle Cycle	Vehicle Operation	Total	Vehicle Cycle Credits	Percentage of each stage: WTP	Vehicle Cycle	Vehicle Operation	Total	Vehicle Cycle Credits
Total energy	1,606	914			0	36.6%	20.8%	42.6%	100.0%	0.0%
Fossil fuels	1,132	826			0	35.2%	25.6%	39.2%	100.0%	0.0%
Coal	410	226			0	35.4%	19.6%	45.0%	100.0%	0.0%
Natural gas	700	477			0	36.6%	25.0%	38.4%	100.0%	0.0%
Petroleum	23	122			0	15.0%	79.0%	6.0%	100.0%	0.0%
Water consumption	0.568	0.079			0	87.7%	12.3%	0.0%	100.0%	0.0%
CO2 (VOC, CO, CO2)	182	59			0	75.6%	24.4%	0.0%	100.0%	0.0%
CH4	0.384	0.213			0	64.3%	35.7%	0.0%	100.0%	0.0%
N2O	0.004	0.002	0.000	0.006	0	65.1%	34.9%	0.0%	100.0%	0.0%
GHGs	194	66	0	260	0	74.7%	25.3%	0.0%	100.0%	0.0%
VOC: Total	0.024	0.338	0.000	0.361	0	6.5%	93.5%	0.0%	100.0%	0.0%
CO: Total	0.088	0.152	0.000	0.240	0	36.6%	63.4%	0.0%	100.0%	0.0%
NOx: Total	0.158	0.070	0.000	0.228	0	69.2%	30.8%	0.0%	100.0%	0.0%
PM10: Total	0.022	0.022	0.031	0.076	0	29.6%	29.2%	41.2%	100.0%	0.0%
PM2.5: Total	0.012	0.010	0.004	0.027	0	46.8%	37.6%	15.6%	100.0%	0.0%
SOx: Total	0.086	0.281	0.000	0.366	0	23.4%	76.6%	0.0%	100.0%	0.0%
BC: Total	0.001	0.000	0.000	0.002	0	43.4%	28.5%	28.1%	100.0%	0.0%
OC: Total	0.003	0.001	0.001	0.005	0	65.5%	21.6%	12.9%	100.0%	0.0%
VOC: Urban	0.002	0.210	0.000	0.211	0	0.8%	99.2%	0.0%	100.0%	0.0%
CO: Urban	0.016	0.003	0.000	0.019	0	84.5%	15.5%	0.0%	100.0%	0.0%
NOx: Urban	0.042	0.005	0.000	0.047	0	88.6%	11.4%	0.0%	100.0%	0.0%
PM10: Urban	0.005	0.001	0.022	0.027	0	17.1%	1.9%	80.9%	100.0%	0.0%
PM2.5: Urban	0.004	0.000	0.003	0.007	0	51.8%	6.3%	41.9%	100.0%	0.0%
SOx: Urban	0.021	0.004	0.000	0.025	0	82.6%	17.4%	0.0%	100.0%	0.0%

C2G GHG emissions

260 g CO_2e/mile

2022 SUV BEV including infrastructure emissions

Battery_Materials | Anode | LiMn2O4 | Li_Chemicals | Other_Cathodes | Battery Recycling | Vehi_Comp_Sum | Vehi_Sum | TEC_Results

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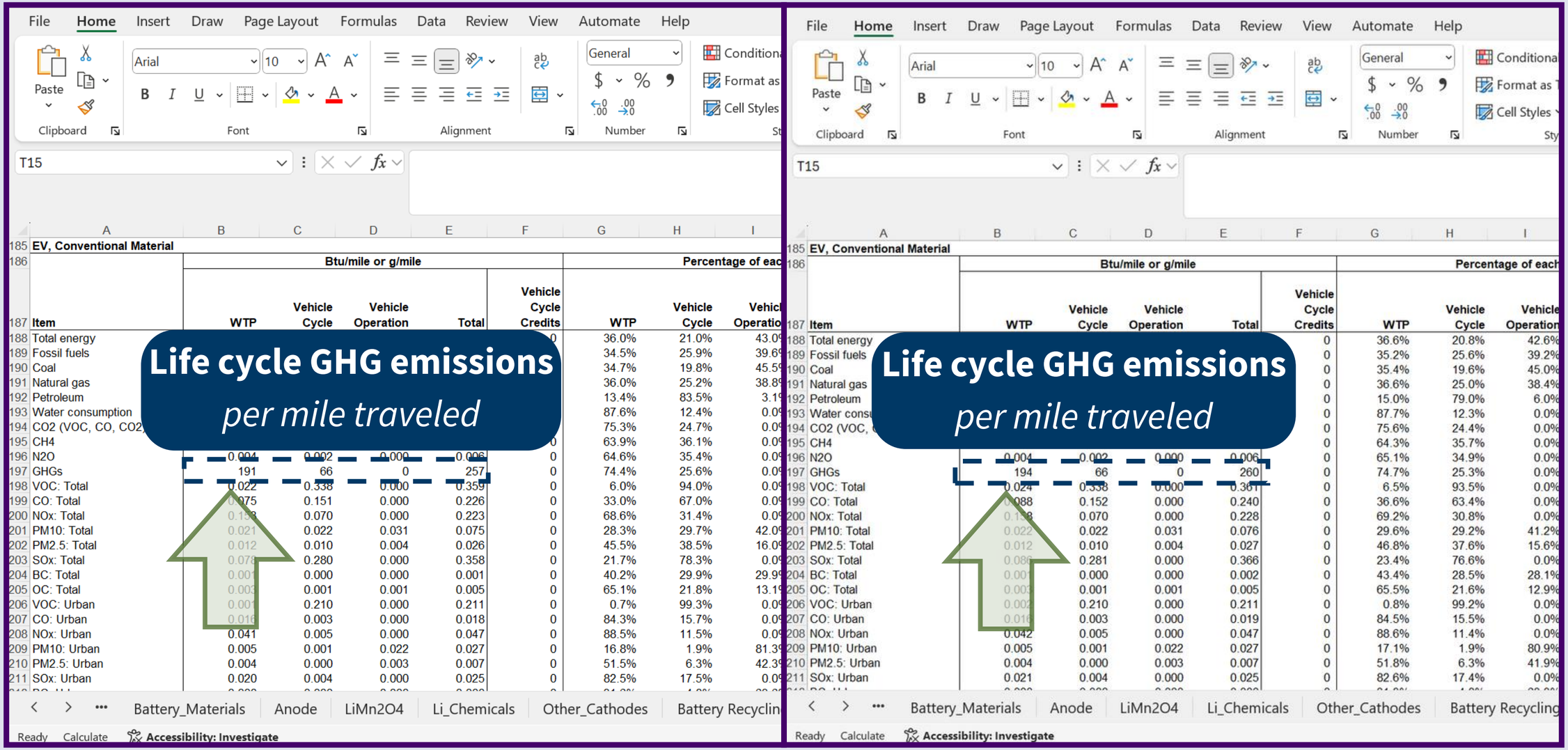
2022 SUV BEV charged in West

2022 SUV BEV including infrastructure emissions



EV, Conventional Material

Item	Btu/mile or g/mile: WTP	Vehicle Cycle	Vehicle Operation	Total	Vehicle Cycle Credits	Percentage of each: WTP	Vehicle Cycle	Vehicle Operation
Total energy					0	36.0%	21.0%	43.0%
Fossil fuels					0	34.5%	25.9%	39.6%
Coal					0	34.7%	19.8%	45.5%
Natural gas					0	36.0%	25.2%	38.8%
Petroleum					0	13.4%	83.5%	3.1%
Water consumption					0	87.6%	12.4%	0.0%
CO2 (VOC, CO, CO2)					0	75.3%	24.7%	0.0%
CH4					0	63.9%	36.1%	0.0%
N2O	0.004	0.002	0.000	0.006	0	64.6%	35.4%	0.0%
GHGs	191	66	0	257	0	74.4%	25.6%	0.0%
VOC: Total	0.022	0.338	0.000	0.359	0	6.0%	94.0%	0.0%
CO: Total	0.075	0.151	0.000	0.226	0	33.0%	67.0%	0.0%
NOx: Total	0.153	0.070	0.000	0.223	0	68.6%	31.4%	0.0%
PM10: Total	0.021	0.022	0.031	0.075	0	28.3%	29.7%	42.0%
PM2.5: Total	0.012	0.010	0.004	0.026	0	45.5%	38.5%	16.0%
SOx: Total	0.078	0.280	0.000	0.358	0	21.7%	78.3%	0.0%
BC: Total	0.001	0.000	0.000	0.001	0	40.2%	29.9%	29.9%
OC: Total	0.003	0.001	0.001	0.005	0	65.1%	21.8%	13.1%
VOC: Urban	0.001	0.210	0.000	0.211	0	0.7%	99.3%	0.0%
CO: Urban	0.016	0.003	0.000	0.018	0	84.3%	15.7%	0.0%
NOx: Urban	0.041	0.005	0.000	0.047	0	88.5%	11.5%	0.0%
PM10: Urban	0.005	0.001	0.022	0.027	0	16.8%	1.9%	81.3%
PM2.5: Urban	0.004	0.000	0.003	0.007	0	51.5%	6.3%	42.3%
SOx: Urban	0.020	0.004	0.000	0.025	0	82.5%	17.5%	0.0%

EV, Conventional Material

Item	Btu/mile or g/mile: WTP	Vehicle Cycle	Vehicle Operation	Total	Vehicle Cycle Credits	Percentage of each: WTP	Vehicle Cycle	Vehicle Operation
Total energy					0	36.6%	20.8%	42.6%
Fossil fuels					0	35.2%	25.6%	39.2%
Coal					0	35.4%	19.6%	45.0%
Natural gas					0	36.6%	25.0%	38.4%
Petroleum					0	15.0%	79.0%	6.0%
Water consu					0	87.7%	12.3%	0.0%
CO2 (VOC,					0	75.6%	24.4%	0.0%
CH4					0	64.3%	35.7%	0.0%
N2O	0.004	0.002	0.000	0.006	0	65.1%	34.9%	0.0%
GHGs	194	66	0	260	0	74.7%	25.3%	0.0%
VOC: Total	0.024	0.338	0.000	0.361	0	6.5%	93.5%	0.0%
CO: Total	0.088	0.152	0.000	0.240	0	36.6%	63.4%	0.0%
NOx: Total	0.158	0.070	0.000	0.228	0	69.2%	30.8%	0.0%
PM10: Total	0.022	0.022	0.031	0.076	0	29.6%	29.2%	41.2%
PM2.5: Total	0.012	0.010	0.004	0.027	0	46.8%	37.6%	15.6%
SOx: Total	0.086	0.281	0.000	0.366	0	23.4%	76.6%	0.0%
BC: Total	0.001	0.000	0.000	0.002	0	43.4%	28.5%	28.1%
OC: Total	0.003	0.001	0.001	0.005	0	65.5%	21.6%	12.9%
VOC: Urban	0.002	0.210	0.000	0.211	0	0.8%	99.2%	0.0%
CO: Urban	0.016	0.003	0.000	0.019	0	84.5%	15.5%	0.0%
NOx: Urban	0.042	0.005	0.000	0.047	0	88.6%	11.4%	0.0%
PM10: Urban	0.005	0.001	0.022	0.027	0	17.1%	1.9%	80.9%
PM2.5: Urban	0.004	0.000	0.003	0.007	0	51.8%	6.3%	41.9%
SOx: Urban	0.021	0.004	0.000	0.025	0	82.6%	17.4%	0.0%

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Onshore Wind Turbine

Model a Passenger *Car* Battery Electric Vehicle (BEV) in 2022 Using an *NMC111* Battery Charged from a Wind Turbine Located Onshore the U.S. *Include Infrastructure Emissions*

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Capacity factor

Capacity Factor (CF)

Ratio of the average power output and rated power, affected by the wind speed

Major wind potentials are in the Midwest and Offshore the U.S.

