

# Exploring Energy

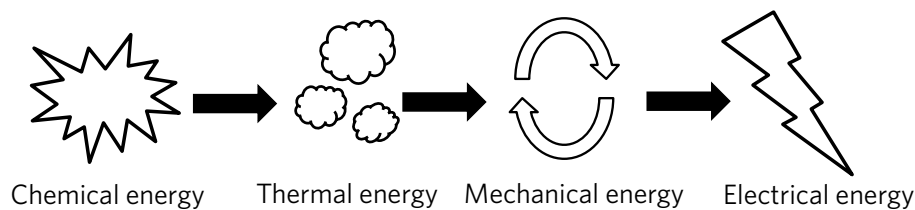
## Science Texts for Close Reading



### Fossil Fuels

Coal, oil/petroleum<sup>1</sup>, and natural gas are three main types of fossil fuels. They are called ‘fossil fuels’ because they formed from the remains of decaying plants and animals that were buried by layers of rock 300 million years ago. As this material was buried by more and more rock, high heat and pressure transformed it over millions of years. And depending on whether this occurred in vegetated swamps or plankton-filled seas, either coal, oil, or natural gas was formed.

When fossil fuels are burned—when they undergo a chemical reaction with oxygen—they release a lot of energy that we can use to power things. For example, in a coal-fired power plant, coal is burned in a boiler, releasing chemical energy that heats water into steam. The steam turns a turbine—a thing with blades that spins—connected to a generator. The generator converts the mechanical energy of the spinning turbine into electrical energy that can be transmitted to homes and buildings through transmission lines. While coal is typically used to produce electricity, oil can be refined into a variety of liquid fuels to power cars, trucks, and airplanes and is also made into a wide variety of everyday products, including plastics, cosmetics, clothes, electronics, and more. Natural gas is commonly used for heating and cooking in homes.

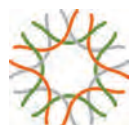


Coal, oil, and gas can generate huge amounts of energy and power a wide variety of things. Fossil fuels are relatively cheap, but as they become harder to extract from the Earth, they will become more expensive. Fossil fuels are easily stored and easily transported, and thus they can be used to power things almost anywhere and anytime.

One problem with fossil fuels is that they are nonrenewable resources, meaning that we are extracting them from the Earth and using them faster than they can form. Mining or pumping fossil fuels from the ground can damage ecosystems and the environment, as can accidents like oil tanker spills that are expensive to clean up<sup>2</sup>. Fossil fuels produce air pollution when they are burned. They also release carbon dioxide and other greenhouse gases into the atmosphere that not only warm the climate, but change the chemistry of the ocean.

<sup>1</sup> ‘Oil’ and ‘petroleum’ are often used interchangeably. For more information on the difference between the two, visit the [U.S. Energy Information Administration’s website](#).

<sup>2</sup> [Fortune Magazine: 6 big oil spills, and what they cost](#)



# Weighing the Benefits and Drawbacks of Fossil Fuels



For a complex problem, we need to evaluate how a solution fares across multiple dimensions:

**Benefits**

**Drawbacks**

**Environmental  
Factors**

**Social & Cultural  
Factors**

**Economic  
Factors**



# Exploring Energy



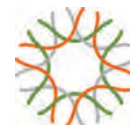
## Weighing the Benefits and Drawbacks of Fossil Fuels

For a complex problem, we need to evaluate how a solution fares across multiple dimensions:	Benefits	Drawbacks
<b>Environmental Factors</b>		<ul style="list-style-type: none"><li>▪ Burning fossil fuels releases carbon dioxide into the atmosphere, contributing to global warming and changing the chemistry of the ocean.</li><li>▪ Burning fossil fuels releases air pollution.</li><li>▪ Mining and extracting fossil fuels from the ground can harm the environment.</li></ul>
<b>Social &amp; Cultural Factors</b>	<ul style="list-style-type: none"><li>▪ Fossil fuels are accessible to a lot of people since they are easily transported and stored.</li></ul>	
<b>Economic Factors</b>	<ul style="list-style-type: none"><li>▪ Fossil fuels are turned into a variety of the products that we use every day, like plastic and clothing.</li><li>▪ Fossil fuels are relatively cheap.</li></ul>	<ul style="list-style-type: none"><li>▪ Fossil fuels are nonrenewable resources.</li><li>▪ Damage to the environment caused by things like oil spills can be expensive to clean up.</li><li>▪ As fossil fuels become harder to find, they will become more expensive.</li></ul>

