Addition of New Conventional and Lightweight Vehicle Models in the GREET™ Model

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1 BACKGROUND

Advanced vehicle technologies are being promoted in order to reduce local air pollutants, greenhouse gas emissions, and the United States' dependence on oil imports. One major factor impacting these current industry trends for improving vehicle fuel economy are recently released US Environmental Protection Agency (EPA) standards for corporate average fuel economy (CAFE) requiring automakers to raise the average fuel economy of passenger vehicles to 35.5 miles per gallon gasoline equivalent (mpgge) by 2016 and to 54.5 mpgge by 2025. The required increase in the associated vehicle fuel economy can only be achieved through improvements in the efficiency with which vehicles utilize energy. This suggests that there may be a meaningful change in vehicle design and material composition.

The GREET (**G**reenhouse gases, **R**egulated **E**missions, and **E**nergy use in **T**ransportation) model was originally developed to evaluate fuel-cycle (or well-to-wheels) energy use and emissions of various transportation technologies (M.Q. Wang 1999). In 2006, the GREET vehicle-cycle model (GREET 2) was released to examine energy use and emissions of vehicle production and disposal processes (Burnham, Wang, and Wu 2006). Along with providing detailed environmental impacts for numerous materials and manufacturing processes, the GREET 2 model breaks down vehicles into their constituent systems, components and parts based on mass and material composition. The data for these breakdowns is culled from a variety of reports, design tools, and expert interviews, as detailed in (Burnham, Wang, and Wu 2006; Burnham 2012). The last update to GREET 2 vehicle specifications was in 2012 and included the addition of two new vehicle types (a mid-size sport utility vehicle, and a full-size pick-up truck) in addition the previous mid-size passenger car, along with the addition of two propulsion technologies (a plug-in grid connected hybrid electric vehicle [HEV] with an SI engine, and a battery electric vehicle [EV]) to the already existing internal combustion engine vehicle (ICEV) with a spark-ignition (SI) engine, grid-independent HEV with an SI engine, and fuel cell vehicle (FCV) with a hybrid configuration. That update built upon previous versions of GREET 2 and added new data based on a wide variety of sources documented in that report (Burnham 2012).

The present update to the GREET 2 model utilizes recently released reports for vehicle lightweighting to describe probable near-term vehicle mass reductions, with a focus on material composition and corresponding fuel economy improvement. Broad industry trends suggest that regulations from the new CAFE standards will cause vehicle manufacturers to lightweight their vehicles as one of many strategies to comply with fuel efficiency mandates. This can be accomplished in many ways, however, the released reports provide both engineering and economic analyses on a system-by-system basis, thereby ensuring that proposed lightweighting approaches are both technically and economically feasible in the near-term. The data in these reports has been evaluated and augmented for inclusion in this GREET 2 release.

Two reports serve as the primary basis for these updates. The National Highway Transportation Safety Administration (NHTSA) commissioned a report on mass reduction for model years 2017-2025 (Singh 2012). That report focused on evaluating the design of a lightweight midsize passenger car for high volume production, based on a 2011 Honda Accord platform. It also evaluated numerous other vehicle classes, but with much less detail than the Accord. In addition to their work on the Accord, their evaluation of large pickup trucks is of particular interest for the present report. The US EPA also commissioned a report to evaluate feasible near-term mass reduction approaches for model year 2017-2020 vehicles (U.S. Environmental Protection Agency 2012). That report focused on the design of a lightweight midsize crossover utility vehicle (CUV), based on a 2010 Toyota Venza. Again, the focus of both reports was to examine near-term solutions that were both economically and technically feasible. These reports serve as a valuable basis for examining near-term lightweighting impacts because they represent well vetted designs, and they often provide details on the material composition of both baseline and lightweight vehicle components. This allows for a realistic perspective on future vehicle material compositions, as well as comparative analyses between the two reports.

2 VEHICLE SPECIFICATIONS

The present release of the GREET 2 model includes six new vehicles that can be used for lifecycle assessment, especially for assessing the impacts of near-term vehicle lightweighting efforts. The release consists of a baseline midsize passenger car, along with a lightweight midsize passenger car. These are based on the data contained within the NHTSA report, which provides a great deal of detail for those vehicles' compositions. There is also a new pickup truck model, and its lightweight version, based on data from the same NHSTA report. The data for the trucks are less granular and required some assumptions regarding composition, as will be described below. Finally, there is a crossover utility vehicle, and its lightweight counterpart. These crossover utility vehicles are based on an EPA study that provides extensive details on the material composition. Table 1 contains the weights of each of these new modeled vehicles, excluding the weight of the vehicle's fuel, which is consistent with previous GREET 2 releases.

