Energy Consumption

The U.S. Department of Energy divides the way we use energy into categories—residential, commercial, industrial, electric power, and transportation. These are called sectors of the economy.

Residential and Commercial Sector

The residential and commercial sector—homes and buildings—consumes 11.48 percent of the energy used in the United States today. We use energy to heat and cool our homes and buildings, to light them, and to operate appliances and office machines. In the last 40 years, Americans have significantly reduced the amount of energy we use to perform these tasks, mostly through technological improvements in the systems we use, as well as in the manufacturing processes to make those systems.

Heating and Cooling

The ability to maintain desired temperatures is one of the most important accomplishments of modern technology. Our ovens, freezers, and homes can be kept at any temperature we choose, a luxury that wasn't possible 100 years ago.

Keeping our living and working spaces at comfortable temperatures provides a healthier environment, but uses a lot of energy. Forty-eight percent of the average home's energy consumption is for heating and cooling rooms.

The three fuels used most often for heating are natural gas, electricity, and heating oil. Today, about half of the nation's homes are heated by natural gas, a trend that will continue, at least in the near future. **Natural gas** is a clean-burning fuel. Most natural gas furnaces used in the 1970s and 1980s were about 60 percent efficient—they converted 60 percent of the energy in the natural gas into usable heat. Some of these furnaces might still be in use today. Depending on maintenance and homeowner use, these furnaces could last for over 20 years.

New furnaces manufactured today can reach efficiency ratings of 98 percent, since they are designed to capture heat that used to be lost up the chimney. These furnaces are more complex and costly, but they save significant amounts of energy.

The payback period for a new high-efficiency furnace is between four and five years, resulting in considerable savings over the life of the furnace. **Payback period** is the amount of time a consumer must use a system before beginning to benefit from the energy savings because of the higher initial investment cost.

Electricity is the second leading source of energy for home heating and provides almost all of the energy used for air conditioning. The efficiency of air conditioners and heat pumps has increased 50 percent in the last 35 years.

In the 1970s, air conditioners and heat pumps had an average **Seasonal Energy Efficiency Ratio**, or **SEER**, of 7.0. Today, the new units must have a SEER of 13, and high-efficiency units are available with SEER ratings as high as 18. These highly-rated units are more expensive to buy, but their payback period is only three to five years.

Heating oil is the third leading fuel for home heating and is widely used in northeastern states. In 1973, the average home used 1,294 gallons of oil a year. Today, that figure is more like 450 gallons, over a 65 percent decrease.

This decrease in consumption is a result of improvements in oil furnaces. Not only do today's burners operate more efficiently, they also burn more cleanly. According to the Environmental Protection Agency, new oil furnaces operate as cleanly as natural gas and propane burners. A new technology under development would use PV cells to convert the bright, white oil burner flame into electricity.

Saving Energy on Heating and Cooling

The four most important things a consumer can do to reduce heating and cooling costs are:

- **Maintenance**

Maintaining equipment in good working order is essential to reducing energy costs. A certified technician should service systems annually, and filters should be cleaned or replaced on a regular schedule by the homeowner.

- **Programmable Thermostats**

Programmable **thermostats** regulate indoor air temperature automatically, adjusting for time of day and season. They can be used with both heating and cooling systems and can lower energy usage appreciably.

- **Insulation**

Most heat enters and escapes from homes through the ceilings and walls. Adequate **insulation** is very important to reduce heat loss and air infiltration. The amount of insulation required varies with the climate of the region in which the house is located.

- **Caulking and Weather Stripping**

Preventing the exchange of inside air with outside air is very important. Weather stripping and caulking around doors and windows can significantly reduce air leakage. Keeping windows and doors closed when systems are operating is also a necessity.

