Enabling the Energy Transition

Industry Report and Investment Case

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Corporate, Investor, and Government Net-Zero and Clean-Energy Initiatives & Commitments are Driving a New Era in the Energy Transition

Defining the Energy Transition

The energy transition is a massive shift in how we produce power, moving from fossil fuels to sources that produce little or no carbon. This transition is enabled by a range of products and services, including:

- **Renewable Energy:** Energy sources including solar, wind, geothermal, and hydroelectric power
- **Energy Storage & Conversion:** A range of offerings such as advanced lithium-ion batteries, next-generation battery chemistries, inverters, and fuel cells
- **Smart Grid & Grid Infrastructure**: Products and services that enable a resilient modern grid, such as transmission and distribution systems, smart devices and meters, and enabling software
- **Energy Intelligence:** Products like smart meters, energy management systems, power controls, and light-emitting diodes (LEDs)
- **Enabling Materials** such as lithium, rare earths, and waste-derived biofuels

Drivers of Significant Change

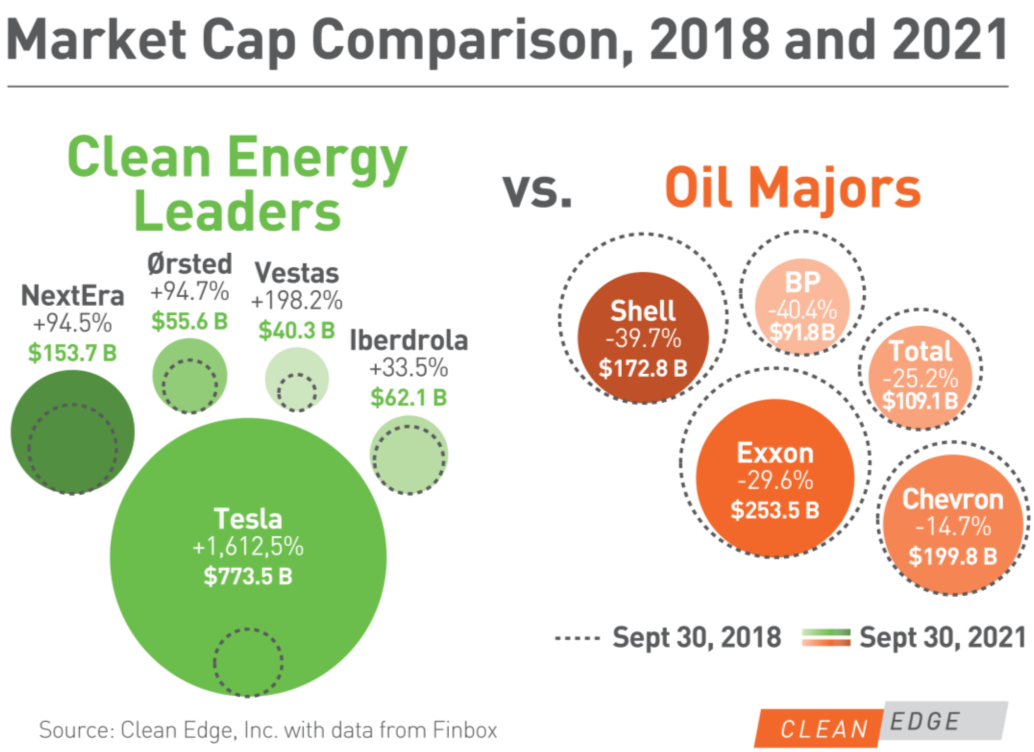
The energy transition is already happening at a rapid pace, as businesses, utilities, consumers, and other stakeholders embrace the benefits of clean energy. At the forefront of this dramatic shift has been the growth of renewable energy (primarily solar and wind), the recent rise of energy storage and EVs, and the advent of smart and connected electric grids.

Technology, capital, and policy-related developments driving this significant change include:

- **Costs Continue to Decline:** In the past decade, costs for solar have declined nearly 90% per Megawatt (MW) installed, and onshore wind prices fell 70.4%[1]. These are now the most cost-effective forms of new electricity generation, beating out nuclear, coal, and even natural gas plants. Technological innovation has enabled entirely new economies of scale for renewable sources that were unthinkable by most market players just a decade earlier. As electricity demand rises globally, renewable sources of power should continue to dominate new installations.

- **Investment Shifts from Fossil Fuels to Clean Energy and Smart Grid:** Investment groups are becoming cognizant of the long-term risks of fossil fuel investments and are responding with divestments from fossil fuels. At the same time, the financial benefits of renewable energy projects are driving investments in this sector. According to the International Energy Agency (IEA) and Centre for Climate Finance at Imperial College Business School, over the past 10 years, average returns from renewable power were more than 7 times higher than those from fossil fuels (422.7% compared to 59%)[2]. This trend has accelerated in recent years, as the market capitalization for oil and gas supermajors has shrunk while the largest clean energy companies experienced significant growth.

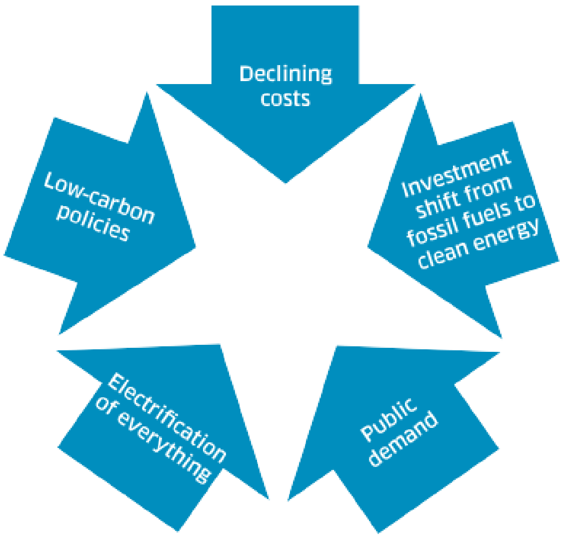
Market Cap Comparison, 2018 and 2021



Source: Clean Edge, Inc., 2021[3]

- **Infrastructure Replacement and Electrification of Everything:** With energy storage and electric vehicles continuing to experience cost declines similar to renewables, the concept of the "electrification of everything" is emerging. The resulting increased electrical load requires utilities to modernize grid infrastructure, driving continued investment in this sector. The move to electric heat (powered by renewable sources) alone represents perhaps the single largest potential driver for expanding residential electrification. Fossil fuels have historically provided 90% of the energy for residential space heating and 80% for water heating in the U.S., according to the Energy Information Administration (EIA)[4]. Also underlying these trends is the digitization of energy, from smart meters to connected IoT devices, and the smart grid backbone that supports it.

