

Coal (carbon dioxide released into the air)

How it works	Coal plants burn coal to make steam. The steam is used to power a type of engine, called a “turbine”. This turbine runs a generator to make electricity. When coal is burned, carbon dioxide is released by the plant. In this plant, the carbon dioxide escapes into the air because no equipment is added to capture the carbon dioxide.
Carbon dioxide released	Traditional coal plants release carbon dioxide to the air.
Environmental Impacts	<ul style="list-style-type: none"> — These plants produce a lot of solid waste (ash). Coal mining also produces waste products. The waste may contain a small amount of hazardous chemicals and radioactive materials. — Some solid waste produced by these plants can be recycled, such as to make concrete. The leftover waste is usually put in a landfill near the plant. Unlike disposal of household waste, the disposal of coal waste in landfills is not regulated by the federal government. — Coal mining near the surface disturbs the land, plants and animals. It also disrupts and pollutes streams. Underground mining can cause acidic water to leak into streams. If the mine collapses, it can also cause the ground to sink or shift.
Other Pollution/Waste	<ul style="list-style-type: none"> — While these plants are much cleaner than in the past, they still release CO₂, nitrogen oxides, sulfur dioxide, mercury and particulates to the air. These pollutants can cause people to have many different health problems. — Traditional coal plants produce a lot of ash that contain hazardous chemicals. Some ash can be recycled, for example, to make concrete. The leftover solid waste is usually put in a landfill near the plant. — Traditional coal plants use a lot of water to cool the plant’s equipment. The water comes from wells, lakes, rivers or oceans. Some of it will evaporate after use. The rest is returned to its source. Since it is hot, the water may disturb plants and animals living in the water source.
Noise	These plants are about as loud as average street traffic.
Land use and ecology	Coal mining near the surface disturbs the land, plants and animals. It also disrupts and pollutes streams. Underground mining can cause acidic water to leak into streams. If the mine collapses, it can also cause the ground to sink or shift.
Safety	These plants are quite safe for operators. Coal mining is dangerous for the miners. However, coal-mining related deaths have gone down over time. Mining now has stricter regulations and safer mining equipment.
Availability	The availability of coal in Germany has decreased tremendously in the past decades; in the U.S. it is projected to last for another 50 to 100 years.
Reliability	Coal can provide steady and dependable electricity.

Wind Power

How it works	Modern wind machines are much larger than the old windmills in Holland, or the metal windmills that pumped water for cattle in the American West. They are often between 100 and 300 feet high. That is about as tall as a 10 to 30 story building. The machines have blades that look like an airplane propeller. The wind turns the blades, and this runs a generator to make electricity.
Carbon dioxide released	Wind machines release no carbon dioxide to the air.
Environmental Impacts	<ul style="list-style-type: none"> — There is almost no solid waste from wind farms. — Wind farms with many machines require hundreds of acres. If the machines are built on farm land, most of it can still be used for farming. In forests, trees must be cleared to build the machines. This can disturb the plants and animals. On mountain ridges, wind farms can be very visible. — Wind farms make some low noise. It is less than the noise from most other power plants. But, since wind farms are in the country, the noise is often more noticeable. — The blades of wind machines sometimes strike and kill birds and bats. New wind machines are being located away from bird (migration) flight paths. Less is known about how to prevent bat deaths.
Other Pollution/Waste	<ul style="list-style-type: none"> — Wind farms, by themselves, release no air or water pollution. However, wind farms alone cannot make a steady amount of electricity. When it is not windy, the wind farms need natural gas plants to fill in these gaps in electricity. These natural gas plants do release nitrogen oxides into the air. — There is almost no solid waste from wind farms. — Wind farms use a very small amount of water to clean the wind machines.
Noise	Wind farms make some low noise. It is less than the noise from most other power plants. But, since wind farms are in the country, the noise is often more noticeable.
Land use and ecology	Each wind machine needs between 45 and 75 acres. That is about the size of 35 to 55 football fields. Wind farms with many machines require hundreds of acres. If the machines are built on farm land, most of it can still be used for farming. In forests, trees must be cleared to build the machines. This can disturb the plants and animals. On mountain ridges, wind farms can be very visible.
Safety	Wind farms do not harm people. The blades of wind machines do sometimes strike and kill birds and bats.
Availability	Wind farms work well when built in windy areas like hilltops or in the open sea ('off-shore wind parks'). However, even the best wind farms in Germany and the U.S. only make a small fraction of the power that would be possible if the wind was always blowing. They cannot make 100% because sometimes the wind is not blowing. Wind farms are often located far away from where people live, since this is where it is the windiest. It is expensive to transmit the wind electricity across long distances. On the other hand, wind parks located close to residential areas can draw citizens' criticism.
Reliability	<ul style="list-style-type: none"> — Wind varies in strength, which can make it less dependable for making electricity. Because of this, wind farms cannot consistently make electricity. Natural gas plants must be built to "back up" or fill in electricity during times when it is not windy. In the future, we might use very large batteries to store electricity from wind, but that is very costly to do today. — On average, a newly built wind farm can make about 0.5 TWh of electricity over the course of the year. The natural gas plant built to fill in electricity when it is not windy will have to make about 1.2 TWh over the course of the year.