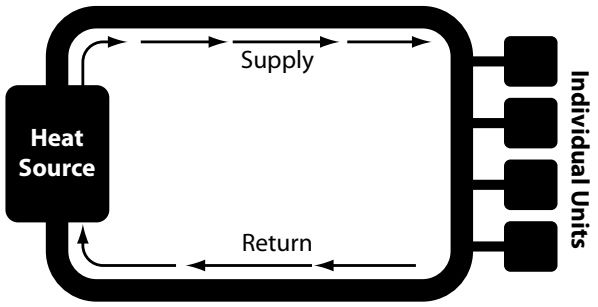
District Energy Systems

Where there are many buildings close together, like on a college campus, it is sometimes more efficient to have a central heating and cooling facility, which is called a **district energy system**. A district system can reduce equipment and maintenance costs, as well as produce energy savings.

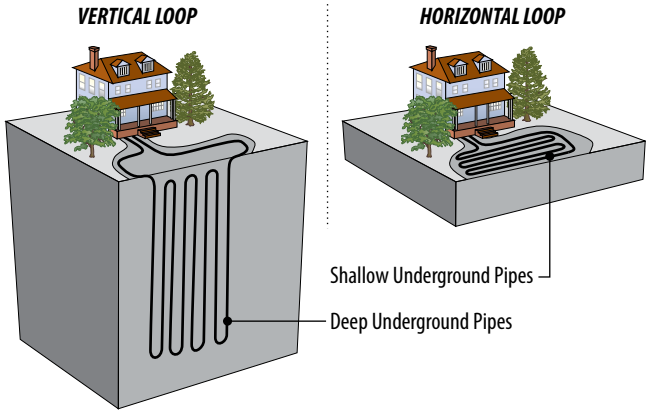
If the system relies on a fossil fuel cogeneration plant for heat, the overall efficiency of the plant can increase from 35 to 80 percent. **Cogeneration** can also reduce emissions per unit of energy produced by 50 percent.

If the district energy system uses a renewable energy source, such as geothermal energy or waste heat, emission levels can be reduced even more. A major benefit of district heating is its ability to use materials as fuel that would otherwise be waste products. These fuels may include biomass, such as waste from the forest product industry, straw, garbage, industrial waste heat, and treated sewage.

District Heating System



Residential Geoexchange Units



Geoexchange Systems

There are only a few areas in the country that have high-temperature geothermal reservoirs, but low-temperature geothermal resources are everywhere. Geothermal heat pumps, or **geoexchange units** as they are often called, can use low temperature geothermal energy to heat and cool buildings.

Geothermal systems cost more to install than conventional systems, but over the life of the system, they can save a significant amount of money and energy. They can reduce heating costs by 30-70 percent and cooling costs by 20-50 percent. Today, there are more than one million geothermal systems in homes and buildings.

Building Design

The placement, design, and construction materials used can affect the energy efficiency of homes and buildings. Making optimum use of the light and heat from the sun is becoming more prevalent, especially in commercial buildings.

Many new buildings are situated with maximum exposure to the sun, incorporating large, south-facing windows to capture the energy in winter, and overhangs to shade the windows from the sun in summer. Windows are also strategically placed around the buildings to make use of natural light, reducing the need for artificial lighting during the day. Using materials that can absorb and store heat can also contribute to the energy efficiency of buildings.

The Department of Energy's National Renewable Energy Lab developed computer programs to design energy-efficient buildings for any area of the country, taking into account the local climate and availability of building materials.

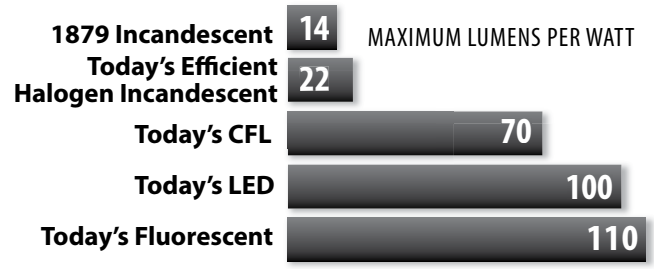
For existing houses and buildings, there are many ways to increase efficiency. Adding insulation and replacing windows and doors with high-efficiency models can significantly reduce energy costs. Adding insulated draperies and blinds and using them wisely, can also result in savings. Even planting trees that provide shade in the summer and allow light in during the winter can make a big difference.

