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Estimated United States Transportation Energy Use 2005

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Estimated United States Transportation Energy Use: 2005

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Abstract

A flow chart depicting energy flow in the transportation sector of the United States economy in 2005 has been constructed from publicly available data and estimates of national energy use patterns. Approximately 31,000 trillion British Thermal Units (trBTUs) of energy were used throughout the United States in transportation activities. Vehicles used in these activities include automobiles, motorcycles, trucks, buses, airplanes, rail, and ships. The transportation sector is powered primarily by petroleum-derived fuels (gasoline, diesel and jet fuel). Biomass-derived fuels, electricity and natural gas-derived fuels are also used. The flow patterns represent a comprehensive systems view of energy used within the transportation sector.
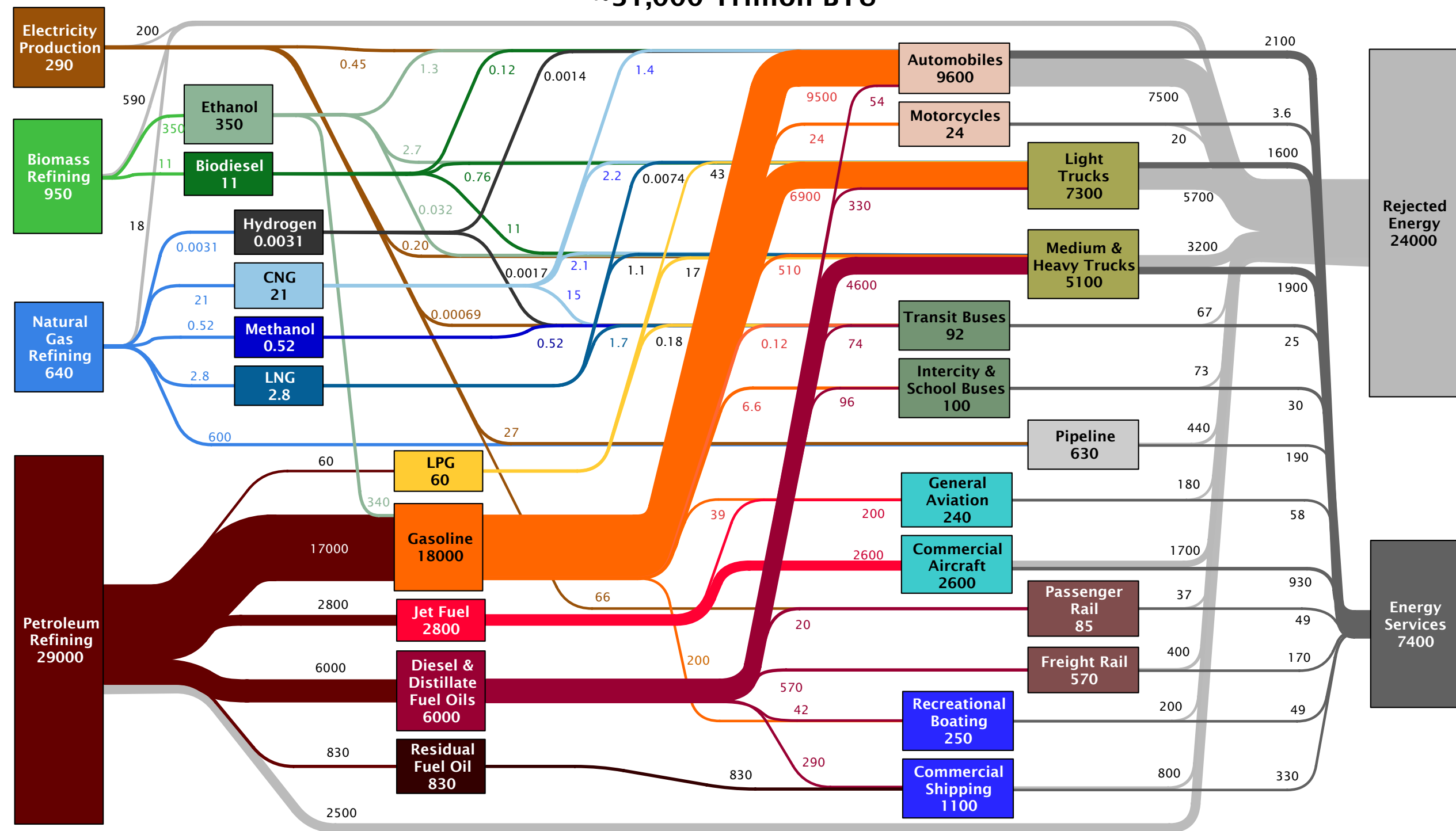
Introduction

Lawrence Livermore National Laboratory (LLNL) has published flow charts (also referred to as "Sankey Diagrams") of important national commodities since the early 1970s. The most widely recognized of these charts is the U.S. energy flow chart (http://flowcharts.llnl.gov). LLNL has also published charts depicting carbon (or carbon dioxide potential) flow and water flow at the national level as well as energy, carbon, and water flows at the international, state, municipal, and organizational (i.e. United States Air Force) level. Flow charts are valuable as single-page references that contain quantitative data about resource, commodity, and byproduct flows in a graphical form that also convey structural information about the system that manages those flows. The flowchart can be read "left-to-right". Energy taken from the environment is refined into transportation fuels These fuels are distributed to vehicles, which convert the energy to propulsive work. That work is the fundamental service provided by the transportation sector.

This is the first presentation of detailed energy flow in the transportation sector of the United States economy. Data on transportation energy use is collected by the U.S. Department of Energy's Energy Information Administration (U.S. EIA) and the Department of Transportation's Bureau of Transportation Statistics (BTS). The primary data source for this report is Oak Ridge National Laboratory's Transportation Energy Data Book (TEDB, 2010), which is based largely on BTS and EIA data. Where TEDB did not have enough detail, U.S. EIA's Alternatives to Traditional Transportation Fuels (ATTF, 2008) served as a secondary reference. A handful of other statistics, as well as vehicle efficiencies and other conversion factors, were calculated from the other references listed in the bibliography. Because many transportation energy statistics are not published on an annual basis, this report is based on data for the year 2005, the most recent year for which a full accounting is possible.

This flow chart of transportation energy usage and explanations of the calculations and assumptions utilized can be found at: http://flowcharts.llnl.gov.

Estimated United States
Transportation Energy Use in 2005
~31,000 Trillion BTU

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Estimated United States Transportation Energy Use in 2005 (~31,000 Trillion BTU). Sankey diagram showing energy flows from sources (Electricity Production 290, Biomass Refining 950, Natural Gas Refining 640, Petroleum Refining 29000) through fuels (Ethanol 350, Biodiesel 11, Hydrogen 0.0031, CNG 21, Methanol 0.52, LNG 2.8, LPG 60, Gasoline 18000, Jet Fuel 2800, Diesel & Distillate Fuel Oils 6000, Residual Fuel Oil 830) to end uses (Automobiles 9600, Motorcycles 24, Light Trucks 7300, Medium & Heavy Trucks 5100, Transit Buses 92, Intercity & School Buses 100, Pipeline 630, General Aviation 240, Commercial Aircraft 2600, Passenger Rail 85, Freight Rail 570, Recreational Boating 250, Commercial Shipping 1100) and finally to Rejected Energy 24000 and Energy Services 7400.

