IEA Bioenergy
Technology Collaboration Programme

Implementation of bioenergy in the United States - 2021 update

Country Reports

IEA Bioenergy: 10 2021

This report was prepared from the 2021 IEA World Energy Balances and Renewables Information, combined with data and information provided by the IEA Bioenergy Executive Committee and Task members[1]. Reference is also made to FAOstat as well as data from national statistics. All individual country reports were reviewed by the national delegates to the IEA Bioenergy Executive Committee, who have approved the content. General background on the approach and definitions can be found in the central introductory report for all country reports.

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HIGHLIGHTS

- Renewables made up 8% of *total energy supply* in the United States in 2019. The renewable energy share in *final energy consumption* is almost 11%[2]. Around 60% of renewable energy is from biomass.
- Solid biofuels were the dominant type of bioenergy in the US in the early 2000s, but their levels remained fairly stable. The main growth of bioenergy in the past decades has been in liquid biofuels.
- Power production in the United States is still over 60% fossil based and 20% nuclear. Coal power has almost halved in the past decade; however, this was almost completely compensated by an increase in natural gas power. The share of renewable power increased from 10% to 17% in the past decade, mainly driven by a growth in wind power. Biobased electricity only has a modest role.
- Heat production in the US is dominated by fossil fuels, particularly natural gas. The use of biomass for heating is the most important type of renewable heat, producing 10% of heat, predominantly in industries.
- Transport energy consumption per capita is very high in the United States and the transport system is dominated by gasoline (in light duty vehicles). There has been a strong increase in

[1] While data for 2020 are starting to become available at national level, it was decided to consider trends up to 2019 for good comparability and benchmarking between the different IEA Bioenergy member countries. Care should also be taken when using 2020 data for analysing trends as these data are distorted by the COVID19 Pandemic.

[2] The difference between the share of renewables in supply and consumption relates to unused heat from power plants (which is counted in energy supply, but not in final consumption).

liquid biofuels up to 2013, particularly bioethanol. In recent years growth has been tempered related to the blend wall of ethanol in gasoline. On average ethanol now represents around 8% by energy of gasoline consumption. Biodiesel represents on average 3-4% of diesel consumption.

- Solid biomass, biogas and renewable MSW use for energy still have considerable growth potentials in the US based on its domestic resources.

COUNTRY PROFILE

Population and land use

The United States of America (USA) is located in North America and consists of 50 States. It has a total land area of 9.15 million km² and a population of 327 million people, which represents a relatively low average population density of 36 persons per km².

With its large size and geographic variety, the US includes many climate types. Around one third of the land area is forest land (*of which 10% protected*). 44% is agricultural land, 27% in permanent grasslands, pastures and shrubland and 17% in arable land. Other land use includes urbanization, bare rock areas and deserts.

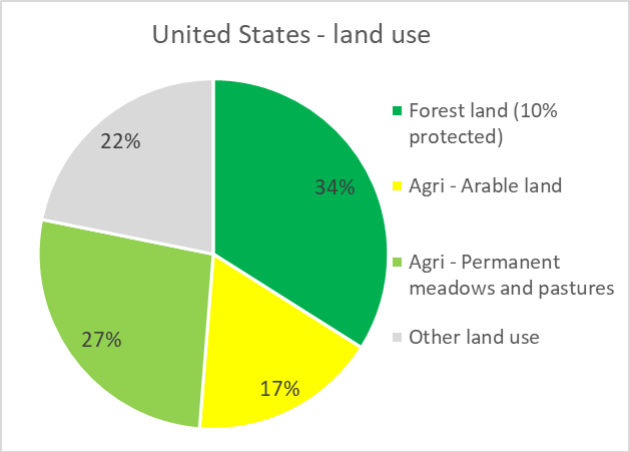


***Figure 1**: Land use in The United States (2018 figures - Source: FAOstat)*

Final energy consumption

Overall final energy consumption in The United States (*also including non-energy use of oil, natural gas, and coal in industry*) equates 4.8 tons of oil equivalent (toe) per capita, which is about two times higher than the average of all member countries of IEA Bioenergy.

Particularly energy use in transport is very high (*about 2.5 times higher than the average of IEA Bioenergy member countries*), which to some extent can be explained by the long distances within the country and the typical vehicle sizes and associated fuel economy. Energy use at residential level and commercial and public services is also higher than in most other countries; the difference is particularly in electricity demand (which could partly be related to cooling demands in certain parts of the US).

Table 1: Distribution of the final consumption of energy carriers by sector in The United States (2019 figures - Source: IEA (2021) World Energy Balances and Renewables Information)

Final consumption energy carriers	Toe/capita (2019)	% of total	*Median* (toe/capita)*
Industry (energy use)	0.81	17%	*0.67*
Industry (non-energy use)	0.48	10%	*0.21*
Transport	1.94	40%	*0.69*
Residential	0.82	17%	*0.57*
Commercial & public services	0.66	14%	*0.34*
other	0.12	2%	
Total	4.83		*2.34*

** Median of the 25 member countries of IEA Bioenergy*[3]

NATIONAL POLICY FRAMEWORK IN THE UNITED STATES

TARGETS AND STRATEGIES

Table 2: renewable energy and climate targets in The United States.

Sector	Targets per sector	GHG reduction targets
Overall target		Goal of net-zero carbon emissions by 2050
Heating and cooling	Heat pumps and other electric heaters account for over 60% of sales by 2030 and almost 100% of sales by 2050. Decrease the production and import of HFCs in the US by 85% by 2036	Hydrofluorocarbons (HFC) phase out's expected reductions of more than 4.5 billion metric tons of carbon dioxide-equivalent by 2050.
Electricity	100% clean electricity by 2035	100% carbon pollution-free by 2035
Transport	Half of all new light-duty cars sold in 2030 to be zero-emission vehicles To produce 3 billion gallons of sustainable aviation fuel by 2030	Production and use of billions of gallons of sustainable aviation fuel that will enable aviation emissions to drop 20% by 2030 when compared to business as usual. Put the aviation industry, and the economy, on track to achieve net-zero greenhouse gas emissions by 2050

[3] Comparative figures of the different IEA Bioenergy member countries are discussed in the central Countries' Report.

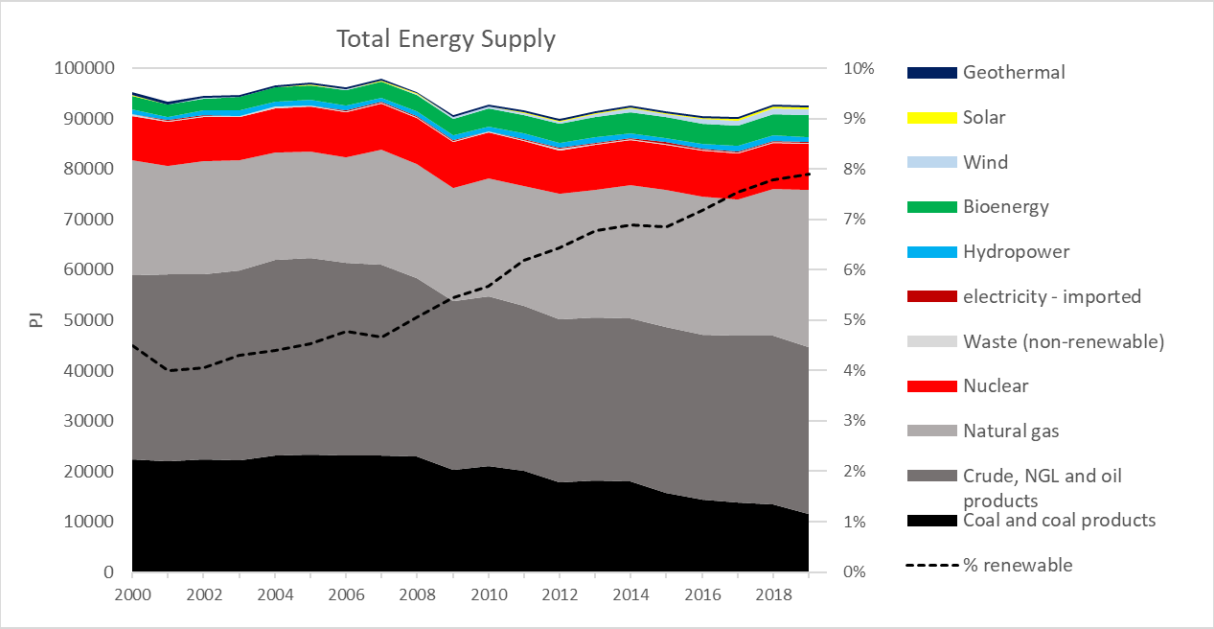
A description of renewable energy and climate policies and measures in the United States is available at the IEA's Policies and Measures Database: https://www.iea.org/policies?country=UnitedStates%2CUnited%20States