Clean Tech Major Drivers



Source: Clean Edge, Inc.

- **Low-Carbon Policies:** Globally, governments are responding to the threat of climate change by signing commitments to reduce their carbon footprints. One key example on the global stage is the U.S. officially rejoining the Paris Climate Accord on February 19th, 2021 after the Biden Administration took office. Shortly after recommitting to the carbon reduction strategies, the Administration released a 2030 Greenhouse Gas Reduction Target of 50-52% from 2005 levels, a day after the European Union (EU) announced a 55% 2030 reduction target below 1990 levels. Most recently, at COP26 in November, more than 100 countries (including the U.S. and EU) pledged to cut methane emissions 30% from 2020 levels by 2030[5].

- **Public Support:** The demand for low-carbon sources of energy is coming not only from governments, but also from corporations and the public at large. A Pew Research survey found that between 2011 and 2020, the proportion of U.S. adults who favored alternative energy over fossil fuel production increased from 63% to 79%. Despite a decline in 2021, almost three times as many Americans (Democrats and Republicans alike) still prioritize clean energy[6]. At the same time, private companies are significantly increasing their efforts to become carbon neutral. More than 300 multinational corporations, including Apple, Nestle, Bloomberg, and GM, have committed to getting 100% of their electricity from renewables as part of the global RE100 campaign[7].

Alternative Energy vs. Fossil Fuels: U.S. Adults Based on Priority for Addressing America's Energy Supply (%)

	DEVELOP ALTERNATIVE ENERGY (WIND, SOLAR, HYDROGEN TECHNOLOGY)	EXPAND FOSSIL FUEL PRODUCTION (OIL, COAL, NATURAL GAS)
2011	63	29
2012	47	39
2013	58	34
2014	60	30
2017	65	27
2019	77	22
2020	79	20
2021	71	27

Source: Pew Research Center's American Trends Panel. Latest survey conducted Apr 20-29, 2021[6]

Challenges Facing the Energy Transition

While the energy transition is bolstered by strong public support and growing economies of scale, there are key challenges remaining in the sector. These challenges include:

- **Higher Interest Rates:** Because renewable energy installations tend to come with high up-front costs, installers have historically had difficulty obtaining capital at an attractive interest rate. While low interest rates in recent years have been a boon for renewables development, the industry could be impacted during the recovery from the COVID-19 pandemic, as interest rates have a higher potential to rise given the inflationary environment. One solution gaining momentum is “green banks”, typically public-owned institutions created to fund climate-focused and sustainable projects like renewable energy installations (covering financing on the margins that make deals pencil out for private-sector investment). These institutions are on the rise globally, with the Natural Resources Defense Council reporting two dozen countries actively exploring the model[8].
- **Availability of Microchips:** Microchips, or semiconductors, are essentially the brains behind all modern technology. They are a required component in the manufacture of everything from LED bulbs to electric vehicles (EVs). Due to global supply chain disruptions during the COVID-19 pandemic, however, manufacturers are struggling to obtain enough chips. The automotive industry is particularly hard-hit, with global output down 4.6% through 2021, though consumer electronics and other industries are also suffering. In response, the U.S. Senate introduced a $52 billion bipartisan bill aimed at advancing domestic semiconductor research and manufacturing capacity[9]. Improving the reliability of this supply chain will be key to enabling the energy transition.
- **Domestic Availability of Materials:** As with microchips, the U.S. market (among others) consistently falls short on supplies of enabling elements and minerals like lithium, cobalt, and nickel. Of approximately 35 minerals that are critical to technologies like advanced batteries and EVs, the U.S. currently has no domestic supply for 14, and relies on imports for at least 50% of another 17. As this provides a threat to the domestic production of clean energy technologies, in March 2021 the U.S. Department of Energy announced $30 million in funds for shoring up critical mineral supply chains[10]. Opportunities in this area include advancing recycling technologies, particularly for e-waste, and enabling a Circular Economy that views waste streams as potential resources.
- **Transmission Bottlenecks:** Renewable energy can be expensive to produce at scale in dense, urban areas. In the U.S., wind power is cheapest to produce in the Great Plains and Intermountain West, while solar power is cheapest in the Southwest and Southeast. For highly populated coastal and other urban areas to reach 100% renewable targets, electricity will need to be transported from where it is cheap to where it is needed. Due to high costs and issues with siting and permitting regulations, transmission projects are not being completed as quickly as is needed to keep up with demand, according to research firm ScottMadden[11]. In 2021, the U.S. added $65 billion of funding for clean energy transmission in the $550 billion Bipartisan Infrastructure Deal. This money will be used to create a Grid Deployment Authority and install thousands of miles of new, resilient transmission lines[12].
- **Entrenched Interests:** Despite strong public support for renewable energy, many political barriers remain. Fossil fuel companies tend to have deep pockets and entrenched political influence. Furthermore, many global economies derive geopolitical power from fossil fuel resources and heavily subsidize the production of fossil fuels. The pending energy transition will turn the tables. In the future, countries that lead renewable energy installations will gain energy independence and global influence while fossil fuel sales decline. (See The Great Pivot below.)

The Great Pivot (May 2021)

While 2020 was a banner year for renewable energy, with renewables accounting for a record 90% of new capacity installations globally[13], the events of May 2021 demonstrated that the energy transition is positioned to fuel the next wave of innovation. Major strides were made to push fossil fuels aside in favor of renewables, across many stages. The actors ranged from international agencies and governing bodies to hedge-fund climate activists, and the results were unprecedented.

On May 17, the traditionally staid and fossil fuel-centric International Energy Administration (IEA) published the world's first comprehensive study on how to transition to a net zero energy system by 2050: *Net Zero by 2050*. The plan calls for massive and rapid investment into renewable energy and existing technologies by 2030, more than tripling current investments to $4 trillion annually. Many facets of the plan also rely on the development of technologies that are not yet widely available on the market, such as mass deployment of green hydrogen. This will require continued focus on R&D, and a transition of money from fossil fuels into clean technologies[14]. Perhaps the most significant portion of the report, however, is a call for investors to stop funding all new oil, gas, and coal supply projects. As the IEA has historically supported fossil fuels, this report demonstrates a major shift in energy sector views.

Two days after the IEA's report was released, G7 member countries announced they would stop funding overseas coal projects[15]. This ban on new coal investments continues a trend of fossil fuels losing investment dollars due to risk. By October 2020, five of the six largest U.S. banks (Citigroup Inc., Goldman Sachs Group Inc., JPMorgan Chase & Co., Morgan Stanley, and Wells Fargo & Co.) had pledged to end funding for new fossil fuel exploration and production in the Arctic[16]. Despite pushback from oil and gas companies, many view the recent actions as a sign that fossil fuels are increasingly risky and will soon become "unbankable".