Analysis

This visualization of energy use in the transportation sector is based upon a "bottom-up" calculation of energy consumption for civilian consumption. Specific energy flows for which data is available are listed first, followed by flows and quantities which are calculated as residuals or summations. Every effort has been made to logically group energy flows by sector and fuel.

Consumption of Refined Fuels:

Energy use in the transportation sector is based on the consumption of refined fuels. In many cases, statistics for the consumption of these commodities in the transportation sector are readily available.

Electricity:

Electricity Production -> Automobiles

Light duty vehicles are reported to have consumed 3.6 million gasoline-equivalent gallons of *Electricity* or 0.45 trBTUs in 2005 (ATTF: Table C5, 2010).[1] Because light duty vehicles are not described in further detail, the *Electricity* usage of 0.45 trBTUs by light duty vehicles is entirely attributed to *Automobiles*.

Electricity Production -> Medium & Heavy Trucks

In 2005, *Electricity* use by medium duty vehicles is reported as 44 thousand gasoline-equivalent gallons or 0.0055 trBTUs and use by heavy duty vehicles (including buses) is reported as 1.6 million gasoline-equivalent gallons or 0.20 trBTUs (ATTF: Table C5, 2010). As described below, Transit Buses used 530 thousand kilowatt hours of electricity, or 0.00069 trBTUs, in 2005 by another source (TEDB: Table A.3, 2010). The *Electricity* attributed to medium duty and heavy duty vehicles not used as fuel by Transit Buses is attributed to *Medium & Heavy Trucks*, which is equivalent to 0.20 trBTUs of energy.

Electricity Production -> Transit Buses

The energy from *Electricity Production* used by *Transit Buses* is reported as 0.00069 trBTUs in 2005 (TEDB: Table A.3, 2010).

Electricity Production -> Pipeline

The pipeline sector consumes electricity at some pumping and compression stations. The energy from *Electricity Production* used by *Pipeline* is calculated to be 27 trBTUs in 2005 (TEDB: Table A.11, 2010).[2]

Electricity Production -> Passenger Rail

The energy from *Electricity Production* used by *Passenger Rail* is calculated to be 66 trBTUs in 2005 (TEDB: Tables A.13-A.15, 2010).

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[1]Over 90% of the estimated number of electric vehicles in service in 2008 are "Low Speed Vehicles" (ATTF: Table V5, 2010), which are assumed to fall in the class of *Automobiles*. As this flow is relatively small and the remainder is not described in further detail, the usage of *Electricity* by light duty vehicles is entirely attributed to *Automobiles*.
[2] *Electricity* usage by *Pipeline* reported is 240 trBTU (TEDB: Table 2.5, 2007) and 27.4 trBTU (TEDB: Table A.11, 2010). The data in Table A.11 is more detailed than the data in Table 2.5, therefore the *Electricity* usage by *Pipeline* in 2005 is reported as 27.4 trBTU.

Ethanol:

Ethanol is consumed by vehicles either as E85 fuel (~85% ethanol, 15% gasoline) or as an oxygenated blending component (typically ~10%) of traditional gasoline. In this analysis, we have depicted the ethanol portion of E85 consumption as a direct flow from *Ethanol* to vehicles and we have depicted oxygenate consumption as a flow from *Ethanol* into the *Gasoline* fuel supply.

Ethanol-> Gasoline

Ethanol is used as a blending component in oxygenated gasoline by *Automobiles* and *Light Trucks.* The use of *Ethanol* in *Gasoline* is reported as 2.8 billion gasoline-equivalent gallons or 340 trBTUs in 2005 (TEDB: Table2.4, 2010).

Ethanol -> Automobiles

In 2005, 37.8 million gasoline-equivalent gallons of E85 were consumed by light duty vehicles (ATTF: Table C5, 2010), 85% of which is *Ethanol*. This flow is split between *Automobiles* (33%) and *Light Trucks* (67%), based on the number of light duty vehicles in service in 2008 using E85 as a fuel (ATTF: Table V5, 2010). Therefore, the use of 10.7 million gasoline-equivalent gallons or 1.3 trBTUs of *Ethanol* is attributed to *Automobiles*.

Ethanol -> Light Trucks

In 2005, 37.8 million gasoline-equivalent gallons of E85 were consumed by light duty vehicles (ATTF: Table C5, 2010), 85% of which is *Ethanol*. This flow is split between *Light Trucks* (67%) and *Automobiles* (33%), based on the number of light duty vehicles in service in 2008 using E85 as a fuel (ATTF: Table V5, 2010.). Therefore, 21.7 million gasoline-equivalent gallons or 2.7 trBTUs of *Ethanol* is attributed to *Light Trucks*.

Ethanol -> Medium & Heavy Trucks

In 2005, 304 thousand gasoline-equivalent gallons of E85 were consumed by medium duty vehicles (ATTF: Table C5, 2010), 85% of which is *Ethanol*. The usage of *Ethanol* by medium duty vehicles is wholly attributed to *Medium & Heavy Trucks*. Therefore, 260 thousand gasoline-equivalent gallons or 0.032 trBTUs of *Ethanol* is used by *Medium & Heavy Trucks*.

Biodiesel:

Specific data on the use of *Biodiesel* by vehicle class could not be found. As a whole, *Biodiesel* use is reported as 92 million gasoline-equivalent gallons in 2005 (TEDB: Table 2.3, 2010). In this analysis, we have assumed that the consumption of *Biodiesel* follows the same pattern as the consumption of *Diesel & Distillate Fuel Oil* in *Automobiles*, *Light Trucks*, and *Medium & Heavy Trucks*.[3]

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[3] The use of *Biodiesel* is not attributed to any one class of transportation vehicle in the Transportation Energy Data Book (TEDB, 2010) or the Alternatives to Traditional Transportation Fuels report (ATTF, 2010), except for *Transit Buses*, for which *Biodiesel* is reported as first being used in 2006. Therefore, *Biodiesel* is assumed to be used by *Automobiles*, *Light Trucks*, and *Medium & Heavy Trucks* in the same fraction as these vehicles use *Diesel & Distillate Fuel Oil*.

Biodiesel -> Automobiles

The usage of *Biodiesel* by *Automobiles* is estimated as 0.011 of the total, the same ratio of *Diesel & Distillate Fuel Oils* used by *Automobiles* to the *Diesel & Distillate Fuel Oils* used by *Automobiles*, *Light Trucks*, and *Medium & Heavy Trucks*. Therefore the use of *Biodiesel* by *Automobiles* is estimated as 1.0 million gasoline-equivalent gallons or 0.12 trBTUs.

