

Simulations of Vehicle Cycle through the GREET 2 Model

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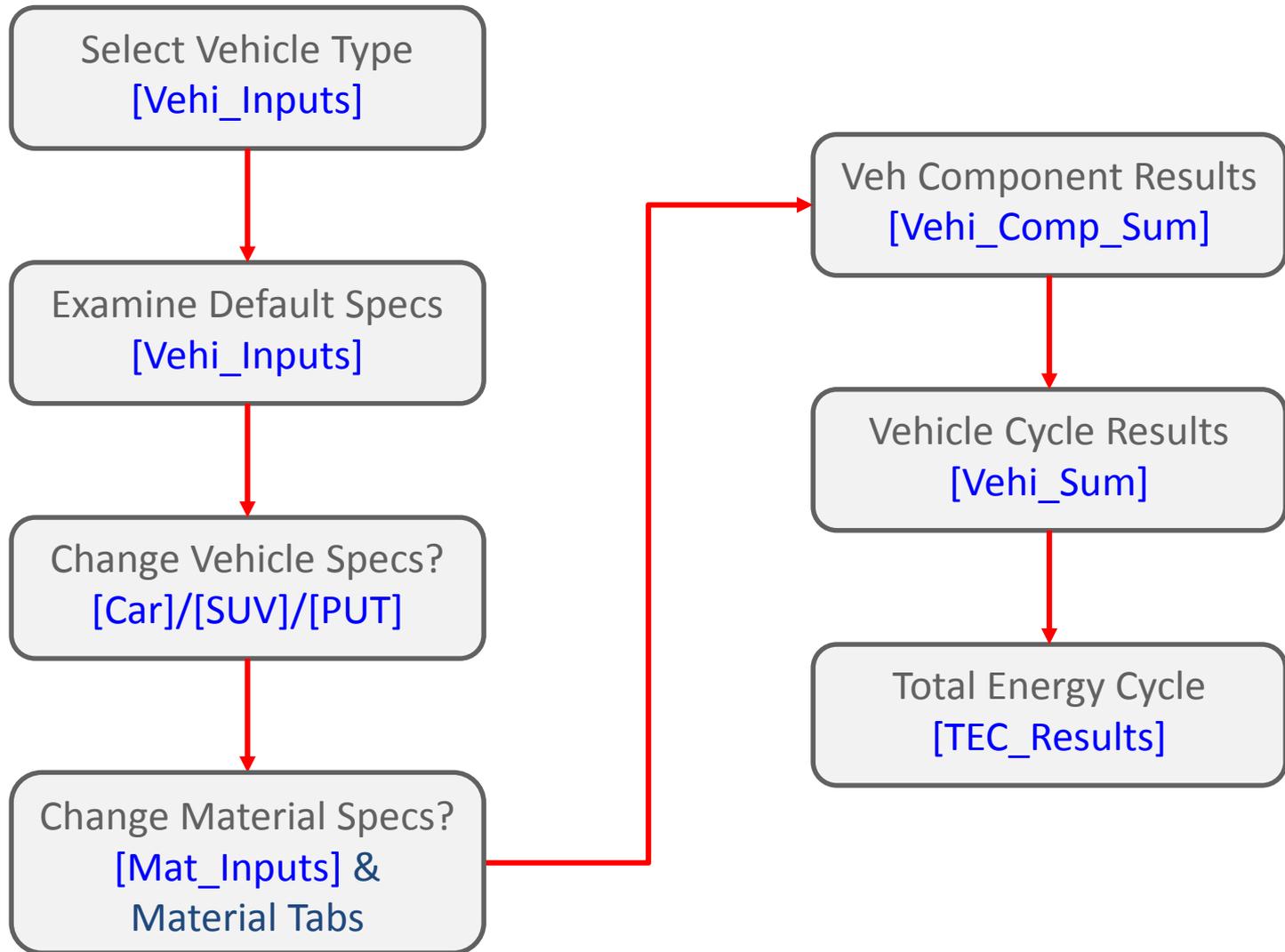
The GREET Training Workshop

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Typical Flow for Vehicle Simulation in GREET 2 Model



Color Scheme for the GREET 2 Model



- Clear cells are primarily for calculations and secondary assumptions



- Yellow cells are key input assumptions that users can change for their own simulations

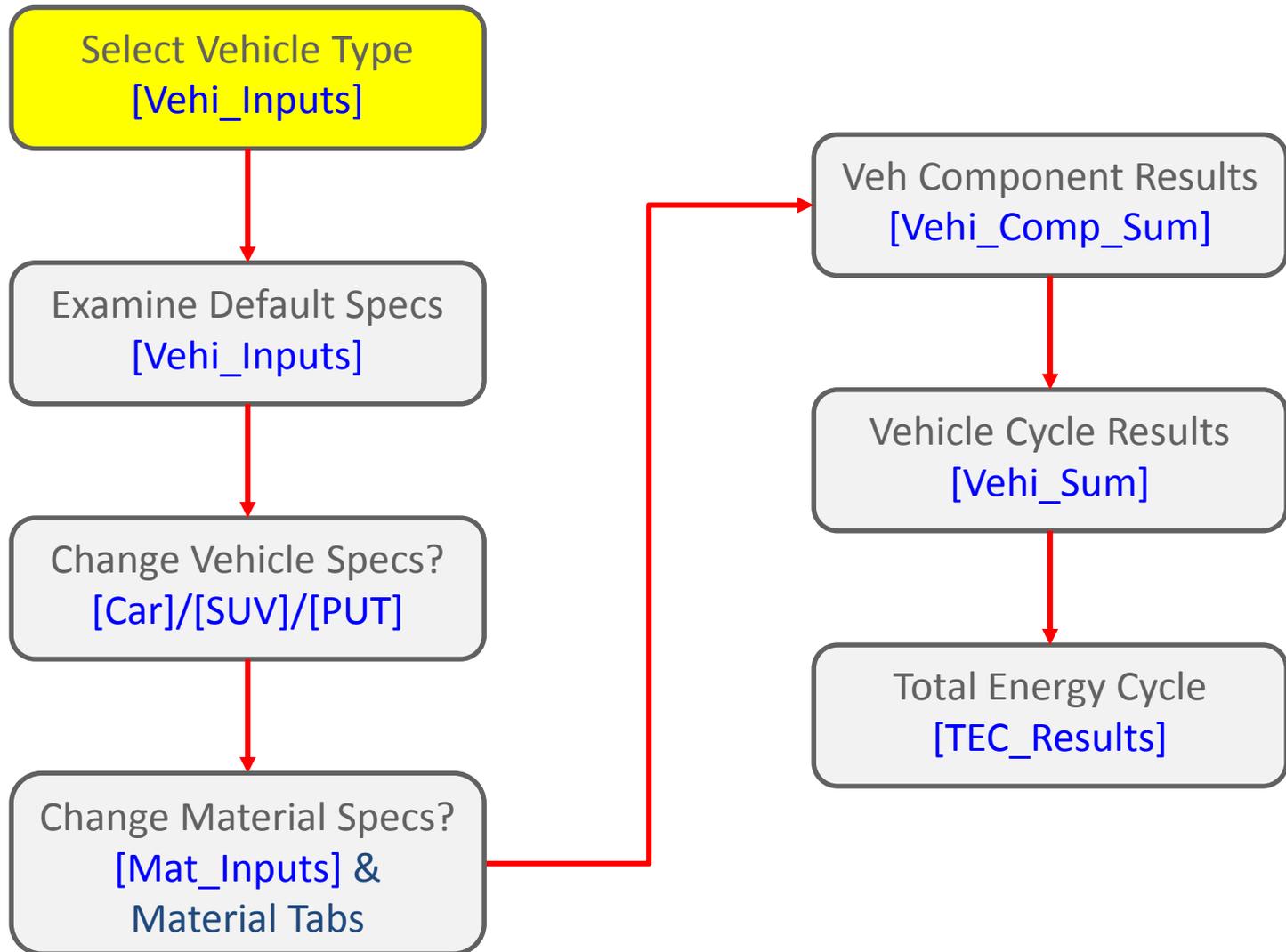


- Peach cells are key options that users can select for their own simulations from drop-down menu

- DO NOT

- Change values in **white** cells unless you know well enough

Typical Flow for Vehicle Simulation in GREET 2 Model



Select Vehicle Type Using [Vehi_Inputs] Tab

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 -- Passenger Cars 1, 2 -- Passenger Cars 2

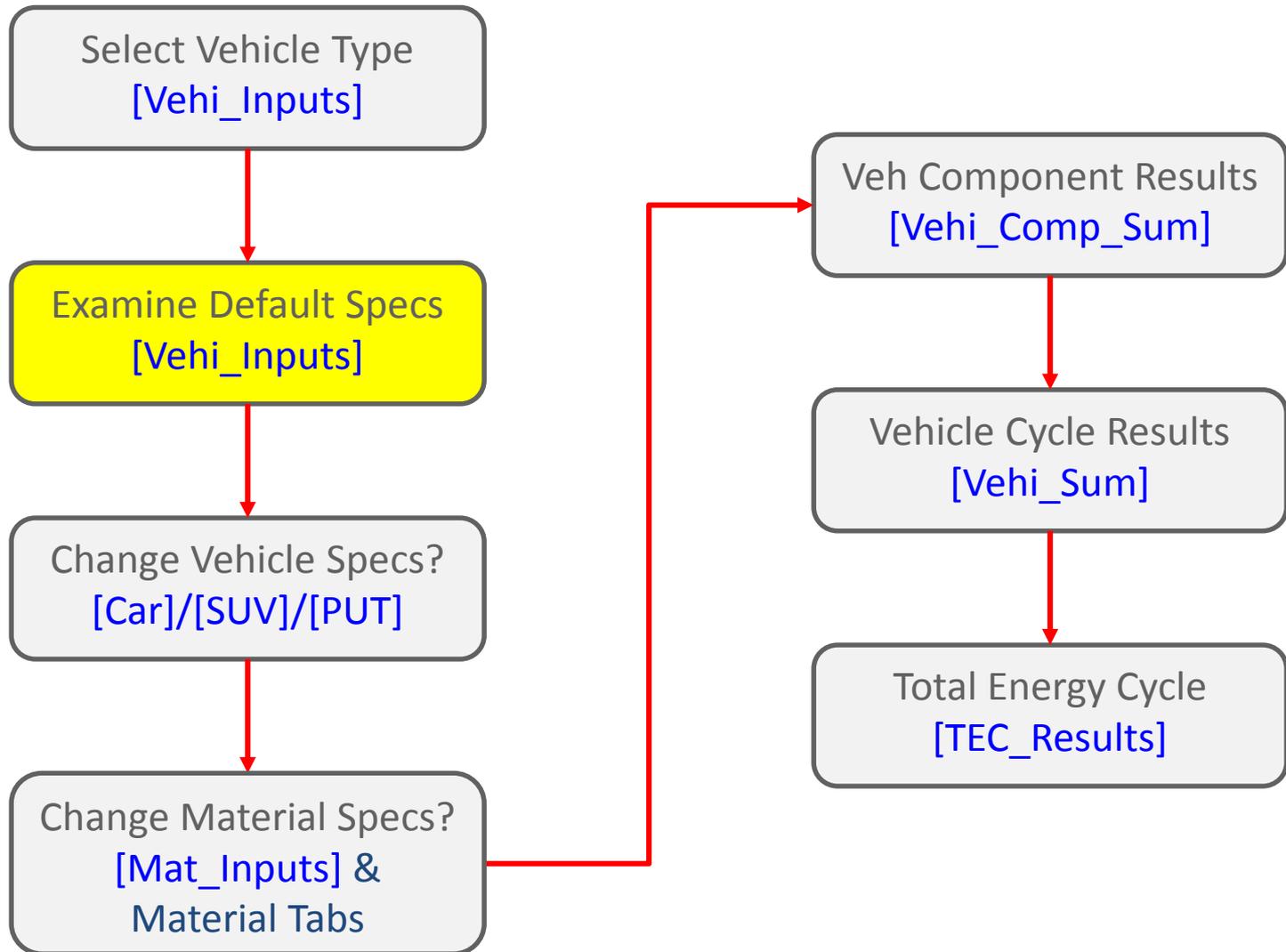
When the "Pick-Up Trucks" option is selected, select one of the following two vehicles for ICEVs