Specific policies related to renewable electricity, renewable heat and transport biofuels will be highlighted in the chapters about the role of bioenergy in different sectors.

THE CONTRIBUTION OF BIOENERGY IN NATIONAL ENERGY SUPPLY

TOTAL ENERGY SUPPLY

The total energy supply (TES) of the United States amounted to 92.7 exajoules (EJ) in 2019. It is still for 82% dominated by fossil fuels, with oil, gas and coal representing respectively 36% (33.2 EJ), 34% (31.1 EJ) and 12% (11.5 EJ) of total energy supply. Nuclear energy represents 10% (9.2 EJ).



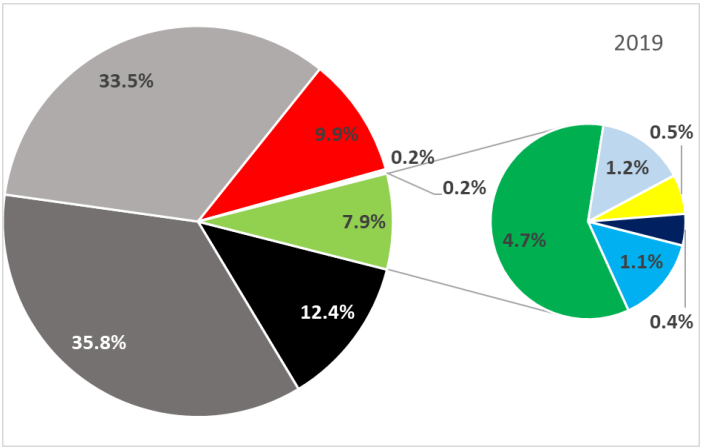


Figure 2: Total energy supply[4] and the contribution of different energy sources in The United States, with distribution in 2019 (Source: IEA (2021) World Energy Balances and Renewables Information)

[4] Total energy supply refers to the use of resources. In terms of the role in the energy system this distribution overestimates the role of resources producing electricity with a high share of unused waste heat (like nuclear plants).

Renewable energy sources had a share of almost 8% of TES or 7.3 EJ. Around 60% of renewable energy supply in 2019 came from biomass (4.34 EJ), followed by wind energy (1.07 EJ), hydropower (1.04 EJ), solar energy (0.48 EJ) and geothermal energy (0.38 EJ).

Overall TES in the United States is relatively stable around 92 EJ. **Oil products** are the most important energy source, their role in total TES has been quite stable around 36% (~33 EJ) in the past decade. **Coal** was quite stable around 22 EJ in the 2000s (24% of TES); its use has steadily declined since 2010 to less than 12 EJ (12% of TES) in 2019. **Natural gas** supply was fairly stable around 22 EJ in the 2000s (25% of TES), but this level steadily increased since 2010 up to 31 EJ in 2019 (34% of TES). Particularly in recent years (2018 and 2019) there have been substantial increases in natural gas use. The increase of natural gas seems to largely compensate for the declines in coal.

The share of renewable energy in the US was around 4% of TES in the early 2000s and has steadily increased to a level of 8% currently, which is still quite modest. **Bioenergy** saw a steady growth from 2.4 EJ in 2002 to 4.1 EJ in 2013 (4.4% of TES), a level that stabilized up to 2017; in 2018 and 2019 some further growth to 4.3 EJ was observed. **Hydropower** has been fairly stable round 1 EJ (1% of TES) in the past decades. **Wind energy** had a steady growth since 2005 up to a level of 1.1 EJ in 2019, which represents 1.2% of TES. Solar energy was quite stable around 0.07 EJ in the 2000s (at that time mostly solar thermal) and increased up to 0.5 EJ in the past decade (0.5% of TES), with most growth in solar power. Geothermal energy was fairly stable around 0.4 EJ (0.4% of TES).

Figure 3 shows the evolution of the different types of bioenergy. In the past decades there has been a continuous growth of the overall level bioenergy, but the main growth has been in liquid biofuels. Currently solid biofuels still dominate, representing 55% of bioenergy at a level of 2.4 EJ. Liquid biofuels represent another 38% at 1.67 EJ. Biogas and renewable MSW, both at 0.15 EJ have a somewhat smaller role.

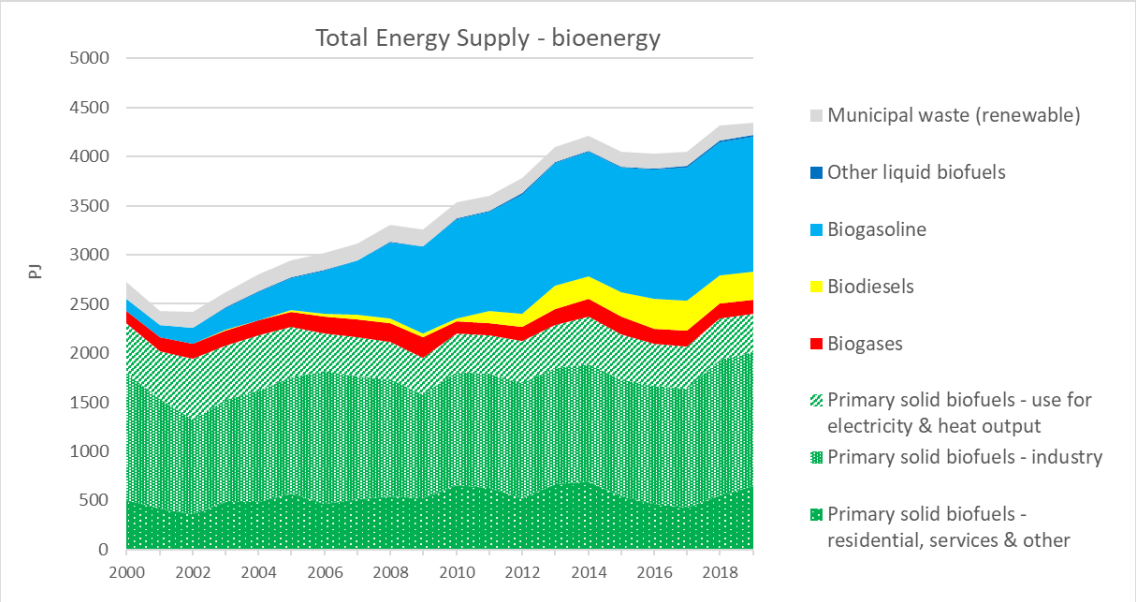


Figure 3: Development of total energy supply from bioenergy in the United States 2000 - 2019 (Source: IEA (2021) World Energy Balances and Renewables Information)