Off-shore average CF > On-shore average CF

Deep water off-shore average CF > shallow water off-shore average CF

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Capacity factor

Capacity Factor Lifetime

The average lifetime of the wind turbine is 20-30 years

Capacity Factor Degradation

CF degrades 85% over the lifetime of the wind turbine

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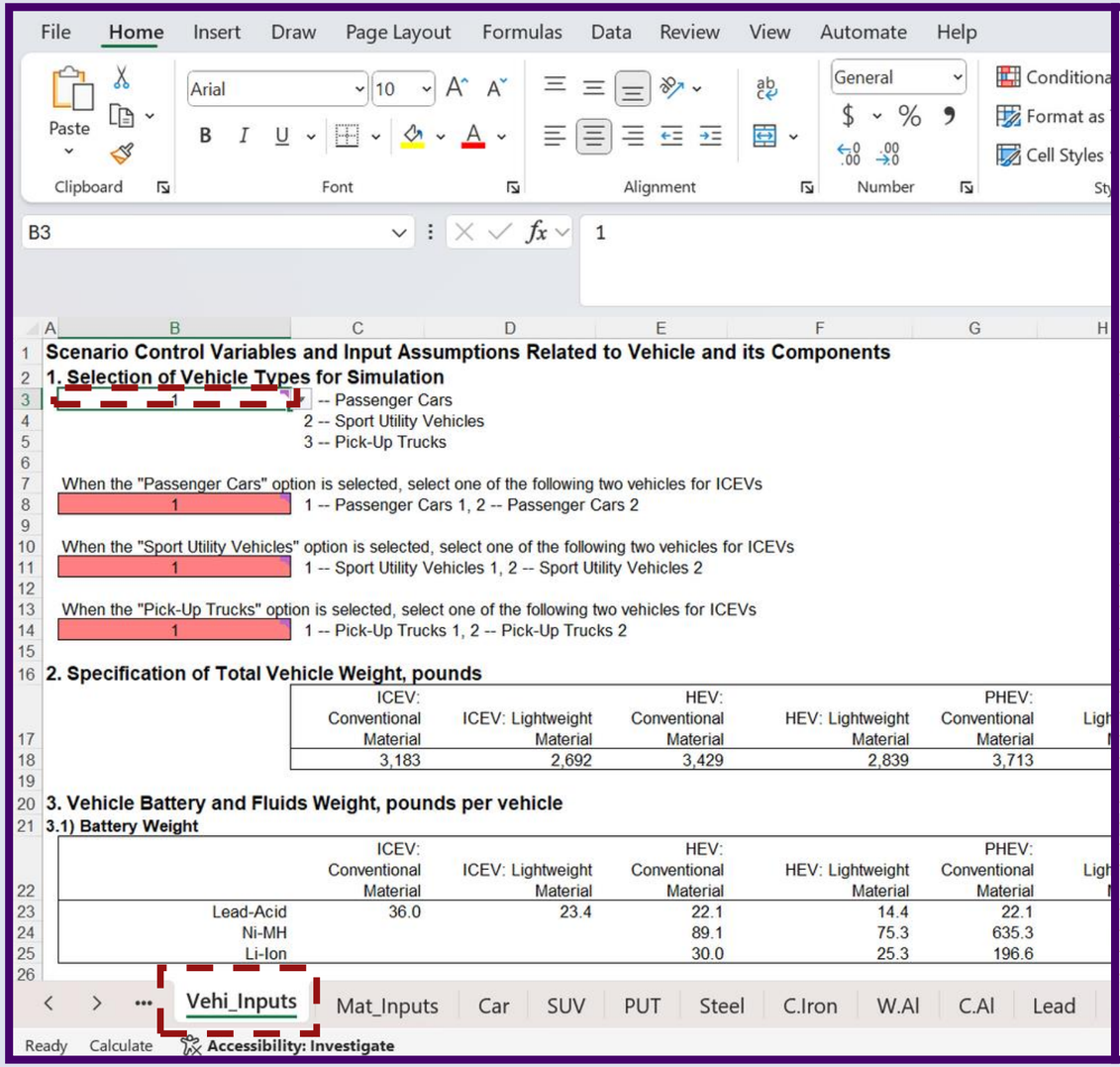
Change R&D GREET 2 inputs to a car using an NMC111 battery



Scenario Control Variables and Input Assumptions Related to Vehicle and its Components

1. Selection of Vehicle Types for Simulation

1 -- Passenger Cars
2 -- Sport Utility Vehicles
3 -- Pick-Up Trucks

When the "Passenger Cars" option is selected, select one of the following two vehicles for ICEVs
1 -- Passenger Cars 1, 2 -- Passenger Cars 2

When the "Sport Utility Vehicles" option is selected, select one of the following two vehicles for ICEVs
1 -- Sport Utility Vehicles 1, 2 -- Sport Utility Vehicles 2

When the "Pick-Up Trucks" option is selected, select one of the following two vehicles for ICEVs
1 -- Pick-Up Trucks 1, 2 -- Pick-Up Trucks 2

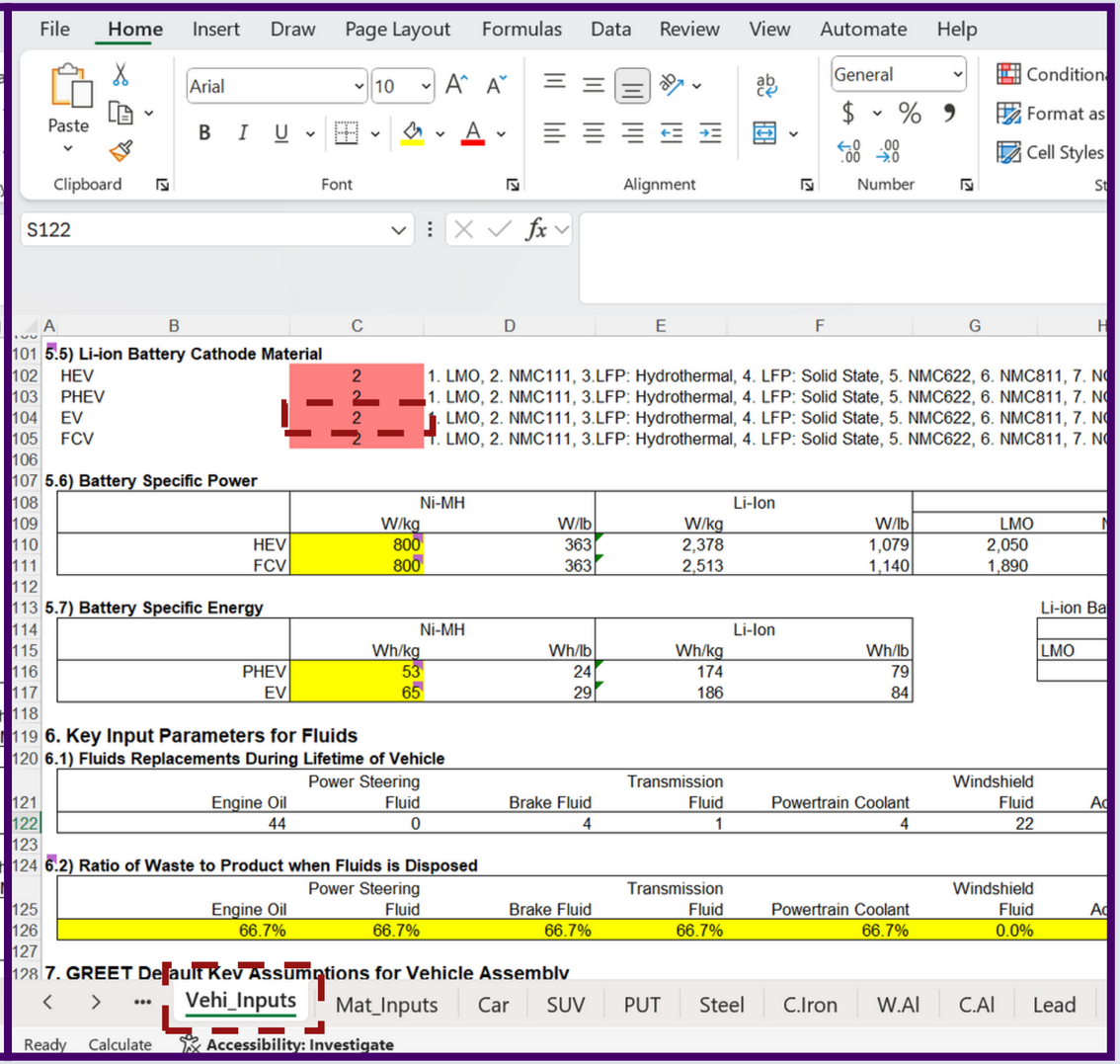
2. Specification of Total Vehicle Weight, pounds

ICEV: Conventional Material	ICEV: Lightweight Material	HEV: Conventional Material	HEV: Lightweight Material	PHEV: Conventional Material
3,183	2,692	3,429	2,839	3,713

3. Vehicle Battery and Fluids Weight, pounds per vehicle

3.1) Battery Weight

	ICEV: Conventional Material	ICEV: Lightweight Material	HEV: Conventional Material	HEV: Lightweight Material	PHEV: Conventional Material
Lead-Acid	36.0	23.4	22.1	14.4	22.1
Ni-MH			89.1	75.3	635.3
Li-Ion			30.0	25.3	196.6



5.5) Li-ion Battery Cathode Material

HEV	2	1. LMO, 2. NMC111, 3.LFP: Hydrothermal, 4. LFP: Solid State, 5. NMC622, 6. NMC811, 7. NC
PHEV	2	1. LMO, 2. NMC111, 3.LFP: Hydrothermal, 4. LFP: Solid State, 5. NMC622, 6. NMC811, 7. NC
EV	2	1. LMO, 2. NMC111, 3.LFP: Hydrothermal, 4. LFP: Solid State, 5. NMC622, 6. NMC811, 7. NC
FCV	2	1. LMO, 2. NMC111, 3.LFP: Hydrothermal, 4. LFP: Solid State, 5. NMC622, 6. NMC811, 7. NC

5.6) Battery Specific Power

	Ni-MH		Li-Ion		
	W/kg	W/lb	W/kg	W/lb	LMO
HEV	800	363	2,378	1,079	2,050
FCV	800	363	2,513	1,140	1,890

5.7) Battery Specific Energy

	Ni-MH		Li-Ion	
	Wh/kg	Wh/lb	Wh/kg	Wh/lb
PHEV	53	24	174	79
EV	65	29	186	84

Li-ion Ba

LMO

6. Key Input Parameters for Fluids

6.1) Fluids Replacements During Lifetime of Vehicle

Engine Oil	Power Steering Fluid	Brake Fluid	Transmission Fluid	Powertrain Coolant	Windshield Fluid
44	0	4	1	4	22

6.2) Ratio of Waste to Product when Fluids is Disposed

Engine Oil	Power Steering Fluid	Brake Fluid	Transmission Fluid	Powertrain Coolant	Windshield Fluid
66.7%	66.7%	66.7%	66.7%	66.7%	0.0%

7. GREET Default Key Assumptions for Vehicle Assembly

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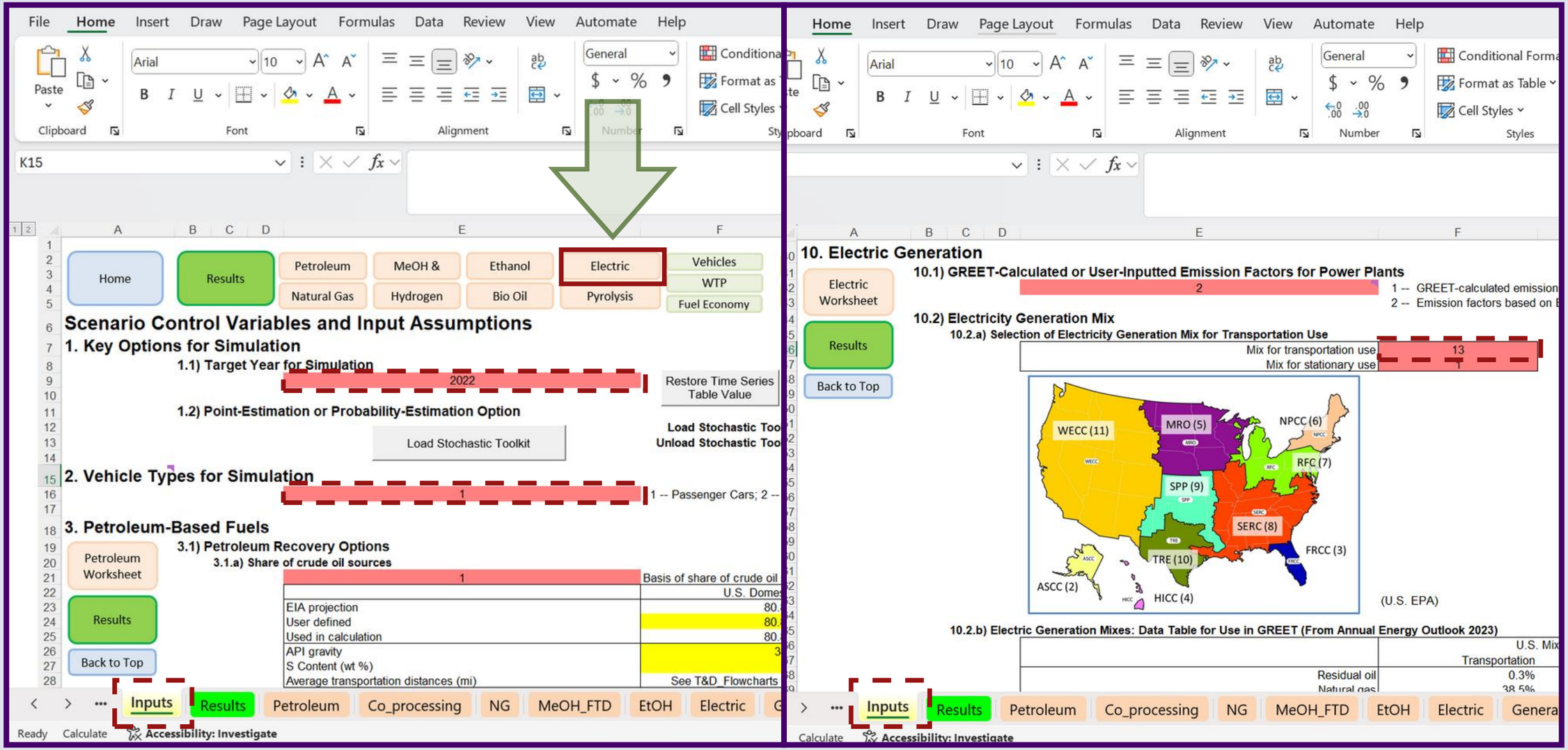
Change R&D GREET 1 inputs to a car using a user input electric grid