### Additional resources

California Academy of Sciences: [Fossil Fuels: Air Pollution and the Greenhouse Effect activity](#)

California Academy of Sciences: [Fossil Fuels: Chocolate Chip Mining activity](#)

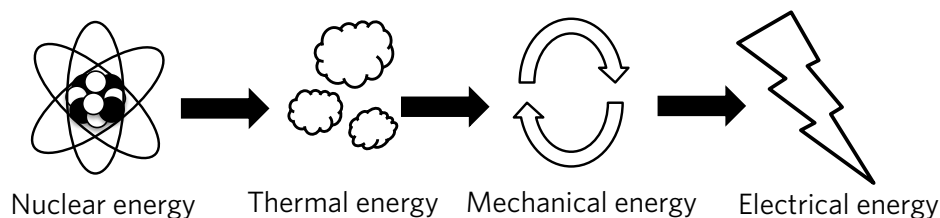




### Nuclear Energy

How is electricity generated at a nuclear power plant? Well, it is often a lot like how electricity is generated at a coal power plant, but with one key difference. In both cases, water is heated into steam, which turns a turbine connected to a generator. The generator converts the mechanical energy of the spinning turbine into electrical energy that can be transmitted to homes and buildings through transmission lines.

The key difference between a coal power plant and a nuclear power plant is in the fuel they use to heat the water. In a coal power plant, burning coal supplies the energy to heat the water, which releases carbon dioxide—a powerful greenhouse gas that contributes to global warming and climate change—and other pollutants into the atmosphere. In a nuclear power plant, this energy comes from nuclear fission, or the splitting of a large atom like uranium into two smaller atoms. Fission happens when a neutron—a neutrally charged particle—collides with a uranium atom. This collision releases more neutrons, which are free to collide with more uranium atoms, causing more fission. When this fission chain reaction is carefully controlled in a nuclear reactor, a constant supply of energy is produced. And it doesn't take much uranium to produce a lot of energy. A single pellet of uranium less than one inch long can produce the same amount of energy as a ton of coal!



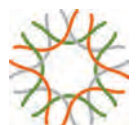
Nuclear energy is nearly greenhouse gas-free, meaning that it doesn't release carbon dioxide into the atmosphere like coal power plants do. However, nuclear energy isn't without some drawbacks. Nuclear fission is a type of radioactivity, and large amounts of this kind of radioactivity, or radiation, can be harmful to life. The uranium used in a nuclear reactor is carefully trapped and contained so that radiation cannot escape, and nuclear power plants are protected by all sorts of systems that can shut the reactors down quickly if something were to go wrong, but that hasn't prevented a few nuclear accidents from happening in the past<sup>2</sup>. Environments that are contaminated by high levels of radiation are dangerous to live in or visit.

Over time, the fuel in a nuclear reactor becomes less and less effective, and must be replaced with new fuel and disposed of. However, this old, or 'spent' fuel is still radioactive and can be so for hundreds of thousands of years<sup>3</sup>, so it needs to be disposed of in a way that won't harm the environment or people. This might mean burying it deep underground, but if this isn't done properly, it could contaminate groundwater that might come in contact with it.