Table 1 Total Vehicle Weight Excluding Fuel (lb)

	Car ICEV	CUV ICEV	PUT ICEV	LW Car ICEV	LW CUV ICEV	LW PUT ICEV
Total weight	3,170	3,768	5,135	2,476	3,074	4,131

Along with the weight of these vehicles, it is imperative to understand each vehicle's fuel economy in order to calculate its lifetime emissions during the use phase. GREET uses an approach that incorporates realistic driving conditions results simulated via Autonomie (Moawad, Sharer, and Rousseau 2013). But, for these six vehicles the following approach was used. The combined (city/highway) fuel economies of each vehicle were determined in one of two ways. First, if the provided literature stated a known fuel economy, then that value was used. Next, if the report did not provide a fuel economy value, then the US EPA's fueleconomy.gov website was used to determine the associated city and highway fuel economy, since those data are taken from official reporting by the automakers. The combined fuel economy was calculated using the weighted harmonic average of the reported city (53%) and highway (47%) fuel economies to increase fidelity versus the reported combined fuel economy values, which has an integer basis. Finally, if the fuel economy of the lightweight version of a vehicle was not provided, then a rule of thumb was used to determine fuel economy increase. Specifically, for each 10% reduction in weight a 7% improvement in fuel economy can be realized. Table 2 presents the fuel economy of each vehicle in the study.

Table 2 Vehicle Fuel Economies (MPG)

	Car ICEV*	CUV ICEV	PUT ICEV	LW Car ICEV*	LW CUV ICEV	LW PUT ICEV
Fuel economy	27.0	24.1	14.6	31.6	27.2	16.6

(* indicates values stated in reports)

2.1 DEFINITION OF VEHICLE COMPONENTS

The total weight of each vehicle is broken down into three major categories: vehicle components, battery, and fluids. The vehicle components category includes four major systems: body, powertrain, transmission, and chassis. The fluid category includes engine oil, power steering fluid, brake fluid, transmission fluid, powertrain coolant, windshield fluid, and adhesives. These categories are all consistent with previous GREET 2 versions.

When collecting data for various vehicles, the specific weights and material compositions often did not correspond perfectly to GREET definitions. Therefore, we needed a more detailed breakdown of each system in order to place part and subsystem data into the right component category in GREET; parts are aggregated into subsystems, and subsystems are aggregated into systems for inclusion in GREET. In the GREET 2 model, users do not see parts or subsystems — only systems, although the details of these parts and subsystems are provided in the documentation that accompany GREET model release. Tables 3 - 8 provide definitions, primarily based on the Automotive System Cost Model (ASCM) developed by IBIS Associates and Oak Ridge National Laboratory (Das 2004), for the major parts and subsystems in each system category (i.e., body, powertrain, transmission, chassis, battery, and fluid). These systems and subsystems are consistent with previous GREET 2 documentation, but the data sources from the reports used in this augmentation are not always consistent with these. So, in some instances, component categories required modification. One specific example is in the body panel component. That component contains doors, whereas in this update, doors are treated as a separate component due to the degree of detail regarding doors in the teardown reports used in this study. Specifically, there are a number of additional parts in those reports (electronics, window mechanisms, interior finish, etc.) that make them inconsistent with our previous documentation of material compositions for body panels (typically one material). Additionally, some body components from past GREET 2 documentation were not available (weld blanks and fasteners most specifically). As components roll up to the entire body system, the system level comparisons are consistent with previous GREET 2 versions, but the component level material compositions within the body system may vary somewhat, and users should be aware of those differences.

Table 3 Body System

Body-in-white	Primary vehicle structure, usually a single-body assembly to which other major components are attached
Body panels	Closure panels and hang-on panels, such as the hood, roof, decklid, doors, quarter panels, and fenders
Front/rear bumpers	Impact bars, energy absorbers, and mounting hardware
Body hardware	Miscellaneous body components
Glass	Front windshield, rear windshield, and door windows
Paint	E-coat, priming, base coats, and clear coats
Exterior trim	Molding, ornaments, bumper cover, air deflectors, ground effects, side trim, mirror assemblies, and nameplates
Body sealers/deadeners	All rubber trim
Exterior lighting	Head lamps, fog lamps, turn signals, side markers, and tail light assemblies
Instrument panel module	Panel structure, knee bolsters and brackets, instrument cluster, exterior surface, console storage, glove box panels, glove box assembly and exterior, and top cover
Trim and insulation	Emergency brake cover, switch panels, ash trays, arm rests, cup holders, headliner assemblies, overhead console assemblies, assist handles, coat hooks, small item overhead storage, pillar trim, sun visors, carpet, padding, insulation, and accessory mats
Door module	Door insulation, trim assemblies, speaker grills, switch panels and handles (door panels are considered as part of the body panels category)
Seating and restraint system	Seat tracks, seat frames, foam, trim, restraints, anchors, head restraints, arm rests, seat belts, tensioners, clips, air bags, and sensor assemblies
Heating, ventilation, air conditioning (HVAC) module	Air flow system, heating system, and air conditioning system (which includes a condenser, fan, heater, ducting, and controls)
Interior electronics	Wiring and controls for interior lighting, instrumentation, and power accessories

Table 4 Powertrain System

Engine unit	Engine block, cylinder heads, fuel injection, engine air system, ignition system, alternator, and containers and pumps for the lubrication system
Engine fuel storage system	Fuel tank, tank mounting straps, tank shield, insulation, filling piping, and supply piping
Powertrain thermal system	Water pump, radiator, and fan
Exhaust system	Catalytic converter, muffler, heat shields, and exhaust piping
Powertrain electrical system	Control wiring, sensors, switches, and processors
Emission control electronics	Sensors, processors, and engine emission feedback equipment