Lighting

Lighting is essential to a modern society. Lights have revolutionized the way we live, work, and play. Lighting accounts for about five percent of the average home's total energy bills, but for stores, schools, and businesses, the figure is slightly higher. On average, the commercial sector uses about 10 percent of its energy for lighting.

Some homes still use the traditional **incandescent light bulbs** invented by Thomas Edison. These bulbs convert only 10 percent of the electricity they use to produce light; the other 90 percent is converted into heat. With new technologies, such as better filament designs and gas mixtures, these bulbs are more efficient than they used to be. In 1879, the average bulb produced 14 **lumens** per watt, compared to up to 17 lumens per watt today. By adding halogen gases, this efficiency can be increased to 22 lumens per watt. Energy-wasting, traditional incandescents have been phased out, beginning in 2012 with the 100-watt and 75-watt bulbs. 60-watt and 40-watt incandescent bulbs followed and were phased out in 2014. Halogen and energy-efficient varieties of incandescents are still available for consumers, along with some special use bulbs.

Lighting Efficiency



Data: Madison Gas and Electric

Compact fluorescent light bulbs (CFL) are fairly common in homes. They last up to ten times longer than incandescents and use much less energy, producing significant savings over the life of the bulb. New fluorescent bulb technology has made more dramatic advances in lighting efficiency. Some of the new fluorescent systems have increased the efficiency of these bulbs to as high as 70 lumens per watt.

Most commercial buildings have converted to linear fluorescent lighting, which costs more to install but uses much less energy to produce the same amount of light. Buildings with fluorescent lighting already installed can lower lighting costs by updating to more efficient fluorescent systems.

Light emitting diodes (LED) have quickly become the most common and efficient lighting choice. Even more efficient and cheaper than CFLs, these bulbs last two and a half times longer than CFLs and have many tech-friendly applications.

Most light bulbs are used in some kind of fixture. The design of fixtures can have a major impact on the amount of light required in buildings. Good fixture designs that capture all of the light produced and direct it to where it is needed can reduce energy costs significantly.

Energy Consumption

Outdoor lighting consumes more energy than you might think. Most of our major highways and residential streets have streetlights, as well as many parking lots. Many of these lights are on for 12 hours or more. It is common to see LEDs used outdoors, but you may still see other types of lighting used too. Automatic sensors are usually installed to reduce energy use.

Consumers should make use of efficient bulbs wherever feasible and use only the amount of light they need for the task at hand. Automatic turn-off and dimmer switches can also contribute to energy savings. Keeping light bulbs free of dust is an energy-saver, too. Some of the most important actions consumers can take is to turn off lights they aren't using, buy lamps that are suited to their needs in different rooms, and make energy conservation a priority in their daily lives. After bulbs have completed their lifespan, they should be recycled.