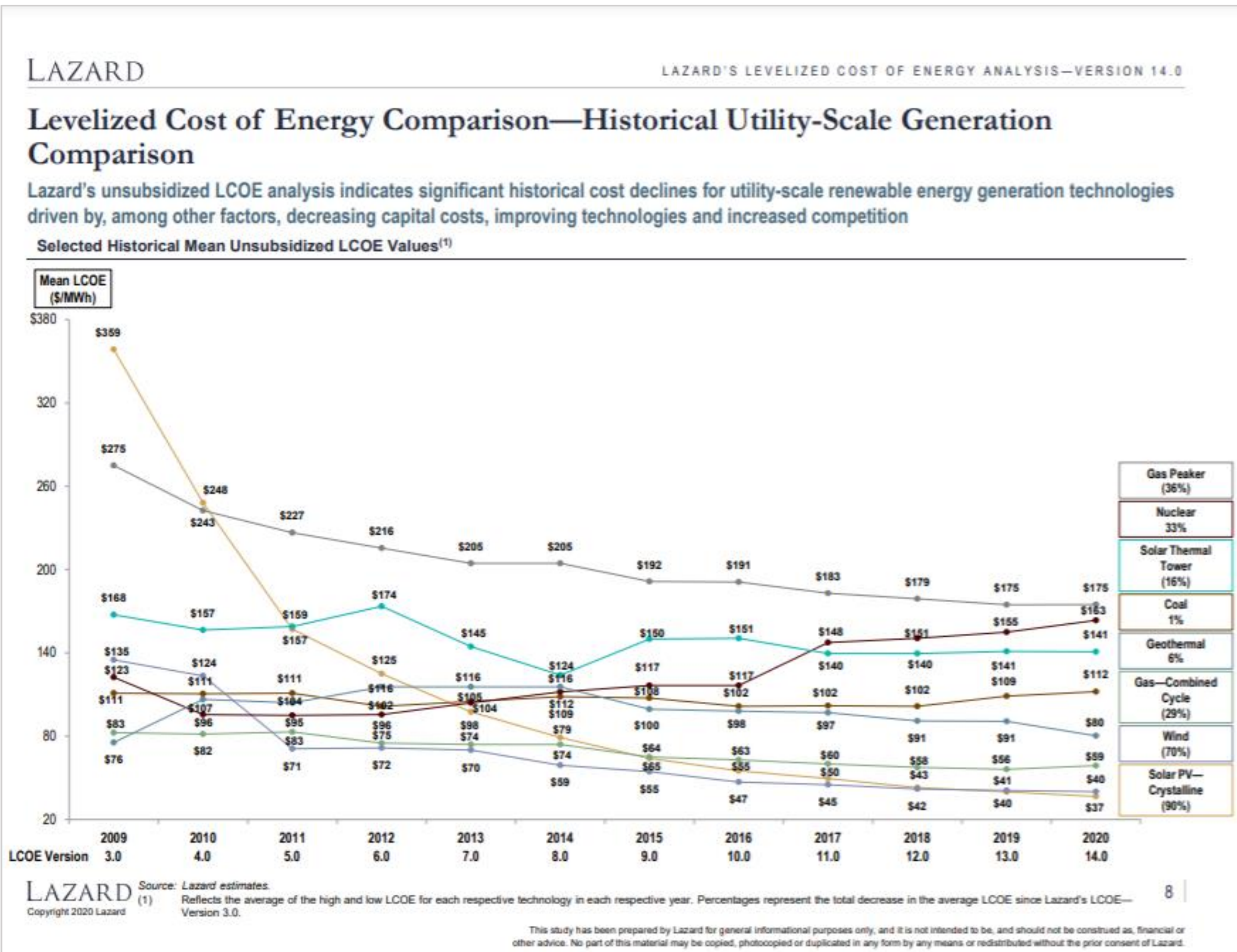
As a result, fossil fuel companies are being forced to clean up their act. In a landmark ruling on May 26, 2021, a Dutch court ruled that Royal Dutch Shell must cut its greenhouse gas emissions by 45% in 2030, compared to its initial goal of 20%[17]. Other oil supermajors were not cut any slack in the month of May, either. On the same day the Dutch court ruled on Shell, Chevron's shareholders approved a resolution for the oil giant to cut Scope 3 emissions from end-of-use products[18]. And to cap off the day, ExxonMobil's board was shaken up with the election of two climate activists from Engine No. 1, an activist investor group dedicated to greening the energy supply. A third activist board seat was confirmed in June. Perhaps the biggest sign of real change was three major institutional investors (Black Rock, Vanguard, and State Street) voting against Exxon's leadership and in favor of the activists[19].

When historians look back, the events of May 2021 will represent a major pivot point not only in how the world embraced the concept of the energy transition, but when major established fossil fuel players started to face their day of reckoning.