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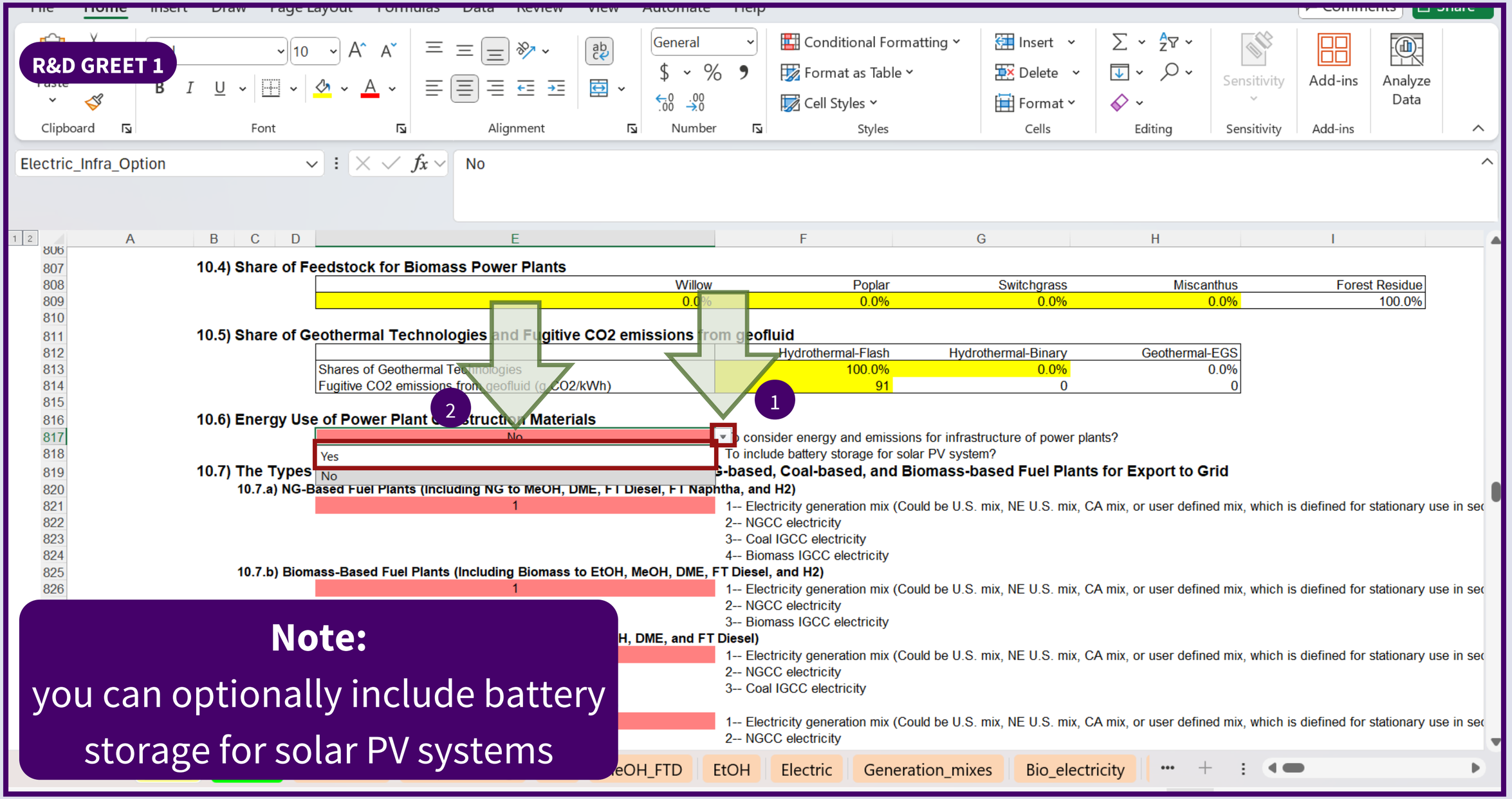

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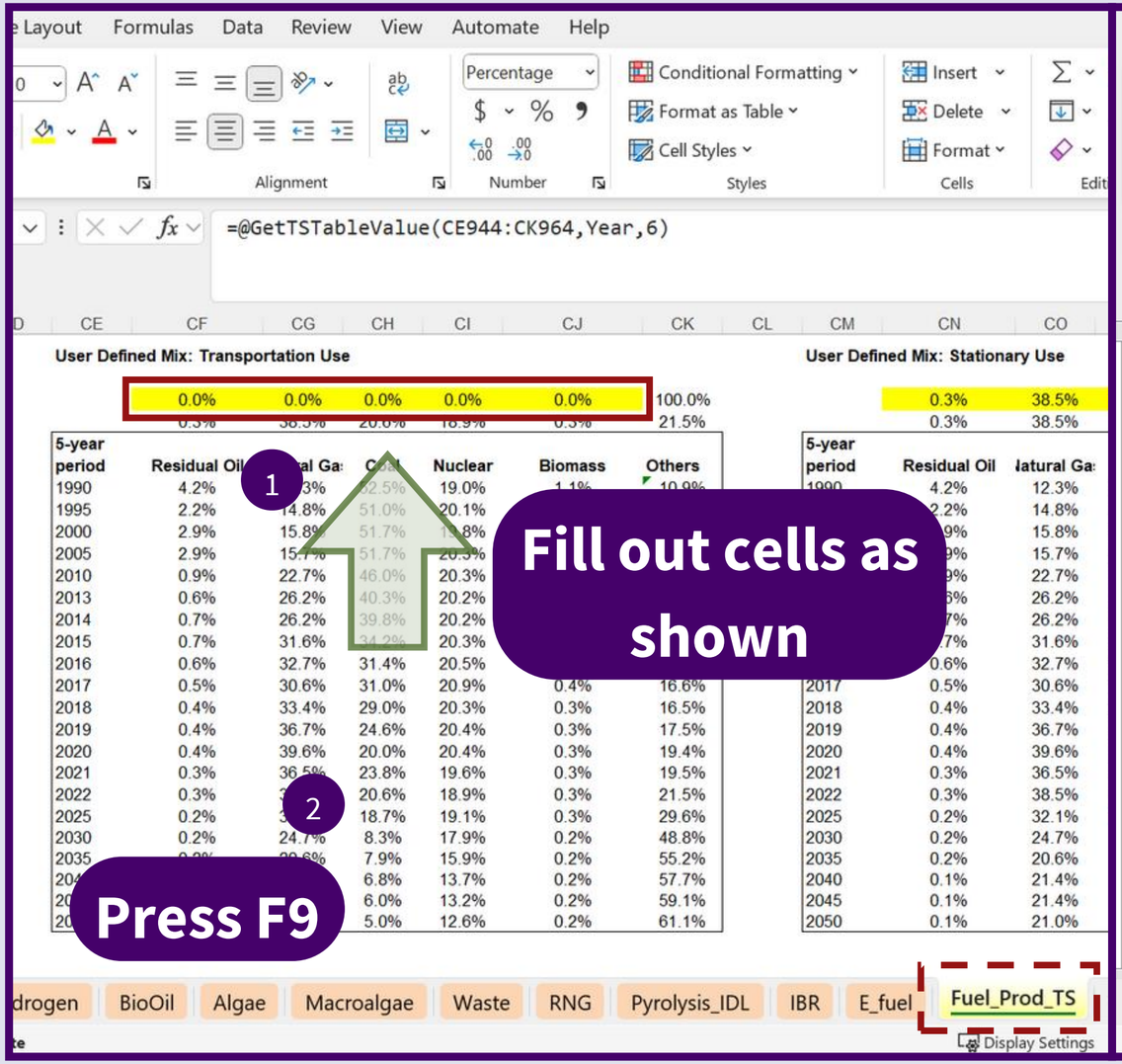
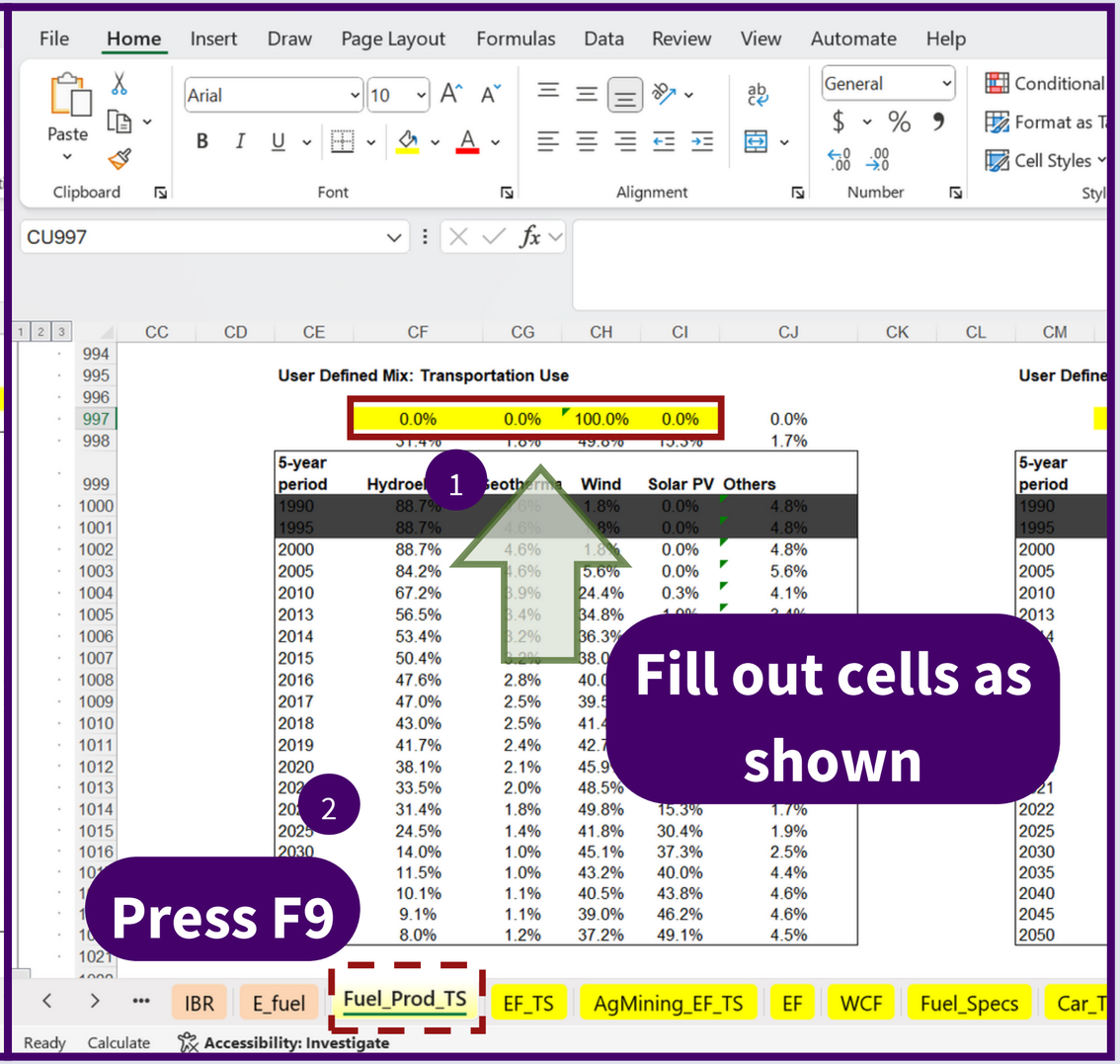
Change R&D GREET 1 inputs to a 100% wind generated transportation





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Capacity Factor (CF), Assumed Lifespan, and Recycled Steel Content for Onshore Wind Turbine in U.S.

