USHERING IN THE CLEAN ENERGY TRANSITION

Once relegated to the sidelines of investors' attention due to broad overreliance on subsidies and a lack of economic edge vs. traditional energy, clean energy and clean technology are in the midst of a new era of growth and competitiveness. Although **wind** and **solar** capacity have been expanding rapidly for over a decade, utilities have only recently wholeheartedly embraced both renewable sources as key generation technologies to upgrade power plant fleets, which has dramatically accelerated the large-scale shutdown of coal.

Meanwhile, the stability of **hydropower** and **geothermal power** has been steadily generating baseload energy for decades. When combining all renewable sources, 2019 marked the first year in the modern electric era that renewable energy surpassed coal in the US energy supply mix. In fact, countrywide annual energy consumption from coal has reached its lowest level since 1965 in the US.[1]

> **2020 coal use was the lowest since 1965, and clean energy has already surpassed coal in the US.**

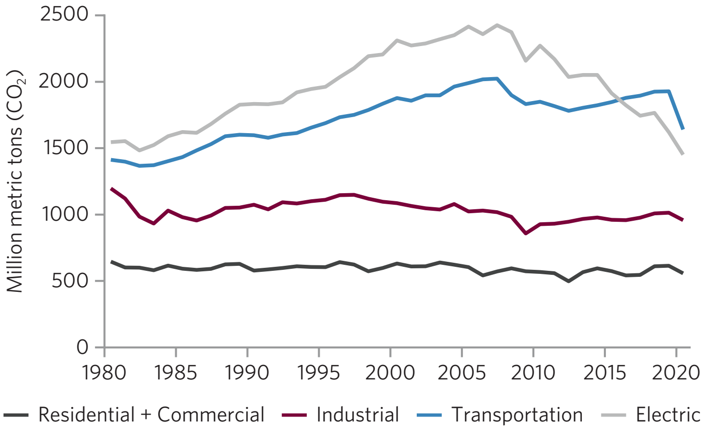
In addition to the continued trend of renewable energy additions, clean technology will play a key role in achieving better **energy management and storage** to help us both conserve energy and minimize greenhouse gas emissions, while also supporting continued economic growth. Advances in technologies are enabling a smart grid capable of integrating more distributed sources of energy while at the same time being more resilient. Advances in **energy storage** technology are helping facilitate the proliferation of clean energy beyond the times of day when renewables are producing.

Nowhere is this technology disruption more evident than in the electrification of transportation. As the technology has advanced, all types of vehicles are being electrified—from passenger cars to large commercial trucks—improving the outlook for **electric vehicles** and **fuel cell** technologies which are likely to increasingly use hydrogen for fuel. Given the meaningful reduction in emissions from the electric sector over the past decade, transportation is now the largest source of greenhouse gas emissions in the US, accounting for approximately 29% of the total.[2]

Bioenergy forms another option for alternative fuels and renewable electricity generation. Next-generation biofuels, modern biomass, and renewable natural gas are helping to secure our energy supply and reduce greenhouse gas emissions.

Carbon reduction has accelerated from clean energy additions

US CO_2 emissions by source



Source: US Energy Information Administration (July 2020).

Numerous policy support initiatives are being proposed around the world, further reinforced by stimulus spending broadly, as momentum builds to address climate change. Governments are accelerating efforts to transition to a clean energy future through further incentives, more stringent mandates and potentially a more prevalent price on carbon. In addition, as technology continues to drive down costs, more companies are speeding up their own transition plans with meaningful commitments to lowering net carbon emissions.

Hundreds of US utilities and other large corporations have committed to net-zero emissions in the coming decades.[3] All of this culminates in an attractive investment environment for the companies delivering on the promise of clean energy today.