<sup>1</sup> [Duke Energy: How Do Nuclear Power Plants Work?](#)

<sup>2</sup> [Union of Concerned Scientists: A Brief History of Nuclear Accidents](#)

<sup>3</sup> [United States Nuclear Regulatory Commission: High Level Waste](#)





# Weighing the Benefits and Drawbacks of Nuclear Energy

For a complex problem, we need to evaluate how a solution fares across multiple dimensions:

**Benefits**

**Drawbacks**

**Environmental  
Factors**

**Social & Cultural  
Factors**

**Economic  
Factors**



# Exploring Energy



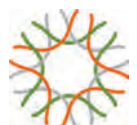
## Weighing the Benefits and Drawbacks of Nuclear Energy

<b>For a complex problem, we need to evaluate how a solution fares across multiple dimensions:</b>	<b>Benefits</b>	<b>Drawbacks</b>
<b>Environmental Factors</b>	<ul style="list-style-type: none"><li>▪ Nuclear energy produces nearly zero greenhouse gases like carbon dioxide that contribute to global warming and climate change.</li></ul>	<ul style="list-style-type: none"><li>▪ If radioactive material were to escape from a nuclear power plant, it could damage the environment.</li><li>▪ Improper disposal of nuclear waste could contaminate the environment.</li><li>▪ Mining the uranium for fuel from the ground can damage the environment.</li></ul>
<b>Social &amp; Cultural Factors</b>	<ul style="list-style-type: none"><li>▪ Since nuclear energy can produce a large amount of energy using minimal materials, it could be a potential solution for all of the people around the world who don't have electricity.</li></ul>	<ul style="list-style-type: none"><li>▪ Some people are concerned about the safety risks associated with nuclear power and don't want to live near a nuclear power plant.</li></ul>
<b>Economic Factors</b>	<ul style="list-style-type: none"><li>▪ Nuclear energy is a constant source of energy that isn't limited by rain, clouds, lack of wind, drought, or nighttime.</li><li>▪ Only a very small amount of fuel is needed to produce a large amount of energy.</li></ul>	<ul style="list-style-type: none"><li>▪ If you take into account the cost of mining uranium for nuclear fuel, ensuring safety, and dealing with waste, nuclear power can be expensive compared to other energy technologies.</li></ul>

### Additional resources

U.S. Energy Information Administration: [U.S. Nuclear Statistics](#)

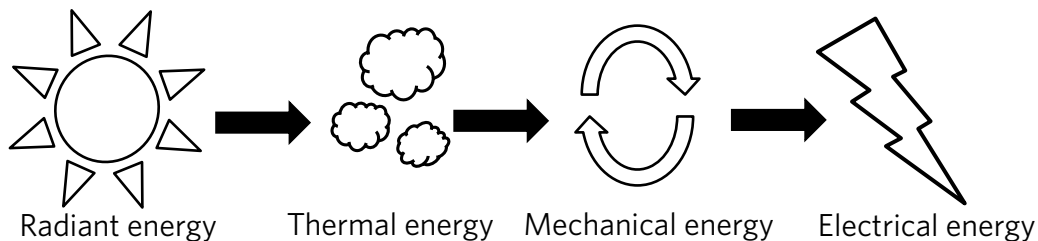
KQED Quest: [How Nuclear Reactors Work](#)





### Solar Energy

Solar energy is a way to harness sunlight for heating or electricity. There are different ways to convert sunlight into usable energy. Concentrated solar power uses mirrors to focus the energy from the sun onto a smaller area. This concentrated thermal energy heats water into steam, which turns a turbine connected to a generator. The generator converts the mechanical energy of the spinning turbine into electrical energy. Concentrated solar power plants need between 500 to over 1,000 acres of land—more than 400 football fields!—to have enough mirrors to generate electricity efficiently. Often they are found in unpopulated desert regions—like the Ivanpah Solar Electric Generating System in the Mojave desert—which means the electricity generated has to be transmitted a long distance to where it will be used. It also means that large regions of desert ecosystems can be impacted<sup>1</sup>.