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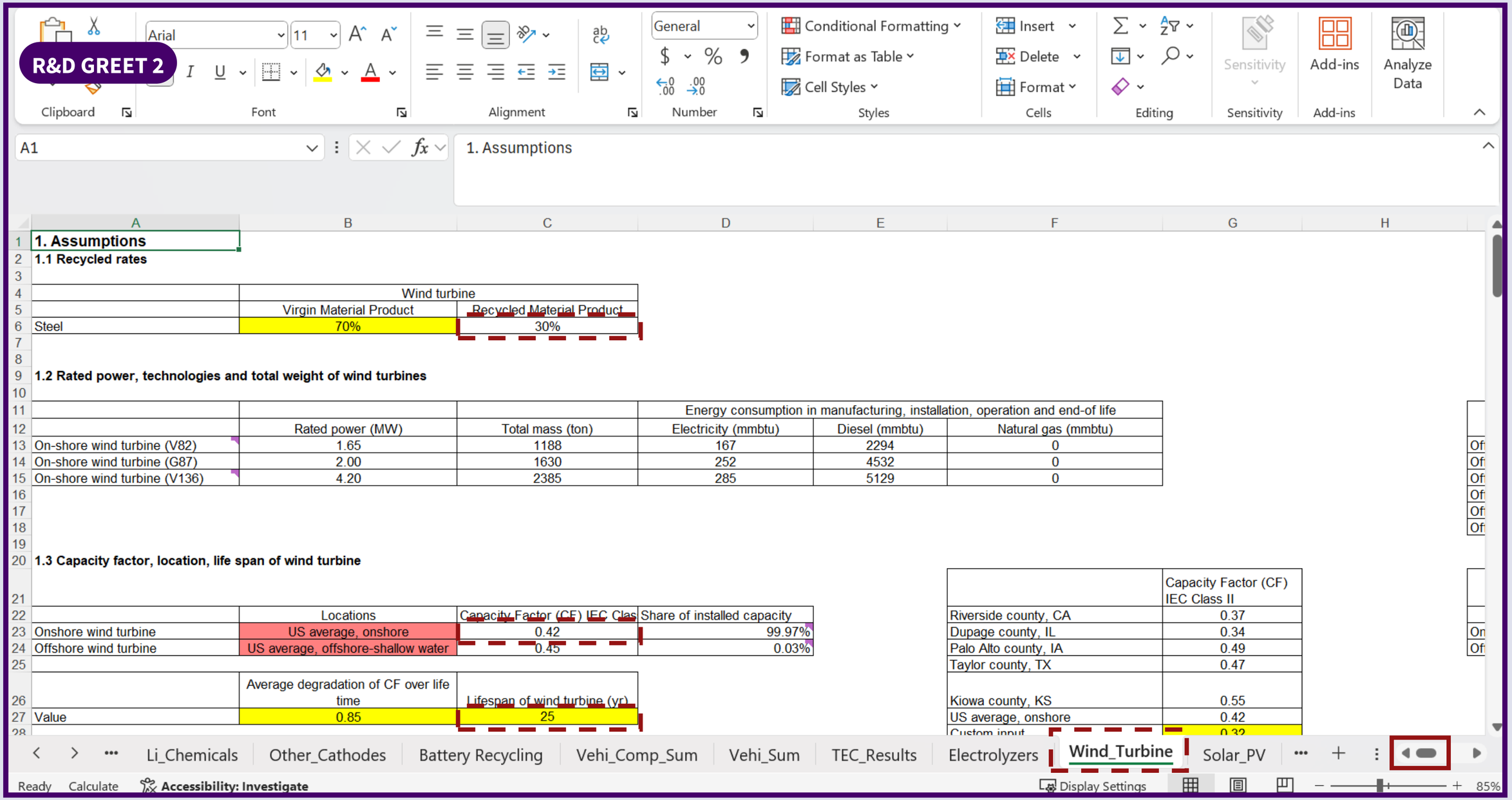

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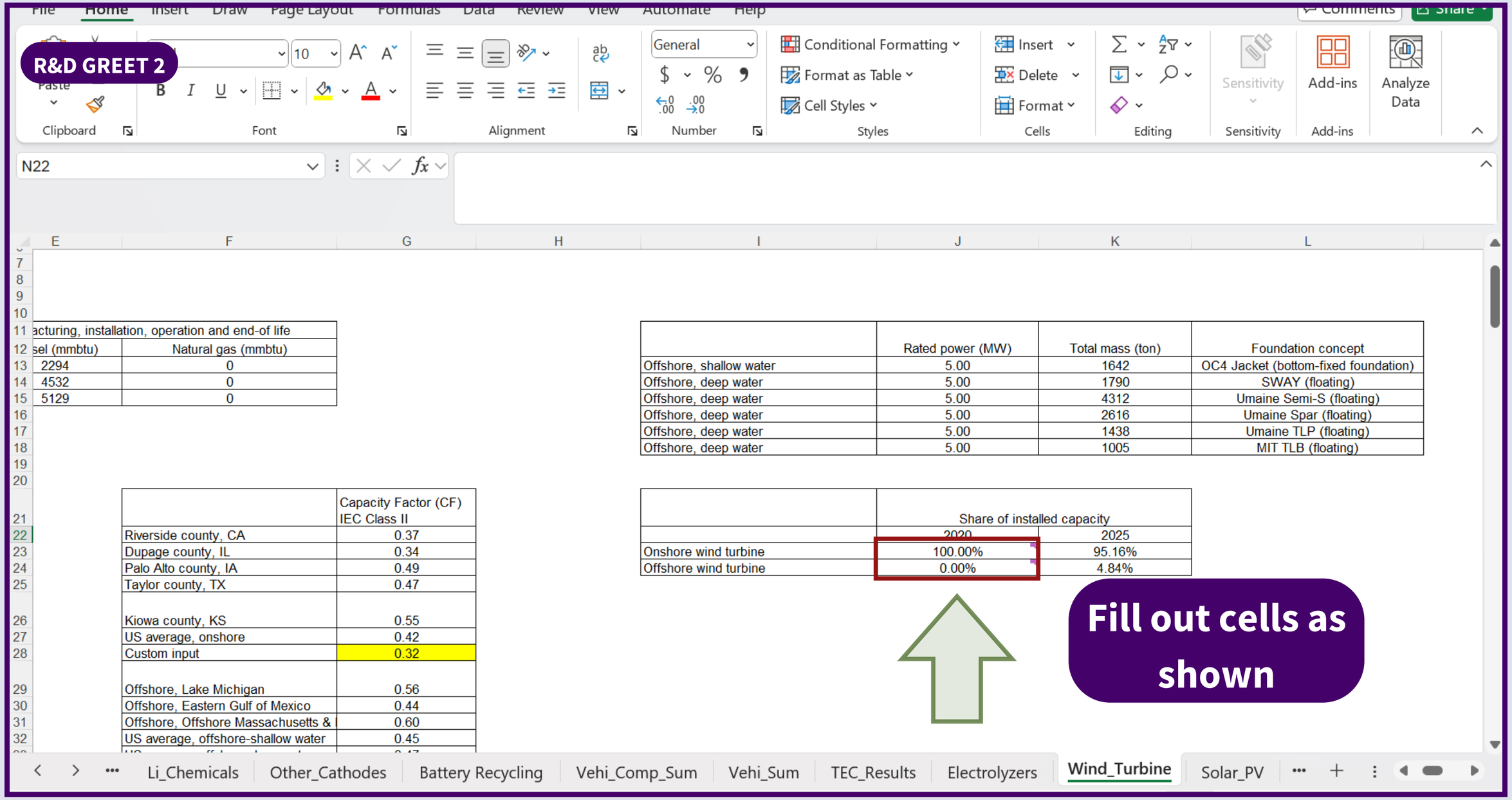

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Default Installation Type for Small Residential Solar Photovoltaic Systems

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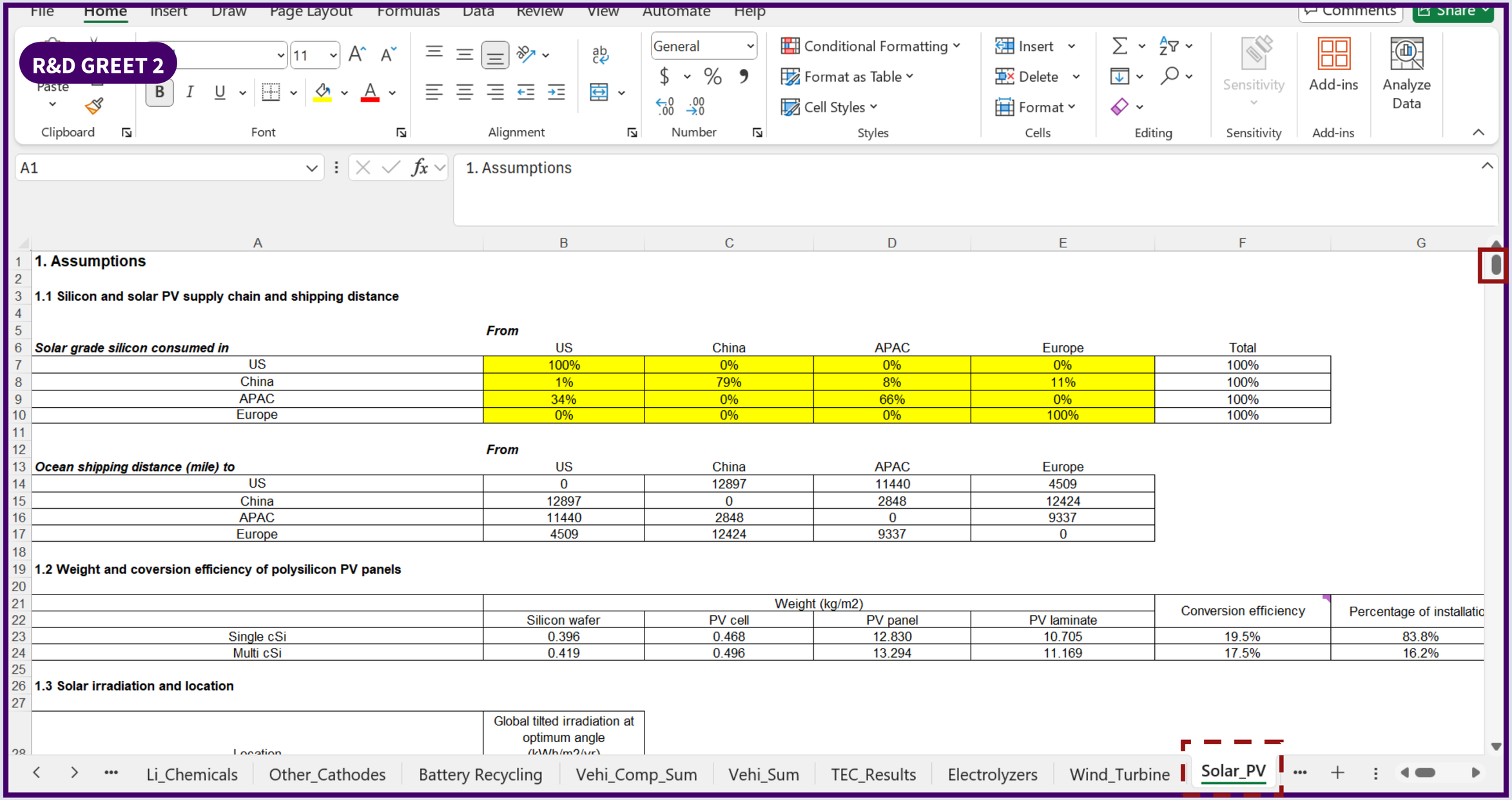