Table 5 Transmission System

Transmission unit	Gearbox, torque converter, and controls
ICEV	Uses an automatic transmission and therefore a torque converter

Table 6 Chassis System

Cradle	Frame assembly, front rails, and underbody extensions, cab and body brackets (the cradle bolts to the BIW and supports the mounting of the engine/fuel cell)
Driveshaft/axle	A propeller shaft, halfshaft, front axle and rear axle (the propeller shaft connects the gearbox to a differential, while the halfshaft connects the wheels to a differential)
Differential	A gear set that transmits energy from the driveshaft to the axles and allows for each of the driving wheels to rotate at different speeds, while supplying them with an equal amount of torque
Corner suspension	Upper and lower control arms, ball joints, springs, shock absorbers, steering knuckle, and stabilizer shaft
Braking system	Hub, disc, bearings, splash shield, and calipers
Wheels	Four main wheels and one spare
Tires	Four main tires and one spare
Steering system	Steering wheel, column, joints, linkages, bushes, housings, and hydraulic-assist equipment
Chassis electrical system	Signals; switches; horn wiring; and the anti-lock braking system wiring, sensors, and processors

Table 7 Battery System

ICEV	Pb-Ac battery to handle the startup and accessory load

Table 8 Fluid System

ICEV	Engine oil, power steering fluid, brake fluid, transmission fluid, powertrain coolant, windshield fluid, and adhesives

2.2 CONVENTIONAL AND LIGHTWEIGHT MIDSIZE PASSENGER CAR

The conventional and lightweight midsize passenger car are based on a NHTSA commissioned study that utilized teardown data for a 2011 Honda Accord to identity baseline vehicle characteristics, and then developed several lightweight options for that vehicle and its components. Detailed technical analyses of the lightweight vehicle structure, and economic and technical feasibility studies provided validation of viable near-term lightweighting options for this vehicle. The study used a detailed approach in identifying, evaluating and selecting available lightweighting options for many vehicle systems, components, and parts. That report contained sufficient information to determine the mass and material composition of many parts for both the conventional and lightweight vehicles. These data were augmented with other studies as needed using studies that are consistent with those used in previous GREET 2 releases. Table 9 contains a material composition breakdown for the components within both the baseline and the lightweight midsize passenger car, and Table 10 contains weights for those components. The final vehicle system mass distribution and material mass distribution within the vehicle and its constituent systems are provided in Tables 15 - 20.

Table 9 Material Composition of Midsize Passenger Car Components (ICEV)

Component	Conventional	Lightweight	Source(s)
Body			
Body-in-white	61% steel 39% HSS	52% steel 48% AHSS	NHTSA
Front doors	78.2% steel 15.5% plastic 4% rubber 1.2% glass 1.1% copper	48.1% wrought Al 25.1% steel 19% plastic 6% rubber 1.8% glass	NHTSA and Dismantling reports
Rear doors	87.7% steel 0.5% copper 7.1% plastic 4.7% rubber	53.4% wrought Al 27.4% steel 12.4% plastic 6.9% rubber	NHTSA and Dismantling reports
Hood	100% steel	73.5% wrought Al 26.5% steel	NHTSA
Decklid/Fenders	100% steel	100% steel	NHTSA
Bumpers	100% steel	100% AHSS	NHTSA
Glass	100% glass	100% glass	NHTSA
Exterior			
Paint	100% paint	100% paint	NHTSA
Fascia and trim	97% plastic 3% steel	97% plastic 3% steel	NHTSA
Exterior lighting	89.8% plastic 5.3% steel 2.3% rubber 2% copper 0.6% glass	89.8% plastic 5.3% steel 2.3% rubber 2% copper 0.6% glass	Dismantling reports
Wiper system	63% steel 31.4% plastic 4.5% rubber 1.1% copper	63% steel 31.4% plastic 4.5% rubber 1.1% copper	NHTSA and our assumptions
Interior			
Instrument panel	59% plastic 37.2% steel 3.8% copper	67% plastic 29% magnesium 4% copper	NHTSA and Dismantling reports
Trim & insulation	66% plastic 33% organic	99% plastic 1% glass	Dismantling reports

Table 9 (Cont.)