- 1 -- Pick-Up Trucks 1, 2 -- Pick-Up Trucks 2

- Select vehicle type from the first drop down menu
- Identify use of either Option 1 or 2 for the type of vehicle selected
 - Note Option 2 models only include conventional and lightweight versions of internal combustion engine vehicles



Typical Flow for Vehicle Simulation in GREET 2 Model



Examine Default Vehicle Specs Using [Vehi_Inputs] Tab

- Two vehicle weight scenarios: conventional and lightweight
- Five different powertrain types are presented
 - ICEV, HEV, PHEV, EV, FCV
- Details of Battery and Fluids presented for each vehicle category
- All *intermediate*: **DO NOT MAKE CHANGES HERE**

2. Specification of Total Vehicle Weight, pounds

| ICEV: Conventional Material | FCV: Lightweight Material |
|-----------------------------------|---------------------------------|
| 2,980 | 2,400 |

3. Vehicle Battery and Fluids Weight, pounds per vehicle

3.1) Battery Weight

| | ICEV: Conventional Material | FCV: Lightweight Material |
|-----------|-----------------------------------|---------------------------------|
| Lead-Acid | 36.0 | 14.4 |
| Ni-MH | | 55.1 |
| Li-Ion | | 30.9 |

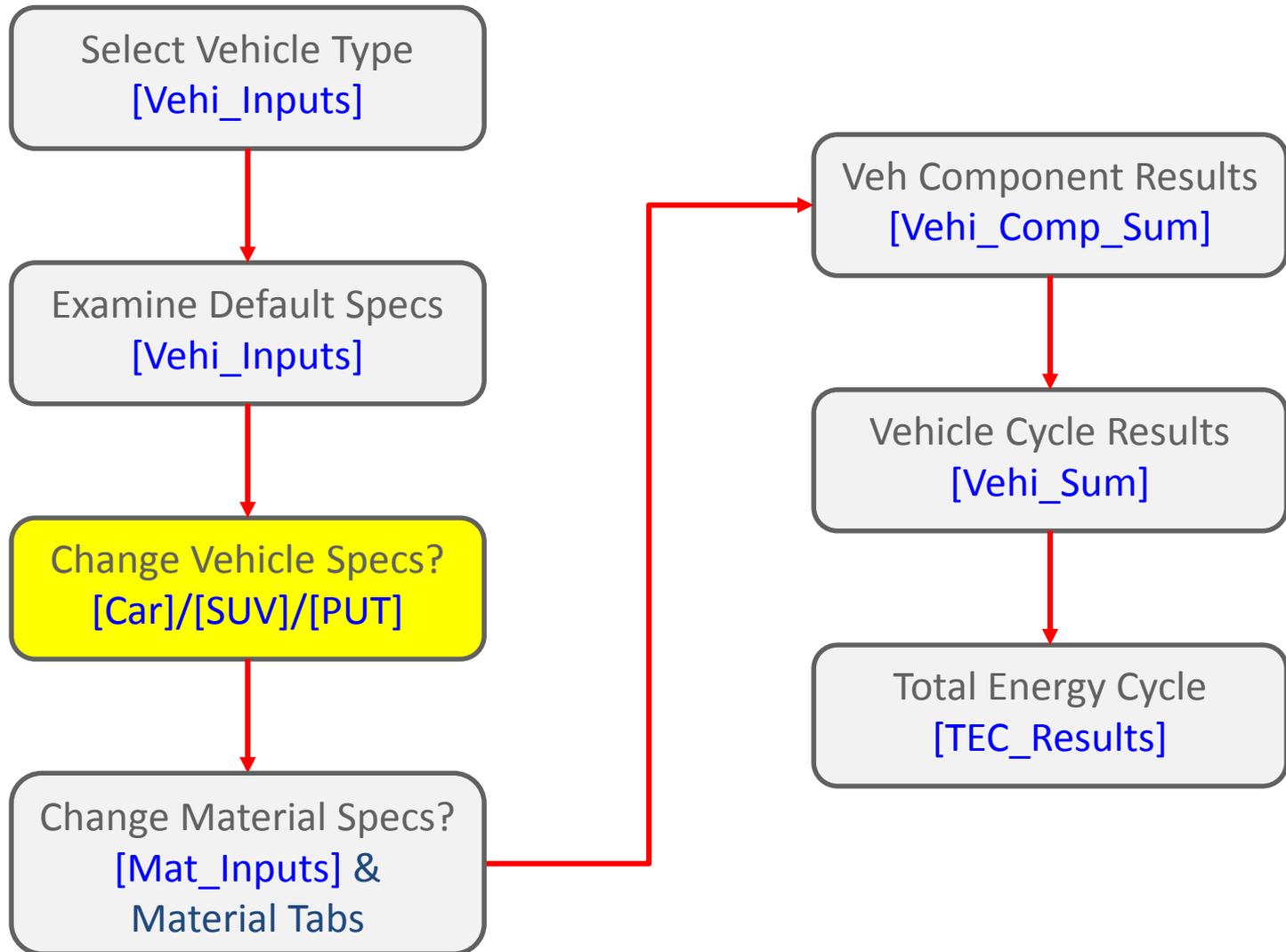
3.2) Fluids Weight

| | Engine Oil | Power Steering Fluid | Brake Fluid | Transmission Fluid | Powertrain Coolant | Windshield Fluid | Adhesives |
|-----------------------------|------------|----------------------|-------------|--------------------|--------------------|------------------|-----------|
| ICEV: Conventional Material | 8.5 | 0.0 | 2.0 | 24.0 | 23.0 | 6.0 | 30.0 |
| ICEV: Lightweight Material | 8.5 | 0.0 | 2.0 | 24.0 | 23.0 | 6.0 | 30.0 |
| FCV | 0.0 | 0.0 | 2.0 | 1.8 | 15.8 | 6.0 | 30.0 |

* Not all vehicles are shown for presentation clarity.



Typical Flow for Vehicle Simulation in GREET 2 Model



Change Vehicle Specs Using [Car, SUV, PUT] Tab

Scenario Control Variables and Input Assumptions Related to Passenger Car and its Components

1. Specification of Total Vehicle Weight, pounds

| | ICEV: Conventional Material | ICEV: Lightweight Material | HEV: Conventional Material | HEV: Lightweight Material | PHEV: Conventional Material | PHEV: Lightweight Material | EV: Conventional Material | EV: Lightweight Material | FCV: Conventional Material | FCV: Lightweight Material |
|------------------------|-----------------------------------|----------------------------------|----------------------------------|---------------------------------|-----------------------------------|----------------------------------|---------------------------------|--------------------------------|----------------------------------|---------------------------------|
| Passenger Car 1 | 2,980 | 1,820 | 3,220 | 2,030 | 3,310 | 2,120 | 4,270 | 2,680 | 3,630 | 2,400 |
| Passenger Car 2 | 3,170 | 2,476 | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A |
| Selected Passenger Car | 2,980 | 1,820 | 3,220 | 2,030 | 3,310 | 2,120 | 4,270 | 2,680 | 3,630 | 2,400 |

2. Vehicle Battery and Fluids Weight, pounds per vehicle

2.1) Battery Weight

| | ICEV: Conventional Material | ICEV: Lightweight Material | HEV: Conventional Material | HEV: Lightweight Material | PHEV: Conventional Material | PHEV: Lightweight Material | EV: Conventional Material | EV: Lightweight Material | FCV: Conventional Material | FCV: Lightweight Material |
|------------------------------------|-----------------------------------|----------------------------------|----------------------------------|---------------------------------|-----------------------------------|----------------------------------|---------------------------------|--------------------------------|----------------------------------|---------------------------------|
| Passenger Car 1 - Lead-Acid | 36.0 | 23.4 | 22.1 | 14.4 | 22.1 | 14.4 | 22.1 | 14.4 | 22.1 | 14.4 |
| Passenger Car 1 - Ni-MH | | | 77.2 | 46.8 | 748.7 | 457.6 | 949.7 | 572.8 | 90.9 | 55.1 |
| Passenger Car 1 - Li-Ion | | | 43.2 | 26.2 | 374.8 | 229.0 | 463.0 | 279.2 | 50.9 | 30.9 |
| Passenger Car 2 - Lead-Acid | 27.3 | 24.9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Passenger Car 2 - Ni-MH | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Passenger Car 2 - Li-Ion | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Selected Passenger Car - Lead-Acid | 36.0 | 23.4 | 22.1 | 14.4 | 22.1 | 14.4 | 22.1 | 14.4 | 22.1 | 14.4 |
| Selected Passenger Car - Ni-MH | | | 77.2 | 46.8 | 748.7 | 457.6 | 949.7 | 572.8 | 90.9 | 55.1 |
| Selected Passenger Car - Li-Ion | | | 43.2 | 26.2 | 374.8 | 229.0 | 463.0 | 279.2 | 50.9 | 30.9 |