Biodiesel -> Light Trucks

The usage of *Biodiesel* by *Light Trucks* is estimated as 0.066 of the total, the ratio of *Diesel & Distillate Fuel Oil* used by *Light Trucks* to that used by *Automobiles*, *Light Trucks*, and *Medium & Heavy Trucks*. Therefore the use of *Biodiesel* by *Light Trucks* is estimated as 6.1 million gasoline-equivalent gallons or 0.76 trBTUs.

Biodiesel -> Medium & Heavy Trucks

The usage of *Biodiesel* by *Medium & Heavy Trucks* is estimated as 0.92 of the total, the ratio of *Diesel & Distillate Fuel Oil* used by *Medium & Heavy Trucks* to that used by *Automobiles*, *Light Trucks*, and *Medium & Heavy Trucks*. Therefore the *Biodiesel* by *Medium & Heavy Trucks* is estimated as 85 million gasoline-equivalent gallons or 11 trBTUs.

Hydrogen:

Hydrogen -> Automobiles

11 thousand gasoline-equivalent gallons of *Hydrogen* or 0.0014 trBTUs are reported as used in light duty vehicles (ATTF: Table C5, 2010).[4] This flow of *Hydrogen*, 0.0014 trBTUs, is entirely attributed to *Automobiles*.

Hydrogen -> Transit Buses

14 thousand gasoline-equivalent gallons of *Hydrogen* or 0.0017 trBTUs are reported as consumed by heavy duty vehicles (ATTF: Table C5, 2010), which are assumed to be *Transit Buses*.[5] Therefore, the flow from *Hydrogen* to *Transit Buses* is 0.0017 trBTUs.

CNG:

CNG -> Automobiles

In 2005, light duty vehicles consumed 29 million gasoline-equivalent gallon of *CNG* (ATTF: Table C5, 2010). Over 40% of the number of light duty vehicles in service in 2008 using *CNG* as a fuel were *Automobiles* in 2008 (ATTF: Table V5, 2010). Assuming this percentage of vehicles holds true in 2005, the usage of *CNG* by *Automobiles* is estimated as 40% of the total: 12 million gasoline-equivalent gallons or 1.4 trBTUs.

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[4] Nearly 75% of the light duty vehicles in service in 2008 using *Hydrogen* as a fuel were *Automobiles* (ATTF: Table V5, 2010). As the remaining flow of energy (0.00035 trBTUs) is small, the entire 0.0014 trBTUs of *Hydrogen* usage is attributed to *Automobiles*.

[5] As reported by the National Renewable Energy Laboratory (NREL, 2011), *Transit Buses* are one of the best early transportation applications for fuel cell technology. All of the active projects reported by this source utilizing *Hydrogen* as a fuel source are *Transit Buses*.

CNG -> Light Trucks

In 2005, light duty vehicles used 29 million gasoline-equivalent gallon of *CNG* (ATTF: Table C5, 2010). Nearly 60% of the number of light duty vehicles in service in 2008 using *CNG* as a fuel were light trucks, vans, or sport utility vehicles in 2008 (ATTF: Table V5, 2010), which are considered to be *Light Trucks* in this analysis. Assuming this percentage of vehicles holds true in 2005, the usage of CNG by *Light Trucks* is estimated as 60% of the total: 17 million gasoline-equivalent gallons or 2.2 trBTUs of *CNG*.

CNG -> Medium & Heavy Trucks

In 2005, *CNG* use by medium duty vehicles is reported as 19 million gasoline-equivalent gallons or 2.4 trBTUs and use by heavy duty vehicles is reported as 120 million gasoline-equivalent gallons or 15 trBTUs (ATTF: Table C5, 2010). As described below, *Transit Buses* used 15 trBTUs of *CNG* in 2005. The *CNG* fuel used by medium and heavy duty vehicles not consumed by *Transit Buses* (2.1 trBTUs) is attributed to *Medium & Heavy Trucks*.

CNG -> Transit Buses

Transit Buses used 120 million diesel-gallon equivalents of *CNG* in 2005 (TEDB: Table A.3, 2010). The *CNG* fuel use attributed to *Transit Buses* is equivalent to 15 trBTUs of energy.

Methanol:

Methanol -> Transit Buses

Transit Buses used 8.1 million gallons of methanol in 2005 (TEDB: Table A.3, 2010). This *Methanol* fuel use attributed to *Transit Buses* is equivalent to 0.52 trBTUs of energy.

LNG:

LNG -> Light Trucks

LNG use by light duty vehicles is reported as 59 thousand gasoline-equivalent gallons in 2005 (ATTF: Table C5, 2010).[6] Assuming the usage of *LNG* is also dominated by pickup trucks in 2005, the entire *LNG* usage of 0.0074 trBTUs by light duty vehicles is attributed to *Light Trucks*.

LNG-> Medium & Heavy Trucks

In 2005, *LNG* use by medium duty vehicles is reported as 190 thousand gasoline-equivalent gallons or 0.024 trBTUs and use by heavy duty vehicles is reported as 22 million gasoline-equivalent gallons or 2.8 trBTUs (ATTF: Table C5, 2010). As described below, *Transit Buses* used 1.7 trBTUs of *LNG* in 2005 (TEDB: Table A.3, 2010). The *LNG* fuel use by medium and heavy duty vehicles not attributed to *Transit Buses* (1.1 trBTUs) is attributed to *Medium & Heavy Trucks*.

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[6] The entire amount of *LNG* used by light duty vehicles in 2005 is attributed to *Light Trucks* in this analysis. As reported in the Alternatives to Traditional Transportation Fuels report, over 90% of the LNG-fueled light duty vehicles are pickup trucks (ATTF: Table V5, 2010). Because the *LNG* energy usage is relatively small (less than 0.01 trBTUs) and the vast majority is used by *Light Trucks*, the entire *LNG* fuel usage is attributed to *Light Trucks*.

LNG-> Transit Buses

Transit Buses used 18 million gallons of *LNG* in 2005 (TEDB: Table A.3, 2010). The *LNG* fuel use attributed to *Transit Buses* is calculated to be 1.7 trBTUs of energy.

LPG:

LPG -> Light Trucks

Light Trucks used 470 million gallons of *LPG* in 2005 (TEDB: Table A.5, 2010). The *LPG* fuel use attributed to *Light Trucks* is calculated to be 43 trBTUs of energy.

LPG -> Medium & Heavy Trucks

Medium & Heavy Trucks used 190 million gallons of *LPG* in 2005 (TEDB: Table A.6, 2010). The *LPG* fuel use attributed to *Medium & Heavy Trucks* is calculated to be 17 trBTUs of energy.

LPG -> Transit Buses

Transit Buses used 2.0 million gallons of *LPG* in 2005 (TEDB: Table A.3, 2010). The *LPG* fuel use attributed to *Transit Buses* is calculated to be 0.18 trBTUs of energy.

Gasoline:

Gasoline -> Automobiles

Automobiles used 52 billion gallons of gasoline, 25 billion gallons of oxygenated gasoline, and 1.9 million gallons of gasoline blended into E85 fuel in 2005 (TEDB: Tables 2.3 and A.1, 2010 and ATTF: Table C5, 2010). The *Gasoline* fuel use attributed to *Automobiles* is calculated to contain 9,500 trBTUs of energy including the ethanol blended as an oxygenate.