> **We continue to believe [this] is the best renewables development environment we have ever seen.**
>
> Jim Robo, CEO, NextEra Energy, January 26, 2021

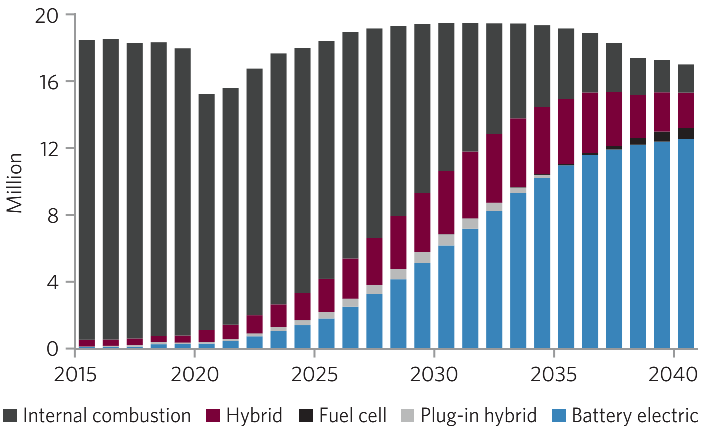
Electric Vehicles

Electric vehicles (EVs) are increasingly accepted as viable alternatives to internal combustion engines as battery technologies improve, charging infrastructure is built out, and car companies offer an expanded range of models. Bloomberg New Energy Finance (BNEF) estimates that EV's will reach price parity as early as 2022 in some geographies, with most achieving price parity by the end of the decade.[4] In fact, electric vehicles encompass much more than just passenger vehicles, with substantial potential for other uses, including buses, scooters, and commercial vehicles like delivery vans, garbage trucks and long-haul tractor trailers.

California and other states are already putting mandates in place, such as the Advanced Clean Trucks (ACT) rule, that broadly seek to achieve sales of only zero-emission commercial vehicles by 2045.[5] These types of policies are often accompanied by hundreds of millions of dollars in spending for EV charging infrastructure, which should help minimize consumer anxiety around range and further the adoption of electric vehicles.

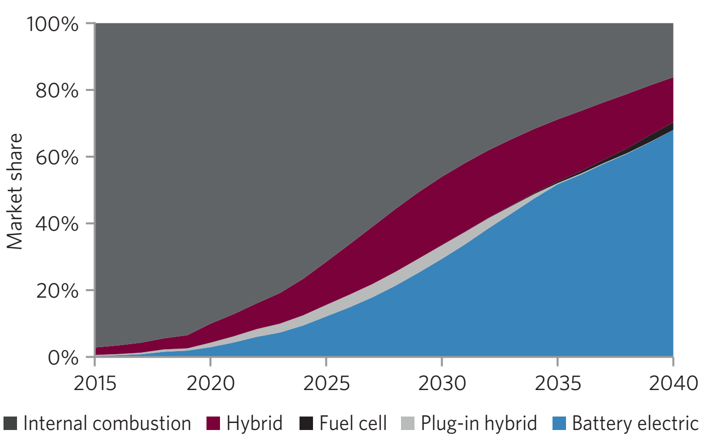
> **By 2035, analysts project over 50% of passenger vehicles sold globally will be battery electric vehicles (BEVs).**
>
> BloombergNEF: Long-Term Electric Vehicle

Mid 2030's: BEV sales pass 10mn in North America



Source: Bloomberg NEF: Long-Term Electric Vehicle Outlook 2020.

BEV's >50% globally by 2035



Source: BloombergNEF: Long-Term Electric Vehicle Outlook 2020.

Fuel Cell / Hydrogen

Fuel cells use an electrochemical process to convert fuel and oxygen from the air into electricity, water and heat. Depending on the fuel source, fuel cells could play a key role in decarbonizing the world economy over the coming decades.