2.2) Fluids Weight

| | Engine Oil | Power Steering Fluid | Brake Fluid | Transmission Fluid | Powertrain Coolant | Windshield Fluid | Adhesives |
|------------------------------------|------------|-------------------------|-------------|-----------------------|-----------------------|---------------------|-----------|
| Passenger Car 1 - ICEV (CM) | 8.5 | 0.0 | 2.0 | 24.0 | 23.0 | 6.0 | 30.0 |
| Passenger Car 1 - ICEV (LW) | 8.5 | 0.0 | 2.0 | 24.0 | 23.0 | 6.0 | 30.0 |
| Passenger Car 1 - HEV | 8.5 | 0.0 | 2.0 | 1.8 | 23.0 | 6.0 | 30.0 |
| Passenger Car 1 - PHEV | 8.5 | 0.0 | 2.0 | 1.8 | 23.0 | 6.0 | 30.0 |
| Passenger Car 1 - EV | 0.0 | 0.0 | 2.0 | 1.8 | 15.8 | 6.0 | 30.0 |
| Passenger Car 1 - FCV | 0.0 | 0.0 | 2.0 | 1.8 | 15.8 | 6.0 | 30.0 |
| Passenger Car 2 - ICEV (CM) | 9.2 | 0.0 | 1.1 | 9.7 | 30.1 | 10.6 | 0.0 |
| Passenger Car 2 - ICEV (LW) | 8.4 | 0.0 | 1.1 | 7.3 | 29.3 | 10.6 | 0.0 |
| Passenger Car 2 - HEV | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Passenger Car 2 - PHEV | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Passenger Car 2 - EV | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Passenger Car 2 - FCV | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Selected Passenger Car - ICEV (CM) | 8.5 | 0.0 | 2.0 | 24.0 | 23.0 | 6.0 | 30.0 |
| Selected Passenger Car - ICEV (LW) | 8.5 | 0.0 | 2.0 | 24.0 | 23.0 | 6.0 | 30.0 |
| Selected Passenger Car - HEV | 8.5 | 0.0 | 2.0 | 1.8 | 23.0 | 6.0 | 30.0 |
| Selected Passenger Car - PHEV | 8.5 | 0.0 | 2.0 | 1.8 | 23.0 | 6.0 | 30.0 |
| Selected Passenger Car - EV | 0.0 | 0.0 | 2.0 | 1.8 | 15.8 | 6.0 | 30.0 |
| Selected Passenger Car - FCV | 0.0 | 0.0 | 2.0 | 1.8 | 15.8 | 6.0 | 30.0 |

Total Vehicle and Component Weights are Key Assumptions to be Provided by the User [Car, SUV, PUT]

- Total vehicle weight (lb)

| | ICEV: Conventional Material | ICEV: Lightweight Material | HEV: Conventional Material | HEV: Lightweight Material | PHEV: Conventional Material | PHEV: Lightweight Material | EV: Conventional Material | EV: Lightweight Material | FCV: Conventional Material | FCV: Lightweight Material |
|------------------------|-----------------------------------|----------------------------------|----------------------------------|---------------------------------|-----------------------------------|----------------------------------|---------------------------------|--------------------------------|----------------------------------|---------------------------------|
| Passenger Car 1 | 2,980 | 1,820 | 3,220 | 2,030 | 3,310 | 2,120 | 4,270 | 2,680 | 3,630 | 2,400 |
| Passenger Car 2 | 3,170 | 2,476 | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A |
| Selected Passenger Car | 2,980 | 1,820 | 3,220 | 2,030 | 3,310 | 2,120 | 4,270 | 2,680 | 3,630 | 2,400 |

- Component weight distribution (battery and fluids examined separately)

| | ICEV: Conventional Material |
|--|--------------------------------|
| Powertrain System | 26% |
| Transmission System | 6% |
| Chassis (w/o battery) | 24% |
| Traction Motor | 0% |
| Generator | 0% |
| Electronic Controller | 0% |
| Fuel Cell Auxiliary System | 0% |
| Body: including BIW, interior, exterior, and glass | 44% |

- Fuel cell weight is calculated by inputting stack power (kW)

| | |
|----|-----------------------|
| 70 | Conventional Material |
| 54 | Lightweight Material |

- Stack and auxiliary system weight (lb)

| | |
|-----|--|
| 226 | Stack: Conventional Material |
| 546 | Auxiliary System: Conventional Material |
| 174 | Stack: Lightweight Material |
| 421 | Auxiliary System: Lightweight Material |



Material Compositions Can be Adjusted by the User for Each Component

- Material composition by component [Car, SUV, PUT]

| | ICEV: Conventional Material |
|---------------------------------|-----------------------------------|
| Body | |
| Steel | 68% |
| Wrought Aluminum | 1% |
| Copper/Brass | 2% |
| Magnesium | 0% |
| Glass | 7% |
| Carbon Fiber-Reinforced Plastic | 0% |
| Average Plastic | 18% |
| Rubber | 1% |
| Others | 4% |

- Vehicle composition aggregated by material [Mat_Inputs]

| | ICEV: Conventional Material |
|------------------|-----------------------------------|
| Steel | 62% |
| Stainless Steel | 0% |
| Cast Iron | 11% |
| Wrought Aluminum | 2% |
| Cast Aluminum | 5% |
| Copper/Brass | 2% |
| Magnesium | 0.02% |
| Glass | 3% |
| Average Plastic | 11% |
| Rubber | 2% |
| Platinum | 0.001% |
| Others | 2% |



Fuel Is Not Examined in the Vehicle-Cycle, While All Other Fluids Are

- Total Fluid Weight (lb) [Car, SUV, PUT]

| | Engine Oil | Power Steering Fluid | Brake Fluid | Transmission Fluid | Powertrain Coolant | Windshield Fluid | Adhesives |
|----------------------|------------|----------------------|-------------|--------------------|--------------------|------------------|-----------|
| Passenger Car - ICEV | 8.5 | 0.0 | 2.0 | 24.0 | 23.0 | 6.0 | 30.0 |
| Passenger Car - HEV | 8.5 | 0.0 | 2.0 | 1.8 | 23.0 | 6.0 | 30.0 |
| Passenger Car - PHEV | 8.5 | 0.0 | 2.0 | 1.8 | 23.0 | 6.0 | 30.0 |
| Passenger Car - EV | 0.0 | 0.0 | 2.0 | 1.8 | 15.8 | 6.0 | 30.0 |
| Passenger Car - FCV | 0.0 | 0.0 | 2.0 | 1.8 | 15.8 | 6.0 | 30.0 |

- Fluid Replacement (per vehicle lifetime) [Vehi_Inputs]

| Engine Oil | Power Steering Fluid | Brake Fluid | Transmission Fluid | Powertrain Coolant | Windshield Fluid | Adhesives |
|------------|----------------------|-------------|--------------------|--------------------|------------------|-----------|
| 40 | 0 | 3 | 1 | 3 | 20 | 0 |



Both Ni-MH and Li-Ion Can Be Simulated as Motive Batteries

- Total battery weight (lb) inputted for lead-acid [Car, SUV, PUT]

| | ICEV: Conventional Material | ICEV: Lightweight Material | HEV: Conventional Material | HEV: Lightweight Material | PHEV: Conventional Material | PHEV: Lightweight Material | EV: Conventional Material | EV: Lightweight Material | FCV: Conventional Material | FCV: Lightweight Material |
|-----------------------------|-----------------------------------|----------------------------------|----------------------------------|---------------------------------|-----------------------------------|----------------------------------|---------------------------------|--------------------------------|----------------------------------|---------------------------------|
| Passenger Car 1 - Lead-Acid | 36.0 | 23.4 | 22.1 | 14.4 | 22.1 | 14.4 | 22.1 | 14.4 | 22.1 | 14.4 |
| Passenger Car 1 - Ni-MH | | | 77.2 | 46.8 | 748.7 | 457.6 | 949.7 | 572.8 | 90.9 | 55.1 |
| Passenger Car 1 - Li-Ion | | | 43.2 | 26.2 | 374.8 | 229.0 | 463.0 | 279.2 | 50.9 | 30.9 |

- Motive battery weight for HEV & FCV is calculated by inputting peak battery power (kW) [Car, SUV, PUT]

| | Ni-MH | Li-Ion |
|----------------------------|-------|--------|
| HEV: Conventional Material | 28 | 28 |
| HEV: Lightweight Material | 17 | 17 |
| FCV: Conventional Material | 33 | 33 |
| FCV: Lightweight Material | 20 | 20 |

- Motive battery weight for PHEV & EV is calculated by inputting peak battery energy (kWh) [Car, SUV, PUT]

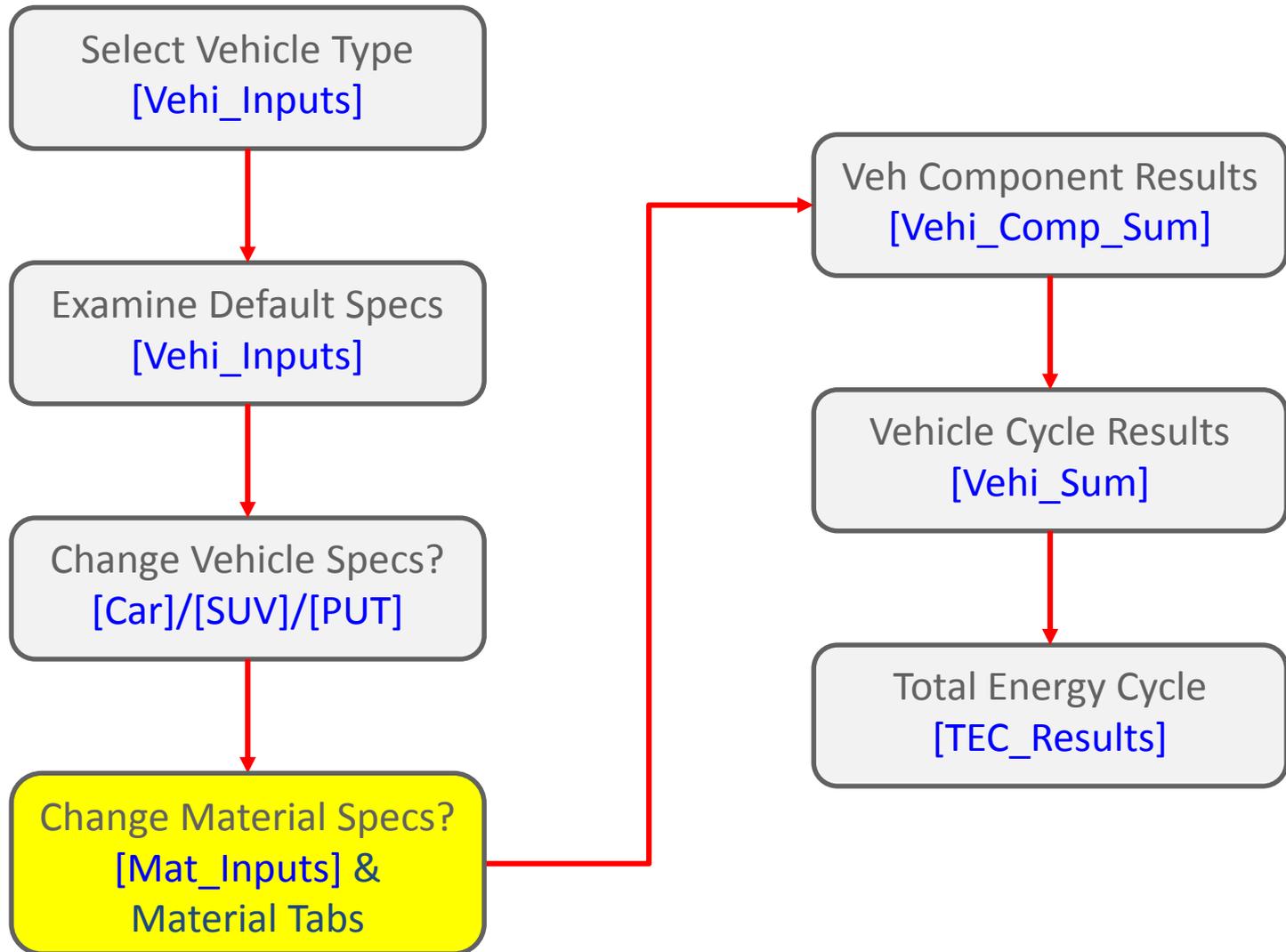
| | Ni-MH | Li-Ion |
|-----------------------------|-------|--------|
| PHEV: Conventional Material | 18 | 18 |
| PHEV: Lightweight Material | 11 | 11 |
| EV: Conventional Material | 28 | 28 |
| EV: Lightweight Material | 17 | 17 |

