Section 5. Renewable energy

Renewable energy production in SEDS includes biofuels (biodiesel, fuel ethanol, renewable diesel, and other biofuels), wood and waste, and noncombustible renewable energy sources (hydroelectric power, and geothermal, solar, and wind energy).

Biofuels

SEDS estimates annual state-level production for three biofuels: biodiesel, fuel ethanol, and renewable diesel. SEDS estimates annual US-level production for other biofuels. SEDS also estimates the losses and co-products[1] associated with biodiesel and fuel ethanol separately.

Biodiesel

Production in physical units

For 2001 forward, EIA publishes U.S.-level biodiesel production data in the *Monthly Energy Review* (MER) and SEDS estimates state-level biodiesel production. When available, SEDS uses state reported biodiesel production data. For states without reported data, SEDS estimates state-level biodiesel production using data from EIA's *Monthly Biodiesel Production Report* and other sources.

Some states publish biodiesel production data for some years. These states include Iowa (2005 forward), Michigan (2018), Minnesota (2005-2009 and 2012-2016, with 2010 and 2011 assumed to equal the 2012 value), Montana (2016 forward), North Dakota (2016 and 2018 forward), and Virginia (2008 forward).

For 2009 forward, SEDS uses published and unpublished data from EIA Form EIA-22M, "Monthly Biodiesel Production Survey" (2009 through 2020) and Form EIA-819, "Monthly Report of Biofuels, Fuels from Non-Biogenic Wastes, Fuel Oxygenates, Isooctane, and Isooctene" (2021 forward) to estimate production of the states with no published data. The *Monthly Biodiesel Production Report*, generated from the survey, publishes production data by Petroleum Administration for Defense District (PADD) and capacity data by state for 2009 forward. Because of the volatility of biodiesel production, instead of nameplate capacity, SEDS uses unpublished monthly data on plant-level operating status to compute an annual average "operating capacity" for each plant and aggregate them to the state level. SEDS uses operating capacity data for 2014 for 2013. To estimate missing state production, SEDS subtracts the available state biodiesel production data from the total production of the corresponding PADD and allocates the remainder to the other states in the PADD using the share of the state's operating capacity.

For 2001 through 2008, PADD-level production data do not exist and nameplate capacity data are sporadic. SEDS uses the reported production data from specific states and estimates the rest as follows. First, SEDS computes a set of operating capacity estimates by state for 2001 through 2008 using the 2009 operating capacity data and information on start date and capacity expansion for individual plants. Then, SEDS subtracts the available state biodiesel production data from the U.S. total and allocates the remainder to the other states proportionally to the share of the state's operating capacity.

Heat content of biomass inputs to the production of biodiesel

To convert biodiesel production to British thermal units (Btu), SEDS uses EIA's biodiesel thermal conversion factor of 5.359 million Btu per barrel, as listed in MER, Appendix A.

Because biodiesel is produced from soybeans, corn, and other biomass inputs, EIA defines the total heat content of biofuel from biodiesel to be the total biomass inputs (feedstock) used to produce biodiesel. At the national level, EIA uses soybean oil input to the production of biodiesel (million Btu soybean oil per barrel biodiesel) as the factor to estimate total biomass inputs to the production of biodiesel. EIA defines losses and co-products from biodiesel production as total biomass inputs minus biodiesel produced.

SEDS allocates the MER U.S.-level losses and co-products from biodiesel production to the states using the

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[3] Losses and co-products are the difference between the heat content of the biomass inputs (feedstock such as corn and soy) to the production of biofuels and the heat content of the biofuels produced.

state-level biodiesel production estimates. The state total heat content of biomass inputs to the production of biodiesel is the sum of the Btu values of biodiesel production and the losses and co-products.

Variable names and definitions

The independent data series identifying codes for biodiesel data are ("ZZ" represents the two-letter state code in the variable names):

BDPRPUS	=	biodiesel liquids production, in thousand barrels, United States;
BDPRPZZ	=	biodiesel liquids production, in thousand barrels, by state; and
BDLCBUS	=	energy losses and co-products from the production of biodiesel, in billion Btu, United States.