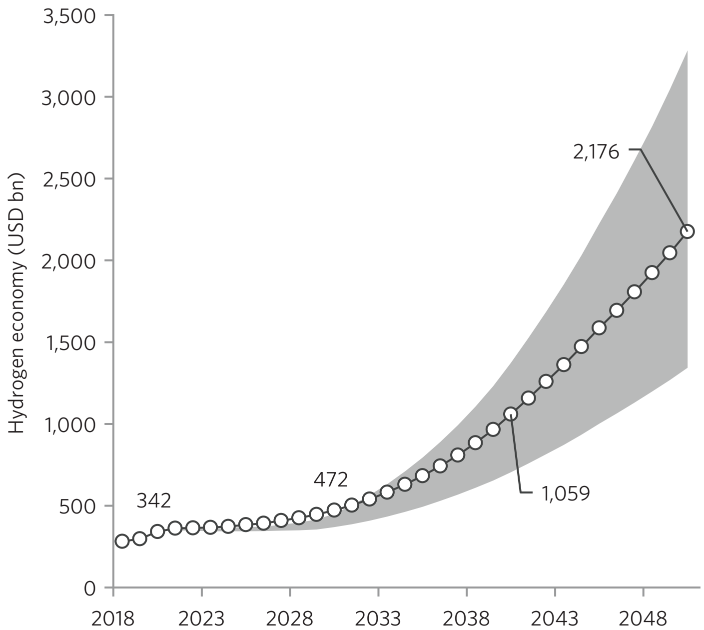
Many of the cleanest fuel cell technologies will utilize hydrogen produced from renewable energy in the future. There are a number of fuel cell technologies being pursued, but most rely on some combination of materials to split molecules into protons and electrons to generate electricity. While fuel cells are being deployed at scale today in niche applications, such as material handling and backup power generation, they have not yet reached a low enough price point to compete in larger market segments such as passenger EVs but are expected to compete effectively in heavy-duty transport over the long-term as hydrogen costs decline.[6]

Fuel cells often use hydrogen as an input to produce electricity but can also use alternatives like renewable natural gas as it becomes more widely available. Pairing fuel cells with hydrogen produced with renewable energy, known as green hydrogen, holds real promise to significantly reduce carbon emissions from some of the more energy-intense segments of the economy. The most obvious application is to decarbonize the heavy transportation industry, particularly heavy-duty trucking and shipping, which requires travel over long distances between refueling. There are several other applications not well suited to battery electric solutions that are expected to help drive broad-based hydrogen and fuel cell adoption as well, including industrial energy, building heat and stationary power generation.

One of the main challenges to scaling hydrogen use in fuel cells while keeping emissions low is transitioning from fossil fuel- based production (grey hydrogen) to fossil fuel-based production with carbon capture and storage (blue hydrogen), and finally to full renewable-energy electrolysis (green hydrogen). But the rapid expansion of wind and solar, driven by significant cost declines, will help achieve this as well. In fact, the cost of electrolysis (which is used to produce hydrogen from renewable electricity) fell 60% from 2010 to 2020 and is expected to fall another 60% by 2030.[7]

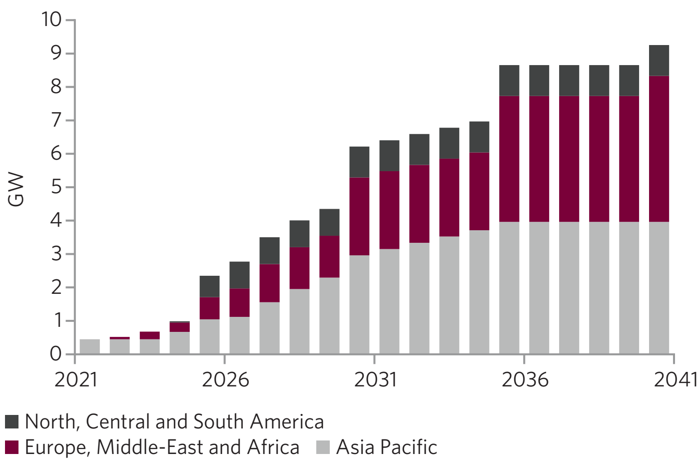
> **The hydrogen economy could reach over $2 trillion by 2050.**
>
> Alliance Bernstein - Hydrogen Highway 2021: Hydrogen One, Carbon Zero

The hydrogen economy could be massive



Source: Alliance Bernstein - Hydrogen Highway 2021: Hydrogen One, Carbon Zero.