- Battery replacement (per vehicle lifetime) [Vehi_Inputs]

| | Lead-Acid | Ni-MH | Li-Ion |
|------|-----------|-------|--------|
| ICEV | 2 | | |
| HEV | 2 | 0 | 0 |
| PHEV | 2 | 0 | 0 |
| EV | 2 | 0 | 0 |
| FCV | 2 | 0 | 0 |



Typical Flow for Vehicle Simulation in GREET 2 Model



Changing Material Specs [Mat_Inputs]

- If you have access to different data for the energy intensity, fuel source, or process emissions of a material in GREET you can edit the source file

– ONLY FOR ADVANCED USERS

- Material production energy intensity, Wrought Aluminum example

5.3) Energy Use of Wrought Aluminum: mmBtu per ton of material product

| | |
|--------|---|
| 0.577 | Bauxite Mining |
| 17.835 | Bauxite Refining: Bayer Process |
| 1.486 | Anode Production |
| 46.778 | Alumina Reduction: Hall-Heroult Process |
| 1.006 | Primary Ingot Casting |
| 1.092 | Scrap Preparation (Recycled Wrought Al) |
| 4.460 | Secondary Ingot Casting (Recycled Al) |
| 3.629 | Hot Rolling |
| 3.022 | Cold Rolling |
| 5.453 | Stamping |
| 5.897 | Extrusion |

- Material specific electricity portfolio, Wrought Aluminum example

4.11.c) Electric Generation Mixes for Alumina Reduction: Hall-Heroult Process (Aluminum Smelting)

| | Wrought Aluminum | | | | |
|---------------|------------------|----------------|----------------|------------------------|------------------|
| | US Mix | NA smelter mix | US smelter mix | US market-weighted mix | User Defined Mix |
| Residual oil | 0.3% | 0 | 0 | 0.004 | 0.0% |
| Natural gas | 27.3% | 0.041 | 0.104 | 0.112 | 4.1% |
| Coal | 38.5% | 0.143 | 0.359 | 0.195 | 14.3% |
| Nuclear power | 18.3% | 0.005 | 0.014 | 0.013 | 0.5% |
| Biomass | 0.9% | 0 | 0 | 0 | 0.0% |
| Others | 14.7% | 0.811 | 0.523 | 0.676 | 81.1% |

Recycled Content of Key Materials [Mat_Inputs]

- Share of primary (virgin) vs. secondary (recycled)
 - Steel, wrought aluminum, cast aluminum, lead, nickel
 - Very important especially when considering aluminum since the difference in production energy intensity is significant

4.1) Share of Virgin and Recycled Materials Used in Vehicle, % by wt

| | Virgin Material | Recycled Material |
|------------------|-----------------|-------------------|
| Steel | 73.6% | 26.4% |
| Wrought Aluminum | 89.0% | 11.0% |
| Cast Aluminum | 15.0% | 85.0% |
| Lead | 27.0% | 73.0% |
| Nickel | 56.0% | 44.0% |
| Magnesium | 66.7% | 33.3% |

Changing Material Specs, Material Tabs [Magnesium]

- You can edit process fuel shares
 - ONLY FOR ADVANCED USERS

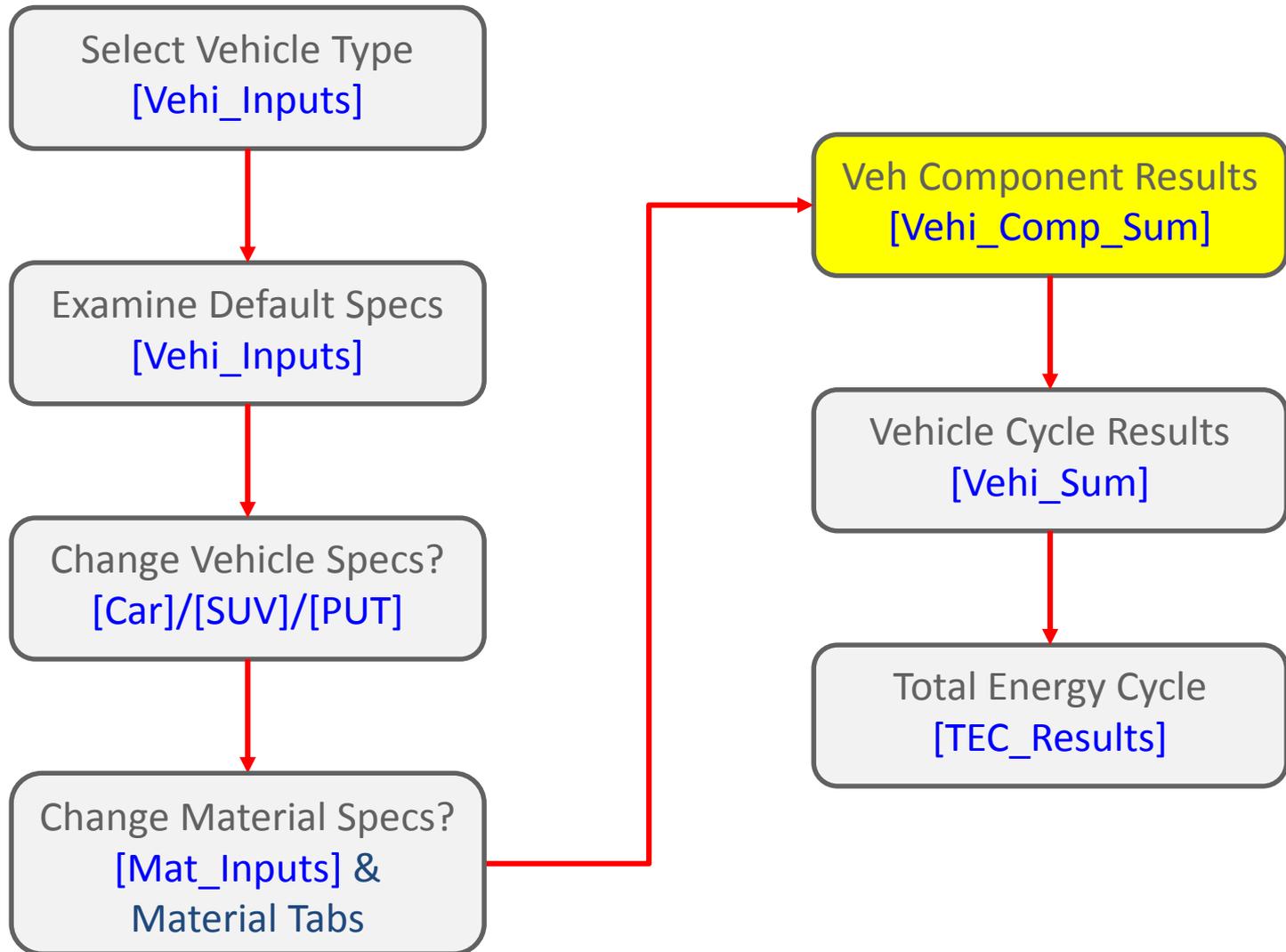
| | Magnesium via Electrolytic production | | Magnesium via Thermal production | |
|--|---------------------------------------|--------------------------|----------------------------------|--------------------------|
| | Combustion Emissions | Non-Combustion Emissions | Combustion Emissions | Non-Combustion Emissions |
| Energy inputs: mmBtu per ton of material product, except as noted | 146.275 | | 225.260 | |
| Urban emission share | 0.0% | | 0.0% | |
| Shares of process fuels | | | | |
| Resid. oil | 0.0% | | 0.0% | |
| Diesel | 0.5% | | 0.8% | |
| Natural gas | 64.6% | | 0.0% | |
| Coal | 0.0% | | 54.5% | |
| Coke | | | 6.0% | |
| Coke oven gas | | | 22.2% | |
| Electricity | 34.9% | | 16.6% | |

- You can edit process emissions
 - ONLY FOR ADVANCED USERS

| Total Emissions: grams per ton of product | | | | |
|--|------------|-----------|------------|-----------|
| VOC | 1,947.760 | | 9,057.958 | |
| CO | 7,681.602 | | 8,972.248 | |
| NOx | 10,218.822 | | 30,687.508 | |
| PM10 | 1,478.952 | | 6,147.297 | |
| PM2.5 | 706.350 | | 2,571.275 | |
| SOx | 11,291.443 | | 82,446.737 | |
| BC | 103.102 | | 97.110 | |
| OC | 222.017 | | 178.705 | |
| CH4 | 32,407.078 | | 38,551.096 | |
| N2O | 322.557 | | 240.356 | |
| CO2 | 13,747,263 | 1,723,651 | 22,862,292 | 4,590,355 |
| SF6 | | 1,496.855 | | 1,496.855 |