Gasoline -> Motorcycles

Motorcycles used 19 million gallons of *Gasoline* (TEDB: Table A.2, 2010). The *Gasoline* fuel use attributed to *Motorcycles* is calculated to contain 24 trBTUs of energy.

Gasoline -> Light Trucks

Light Trucks used 37 billion gallons of gasoline, 19 billion gallons of oxygenated gasoline, and 3.8 million gallons of gasoline blended into E85 fuel in 2005 (TEDB: Tables 2.3 and A.5, 2010 and ATTF: Table C5, 2010). The *Gasoline* fuel use attributed to *Light Trucks* is calculated to contain 6,900 trBTUs of energy including ethanol blended as an oxygenate.

Gasoline -> Medium & Heavy Trucks

Medium & Heavy Trucks used 4.1 billion gallons of gasoline and 46 thousand gallons of gasoline blended into E85 fuel in 2005 (TEDB: Table A.6, 2010 and ATTF: Table C5, 2010). The *Gasoline* fuel use attributed to *Medium & Heavy Trucks* is calculated to contain 510 trBTUs of energy.

Gasoline -> Transit Buses

Transit Buses used 1.0 million gallons of *Gasoline* in 2005 (TEDB: Table A.3, 2010). The *Gasoline* fuel use attributed to *Transit Buses* is calculated to contain 0.12 trBTUs of energy.

Gasoline -> Intercity & School Buses
Intercity & School Buses used 53 million gallons of *Gasoline* in 2005 (TEDB: Table A.4, 2010). The *Gasoline* fuel use attributed to *Intercity & School Buses* is calculated to contain 6.6 trBTUs of energy.

Gasoline -> General Aviation
General Aviation used 320 million gallons of aviation gasoline in 2005 (TEDB: Table A.7, 2010). While the actual formulation of aviation gasoline is different from gasoline used in *Automobiles* and *Light Trucks*, the energy content of the fuel is similar. Because of this, Aviation Gasoline is included on this flowchart as *Gasoline*. The *Gasoline* fuel use attributed to *General Aviation* is calculated to contain 39 trBTUs of energy.

Gasoline -> Recreational Boating
Recreational Boating used 1.6 billion gallons of *Gasoline* in 2005 (TEDB: Table A.10, 2010). The *Gasoline* fuel use attributed to *Recreational Boating* is calculated to contain 200 trBTUs of energy.

Jet Fuel:
Jet Fuel -> General Aviation
General Aviation used 1.5 billion gallons of *Jet Fuel* in 2005 (TEDB: Table A.7, 2010). The *Jet Fuel* use attributed to *General Aviation* is calculated to contain 200 trBTUs of energy.

Jet Fuel -> Commercial Aircraft
Commercial Aircraft include commercial passenger carriers and air freight carriers, and the fuel use described in this flowchart encompasses domestic and international departures. *Commercial Aircraft* used 19 billion gallons of *Jet Fuel* in 2005 (TEDB: Table A.8, 2010). The *Jet Fuel* use attributed to *Commercial Aircraft* is calculated to contain 2,600 trBTUs of energy.

Diesel & Distillate Fuel Oil:
Diesel & Distillate Fuel Oil -> Automobiles
Automobiles used 390 million gallons of *Diesel Fuel* in 2005 (TEDB: Table A.1, 2010). The *Diesel & Distillate Fuel Oil* fuel use attributed to *Automobiles* is calculated to contain 54 trBTUs of energy.

Diesel & Distillate Fuel Oil -> Light Trucks
Light Trucks used 2.4 billion gallons of *Diesel Fuel* in 2005 (TEDB: Table A.5, 2010). The *Diesel & Distillate Fuel Oil* fuel use attributed to *Light Trucks* is calculated to contain 330 trBTUs of energy.

Diesel & Distillate Fuel Oil -> Medium & Heavy Trucks
Medium & Heavy Trucks used 33 billion gallons of *Diesel Fuel* in 2005 (TEDB: Table A.6, 2010). The *Diesel & Distillate Fuel Oil* fuel use attributed to *Medium & Heavy Trucks* is calculated to contain 4,600 trBTUs of energy.

Diesel & Distillate Fuel Oil -> Transit Buses
Transit Buses used 530 million gallons of *Diesel Fuel* in 2005 (TEDB: Table A.3, 2010). The *Diesel & Distillate Fuel Oil* fuel use attributed to *Transit Buses* is calculated to contain 74 trBTUs of energy.

Diesel & Distillate Fuel Oil -> Intercity & School Buses
Intercity & School Buses used 690 million gallons of *Diesel Fuel* in 2005 (TEDB: Table A.4, 2010). The *Diesel & Distillate Fuel Oil* fuel use attributed to *Intercity & School Buses* is calculated to contain 96 trBTUs of energy.

Diesel & Distillate Fuel Oil -> Passenger Rail
Passenger Rail used 140 million gallons of *Diesel Fuel* in 2005 (TEDB: Tables A.13-A.15, 2010). The *Diesel & Distillate Fuel Oil* fuel use attributed to *Passenger Rail* is calculated to contain 20 trBTUs of energy.

Diesel & Distillate Fuel Oil -> Freight Rail
Freight Rail used 4.1 billion gallons of *Diesel Fuel* in 2005 (TEDB: Table A.12, 2010). The *Diesel & Distillate Fuel Oil* fuel use attributed to *Freight Rail* is calculated to contain 570 trBTUs of energy.

Diesel & Distillate Fuel Oil -> Recreational Boating
Recreational Boating used 300 million gallons of *Distillate Fuel Oil* in 2005 (TEDB: Table A.10, 2010). The *Diesel & Distillate Fuel Oil* fuel use attributed to *Recreational Boating* is calculated to contain 42 trBTUs of energy.

Diesel & Distillate Fuel Oil -> Commercial Shipping
Commercial Shipping used 2.1 billion gallons of *Distillate Fuel Oil* in 2005 (TEDB: Table A.9, 2010). The *Diesel & Distillate Fuel Oil* fuel use attributed to *Commercial Shipping* is calculated to contain 290 trBTUs of energy.

Residual Fuel Oil:
Residual Fuel Oil -> Commercial Shipping
Commercial Shipping used 5.5 billion gallons of *Residual Fuel Oil* in 2005 during international as well as domestic departures (TEDB: Table A.9, 2010). The *Residual Fuel Oil* fuel use attributed to *Commercial Shipping* is calculated to contain 830 trBTUs of energy.

Refined Fuels Production:
The fuels described above are manufactured from energy resources present in the environment. In some cases (e.g. petroleum refining) entire industrial sectors exist primarily to support the production of transportation fuels. In other cases (e.g. electricity production) transportation consumes a small fraction of the sector's output. In all cases, the quantities depicted here pertain only to the portion of fuel consumed by the transportation sector.

All transportation fuels depend on a chain of energy transformations beginning with resource extraction and ending with final fuel production. This analysis depicts that final step, and excludes all steps

upstream of manufacture. This choice in system boundaries creates some "overlap" with other energy flow chart analyses.