Economics and The Rise of Clean Energy

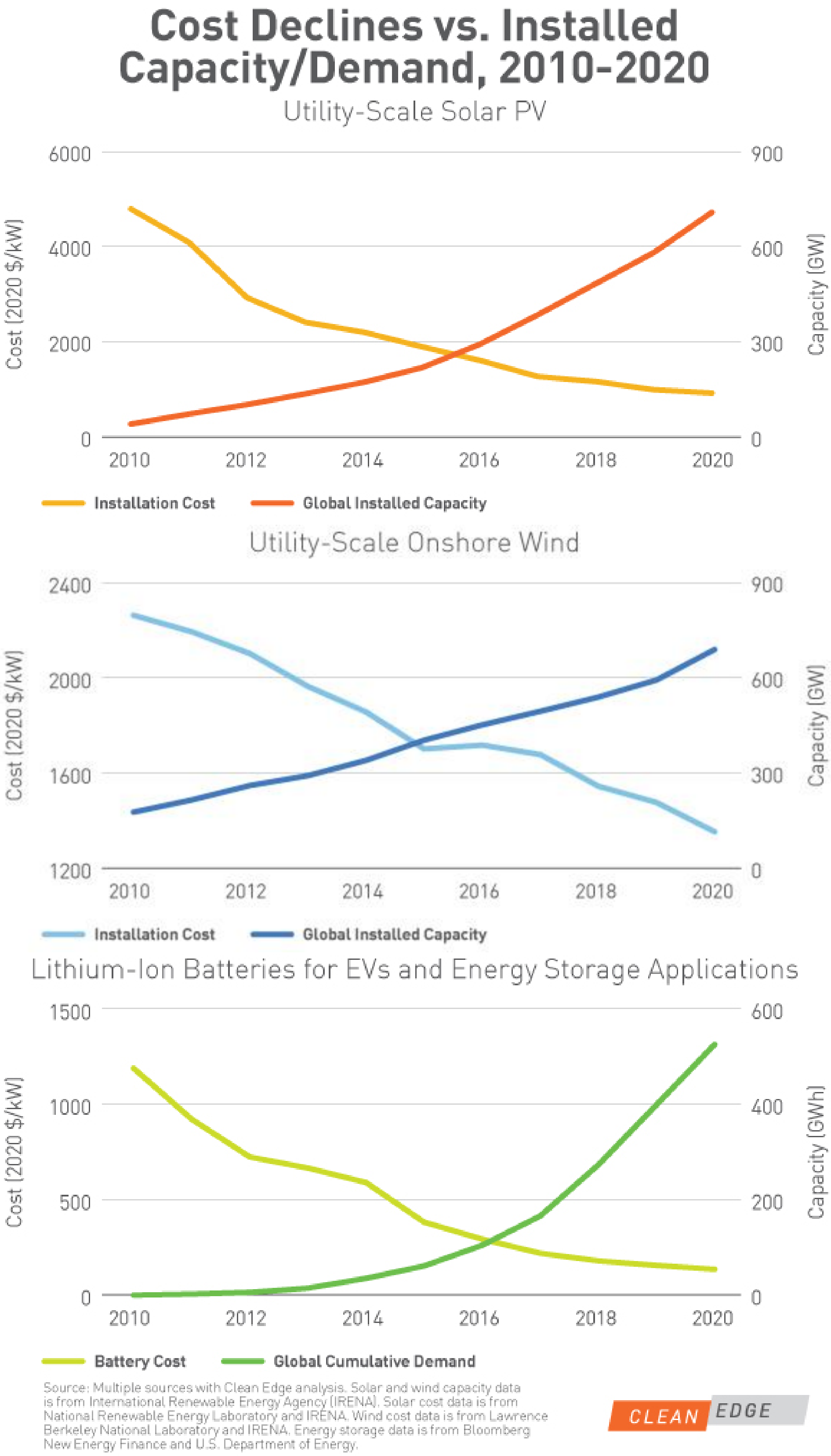
As noted earlier, solar and wind power are now the most cost-effective forms of new electricity generation in many regions – beating out coal, nuclear, and even natural gas. Lazard, a financial advisory and asset management firm which has been tracking the levelized cost of energy (LCOE) for more than a decade, has research showing that the LCOE for wind power dropped from $135 per megawatt hour (MWh) in 2009 to just $40 per MWh in 2020, a decline of 70%. Even more dramatically, utility-scale solar declined 89.6% over the same period, from $359 to $37 per MWh. As a result, 2020 marked the sixth consecutive year in which wind and solar both cost less than natural gas combined-cycle power generation. And both coal and nuclear power were above the $100 per MWh range, making them approximately two to three times the cost of new solar and wind on a levelized cost basis[20].

Renewables and Conventional Comparison (2009-2020)



Source: Lazard, 2021[20]

Global Cost Declines and Capacity Increases: Solar, Wind, and Lithium-ion Batteries (2010-2020)

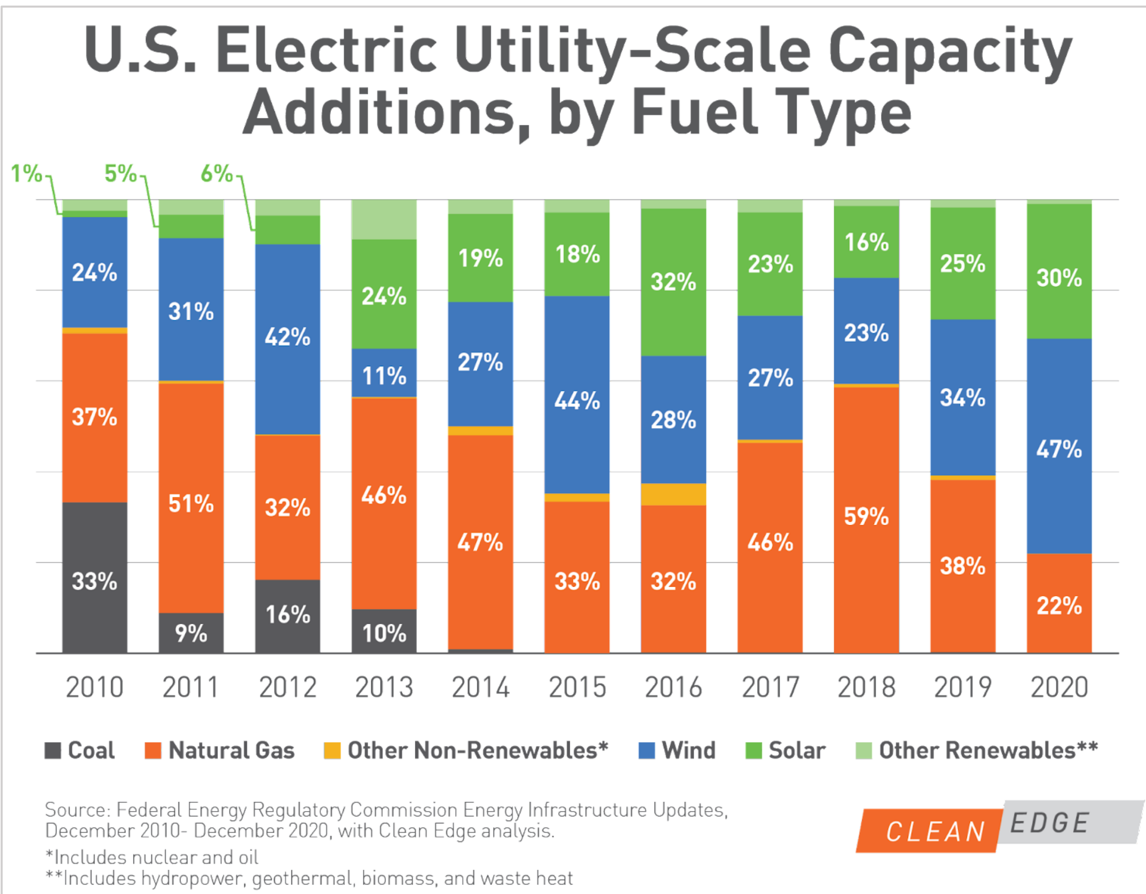


Source: Clean Edge, 2021[21]

The lower cost of clean energy is having a huge impact, with renewables now overtaking coal in the U.S. for overall electricity generation. In 2020, electricity generated from renewable sources (including hydropower) made up 21% of the total, exceeding coal's 19%[22]. Along with the cost difference, air quality regulations have caused coal-powered capacity in the U.S. to decline steadily since 2011. According to EIA predictions, by 2025 the expected capacity from coal will be less than 200 GW, down more than a third since its peak of 314 GW in 2011. Coal plants now tend to be used only during peak demand, and operators have asserted they are likely to switch to seasonal production in only the higher-demand winter and summer months if current trends continue[23].