Appliances

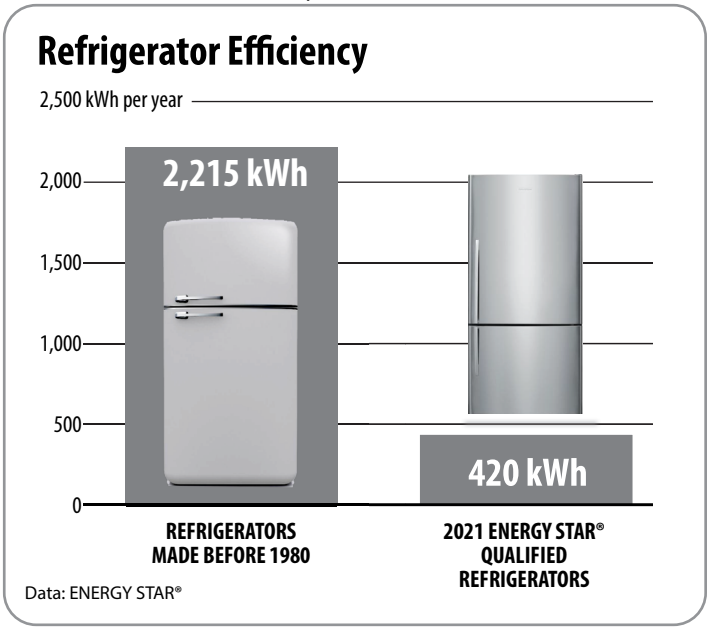
In the last 100 years, appliances have revolutionized the way we spend our time at home. Tasks that used to take hours are now accomplished in minutes, using electricity most of the time instead of human energy. In 1990, Congress passed the National Appliance Energy Conservation Act, which requires appliances to meet strict energy efficiency standards.

▪ Water Heating

Heating water uses more energy than any other task, except for home heating and cooling. Most water heaters use natural gas or electricity as fuel. New water heaters are much more energy efficient than earlier models. Many now have timers that can be set to the times when hot water is needed, so that energy is not being used 24 hours a day. New systems on the market combine high efficiency water heaters and furnaces into one unit to share heating responsibilities. Combination systems can produce a 90 percent efficiency rating.

In the future, expect to see water heaters that utilize heat that is usually pumped outside as waste heat. Systems will collect the waste heat and direct it into the water heater, resulting in efficiency ratings three times those of conventional water heaters.

Most consumers set the temperature on their water heaters much too high. Lowering the temperature setting can result in significant energy savings. Limiting the amount of hot water usage with low-flow showerheads and conservation behaviors also contributes to lower energy bills.



▪ Refrigerators

Refrigerators have changed the way we live and have brought health benefits to our lives. With these appliances, we can safely store foods for long periods of time. Since refrigerators involve heat exchange, they also consume a significant amount of electricity each year.

New refrigerators are many times more efficient than early models. Manufacturers have improved the insulation and the seals, or **gaskets**, to hold in the cold air better. The industry has also made technological advances in defrost systems, as well as in more energy efficient motors and compressors.

The appliance industry has worked with the chemical industry to develop refrigerants that are not harmful to the ozone layer, as the early CFCs were. As with all appliances, the most efficient models are more expensive to purchase but produce energy savings over the life of the refrigerator.

▪ Washers and Dryers

Before washers and dryers, doing the laundry meant hard physical work all day, no matter what the weather. Today, the most difficult thing about laundry is deciding which cycle to use. Today's machines have many innovations that save energy. Dryers with automatic sensors can tell when clothes are dry.

High-efficiency washing machines are being designed with either a horizontal axis or the traditional top-load design. These machines use 35 percent less water and 20 percent less energy than a regular washer. They also have higher capacity; they can wash large items such as comforters and sleeping bags.

▪ Appliance Efficiency Ratings

We use many other appliances every day. Some use less than 10 cents worth of electricity a year, while others use much more. Have you noticed that those appliances that produce or remove heat require the most energy?

When purchasing any appliance, consumers should define their needs and pay attention to the **Energy Efficiency Ratio (EER)** included on the yellow label of every appliance. The EER allows consumers to compare not just purchase price, but operating cost as well, to determine which appliance is the best investment.

Usually, more energy efficient appliances cost more to buy, but result in significant energy savings over the life of the appliance. Buying the cheapest appliance is rarely a bargain in the long run.

In the next few years, consumers will have the choice of many smart appliances that incorporate computer chip technology to operate more efficiently, accurately, and effectively.