The heat content data series are:

BDPRBZZ	=	biodiesel liquids production, in billion Btu, by state
	=	BDPRPZZ * 5.359
BDLCBZZ	=	energy losses and co-products from the production of biodiesel, in billion Btu, by state
	=	BDLCBUS * (BDPRBZZ / BDPRBUS)
BDFDBZZ	=	biodiesel production (total biomass inputs as feedstock), including liquids and losses & co-products, in billion Btu, by state
	=	BDPRBZZ + BDLCBZZ

The U.S. totals that are not from external sources are the sum of the states' values:

BDPRBUS	=	ΣBDPRBZZ
BDFDBUS	=	ΣBDFDBZZ

Data sources

BDPRPUS — Biodiesel liquids production, in thousand barrels, United States.

- 2001 forward: EIA, *Monthly Energy Review*, Table 10.4a.

BDPRP (PADD-level) — Biodiesel liquids production, in million gallons, Petroleum Administration for Defense District.

- 2009 through 2020: EIA, *Monthly Biodiesel Production Report*, Table 5.

BDPRPZZ — Biodiesel liquids production, in thousand barrels, by state.

- 2021 forward: Production data from available state data sources and EIA estimates based on operating capacity data from EIA Form EIA-819, "Monthly Report of Biofuels, Fuels from Non-Biogenic Wastes, Fuel Oxygenates, Isooctane, and Isooctene."
- 2001 through 2020: Production data from available state data sources and EIA estimates based on operating capacity data from EIA Form EIA-22M, "Monthly Biodiesel Production Survey" and other sources.

BDLCBUS — Energy losses and co-products from the production of biodiesel, in billion Btu, United States.

- 2001 forward: EIA, *Monthly Energy Review*, Table 10.4a.

Fuel ethanol

Production in physical units

For 1981 forward, EIA publishes U.S.-level fuel ethanol production data in the *Monthly Energy Review* (MER) and SEDS estimates annual state-level fuel ethanol production. When available, SEDS uses reported fuel ethanol production data. For states without reported data, SEDS estimates state-level fuel ethanol production using data from various sources.

For 2010 forward, EIA estimates state-level fuel ethanol production for SEDS using data from Form EIA-819

"Monthly Report of Biofuels, Fuels from Non-Biogenic Wastes, Fuel Oxygenates, Isooctane, and Isooctene" and monthly plant-level operating production capacity from the Nebraska Energy Office. SEDS uses unpublished EIA-819 ethanol production data for 12 states in PADD 2 that would not result in the disclosure of identifiable data reported by operators using Form EIA-819. These 12 states in PADD 2 cover about 90% of total U.S. production.

For the remaining states, SEDS allocates the PADD region remainder proportionally to the states using their operating production capacity. SEDS uses monthly data on plant-level operating production capacity to compute the annual average state-level operating capacity. SEDS subtracts the available state fuel ethanol production data from the corresponding PADD total production and allocates the remainder to the other states in the PADD using the share of the state's operating capacity.

Before 2010, SEDS estimates state-level fuel ethanol production using state reported data and state-level operating production capacity estimates. SEDS obtained production data from Iowa and Washington (through 2009), and Minnesota, Nebraska, and South Dakota (through 2007).[2] These five states accounted for about two-thirds of total U.S. fuel ethanol production in 2007. SEDS allocates the remaining portion of the U.S. fuel ethanol production to the other states using state-level operating production capacity estimates.

SEDS compiles state-level operating capacity data from multiple sources. For 2005 through 2009, SEDS uses monthly plant-level data published by the Nebraska Energy Office (which were based on operating capacity data from the Renewable Fuels Association and plant locations for multi-state companies) to compile the annual average state-level operating capacity. SEDS also uses the January 2005 capacity data to approximate 2004 capacity. For 1992 through 1994, SEDS uses operating capacity data as of January 1, 1993 through 1995 published in EIA's *Petroleum Supply Annual*. For the remaining years, SEDS collects information on plant opening, expansion, and closing to estimate state-level capacity. When no information is available for a state, SEDS estimates capacity using linear interpolation for 1995 through 2003 and assumes capacity before 1992 to be the same as 1992.