With the capacity for coal declining and demand for electricity on the rise, renewables are filling the gap. Over the past decade in the U.S., a flip has occurred in installations. In 2010, about 70% of new capacity additions came from natural gas and coal. In 2020, 77% of new capacity consisted of solar and wind – and these trends are expected to accelerate[24].

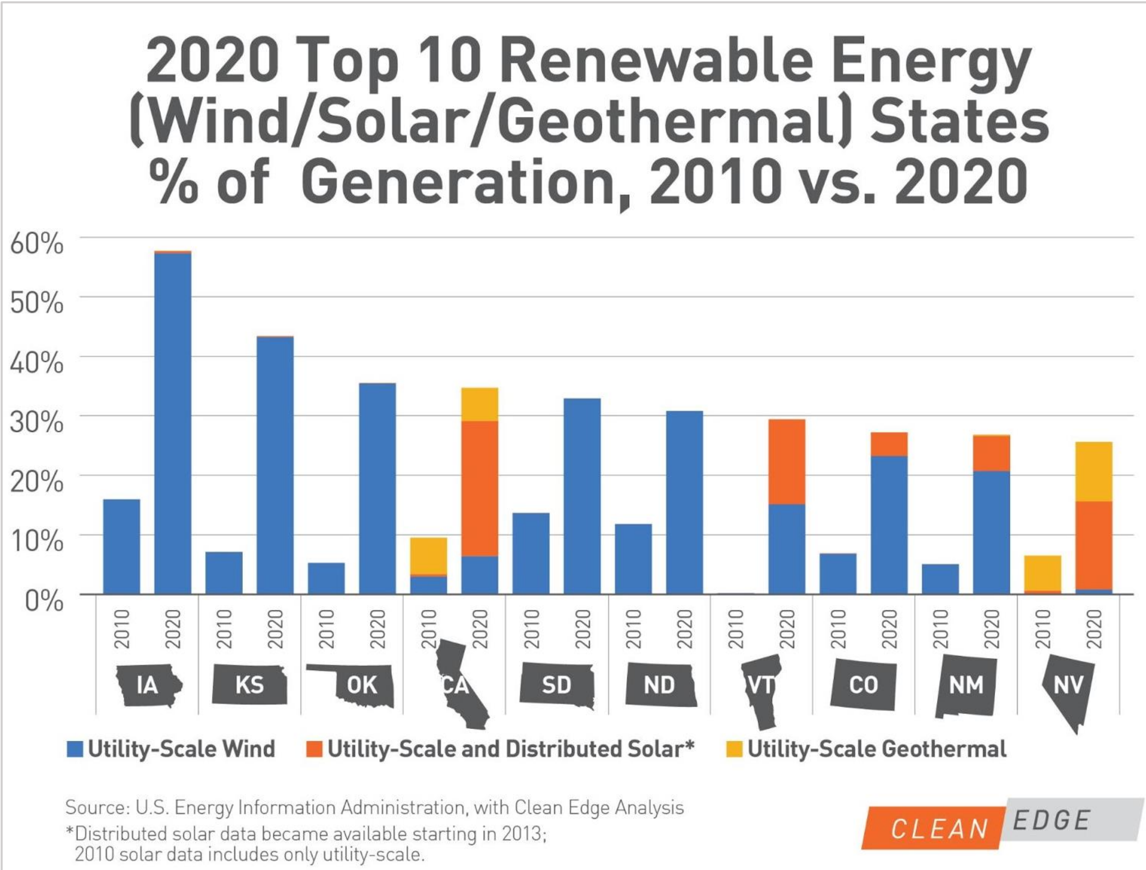
U.S. Electric Utility-Scale Capacity Additions, by Fuel Type



Source: Clean Edge, Inc., 2021[24]

At the state level, the rise in renewable energy sources is even more dramatic. A decade ago, just three states received 10% or more of their in-state electricity generation from non-hydro utility-scale renewables (solar, wind, and geothermal). In 2020, 22 states were part of the 10% club, with six states – Iowa, Kansas, Oklahoma, California, and the Dakotas – getting 30% or more of their electrons from renewables. Iowa reached a historic milestone in 2020, producing 57.3% of its total energy supply from wind[25]– the first year any U.S. state has generated more than half of its power from non-hydro renewables.

2020 Top 10 Renewable Energy (Wind/Solar/Geothermal) States, % of Generation, 2010 vs. 2020



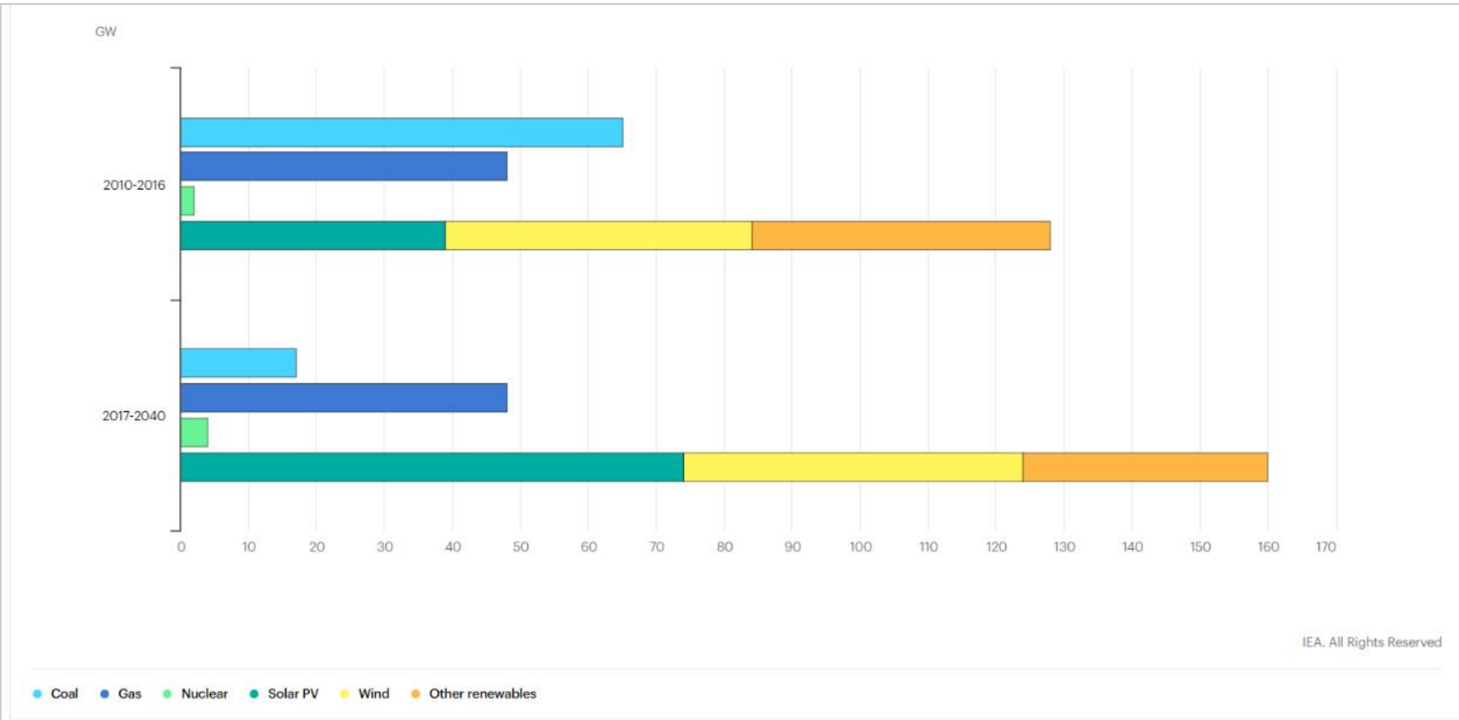
Source: Clean Edge, Inc., 2021[26]