Evolution of the bioenergy carriers:

- Solid biofuels were the dominant type of bioenergy in the early 2000s. However, their use for energy share has hardly grown and fluctuated between 2.0 and 2.4 EJ. Most solid biofuels (~1.2 EJ) are used in industry, likely wood processing industries. Levels are slightly increasing again in the past 2 years. The use of solid biofuels for heating in residential applications fluctuated between 0.4 and 0.6 EJ. Solid biofuel use for power production was rather stable around 0.4 EJ.
- Liquid biofuels are the main growth component in bioenergy. Particularly bioethanol saw an important growth from 0.12 EJ in the early 2000s up to 1.2 EJ in 2012. These levels only slightly increased in recent years up to 1.37 EJ, which is likely related to the blend wall of ethanol in gasoline.
- Biodiesel levels are lower than bioethanol. There was a major increase between 2010 and 2013 from 0.04 EJ to 0.24 EJ. Levels have rather stabilized between 0.28 and 0.30 EJ in recent years.
- Biogas, mostly landfill gas, has been fairly stable around 0.15 EJ in the past decades.
- The use of renewable MSW has also been stable around 0.15 EJ.

Table 3 displays the 2019 total bioenergy supply values on a per capita basis. Compared to the other 24 member countries of IEA Bioenergy (expressed per capita), the United States ranks very high for liquid biofuels, in the middle for solid biofuels and on the lower side for renewable MSW and biogas.

***Table 3**: Total energy supply per capita in 2019 for different bioenergy carriers*

	Supply per capita	*Median IEA Bioenergy members*
Bioenergy	13.2 GJ/cap	*10.6*
Solid biofuels	7.3 GJ/cap	*7.0*
Renewable MSW	0.4 GJ/cap	*0.8*
Biogas	0.4 GJ/cap	*0.7*
Liquid biofuels	5.1 GJ/cap	*1.5*

Source: IEA (2021) World Energy Balances and Renewables Information

Table 4 indicates the amounts of the different bioenergy carriers compared to some relevant reference points, namely the amount of forest in the country (for solid biomass), the amount of generated MSW (for renewable MSW used for energy), the amount of natural gas consumed in the country (for biogas) and the amount of fossil oil products consumed (for liquid biofuels).

Table 4: Comparison of the supply of different bioenergy carriers in 2019 to specific reference points

Compared to reference points				Median*
Bioenergy	4.7	%	of total energy supply	*7.2 %*
Solid biofuels	8.6	GJ/ha_forest	compared to the domestic hectares of forest land (excl. protected)	*21.3 GJ/ha_forest*
Renewable MSW	0.50	GJ/ton_MSW	compared to the total generated MSW in the country	*1.4 GJ/ton_MSW*
Biogas	0.005	GJ/GJ_NG	compared to natural gas supply	*0.023 GJ/GJ_NG*
Liquid biofuels	0.050	GJ/GJ_oil	compared to oil products supply	*0.028 GJ/GJ_oil*

Source: energy data from IEA (2021) World Energy Balances and Renewables Information; forest figures from FAOStat; waste figures from World Bank
** Median of the 25 member countries of IEA Bioenergy*[5]

Specific comments in relation to the reference points:

- The amount of solid biofuels is quite low when compared to the domestic forest area (<0.5 tons of dry mass of wood per hectare[6]), certainly considering high growth rates in certain regions like the US south. Mind that some solid biomass is exported to other countries, particularly for power production. Nevertheless, there are important opportunities in the US to increase the levels of solid biofuels for domestic energy production.
- Liquid biofuels are at quite high levels when expressed per capita. However, considering the high energy use for transport in the US, their level compared to fossil oil consumption is more modest.
- The use of renewable MSW for energy production is somewhat behind other countries with more developed waste management systems.
- Biogas is quite modest per capita and is very low compared to the domestic use of natural gas (which has an important role in the US energy mix). There are important opportunities to further deploy biogas production based on organic wastes.

[5] Comparative figures of the different IEA Bioenergy member countries are discussed in the central Countries' Report.
[6] Counted with a typical calorific value of wood (dry mass) of 19 GJ/ton$_{\text{dry mass}}$

ROLE OF BIOENERGY IN DIFFERENT SECTORS

OVERVIEW

The overall 2019 share of renewables in **final energy consumption** among electricity, transportation and heat sectors is almost 11%, with bioenergy making up 6.3% of the energy share (Table 5). Note that these figures are higher than the shares in total energy supply (where unused waste heat, e.g., in fossil and nuclear power production, is also included).

***Table 5**: Role of bioenergy and renewable energy in electricity, transport energy and fuel/heat consumption, as well as total final energy consumption in 2019*

Sector	Share of bioenergy	Share of renewable energy	Overall consumption
Electricity[7]	1.4%	17.3% *(6.6% hydro)*	4401 TWh (15.8 EJ)
Transport energy (final consumption)	5.9%	5.9%	26.7 EJ
Overall fuel and heat consumption[8]	Direct biomass: 10.6% Biobased heat: 0.2%	12.0%	19.8 EJ
TOTAL FINAL ENERGY CONSUMPTION	**6.3%**	**10.7%**	**62.3 PJ**

Source: IEA (2021) World Energy Balances and Renewables Information

The following paragraphs will consider the evolutions in the different sectors.

ELECTRICITY

Power production in the United States is still for 62% fossil based, slightly down from 70% in the early 2000s. While in the 2000s coal power represented around 50% of electricity production (2,100 TWh), this level has almost halved in the past decades to 1,070 TWh in 2019. On the other hand, the role of natural gas power has more than doubled from 17% (700 TWh) in the early 2000s up to 37% (1,640 TWh) in 2019. Nuclear power was quite stable at 800-840 TWh in the past decades, representing around 20% of electricity production.

[7] Renewable electricity production compared to final consumption. Potential renewable shares of imported electricity are not included.

[8] This includes final consumption of fuels and heat in industry, the residential sector, commercial and public services and agriculture/forestry. Transport fuels are excluded. Energy used for transformation and for own use of energy producing industries is also excluded.
Electric heating (direct or through heat pumps) is not included in these figures as this is not separately reported.