Typical Flow for Vehicle Simulation in GREET 2 Model



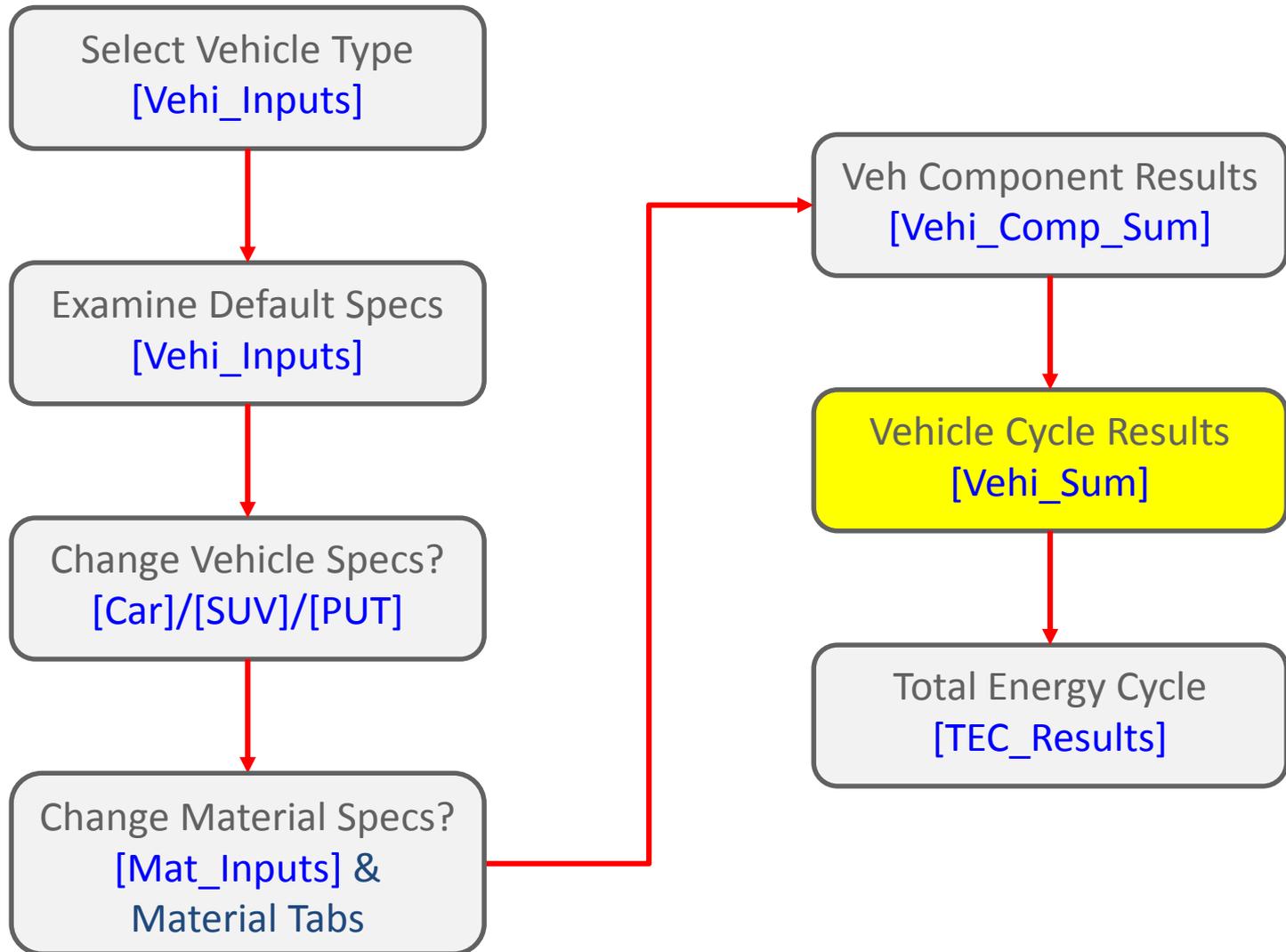
Component Results on [Vehi_Comp_Sum] Tab

3.8) FCV: Conventional Material

| | mmBtu or grams per vehicle lifetime | | | | | | | |
|------------------------|-------------------------------------|-------------------|---------------------|-----------------------|----------------|-----------|-----------------------|---------------------|
| | Body | Powertrain System | Transmission System | Chassis (w/o battery) | Traction Motor | Generator | Electronic Controller | Fuel Cell Auxiliary |
| Energy use | | | | | | | | |
| Total energy | 32.902 | 33.033 | 2.350 | 20.525 | 2.645 | | 2.606 | 43.998 |
| Fossil fuels | 30.615 | 30.433 | 1.856 | 19.156 | 2.216 | | 2.244 | 39.877 |
| Coal | 14.243 | 5.758 | 1.002 | 10.163 | 1.021 | | 0.437 | 9.939 |
| Natural gas | 13.660 | 20.708 | 0.683 | 7.076 | 0.994 | | 1.395 | 25.348 |
| Petroleum | 2.711 | 3.966 | 0.170 | 1.918 | 0.201 | | 0.413 | 4.590 |
| Water consumption | 4,302 | 3,086 | 779 | 2,675 | 664 | | 530 | 5,357 |
| Total Emissions | | | | | | | | |
| VOC | 1,871.203 | 315.463 | 99.555 | 1,822.137 | 93.690 | | 48.919 | 729.916 |
| CO | 13,008.443 | 1,257.178 | 658.234 | 8,851.034 | 621.783 | | 201.171 | 3,853.260 |
| NOx | 2,153.965 | 2,029.829 | 135.455 | 1,530.570 | 167.908 | | 138.046 | 2,705.377 |
| PM10 | 1,142.804 | 690.979 | 90.693 | 785.710 | 85.682 | | 60.793 | 820.946 |
| PM2.5 | 502.014 | 216.073 | 42.937 | 370.467 | 40.876 | | 26.298 | 347.667 |
| SOx | 9,307.265 | 2,071.376 | 1,561.452 | 4,899.483 | 2,803.468 | | 1,004.587 | 8,146.073 |
| BC | 12.420 | 16.025 | 0.999 | 9.017 | 1.507 | | 1.128 | 21.450 |
| OC | 26.285 | 33.940 | 1.766 | 18.488 | 2.378 | | 2.053 | 44.197 |
| CH4 | 5,844.369 | 4,989.314 | 281.719 | 2,964.629 | 342.575 | | 452.655 | 6,614.797 |
| N2O | 54.723 | 50.666 | 2.292 | 24.216 | 2.985 | | 5.128 | 67.345 |
| CO2 | 2,258,679 | 2,052,840 | 165,990 | 1,596,732 | 186,607 | | 136,128 | 2,843,020 |
| CO2 (VOC, CO, CO2) | 2,284,953 | 2,055,799 | 167,335 | 1,616,319 | 187,876 | | 136,596 | 2,851,350 |
| GHGs | 2,488,652 | 2,233,355 | 181,352 | 1,712,236 | 202,357 | | 155,401 | 3,092,759 |
| Urban Emissions | | | | | | | | |
| VOC | 12.487 | 18.005 | 1.091 | 8.120 | 1.674 | | 1.494 | 23.258 |
| CO | 76.930 | 89.168 | 4.961 | 46.630 | 6.381 | | 5.813 | 117.092 |
| NOx | 108.045 | 121.633 | 7.542 | 68.145 | 8.971 | | 8.149 | 161.015 |
| PM10 | 22.260 | 17.606 | 2.689 | 13.994 | 4.070 | | 1.723 | 28.568 |
| PM2.5 | 8.462 | 7.523 | 0.703 | 5.657 | 0.773 | | 0.498 | 10.795 |
| SOx | 377.587 | 328.232 | 33.220 | 244.624 | 35.193 | | 22.749 | 475.500 |
| BC | 0.645 | 0.593 | 0.049 | 0.437 | 0.056 | | 0.037 | 0.837 |
| OC | 1.754 | 1.526 | 0.132 | 1.197 | 0.148 | | 0.095 | 2.178 |