The adoption of low-cost, low-carbon energy solutions has seen a similar uptick globally. In fact, between 2019 and 2020, renewable capacity additions increased more than 45%, with the global wind market expanding by 90%, according to the IEA[27]. It may come as no surprise that China leads the world in total installed renewables capacity, at 907 GW in 2020[28]. This is likely to continue, as that nation is set to install 29 GW of new onshore wind capacity in 2021, more than any other country. According to the IEA's Renewables 2020 Data Explorer, China is predicted to have between 452 and 501 GW of installed PV solar capacity (mostly utility-scale) by 2025, generating over 535 TWh, or 18% of the country's total projected energy demand[29]. All this feeds into China's goal for net zero emissions by 2060[30]. Many other countries are investing heavily in renewable projects, including South Korea (see segment on Offshore Wind on **page 15**) and the EU.

In the EU, a green stimulus plan was announced in December 2020, meant to stimulate the economy after the COVID-19 downturn and fund energy projects. It's the world's largest green stimulus plan to date, with 37% of €672 billion going toward climate-related projects[31]. In July 2021, the EU also unveiled its highly aggressive "Fit for 55" plan to cut emissions 55% by 2030 as an intermediate step to becoming net-zero by 2050. The plan includes more stringent regulations on energy efficiency and greater investment in renewable energy, in addition to eliminating exemptions for high-emitting sectors like aviation and shipping[32].

These and other "green stimulus" plans demonstrate the increasing public support (and government funding) for renewables installations. In 2019, the IEA forecasted 160 GW of renewables to be installed annually through 2040, with only 17 GW of coal and 48 GW of natural gas capacity added each year[33]. However, in 2020 a record-setting 278.3 GW of renewables were installed globally. The IEA revised its forecast in 2021 and now predicts renewables will make up 90% of capacity additions globally by 2022[27].

Global Average Annual Net Capacity Additions



Source: International Energy Agency, 2019[34]

Smart Grid Infrastructure

Unlike computer technology, which saw the number of transistors crammed onto computer chips double every 18-24 months for more than 50 years (Moore's Law) and the dramatic move from large mainframe computers to today's smart phones, the electric grid's underlying technology has remained relatively constant. In fact, more than a century after its invention, early grid innovators like Thomas Edison and Nikola Tesla would still be familiar with much of today's grid technology. This has offered great reliability and consistency, and until recently, grid operators were wary of messing with a system that has been ranked as one of civilization's greatest engineering achievements. But with the dawn of the always-on, digital internet-driven era, along with the recent upsurge in demand for low-carbon energy sources and greater resiliency to counter natural and human-made disasters, the grid is now experiencing its own technological renaissance.

This new emerging grid is based on advances in big data, artificial intelligence, distributed networks, and other technologies, enabling the digitization of the electric grid. A host of relatively recent innovations, from demand-side management and smart meters to blockchain-enabled energy trading networks and microgrids, are changing the grid from a centralized network to a nodal one, with a myriad of connected devices. It is creating a distributed ecosystem of "prosumers" who can sell their surplus energy (whether produced onsite or stored in a battery pack), as well as buy from sources across the network.

High-voltage direct current (HVDC) transmission lines are also needed to deliver power from areas of abundant wind and solar power to regions that have insufficient local capability for generating renewable power. Particularly over distances greater than 300 miles, HVDC power lines lose significantly less energy through distribution and allow for rapid change in the direction of energy flow, so renewables can be hooked into the grid with more ease. Several long distance HVDC transmission projects have been completed, such as the line connecting Spain and France, which is the most powerful HVDC line in the world[35]. Many others are underway, including the SOO Green HVDC Link, Gateway West, Champlain Hudson Power Express, and TransitWest Express initiatives in the U.S., and a potentially record-breaking line in Brazil that stretches 2,375 km between a hydro plant in the Madeira River and the southeast portion of the country[36].