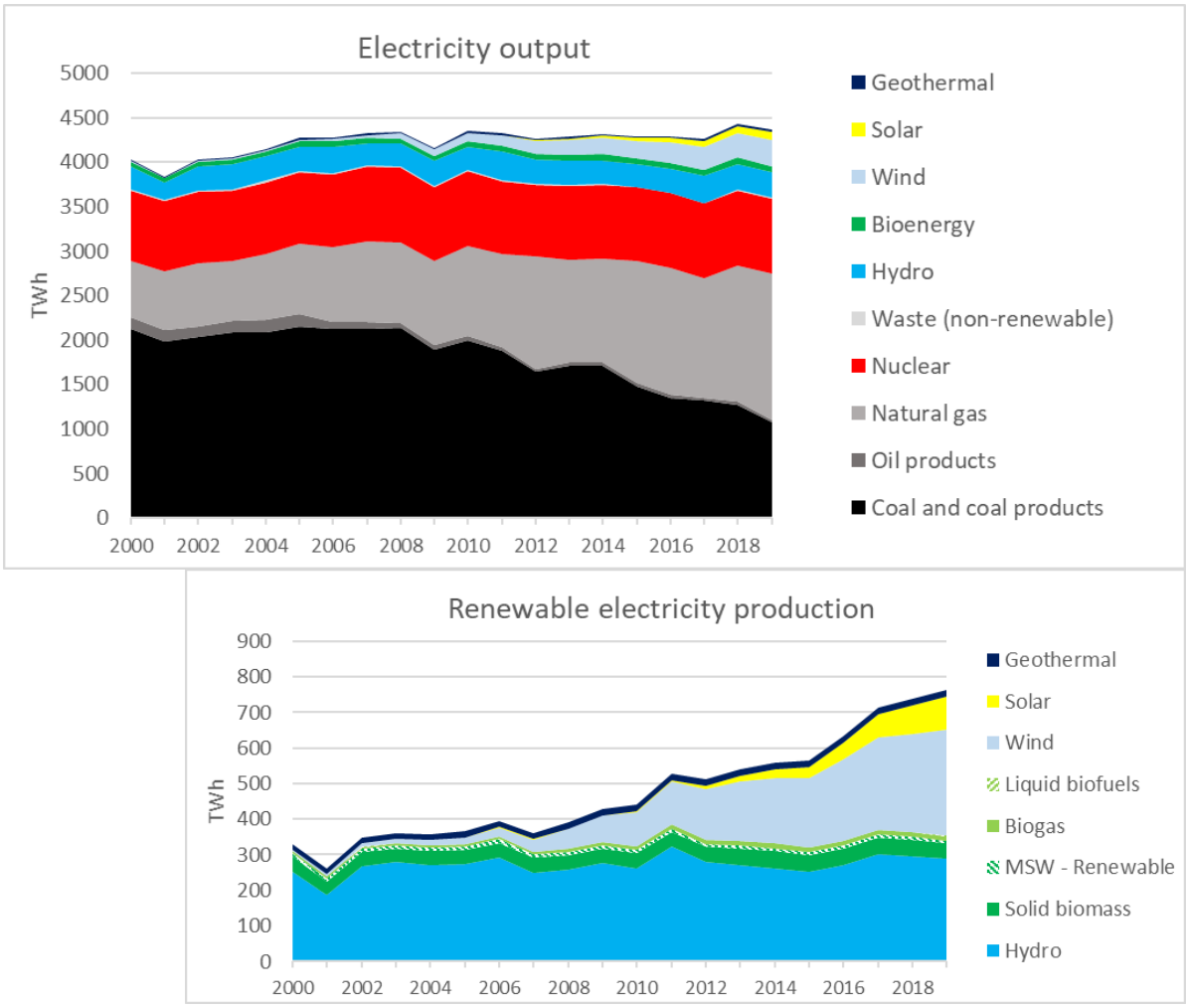


***Figure 4**: Evolution of the electricity mix in the United States 2000 – 2019 (Source: IEA (2021) World Energy Balances and Renewables Information)*

Renewable power increased steadily, particularly since 2008, from 400 TWh to almost 800 TWh recently, which represents 17% of electricity consumption in the US. Hydropower was initially the dominant source of renewable power and its production levels have remained quite stable at 250-300 TWh (6-7% of electricity consumption). Biomass based electricity had a relatively modest role around 60-70 TWh (1.5% share of electricity) and has hardly increased in the past decades. The role of wind power is growing, reaching almost 7% of electricity consumption (300 TWh) in 2019. Solar power is also growing, but so far at more modest levels, reaching 2% of electricity consumption (94 TWh) in 2019.

Policy framework

The United States has multiple incentives in place to support the expansion of electricity from clean energy sources, including incentives to support the expansion of bioelectricity. These incentives include government financial incentives, renewable portfolio standards and state mandates or goals, Renewable Energy Certificates or Credits (RECs), net metering, feed-in tariffs (FITs) and green power purchasing.

Government Financial Incentives

The U.S. federal government provides tax credits, grants, and loan programs for qualifying renewable energy technologies and projects including those with bio-based sources.

The Renewable Electricity Production Tax Credit (PTC) provides a per kilowatt-hour federal tax credit for electricity generated by qualified renewable energy resources. It provides a corporate tax credit of 0.013 cents/kWh for electricity generated from landfill gas, open-loop biomass, municipal solid waste resources, and qualified hydroelectric and marine and hydrokinetic. Electricity from wind, closed-loop biomass and geothermal resources receive as much as 0.025 cents/kWh. This tax credit is targeted at the owner of the facility or the operator of the facility.

The Energy Credit as found within the 2020 Investment Credit provides a tax credit for qualifying energy properties incentivizes systems designed so that 90% of the energy sources is produced using biomass.

Under the Modified Accelerate Cost-Recovery System (MACRS), owners of qualified property are capable to receive a special depreciation allowance to recover part of the cost of qualified property for the first year the property is in service. This allocates a 50% special depreciation allowance for qualified second-generation biofuel plant properties.

Grants and loan programs are available to support electricity generation from bio-based sources from several government agencies. The U.S. Department of Agriculture (USDA) provides grants for energy audits and renewable energy development assistance to state, tribal or local governments, land-grant colleges and universities, rural electric cooperatives, and public power entities through the Rural Energy for American Program (REAP). Additionally, REAP provides loan guarantees and grants for energy efficiency improvements in renewable energy systems (RESs). RESs include biofuels and power generation from biomass, in addition to other sources of renewable power generation.

Standards and Mandates

Renewable Portfolio Standards (RPS) are standards typically requiring a certain percentage of electric power generated within a state comes from renewable energy sources. In addition to RPS, some states have instituted voluntary renewable energy targets or goals for the electricity sector. RPS can encompass a range of differing policies and requirements but generally require some share of the electric supply comes from resources such as wind, solar, geothermal, biomass, and hydroelectricity. As of September 2020, within the U.S. 38 states have some form of RPS or renewable portfolio goals in place. From those 38, 12 states and the District of Columbia have set requirements 100% clean energy by at least 2050.

Since 2000, state RPS requirements are associated with almost 50% of renewable electricity generation and capacity growth in the United States. While the role of RPS policies has diminished over time, in regions such as the Northeast and Mid-Atlantic they continue to act as a central factor in motivating renewable electricity generation growth.

California's Renewable Portfolio Standard applies to investor-owned utilities, and municipal utilities. It includes near and long-term strategies of 44% renewable electricity by 2040, 54% by 2027, 60% by 2030 and 100% clean energy by 2045. Other states extend RPS to include cooperative utilities and retail suppliers, such as Minnesota and New York. Some states have elected for the use cost caps for RPS policies to limit increases to a certain percentage of ratepayer's bills.

Renewable Energy Certificates or Credits

Renewable Energy Certificates or Credits (RECs) play a central role in the success of RPS. RECs increase compliance in states that mandate RPS by allowing utilities that generate more renewable electricity than the RPS requirement to sell or trade RECs to other electricity suppliers who may not be able to meet their requirements.

New Jersey is among one of many states that allows for electricity generated from biomass feedstocks to qualify for RECs with specific emphasis places on energy generated from wastewater, food waste, landfill gas, and non-recycled municipal solid waste.

Net Metering

Net metering allows for qualifying renewable energy systems installed on the property of electric utility customers to be connected to the wider electric utility distribution system (grid). It allows customer's electricity bills to decrease by subtracting the net amount their renewable energy system generates from their total electricity consumption. Some states also allow for the selling of excess electricity generated on a utility customer's property through their renewable energy system back to the utility.

While there is no federal policy mandating net metering, many states in the U.S. have developed some form of generation compensation policy. 37 states, the District of Columbia, and four US territories have developed mandatory net metering for particular utilities as of August 2021. Eight states also have state-wide generation compensation rules other than net-metering. In some states there are utilities that allow for net metering where there are no mandatory state-wide net metering rules in place. At least 45 states have some form of generation compensation that regards some form of bio-based sourced as an eligible source either at the state-wide, city-wide, or utility specific level.