Biomass Refining

The biofuels sector is comprised of ethanol manufacturing and biodiesel manufacturing.

Biomass Refining -> Ethanol

The amount of *Ethanol* consumed by vehicles in 2005 is reported as 38 million gasoline-equivalent gallons of E85 of which 85% is *Ethanol* and 2.8 billion gasoline equivalent-gallons of *Ethanol* used in oxygenated gasoline in 2005 (TEDB Table 2.3, 2010). From these quantities, the energy from *Biomass Refining* transformed into *Ethanol* is calculated to be 350 trBTUs in 2005.

Biomass Refining -> Biodiesel

The amount of *Biodiesel* used as an alternative fuel in 2005 is reported as 92 million gasoline-equivalent gallons (TEDB Table 2.3, 2010). With 125,000 BTUs per gasoline-equivalent gallon, the energy from *Biomass Refining* transformed into *Biodiesel* is calculated to be 11 trBTUs in 2005.

Natural Gas Refining

Transportation fuels derived from natural gas include Compressed Natural Gas (CNG), Liquefied Natural Gas (LNG), methanol and hydrogen. Natural gas is also consumed directly at pipeline compression stations – after it has undergone processing but before it is packaged for consumption by other parts of the transportation sector.

Natural Gas Refining -> Hydrogen

The amount of *Hydrogen* used as an alternative fuel in 2005 is estimated as 25 thousand gasoline-equivalent gallons (TEDB Table 2.3, 2010). Most hydrogen is produced via the steam reforming of natural gas. The energy from *Natural Gas Refining* transformed into *Hydrogen* is calculated to be 0.0031 trBTUs.

Natural Gas Refining -> CNG

The amount of *CNG* used as an alternative fuel in 2005 is estimated as 170 million gasoline-equivalent gallons (TEDB Table 2.3, 2010). From this, the energy from *Natural Gas Refining* transformed into *CNG* is calculated to be 21 trBTUs in 2005.

Natural Gas Refining -> Methanol

The amount of *Methanol* used as an alternative fuel in 2005 is reported as 8.1 million gallons (TEDB: Table A.3, 2010). The energy from *Natural Gas Refining* transformed into *Methanol* is calculated to be 0.52 trBTUs in 2005.

Natural Gas Refining -> LNG

The amount of *LNG* used as an alternative fuel in 2005 is reported as 22 million gasoline-equivalent gallons (TEDB: Table 2.3, 2010). The energy from *Natural Gas Refining* transformed into *LNG* is calculated to be 2.8 trBTUs.

Natural Gas Refining -> Pipeline

Fuels are moved throughout the United States using pipelines. In 2005, the transportation of these fuels used 580 billion cubic feet of *Natural Gas* (600 trBTUs) and 2.6 billion kilowatt hours of electricity (24 trBTUs). The fuel from *Natural Gas Refining* attributed to transporting fuels by *Pipeline* is calculated to be 600 trBTUs of energy.

Petroleum Refining

Petroleum Refining -> LPG

The amount of *LPG* used in the transportation sector in 2005 is reported as 660 million gallons (TEDB: Tables A.3, A.5, and A.6, 2010). Therefore, the energy from *Petroleum Refining* transformed into *LPG* is calculated to be 60 tBTUs.

Petroleum Refining -> Gasoline

The amount of *Gasoline* used in 2005 is reported as 95 billion gallons: 93 billion gallons as gasoline, 5.7 million gallons as the gasoline portion of E85, and 44 billion gallons as oxygenated gasoline- also referred to as gasohol (TEDB: Tables 2.3 and Appendix A, 2010). Therefore, the energy from *Petroleum Refining* transformed into *Gasoline* is calculated to be 17,000 trBTUs including the gasoline portion of E85 (TEDB, 2008).

Petroleum Refining -> Jet Fuel

The amount of *Jet Fuel* used in 2005 is reported as 21 billion gallons (TEDB: Tables A.7 and A.8, 2010). The energy from *Petroleum Refining* transformed into *Jet Fuel* is calculated to be 2,800 trBTUs in 2005 (TEDB, 2010).

Petroleum Refining -> Diesel & Distillate Fuel Oils

The amount of *Diesel & Distillate Fuel Oils* used in 2005 is reported as 44 billion gallons (TEDB: Tables A.1, A.3-A.6, A.9-A.10, A.12-A.13, and A.15, 2010). The energy from *Petroleum Refining* transformed into *Diesel & Distillate Fuel Oils* is calculated to be 6,000 trBTUs in 2005 (TEDB, 2010).

Petroleum Refining ->Residual Fuel Oil

The amount of *Residual Fuel Oil* used in 2005 is reported as 5.5 billion gallons (TEDB: Tables A.9, 2010). The energy from *Petroleum Refining* transformed into *Residual Fuel Oil* is calculated to be 830 trBTUs in 2005 (TEDB, 2010).

Energy Disposition:

Energy Services
This value is estimated as the sum of all propulsive and other useful work from transportation activities including *Automobiles, Motorcycles, Light Trucks, Medium & Heavy Trucks, Transit Buses, Intercity & School Buses, Pipeline, General Aviation, Commercial Aircraft, Passenger Rail, Freight Rail, Recreational Boating*, and *Commercial Shipping*.

Rejected Energy
Rejected energy represents the energy consumed by the transportation sector, which is not converted to propulsive or other useful work. This is the sum of all *Rejected Energy* from all transportation activities including *Automobiles, Motorcycles, Light Trucks, Medium & Heavy Trucks, Transit Buses, Intercity & School Buses, Pipeline, General Aviation, Commercial Aircraft, Passenger Rail, Freight Rail, Recreational Boating*, and *Commercial Shipping*.

Energy Services
Energy services in the transportation sector can be approximated by the sum of propulsive work (the mechanical work required to overcome aerodynamic drag, rolling resistance and vehicle inertia) and other useful work (minimum work required to run auxiliary and accessory loads in vehicles). In this analysis, we have assumed that all auxiliary and accessory services are delivered at 50% efficiency (i.e. 50% of energy delivered to auxiliary and accessory loads is a service, while the remainder is rejected).

Automobiles -> Energy Services
Energy use by *Automobiles* for combined city and highway driving has been estimated using the following percentages: 70 - 72% to engine losses, 3% to standby or idling, 5 - 6% to accessories, 8 - 10% to aerodynamic drag, 5 - 6% to rolling resistance, 5 - 6% to drivetrain losses, and 4 - 5% to braking (Fuel Economy, 2011). Defining useful energy to include the energy necessary to overcome aerodynamic drag, rolling resistance, braking, and half of the energy used by accessories, using the average percentages of the provided ranges, 22% of the total energy is attributed to *Energy Services*. Therefore, the flow from *Automobiles* to *Energy Services* is calculated as 2,100 trBTUs.

Motorcycles -> Energy Services
The energy efficiency of *Motorcycles* powered by gasoline is reported to be 15% (Chiu, 1999). Therefore, the flow from *Motorcycles* to *Energy Services* is calculated as 15% of the energy from *Motorcycles,* or 3.5 trBTUs.