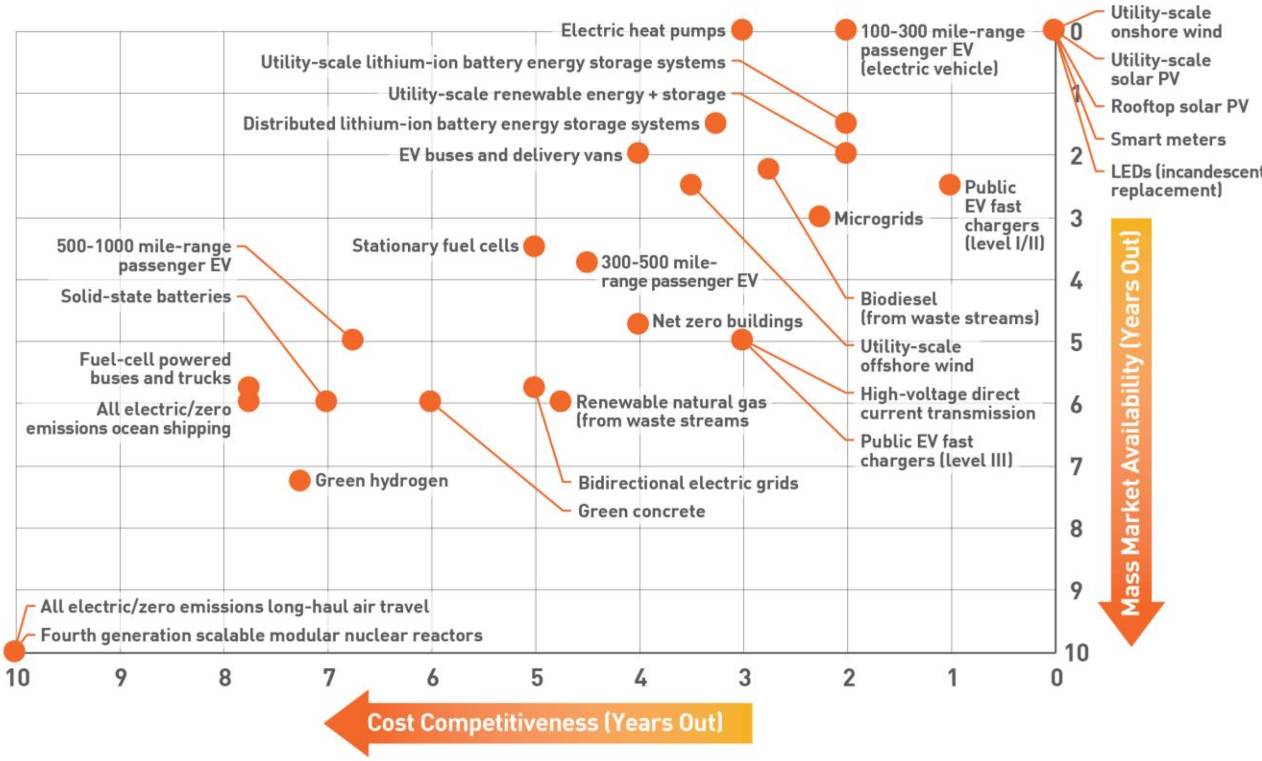
To reduce the cost of energy trading and enable a more diverse group of players to participate, blockchain technology is enabling customers of various sizes to engage in real-time energy transactions with a range of energy providers – among them large wind farms, distributed solar panels, microgrids, and aggregated demand-side management from multiple users. Companies investing in these blockchain-enabled energy networks range from The Sun Exchange, a startup in South Africa, to well-established energy giants Iberdrola and Acciona Energy in Spain[37].

However, given the extremely high energy demand of current blockchain technologies, like cryptocurrency, it remains to be seen if blockchain will enable clean energy networks, or vice versa. According to the University of Cambridge Bitcoin Electricity Consumption Index, the blockchain-enabled cryptocurrency consumes about 0.31% of the world's total electricity[38]. As the technology becomes more commonplace (there are around 1 million active users[39]), this total demand will rise. To enable blockchain technology, more renewables are needed. To better manage renewables, more blockchain may be needed. In this interplay of distributed technologies, it is unclear who is saving whom.

Smart meters, which can be used to manage aggregated demand from residential and commercial buildings, can also help to provide greater customer insights, pinpoint outages, and better manage electrons overall. The U.S. hit two-thirds penetration of smart meters in 2020 and expects to reach 80% by 2025. Meanwhile France, Spain, and the Netherlands all hit the EU's goal of 80% penetration in 2020[40]. Smart meters are enabling more consumers to participate in demand response programs, and OpenADR (Automated Demand Response) 2.0 has become the prevailing communications standard, which will spur the market to grow even faster. California's 2019 energy code, for example, specifies that all demand response controls need to be OpenADR 2.0-certified.

Smart meters and other IoT devices are being connected to utility back-office systems via new networking technologies to provide greater visibility into device reliability, performance, and security. Utilities are expected to spend up to $53.8 billion on IoT devices and software in 2024, up from $28.6 billion in 2019, according to research firm Market and Markets[41]. These devices, communicating via 5G and LTE networks, will improve service reliability by optimizing usage in real time while also reducing costs. As a result, distributed energy, electric vehicles, and energy storage are poised to dramatically rewire the electric grid, much like cell phones did for the telecommunications system. We are moving beyond siloed technologies and into a new age where it's the interplay of technologies that matters. Technology mash-ups such as rooftop solar + energy storage, wind turbines + offshore platforms, and microgrids + blockchain-enabled trading networks are becoming the norm. The Clean Edge Tech Maturation Model, shown below, is a tool for investors, government, and other stakeholders to assess the market availability and cost competitiveness of these technologies over the next 10 years.

The Clean Edge Tech Maturation Model



In creating our inaugural Tech Maturation Model, the Clean Edge team drew on our decades of collective industry experience to analyze 30 clean energy technologies. This model can be used by investors, governments, and other stakeholders to assess market availability and cost competitiveness of these technologies over the next 10 years. Technologies at the top right of the chart (e.g., **utility-scale solar PV** and **onshore wind**) are both widely available and cost-competitive with their established counterparts now or in the next 1-3 years, while those at the bottom left are 7-10+ years from maturity in our view. In future model updates, we expect less established technologies to gain traction, becoming more commonplace and moving toward technological maturity (such as **green hydrogen**, **solid-state batteries**, and **bidirectional grids**). Although we include **scalable modular nuclear reactors** (SMRs) in this model, the industry must address the issues of nuclear waste and weapons proliferation before SMRs ultimately meet Clean Edge's criteria for clean technologies. Our maturity projection for **green concrete** applies more generally to the carbon capture and utilization (CCU) sector. We welcome your feedback on our model, which we plan to update annually.

