# THE ENERGY LANDSCAPE

**background reading | energy unit**

EARTH matters

Studies For Our Global Future

Energy drives our modern life. It cooks our food, heats our homes, runs our machinery for agriculture and industry and powers our transportation and communication systems. From the dawn of the **Industrial Revolution**, we have steadily increased our use of energy sources, primarily from fossil fuels (coal, oil, and gas). While marking progress and increasing our quality of life in numerous ways, this fuel use came with unintended consequences – pollution and **climate change**. Now, our global society is considering how to balance our future energy needs with our needs to protect ecosystems and human health.

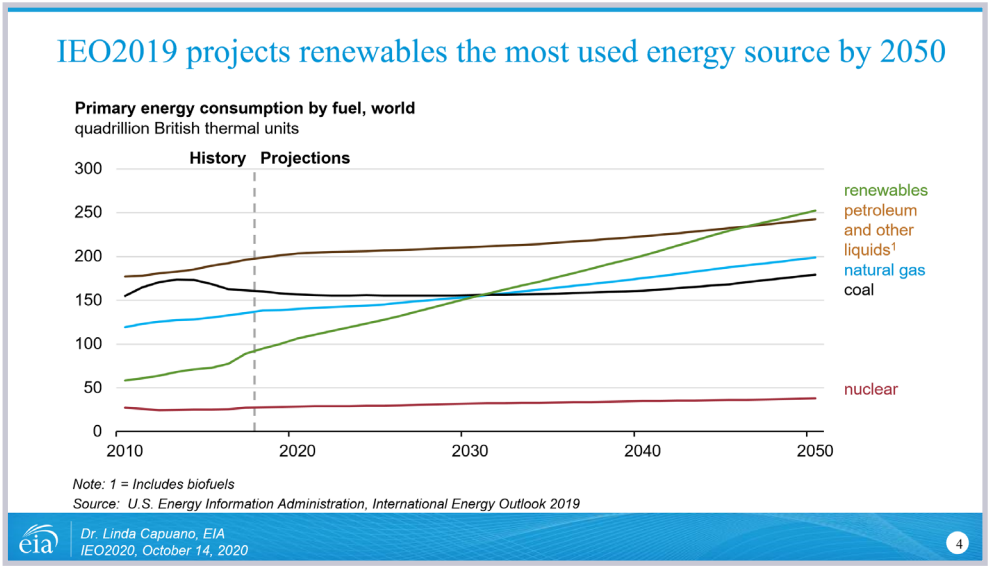
## From the ground up

Human ancestors began harnessing fire for cooking and heating over 1 million years ago.[1] Up until the Industrial Revolution, our fuel consisted mainly of wood, grasses, other **biomass** and some coal gathered from the Earth's surface. The factories and locomotives of the 18th and 19th centuries demanded greater quantities of fuel that could only be found from digging into the Earth to extract **fossil fuels**. Coal, oil, and natural gas are called fossil fuels because they have been formed from the fossilized remains of prehistoric plants and animals. Fossil fuels are a **nonrenewable energy** source since they take millions of years to form.

### Coal

Beginning 200 years ago, coal became synonymous with industrialization. The popularity of coal in the Industrial Revolution led to the beginning of mining operations in the 18th century. Coal was first used to generate electricity in homes and factories in the 1880s and still dominates as the leading fuel for electricity generation worldwide today. Coal is found in larger supply than any other fossil fuel on Earth. In fact, the United States, a net exporter of coal, still has enough coal underground to provide energy for the next 300 to 400 years.[2] Over half of the world's coal supply is found in the United States, China, and Russia.

Though plentiful, coal's popularity is starting to recede and it is now the slowest-growing energy source in the world.[3] Of all the fossil fuels, coal is the most polluting. It contains traces of impurities – sulfur and nitrogen – which combine with droplets in clouds to form sulfuric acid and nitric acid (acid rain). Coal is also the most carbon-intensive of the fossil fuels, accounting for 39 percent of all energy-related **carbon dioxide ($CO_2$)** emissions in 2019.[4] Other environmental concerns about coal include land degradation and water pollution from mining and disposal of hazardous coal ash.