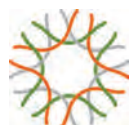
Another technology that can convert the energy of sunlight into electricity is solar photovoltaics (PV). When sunlight strikes a solar photovoltaic cell, it is absorbed by a semiconductor—a material like silicon that can conduct electricity under the right conditions. This excites electrons in the semiconductor, which then flow, generating an electrical current. A bunch of solar photovoltaic cells can be grouped together to create a solar panel. Solar panels can be installed on the roofs of homes and buildings in solar arrays, so they are better options for cities. Solar panels are relatively easy to take care of and aren't noisy.

Solar photovoltaic technology produces no direct carbon dioxide or other greenhouse gases that can warm the climate. Sunlight is free, abundant, and renewable, since it won't run out for billions of years. The Earth's surface continuously receives 10,000 times more energy from the sun than the world currently uses<sup>2</sup>!

Unfortunately, solar energy isn't a great option everywhere or all of the time. Regions that don't get a lot of constant or direct sunlight aren't ideal places to use solar energy. Solar panels don't work at night and don't work as well when it is cloudy. Solar technology is becoming cheaper, but there is a cost to build a large concentrated solar power plant or install solar panels.

<sup>1</sup> [The New York Times: BrightSource Alters Solar Plant Plan to Address Concerns Over Desert Tortoise \(Feb. 2010\)](#)

<sup>2</sup> [U.S. Department of Energy](#)



# Weighing the Benefits and Drawbacks of Solar Energy



For a complex problem, we need to evaluate how a solution fares across multiple dimensions:

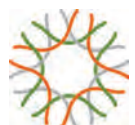
**Benefits**

**Drawbacks**

**Environmental  
Factors**

**Social & Cultural  
Factors**

**Economic  
Factors**





# Exploring Energy



## Weighing the Benefits and Drawbacks of Solar Energy

For a complex problem, we need to evaluate how a solution fares across multiple dimensions:	Benefits	Drawbacks
<b>Environmental Factors</b>	<ul style="list-style-type: none"><li>• Solar PV does not directly produce greenhouse gases like carbon dioxide that contribute to global warming and climate change.</li></ul>	<ul style="list-style-type: none"><li>• Large concentrated solar power plants can impact ecosystems because of their large land footprint.</li></ul>
<b>Social &amp; Cultural Factors</b>	<ul style="list-style-type: none"><li>• There is more than enough solar energy to go around.</li></ul>	
<b>Economic Factors</b>	<ul style="list-style-type: none"><li>• Sunlight is free!</li></ul>	<ul style="list-style-type: none"><li>• There is a cost to installing solar panels.</li><li>• Building large concentrated solar power plants can be expensive.</li><li>• Solar power isn't a feasible option for energy generation everywhere, since not every region has a lot of direct or constant sunlight.</li></ul>

### Additional resources

[GRID Alternatives](#): Making solar technology accessible to underserved communities  
[Solar Energy Basics](#) from the National Renewable Energy Laboratory

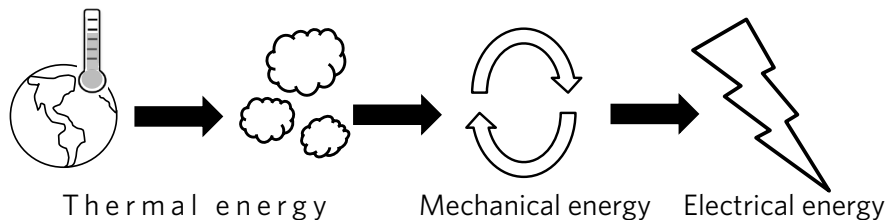




### Geothermal Energy

How is electricity generated at a geothermal power plant? Well, it is often a lot like how electricity is generated at a coal-fired power plant, but with one key difference. In both cases, water is heated into steam, which turns a turbine connected to a generator. The generator converts the mechanical energy of the spinning turbine into electrical energy that can be transmitted to homes and buildings through transmission lines.