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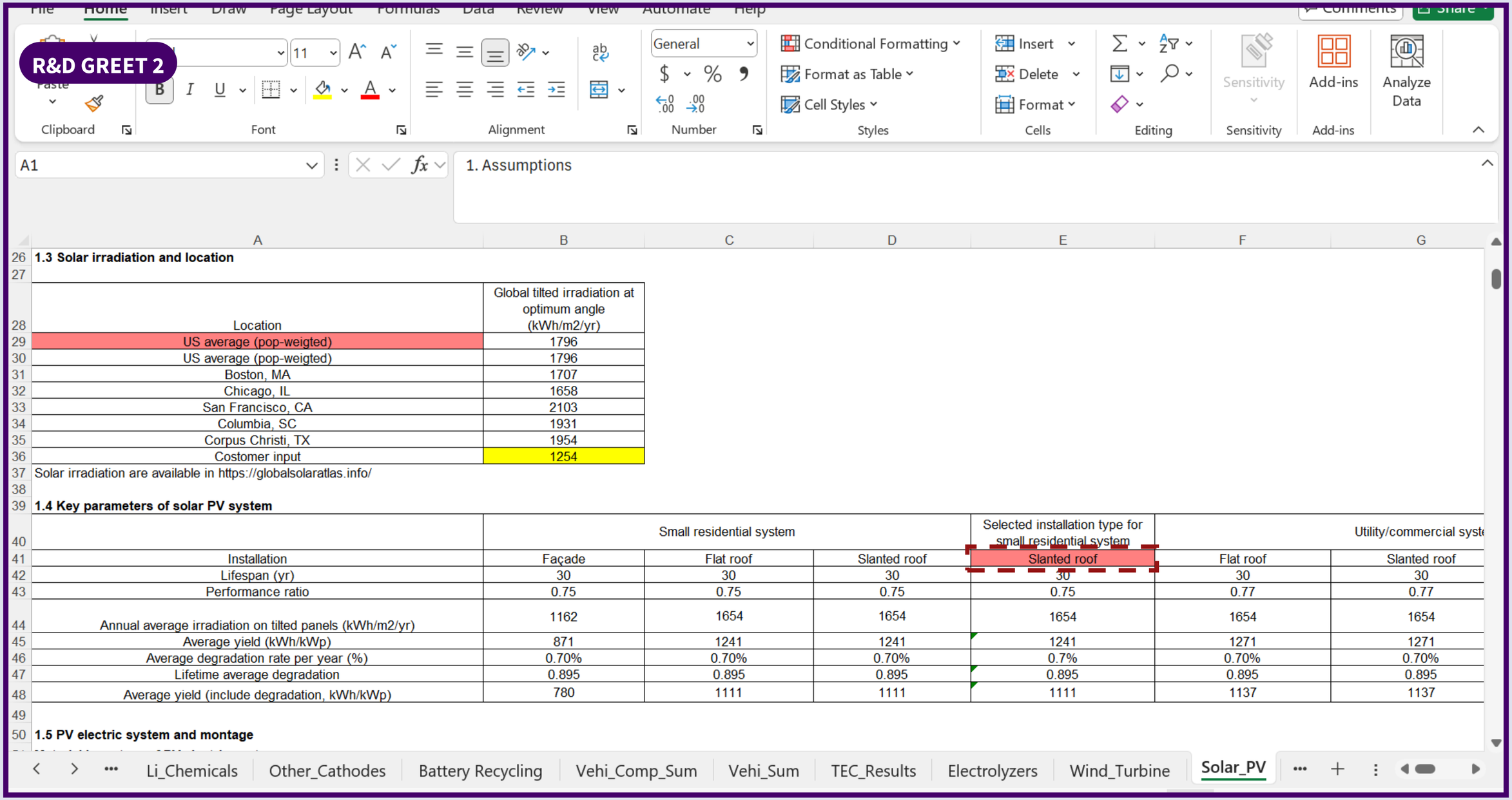

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Cradle-to-Grave (C2G) GHG Emissions

R&D GREET 2

A1: Energy Use and Emissions of Well-to-Pump, Vehicle Cycle and Vehicle Operation

EV, Conventional Material

	Btu/mile or g/mile					Percentage of each stage				
Item	WTP	Vehicle Cycle	Vehicle Operation	Total	Vehicle Cycle Credits	WTP	Vehicle Cycle	Vehicle Operation	Total	Vehicle Cycle Credits
Total energy	109	905				4.9%	40.5%	54.7%	100.0%	0.0%
Fossil fuels	3	812				0.4%	95.0%	4.6%	100.0%	0.0%
Coal	1	232				0.5%	93.5%	6.0%	100.0%	0.0%
Natural gas	1	472				0.2%	97.4%	2.4%	100.0%	0.0%
Petroleum	1	108				0.9%	88.6%	10.5%	100.0%	0.0%
Water consumption	0.004	0.086				4.1%	95.9%	0.0%	100.0%	0.0%
CO2 (VOC, CO, CO2)	3	58				5.7%	94.3%	0.0%	100.0%	0.0%
CH4	0.006	0.211			0	2.7%	97.3%	0.0%	100.0%	0.0%
N2O	0.000	0.002	0.000	0.002	0	3.2%	96.8%	0.0%	100.0%	0.0%
GHGs	4	65	0	68	0	5.4%	94.6%	0.0%	100.0%	0.0%
VOC: Total	0.002	0.193	0.000	0.196	0	1.2%	98.8%	0.0%	100.0%	0.0%
CO: Total	0.014	0.151	0.000	0.165	0	8.5%	91.5%	0.0%	100.0%	0.0%
NOx: Total	0.004	0.067	0.000	0.071	0	5.6%	94.4%	0.0%	100.0%	0.0%
PM10: Total	0.002	0.027	0.031	0.059	0	2.8%	45.2%	51.9%	100.0%	0.0%
PM2.5: Total	0.001	0.010	0.004	0.015	0	5.0%	68.6%	26.5%	100.0%	0.0%
SOx: Total	0.008	0.218	0.000	0.226	0	3.4%	96.6%	0.0%	100.0%	0.0%
BC: Total	0.000	0.000	0.001	0.001	0	1.9%	42.9%	55.2%	100.0%	0.0%
OC: Total	0.000	0.001	0.001	0.002	0	2.7%	58.0%	39.3%	100.0%	0.0%
VOC: Urban	0.000	0.111	0.000	0.111	0	0.2%	99.8%	0.0%	100.0%	0.0%
CO: Urban	0.000	0.003	0.000	0.003	0	6.5%	93.5%	0.0%	100.0%	0.0%
NOx: Urban	0.000	0.005	0.000	0.006	0	5.7%	94.3%	0.0%	100.0%	0.0%
PM10: Urban	0.000	0.001	0.021	0.022	0	0.5%	2.4%	97.1%	100.0%	0.0%
PM2.5: Urban	0.000	0.000	0.003	0.003	0	1.5%	13.2%	85.3%	100.0%	0.0%
SOx: Urban	0.000	0.004	0.000	0.005	0	4.7%	95.3%	0.0%	100.0%	0.0%

C2G GHG emissions

68 g CO_2e/mile

2022 car BEV with onshore wind electricity including infrastructure emissions

Li_Chemicals | Other_Cathodes | Battery Recycling | Vehi_Comp_Sum | Vehi_Sum | TEC_Results | Electrolyzers | Wind_Turbine | Solar_PV

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Offshore Wind Turbine

Model a Passenger Car Battery Electric Vehicle (BEV) in 2022 Using an NMC111 Battery Charged from a Wind Turbine Located Offshore the U.S. in Deep Water. *Include Infrastructure Emissions*

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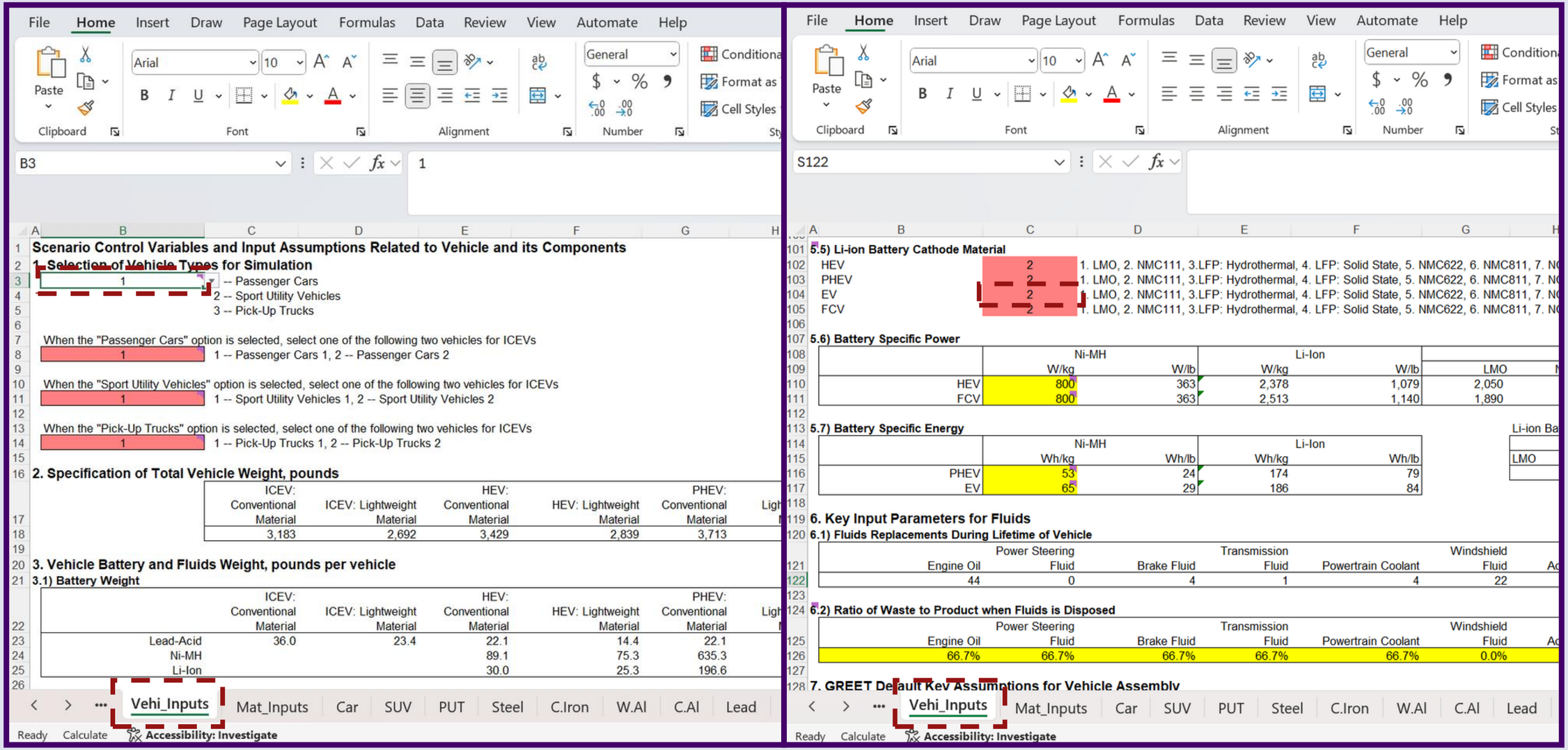
Change R&D GREET 2 inputs to a car using an NMC111 battery



Scenario Control Variables and Input Assumptions Related to Vehicle and its Components

1. Selection of Vehicle Types for Simulation

1 -- Passenger Cars
2 -- Sport Utility Vehicles
3 -- Pick-Up Trucks

When the "Passenger Cars" option is selected, select one of the following two vehicles for ICEVs: 1 -- Passenger Cars 1, 2 -- Passenger Cars 2

When the "Sport Utility Vehicles" option is selected, select one of the following two vehicles for ICEVs: 1 -- Sport Utility Vehicles 1, 2 -- Sport Utility Vehicles 2

When the "Pick-Up Trucks" option is selected, select one of the following two vehicles for ICEVs: 1 -- Pick-Up Trucks 1, 2 -- Pick-Up Trucks 2

2. Specification of Total Vehicle Weight, pounds

ICEV: Conventional Material	ICEV: Lightweight Material	HEV: Conventional Material	HEV: Lightweight Material	PHEV: Conventional Material
3,183	2,692	3,429	2,839	3,713

3. Vehicle Battery and Fluids Weight, pounds per vehicle

3.1) Battery Weight

	ICEV: Conventional Material	ICEV: Lightweight Material	HEV: Conventional Material	HEV: Lightweight Material	PHEV: Conventional Material
Lead-Acid	36.0	23.4	22.1	14.4	22.1
Ni-MH			89.1	75.3	635.3
Li-Ion			30.0	25.3	196.6

5.5) Li-ion Battery Cathode Material

HEV	2
PHEV	2
EV	2
FCV	2

1. LMO, 2. NMC111, 3.LFP: Hydrothermal, 4. LFP: Solid State, 5. NMC622, 6. NMC811, 7. NC

5.6) Battery Specific Power

	Ni-MH W/kg	Ni-MH W/lb	Li-Ion W/kg	Li-Ion W/lb	LMO
HEV	800	363	2,378	1,079	2,050
FCV	800	363	2,513	1,140	1,890

5.7) Battery Specific Energy

	Ni-MH Wh/kg	Ni-MH Wh/lb	Li-Ion Wh/kg	Li-Ion Wh/lb
PHEV	53	24	174	79
EV	65	29	186	84

Li-ion Ba: LMO

6. Key Input Parameters for Fluids

6.1) Fluids Replacements During Lifetime of Vehicle

Engine Oil	Power Steering Fluid	Brake Fluid	Transmission Fluid	Powertrain Coolant	Windshield Fluid
44	0	4	1	4	22