Natural Gas

How it works	<ul style="list-style-type: none"> — Much of the natural gas in Europe is used to heat homes. But, it can also be used in power plants to make electricity. In the plant, natural gas is burned in a type of engine, called a “turbine”. This turbine then runs a generator to make electricity. The left-over hot gas is used to make steam. The steam also powers a turbine connected to a second generator to make more electricity. Because it uses two turbines, the plant is more efficient. — Natural gas comes from several sources. Conventional natural gas is found deep underground in sandstone and other sponge-like layers of rock. Gas wells are created by drilling down into these rocks, which causes the gas to naturally rise to the surface because of changes in pressure underground. One type of unconventional natural gas is shale gas. This natural gas is also found deep underground, but it is trapped inside hard layers of rock called shale. To get to this gas requires first drilling down deep underground. Next a hole is drilled sideways through the shale. A salty water solution is pushed down through the well at high pressure to break up the rock. This releases the natural gas from the rock, and the gas can then rise to the surface.
Carbon dioxide released	Natural gas plants release about half as much carbon dioxide to the air as traditional coal plants.
Environmental Impacts	There is almost no solid waste from gas plants. Natural gas pipelines sometimes must be built under private land. The landowner and pipeline company will have to agree about how to maintain the land around the pipeline. Drilling for natural gas can disturb local land, plants, and animals. This is especially true in unpopulated areas, like parts of Alaska.
Other Pollution/Waste	<ul style="list-style-type: none"> — Natural gas plants release nitrogen oxides into the air. These plants are often used along with solar plants or wind power. Natural gas plants fill in power when it is not sunny or windy. In this case, the natural gas plant must be turned on quickly. This can increase the nitrogen oxides released into the air. This pollutant can cause people to have some health problems. — There is almost no solid waste from gas plants. — Natural gas plants use a lot of water to cool the plant’s equipment. The amount is less than traditional coal plants. The water comes from wells, lakes, rivers or oceans. Some of it will evaporate after use. The rest is returned to its source. Since it is hot, the water may disturb plants and animals living in the water source
Noise	These plants are about as loud as average street traffic.
Land use and ecology	These plants do not use much land. But, pipelines sometimes must be built under private land. The landowner and pipeline company will have to agree about how to maintain the land around the pipeline. Drilling for natural gas can disturb local land, plants and animals. This is especially true in unpopulated areas, like Alaska.
Safety	<ul style="list-style-type: none"> — These plants are quite safe for operators. It is rare for natural gas to leak from a pipeline. If it does occur, unlike carbon dioxide, natural gas can burn or explode. Like carbon dioxide, people can suffocate from natural gas. — All types of natural gas production must meet strict environmental and safety standards. Thus, drilling for gas shale should be just as safe as it is for other types of natural gas. *
Availability	Today, most natural gas used in Germany and parts of the U.S. comes by pipeline (e.g., from the Gulf Coast, Russia, and other places). This natural gas is produced from conventional gas wells or transported from foreign countries (such as the Middle East) in large tanker ships. In the future, more natural gas will come from unconventional sources. Experts say that the U.S. has enough natural gas to meet its needs for at least 100 years. This is not the case in Germany, which depends on imported gas. Much of the gas in the U.S. is from unconventional sources, including gas shales.
Reliability	Natural gas can provide steady and dependable electricity.