Component	Conventional	Lightweight	Source(s)
Interiors (Cont.)			
Front seats	73% steel 21% plastic 6% other	64.9% carbon fiber composite 24% plastic 8.5% other 2.6% cast Al	NHTSA and Dismantling reports
Rear seats	54.2% steel 36.8% plastic 9% other	35.2% carbon fiber composite 37.8% plastic 13% other 14% cast Al	NHTSA and Dismantling reports
Safety systems	53% plastic 47% steel	53% plastic 47% steel	NHTSA and Dismantling reports
HVAC	47.4% plastic 22% wrought Al 16.1% steel 7.5% cast Al 3.2% rubber 2.2% copper 0.5% zinc 1.2% other	42.5% plastic 24% wrought Al 17.6% steel 8.2% cast Al 3.5% rubber 2.4% copper 0.5% zinc 1.3% other	NHTSA and Dismantling reports
Entertainment	82.8% plastic 17.2% copper	84% plastic 16% copper	NHTSA and Dismantling reports
Powertrain			
Engine	65.3% steel 25.9% cast Al 7% plastic 0.9% copper 0.5% cast iron 0.5% wrought Al	65.6% steel 24.8% cast Al 7.6% plastic 1.0% copper 0.5% cast iron 0.5% wrought Al	NHTSA and US EPA
Engine fuel storage system	100% plastic	100% plastic	NHTSA
Powertrain thermal	82.2% plastic 17.8% cast Al	81.4% plastic 18.6% cast Al	NHTSA and our assumptions
Exhaust	94.984% steel 5.012% wrought Al 0.004% platinum	94.534% steel 5.462% wrought Al 0.004% platinum	NHTSA, Cuenca 2005 and our assumptions
Powertrain electrical	65% copper 35% plastic	65% copper 35% plastic	NHTSA and our assumptions
Transmission	30.5% steel 32.3% cast Al 27.1% cast iron 5.1% plastic 5.1% rubber	31.6% steel 29.7% cast Al 28.2% cast iron 5.2% plastic 5.2% rubber	NHTSA, Muir 2005 and our assumptions

Table 9 (Cont.)

Component	Conventional	Lightweight	Source(s)
Chassis			
Front suspension	77.8% steel 4.8% HSS 15.1% cast iron 2.2% rubber	30.6% wrought Al 26.2% AHSS 13.9% steel 77.8% cast Al 11.1% cast iron 4.4% rubber	NHTSA
Rear suspension	85.8% steel 12.8% cast Al 1.5% rubber	66.1% steel 23.0% cast Al 9.0% cast Al 1.9% rubber	NHTSA
Tires and Wheels	50% HSS 46.3% rubber 3.7% steel	49.7% AHSS 47.7% rubber 2.6% steel	NHTSA
Braking system	72.2% steel 26.3% cast iron 1.5% plastic	73.2% steel 22.3% wrought Al 3.5% plastic 1% copper	NHTSA and our assumptions
Steering system	65.9% steel 9.5% magnesium 9% cast Al 7.4% plastic 4.3% copper 3.9% zinc	63.2% steel 11.8% magnesium 8.6% cast Al 8.5% plastic 4.1% copper 3.8% zinc	NHTSA Dismantling reports
Drive shaft (no axles)	95% steel 5% rubber	95% steel 5% rubber	Our assumptions

Table 10 Midsize Passenger Car Component Weights (lb)

Component	Conventional	Lightweight
Body		
BIW	723.12	562.62
Front door	117.81	79.19
Rear door	90.96	61.99
Hood	39.46	22.47
Decklid	27.27	15.79
Fenders	16.20	8.99
Bumpers	34.83	19.18
Glass	73.03	72.92
Exterior		
Paint	26.46	26.46
Fascia and trim	28.59	28.59
Exterior lighting	20.72	15.56
Wipers	12.30	12.30
Interior		
Instrument panel	70.33	49.49
Trim & insullation	20.61	13.56
Front seat	100.84	70.66
Rear seat	46.36	32.39
Safety Systems	40.12	40.12
HVAC	30.66	30.66
Entertainment	6.50	4.76
Powertrain		
Engine	365.39	338.01
Powertrain Electrical	47.84	38.36
Exhaust	45.75	41.98
Fuel system	26.46	18.85
Powertrain thermal system	32.61	28.44
Transmission	203.49	144.62
Chassis		
Front suspension	179.24	91.27
Rear suspension	117.22	89.88
Tires and Wheels	206.93	175.53
Brakes	144.25	104.41
Steering	58.69	47.11
Drive Shaft (no axles)	33.51	25.79

2.3 CONVENTIONAL AND LIGHTWEIGHT CROSSOVER UTILITY VEHICLE

The conventional and lightweight CUV are based on an EPA commissioned study that utilized teardown data for a 2010 Toyota Venza to identity baseline vehicle characteristics, and then developed several lightweight options for that vehicle and its components. Detailed technical analyses of the lightweight vehicle structure, and economic and technical feasibility studies provided validation of viable near-term lightweighting options for this vehicle. The study used a detailed approach in identifying, evaluating and selecting available lightweighting options for many vehicle systems, components, and parts. That report contained sufficient information to determine the mass and material composition of many parts for both the conventional and lightweight vehicles. These data were augmented with other studies as needed using studies that are consistent with those used in previous GREET 2 releases. Table 11 contains a material composition breakdown for the components within both the baseline and the lightweight CUV, and Table 12 contains weights for those components. The final vehicle system mass distribution and material mass distribution within the vehicle and its constituent systems are provided in Tables 15 - 20.