Light Trucks -> Energy Services
The energy efficiency of *Light Trucks* is estimated by assuming the percent of useful work accomplished by *Light Trucks* is equivalent to that of *Automobiles*. Therefore, the total energy efficiency for *Light Trucks* is 22% and the flow from *Light Trucks* to *Energy Services* is calculated as 22% of the energy from *Light Trucks,* or 1,600 trBTUs.

Medium &Heavy Trucks -> Energy Services
Energy use by *Medium & Heavy Trucks* is estimated using the following percentages: 60% to engine losses, 21% to aerodynamic drag, 13% to rolling resistance, 4% to auxiliary losses, and 2% to drivetrain (US CCTP, 2003). Defining useful energy services as the energy needed to overcome the aerodynamic drag, rolling resistance, half the auxiliary losses, and drivetrain, the percentage of useful energy for *Medium & Heavy Trucks* is 38%. Therefore, the flow from *Medium & Heavy Trucks* to *Energy Services* is calculated to be 1,900 trBTUs.

Transit Buses -> Energy Services
The energy use by different functions in *Transit Buses* has been analyzed as a function of speed ranging from 20 – 50 miles per hour (mph) (Delorme, 2010). For this analysis, the energy usage by *Transit Buses* is calculated for a speed of 20 mph, assumed to be representative of average operating conditions. At a speed of 20 mph, 61% of the energy is consumed by engine losses, 20.5% by accessories, 1.8% by transmission, 0.1% by axles, 14.4% by rolling resistance, and 2.2% by aerodynamic drag. The energy efficiency of *Transit Buses* is estimated by summing the contributions from rolling resistance, aerodynamic drag, and half of the accessories for a total of 27%. Therefore, the flow from *Transit Buses* to *Energy Services* is calculated to be 25 trBTUs.

Intercity & School Buses -> Energy Services
For this analysis, the energy efficiency for *Intercity & School Buses* is estimated by using the energy distribution calculated for *Transit Buses* at a speed of 20 mph for School Buses and 50 mph for Intercity Buses (Delorme, 2010). Similar to *Transit Buses*, the *Energy Services* for School Buses traveling at an average of 20 mph is estimated to be 27%. The total energy used by School Buses is 73 trBTUs, therefore the flow from School Buses to *Energy Services* is calculated to be 20 trBTUs.

At a speed of 50 mph, 59% of the energy in Intercity Buses is consumed by engine losses, 8% by accessories, 1.1% by transmission, 1.0% by axles, 16% by rolling resistance, and 15% by aerodynamic drag. The energy efficiency of Intercity Buses is estimated by summing the contributions from rolling resistance, aerodynamic drag, and half of the energy used by accessories for a total of 35%. The total energy used by Intercity Buses is 30 trBTUs, therefore the flow from Intercity Buses to *Energy Services* is calculated as 10 trBTUs.

The total flow from *Intercity & School Buses* to *Energy Services* is the sum of these two flows for a weighted average of 29% energy efficiency, or 30 trBTUs.

Pipeline -> Energy Services
The energy service provided by the *Pipeline* sector is equal to the work done overcoming fluid friction within the pipelines. The energy efficiency in *Pipeline* is estimated to be 30%, about the efficiency of a compressor powered by a natural gas engine (Leslie, 2009). Therefore, the flow from *Pipeline* to *Energy Services* is calculated as 30% of the energy from *Pipeline,* or 190 trBTUs.

General Aviation -> Energy Services

The most efficient aircraft have a thermal efficiency of 55 - 60% and propulsive efficiency of 65 - 70% (Schafer, 2009). A separate source finds the thermal efficiency of small aircraft to be 30% (Paulus, 2003). Because the fleet of aircraft used in *General Aviation* is assumed to have lower efficiencies than the most efficient aircraft, the overall energy efficiency is estimated using 40% thermal efficiency (between the thermal efficiencies of the two sources) and 60% propulsive efficiency or 40% x 60%, for an overall efficiency of 24%. Therefore, the flow from *General Aviation* to *Energy Services* is calculated to be 58 trBTUs.

Commercial Aircraft -> Energy Services

The most efficient aircraft have a thermal efficiency of 55 - 60% and propulsive efficiency of 65 - 70% (Schafer, 2009). To take into account less efficient aircraft, the efficiencies for *Commercial Aircraft* are estimated using the percentages at the low end of the ranges or 55% x 65%, for an overall efficiency of 36%. Therefore, the flow from *Commercial Aircraft* to *Energy Services* is calculated to be 930 trBTUs.

Passenger Rail -> Energy Services

The energy efficiency for *Passenger Rail* varies significantly for trains fueled by diesel fuel or electricity; both fuels are used in significant amounts. *Passenger Rail* electric engines used 66 trBTUs of energy as electricity in 2005, which are 65% efficient (Lindgreen, 2005). *Passenger Rail* diesel engines used 20 trBTUs of energy as diesel fuel in 2005, the efficiency of which are assumed to be equivalent to Freight Rail at 30% (Lindgreen, 2005). The overall energy efficiency in *Passenger Rail* is calculated to be 57% from a weighted average. Therefore, the flow from *Passenger Rail* to *Energy Services* is calculated to be 49 trBTUs.

Freight Rail -> Energy Services

The energy efficiency of *Freight Rail* using diesel engines is estimated to be 30% (Lindgreen, 2005). Therefore, the flow from *Freight Rail* to *Energy Services* is calculated to be 170 trBTUs.

Recreational Boating -> Energy Services

The propulsive coefficient of marine pleasure craft is reported as 66% and the thermal efficiency of marine gasoline engines is reported to be between 25 - 35% (AEA, 2008). The energy efficiency of Recreational Boating is estimated to be 66% x 30%, for an overall efficiency of 20%. Therefore, the flow from *Recreational Boating* to *Energy Services* is calculated to be 49 trBTUs.

Commercial Shipping -> Energy Services

The propulsive coefficient (ratio of the effective power to the power measured at the thrust block) of merchant ships is reported as ranging between 60 - 70% (Barrass, 2004). The thermal efficiency of marine diesel engines is reported to be 45% (Rowen, 2008). Therefore, the energy efficiency of *Commercial Shipping* is estimated to be 65% x 45%, for an overall efficiency of 29%. Therefore, the flow from *Commercial Shipping* to *Energy Services* is calculated to be 330 trBTUs.

Rejected Energy

Energy rejected from the transportation sector includes all of the energy rejected (usually as waste heat or drivetrain losses) from the operation of vehicles and their accessories. This analysis also includes the energy rejected as waste heat or materials from the final manufacturing step in the fuels production supply chains.

Automobiles -> Rejected Energy

As described above, *Automobiles* are estimated to have an efficiency of 22%. Therefore, the flow from *Automobiles* to *Rejected Energy* is calculated as 78% of the energy from *Automobiles*, or 7,500 trBTUs.