- Examine energy and emissions at the component level

Typical Flow for Vehicle Simulation in GREET 2 Model

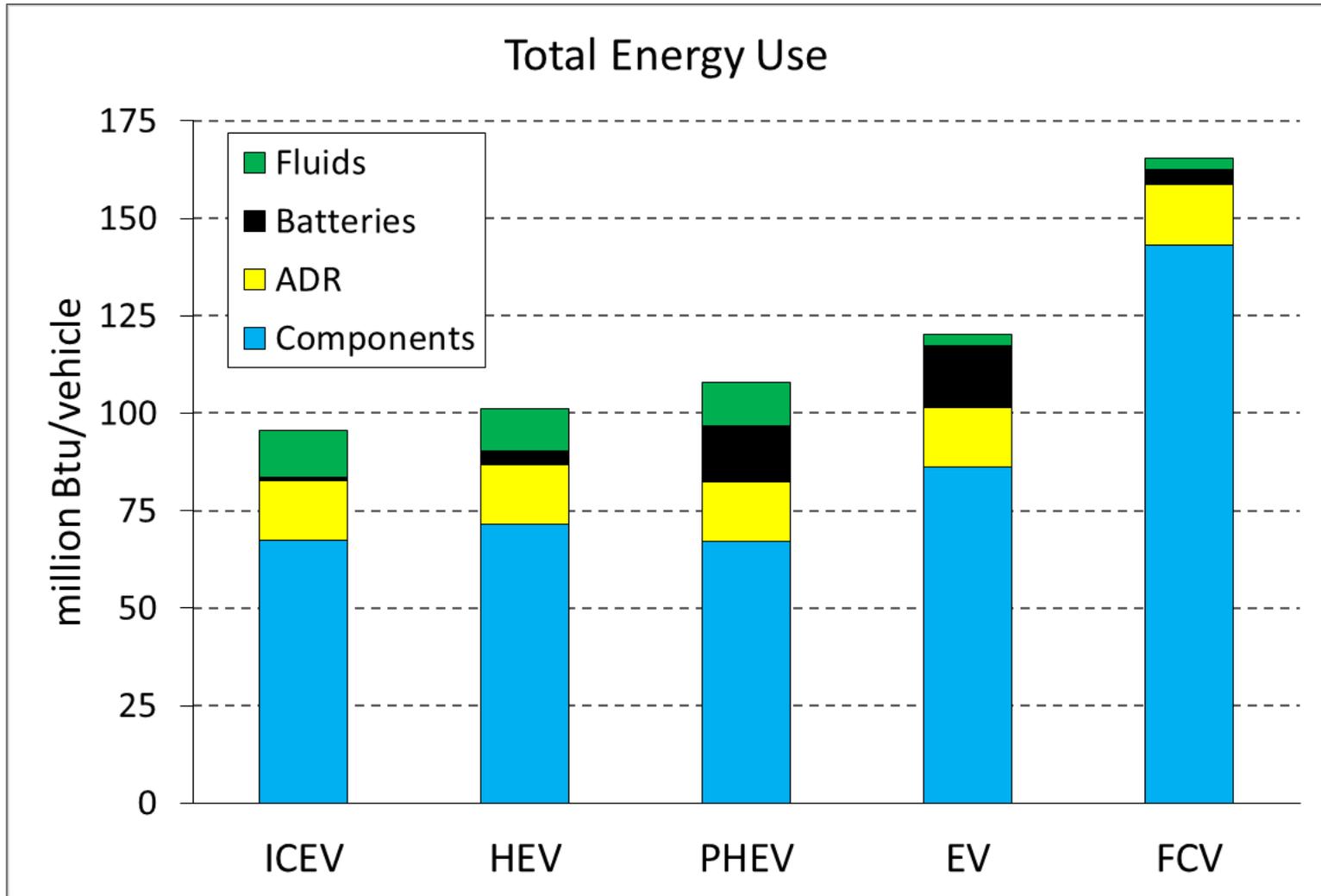


Vehicle Cycle Results on [Vehi_Sum] Tab

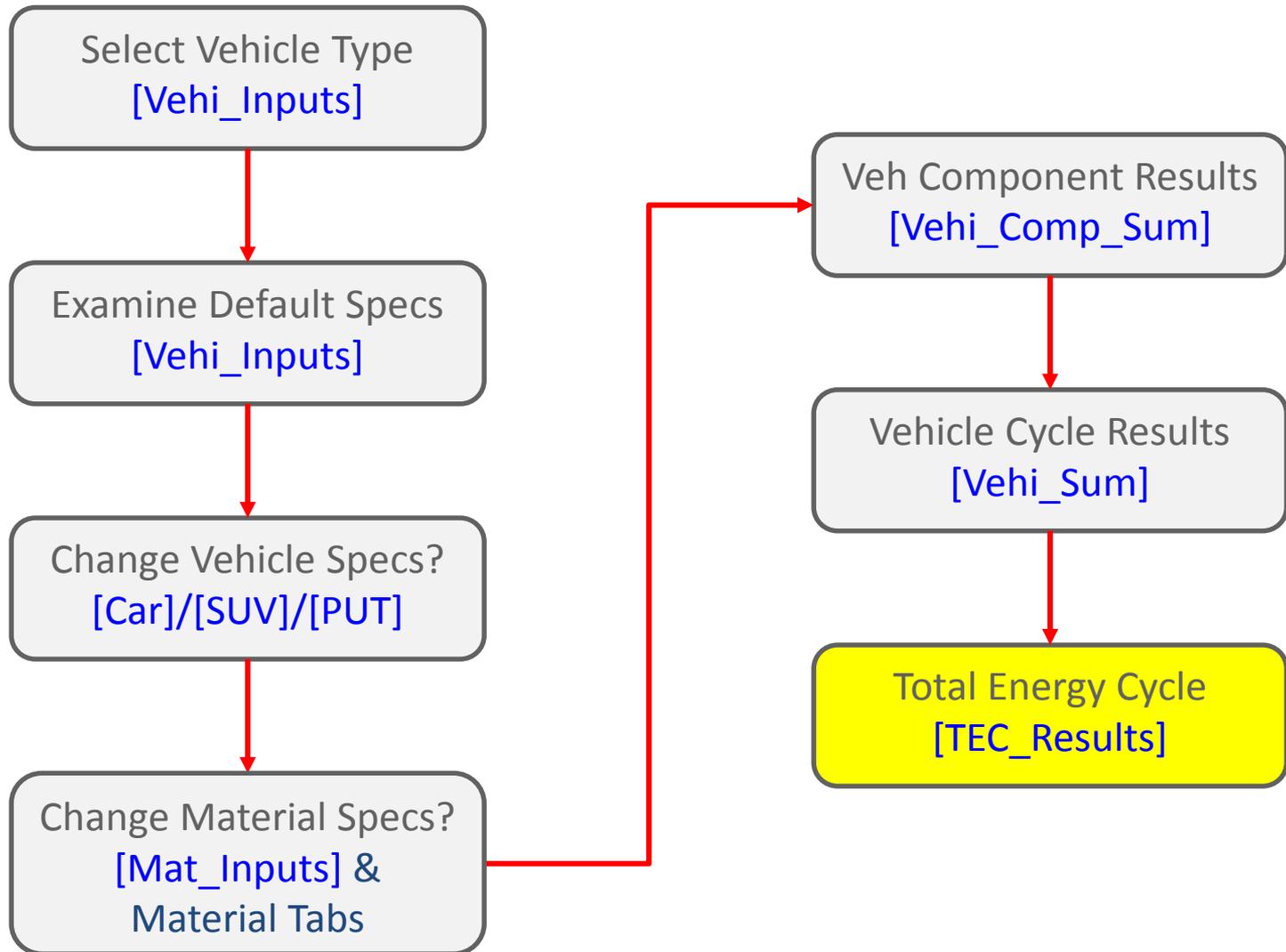
| | mmBtu or grams per vehicle lifetime | | | | |
|--------------------|-------------------------------------|-----------|-----------|-----------|------------|
| | Components | ADR | Batteries | Fluids | Total |
| Total energy | 64.978 | 14.234 | 0.783 | 11.941 | 91.936 |
| Fossil fuels | 59.411 | 12.649 | 0.748 | 11.856 | 84.663 |
| Coal | 29.008 | 4.367 | 0.386 | 0.237 | 33.999 |
| Natural gas | 24.590 | 8.135 | 0.293 | 3.015 | 36.033 |
| Petroleum | 5.812 | 0.146 | 0.068 | 8.604 | 14.631 |
| Water consumption | 9,836 | 1,391 | 45 | 277 | 11,549 |
| CO2 | 4,415,726 | 934,963 | 36,487 | 683,217 | 6,070,394 |
| CO2 (VOC, CO, CO2) | 4,464,366 | 941,097 | 36,625 | 770,710 | 6,212,798 |
| CH4 | 10,311.626 | 2,096.606 | 188.409 | 1,179.434 | 13,776.076 |
| N2O | 90.832 | 20.664 | 0.743 | 16.237 | 128.476 |
| GHGs | 4,833,145 | 1,009,472 | 42,474 | 810,396 | 6,695,487 |

- Vehicle cycle energy and emissions results
- Stages include:
 - Components
 - Assembly, disposal, recycling
 - Batteries
 - Fluids

Sample Vehicle-Cycle Results for Conventional Material Vehicles [Vehi_Sum]



Typical Flow for Vehicle Simulation in GREET 2 Model



Total Energy-Cycle Major Assumptions Requires Use of Both GREET 1 and 2

- Lifetime VMT of vehicle:
 - Cars: 160,000 miles
 - SUV and Pickup Truck: 180,000 miles
- Fuel cycle assumptions are based on GREET 1
- Vehicle operation assumptions are based on GREET 1
 - Except fuel economy equations for lightweighting are built into GREET 2
- Fuel economy based on Autonomie simulations
 - LW vehicle assumptions from mass sensitivity analysis



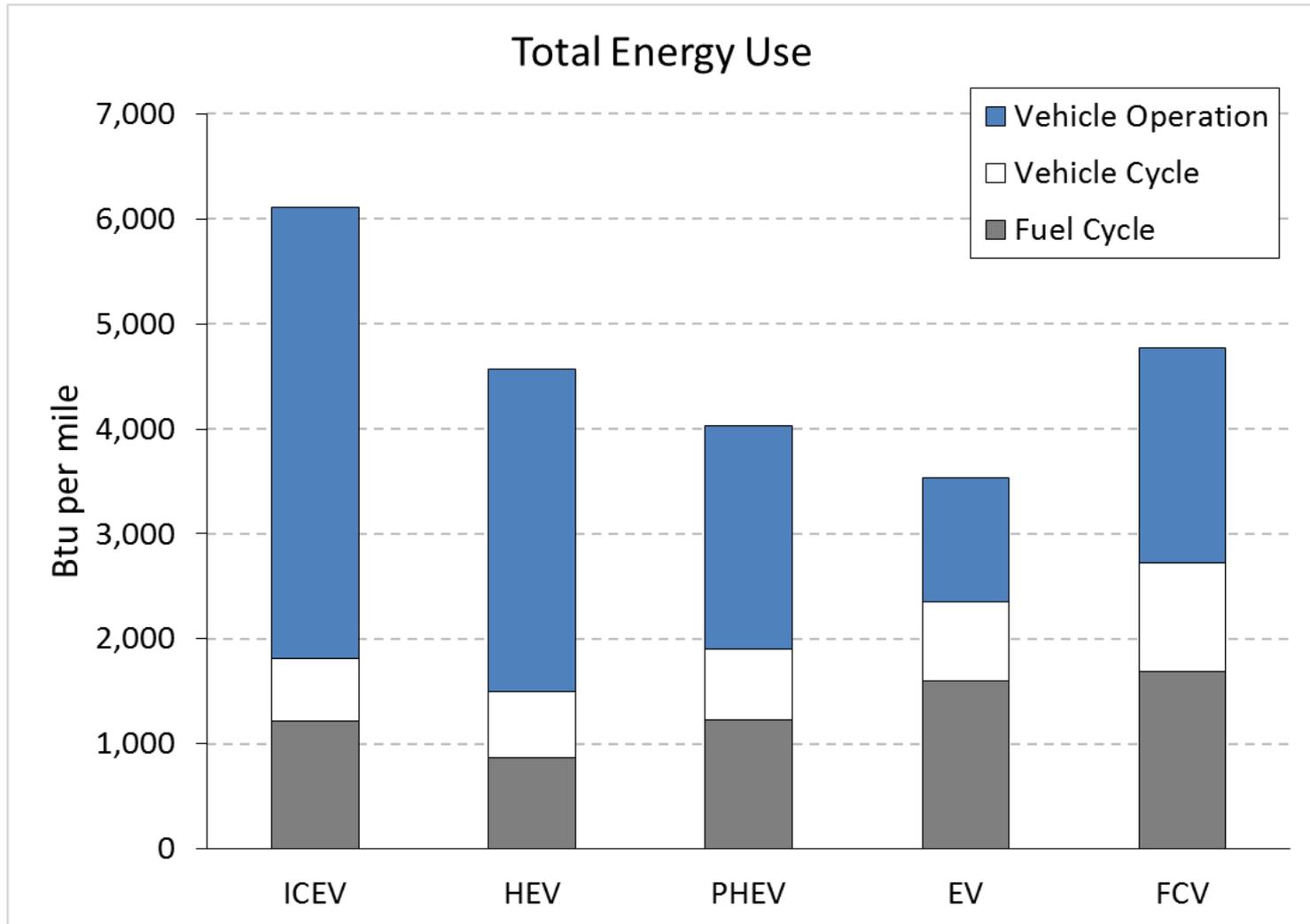
Confirm Vehicle Specs Using [TEC_Results] Tab

| Gasoline Vehicle: CG and RFG, Conventional Material | | | | | | | | | |
|---|--------------------|---------------|-------------------|-------|--------------------------|---------------|-------------------|--------|--|
| Item | Btu/mile or g/mile | | | | Percentage of each stage | | | | |
| | WTP | Vehicle Cycle | Vehicle Operation | Total | WTP | Vehicle Cycle | Vehicle Operation | Total | |
| Total energy | 814 | 575 | 2,989 | 4,378 | 18.6% | 13.1% | 68.3% | 100.0% | |
| Fossil fuels | 777 | 529 | 2,790 | 4,096 | 19.0% | 12.9% | 68.1% | 100.0% | |
| Coal | 63 | 212 | 0 | 276 | 22.9% | 77.1% | 0.0% | 100.0% | |
| Natural gas | 487 | 225 | 0 | 713 | 68.4% | 31.6% | 0.0% | 100.0% | |
| Petroleum | 227 | 91 | 2,790 | 3,108 | 7.3% | 2.9% | 89.8% | 100.0% | |
| Water consumption | 0.170 | 0.072 | 0.000 | 0.242 | 70.2% | 29.8% | 0.0% | 100.0% | |
| CO2 (VOC, CO, CO2) | 43 | 39 | 229 | 311 | 13.8% | 12.5% | 73.7% | 100.0% | |
| CH4 | 0.266 | 0.086 | 0.005 | 0.358 | 74.5% | 24.1% | 1.4% | 100.0% | |
| N2O | 0.008 | 0.001 | 0.005 | 0.014 | 58.8% | 5.8% | 35.4% | 100.0% | |
| GHGs | 53 | 42 | 231 | 326 | 16.3% | 12.8% | 70.8% | 100.0% | |