Table 11 Material Composition of Crossover Utility Vehicle Components (CUV)

Component	Conventional	Lightweight	Source(s)
Body			
Body-in-white	73.4% steel 26.6% HSS	50.6% steel 28.6% AHSS 20.8% HSS	US EPA
Front doors	67.2% steel 25.1% HSS 3.5% plastic 2.7% rubber 1.1% glass 0.4% copper	67.4% steel 25.8% HSS 4.3% plastic 1% glass 1% rubber 0.4% copper	US EPA and Dismantling reports
Rear doors	70.7% steel 25.9% HSS 2.9% rubber 0.3% copper 0.2% plastic	70.7% steel 26.6% HSS 1.3% plastic 1.1% rubber 0.3% copper	US EPA and Dismantling reports
Hood	70.2% steel 29.1% HSS 0.7% rubber	95.2% wrought Al 3.9% steel 0.4% plastic 0.4% rubber	US EPA
Decklid	99.9% steel 0.1% copper	57.9% wrought Al 41.9% steel 0.1% plastic 0.1% copper	US EPA
Fenders	97.5% steel 2.5% rubber	96.9% wrought Al 1.6% plastic 1.6% rubber	US EPA
Bumpers	68% AHSS 32% wrought Al	66.2% AHSS 33.8% wrought Al	US EPA
Glass	100% glass	100% glass	US EPA
Exterior			
Fascia and trim	100% plastic	100% plastic	US EPA
Exterior lighting	89.7% plastic 5.2% steel 2.3% rubber 2.2% copper 0.6% glass	89.7% plastic 5.2% steel 2.3% rubber 2.2% copper 0.6% glass	Dismantling reports
Wiper system	63.3% steel 30.9% plastic 4.2% rubber 1.6% copper	64.2% steel 30% plastic 4.3% rubber 1.5% copper	US EPA and our assumptions

Table 11 (Cont.)

Component	Conventional	Lightweight	Source(s)
Interiors			
Instrument panel	65.3% plastic 32.2% steel 2.4% copper	69.4% plastic 20.5% magnesium 7.8% steel 2.3% copper	US EPA and Dismantling reports
Trim & insulation	90.1% plastic 6.4% rubber 3.5% steel	93.2% plastic 4% steel 2.8% rubber	US EPA and Dismantling reports
Front seats	75% steel 25% plastic	50% magnesium 40% plastic 10% steel	US EPA and Dismantling reports
Rear seats	75% steel 25% plastic	50% magnesium 40% plastic 10% steel	US EPA and Dismantling reports
Safety systems	49.8% steel 49.4% plastic 0.8% copper	64.9% plastic 34.2% steel 0.9% copper	US EPA and Dismantling reports
HVAC	45% wrought Al 34.4% plastic 16.4% steel 4.3% copper	44.8% wrought Al 38.7% plastic 12.2% steel 4.2% copper	US EPA and Dismantling reports
Powertrain			
Engine	54.9% steel 34% cast Al 7.9% plastic 1.6% cast iron 1.1% copper 0.5% wrought Al	62.6% steel 12.1% magnesium 11.7% plastic 11.3% cast Al 1.3% copper 1% wrought Al	US EPA
Engine fuel storage system	93.3% steel 6.7% plastic	95.3% steel 4.7% plastic	US EPA
Powertrain thermal	90% cast Al 10% plastic	75% cast Al 25% plastic	US EPA and our assumptions
Exhaust	99.997% steel 0.003% platinum	99.996% steel 0.004% platinum	US EPA, Cuenca 2005 and our assumptions
Powertrain electrical	65% copper 35% plastic	60% copper 35% plastic 5% wrought Al	US EPA and our assumptions

Table 11 (Cont.)

Component	Conventional	Lightweight	Source(s)
Powertrain (cont.)			
Transmission	57.3% steel 26.8% cast Al 12.7% cast iron 2.3% plastic 0.5% copper 0.4% rubber	57.3% steel 22.8% magnesium 12.9% cast Al 4.4% cast iron 1.1% plastic 0.7% copper 0.5% rubber 0.4 wrought Al	US EPA, Muir 2005 and our assumptions
Chassis			
Front suspension	88.5% steel 11.1% cast iron 0.4% rubber	49.7% steel 21.5% cast Al 18.5% magnesium 4.1% HSS 4.1% rubber 2% plastic	US EPA
Rear suspension	78.9% steel 20.3% cast Al 0.7% rubber	34.6% steel 23.8 cast Al 18.7% wrought Al 10% HSS 10% rubber 3% plastic	US EPA
Tires and Wheels	7.5% steel 44.5% cast Al 48.1% rubber	8.7% steel 35.9% cast Al 55.4% rubber	US EPA
Braking system	43.1% steel 55.5% cast iron 0.5% cast Al 0.9% plastic	33.4% steel 25.2% cast iron 33.9 cast Al 5.1% plastic 1.3% copper 0.1% magnesium	US EPA and our assumptions
Steering system	85.2% steel 8.5% magnesium 2.4% cast Al 1.6% plastic 1.2% copper 1.1% zinc	76.3% steel 10.9% cast Al 10.9% plastic 1.0% copper 0.9% zinc	US EPA and Dismantling reports
Drive shaft (no axles)	97.2% steel 2.8% rubber	97.2% steel 2.8% rubber	Our assumptions

Table 12 Crossover Utility Vehicle Component Weights (lb)