Industrial Sector

The United States is a highly industrialized society. We use a lot of energy. Industry consumed 23.19 percent of the energy in 2021, but U.S. industry produces about 20 percent of the world's manufacturing output. Advanced technologies have allowed industry to do more with less. Industry has also been a leader in developing cogeneration technology. Cogenerators produce electricity and use the waste heat for manufacturing, increasing overall energy efficiency by 35 percent.

Every industry uses energy, but there are six energy-intensive industries that use the majority of the energy consumed by the industrial sector.

Petroleum Refining

Refineries need energy to convert crude oil into transportation fuels, heating fuels, chemicals, and other products. Enormous amounts of heat are required to separate crude oil into its components, such as gasoline, diesel, aviation fuel, and important gases. Heat is also needed to crack, or break, big hydrogen and carbon molecules into lighter, more valuable petroleum products.

Refineries use a mixture of fuels to operate, including by-product gases made during the refining process. On a per barrel basis, today's refineries use about 30 percent less energy than they did in the 1970s.

Steel Manufacturing

The steel industry consumes about two percent of total U.S. energy demand. The energy is used to convert iron ore and scrap metal into hundreds of products we use daily. The cost of energy represents 15 percent of the manufacturing cost of steel. Most of this energy comes directly from the heating of coal, and natural gas, and also from electricity generated by coal or natural gas plants.

Since 1990, the steel industry has reduced its energy consumption by 30 percent per ton of steel. This increase in efficiency has been accomplished through advanced technologies, the closing of older plants, and the increased use of recycled steel.

The increased use of recycled steel also saves energy. It requires 75 percent less energy to recycle steel than to make it from iron ore. Today, steel is one of the nation's leading recycled products, with two-thirds of new steel being manufactured from recycled scrap.

Aluminum Manufacturing

It takes huge amounts of electricity to make aluminum from **bauxite**, or aluminum ore. It requires six to seven kilowatt-hours of electricity to convert bauxite into one pound of aluminum. The cost of electricity accounts for one-third of the total manufacturing cost.

It requires 20 percent less energy to produce a pound of aluminum than it did 20 years ago, mostly because of the growth of recycling. Aluminum recycling has grown substantially over the last 4 decades. Using recycled aluminum requires 95 percent less energy than converting bauxite into aluminum.

Paper Manufacturing

The U.S. uses enormous amounts of paper every day and energy is required in every step of the papermaking process. Energy is used to chip, grind, and cook the wood into pulp, and more is needed to roll and dry the pulp into paper. Paper and paper products manufacturing is the third largest energy consumer in the industrial sector.

PETROLEUM REFINERY

Photo courtesy of BP

The pulp and paper industry has reduced its fossil fuel consumption per ton of paper by about 30 percent in the last 20 years, mostly through the use of better technology and cogeneration systems. Over 63 percent of the fuel the industry uses to power the cogeneration equipment comes from wood waste, a renewable energy source.

Chemical Manufacturing

Chemicals are essential to our way of life. We use chemicals in our medicines, cleaning products, fertilizers, and plastics, as well as in many of our foods. The chemical industry uses natural gas, coal, and oil to power the equipment they use to manufacture chemicals. Chemical manufacturing also needs a **hydrocarbon** source of raw materials, or **feedstock**, to process into chemical products. Petroleum, propane, and natural gas are the major feedstocks.

Improved technology has made the chemical industry about 50 percent more energy efficient today than it was 30-40 years ago. Technology has allowed the industry to use less energy, as well as produce more product from an equivalent amount of feedstock.

Cement Manufacturing

Some people think the United States is becoming a nation of concrete. New roads and buildings are being built everywhere, every day. Concrete is made from cement, water, and crushed stone. Making cement is an energy-intensive industry because of the extremely high temperatures required—up to 3,400 degrees Fahrenheit (more than 2,000°C).

Thirty years ago, cement plants all burned fossil fuels to produce this heat. Today, the industry has reduced its energy consumption by more than one-third using innovative waste-to-energy programs.