Nuclear

How it works	Nuclear plants use uranium that has been slightly processed, or “enriched”. In a nuclear plant, the uranium atoms break apart and release heat that is used to make steam. The steam is used to power a type of engine, called a “turbine”. This turbine runs a generator to make electricity. Nuclear plants built in the future will have a more advanced design than existing ones. Nuclear power plants are described as safe by the industry, but history has shown that accidents involving nuclear power plants create extreme consequences for humans, animals, and plants, which are not comparable to any other power plant technology. In Germany, the government has decided to phase out all nuclear power plants in the near future.
Carbon dioxide released	Advanced nuclear plants release no carbon dioxide to the air.
Environmental Impacts	<ul style="list-style-type: none"> — Uranium fuel must be mined, but the amount that is mined is much less than that of coal. — Nuclear plants do have a small amount of waste. It is much less than the waste from coal plants. — The leftover fuel (waste) from a nuclear plant will produce radiation for thousands of years. This is why the German government mandates a secure storage of nuclear waste for at least 1 million (!) years. Radiation can cause cancer in people. Today, the leftover fuel is being stored in facilities close to the power plants, but central and long-term solutions have not yet been found. How soon that will happen is unclear. Engineers can design nuclear waste storage facilities that prevent radiation from getting out. Incidents like the Fukushima nuclear catastrophe (Japan, 2011) or in Chernobyl (USSR, 1986) remind us that accidents in the wake of earthquakes, or potential cyber or terrorist attacks continue to pose a risk.
Other Pollution/Waste	<ul style="list-style-type: none"> — Normally operating nuclear plants cause almost no air or water pollution. — Nuclear plants release some radiation into the air, ground, and water. Although nuclear power plant operators deny it, even such low levels of radiation have been found to cause cancer and birth defects in people living close to the facilities. — The leftover fuel from a nuclear plant will produce radiation for thousands of years (see above). Nuclear accidents have been quite frequent since the end of World War II. — Advanced nuclear plants use a lot of water to cool the plant’s equipment. Existing nuclear plants use about the same amount as traditional coal plants. But, advanced nuclear plants will likely use much less. The water comes from wells, lakes, rivers or oceans. Some of it will evaporate after use. The rest is returned to its source. Since it is hot, this water disturbs plants and animals living in the water source.
Noise	These plants are about as loud as average street traffic.
Land use and ecology	Uranium fuel must be mined. This can disturb land, plants and animals. The amount of uranium that is mined is much less than that of coal.
Safety	<ul style="list-style-type: none"> — Like coal plants, nuclear plants are safe for operators. All mining is dangerous for the miners. But mining uranium is generally much safer than mining coal. — Nuclear plants release some radiation into the air, ground, and water. Although nuclear power plant operators deny it, even such low levels of radiation have been found to cause cancer and birth defects in people living close to the facilities. — The threat of a nuclear accident is real. Nuclear material might leak into the air and water if there is an accident. Although nuclear plants cannot explode like an atomic bomb, past accidents have shown that they are not safe from accidents and natural catastrophes (like earthquakes). Cyber and terrorist attacks can also create risks. — Unlike older plants in some parts of the world (Russia), all U.S. and German plants are built inside strong concrete buildings. These are built to prevent leaks if there is an accident. Since the end of World War II, over two dozen nuclear accidents have occurred worldwide. — Many citizens worry about terrorism involving a nuclear plant, although governments, electric utility companies and other industries are working to make all industrial plants safer against terrorism. In France, Japan and England, portions of the nuclear fuel are separated and reused. This process changes the fuel into a product that could be used in nuclear weapons.
Availability	There is enough uranium available to power any new nuclear plants built in Germany and the U.S. for the life of the plants. Nevertheless, uranium cannot be generated on earth and is a very rare resource.
Reliability	Nuclear power can provide steady and dependable electricity.

The fact sheets are adapted from materials by the Gelfand Center at Carnegie Mellon University, Pittsburgh, PA. (URL: <https://www.cmu.edu/gelfand/documents/succeed/understanding-electricity-1/TechnologySheets.pdf>). These materials were produced with support from the Center for Climate and Energy Decision Making (SES-0949710), through a cooperative agreement between the National Science Foundation and Carnegie Mellon University. Information on biomass was also retrieved from <https://www.studentenergy.org/topics/biomass>.