Component	Conventional	Lightweight
Body		
BIW	851.42	733.48
Front door	139.96	136.47
Rear door	108.35	105.49
Hood	40.43	23.39
Decklid	45.44	29.34
Fenders	15.38	11.15
Bumpers	16.53	15.65
Glass	88.93	79.71
Exterior		
Fascia and trim	63.95	58.84
Exterior lighting	22.14	20.97
Wipers	13.14	12.93
Interior		
Instrument panel	85.26	68.77
Trim & insulation	9.93	9.33
Front seat	109.48	91.07
Rear seat	94.55	61.39
Safety Systems	39.54	37.21
HVAC	33.46	28.11
Powertrain		
Engine	333.15	272.17
Powertrain electrical	52.79	50.83
Exhaust	74.97	58.39
Fuel system	53.52	38.52
Powertrain thermal system	31.08	25.37
Transmission	204.51	162.84
Chassis		
Front suspension	247.53	171.04
Rear suspension	122.92	88.43
Tires and Wheels	312.65	240.71
Brakes	188.75	103.41
Steering	53.41	49.41
Drive Shaft (no axles)	74.20	70.89

2.4 CONVENTIONAL AND LIGHTWEIGHT PICKUP TRUCK

The conventional and lightweight pickup trucks are based on the previously mentioned NHTSA study. It addition to the Honda Accord data, that report also utilized teardown data for a 2003 Ford F150 to identity baseline vehicle characteristics for pickup trucks. The report then utilized its studies in lightweighting the midsized passenger car to inform lightweight options for the pickup truck and its components. Detailed technical analyses of the lightweight vehicle structure, and economic and technical feasibility studies were not performed in this analysis, thus these data should be considered more prospective than the ICEV and CUV studies mentioned previously.

The report only provided system and subsystem masses, with no detail on the distribution of that mass by material. Therefore, the previously defined mass distribution for conventional vehicles from GREET 2 served as the basis for the material distribution within this vehicle. To do this, the material composition associated with the components in the GREET 2 documentation was applied to the corresponding components in the NHTSA study data.

The report provided some detail on materials used for lightweighting, but it does not explicitly describe what material was being replaced, or exactly how much of the substituting material was used for each subsystem. So, the available information in the report was coupled with the GREET 2 material composition data for pickup trucks, and engineering judgment to determine a final material mass distribution for each listed component. Table 13 contains a material composition breakdown for the components within both the baseline and the lightweight midsize passenger car, and Table 14 contains weights for those components. The final vehicle system mass distribution and material mass distribution within the vehicle and its constituent systems are provided in Tables 15 - 20.

Table 13 Material Composition of Pickup Truck Components (PUT)

Component	Conventional	Lightweight	Source(s)
Body			
Body-in-white	100% steel	66.3% wrought Al 33.7% steel	NHTSA and Burnham 2012
Front doors	55.9% steel 30.5% plastic 13.6% other	41.1% wrought Al 38.6% plastic 1.4% other 2.9% steel	NHTSA and Burnham 2012
Rear doors	63.3% steel 26.2% plastic 10.5 other	48.1% wrought Al 34.1% plastic 13.9% other 3.9% steel	NHTSA and Burnham 2012
Hood	98% steel 2% plastic	58.4% steel 39.3% wrought Al 2.2% plastic 0.1% other	NHTSA and Burnham 2012
Decklid	93.1% steel 6.5% plastic 0.4% other	92.2% steel 7.4% plastic 0.4% other	NHTSA and Burnham 2012
Fenders	100% steel	100% wrought Al	NHTSA and Burnham 2012
Bumpers	100% steel	100% steel	NHTSA and Burnham 2012
Glass	100% glass	100% glass	NHTSA and Burnham 2012
Misc. (accessories, fasteners)	52.3% plastic 47.5% steel 0.1% rubber 0.1% copper	52.3% plastic 47.5% steel 0.1% rubber 0.1% copper	NHTSA and Burnham 2012
Exterior			
Lighting	89.8% plastic 5.3% steel 2.3% rubber 2.0% copper 0.6% glass	89.8% plastic 5.3% steel 2.3% rubber 2.0% copper 0.6% glass	NHTSA and Burnham 2012
Wiper system	75% steel 20% plastic 5% rubber	75% steel 20% plastic 5% rubber	NHTSA and Burnham 2012

Table 13 (Cont.)

Component	Conventional	Lightweight	Source(s)
Interiors			
Instrument panel	47% plastic 46% steel 4% other 1% magnesium 1% rubber 1% wrought Al	35.5% plastic 34.7% steel 25.3% magnesium 3% other 0.8% rubber 0.8% wrought Al	NHTSA and Burnham 2012
Trim & insulation	58.9% plastic 25.9% steel 12.3% rubber 2.8% other 0.1% wrought Al	58.5% plastic 25.7% steel 13% rubber 2.8% other 0.1% wrought Al	NHTSA and Burnham 2012
Front seats	58% steel 39% plastic 3% other	50% magnesium 50% carbon fiber	NHTSA and Burnham 2012
Rear seats	58% steel 39% plastic 3% other	50% magnesium 50% carbon fiber	NHTSA and Burnham 2012
Safety systems	58% steel 39% plastic 3% other	64.9% plastic 34.2% steel 0.9% copper	NHTSA and Burnham 2012
HVAC	56.2% steel 21.5% wrought Al 16.7% copper 2.4% plastic 2% rubber 0.7% other 0.5% zinc	56.2% steel 21.5% wrought Al 16.7% copper 2.4% plastic 2% rubber 0.7% other 0.5% zinc	NHTSA and Burnham 2012
Powertrain			
Engine	50% cast iron 30% cast Al 10% steel 4.5% plastic 4.5% rubber 1.0% copper	50% cast iron 30% cast Al 10% steel 4.5% plastic 4.5% rubber 1.0% copper	NHTSA and Burnham 2012
Engine fuel storage system	100% steel	100% steel	NHTSA and Burnham 2012
Powertrain thermal	50% steel 50% plastic	50% steel 50% plastic	NHTSA and Burnham 2012
Exhaust	99.985% steel 0.015% platinum	99.985% steel 0.015% platinum	NHTSA and Burnham 2012
Powertrain electrical	59% plastic 41% copper	59% plastic 41% copper	NHTSA and Burnham 2012