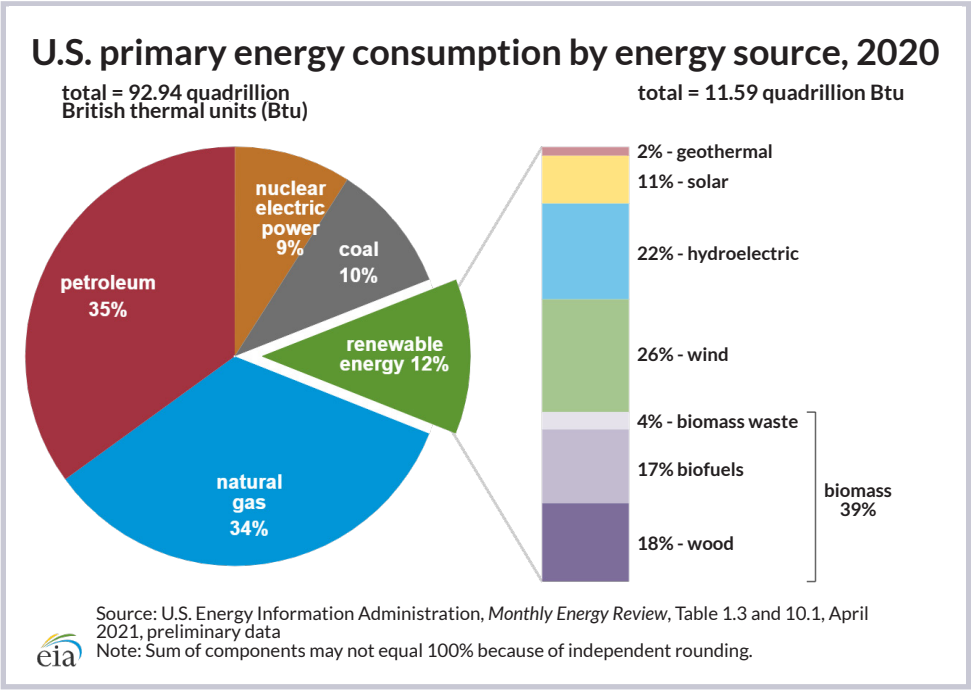
China accounts for half of all the world's coal consumption each year, with India and the United States as the next two largest coal consumers.[5] Reports in recent years of worsening air pollution, especially in China's and India's megacities, are causing those countries' leaders to reconsider the dominance of coal for powering homes and industries. Of all the major sources of energy, coal is the most harmful to human health, linked to heart disease, cancer, stroke, and chronic lower respiratory diseases. In the U.S., coal is no longer the most economically viable fossil fuel. It is now being eclipsed by cleaner-burning natural gas, which is cheaper to extract and transport.

## Petroleum

Liquid fuels – mostly **petroleum** based – are the largest source of world energy consumption. As a result, global economic markets often rise and fall with the price of crude oil. Oil drilling started in the mid-19th century, but it took the age of the automobile, airplane, and tractor to fuel the demand for liquid energy. Today, the world consumes close to 100 million barrels of oil daily and demand is growing as more of the world attains affluence.[6] Most of this growth is in the transportation and industrial sectors. Nearly half (47 percent) of oil is turned into gasoline; another 30 percent is used for diesel fuel and heating oil; 14 percent for hydrocarbon gas liquids such as propane, ethane and butane; 10 percent for jet fuel.[7] The United States is, by far, the largest consumer of petroleum in the world (20 percent), followed by China (14 percent). In 2020, the U.S. was also the largest producer of petroleum, pumping out over 18 million barrels per day.[8] Oil consumption is expected to grow as we put more cars on the roads around the globe. In 2019, oil accounted for 34 percent of $CO_2$ emissions.[9]

## Natural gas

Natural gas is now the fastest growing fossil fuel in terms of use. Although the first natural gas wells were drilled nearly two centuries ago, it wasn't widely used until a network of pipelines was built in the middle of the 1900s. Today the U.S. pipeline network, laid end to end, would stretch to the moon and back twice.[10] Natural gas provides roughly one-third of all energy consumed in the United States, especially in homes, where it supplies half of all the energy used for cooking, heating, and running appliances.[11] Worldwide, natural gas consumption is projected to grow by 40 percent, second only to renewable energy sources.[12]



Natural gas is comprised mostly of methane, a highly flammable gas that burns almost completely, leaving no ash and emitting very little air pollution. Burning natural gas produces only half as much carbon dioxide per unit of energy compared with coal. Natural gas is thus considered by many to be a "bridge fuel" that can help nations lower carbon emissions while they transition more slowly from fossil fuels to renewable, carbon-neutral forms of energy. Natural gas currently accounts for 20 percent of carbon emissions worldwide.[13] The United States, China, and Russia are the largest producers of natural gas.

Hydraulic fracturing drills on the prairies of Texas.