Heat content of biomass inputs to the production of fuel ethanol

EIA defines the heat content of biofuel from fuel ethanol to be the total biomass inputs (feedstock, mostly corn) used to produce fuel ethanol. At the national level, EIA uses corn input to the production of fuel ethanol (million Btu corn per barrel fuel ethanol) as the factor to estimate total biomass inputs. The losses and co-products from fuel ethanol is equal to total biomass inputs minus fuel ethanol produced.

Before calculating the heat content of fuel ethanol produced, SEDS makes an adjustment to the fuel ethanol volume in physical units to remove the denaturant (typically natural gasoline added to the ethanol to make it unfit for human consumption). For 2009 forward, EIA's *Monthly Energy Review* estimates the volume of denaturant for the United States using survey data. Before 2009, EIA assumes the denaturant to be 2% of fuel ethanol production. SEDS applies the annual national adjustment ratio to the states.

SEDS converts the adjusted fuel ethanol production in physical units to Btu using EIA's undenatured ethanol thermal conversion factor of 3.539 million Btu per barrel. SEDS estimates state-level losses and co-products by applying the state fuel ethanol production shares to the national losses and co-products. The heat content of the biomass inputs to the production of fuel ethanol is equal to the sum of the fuel ethanol production and losses and co-products.

Variable names and definitions

The independent data series identifying codes for fuel ethanol data are ("ZZ" represents the two-letter state code in the variable names):

ENPRPUS = fuel ethanol production, including denaturant, in thousand barrels, United States;
ENPRPZZ = fuel ethanol production, including denaturant, in thousand barrels, by state;
EMPRPUS = fuel ethanol production, excluding denaturant, in thousand barrels, United States; and
EMLCBUS = energy losses and co-products from the production of fuel ethanol, in billion Btu, United States.

The computed data series are:

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[4] Some data in the earlier years for Minnesota, Nebraska, South Dakota, and Wisconsin are not available and SEDS estimates them using plant capacity information or with assumptions.

EMPRPZZ =   fuel ethanol production, excluding denaturant, in thousand barrels, by state
             =   ENPRPZZ * (EMPRPUS / ENPRPUS)
EMPRBZZ =   fuel ethanol production, excluding denaturant, in billion Btu, by state
             =   EMPRPZZ * 3.539
EMLCBZZ =   energy losses and co-products from the production of fuel ethanol, in billion Btu, by state
             =   EMLCBUS * (EMPRBZZ / EMPRBUS)
EMFDBZZ =   fuel ethanol production (total biomass inputs as feedstock), including liquids and losses & co-products, in billion Btu, by state
             =   EMPRBZZ + EMLCBZZ

The U.S. totals that are not from external sources are the sum of the states' values:

EMPRBUS = ΣEMPRBZZ
EMFDBUS = ΣEMFDBZZ

Data sources

ENPRPUS — Fuel ethanol production, including denaturant, in thousand barrels, United States.

EMPRPUS — Fuel ethanol production, excluding denaturant, in thousand barrels, United States.

EMLCBUS — Energy losses and co-products from the production of fuel ethanol, in billion Btu, United States.

- 1981 forward: EIA, *Monthly Energy Review*, Table 10.3.

ENPRPZZ — Fuel ethanol production, including denaturant, in thousand barrels, by state.

- 1981 through 2009: Based on monthly operating production capacity data from Nebraska Energy Office (https://neo.ne.gov/); production data (for selected years) supplied by Iowa, Minnesota, Nebraska, South Dakota, and Wisconsin; capacity data from *Petroleum Supply Annual* (1992, 1993, and 1994); and other sources.
- For 2010 forward: Unpublished production data from Form EIA-819 "Monthly Report of Biofuels, Fuels from Non-Biogenic Wastes, Fuel Oxygenates, Isooctane, and Isooctene" and monthly operating production capacity data from the Nebraska Energy Office.