Feed-in Tariffs

In the United States many states have established special rates (or feed-in tariffs) for purchasing electricity from certain types of renewable energy systems to encourage new projects for renewable energy technologies. There six states in the U.S. that have established feed-in tariffs for renewable electricity. Half of these states recognize electricity generated from some form of bio-based source as a qualifying renewable energy system.

Green Power Purchasing

The Environmental Protection Agency's Green Power Partnership is a federal program that works with organizations with U.S. based operations to purchase and use green power. Every state in the U.S. purchases green power. Green power purchasing puts the power in the consumer to meet their requirements under renewable portfolio standards and go beyond them. Green power purchasing has sizable impacts including improving the environment, increasing demand for renewable energy, supporting growth in the domestic economy, and lowers the cost of electricity prices and natural gas overall.

The sale of electricity generated from renewable energy sources is what makes up green power, typically sold in blocks of megawatt-hours (MWh. In 2020, the market for voluntary green power grew to 192 million megawatt-hours, up 38% since 2018. This includes the sale of electricity generated from biogas and biomass.

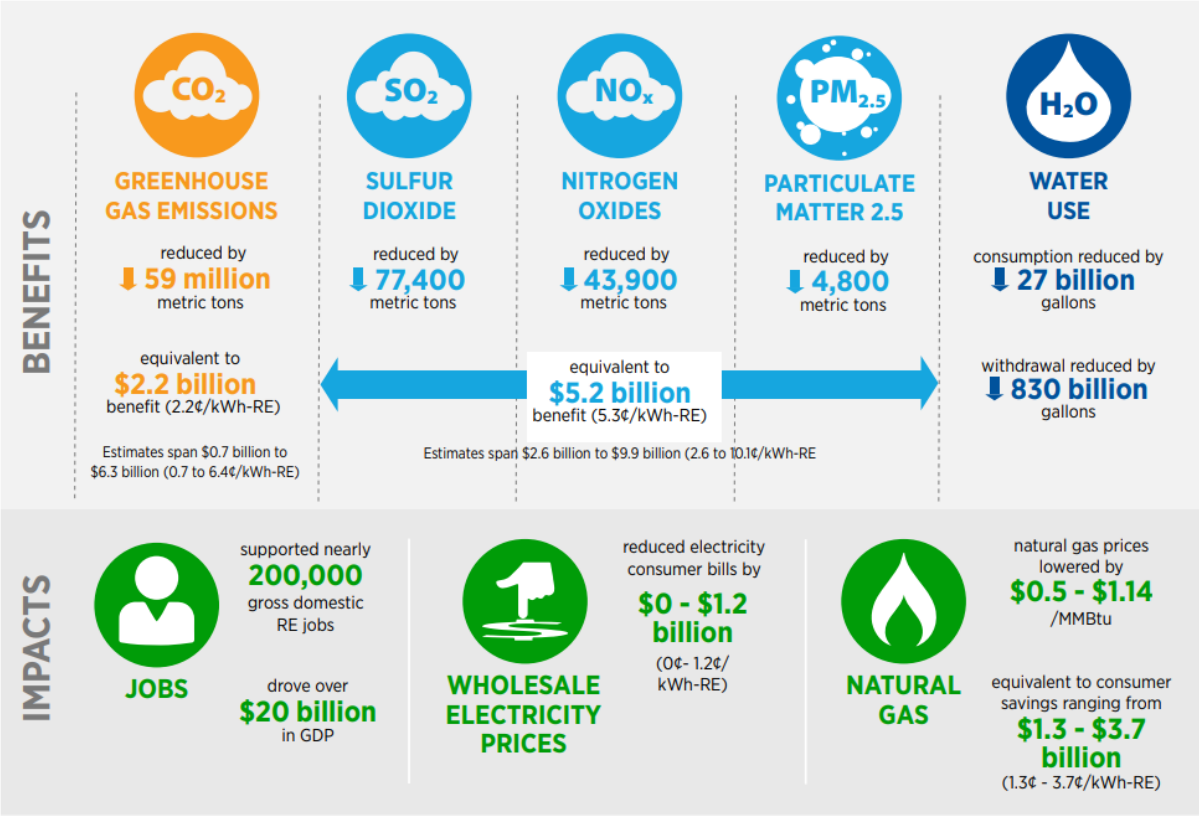


***Figure 5**: Environmental Benefits and Impacts of New Renewables Electricity as Evaluated to Meet 2013 RPS Compliance (Source: EPA (2018) Guide to Green Power Purchasing)*

HEAT/FUEL

Figure 6 shows the role of different fuels/energy carriers for providing heat in different sectors (industry, residential sector, commercial and public services and other). It also includes heat sold to customers, e.g., through district heating. Fuel use by energy producing industries for transformation and for own use is excluded. Mind that electric heating (direct or through heat pumps) is not included in these figures as this is not separately reported in the IEA database.

Overall consumption of fuels for heating has been relatively stable in the past decades, fluctuating between 18 and 20 EJ. The provision of heat in the US is still largely dominated (>85%) by fossil fuels, particularly natural gas, which represents 71%. Oil products represent 12% and coal 3%. The use of biomass for heating represents around 10%, at quite stable level, with only some slight growth in the past few years. Three quarters of this biomass is used for industrial heat; a quarter for heat in residential applications.

Heat output generated and sold by CHP plants and heat plants represents only 2% of fuel/heat provided, of which 88% is produced from fossil fuels (predominantly natural gas) and 10% from biomass.