In a coal power plant, burning coal supplies the energy to heat the water. This process releases carbon dioxide—a powerful greenhouse gas that contributes to global warming and climate change—and other pollutants that can be harmful to the environment and human health into the atmosphere. But in a geothermal power plant, this energy comes from heat that is already present below the Earth’s surface. Geothermal energy is a good energy option in places where there is hot magma close to the Earth’s surface that naturally heats water in the ground into steam. In such places, geothermal energy is a constant and reliable source of energy.



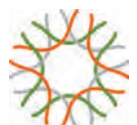
Compared to coal and other fossil fuels, geothermal energy releases much less carbon dioxide into the atmosphere<sup>1</sup> and produces much less pollution. But geothermal energy isn’t a good option everywhere. The best places for geothermal energy production are where there is a heat source, like magma, close to the Earth’s surface, as well as a constant supply of water in the ground that can be heated into steam. Some water can be pumped back into the ground after it is used, but some of it evaporates into the atmosphere, so over time the water in the ground often needs to be replenished. During a drought, this can be an issue. Also, there is evidence that the pumping of water into and out of the ground associated with geothermal power can generate small earthquakes<sup>2</sup>.

With geothermal energy, there is no fuel cost, since the fuel is naturally-occurring magma. However, upfront costs associated with building a new geothermal power plant and drilling wells to access the steam underground can be high<sup>3</sup>.

<sup>1</sup> [National Renewable Energy Laboratory: Energy Analysis](#)

<sup>2</sup> [University of California, Santa Cruz Newscenter: Geothermal power facility induces earthquakes, study finds](#)

<sup>3</sup> [Geothermal Energy Association](#)





# Weighing the Benefits and Drawbacks of Geothermal Energy

For a complex problem, we need to evaluate how a solution fares across multiple dimensions:

**Benefits**

**Drawbacks**

**Environmental  
Factors**

**Social & Cultural  
Factors**

**Economic  
Factors**



# Exploring Energy

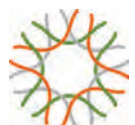


## Weighing the Benefits and Drawbacks of Geothermal Energy

For a complex problem, we need to evaluate how a solution fares across multiple dimensions:	Benefits	Drawbacks
<b>Environmental Factors</b>	<ul style="list-style-type: none"><li>• Geothermal power plants produce less pollution and greenhouse gas emissions than coal-fired power plants.</li></ul>	<ul style="list-style-type: none"><li>• Pumping water into and out of the ground might induce small earthquakes around a geothermal power plant.</li></ul>
<b>Social &amp; Cultural Factors</b>		
<b>Economic Factors</b>	<ul style="list-style-type: none"><li>• The 'fuel' for geothermal energy is free since it is naturally-occurring magma.</li><li>• In places where geothermal energy is a viable option, it is a constant and reliable source of energy.</li></ul>	<ul style="list-style-type: none"><li>• Geothermal energy is location-specific and isn't an option where there isn't enough heat below the ground.</li><li>• The initial costs associated with building a geothermal power plant and drilling steam wells can be high.</li></ul>

### Additional resources

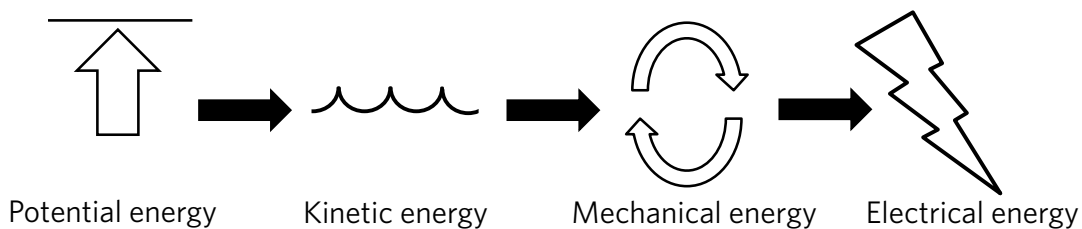
Learn about [The Geysers geothermal power plant in California](#)





### Hydroelectric Power

Hydroelectric power (or 'hydropower') uses the energy of moving water to generate electricity. But how exactly can we capture and transform this energy into usable electricity? One of the main ways to do this is by building a dam on a river. By trapping water behind a dam, we can increase the level of the water behind the dam, building up its potential energy. When special gates in the dam are opened, the water—pulled by gravity—flows down through the dam and through turbines connected to a generator. The potential energy of the water is turned into kinetic energy as it flows, and then mechanical energy that turns the turbines. The generator converts the mechanical energy of the spinning turbines into electrical energy that can be transmitted to homes and buildings through transmission lines.