While emissions are lower with natural gas, there are other environmental considerations particular to the drilling process. Natural gas can be found in shale formations, sandstone beds, and coal seams. To access the fuel from shale, drilling companies use **hydraulic fracturing ("fracking")**. This is a process whereby drills force high-pressure water into the rock formation, creating tiny cracks through which the gas can more easily flow. A "propping agent" (like sand or glass beads) is added to the fluid to prop open the fractures when the pressure is decreased. In addition to natural gas, fracking fluids and salt water trapped in the same formation as the gas are returned to the surface. These wastewaters are frequently disposed of by injection into deep wells. The injection of wastewater and salt water into the subsurface can cause earthquakes that are large enough to be felt and may cause damage.

## Nuclear energy

In the years following World War II, scientific discoveries that led to the production of atomic weapons were redeployed for peaceful energy purposes. Nuclear fission emerged as a usable source of energy. In nuclear fission, atoms are split apart to form smaller atoms, releasing energy. Nuclear power plants use nuclear fission of uranium atoms to produce electricity. A machine called a nuclear reactor converts energy stored in atoms into heat or electricity. A single uranium fuel pellet the size of a pencil eraser contains the same amount of energy as 1,780 pounds of coal or 149 gallons of oil.[14] **Nuclear energy** is often called a sustainable energy source because there is enough uranium in the world to fuel reactors for 100 years or more.

Just over 10 percent of the world's electricity is produced by nuclear power generation. Nuclear power plants are found in 30 countries; 13 of those countries rely on nuclear energy to supply at least one-quarter of their total electricity. Nearly three-quarters of the electricity in France is supplied by nuclear energy. The United States generates the most nuclear energy of any country, with one-fifth of the nation's electricity generated from nuclear energy.[15]

The nuclear power plant on Three Mile Island, just south of Middleton, Pennsylvania. Though currently in operation, the generator was the site of the U.S.'s most significant nuclear accident.

Unlike fossil fuels, nuclear energy emits no **greenhouse gases** or air pollution. For this reason, it's considered a "clean" energy but is not without risks to the environment and human health. The byproduct of nuclear generation is hazardous waste which must be disposed of safely, as it remains radioactive and dangerous to human health for thousands of years. Any breaches to the reactor core can put local residents at risk of radiation poisoning. The worst such disaster occurred in 1986 at Chernobyl in the Ukraine. Explosions at one of the Chernobyl reactors led to radioactive fallout that contaminated an area of 1,000 square miles. More recently, the Fukushima Daiichi nuclear plant in Japan in 2011 suffered meltdowns and radioactive fallout following a major earthquake and tsunami. Each of these events displaced tens of thousands of local residents and the long-term health impacts are still unknown.

Understandably, the Fukushima disaster has spurred opposition to nuclear power in Japan. Other developed countries, including Germany and France, have resolved to reduce nuclear power use moving forward. Yet, in much of the developing world, interest in nuclear power as a cleaner alternative to fossil fuels is growing. China is increasing its nuclear capacity by 10 percent each year. India has been increasing its use of nuclear power by 8 percent annually. As a result, nuclear energy generation is expected to double worldwide by 2040.[16]

## The rise of renewables

The fastest growing source of electricity generation worldwide is **renewable energy** – solar, wind, hydroelectric, biomass, and geothermal. In 2018, renewable sources provided 15 percent of the world's energy. By 2050, renewables are expected to provide about 28 percent of the world's energy supply, with the majority produced by wind and solar.[17] As world leaders have assessed the threats to our climate of adding more greenhouse gases to the atmosphere, they have looked to the growth of renewable energy as a cleaner, more sustainable road forward.

Currently, the most used renewable energy sources are neither solar or wind. As the primary energy source for cooking and heating homes in the developing world, **biofuels** (including wood, charcoal, and animal dung) are, by far, the largest renewable energy source, representing 43 percent of global renewables supply.[18] While the burning of this biomass emits less carbon dioxide than fossil fuel combustion, it does create air pollution, especially from particulate matter. Breathing particulate matter indoors without proper ventilation, endangers respiratory health.