Green hydrogen is set to expand



Source: Alliance Bernstein - Hydrogen Highway 2021: Hydrogen One, Carbon Zero.

Wind

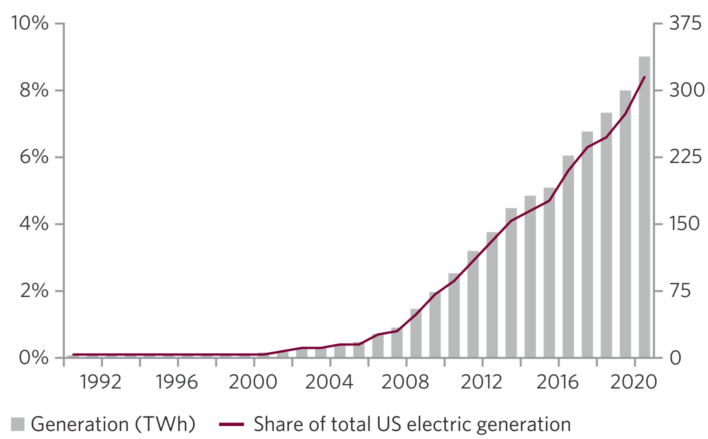
Wind energy has been one of the fastest-growing technologies in the electric generation mix of the US, growing from only 6 billion kilowatt hours in 2000 to 338 billion kilowatt hours in 2020, making up over 8.4% of US utility scale electricity generation and surpassed hydro as the most used renewable source in the country in 2019.[8], [9] Total wind capacity was over 125 GW in the US at the end of 2020, and the wind industry supported over 120,000 jobs in the country (25,000 in Texas alone).[10]

Although the wind industry has been supported by tax credits historically, government support is much less relevant today. Utilities are increasingly supportive of wind energy, as evidenced by the substantial increase in market share of electricity generation in the US. The largest wind developer in the country, NextEra Energy, projects that wind and solar will be cost-competitive with existing coal and nuclear power generation by the mid 2020s with no subsidies.[11]

The economics of wind power are largely based on turbine size and height, and wind turbines have consistently grown in size and scale for decades. The secret of wind economics lies in the fact that larger blades generate exponentially more power as they capture significantly more wind. In the mid-1990s, average wind turbines had less than 1 megawatt capacity, were approximately 160 feet in diameter, and were approximately 260 feet tall from bottom to tip.[12] Modern wind turbines are substantially larger, and the largest turbine in the world currently slated for production is already at a 15-megawatt capacity, with 380 feet blades and standing 855 feet tall for offshore wind power.[13] Further, a single turbine can produce enough power for around 20,000 homes. Large wind installations can reach into the hundreds of turbines. While the average turbine installed today is not this large, future turbine trajectories continue to increase in size, power and generation, while cost is lower.

> **Wind power generates over 8% of US electricity already and is the number-one source of renewable energy in the US**
>
> US Energy Information Administration (EIA)

Wind energy has rapidly accelerated in the last decade



Source: US Energy Information Administration (EIA), as of March 2021.

Solar

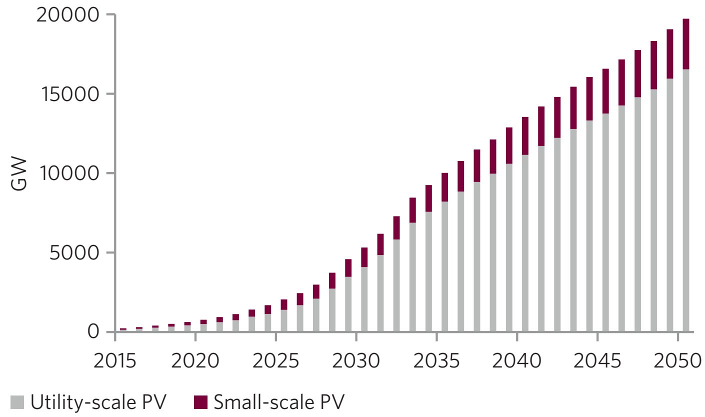
Solar energy has expanded rapidly in the US and globally over the last decade, accounting for over 73 GW of existing utility and small-scale power production capacity by year-end 2020 in the US, compared to only 1 GW in 2011. However, this compares to approximately 1,120 GW for the total US power-generating capacity, so solar is still a relatively small portion of the total and is a similarly low percentage of the total in most advanced economies.[13]