Table 13 (Cont.)

Component	Conventional	Lightweight	Source(s)
Powertrain (cont.)			
Transmission	30% steel 30% wrought Al 30% cast iron 4.5% rubber 4.5% plastic 1% copper	30% steel 30% wrought Al 30% cast iron 5% rubber 5% plastic	NHTSA and Burnham 2012
Chassis			
Chassis (misc.)	100% steel	100% steel	NHTSA and Burnham 2012
Front suspension	100% steel	53.2% steel 46.8% cast Al	NHTSA and Burnham 2012
Rear suspension	100% steel	100% steel	NHTSA and Burnham 2012
Tires and Wheels	56.6% steel 43.4% rubber	55.1% steel 44.9% rubber	NHTSA and Burnham 2012
Braking system	60% cast iron 35% steel 5% other	43.8% cast iron 27.8 cast Al 25.3% steel 3.6% other	NHTSA and Burnham 2012
Steering system	80% steel 15% wrought Al 5% rubber	80% steel 15% wrought Al 5% rubber	NHTSA and Burnham 2012
Drive shaft (no axles)	100% steel	100% steel	NHTSA and Burnham 2012

Table 14 Pickup Truck Component Weights (lb)

Component	Conventional	Lightweight
Body		
BIW	811.74	573.11
Front Door	224.39	175.09
Rear Door	148.25	111.28
Hood	42.97	32.41
Decklid	57.32	45.59
Fenders	33.89	18.63
Bumpers	144.98	105.87
Glass	67.07	67.07
Misc	240.59	240.59
Exterior		
Lighting	20.88	16.71
Wipers	12.41	11.18
Interior		
Instrument Panel	83.31	65.06
Trim & Interior	7.56	6.81
Front Seat	142.42	99.69
Rear Seat	77.12	53.97
Safety Systems	57.58	57.58
HVAC	64.86	51.90
Powertrain		
Engine	524.10	407.13
Powertrain Electrical	54.10	43.28
Exhaust	144.58	130.12
Fuel System	51.43	44.97
Powertrain Thermal	38.67	34.81
Transmission	281.04	218.30
Chassis		
Chassis (misc.)	483.91	411.34
Front Suspension	204.48	158.36
Rear Suspension	274.78	223.97
Tires and Wheels	324.48	294.12
Brakes	178.66	131.77
Steering	79.90	67.90
Drive Shaft	51.61	41.29

Table 15 Component Weight Breakdown (%)

Component	ICEV	CUV ICEV	PUT ICEV	LW ICEV	LW CUV ICEV	LW PUT ICEV
Body	52.6	52.5	46.7	52.2	55.4	45.5
Powertrain	16.8	14.8	16.1	19.5	14.9	16.3
Transmission	6.6	5.6	5.6	6.0	5.4	5.4
Chassis	24.0	27.1	31.6	22.3	24.2	32.8

Table 16 Aggregated Material Composition of Vehicle (%)

Material	ICEV	CUV ICEV	PUT ICEV	LW ICEV	LW CUV ICEV	LW PUT ICEV
Steel	66.7%	64.7%	66.5%	54.9%	55.4%	46.9%
Cast Iron	4.0%	5.1%	9.0%	2.2%	1.1%	8.0%
Wrought Aluminum	0.6%	0.6%	2.2%	8.5%	3.0%	15.8%
Cast Aluminum	6.2%	9.2%	3.1%	7.0%	8.6%	5.7%
Copper/Brass	1.4%	1.2%	0.8%	0.5%	1.4%	0.3%
Zinc	0.1%	0.0%	0.0%	0.1%	0.0%	0.0%
Magnesium	0.2%	0.1%	0.0%	0.8%	6.4%	2.3%
Glass	2.4%	2.5%	1.3%	3.1%	2.7%	1.7%
Average Plastic	12.4%	11.9%	10.6%	14.3%	15.9%	9.9%
CFRP	0.0%	0.0%	0.0%	2.4%	0.0%	1.9%
Rubber	4.1%	4.7%	3.8%	4.6%	5.4%	4.3%
Platinum	0.0001%	0.0001%	0.0004%	0.0001%	0.0001%	0.0005%
Others	1.9%	0.0%	2.7%	1.6%	0.0%	3.0%