6.2) Ratio of Waste to Product when Fluids is Disposed

Engine Oil	Power Steering Fluid	Brake Fluid	Transmission Fluid	Powertrain Coolant	Windshield Fluid
66.7%	66.7%	66.7%	66.7%	66.7%	0.0%

7. GREET Default Key Assumptions for Vehicle Assembly

Vehi_Inputs | Mat_Inputs | Car | SUV | PUT | Steel | C.Iron | W.Al | C.Al | Lead

Ready | Calculate | Accessibility: Investigate

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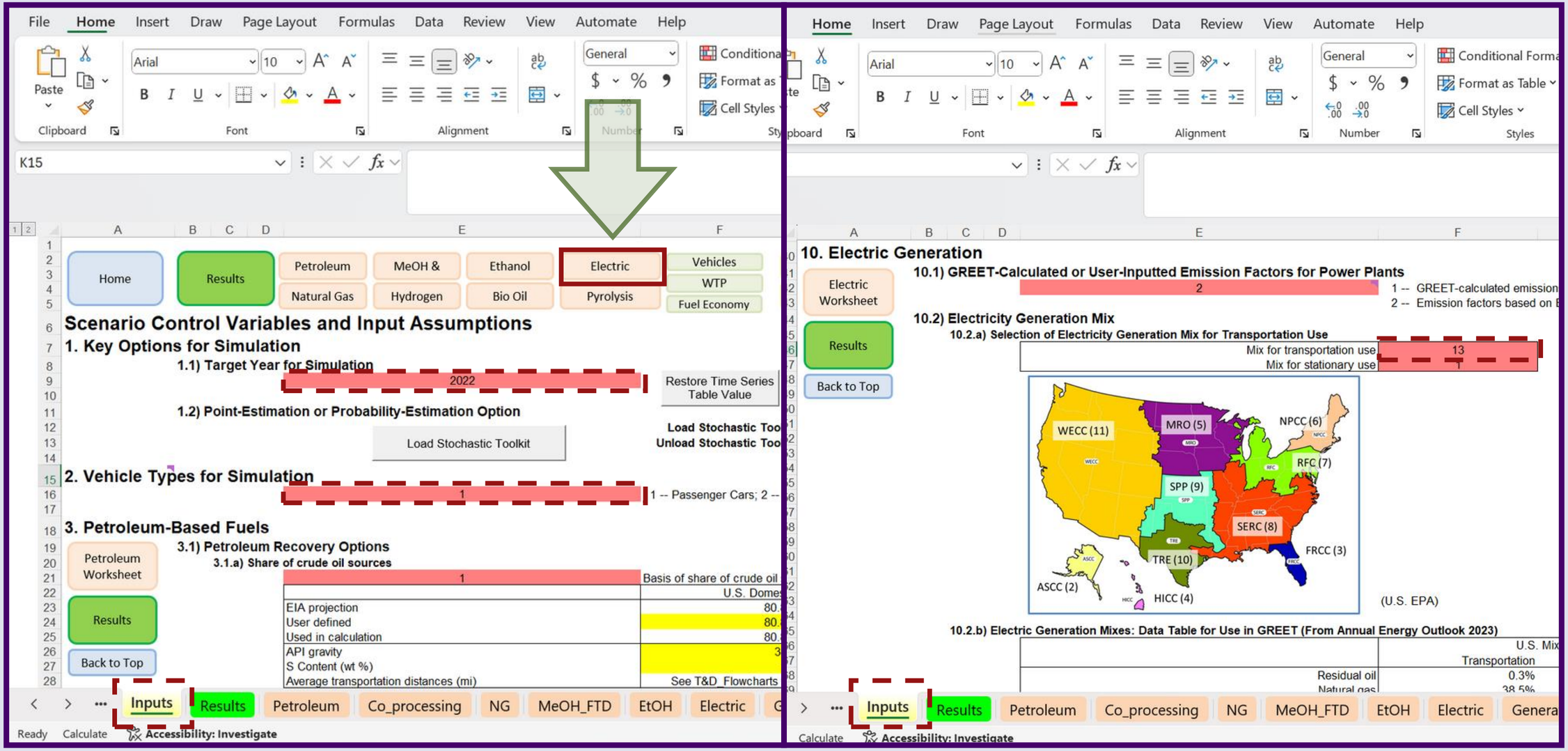
Change R&D GREET 1 inputs to a car using a user input electric grid



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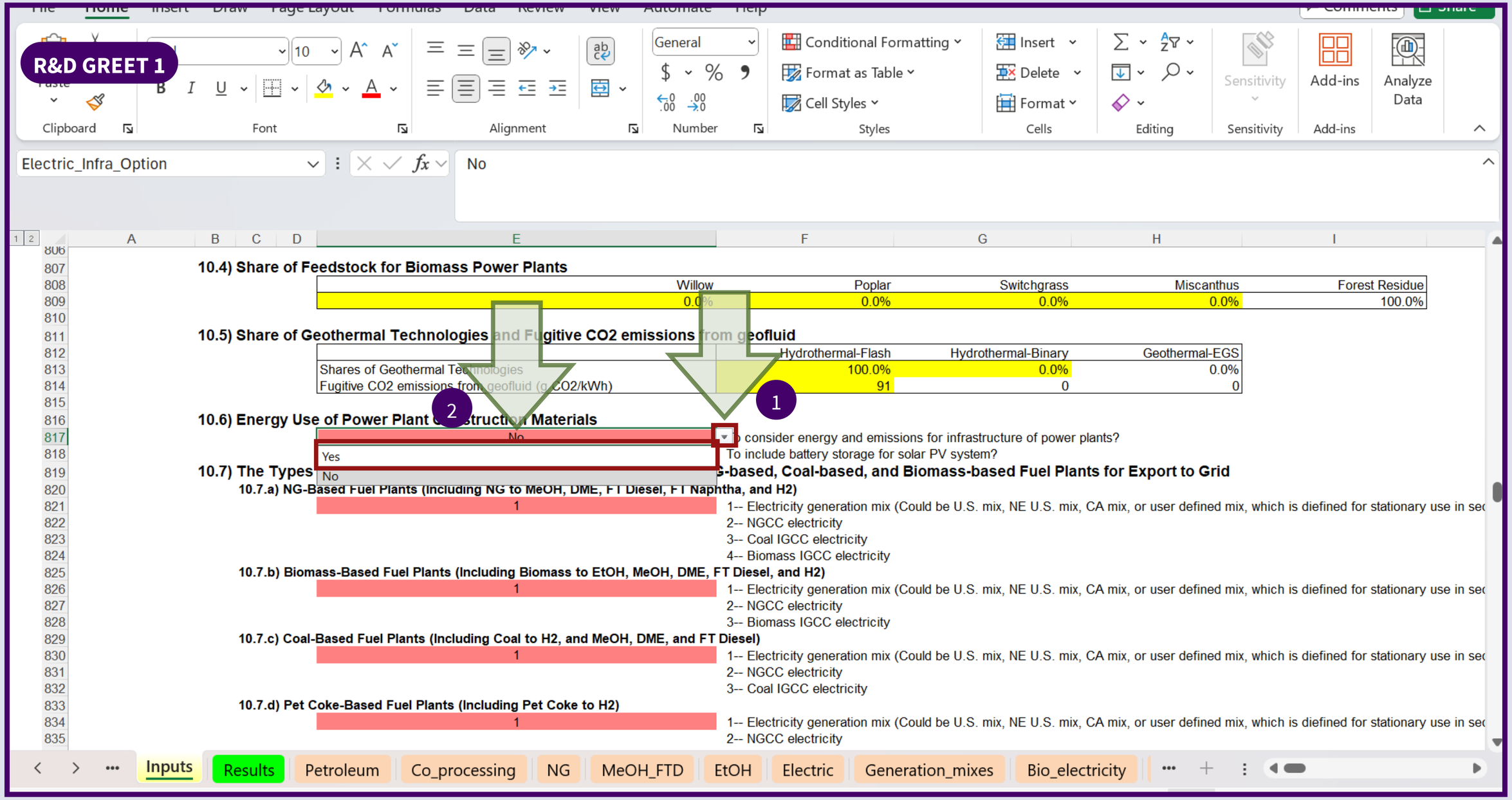
R&D GREET 1



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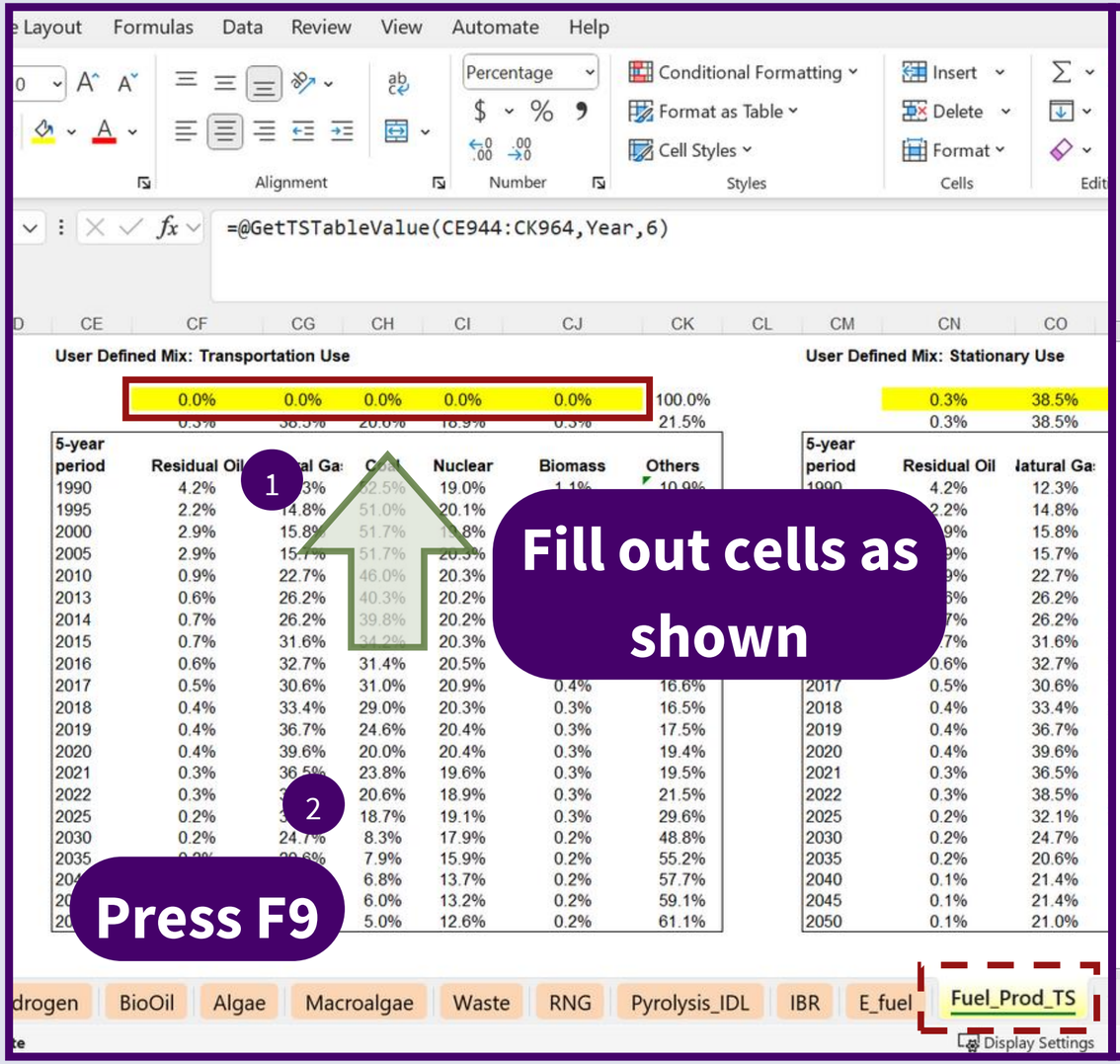
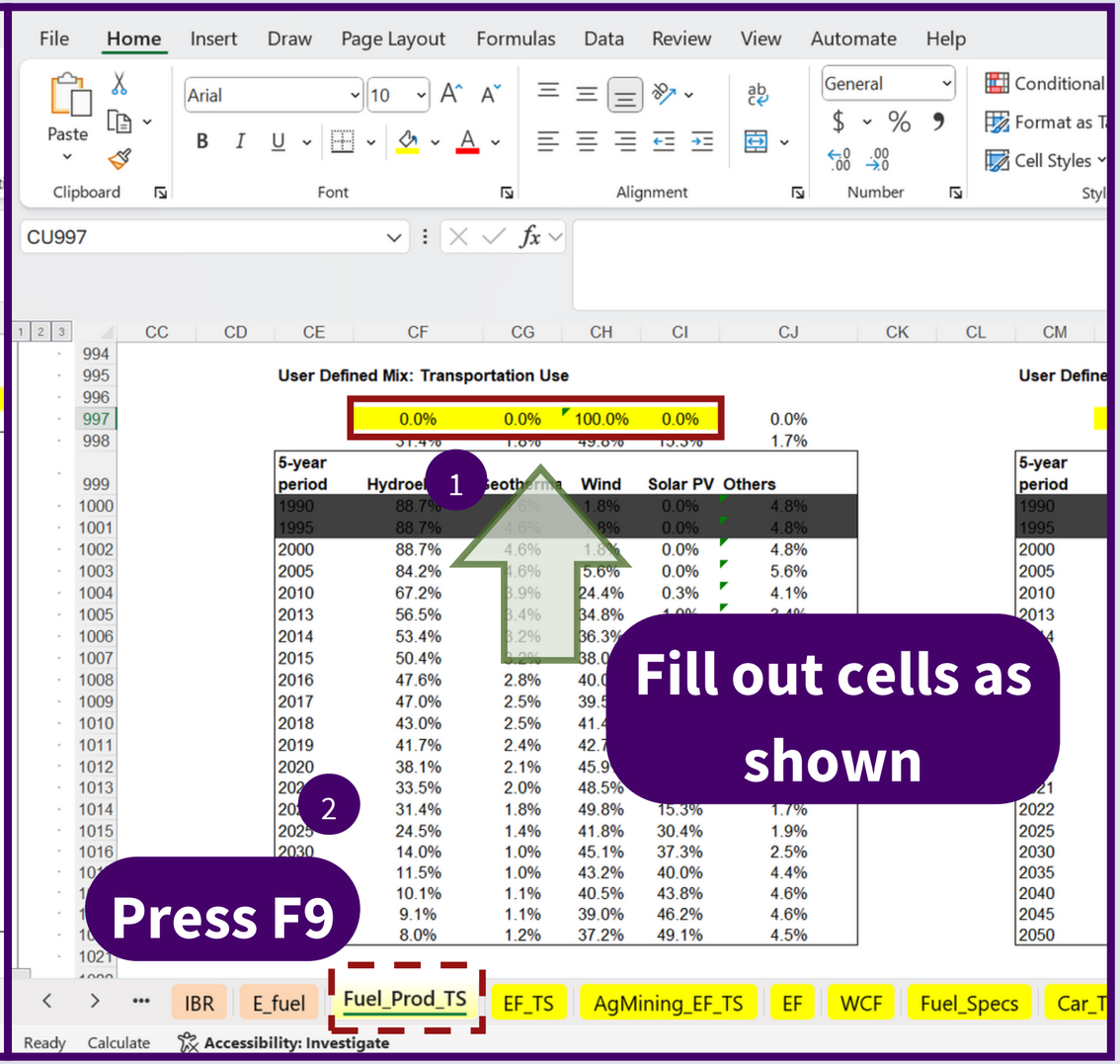
Change R&D GREET 1 inputs to a 100% wind generated transportation