While the majority (95%+) of the electricity is produced by photovoltaic (PV) power cells, solar thermal generation can help provide power when the sun is not shining, though advances in battery technology are making a combination of PV power cells and batteries increasingly viable. Additionally, small-scale rooftop solar is increasingly important, since many houses can support solar panels. It is this sizing and scalability that makes solar unique among renewable technologies, as it can apply to anything from a calculator battery to a massive utility-scale solar installation. Like much of the renewable energy industry, solar's success is due in large part to massive cost reductions: US average PV system costs have dropped more than 70% over the last decade.[14]

While solar PV has been used for decades, electric utilities only started to embrace solar as a cost-competitive source of generation between 2015 and 2020, which substantially accelerated industry growth. According to the Edison Electric Institute, more than half of all new electricity generation capacity added over the past eight years in the US has been wind and solar.[15] As of 2020, carbon dioxide emissions from the electric power sector are approximately 40% lower than 2005 levels, and the industry is targeting significant further reductions by 2050, with some companies targeting a net-zero carbon emissions in that same time period.[16] The electric industry's most obvious method to achieve this is through replacing fossil fuel-based generation, particularly coal, with renewable generation sources like wind and solar, which also need to be paired with battery storage for supply when renewable resources are low. While the US provides an illustrative example of the power of renewables, global solar installations are well above 700 GW and are projected to increase nearly 600% over the next decade, with further growth beyond, as shown in the chart.

> **Average cost of solar has declined 70% since 2010, and global annual installations could double in the next decade.**
>
> BloombergNEF, New Energy Outlook 2021

Total solar capacity likely has multiple decades of expansion ahead



Source: BloombergNEF, New Energy Outlook 2021, data as of July 2021.

Energy Management and Storage

Increased integration of clean technologies and clean energy requires more than just wind and solar; it requires effective energy management, delivery, and storage. The International Energy Agency (IEA) measures energy intensity of economies around the world, and data over the last several decades has shown a clear decoupling of economic growth from energy usage, which is partially the result of effective energy management. Said differently, gross domestic product is increasing faster than energy consumption over time. For example, the energy intensity of economies decreased globally by 36% between 1990 and 2018, with greater declines in countries outside of the Organization for Economic Co-operation and Development.[17] When companies, governments, and individuals gain greater agency regarding their energy use, the entire energy system becomes more efficient and encourages greater clean energy development, creating a virtuous cycle.

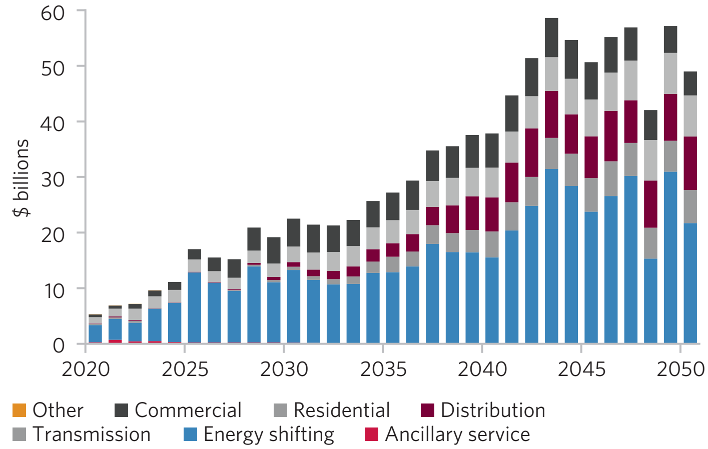
The electrical grid has been deployed in some form since the early 1900s, but the modern electrical grid is increasingly dependent on advanced technology, multi-way communication and grid resiliency—all of which fall under the umbrella of energy management or smart grid. The traditional US electrical grid is a true engineering marvel, made up of hundreds of thousands of miles of transmission lines, thousands of power plants, over five million miles of distribution lines, and innumerable substations, transformers and meters.[18] However, the grid of the 21st century is increasingly focused on effectively managing clean energy delivery. For example, smart meters enable two-way communication, electricity synchronization, complex minute-by-minute shifts to account for smart electronics and can also help integrate distributed and intermittent energy generation (like rooftop solar). US consumers and businesses are more reliant on the electrical grid than ever before, so much of the smart grid will increasingly blur the lines between network security, efficiency, grid resiliency to reduce outages, and better integration with smart electronics. Ultimately, the smart grid will enable the electrification transformation by helping bring all of these various technologies together more effectively.