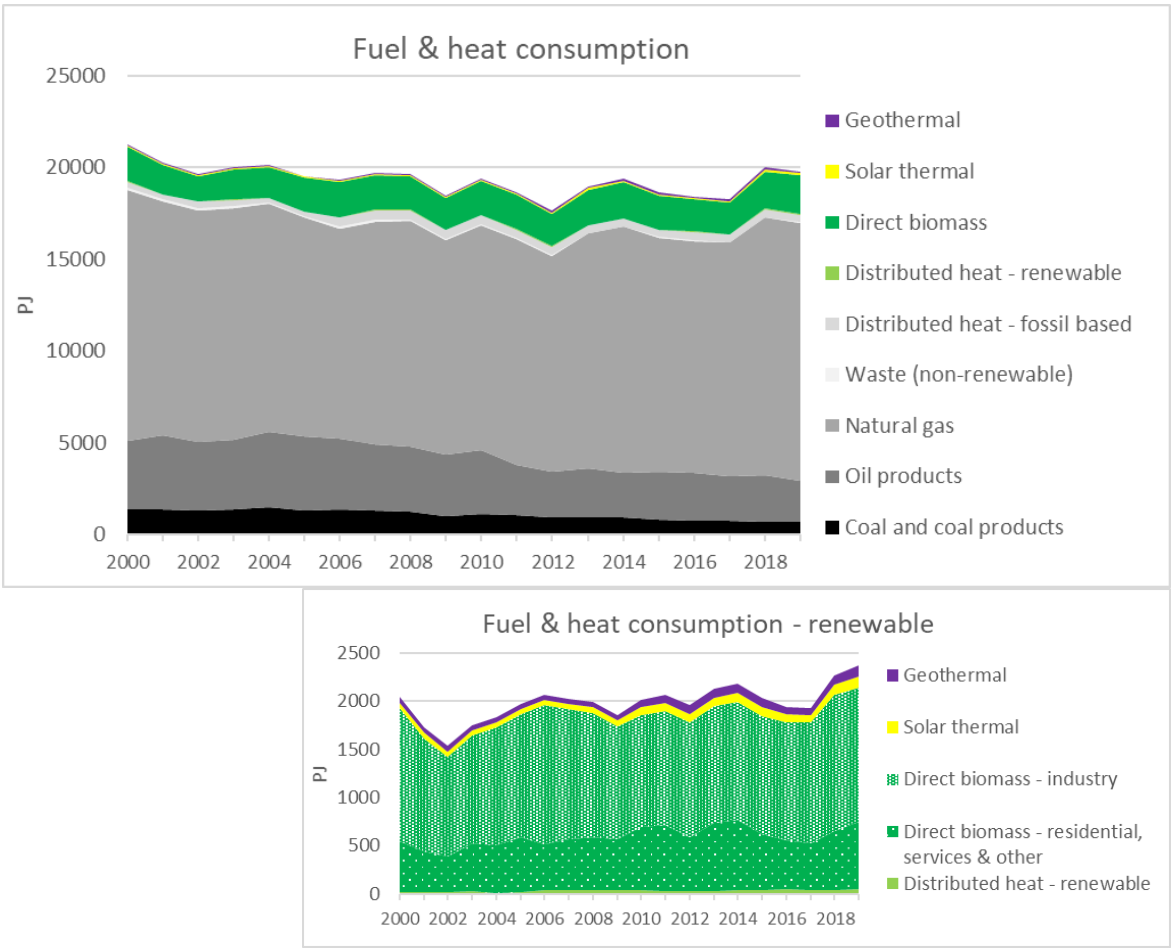


***Figure 6**: Evolution of fuel and heat consumption in the United States 2000 – 2019 (Source: IEA (2021) World Energy Balances and Renewables Information)*

Policy framework

In the United States there are several incentives that promote the use of bioenergy in heat production. The majority of these incentives are financial such as tax credits, loans, and grants for individuals and business. The federal government has also created regulatory policy to support the use of bioenergy in heat production through standards and guidelines.

Financial Incentives:

The federal government utilizes a wide array of financial incentives that have supported growth in bioenergy within the United States. Not only do these incentives target a wide array of sectors and stakeholders, but they also include financial incentives that support minority populations such as tribal communities and low-income households.

The Residential Energy Credits is a tax credit that targets non-business energy properties and residential energy efficiency. Under this credit, residential energy property costs for new qualified energy property qualify for credit including the use of stoves that use biomass fuel for heating the home or water. Under the Consolidated Appropriations Act of 2021, individuals can qualify for a personal tax credit for the purchase and installation of wood or pellet stoves and/or larger residential biomass heating systems that meet at least a 75% Thermal Efficiency Rating

The U.S. Internal Revenue Service under the Modified Accelerated Cost-Recovery System offers recovered investments for certain properties owned by business through a depreciation of deductions. Properties eligible for this energy investment tax credit include those that utilize combined heat and power, including CHP those field by biomass.

The U.S. Department of Energy's Office of Indian Energy Policy and Programs offers financial assistance, technical assistance, and education and training to tribes for development of renewable energy and energy efficiency technologies and measures. Under this program the Office has allocated funding for the development of combined heat and power (CHP) systems, including those fueled by biomass, biogas, solid waste, waste gases, or waste process heat as a qualifying renewable energy system. The requirements to receive funding accounts for the sustainability of the resource. In 2020, the U.S. DOE allocated over $12 million in funding to American Indian and Alaska Native Communities for projects to reduce energy costs, increase energy security, and enable energy resiliency.

The Rural Energy for America Program provides financial incentives for rural small businesses and agricultural producers in the United States for renewable energy systems and for the purchase, installation and construction of energy efficiency improvements including biomass and high efficiency heating, ventilation, and air conditioning systems. These incentives include loans for up to 75% of the total eligible project costs, grants for up to 25% of the total eligible project costs, and combined grant and loan guarantee funding.

The US Department of Agriculture allocates funding to assist energy providers and other eligible entities to lower the costs of energy for consumers with high per-household energy costs through the provision of grants. The grant funds can be used to finance renewable energy facilities used for on- or off-grid electric power generation, water or space heating, and process heating and power.

Standards:

The Interconnection Standards for Small Generators is a regulatory policy targeting commercial, industrial, local government, nonprofits, residential, schools, state government, federal government, tribal government, agricultural, and institutional sectors that applies standards to all transmission level interconnection. These interconnection standards apply to small generators using biofuel.

The Renewable Fuel Standard Program indicates a required volume of renewable fuel to replace or reduce petroleum-based transportation fuel, heating oil or jet fuel. This includes biomass-based diesel, cellulosic biofuel, advanced biofuel, and total renewable fuel. The standards for total renewable fuel have increased by at least 27% since 2018. These standards also set a threshold to meet a specific percentage lifecycle GHG reduction.

TRANSPORT

Figure 7 shows an overview of the energy used in transport in the United States, split up by different fuels/energy carriers.

While transport energy use in the US is already very high, these levels have still slightly increased in the past decade. The transport sector represents 29% of all U.S. emissions. Gasoline (including bioethanol), which is mostly associated with light duty transport, remains the dominant fuel in the US transport system at around 65% of transport energy consumption. Diesel (including biodiesel), mostly associated with heavy duty transport, represents 22%. Mind also the share of 'other oil-based

fuels' at 10% of transport energy, mostly aviation fuel for domestic flights. Natural gas is also used as transport fuel (~4%).