Motorcycles ->Rejected Energy

As described above, *Motorcycles* are estimated to have an efficiency of 15%. Therefore, the flow from *Motorcycles* to *Rejected Energy* is calculated as 85% of the energy from *Motorcycles,* or 20 trBTUs.

Light Trucks -> Rejected Energy

As described above, *Light Trucks* are estimated to have an efficiency of 22%. Therefore, the flow from *Light Trucks* to *Rejected Energy* is calculated as 78% of the energy from *Light Trucks,* or 5,700 trBTUs.

Medium & Heavy Trucks -> Rejected Energy

As described above, *Medium & Heavy Trucks* are estimated to have an efficiency of 38%. Therefore, the energy flow from *Medium & Heavy Trucks* to *Rejected Energy* is calculated as 62% of the energy from *Medium & Heavy Trucks,* or 3,200 trBTUs.

Transit Buses -> Rejected Energy

As described above, *Transit Buses* are estimated to have an efficiency of 27%. Therefore, the energy flow from *Transit Buses* to *Rejected Energy* is calculated as 73% of the energy from *Transit Buses*, or 67 trBTUs.

Intercity & School Buses -> Rejected Energy

As described above, *Intercity & School Buses* are estimated to have a weighted energy efficiency of 29%. Therefore, the energy flow from *Intercity & School Buses* to *Rejected Energy* is calculated as 71% of the energy from *Intercity & School Buses,* or 73 trBTUs.

Pipeline -> Rejected Energy

As described above, *Pipeline* is estimated to have an efficiency of 30%. Therefore, the flow from *Pipeline* to *Rejected Energy* is calculated as 70% of the energy from *Pipeline,* or 440 trBTUs.

General Aviation -> Rejected Energy

As described above, *General Aviation is* estimated to have an efficiency of 24%. Therefore, the flow from *General Aviation* to *Rejected Energy* is calculated as 76% of the energy from *General Aviation,* or 180 trBTUs.

Commercial Aircraft -> Rejected Energy
As described above, *Commercial Aircraft* are estimated to have an energy efficiency of 36%. Therefore, the flow from *Commercial Aircraft* to *Rejected Energy* is calculated as 64% of the energy from *Commercial Aircraft,* or 1,700 trBTUs.

Passenger Rail -> Rejected Energy
As described above, *Passenger Rail* is estimated to have a weighted energy efficiency of 57%. Therefore, the flow from *Passenger Rail* to *Rejected Energy* is calculated as 43% of the energy from *Passenger Rail,* or 37 trBTUs.

Freight Rail -> Rejected Energy
As described above, *Freight Rail* is estimated to have an energy efficiency of 30%. Therefore, the flow from *Freight Rail* to *Rejected Energy* is 70% of the energy from *Freight Rail,* or 400 trBTUs.

Recreational Boating -> Rejected Energy
As described above, *Recreational Boating* is estimated to have an energy efficiency of 20%. The flow from *Recreational Boating* to *Rejected Energy* is calculated as 80% of the energy from *Recreational Boating,* or 200 trBTUs.

Commercial Shipping -> Rejected Energy
As described above, *Commercial Shipping* is estimated to have an energy efficiency of 29%. The flow from *Commercial Shipping* to *Rejected Energy* is calculated as 71% of the energy from *Commercial Shipping, o*r 800 trBTUs.

Electricity Production -> Rejected Energy
Electricity Production efficiency ranges from 33-52% and electricity delivery losses are estimated at 8% of generated electricity. From these values, the total efficiency of *Electricity Production* is estimated to be 32%. Therefore, as 94 trBTUs of electricity are used by the transportation sector, the total energy required to produce this amount of electricity is 94 trBTUs / 32%, or 290 trBTUs. Therefore, the energy flow from *Electricity* to *Rejected Energy* is calculated as 290 – 94 trBTUs, or 200 trBTUs.

Biomass Refining -> Rejected Energy
The processing of *Ethanol* by dry mill from corn uses 202,000 BTUs per gallon: 153,000 BTUs present in corn and 49,000 BTUs used to convert the corn into *Ethanol* (PennState, 2009; Rowlett, 2001; Shapouri, 2002). This process produces one gallon of *Ethanol* containing 76,000 BTUs using a dry mill (Shapouri, 2002; TEDB, 2010). Therefore, the processing of ethanol is estimated to be 38% efficient.

In comparison, 390,000 BTUs of energy are consumed during the processing of one gallon of *Biodiesel* from soybeans: 350,000 BTUs present in soybeans (Mourad, 2011; Conley, 2006), 23,200 BTUs in

soybean crushing, and 18,800 BTUs in *Biodiesel* conversion (Pradhan, 2009).[7] The product, 1 gallon of *Biodiesel*, contains 120,000 BTUs (TEDB, 2010). *Biodiesel* processing is estimated to be 31% efficient.

Given the useful energy of 350 trBTUs in ethanol and 11 trBTUs in biodiesel, the *Rejected Energy* from *Biomass Refining* is calculated as (350 / 38% - 350) or 571 trBTUs from ethanol conversion and (11 / 31% - 11) or 24 trBTUs from biodiesel conversion. The total flow from Biomass Refining to Rejected Energy is the sum of these two flows, 590 trBTUs.

Natural Gas Refining -> Rejected Energy
In 2007, the processing of natural gas in North America was estimated as 97.2% efficient (CEC, 2007). Natural gas liquefaction and compression incur additional losses, as do the production of hydrogen or methanol from natural gas. However, because 96% of natural gas use in transportation consumes gas directly from the pipelines, those processing losses are negligible. Therefore, the energy flow from *Natural Gas Refining* to *Rejected Energy* is calculated as 2.8% of the total energy, 18 trBTUs.

Petroleum Refining -> Rejected Energy
Using a top-down approach, the efficiency of *Petroleum Refining* is calculated using the energy and material inputs and outputs. The inputs in *Petroleum Refining* for the transportation sector are estimated to be 27,000 trBTUs in 2005: 25,000 trBTUs of crude oil (Refinery Receipts, 2010), 100 trBTUs of electricity, 600 trBTUs of natural gas, 1,200 trBTUs of still gas, 450 trBTUs of petroleum coke, and 50 trBTUs of steam (U.S. EIA, 2010). The products have energy contents of 25,000 trBTUs. From this calculation, the *Petroleum Refining* process is estimated to be 91% efficient. Using the bottom-up approach to calculating energy present in petroleum products used in the transportation sector in 2005, the total energy flow to products is 27,000 trBTUs. Therefore, the energy flow from *Petroleum Refining* to *Rejected Energy* is calculated from 27,000 / 91.5% - 27,000, or 2,500 trBTUs.

Fuel production Sector:
Electricity Production:
Electricity Production represents the sum of electricity used by *Automobiles*, *Medium & Heavy Trucks*, *Transit Buses*, *Pipeline*, and *Passenger Rail* and the energy rejected in producing this electricity. The total energy flow through *Electricity Production* in 2005 is 290 trBTUs.