In addition to powering the shift to EVs, batteries are also enabling further penetration of renewables. Due to the intermittent nature of wind and solar, continued adoption of renewables will require storage to provide backup power and maintain grid stability. Stationary storage becomes the critical link to provide that resiliency. Battery storage has emerged as a solution, given its rapidly declining cost and improved safety and performance. Pairing batteries with renewables extends the time that renewable power can meet demand as well as smooths out the inherent fluctuations that come from the wind and sun.

Utilities have already begun to install large-scale batteries on the grid with projections for a massive increase in deployments to come. At the end of 2019, there were 11 gigawatts (GW) of energy storage systems installed worldwide, which is expected to increase to nearly 1700 GW by 2050, according to BNEF. This is expected to attract $964 billion in investment over the next three decades, according to the same analysis.[19]

> **Global investment in storage could require almost $1 trillion of investment through 2050.**
>
> BloombergNEF, 2020 Long-Term Energy Storage Outlook

Annual investment in power storage could pass $20 billion by 2028



Source: BloombergNEF, 2020 Long-Term Energy Storage Outlook, data as of December 2020.

Bioenergy

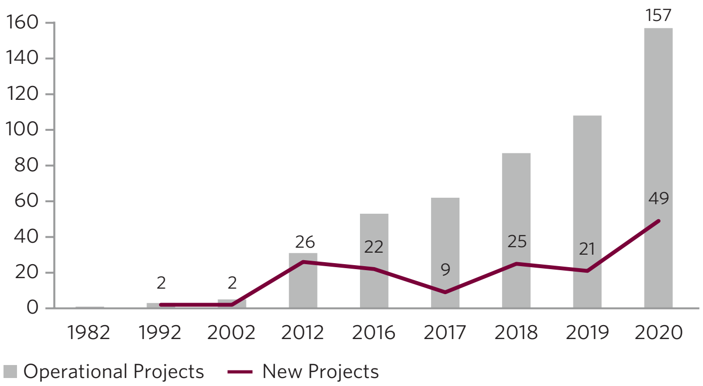
Bioenergy is an overarching term meant to signify renewable fuels derived from plants or waste feedstocks, used either to produce electricity like a traditional power plant or to replace petroleum products for use as liquid fuels. First-generation biofuels, principally ethanol and biodiesel, account for the majority of liquid biofuels produced in the US today at approximately one million barrels per day.[20]

In the US, biofuels have received substantial government support and have been criticized for competing with food consumption, rendering them less popular recently from an economic and food security standpoint. However, next-generation biofuels, like renewable diesel, cellulosic ethanol and algae-derived fuels, hold more promise in the future.

Modern biomass energy production based on sustainable forestry practices is growing rapidly to displace coal and significantly reduce net carbon emissions. In addition, capturing methane (natural gas) from renewable sources such as landfills, water treatment plants, agricultural and forest residue is particularly effective at reducing greenhouse gas emissions as it prevents natural release. As a result, the development of renewable natural gas (RNG) offers another clean pathway to economically source energy from biomass today and doesn't require any changes to the country's gas distribution systems. A 2019 study by the American Gas Foundation (AGF) estimates there are between 1.5 to 3.7 trillion British thermal units of recoverable renewable gas resource in the US, enough to displace approximately 5% to 13% of current US natural gas consumption.[21]

> **Renewable natural gas has potential to displace 5% to 13% of US gas consumption.**
>
> RNG Coalition

RNG projects continue build out



Source: RNG Coalition, 2020.