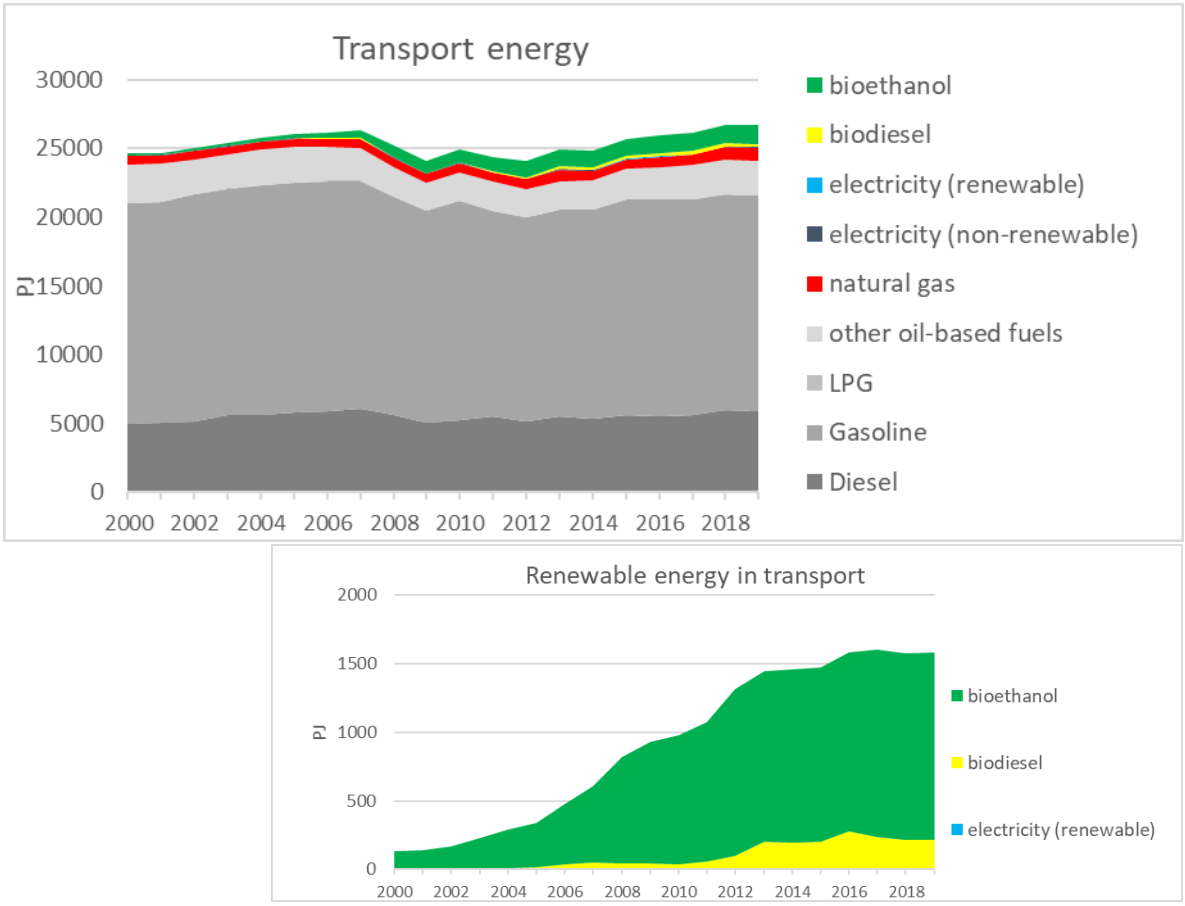


***Figure 7**: Evolution of transport fuels in the United States 2000 - 2019 (Source: IEA (2021) World Energy Balances and Renewables Information)*

Bioethanol has already been introduced in gasoline since the 1980s, mainly as oxygenate to reduce harmful emissions. Between 2003 and 2012 there was a strong increase in the use of ethanol from 230 PJ to over 1200 PJ. This level only slightly increased in the years after to 1,360 EJ, which is likely hampered by the 10% (by volume) blend wall of ethanol in gasoline. On average ethanol now represents around 8% by energy of gasoline consumption.

Biodiesel levels are lower than bioethanol, which is also related to the dominance of gasoline use in the US. There was a major increase of biodiesel between 2010 and 2013 from 40 PJ to 200 PJ. This level has rather stabilized in recent years. On average biodiesel now represents around 3-4% by energy of diesel consumption.

Electricity represents a very small share of 0.2% of total transport energy use in the US. The use of electricity in road vehicles is still marginal in 2019 (0.09% of total transport energy use) but can be expected to grow in the coming years.

Policy framework

The USG has several federal programs to incentivize alternative fuel and advanced vehicle technology. These include government financial incentives and renewable energy standards and mandates that support the use of bio-based power within the transport sector.

Financial Incentives:

There are a vast array of financial incentives that galvanize the use of biofuel within the transport sector in the United States. These include tax credits and loan programs. The Alternative Fuel Excise Tax Credit established under the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU; P.L. 109-59) provides a 50-cent-per-hallon tax credit for taxpayers who sell or qualifying fuel including fuels derived from liquefied hydrocarbons derived from biomass.

There are several tax credits in place to incentivize the increased production and use of biodiesel. The Alternative Fuel Refueling Property Credit established by the Energy Policy Act of 2005 provides consumers and businesses that installed qualifying fueling equipment with a 30% tax credit of up to $30,000 for properties subject to an allowance for depreciation and $1000 for all other properties. This includes biodiesel.

The Biodiesel or Renewable Diesel Mixture Excise Tax Credit was established within the 2005 Energy Policy Act and later amended by the Energy Improvement and Extension Act of 2008. The tax credit allows producers of diesel/biodiesel blends to claim $1.00 per gallon tax credit through the end of 2022 for biodiesel or renewable diesel used to produce a qualified biodiesel mixture. The Biodiesel or Renewable Diesel Income Tax Credit was established under the American Jobs Creation Act of 2004, extended by the Energy Policy Act of 2005, and Amended by the Energy Improvement and Extension Act of 2008. The income tax credit establishes that producers, blenders, or retailers of biodiesel, renewable diesel, or agri-biodiesel can claim $1.00 per-gallon income tax credit through the end of 2022.

The Small Agri-Biodiesel Producer Credit targets producers who source biodiesel solely from virgin oils. The credit is valued at 10 cents per gallon of agri-biodiesel.

The Second-Generation Biofuel Producer Credit was established in 2009 under the Food, Conservation and Energy Act. Qualifying producers of cellulosic biofuels can claim a tax credit of up to $1.01 per gallon.

The USDA's Discretionary Use of the Commodity Credit Corporation, a mandatory funding mechanism for agricultural programs, authorized a funding level of $100 million USD for the Biofuels Infrastructure Partnership Program for FY2015 to FY2020.

Standards:

The Environmental Protection Agency Renewable Fuel Standard requires the use of renewable fuels in transportation fuels including biodiesel and advanced biofuels. It includes specific quotas for cellulosic biofuels and for biomass-based diesel and rules for regarding lifecycle analysis to categorize fuels as advanced biofuels. The EPA mandates this use primarily through the Office of Transportation and Air Quality. The RSF has supported the expansion of ethanol and other biofuel production within the US, as well as supporting the development of biofuel from cellulose, farm and municipal waste, and/or algae within and outside the U.S. The RSF mandates some classes of biofuels must achieve GHG emissions reductions relative to gasoline.

US Programs:

There are multiple federal programs that promote the use of biofuels within the transport section. The majority of these programs fall under the U.S. Department of Agriculture (USDA) but there are also several programs that provide incentives from the Department of Energy and the Department of Transportation.

The USDA has several programs aimed at supporting the expansion of agricultural production of biofuels feedstocks, R&D on biofuels and bioenergy, and to establish and expand facilities to produce biofuels, bioenergy, and bio products primarily through the Rural Business-Cooperative Service.

The Biorefinery, Renewable Chemical, and Biobased Product Manufacturing Assistance Program facilitates development of new and emerging technologies through loan guarantees for development, construction or retrofitting of commercial scale biorefineries for advanced biofuels; renewable chemicals and biobased product manufacturing.

The Bioenergy Program for Advanced Biofuels (or Advanced Biofuel Payment Program) provides payments to fuel producers to support and expand production of an advanced biofuel based on the quantity produced and the amount of production increase. The program is authorized for appropriation of up to $20 million per fiscal year for 2019 through 2023.

The Biodiesel Fuel Education Program allocates grants to non-profit organizations and institutions of higher education that educate on the benefits of biodiesel. In FY 2019 the program saw a $1 million increase in authorized appropriations from past years, for a total of $2 million per fiscal year through 2019 to 2023.

The Biomass Research and Development Program, in cooperation with USDA and US DOE, provides competitive funding through grants, contracts, and financial assistance for research, development, and demonstration of biofuels and biobased products.

The Feedstock Flexibility Program authorizes the purchase of sugar from processors for resale to fuel ethanal producers under the USDA's Commodity Credit Corporation which helps stabilize sugar prices.

The Department of Transportation's Corporate Average Fuel Economy Program Alternative Fuel Vehicle Credits provides promotes the production and sale of alternative fuel vehicles and provides flexibility in compliance for automakers to accrue Corporate Average Fuel Economy credits. Incentives apply to vehicles capable of operating on biologically derived fuels in addition to other alternative fuel sources and electricity.

The Department of Energy has several programs that incentives the expansion of bioenergy in the United States through financial assistance programs and funding for research and development.

In 2021, the DOE announced $35 million in funding awards to help reduce the carbon footprint of biofuel production. The funding is focused on scaling up the volume and efficiency of renewable biofuel while decreasing carbon emissions.

