

## Renewable energy and storage systems

Energy storage is a technology that holds energy at one time so it can be used at another time. Building more energy storage allows renewable energy sources like wind and solar to power more of our electric grid. As the cost of solar and wind power has in many places dropped below fossil fuels, the need for cheap and abundant energy storage has become a key challenge for building an energy system that does not emit greenhouse gases or contribute to climate change.

Energy storage will be even more important if we change our transportation system to run mainly on electricity, increasing the need for on-demand electric power. Because transportation and electricity together produce almost half of the world's greenhouse gas emissions, cheap energy storage has a huge role to play in fighting climate change.

Solar and wind provide "intermittent" electricity, meaning their energy production changes depending on the weather. People often need energy when the wind is not blowing or the sun isn't shining, so we can end up with too much electricity at some times, and not enough electricity at other times. This is commonly referred to as the "grid level energy storage problem." If we could store the extra energy when we have it, save it for later, then use it when we need it, we could get all or nearly all our electricity from wind and solar.

However, storing energy is expensive. In fact, when you add the cost of an energy storage system to the cost of solar panels or wind turbines, solar and wind are no longer competitive with coal or natural gas. As a result, the world is racing to make energy storage cheaper, which would allow us to replace fossil fuels with wind and solar on a large scale.

There are various forms of energy storage in use today. Electrochemical batteries, like the lithium-ion batteries in electric cars, use electrochemical reactions to store energy. Energy can also be stored by making fuels such as hydrogen, which can be burned when energy is most needed. Pumped hydroelectricity, the most common form of large-scale energy storage, uses excess energy to pump water uphill, then releases the water later to turn a turbine and make electricity. Compressed air energy storage works similarly, but by pressurizing air instead of water. Another technology being developed is called thermal energy storage, which stores energy as heat in an inexpensive medium such as rocks, liquid salt or cheap elements.

Each form of energy storage has its own challenges and advantages. In comparing the costs of energy storage systems, experts consider the cost of the system, its lifetime before it needs to be replaced, and the amount of energy lost between charging and discharging the system. Time will tell which technologies emerge as widely adopted solutions.

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Hydrogen and fuel cells can be incorporated into existing and emerging energy and power systems to avoid curtailment of variable renewable sources, such as wind and solar; enable a more optimal capacity utilization of baseload nuclear, natural gas, and other hydrocarbon-based plants; provide voltage and frequency stabilization support for the electric grid; and/or provide clean, reliable distributed and backup power generation. The use of hydrogen for energy storage can play a key role in these systems.

Systems development and integration (SDI) projects in this application space help to enable the production, storage, and/or transport of low-cost clean hydrogen from intermittent and curtailed renewable sources, while providing grid reliability and dynamic response to match grid demands. They also support market penetration of renewable energy systems, such as wind and solar, and help provide additional revenue streams for nuclear power plants producing clean hydrogen with otherwise curtailed power when power prices are low.

The SDI subprogram's strategic priorities in energy storage and power generation focus on grid integration of hydrogen and fuel cell technologies, integration with renewable and nuclear power, and can provide primary or backup power, such as data centers.

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