Biomass Refining:
Biomass Refining represents the energy delivered to *Automobiles, Light Trucks, Medium & Heavy Trucks*, and *Transit Buses* via ethanol fuel (E85), biodiesel and ethanol blended into gasoline. It also includes the energy rejected in the manufacture of those fuels. The total energy flow through *Biomass Refining* in 2005 is therefore 950 trBTUs.

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[7] These calculations do not remove the energy associated with making co-products including soybean meal and crude glycerin. Removing the energy associated with making these products would greatly increase the efficiency of this *Biomass Refining* of *Biodiesel*.

Natural Gas Refining:

Natural Gas Refining represents the fuel and energy used to produce *Hydrogen*, *Compressed Natural Gas* (CNG), *Methanol*, *Liquefied Natural Gas* (LNG), along with the natural gas used in *Pipeline* activities in the transportation sector and the energy rejected in producing these products. In 2005, 23 billion cubic feet of natural gas (24 trBTUs) were used to power vehicles, while 580 billion cubic feet (600 trBTUs) were used to power compression stations in the natural gas transmission and distribution systems (NGCEU, 2011), and 18 trBTUs were rejected, for a total of 640 trBTUs.

Petroleum Refining:

Petroleum Refining represents the fuel and energy used to produce *Liquefied Petroleum Gas* (LPG), *Gasoline*, *Jet Fuel*, *Diesel & Distillate Fuel Oil*, and *Residual Fuel Oil* for the transportation sector. It also includes the 2,500 trBTUs rejected in the manufacturing of these fuels. The energy flow through *Petroleum Refining* in 2005 is therefore 29,000 trBTUs.

Conclusion

The flow chart described in this report is a compact depiction of the national energy use in the transportation sector in 2005. This diagram is available at: http://flowcharts.llnl.gov

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Appendix

Conversions used (TEDB, 2010):

Gasoline-equivalent	125,000	BTUs/gasoline equivalent gallon
Diesel-equivalent	138,700	BTUs/diesel-equivalent gallon
Ethanol	75,700	BTUs/gallon of ethanol
Biodiesel	117,100	BTUs/gallon of biodiesel
Methanol	64,600	BTUs/gallon of methanol
Natural Gas	1,031	BTUs/cubic foot of natural gas
LNG	90,800	BTUs/gallon of LNG
LPG	91,300	BTUs/gallon of LPG
Gasoline	125,000	BTUs/gallon of gasoline
Gasohol	120,900	BTUs/gallon of gasohol
Aviation Gasoline	120,200	BTUs/gallon of aviation gasoline
Jet Fuel	135,000	BTUs/gallon of jet fuel
Diesel Fuel	138,700	BTUs/gallon of diesel fuel
Distillate Fuel Oil	138,700	BTUs/gallon of distillate fuel oil
Residual Fuel Oil	149,700	BTUs/gallon of residual fuel oil
Electricity	10,339	BTUs/kW-hr

Glossary

Fuels:

Ethanol:

Ethanol is refined from *Biomass*. This fuel represents the *Ethanol* in E85 used by *Automobiles, Light Trucks*, and *Medium & Heavy Trucks* and *Ethanol* used as a blending component in *Gasoline*.

Biodiesel:

Biodiesel is produced from *Biomass Refining* and is used by *Automobiles*, *Light Trucks*, and *Transit Buses*.

Hydrogen:

In 2005, Hydrogen was produced by steam-reforming of natural gas. *Hydrogen* is used to fuel *Automobiles and Transit Buses*.

Compressed Natural Gas (CNG):

CNG is refined and compressed from Natural Gas and is used by *Automobiles, Light Trucks, Medium & Heavy Trucks,* and *Transit Buses*.

Methanol:

Methanol is refined from *Natural Gas* and is used by *Transit Buses*.

Liquefied Natural Gas (LNG):

LNG is refined from *Natural Gas* and is used by *Light Trucks*, *Medium & Heavy Trucks*, and *Transit Buses*.

Liquefied Petroleum Gas (LPG):

LPG is refined from *Petroleum* and is used by *Light Trucks, Medium & Heavy Trucks,* and *Transit Buses*.

Gasoline:

Gasoline is refined from *Petroleum* and is used by *Automobiles, Motorcycles, Light Trucks, Medium/Heavy Trucks, Transit Buses, Intercity & School Buses, General Aviation*, and *Recreational Boating*.

Jet Fuel:

Jet Fuel is refined from *Petroleum* and is used by *General Aviation* and *Commercial Aircraft*.

Diesel & Distillate Fuel Oils:

Diesel & Distillate Fuel Oils are refined from *Petroleum* and are used by *Automobiles, Light Trucks, Medium & Heavy Trucks, Transit Buses, Intercity & School Buses, Passenger Rail, Freight Rail, Recreational Boating*, and *Commercial Shipping*.

Residual Fuel Oil:

Residual Fuel Oil is refined from *Petroleum* and is used by *Commercial Shipping*.

Energy Use:

Light-duty vehicles
Light duty vehicles include motorcycles, automobiles, and light trucks.

Automobiles
The energy used by *Automobiles* is calculated as the sum of flows from *Electricity Production, Ethanol, Biodiesel, Hydrogen, CNG, LNG, LPG, Gasoline*, and *Diesel & Distillate Fuel Oils*.

Motorcycles
The energy used by *Motorcycles* is equal to the flow from *Gasoline*.

Light trucks
The energy used by *Light Trucks* is calculated as the sum of flows from *Ethanol*, *Gasoline*, and *Diesel & Distillate Fuel Oils*.

Medium & Heavy Trucks
The energy used by *Medium & Heavy Trucks* is calculated as the sum of flows from *Gasoline* and *Diesel & Distillate Fuel Oils*.

Transit Buses
The energy used by *Transit Buses* is calculated as the sum of flows from *Electricity Production*, *CNG*, *Methanol*, *LNG*, *LPG*, *Gasoline*, and *Diesel & Distillate Fuel Oils*.

Intercity & School Buses
The energy used by *Intercity & School Buses* is calculated as the sum of flows from *Gasoline* and *Diesel & Distillate Fuel Oils*.

Pipeline
The energy used by *Pipeline* is calculated as the sum of flows from *Electricity Production* and *Natural Gas Refining*.

General Aviation
The energy used by *General Aviation* is calculated as the sum of flows from *Gasoline* and *Jet Fuel*.

Commercial Aircraft
The energy used by *Commercial Aircraft* is equal to the flow from *Jet Fuel* and includes activities for domestic and all international air carriers.

Passenger Rail:
The energy used by *Passenger Rail* is equal to the flow from *Diesel & Distillate Fuel Oils* and includes both transit, intercity, and commuter rail operations.

Freight Rail:
The energy used by *Freight Rail* is equal to the flow from *Diesel & Distillate Fuel Oils*.

Recreational Boating:
The energy used by *Recreational Boating* is calculated as the sum of flows from *Gasoline* and *Diesel & Distillate Fuel Oils*.

Commercial Shipping:
The energy used by *Commercial Shipping*, also referred to as *Vessel Bunkering,* is calculated as the sum of flows from *Diesel & Distillate Fuel Oils* and *Residual Fuel Oil* and includes fuel use for both domestic and international activities.