The DOE's Bioenergy Technologies Office (BETO) has several programs aimed at securing the future of bioenergy in the United States. BETO works to achieve this through a number of avenues including resources for bioenergy workforce training opportunities across the United State, the BETO fellowship program, and the ATEC: Algae Technology Educational Consortium which develops educational programs to strengthen workforce capabilities in bioenergy in collaboration with the

Algae Foundation and NREL. BETO has also funded bioenergy conversion research that has led to developments and innovation associated with leading bioenergy conversion organization and other technologies. From 1976 to 2018, 974 bioenergy conversion patens were found to be associated with BETO funding out of a total of 29,209 bioenergy conversion technology patents identified. A further 467 of bioenergy conversion patents were associated with other DOE funding**.** High-impact BETO-funded patents include a Battelle Memorial Institute (Pacific Northwest National Laboratory) patent for bio-oil production and MRIGlobal (Midwest Research Institute) patents describing ethanol production and refuse derived fuels.

The Clean Cities Program is administered by the EERE that works to reduce consumption of petroleum in the transport sector. The program started in 1993 and now includes 75 Clean Cities coalitions encompassing 79% of the US population and with nearly 18,000 stakeholders. The program promotes the deployment of alternative and renewable fuels, idle-reduction measures, fuel economy improvements, emerging transportation technologies, and new mobility choices. The Clean Cities Program supports the expansion of biofuels through technical, informational, and financial assistance to communities. Coalition projects have led to a cumulative impact in energy use of almost 11 billion gasoline gallon equivalents as a result of measures to reduce fuel use and increase fuel diversity. The program also helped to expand the number of alternative fueling stations in the United States to more than 47,0000.

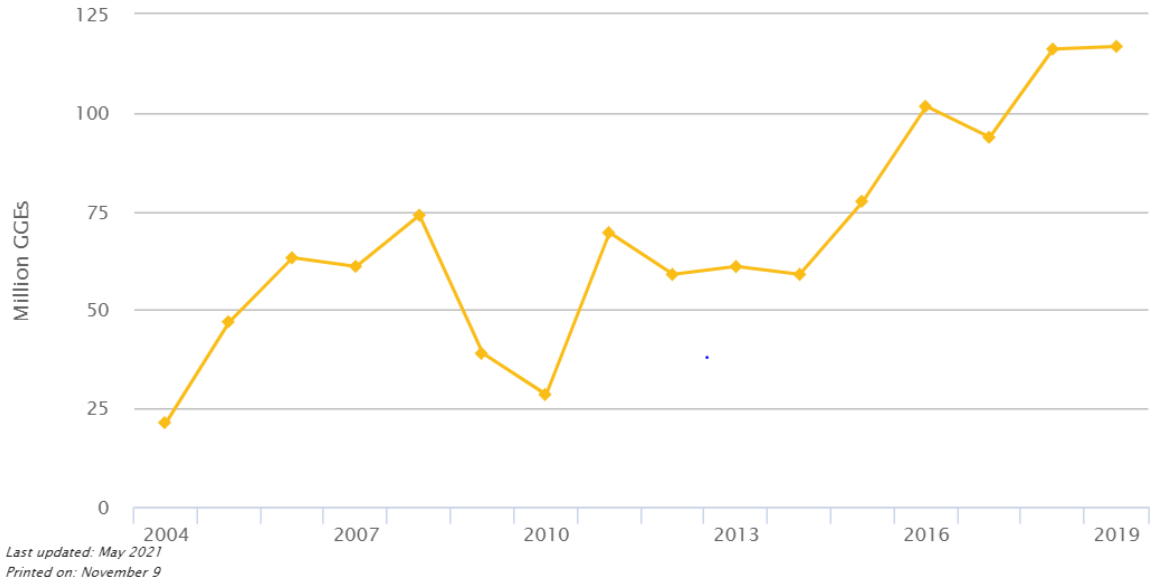


Figure 8: *Clean Cities Energy Use Impact on Biofuel 2004-2019 (Source: Clean Cities Coalitions Annual Activity Reports (2021)*

RECENT MAJOR BIOENERGY DEVELOPMENTS

The Sustainable Aviation Fuel Grand Challenge (SAF Grand Challenge) is part of a multi-agency strategy launched on September 9, 2021, to reduce the cost, enhance the sustainability, and expand the production and use of sustainable aviation fuel. The new SAF Grand Challenge is intended to inspire the dramatic increase in the production of sustainable aviation fuels, and to complement a broad set of actions the Administration intends to take to reduce aviation emissions in line with President Biden's commitment to achieve net-zero economy-wide emissions no later than 2050. These actions include policy measures, technological advancements, and executive actions that will reduce domestic aviation carbon dioxide emissions and create good paying jobs within the decade.

In 2021, aviation (including all non-military flights within and departing from the United States) represents 11% of United States transportation-related emissions. Without increased action, aviation's share of emissions is likely to increase as more people and goods fly. Achieving a sustainable aviation industry requires energy efficiency improvements in aircraft technology and better operations. In the future, electric and hydrogen-powered aviation may unlock affordable and convenient local and regional travel. But for today's long-distance travel, we need bold partnerships to spur the deployment of billions of gallons of sustainable aviation fuels quickly.

The Biden Administration has also proposed a Sustainable Aviation Fuel tax credit. This credit will help cut costs and rapidly scale domestic production of sustainable fuels for aviation. The proposed tax credit requires at least a 50% reduction in lifecycle greenhouse gas emissions and offers increased incentive for greater reductions. The SAF Grand Challenge announcements build upon this proposal through a whole-of-government effort to advance cleaner aviation, as well as work in concert with bold actions taken by the aviation-related industries. Key federal actions include:

- A new Sustainable Aviation Fuel Grand Challenge to inspire the dramatic increase in the production of sustainable aviation fuels to at least 3 billion gallons per year by 2030;
- New and ongoing funding opportunities to support sustainable aviation fuel projects and fuel producers totaling up to $4.3 billion;
- An increase in R&D activities to demonstrate new technologies that can achieve at least a 30% improvement in aircraft fuel efficiency;
- Efforts to improve air traffic and airport efficiency to reduce fuel use, eliminate lead exposure, and ensure cleaner air in and around airports; and
- The demonstration of U.S. leadership both internationally and through the federal example.

Building on the SAF Grand Challenge announcements, the Administration also plans to release an aviation climate action plan in early 2022, which will set forth a comprehensive plan for aviation.

The Department of Energy announced $64 million in funding for developing technologies and processes for the production of low-cost and low-carbon biofuels in September 2021. The funding is directed towards 22 projects aimed at supporting the SAF grand challenge.

Within the $64 million in awards, DOE announced funding of nearly $34 million under the Scale-Up Funding Opportunity (FOA) which includes 11 projects to support high-impact R&D to improve and produce biofuels, biopower, and bioproducts using biomass resources such as municipal solid waste streams and algae. In Fiscal Year 2022, the US DOE's Office of Energy Efficiency and Renewable Energy (EERE) Bioenergy Technologies Office (BETO) plans to issue a second Scale-Up FOA that will provide funds to accelerate and scale up biofuel and bioproduct biorefineries.

These new announcements have significant potential for high-impact results towards decarbonizing the transport sector and reaching the 2050 target for net-zero emissions.

LINKS TO SOURCES OF INFORMATION

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Standard Interconnection Agreements and Procedures for Small Generators | Federal Energy Regulatory Commission (ferc.gov)

Task Force on Agriculture and Rural Prosperity Report (usda.gov)

R42566 (congress.gov)

Clean Cities Coalition Network: Building Partnerships to Advance Affordable, Domestic Transportation Fuels and Technologies (energy.gov)

USDA ERS - Energy

U.S. Department of Energy Announces More Than $64 Million for Biofuels Research to Reduce Transportation Emissions | Department of Energy New Notice of Intent for the Scale-Up of Biofuel and Bioproduct Refineries Award | Department of Energy

Department of Energy Announces Nearly $34 Million to Advance Waste and Algae Bioenergy Technology | Department of Energy