Nearly 70 percent of the cement plants in the U.S. now use some type of waste by-product for fuel, including used printing inks, dry cleaning fluids, and used tires—all of which have high energy content. One pound of used tires, for example, has more energy than one pound of coal.

Today, a modern cement plant can meet between 20 and 70 percent of its energy needs by burning waste materials that otherwise would not be used for their energy value.

Transportation Sector

America is a nation on the move. 27.63 percent of the energy we use every day goes to transporting people and goods from one place to another.

The Automobile

The people in the United States have always had a love affair with the automobile. Until the **oil embargoes** of the 1970s, Americans drove without thought of fuel economy or environmental impacts.

In 1973, there were 125 million vehicles on the road, driving an average of 10,000 miles a year. Today, there are over 284 million vehicles, driving over 12,000 miles a year. Even with the scares of oil embargoes, political unrest in oil-producing areas, and damaging storms in the Gulf of Mexico, we are driving more cars, more miles. It's a good thing we're doing it more efficiently and cleanly, but the U.S. accounts for about 25% of the world's transportation energy demand.

Although the oil crises didn't alter Americans' driving habits much, they did bring about changes in vehicle design. Automakers downsized many large and mid-sized models and significantly reduced vehicle weight. Aerodynamic designs were incorporated and engine size reduced. More important, engines were improved to increase fuel efficiency with fuel injectors and electronic transmissions. All of these improvements have resulted in almost doubling the fuel efficiency for vehicles since the 1970s.

▪ Mileage Requirements

Most of the improvements in automobile efficiency have been the result of mandates by the Federal Government such as CAFE standards. First enacted by Congress in 1965, the purpose of Corporate Average Fuel Economy (CAFE) standards is to reduce energy consumption by increasing the fuel economy of cars and light trucks. The National Highway Traffic Safety Administration (NHTSA) sets fuel economy standards for cars and light trucks sold in the U.S., while the U.S. Environmental Protection Agency (EPA) calculates the average fuel economy for each manufacturer. Today, new passenger cars and light duty trucks are required to achieve a combined city and highway mileage of upwards of 28 **per gallon (mpg)**.

When gas prices were low, consumers made no great effort to buy fuel-efficient vehicles. In 2004, for example, sales of the ten most efficient cars and ten most efficient trucks totaled less than one percent of total sales. On the other hand, sport utility vehicles (SUVs) and light trucks made up half of total passenger vehicle sales. Today is not much different, with nearly 70% of the vehicles sold in 2018 being SUVs and light trucks.

Many car manufacturers are producing hybrid vehicles powered by a combination of gasoline and electricity. These vehicles are much more fuel efficient than their gasoline-only counterparts because they are designed to run on only electricity during periods of low power demand. In many states, commuters driving hybrid vehicles are allowed in limited access lanes and are given tax deductions.

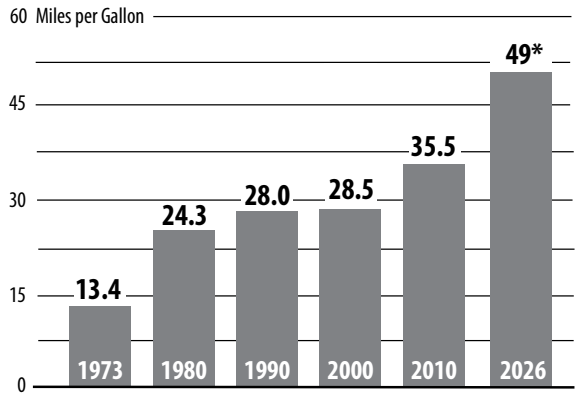
In 2012, the NHTSA had proposed CAFE standards for model year 2021-2026 for all passenger vehicles (including light trucks, subcompact cars, large sedans, station wagons, crossover utility vehicles, SUVs, minivans, and pickup trucks) of an average of 40.1 mpg in 2021 and 46.7 mpg in 2026. In 2017, the proposed rules were revoked and placed under further review. In early 2022 new CAFE standards for model years 2024-2026. Automobile manufacturers must now meet or exceed an average of 49 mpg by model year 2026.