Renewable diesel

Production in physical units

For 2011 forward, EIA publishes U.S.-level renewable diesel production data in the *Monthly Energy Review* (MER) and SEDS estimates state-level renewable diesel production. SEDS estimates state-level renewable diesel production using data from EIA's *U.S. Renewable Diesel Fuel and Other Biofuels Plant Production Capacity* report and other sources.

For 2021 forward, SEDS estimates state-level renewable diesel production using unpublished data from EIA survey Form EIA-819, "Monthly Report of Biofuels, Fuels from Non-Biogenic Wastes, Fuel Oxygenates, Isooctane, and Isooctene", which generates the annual *U.S. Renewable Diesel Fuel and Other Biofuels Plant Production Capacity* report. Because of the volatility of renewable diesel production, instead of nameplate capacity, SEDS uses unpublished monthly data on plant-level operating status to compute an annual average "operating capacity" for each plant and aggregate them to the state level. SEDS allocates the U.S.-level renewable diesel production from the MER to the states proportionally to each state's operating capacity.

For 2011 through 2020, Form EIA-819 data are not available. SEDS estimates historical plant-level renewable diesel production "operating capacities" using available public information on individual renewable diesel plant start dates, capacity testing ramp ups, capacity expansions, capacity reductions, and shutdowns. SEDS aggregates the plant-level operating capacities by state. Then, SEDS allocates the U.S.-level renewable diesel production from the MER to the states proportionally to each state's operating capacity.

Heat content of renewable diesel

To convert renewable diesel production to British thermal units (Btu), SEDS uses EIA's renewable diesel thermal

conversion factor of 5.494 million Btu per barrel, as listed in MER, Appendix A.

Unlike biodiesel and fuel ethanol, EIA does not estimate the "biomass inputs" (feedstock) used to produce renewable diesel because EIA does not collect the information. Therefore, EIA also does not estimate losses and co-products from renewable diesel production.

Variable names and definitions

The independent data series identifying codes for renewable diesel data are ("ZZ" represents the two-letter state code in the variable names):

    B1PRPUS   =   renewable diesel production, in thousand barrels, United States; and
    B1PRPZZ   =   renewable diesel production, in thousand barrels, by state.

The heat content data series are:

    B1PRBZZ   =   renewable diesel production, in billion Btu, by state
               =   B1PRPZZ * 5.494

The U.S. total is the sum of the states:

    B1PRBUS   =   ΣB1PRBZZ

Data sources

B1PRPUS — Renewable diesel production, in thousand barrels, United States.

- 2011 forward: EIA, *Monthly Energy Review*, Table 10.4b.

B1PRPZZ — Renewable diesel production, in thousand barrels, by state.

- 2011 through 2020: Estimated operating capacity based on public information for historical plant start dates, ramp ups, expansions, reductions, and shutdowns.
- 2021 forward: Unpublished operating capacity data from EIA survey Form EIA-819 "Monthly Report of Biofuels, Fuels from Non-Biogenic Wastes, Fuel Oxygenates, Isooctane, and Isooctene."

Other biofuels

Production in physical units

For 2014 forward, EIA publishes U.S.-level other biofuels production data in the *Monthly Energy Review* (MER). "Other biofuels" is an aggregate category for biofuels that are not biodiesel, fuel ethanol, or renewable diesel, as collected in EIA's survey Form EIA-819 "Monthly Report of Biofuels, Fuels from Non-Biogenic Wastes, Fuel Oxygenates, Isooctane, and Isooctene." Other biofuels include renewable jet fuel, renewable naphtha, renewable propane, and others. EIA does not have enough information on individual fuels or state production to estimate the states, so SEDS other biofuels production data are for the U.S.-level only.

For 2014 forward, SEDS includes U.S.-level production of other biofuels, as published in the MER.