Solar Cell Power

How it works	<p>There are two ways to make electricity from sunlight. In the first, sunlight is absorbed into solar cells. The energy from sunlight is then turned directly into electricity. In deserts, a second way is used. The heat from the sun is used to make steam. The steam is used to power a type of engine, called a “turbine”. This turbine runs a generator to make electricity. While the second way is cheaper, it cannot be used in many parts of the U.S. and either in Germany because there the sun is not intense enough.</p> <p>Many solar cells can be joined together on open land to make a large-scale solar power plant. On a smaller scale, solar cells can be put on the roofs of homes and businesses. Even though the governments may provide some rebates, the initial cost to the home- or business-owner can be very large.</p>
Carbon dioxide released	Solar plants release no carbon dioxide to the air.
Environmental Impacts	<ul style="list-style-type: none"> — While there is almost no solid waste from solar cell power, the cells are made of some toxic materials. There may be some pollution if they are not properly disposed of at the end of their lifetime. — Many solar cells must be put together to make a solar plant. Therefore, they use a lot of land. Unlike wind, this land cannot be used for other purposes. — The production of solar cells requires many resources and so although the cells themselves do not produce emissions, their production does.
Other Pollution/Waste	<ul style="list-style-type: none"> — Solar plants, by themselves, release no air or water pollution. However, solar plants alone cannot make a steady amount of electricity. When it is not sunny, the solar plants need natural gas plants to fill in these gaps in electricity. These natural gas plants do release nitrogen oxides into the air. — Solar cells are made of some toxic materials. They can cause pollution if they are not properly disposed of at the end of their lifetime. — Solar plants use a very small amount of water to clean the solar cells.
Noise	Solar plants are silent.
Land use and ecology	Many solar cells must be put together to make a solar plant. Therefore, they use a lot of land. Unlike wind, this land cannot be used for other purposes.
Safety	These plants are quite safe for operators and for the people who live around them.
Availability	There is no sunlight at night. There is less sunlight on cloudy days. In Germany and many (northern) parts of the U.S., the solar plants only make a small fraction of their possible power. They cannot make 100% because the sun does not always shine at maximum strength or for 24 hours per day. Also, solar panels can become 25% less productive when they are not regularly cleaned from dust or when the level of air pollution is too high.
Reliability	<ul style="list-style-type: none"> — The dependability of solar cell power varies with the amount of sunlight. Because of this, solar plants cannot consistently make electricity. Natural gas plants must be built to “back up” or fill in electricity during times when it is not sunny. In the future, we might use very large batteries to store electricity from solar power, but that is very costly to do today. — On average, a newly built large-scale solar farm can make 0.1 TWh of electricity over the course of the year. The natural gas plant built to fill in electricity when it is not sunny will have to make about 0.8 TWh over the course of the year.

Biomass

How it works	<p>Biomass refers to the organic material that is used for production of energy. Biomass is primarily found in the form of living or recently living plants and biological wastes from industrial and home use. Due to the breadth of the term, the physical composition of biomass is inconsistent, but generally includes carbon, water and organic volatiles.</p> <p>To produce energy from biomass, feedstock (= whatever type of organic material will be used to produce a form of energy) is needed. The feedstock must then be converted to a usable energy form through one of many processes:</p> <p><u>Feedstock + Process -> Usable Energy Form</u></p> <p>Common biomass conversion processes include: combustion (burning flammable materials to produce heat), gasification (using heat, pressure, and partial combustion to produce gas that can be used in place of natural gas), anaerobic digestion (bacteria are used to break down organic material, producing methane and solid residue from which energy can be produced), fermentation (adding bacteria or yeast to the feedstock to convert the plants' glucose into alcohol or acid).</p>
Carbon dioxide released	<p>While some biomass processes such as waste-to-energy are touted for their lower carbon dioxide emissions, some processes, such as combustion, release carbon dioxide and particulate matter that is a significant concern for human health.</p> <p>In some contexts, biomass has been declared a "carbon neutral" energy source. This is based upon the logic that carbon emissions from burning biomass will be recaptured by the plants grown to feed biomass reactors in the future, thus forming a carbon cycle for the plant.</p>
Environmental Impacts	<ul style="list-style-type: none"> Large land areas are often necessary to grow the feedstock for biomass plants. Often this feedstock will be grown in monocultures with severe impacts on biodiversity (diversity of plants and animals). Chemicals used to grow biomass can pollute the soil and water. Some biomass comes from woody waste products. But, on a larger scale, new trees or plants will need to be grown for biomass. This could mean that farms will grow less food, driving food prices up. Land may need to be cleared to grow more biomass or food. This could cause soil erosion and disturb the animals and plants.
Other Pollution/Waste	<ul style="list-style-type: none"> Depending on the type of biomass conversion processes involved, by-products like char and other solid residues. These can be either burned to produce power, or in some cases be used as cattle feed.
Noise	<p>Biomass plants produce noise caused by vents, boilers, conveyor systems etc. inside the plant as well as by truck/fuel unloading operations.</p>
Land use and ecology	<p>Depending upon the source of biomass used, deforestation, cropland degradation (due to diverting agricultural residues), and changes in land use can all be relevant issues associated with biomass. Large areas of land may be used for growing the feedstock instead of growing food products, which is a concerning issue especially in developing countries.</p>
Safety	<p>The lack of appropriate ventilation mechanisms for burning biomass is a major health concern and contributes to short life expectancies in much of the developing world.</p>
Availability	<p>Generally, land and resources (water, work, sunlight, etc.) are necessary to grow or produce the feedstock for biomass plants.</p> <p>Biomass can be found everywhere in the U.S. and Germany. But, many types of biomass are traditionally used for other things, such as for food (from farm crops). This means that electricity companies will have to compete with other buyers of the biomass "fuel".</p> <p>Often, the question of what feedstock and processes will be used is determined by their local availability. For example, often residual products from agriculture and waste are used to fuel biomass plants.</p>
Reliability	<ul style="list-style-type: none"> Biomass power can provide steady and dependable electricity.