As the nation's automakers re-invent themselves, energy efficiency is a major consideration of future auto makes and models. Auto makers are expanding their options for electric powered vehicles and alternative fuels.

▪ Alternative Fuels

There is also a push to develop vehicles that run on fuels other than petroleum products or on blended fuels. Today, there are vehicles that run on electricity, natural gas, propane, biodiesel, ethanol, and hydrogen. In the 1970s, there were only a few vehicles that ran on alternative fuels. Today, there are several million alternative fuel vehicles in the United States. That number will continue to increase as barriers to acceptance across the nation are overcome. These include:

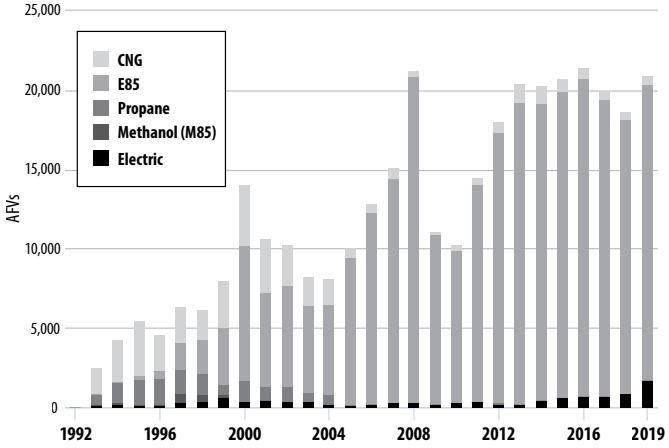
Average Fuel Economy of New Passenger Cars



*By 2026, new CAFE standards will require cars and light trucks to meet a 40.4 mpg fuel economy standard.

Data: U.S. Department of Energy

Alternative Fuel Fleet Vehicle Purchases by Fuel



Source: National Renewable Energy Laboratory EPAct State and Alternative Fuel Provider Fleet Task

Refueling Infrastructure: Manufacturers are now capable of producing a large volume of alternative fuel vehicles, but there needs to be a convenient infrastructure for obtaining the fuels. Not many people are willing to drive 15 miles or more to refuel or re-charge.

Consumer Education: Most Americans know very little about **alternative fuel vehicles**. Consumers must be educated about environmental and other benefits of these vehicles before they will consider them a choice.

If these barriers can be removed, alternative fuel vehicles can develop a strong niche market in the U.S. New technologies are being developed to make these vehicles more practical and convenient for consumers.

Commercial Transportation

The United States is a large country. We use a lot of energy moving goods and groups of people from one place to another. Passenger vehicles consume about 60% of the transportation fuel and commercial vehicles and transport modes consume the remaining 40%. The fuel efficiency of trains, trucks, buses, and planes has increased significantly in the last 50 years, as well as the number of miles traveled.

▪ Trucks

Trucks use more transportation fuel than any other commercial vehicle. Almost all products are at some point transported by truck. In the early 1970s, the average tractor-trailer traveled 5.5 miles on a gallon of fuel. New trucks manufactured today can travel about seven miles on a gallon of fuel. This increase in fuel efficiency is due mainly to improvements in engine design and computerized electronic controls.