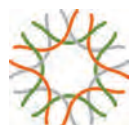
The water reservoirs (lakes and ponds) created behind dams can serve as recreational spaces for people who enjoy fishing, swimming, or boating. The water in these reservoirs can also be used for irrigation in agricultural areas.

Hydropower does not pollute the water nor the air. It also produces no direct carbon dioxide or other greenhouse gases that can cause damage to the climate. However, building a dam on a river can have significant impacts on ecosystems. Some fish species like salmon that migrate seasonally up rivers and streams to spawn are blocked from reaching their spawning destinations by dams<sup>1</sup>. The reservoir created behind a dam often floods land that wasn't originally underwater. In addition to impacting the plants and animals living on this land, this can displace people too.

Hydropower is reliable as long as there is enough available water. During a drought, this can be a problem. And while flowing water is free, building a dam can be expensive. Dams also don't just trap water, but anything being moved by the river. Sand and rocks can build up behind a dam over time, not only decreasing the amount of water the dam can store and release, but reducing the amount of sand that is carried into the coastal ocean to supply beaches<sup>2</sup>.

<sup>1</sup> [NOAA Fisheries: About Dams & Fish](#)

<sup>2</sup> [CoastalCare.org: Dams-Cutting Off Our Beach Sand](#)





# Weighing the Benefits and Drawbacks of Hydroelectric Power

For a complex problem, we need to evaluate how a solution fares across multiple dimensions:

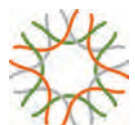
**Benefits**

**Drawbacks**

**Environmental  
Factors**

**Social & Cultural  
Factors**

**Economic  
Factors**



# Exploring Energy



## Weighing the Benefits and Drawbacks of Hydroelectric Power

For a complex problem, we need to evaluate how a solution fares across multiple dimensions:	Benefits	Drawbacks
<p><b>Environmental Factors</b></p>	<ul style="list-style-type: none"> <li>Hydroelectric dams do not pollute the water nor air and do not directly produce carbon dioxide.</li> </ul>	<ul style="list-style-type: none"> <li>Hydroelectric dams can block fish migrations up and downstream.</li> <li>The reservoirs created by dams can flood sensitive and important habitats and ecosystems.</li> <li>Dams can prevent sand from being carried down rivers and out to beaches along the coast.</li> </ul>
<p><b>Social &amp; Cultural Factors</b></p>	<ul style="list-style-type: none"> <li>The reservoirs created by dams can often be used for recreational purposes, like fishing, boating, or swimming.</li> <li>The reservoirs created by dams can often be used for agricultural irrigation.</li> </ul>	<ul style="list-style-type: none"> <li>Dams can flood land where people are living, forcing them to move elsewhere.</li> </ul>
<p><b>Economic Factors</b></p>	<ul style="list-style-type: none"> <li>Flowing water is a free and renewable source of energy.</li> </ul>	<ul style="list-style-type: none"> <li>Building a dam can be very expensive.</li> <li>Dams might not be a reliable source of energy when there is a drought.</li> <li>Dams can become less useful over time as the reservoirs fill up with sand and rocks.</li> </ul>