Heat content of other biofuels

To convert other biofuels production to British thermal units (Btu), SEDS uses EIA's other biofuels conversion factor of 5.359 million Btu per barrel, as listed in MER, Appendix A.

Unlike biodiesel and fuel ethanol, EIA does not estimate the "biomass inputs" (feedstock) used to produce other biofuels because EIA does not collect the information. Therefore, EIA also does not estimate losses and co-products from other biofuels production.

Variable names and definitions

The independent data series identifying codes for other biofuels data are:

    BOPRPUS   =   other biofuels total production, in thousand barrels, United States.

The heat content data series is:

BOPRBUS　　=　　other biofuels total production, in billion Btu, United States
　　　　　　　=　　BOPRPUS * 5.359

Data sources

BOPRPUS — Other biofuels total production, in thousand barrels, United States.

- 2011 forward: EIA, *Monthly Energy Review*, Table 10.4c.

Total biofuels

Total biofuel data series are:

Physical units:

BFPRPZZ　　=　　biofuels liquid production, in thousand barrels, by state
　　　　　　　=　　BDPRPZZ + ENPRPZZ + B1PRPZZ
BFPRPUS　　=　　biofuels liquid production, in thousand barrels, United States
　　　　　　　=　　BDPRPUS + ENPRPUS + B1PRPUS + BOPRPUS

British thermal units:

BFPRBZZ　　=　　biofuels production (total biomass inputs as feedstock), including liquids and losses & co-products, in billion Btu, by state
　　　　　　　=　　BDFDBZZ + EMFDBZZ + B1PRBZZ
BFPRBUS　　=　　biofuels production (total biomass inputs as feedstock), including liquids and losses & co-products, in billion Btu, United States
　　　　　　　=　　BDFDBUS + EMFDBUS + B1PRBUS + BOPRBUS

The U.S. totals are not equal to the sum of the states' values because other biofuels are only available at the U.S. level.

Wood and waste

In general, EIA accounts for wood and waste energy production when they are consumed as energy. For 2016 forward, EIA collects data on densified biomass fuel (mostly wood pellets) production and exports. Because the United States exports about two-thirds of the densified biomass pellets, which are not domestically consumed, EIA defines wood energy production for 2016 forward as wood energy consumption plus densified biomass exports.

EIA calculates total U.S. densified biomass exports in British thermal units (Btu) from survey Form-63C, "Densified Biomass Fuel Report" and are available as an intermediate data series in EIA's *Monthly Energy Review*.

To allocate the U.S. densified biomass exports to the states, SEDS assumes that all densified biomass exports are utility wood pellets produced in the South Census Region. First, SEDS aggregates the annual operating capacity of the plants in the South Central Region that generally export densified biomass to the state-level, using EIA's *Monthly Densified Biomass Fuel Report*, Table 1. SEDS calculates state-level exports by applying the state's operating capacity share to the U.S. total densified biomass exports. Total state-level wood energy production is the sum of the estimated wood exports and consumption.

Before 2016, SEDS assumes wood energy production is equal to the SEDS wood consumption estimates.

Consumption estimates of wood and waste energy, in billion Btu, are from the SEDS consumption dataset.

Variable names and definitions

The independent data series identifying codes for renewable energy data are ("ZZ" represents the two-letter state code in the variable names):

WDEXBZZ   =   densified biomass exports, in billion Btu, by state (available for 2016 forward);
WDTCBZZ   =   wood energy total consumption, in billion Btu, by state; and
WSTCBZZ   =   waste energy total consumption, in billion Btu, by state.

Other data series in billion Btu are:

WDPRBZZ   =   wood energy production, in billion Btu, by state
          =   WDTCBZZ   before 2016
          =   WDTCBZZ + WDEXBZZ   for 2016 forward

WWPRBZZ   =   wood and waste energy production, in billion Btu, by state
          =   WDPRBZZ + WSTCBZZ

The U.S. totals are the sum of the states' values:

WDPRBUS   =   ΣWDPRBZZ
WSTCBUS   =   ΣWSTCBZZ
WWPRBUS   =   ΣWWPRBZZ

Data sources

WDEXBUS — Densified biomass exports, in billion Btu, United States.