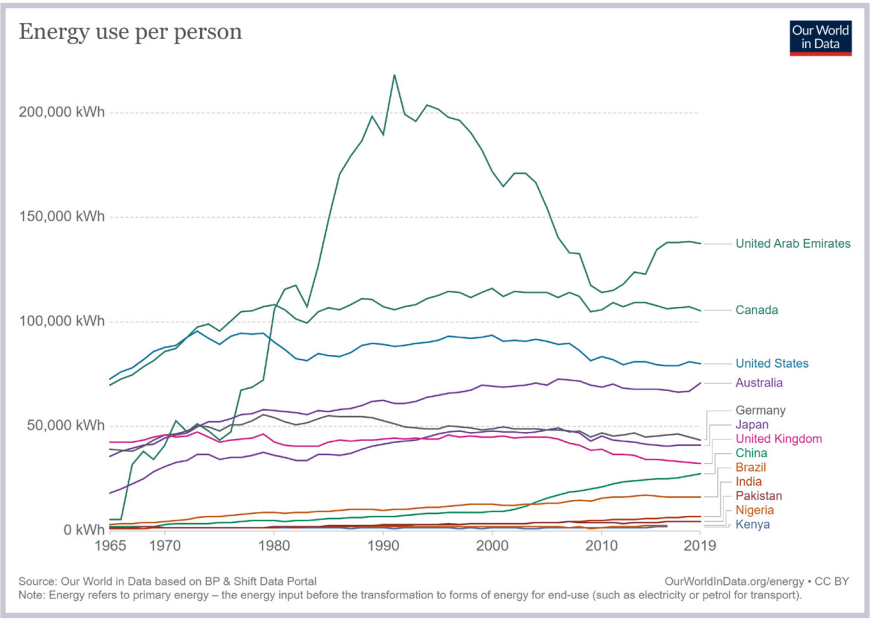
The second most-used renewable source is **hydroelectric power**. Hydropower is the largest electricity producer among renewable energy sources (about 22 percent) worldwide.[19] In 2019, the largest hydroelectric power generating countries were China, Brazil, and the United States. These three countries alone represent more than

half of the world's hydroelectric power production.[20] To produce hydropower, water flows through a pipe that pushes wind turbines to create electricity. Though it is clean energy, hydropower does have environmental drawbacks. The building of dams and reservoirs required for the harnessing of hydropower leads to flooding, siltation, and wildlife endangerment.


Photo Credit: imacoconut/iStockphoto.com

The highest growth in renewables in recent years has been with **solar photovoltaic (PV) energy** and **wind energy**. Solar energy, which converts sunlight into electricity, is likely to be the cornerstone of a future sustainable energy system. Sunshine is available in great quantity and is more widely distributed than any other source. In the non-too-distant future, societies may use the sun to heat most of their water, and new buildings may take advantage of natural heating and cooling to cut energy use by more than 90 percent. Wind power, which uses propeller-driven mechanical turbines perched on strategically located towers, also has great potential to provide electricity in most countries. As of 2019, wind turbines produced 20 percent of the world's renewable energy.[21]

**Geothermal energy**, the latent heat from the Earth's core, can provide electricity when there is no sun or wind. After hydroelectric power, geothermal is the next most used renewable energy source. Currently, it is most prevalent in geologic "hot spots" where it is easiest to harness underground heat. The United States is the largest producer of geothermal energy, followed by Indonesia, the Philippines, and Turkey.[22]




Renewable energy sources hold a lot of promise for providing cleaner energy as nations work to contain greenhouse gas emissions. In 2020, renewable energy accounted for nearly 90 percent of all new power installations around the globe. Renewable energy installations are expected to increase dramatically within the coming years and will likely surpass coal as the largest source of electricity generation by 2025.[23] Already, the cost of using renewable energy is becoming competitive with traditional fossil fuels and market forces are likely to make renewable sources more widespread in the decades to come, especially in more developed countries.