Hydro/geothermal

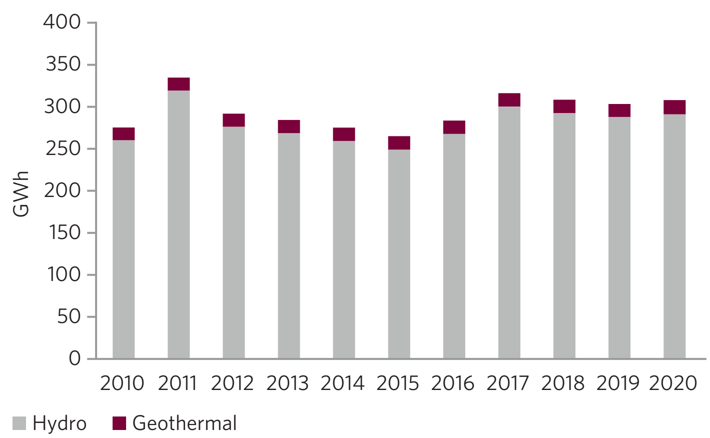
Hydroelectric and geothermal plants use natural resources to produce electricity from sources that are able to provide baseload power, either year-round (geothermal) or seasonally (hydro). Unlike wind and solar, both hydro and geothermal are more limited in their ability to grow given their dependence on available resources, but they are expected to remain an important component of the renewable energy mix, given their more consistent generation profile.

The world's first hydroelectric power plant was commissioned in 1882, and there are still several hydroelectric dams operating today that were built before 1930.17 This makes hydroelectric-generating stations the oldest power plants in the US. The vast potential of running water also allows for massive installations that can dwarf fossil fuel plants with the right resources. The Robert-Bourassa hydroelectric-generating station in northern Quebec, Canada has a capacity of 7.7 GW—almost twice as large as the largest US nuclear plant capacity (Palo Verde: 3.93 GW). But even this is much smaller than the Three Gorges Dam in China, which has a generating capacity of 22.5 GW and is the largest power plant in the world. Hydropower is one of the steadiest and simplest solutions to generating renewable energy at a relatively low cost, given scale benefits.

Similar to hydropower, geothermal power plants have been operating for many decades, although the technology is less mature and is only cost competitive with conventional power in regions where magma heat is close to the surface of the earth. The largest geothermal complex in the world is located at The Geysers in California and is a series of power plants which are roughly comparable to a medium-sized fossil fuel plant.[22] Utility-scale geothermal usually operates on steam production and is also capable of providing baseload power since the earth's molten core is a constant source of energy.

> **Renewable natural gas has potential to displace 5% to 13% of US gas consumption.**
>
> RNG Coalition

US hydro and geothermal generation have been remarkably steady



Source: EIA, as of July 2021.

[1] https://www.eia.gov/todayinenergy/detail.php?id=48696
[2] https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions
[3] https://sciencebasedtargets.org/companies-taking-action
[4] BNEF electric vehicle outlook 2021. https://www.bnef.com/insights/26533/view
[5] https://ww2.arb.ca.gov/our-work/programs/advanced-clean-fleets
[6] Alliance Bernstein, Hydrogen Highway 2021: Hydrogen One, Carbon Zero
[7] Alliance Bernstein, Hydrogen Highway 2020: Ready for Primetime
[8] https://www.eia.gov/energyexplained/wind/electricity-generation-from-wind.php
[9] https://hydrogencouncil.com/wp-content/uploads/2020/01/Path-to-Hydrogen-Competitiveness_Full-Study-1.pdf
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[21] AGF, Renewable Sources of Natural Gas, Dec 2019.
[22] https://www.eia.gov/todayinenergy/detail.php?id=30312#tab1

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