- 2016 forward: Estimated by EIA based on EIA's *Monthly Densified Biomass Fuel Report*, exports and heat content values.

WDEXBZZ — Densified biomass exports, in billion Btu, by state.

- 2016 forward: Estimated by EIA using capacity data from EIA's *Monthly Densified Biomass Fuel Report*, Table 1 and information on the likelihood of exports.

Btu consumption estimates from SEDS are available in comma-separated value (CSV) format: https://www.eia.gov/ state/seds/sep_use/total/csv/use_all_btu.csv.

Noncombustible renewable energy sources

Noncombustible renewable energy sources covered in SEDS include:

- Geothermal energy
- Conventional hydroelectric power
- Solar thermal and photovoltaic energy
- Wind energy

EIA assumes that the production of noncombustible renewable energy is equal to consumption. The estimation methods and data sources for renewable energy consumption are described in Section 5: Renewable energy, SEDS consumption technical notes.

Variable names and definitions

The independent data series identifying codes for renewable energy data are ("ZZ" represents the two-letter state code in the variable names):

GETCBZZ   =   geothermal energy total consumption, in billion Btu, by state;
HYTCBZZ   =   hydropower total consumption, in billion Btu, by state;
SOTCBZZ   =   solar energy total consumption, in billion Btu, by state; and
WYTCBZZ   =   wind energy total consumption, in billion Btu, by state.

The noncombustible renewable energy production series is:

NCPRBZZ = noncombustible renewable energy production, in billion Btu, by state
         = GETCBZZ + HYTCBZZ + SOTCBZZ + WYTCBZZ

The U.S. totals are the sum of the states' values:

GETCBUS = ΣGETCBZZ
HYTCBUS = ΣHYTCBZZ
SOTCBUS = ΣSOTCBZZ
WYTCBUS = ΣWYTCBZZ
NCPRBUS = ΣNCPRBZZ

Data sources

Btu consumption estimates from SEDS are available in comma-separated value (CSV) format: https://www.eia.gov/ state/seds/sep_use/total/csv/use_all_btu.csv.

Additional notes

1. Noncombustible renewable energy sources are mostly consumed by the electric power sector. Data for electric power generation are net generation data. Negative generation denotes that electric power consumed for plant use exceeds gross generation. A few such cases can be found in electric power generated by hydroelectric power plants.

2. During the SEDS 2022 data cycle, EIA updated the way we calculate primary energy consumption of electricity generation from noncombustible renewable energy sources (solar, wind, hydroelectric, and geothermal) to Btu using the constant conversion of 3,412 Btu per kWh (the heat content of electricity). This method is called the *captured energy approach*. Before the SEDS 2022 cycle, EIA converted noncombustible renewable energy sources to Btu using the annual U.S. average heat content of fossil fuels consumed at steam-electric power plants (FFETKUS) as a conversion factor. That method is called the *fossil fuel equivalency approach*. The *captured energy approach* is more consistent with international energy statistics standards from the United Nations than the *fossil fuel equivalency approach*. See EIA's *Monthly Energy Review* Appendix E for more information. The annual values for FFETKUS are shown in the consumption technical notes, Appendix B, Table B1, https://www.eia.gov/state/seds/seds-technical-notes-complete.php and in the SEDS thermal conversion factors time series data files https://www.eia.gov/state/seds/sep_use/total/csv/use_convfac.csv.

Total renewable energy

Total renewable energy production is:

REPRBZZ = renewable energy production, in billion Btu, by state
         = BFPRBZZ + WWPRBZZ + NCPRBZZ
REPRBUS = renewable energy production, in billion Btu, United States
         = BFPRBUS + WWPRBUS + NCPRBUS

The U.S. totals are not equal to the sum of the states' values because other biofuels are only available at the U.S. level.