### Additional resources

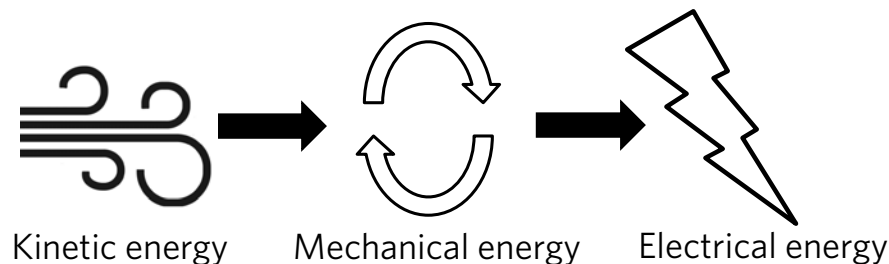
KQED News: [California Plumbing: A Mind-Boggling Web](#)





### Wind Energy

Have you ever tried to make a toy pinwheel spin by blowing on it? We can harness the power of moving air on a much larger scale and use it to produce electricity with wind turbines. When the wind is strong enough (has enough kinetic energy), the blades of a wind turbine turn, which spins a shaft connected to a generator. The generator converts the mechanical energy of the spinning shaft into electrical energy that can be transmitted to homes and buildings through power lines.



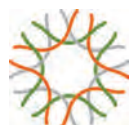
There are many different kinds of wind turbines, from small turbines that can be put on the roof of a house to really large turbines that can be built together in wind farms to power entire communities. Wind energy—a renewable resource—can be produced anywhere where there is wind, but the stronger and more consistently the wind blows, the better. Unfortunately, in most places the wind isn't blowing all of the time, and in places that aren't very windy, wind turbines probably aren't a good way to generate reliable electricity.

Wind energy doesn't directly produce carbon dioxide or other greenhouse gases that can cause damage to the climate. Wind power is also relatively inexpensive. The wind itself is a free resource, and although it costs money to build and operate wind turbines, advancements in technology have significantly reduced these costs over time. Wind energy doesn't pollute like coal burning, and pollution can cause health problems for people<sup>1</sup>. However, like with any infrastructure, some people express concern about wind turbines being too noisy or ruining the look of a landscape, and therefore don't necessarily want wind turbines near their homes.

Some kinds of wind turbines, particularly larger ones, can cause harm to birds and bats<sup>2</sup>; however, people are working on ways to reduce the impact of wind turbines on birds and bats, such as changing the height or location of the turbines.

<sup>1</sup> [World Health Organization: What are the effects on health of transport-related air pollution?](#)

<sup>2</sup> [Smallwood, 2013](#)





# Weighing the Benefits and Drawbacks of Wind Energy



For a complex problem, we need to evaluate how a solution fares across multiple dimensions:

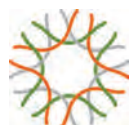
**Benefits**

**Drawbacks**

**Environmental  
Factors**

**Social & Cultural  
Factors**

**Economic  
Factors**



# Exploring Energy



## Weighing the Benefits and Drawbacks of Wind Energy

For a complex problem, we need to evaluate how a solution fares across multiple dimensions:	Benefits	Drawbacks
<b>Environmental Factors</b>	<ul style="list-style-type: none"><li>• Wind energy does not produce greenhouse gases like carbon dioxide that contribute to global warming and climate change.</li><li>• Wind power does not produce air and water pollution.</li></ul>	<ul style="list-style-type: none"><li>• Wind turbines can harm bats and birds.</li></ul>
<b>Social &amp; Cultural Factors</b>		<ul style="list-style-type: none"><li>• Some people are concerned about the way wind turbines might look or the noise they might generate.</li></ul>
<b>Economic Factors</b>	<ul style="list-style-type: none"><li>• The ‘fuel’ for wind power—the wind!—is free.</li><li>• Wind power technology is relatively inexpensive</li></ul>	<ul style="list-style-type: none"><li>• Wind power isn’t a feasible option for energy generation everywhere, since not every region has a lot of wind. Even in places that have a lot of wind, it still isn’t blowing all of the time.</li></ul>

### Additional resources

California Academy of Sciences: [Our Clean Energy Future](#)

California Academy of Sciences: [Birds vs. Energy](#)