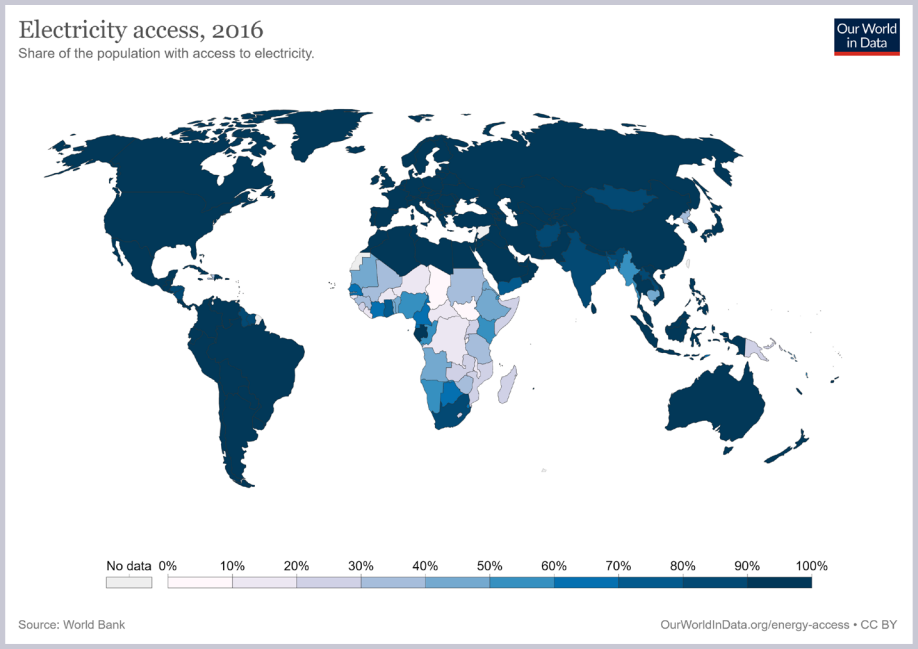
## More for less

Fossil fuels, particularly natural gas and oil, will probably continue to be a bedrock of the global energy system for decades to come. In fact, according to a 2020 BP report, experts project that fossil fuels will still account for over 65 percent of energy use in 2050.[24] One important way to reduce the use of fossil fuels is to improve **energy efficiency**, for our cars, household appliances, lights, and heating and cooling systems. Examples of energy saving technologies include compact fluorescent (CFL) lightbulbs which use about 70 percent less energy than incandescent bulbs. Automated "smart home" technologies can adjust your thermostat remotely to improve efficiency, and energy-saving windows are designed to help control a home's temperature.

More than half of the liquid energy we consume winds up in our vehicle gas tanks. Making cars more energy efficient goes a long way toward reducing fossil fuel use and lowering our carbon footprint. Higher fuel efficiency standards saves gas, as does changing our transportation habits. Data analysis of the U.S. Census Bureau's American Community Survey found that 76 percent of commuters drive alone in their cars to work. Only 9 percent carpool and a mere 5 percent use public transportation.[25] Providing alternatives to driving like bike sharing programs and more accessible public transit is known to reduce car ridership. The gaining popularity of electric plug-in vehicles might also begin to change the way we use fuel.

## Energy poverty

Talk of electric vehicles and smart homes are only relevant where electrification is universal. Not so in parts of the developing world. Although the percentage of people around the world living with access to electricity continues to increase, 700 million people still lack access to modern energy sources.[26] Lack of electricity stymies progress in many ways from the student trying to use the internet to the small business running machinery and lights. It also poses threats to human health. One-third of the world population (2.6 billion) relies on biomass as a cooking fuel. **Indoor air pollution** from cooking with solid biofuel is linked to 2.5 million premature deaths each year.[27]




The **United Nations Sustainable Development Goals (SDGs)** include ensuring "access to affordable, reliable, sustainable and modern energy for all" (SDG #7). Meeting this goal will require international investment in infrastructure in the poorest and least accessible parts of the world. This infrastructure will need to make use of cleaner energy sources to help meet global goals for caps on carbon emissions even as demand for energy grows.

# Our energy future

The global energy landscape is transforming, but maybe not quickly enough to avert a rapidly changing climate. In December 2015, 195 countries adopted the first-ever, universal legally-binding global climate deal, known as the **Paris Agreement**. In the agreement, countries agreed to work to limit global temperature rise to well below 2°Celsius, and to strive for a limit of 1.5°Celsius to prevent major impacts to ecosystems and human communities across the globe. Changes to the electricity sector are a focus of many of the pledges countries made to reduce greenhouse emissions. Shifting electricity generation to primarily renewable sources is one of these goals. Building infrastructure that promotes energy efficiency in our homes and businesses and on our roads is another. And working toward a more equitable distribution of energy production and consumption will give everyone the means to participate in a sustainable energy future.

In 2020, the COVID-19 pandemic gripped the globe, and government efforts to mitigate the spread of the disease created dramatic, though temporary, changes in energy demand. Measures like travel restrictions, lockdowns, quarantines, and social distancing led to a 6 percent reduction in global energy consumption compared to 2019 levels. Due to the lack of demand, low costs, and priority access to the power grid, the U.S. saw renewable energy outpace coal-fired power plants during March to May 2020, the most stringent period of lockdown measures.[28] These energy consumption changes were also reflected in reduced emissions.

Globally, $CO_2$ emissions fell by 5.8 percent in 2020, and the U.S. saw a whopping 10 percent decrease in emissions, led primarily by the decline of vehicle use throughout the year. The lockdown measures taken to curtail the spread of COVID-19 put many countries, including the United States, back on track to reach their targets set in the Paris Agreement.[29]As countries began to re-open, energy demand, as well as emissions, rebounded closer to 2019 levels. While it is no surprise that lack of energy consumption results in fewer emissions, it is still an important example of what is possible to achieve as a planet. Continued progress on renewable energy sources in the transportation sector, coupled with regulations on our dirtiest fuel sources, could eventually make 2020 look more like an emissions norm than an anomaly.

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