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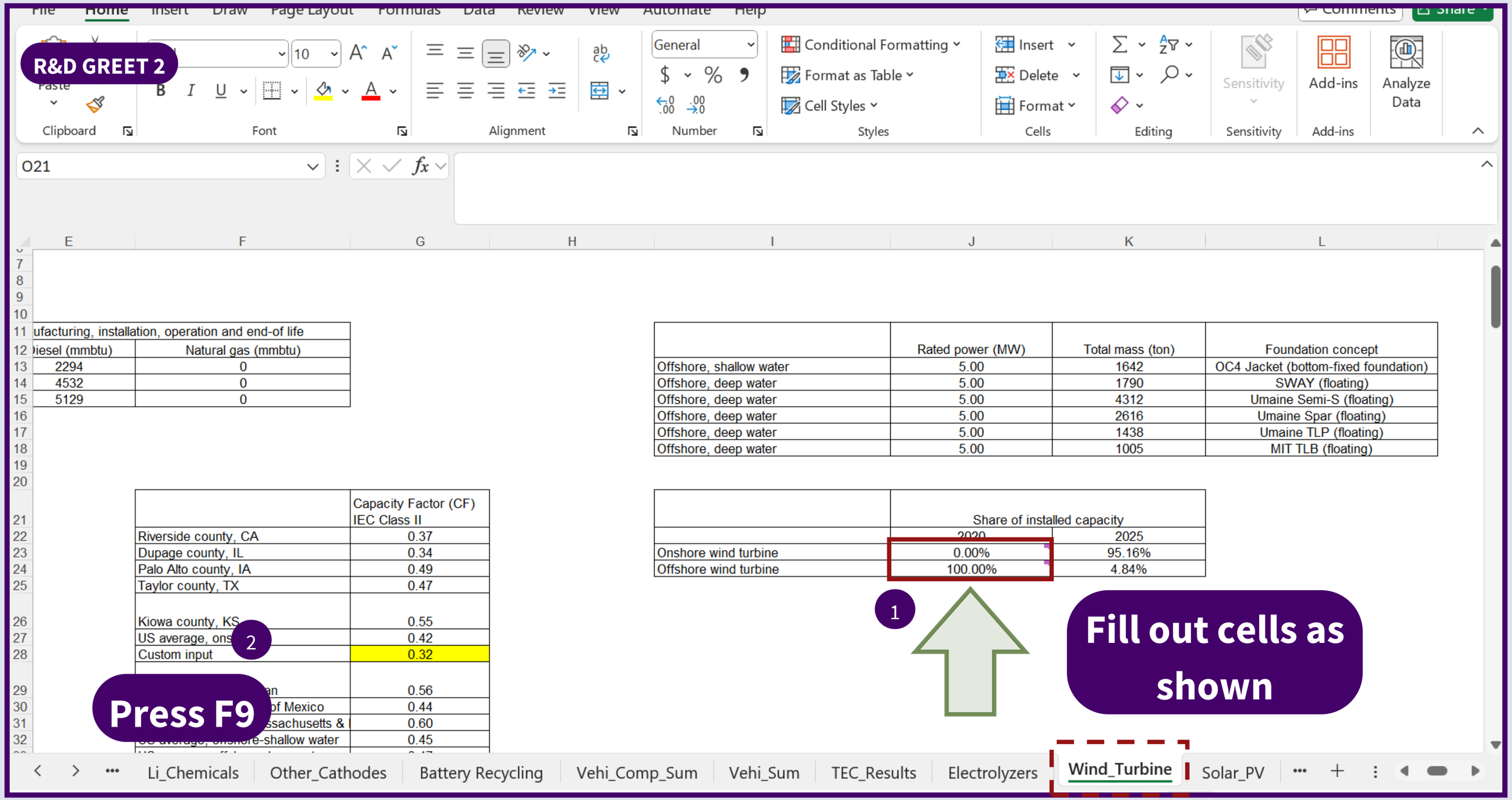

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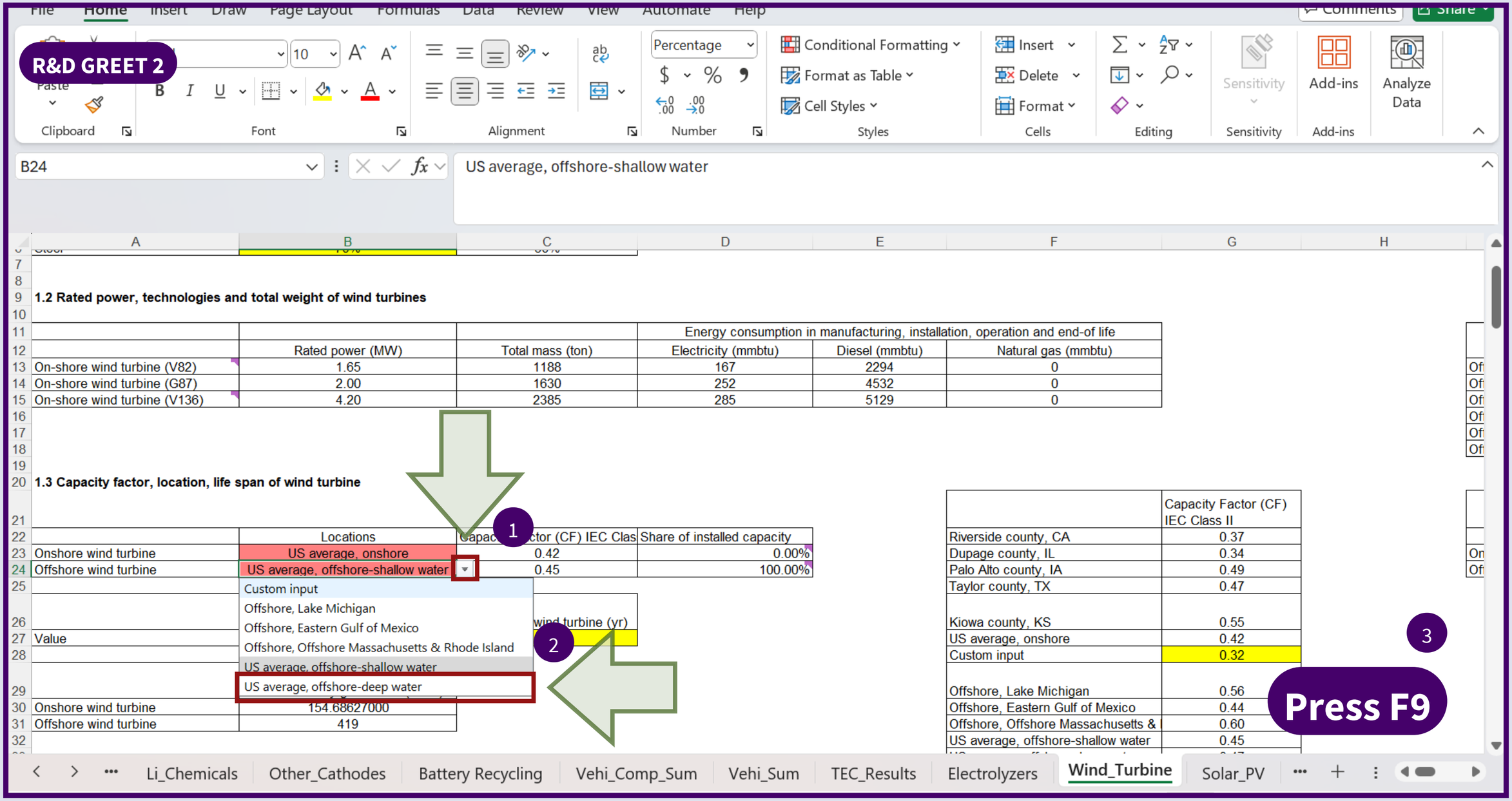

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Capacity Factor (CF) for Offshore Wind Turbine in Deep Water

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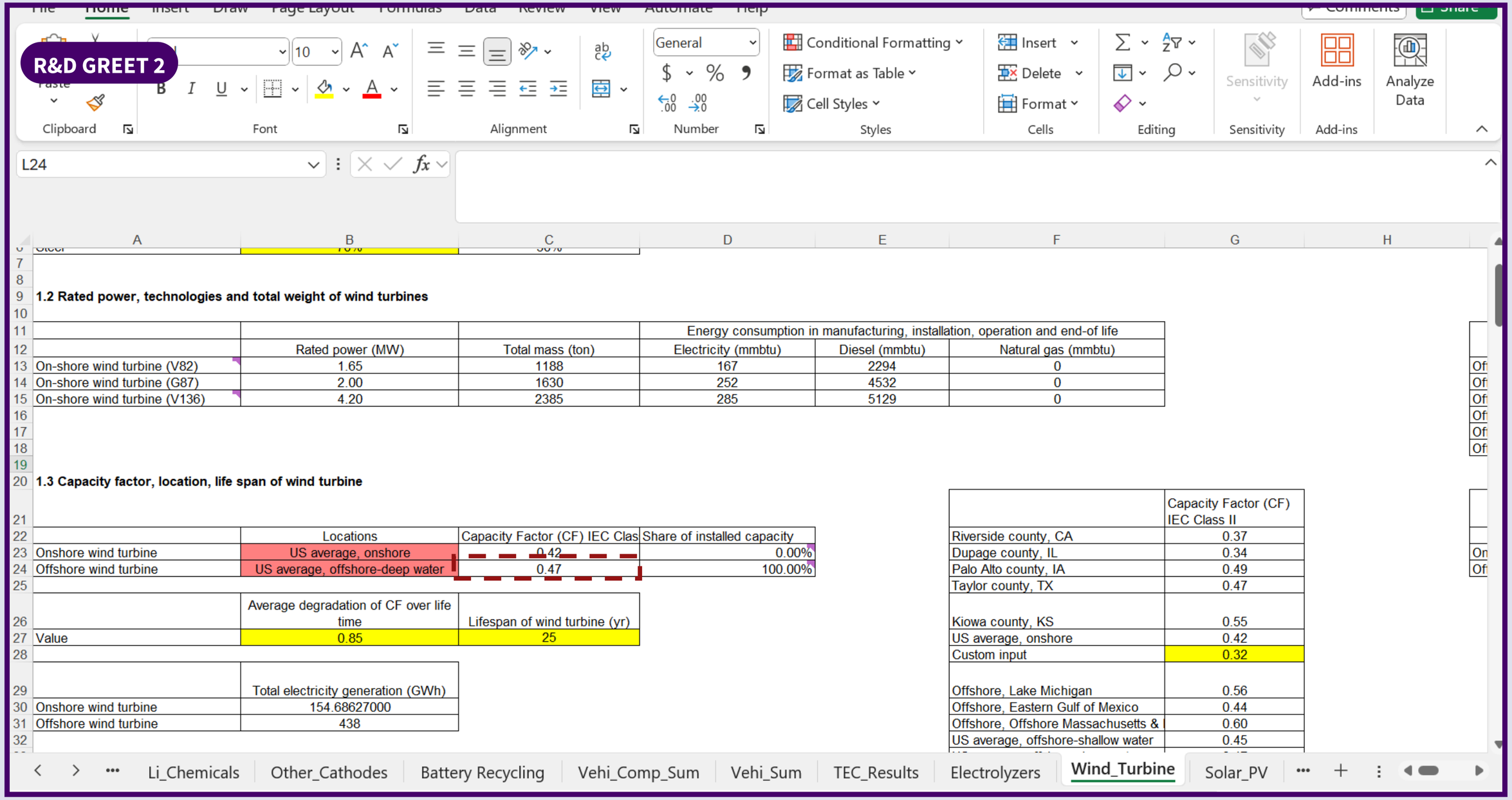