- Energy and emissions results for total life cycle of vehicle
- Additional emission not shown include: SOx, NOx, PM, VOC, OC, BC
 - Total and urban shares



Sample Total Energy-Cycle Results for Conventional Material Vehicles [TEC_Results]



Demonstrations using GREET 1 & 2, and GREET .NET

- Vehicle Cycle – Plugin Hybrid Electric Vehicle (GREET 1 and 2)
 - PHEV 40 vs. PHEV 20
 - And comparison against all other powertrains
- Total Life Cycle - Plugin Hybrid Electric Vehicle (GREET 1 and 2)
 - PHEV 20 using US grid vs. California electrical grid
 - And comparison against all other powertrains
- Vehicle and Total Energy Cycle - Plugin Hybrid Electric Vehicle (GREET . NET)
 - Examine PHEV 40 using US and California grid



Demonstrations



Demonstrations - Vehicle Cycle, Vehicle Selection

- Use GREET 2, but make sure GREET 1 is open
- Select [Vehi_Inputs] Tab
- Select 1 – Passenger Cars
- Select 1 – Passenger Cars 1
- Press F9

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

1. Selection of Vehicle Types for Simulation

1

- 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 -- Passenger Cars 1, 2 -- Passenger Cars 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

Demonstrations - Vehicle Cycle, Examine PHEV Specs

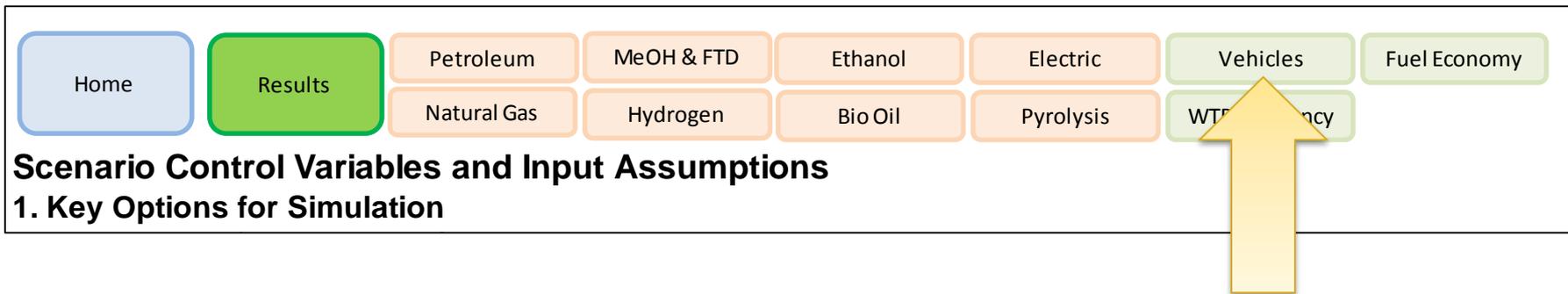
- In GREET 2, look at [Car] Tab, check values

| Scenario Control Variables and Input Assumptions Related to Passenger Car and its Components | | | | | | | | | | | |
|---|-----------------------------------|----------------------------------|----------------------------------|---------------------------------|-----------------------------------|----------------------------------|---------------------------------|--------------------------------|----------------------------------|---------------------------------|--|
| 1. Specification of Total Vehicle Weight, pounds | | | | | | | | | | | |
| | ICEV: Conventional Material | ICEV: Lightweight Material | HEV: Conventional Material | HEV: Lightweight Material | PHEV: Conventional Material | PHEV: Lightweight Material | EV: Conventional Material | EV: Lightweight Material | FCV: Conventional Material | FCV: Lightweight Material | |
| Passenger Car 1 | 2,980 | 1,820 | 3,220 | 2,030 | 3,310 | 2,120 | 4,270 | 2,680 | 3,630 | 2,400 | |
| Passenger Car 2 | 3,170 | 2,476 | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | |
| Selected Passenger Car | 2,980 | 1,820 | 3,220 | 2,030 | 3,310 | 2,120 | 4,270 | 2,680 | 3,630 | 2,400 | |
| 2. Vehicle Battery and Fluids Weight, pounds per vehicle | | | | | | | | | | | |
| 2.1) Battery Weight | | | | | | | | | | | |
| | ICEV: Conventional Material | ICEV: Lightweight Material | HEV: Conventional Material | HEV: Lightweight Material | PHEV: Conventional Material | PHEV: Lightweight Material | EV: Conventional Material | EV: Lightweight Material | FCV: Conventional Material | FCV: Lightweight Material | |
| Passenger Car 1 - Lead-Acid | 36.0 | 23.4 | 22.1 | 14.4 | 22.1 | 14.4 | 22.1 | 14.4 | 22.1 | 14.4 | |
| Passenger Car 1 - Ni-MH | | | 77.2 | 46.8 | 748.7 | 457.6 | 949.7 | 572.8 | 90.9 | 55.1 | |
| Passenger Car 1 - Li-Ion | | | 43.2 | 26.2 | 374.8 | 229.0 | 463.0 | 279.2 | 50.9 | 30.9 | |
| Passenger Car 2 - Lead-Acid | 27.3 | 24.9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Passenger Car 2 - Ni-MH | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Passenger Car 2 - Li-Ion | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Selected Passenger Car - Lead-Acid | 36.0 | 23.4 | 22.1 | 14.4 | 22.1 | 14.4 | 22.1 | 14.4 | 22.1 | 14.4 | |
| Selected Passenger Car - Ni-MH | | | 77.2 | 46.8 | 748.7 | 457.6 | 949.7 | 572.8 | 90.9 | 55.1 | |
| Selected Passenger Car - Li-Ion | | | 43.2 | 26.2 | 374.8 | 229.0 | 463.0 | 279.2 | 50.9 | 30.9 | |



Demonstrations - Vehicle Cycle, Examine PHEV Specs

- Go to GREET 1, [\[Inputs\]](#) Tab
- Click “Vehicles” button, or go to section 12 “Vehicle Operations”
- Check Rated All-Electric Range



The screenshot shows a navigation menu with the following buttons:

| | | | | | | | |
|------|---------|-------------|------------|---------|-----------|----------------|--------------|
| Home | Results | Petroleum | MeOH & FTD | Ethanol | Electric | Vehicles | Fuel Economy |
| | | Natural Gas | Hydrogen | Bio Oil | Pyrolysis | WTE Efficiency | |

Scenario Control Variables and Input Assumptions
1. Key Options for Simulation

A yellow arrow points to the 'Vehicles' button in the top row of the navigation menu.

Demonstrations - Vehicle Cycle, Examine PHEV Specs

- Go to GREET 1, [Inputs] Tab
- Click “Vehicles” button, or go to section 12 “Vehicle Operations”
- Check Rated All-Electric Range (should be 40)

12. Vehicle Operations

Vehicles Worksheet

Results

Back to Top

12.1) Share of Alternative Fuel in Conventional fuel and Alternative Fuel Blend: Volumetric Percentage

| | | |
|--|--------|------|
| Methanol in FFV fuel | 85.0% | |
| Methanol in dedicated vehicle fuel | 90.0% | |
| Ethanol in low-level blend of gasoline and ethanol | 10.0% | 2.0% |
| Ethanol in FFV fuel | 85.0% | 2.0% |
| Ethanol in dedicated vehicle fuel | 85.0% | 2.0% |
| Butanol in FFV fuel | 100.0% | |
| FT diesel in CIDI fuel | 100.0% | |
| Biodiesel in CIDI fuel | 20.0% | |
| Renewable diesel in CIDI fuel | 100.0% | |
| Renewable gasoline in SI fuel | 100.0% | |
| Ethanol in E-diesel | 10.0% | |
| Additives in E-diesel | 1.0% | |

12.2) Type of Gasoline or Diesel for Alternative Fuel Blends

| Share of Gasoline out of Gasoline and Blendstock | |
|--|--------|
| Gasoline for methanol blend | 0.0% |
| Gasoline for low-level ethanol blend | 0.0% |
| Gasoline for high-level ethanol blend | 0.0% |
| Gasoline for butanol blend | 0.0% |
| Gasoline for renewable gasoline blend | 0.0% |
| Share of LSD out of LSD and CD | |
| Diesel for Fischer-Tropsch diesel blend | 100.0% |
| Diesel for biodiesel blend | 100.0% |
| Diesel for renewable diesel blend | 100.0% |
| Diesel for e-diesel blend | 100.0% |

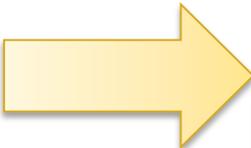
12.3) Key Parameters for Grid-Connected (Plug-in) Hybrid Electric Passenger Vehicle Technologies

| | | | |
|--|-------|----------------------------|-----|
| 12.3.a) Rated All Electric Range (RAER) [miles] | 40 | (Note: PHEVs with RAER lon | 100 |
| 12.3.b) Grid-Connected (Plug-in) HEV and EV charger efficiency | 85.0% | | |



Demonstrations - Vehicle Cycle, Examine Vehicle Cycle Results

- Go to GREET 2, [[Vehi_Sum](#)] Tab
- Examine Results
- Focus on PHEV Results



1.5) PHEV: Conventional Material

| | mmBtu or grams per vehicle lifetime | | | | |
|--------------------|-------------------------------------|-----------|-----------|-----------|------------|
| | Components | ADR | Batteries | Fluids | Total |
| Total energy | 67.050 | 15.268 | 14.465 | 11.013 | 107.796 |
| Fossil fuels | 61.733 | 13.810 | 12.026 | 10.940 | 98.509 |
| Coal | 30.697 | 5.090 | 4.653 | 0.259 | 40.699 |
| Natural gas | 25.329 | 8.515 | 5.429 | 2.942 | 42.215 |
| Petroleum | 5.707 | 0.205 | 1.944 | 7.739 | 15.596 |
| Water consumption | 10,322 | 1,394 | 3,801 | 264 | 15,782 |
| CO2 | 4,790,760 | 1,033,853 | 919,303 | 624,940 | 7,368,855 |
| CO2 (VOC, CO, CO2) | 4,841,596 | 1,040,125 | 921,221 | 712,356 | 7,515,298 |
| CH4 | 10,587.126 | 2,261.189 | 1,880.396 | 1,084.589 | 15,813.300 |
| N2O | 94.392 | 22.250 | 15.770 | 15.047 | 147.459 |
| GHGs | 5,216,869 | 1,113,857 | 1,004,525 | 748,881 | 8,084,133 |

Demonstrations - Vehicle Cycle, Change PHEV Specs to a 20 mile RAER

- Go to GREET 1, [Inputs] Tab
- Click “Vehicles” button, or go to section 12 “Vehicle Operations”
- Change Rated All-Electric Range to 20
- Press F9