Table 17 Material Composition of Body (%)

Material	ICEV	CUV ICEV	PUT ICEV	LW ICEV	LW CUV ICEV	LW PUT ICEV
Steel	72.6%	73.4%	71.3%	55.1%	62.7%	32.1%
Wrought Aluminum	0.9%	1.1%	0.6%	8.2%	4.1%	29.7%
Cast Aluminum	0.3%	0.0%	0.0%	0.9%	0.0%	0.0%
Copper/Brass	0.5%	0.3%	0.5%	0.4%	0.3%	0.5%
Zinc	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Magnesium	0.0%	0.0%	0.0%	1.1%	5.5%	5.1%
Glass	4.6%	4.7%	2.9%	6.0%	4.9%	3.6%
Average Plastic	16.7%	19.6%	18.8%	19.7%	22.0%	17.9%
CFRP	0.0%	0.0%	0.0%	4.6%	0.0%	4.2%
Rubber	0.8%	1.0%	0.5%	1.0%	0.5%	0.5%
Others	3.6%	0.0%	5.4%	3.0%	0.0%	6.4%

Table 18 Material Composition of Chassis (%)

Material	ICEV	CUV ICEV	PUT ICEV	LW ICEV	LW CUV ICEV	LW PUT ICEV
Steel	72.2	53.9	82.9	59.6	40.5	76.1
Cast Iron	8.8	15.7	6.7	1.9	3.6	4.3
Wrought Aluminum	0.0	0.0	0.8	13.5	2.3	0.8
Cast Aluminum	2.7	14.1	0.0	4.6	25.7	8.3
Copper/Brass	0.3	0.1	0.0	0.6	0.3	0.0
Zinc	0.3	0.1	0.0	0.3	0.1	0.0
Magnesium	0.8	0.5	0.0	1.0	4.4	0.0
Average Plastic	0.9	0.3	0.0	1.4	2.3	0.0
Rubber	13.9	15.4	9.1	17.0	20.9	10.2
Others	0.0	0.0	0.6	0.0	0.0	0.4

Table 19 Material Composition of Powertrain (%)

Material	ICEV	CUV ICEV	PUT ICEV	LW ICEV	LW CUV ICEV	LW PUT ICEV
Steel	54.4	56.4	32.9	56.2	51.8	35.3
Cast Iron	0.3	1.0	32.2	0.4	0.0	30.8
Wrought Aluminum	0.8	0.3	0.0	6.2	1.2	2.7
Cast Aluminum	19.4	25.9	19.3	19.2	11.2	18.5
Copper/Brass	6.6	7.0	3.4	0.7	7.6	0.6
Magnesium	0.0	0.0	0.0	0.0	7.4	0.0
Average Plastic	18.5	9.4	9.2	17.4	20.8	9.3
Rubber	0.0	0.0	2.9	0.0	0.0	2.8
Platinum	0.0	0.0	0.0	0.0	0.0	0.0
Others	0.0	0.0	0.0	0.0	0.0	0.0

Table 20 Material Composition of Transmission (%)

Material	ICEV	CUV ICEV	PUT ICEV	LW ICEV	LW CUV ICEV	LW PUT ICEV
Steel	30.5	57.3	30.0	31.6	57.3	30.0
Cast Iron	27.1	12.7	30.0	28.2	4.4	30.0
Wrought Aluminum	0.0	0.0	30.0	0.0	0.4	30.0
Cast Aluminum	32.3	26.8	0.0	29.7	12.9	0.0
Copper/Brass	0.0	0.5	0.0	0.0	0.7	0.0
Magnesium	0.0	0.0	0.0	0.0	22.8	0.0
Average Plastic	5.1	2.3	5.0	5.2	1.1	5.0
Rubber	5.1	0.4	5.0	5.2	0.5	5.0
Others	0.0	0.0	0.0	0.0	0.0	0.0

3 IMPLEMENTATION DETAILS

Within this release of GREET 2, the user can select either previous versions of GREET vehicle models, or they can select the vehicles described in this document. In selecting the previous GREET vehicles, the user will be presented with versions of these vehicles that include ICEV, HEV, PHEV, EV and FCV powertrains. Those vehicle powertrains have been studied and developed in detail, and are described in prior GREET documentation. The new vehicles included in this update only have ICEV powertrains and, by default, the other powertrains will return null values when these updated vehicles are selected.

The details of the new conventional and lightweight midsize passenger car versions are incorporated within the CAR sheet of GREET. The new CUV and lightweight CUV details are presented within the SUV sheet. Finally, the new pickup and lightweight pickup truck data are provided within the PUT sheet.

The associated fuel economies for these vehicles, Table 2, are valid for the vehicle weights provided within GREET. Past GREET vehicle fuel economies (and hence fuel consumption results over the vehicle's lifetime) were based on extensive simulation in the Autonomie vehicle modeling software. Those relationships have been correlated with the newly added vehicles such that modifying the vehicle's weight will cause a change in the associated fuel economy, however, users that opt to change the weight of these new vehicles should be cautious with the results as this correlation has not been rigorously evaluated for these new vehicles.

4 REFERENCES

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