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Cradle-to-Grave (C2G) GHG Emissions

R&D GREET 2

A1: Energy Use and Emissions of Well-to-Pump, Vehicle Cycle and Vehicle Operation

EV, Conventional Material

Item	Btu/mile or g/mile					Percentage of each stage				
	WTP	Vehicle Cycle	Vehicle Operation	Total	Vehicle Cycle Credits	WTP	Vehicle Cycle	Vehicle Operation	Total	Vehicle Cycle Credits
Total energy	117	905				5.2%	40.3%	54.5%	100.0%	0.0%
Fossil fuels	4	812				0.5%	94.1%	5.4%	100.0%	0.0%
Coal	2	232				0.7%	92.2%	7.1%	100.0%	0.0%
Natural gas	1	472				0.3%	97.0%	2.7%	100.0%	0.0%
Petroleum	1	108				1.2%	86.4%	12.4%	100.0%	0.0%
Water consumption	0.003	0.086				3.1%	96.9%	0.0%	100.0%	0.0%
CO2 (VOC, CO, CO2)	4	58				6.8%	93.2%	0.0%	100.0%	0.0%
CH4	0.007	0.211			0	3.2%	96.8%	0.0%	100.0%	0.0%
N2O	0.000	0.002	0.000	0.002	0	3.5%	96.5%	0.0%	100.0%	0.0%
GHGs	4	65	0	69	0	6.4%	93.6%	0.0%	100.0%	0.0%
VOC: Total	0.003	0.193	0.000	0.196	0	1.5%	98.5%	0.0%	100.0%	0.0%
CO: Total	0.020	0.151	0.000	0.171	0	11.8%	88.2%	0.0%	100.0%	0.0%
NOx: Total	0.005	0.067	0.000	0.072	0	6.4%	93.6%	0.0%	100.0%	
PM10: Total	0.002	0.027	0.031	0.059	0	3.3%	45.0%	51.7%	100.0%	
PM2.5: Total	0.001	0.011	0.004	0.015	0	5.9%	67.9%	26.2%	100.0%	
SOx: Total	0.010	0.218	0.000	0.228	0	4.5%	95.5%	0.0%	100.0%	
BC: Total	0.000	0.000	0.001	0.001	0	2.1%	42.8%	55.1%	100.0%	
OC: Total	0.000	0.001	0.001	0.002	0	3.1%	57.8%	39.1%	100.0%	
VOC: Urban	0.000	0.111	0.000	0.111	0	0.1%	99.9%	0.0%	100.0%	
CO: Urban	0.000	0.003	0.000	0.003	0	4.0%	96.0%	0.0%	100.0%	
NOx: Urban	0.000	0.005	0.000	0.006	0	4.1%	95.9%	0.0%	100.0%	
PM10: Urban	0.000	0.001	0.021	0.022	0	0.1%	2.4%	97.5%	100.0%	
PM2.5: Urban	0.000	0.000	0.003	0.003	0	0.7%	13.3%	86.0%	100.0%	0.0%
SOx: Urban	0.000	0.004	0.000	0.005	0	4.0%	96.0%	0.0%	100.0%	0.0%

C2G GHG emissions

69 g CO_2e/mile

2022 car BEV with offshore wind electricity including infrastructure emissions

Battery_Materials | Anode | LiMn2O4 | Li_Chemicals | Other_Cathodes | Battery Recycling | Vehi_Comp_Sum | Vehi_Sum | TEC_Results

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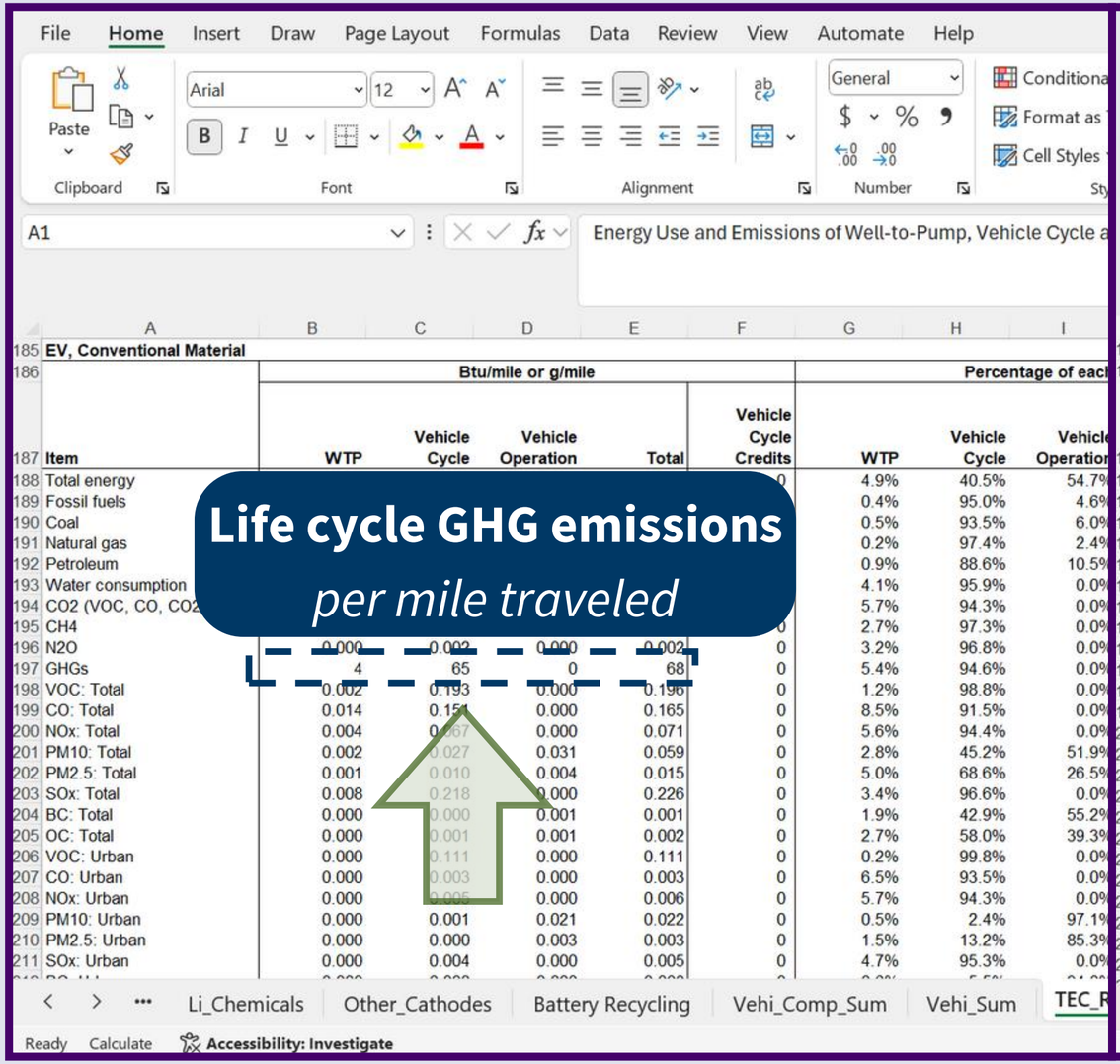
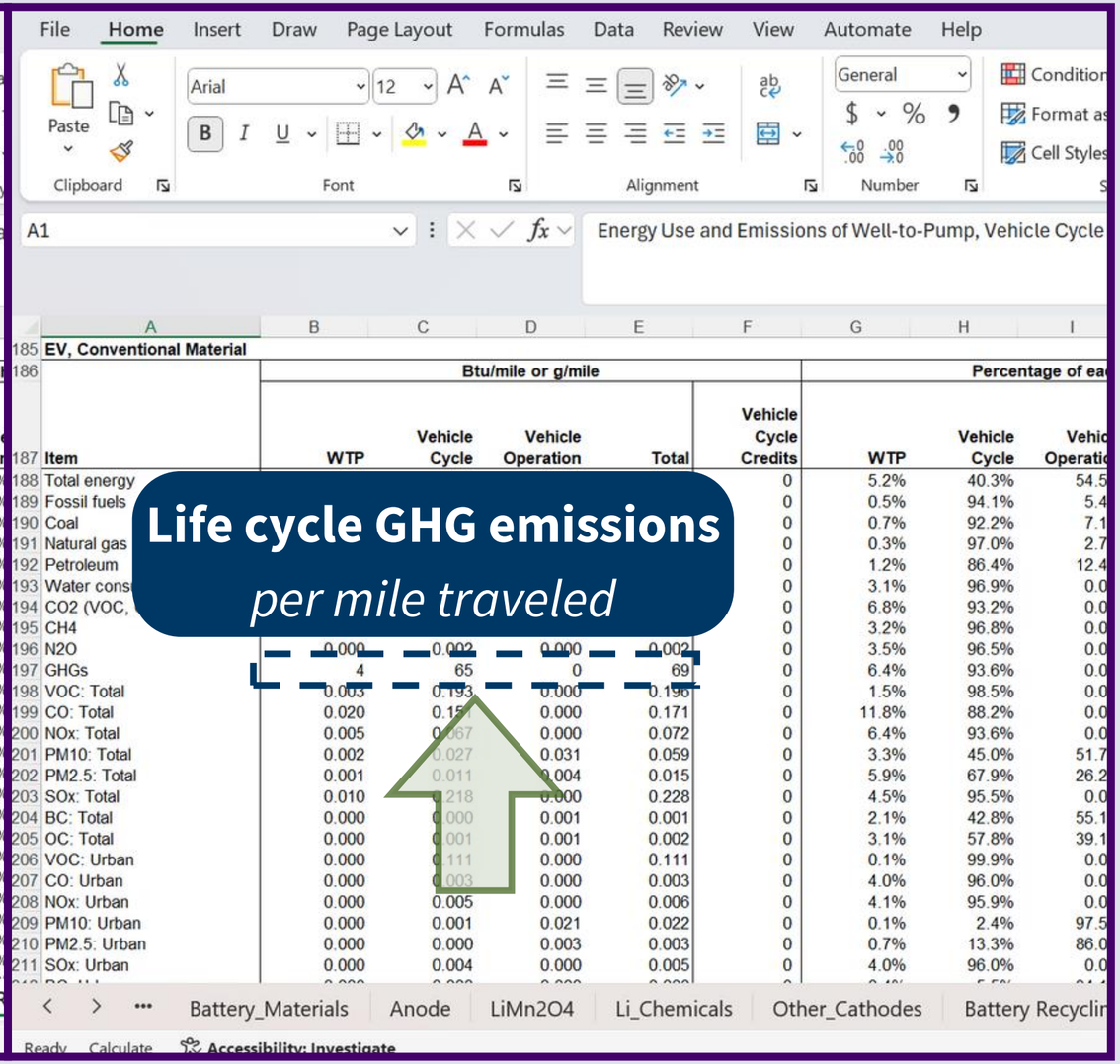
Onshore wind electricity

Offshore deep-water wind electricity





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