12. Vehicle Operations

Vehicles Worksheet

Results

Back to Top

12.1) Share of Alternative Fuel in Conventional fuel and Alternative Fuel Blend: Volumetric Percentage

| | |
|--|--------|
| Methanol in FFV fuel | 85.0% |
| Methanol in dedicated vehicle fuel | 90.0% |
| Ethanol in low-level blend of gasoline and ethanol | 10.0% |
| Ethanol in FFV fuel | 85.0% |
| Ethanol in dedicated vehicle fuel | 85.0% |
| Butanol in FFV fuel | 100.0% |
| FT diesel in CIDI fuel | 100.0% |
| Biodiesel in CIDI fuel | 20.0% |
| Renewable diesel in CIDI fuel | 100.0% |
| Renewable gasoline in SI fuel | 100.0% |
| Ethanol in E-diesel | 10.0% |
| Additives in E-diesel | 1.0% |

12.2) Type of Gasoline or Diesel for Alternative Fuel Blends

| Share of Gasoline out of Gasoline and Blendstock | |
|--|--------|
| Gasoline for methanol blend | 0.0% |
| Gasoline for low-level ethanol blend | 0.0% |
| Gasoline for high-level ethanol blend | 0.0% |
| Gasoline for butanol blend | 0.0% |
| Gasoline for renewable gasoline blend | 0.0% |
| Share of LSD out of LSD and CD | |
| Diesel for Fischer-Tropsch diesel blend | 100.0% |
| Diesel for biodiesel blend | 100.0% |
| Diesel for renewable diesel blend | 100.0% |
| Diesel for e-diesel blend | 100.0% |

12.3) Key Parameters for Grid-Connected (Plug-in) Hybrid Electric Passenger Vehicle Technologies

| | |
|--|---|
| 12.3.a) Rated All Electric Range (RAER) [miles] | 40 (Note: PHEVs with RAER less than 40 miles) |
| 12.3.b) Grid-Connected (Plug-in) HEV and EV charger efficiency | 85.0% |

Change to 20



Demonstrations - Vehicle Cycle, Change PHEV Battery Size

- Go to GREET 2, [Car] Tab
- Click “Vehicles” button, or go to section 12 “Vehicle Operations”
- Change Li-Ion Battery weights of PHEV to 7 and 4 kWh
- Press F9

4.2) Passenger Car Battery Size in Peak Battery Energy (High Power Applications), kWh

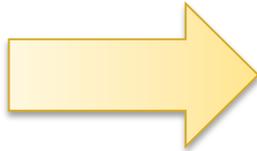
| | Ni-MH | Li-Ion |
|-----------------------------|-------|--------|
| PHEV: Conventional Material | 18 | 18 |
| PHEV: Lightweight Material | 11 | 11 |
| EV: Conventional Material | 28 | 28 |
| EV: Lightweight Material | 17 | 17 |

Change to 7

Change to 4

Demonstrations - Vehicle Cycle, Examine Vehicle Cycle Results

- Go to GREET 2, [[Vehi_Sum](#)] Tab
- Examine Results
- Focus on PHEV Results



1.5) PHEV: Conventional Material

| | mmBtu or grams per vehicle lifetime | | | | |
|--------------------|-------------------------------------|-----------|-----------|-----------|------------|
| | Components | ADR | Batteries | Fluids | Total |
| Total energy | 72.350 | 15.268 | 6.014 | 11.013 | 104.645 |
| Fossil fuels | 66.592 | 13.810 | 5.105 | 10.940 | 96.448 |
| Coal | 33.225 | 5.090 | 2.042 | 0.259 | 40.615 |
| Natural gas | 27.293 | 8.515 | 2.348 | 2.942 | 41.098 |
| Petroleum | 6.075 | 0.205 | 0.715 | 7.739 | 14.734 |
| Water consumption | 11,178 | 1,394 | 1,366 | 264 | 14,202 |
| CO2 | 5,167,776 | 1,033,853 | 382,805 | 624,940 | 7,209,374 |
| CO2 (VOC, CO, CO2) | 5,222,682 | 1,040,125 | 383,596 | 712,356 | 7,358,760 |
| CH4 | 11,434.554 | 2,261.189 | 824.775 | 1,084.589 | 15,605.107 |
| N2O | 101.800 | 22.250 | 6.712 | 15.047 | 145.808 |
| GHGs | 5,628,150 | 1,113,857 | 417,657 | 748,881 | 7,908,545 |



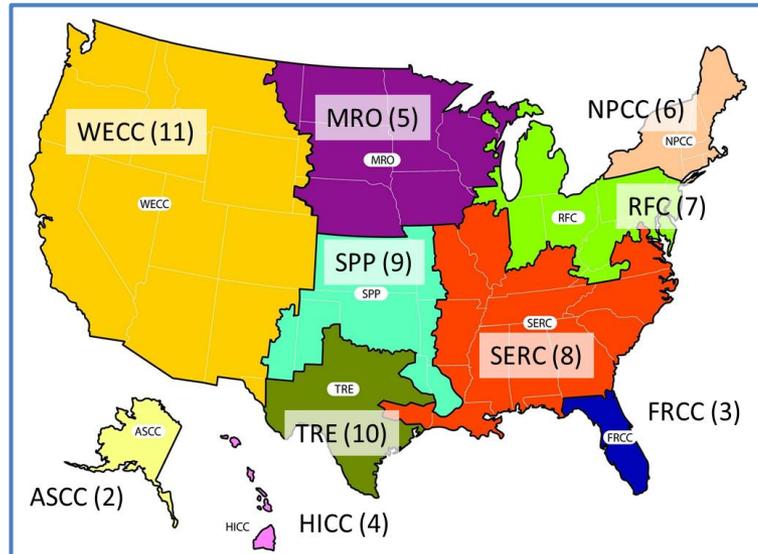
Demonstrations - Total Life Cycle, Examine Electrical Grid Specs

- Go to GREET 1, [Inputs] Tab
- Click “Electric” button, or go to section 10 “Electric Generation”
- Check Electricity Generation Mix
- Should be 1 for US Grid Mix

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 |

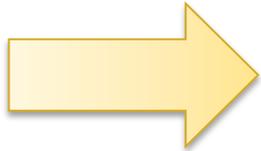


(U.S. EPA)

- 1 U.S. Mix
- 2 ASCC Mix
- 3 FRCC Mix
- 4 HICC Mix
- 5 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
- 14 NG Power Plants
- 15 Coal Power Plants
- 16 Nuclear Power Plants
- 17 Hydro Power Plants
- 18 NGCC Turbine
- 19 Geothermal

Demonstrations - Total Life Cycle, Examine Total Energy Cycle Results with US Grid

- Go to GREET 2, [TEC_Results] Tab
- Examine Results
- Focus on PHEV Results



| Grid-Connected SI PHEV: CG and RFG, Conventional Material | | | | |
|--|---------------------------|----------------------|--------------------------|--------------|
| Item | Btu/mile or g/mile | | | Total |
| | WTP | Vehicle Cycle | Vehicle Operation | |
| Total energy | 1,080 | 654 | 2,557 | 4,291 |
| Fossil fuels | 975 | 603 | 2,355 | 3,933 |
| Coal | 292 | 254 | 188 | 734 |
| Natural gas | 493 | 257 | 92 | 842 |
| Petroleum | 190 | 92 | 2,075 | 2,357 |
| Water consumption | 0.252 | 0.089 | 0.000 | 0.341 |
| CO2 (VOC, CO, CO2) | 90 | 46 | 170 | 306 |
| CH4 | 0.287 | 0.098 | 0.003 | 0.388 |
| N2O | 0.008 | 0.001 | 0.005 | 0.014 |
| GHGs | 100 | 49 | 172 | 321 |



Demonstrations - Total Life Cycle, Change Electrical Grid Assumption

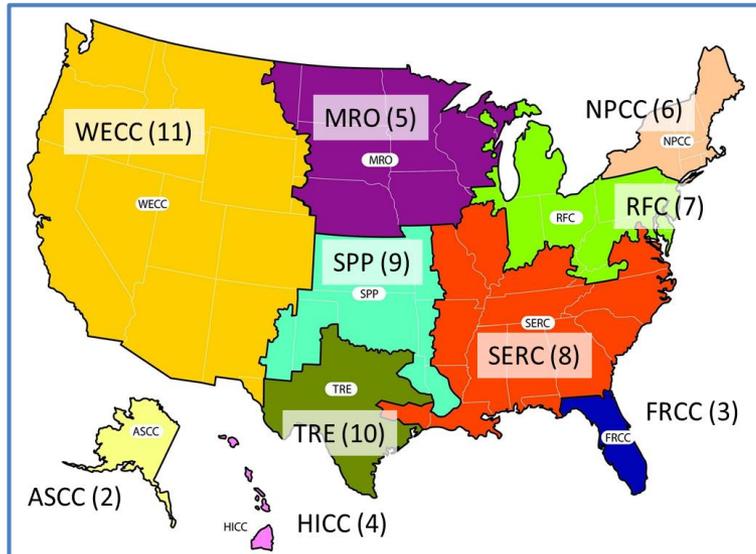
- Go to GREET 1, [Inputs] Tab
- Click “Electric” button, or go to section 10 “Electric Generation”
- Change Electricity Generation Mix to 12 (California Mix)
- Press F9

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 |

Change to 12

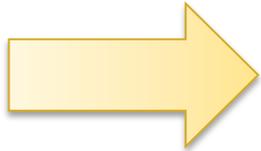


(U.S. EPA)

- 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
- 14 NG Power Plants
- 15 Coal Power Plants
- 16 Nuclear Power Plants
- 17 Hydro Power Plants
- 18 NGCC Turbine
- 19 Geothermal

Demonstrations - Total Life Cycle, Examine Total Energy Cycle Results with California Grid

- Go to GREET 2, [TEC_Results] Tab
- Examine Results
- Focus on PHEV Results



| Grid-Connected SI PHEV: CG and RFG, Conventional Material | | | | |
|---|--------------------|---------------|-------------------|-------|
| Item | Btu/mile or g/mile | | | |
| | WTP | Vehicle Cycle | Vehicle Operation | Total |
| Total energy | 974 | 654 | 2,557 | 4,185 |
| Fossil fuels | 867 | 603 | 2,332 | 3,802 |
| Coal | 85 | 254 | 32 | 371 |
| Natural gas | 601 | 257 | 227 | 1,085 |
| Petroleum | 181 | 92 | 2,072 | 2,345 |
| Water consumption | 0.306 | 0.089 | 0.000 | 0.395 |
| CO2 (VOC, CO, CO2) | 67 | 46 | 170 | 284 |
| CH4 | 0.270 | 0.098 | 0.003 | 0.370 |
| N2O | 0.008 | 0.001 | 0.005 | 0.014 |
| GHGs | 77 | 49 | 172 | 299 |