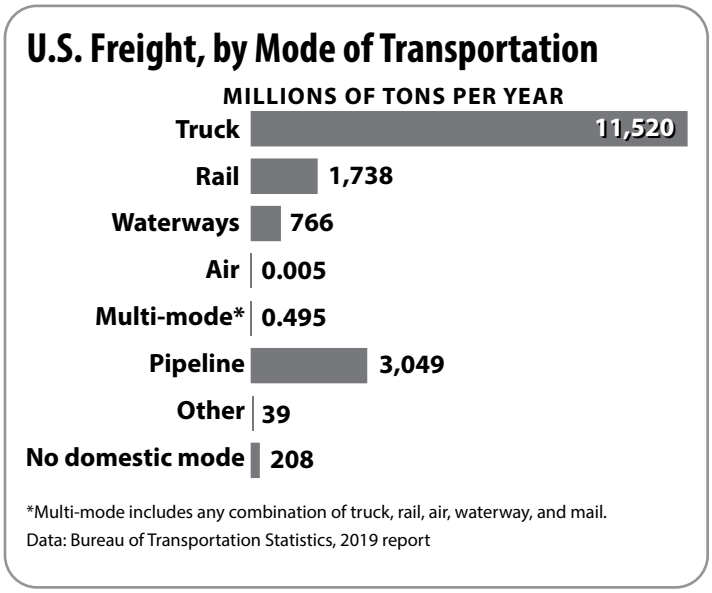
New diesel engines can convert about 45 percent of the energy in the fuel into vehicle movement, while gasoline engines can convert only about 30 percent. Federal research is aimed at improving diesel efficiency to 55 percent, by redesigning engines, redesigning braking systems to use air flow to help slow down vehicles, and engineering tires to roll more easily. Electric trucks for long-haul and local delivery are being tested and deployed by many companies.

▪ Planes

Since 1980, the number of passengers on planes has more than doubled. Planes all use petroleum products for fuel, which is the largest cost item for air transport after labor. The airline industry has been a leader in efficiency.

Since the 1970s, airlines have increased their fuel efficiency 70 percent. Many factors have led to better efficiency—newer engines, better flight routing, single engine taxiing, and design modifications. Boeing's newest plane, the 787 Dreamliner, is touted to be 20 percent more efficient than comparable sized planes by using new engines, lighter weight materials, improvements in aerodynamics, and other engineering advances.

Airlines are also using alternative fuels for airplanes. Airbus flew an A380 with one engine powered by a gas-to-liquid fuel in 2008. The same year Virgin Atlantic flew a Boeing 747-400 with one engine operating on a 20 percent biofuel blend. In 2009, Continental Airlines conducted a successful Boeing 737 test flight using jet fuel blended with algae oil and jatropha. In 2010, the U.S. Navy flew an F/A-18 fighter jet on a 50/50 jet fuel/biofuel blend. These tests have demonstrated that biofuels can be blended with existing fuels and not impact an airplane's performance. United Airlines began flights using biojet fuel in 2016. Sustainable aviation fuels are more widely provided and accepted by major airlines as away to curb emissions.



▪ Railroads

Since the 1970s, the fuel efficiency of freight trains has increased by more than half. This reduction in energy use was accomplished by using longer trains with less handling and fewer changes and stops. The equipment is stronger and lighter to handle more cargo. There have also been major improvements in rail technology that have contributed to ease of movement.

The trucking and marine shipping industries work with the railroad industry to move cargo efficiently. More freight is being transported on trains directly in truck trailers and uniform containers so that there is less handling. Today, containers often travel by ship, rail, and truck in one shipment called multi-mode or intermodal transportation.

In the future, there will be an increase in the use of AC motors on diesel electric engines on locomotives. With AC motors, there are fewer moving parts, so less heat is generated, resulting in more efficient use of fuel. A train that today requires six locomotives might require only four with this new technology.

▪ Mass Transit: Public Transportation

Mass transit is the system of public transportation for moving people on buses, trains, light rail, and subways. In 1970, nine percent of workers who traveled to work used public transit systems, two-thirds on buses. Today, less than ten percent of commuters use public transportation, half on buses. Why this decrease? Americans love cars. Most families own more than one. As more people have moved from cities into suburbs, public transportation has not been economically feasible for many dispersed locations.

Americans can spend 40 hours each year delayed by traffic congestion when traveling to an office or school. Building more roads isn't the only answer, especially with environmental concerns over vehicle emissions and the higher cost of transportation fuels.