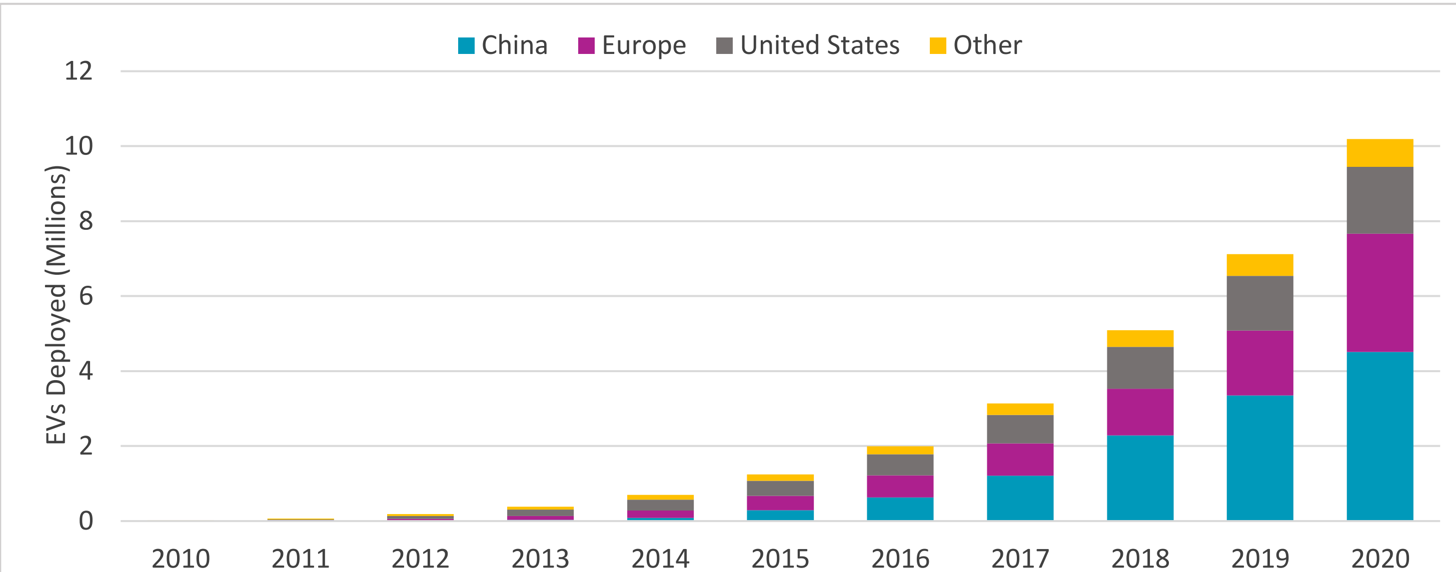
Source: Clean Edge, Inc., 2021

CLEAN EDGE

Source: Clean Edge, Inc., 2021[42]

Across the globe, demand for electric vehicles (EVs) has been rising. In 2020, the total global stock of EVs rose 43% from 2019 and hit the 10 million milestone for the first time, while total light vehicle sales declined 14%[43]. As stated in a 2021 report from research firm Canalys, EVs represented almost 5% of new passenger car sales globally in 2020[44]. According to the IEA, the fastest-growing regions are China, Europe, and the U.S.[45]

Electric Vehicle Deployment, 2010-2020



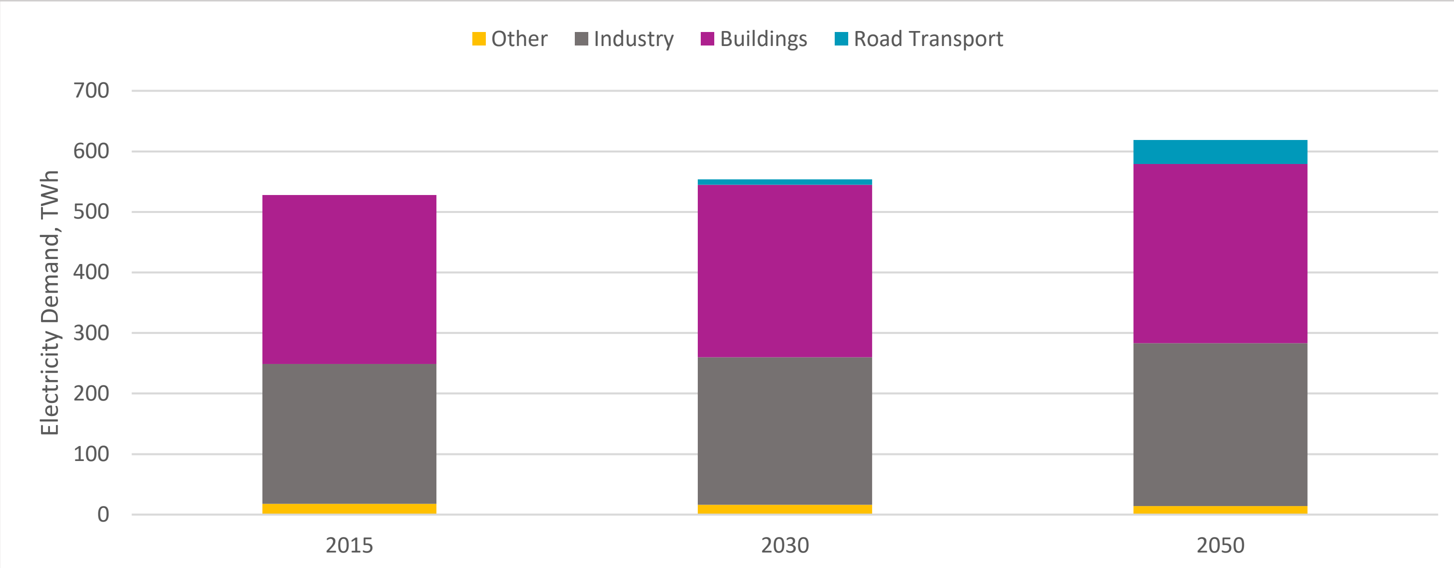
Source: International Energy Agency, 2021[45]

*Totals include battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs). Does not include conventional hybrids.

As consumer demand increases, major auto manufacturers and technology startups are positioning themselves to compete in this new electrified world. In May 2021, Ford unveiled the F-150 Lighting, an electric version of their bestselling truck in the U.S. for the past 44 years[46]. The growing need to recharge vehicle batteries will require innovations in developing higher power and more ubiquitous EV charging infrastructure. Many energy generation and distribution companies see offering charging infrastructure as a necessary means of diversifying beyond liquid fuels to safeguard future revenue. Also, many utilities are developing or have applied for permission to develop a limited backbone of charging locations to better serve customers in their service territories. As part of the 2021 Bipartisan Infrastructure Deal, the U.S. government will invest $7.5 billion to build out the nation's first national network of EV chargers[12].

While charging EVs will increase electricity demand, electrified road transportation will not exceed utility capacity, remaining under 6.5% of total electricity demand through 2050, according to McKinsey & Company[47]. In fact, integrating electric vehicles provides grid operators with a somewhat flexible load that can absorb excess capacity and offset the variability of renewable generation. To grow the vehicle grid integration market, utilities and automakers have launched pilot programs that use the Open Vehicle Grid Integration Protocol (OVGIP) to send demand response messages from the utilities directly to the EV's telematics systems. These programs run by utilities such as Xcel Energy and Southern California Edison enable EVs to stop, slow, or ramp up their charging based on price signals, demand response events, or the fluctuating levels of renewables on the grid. Vehicle grid integration services will become even more critical when there are tens of millions of EVs plugging in.

Global Electricity Demand Projections by Sector



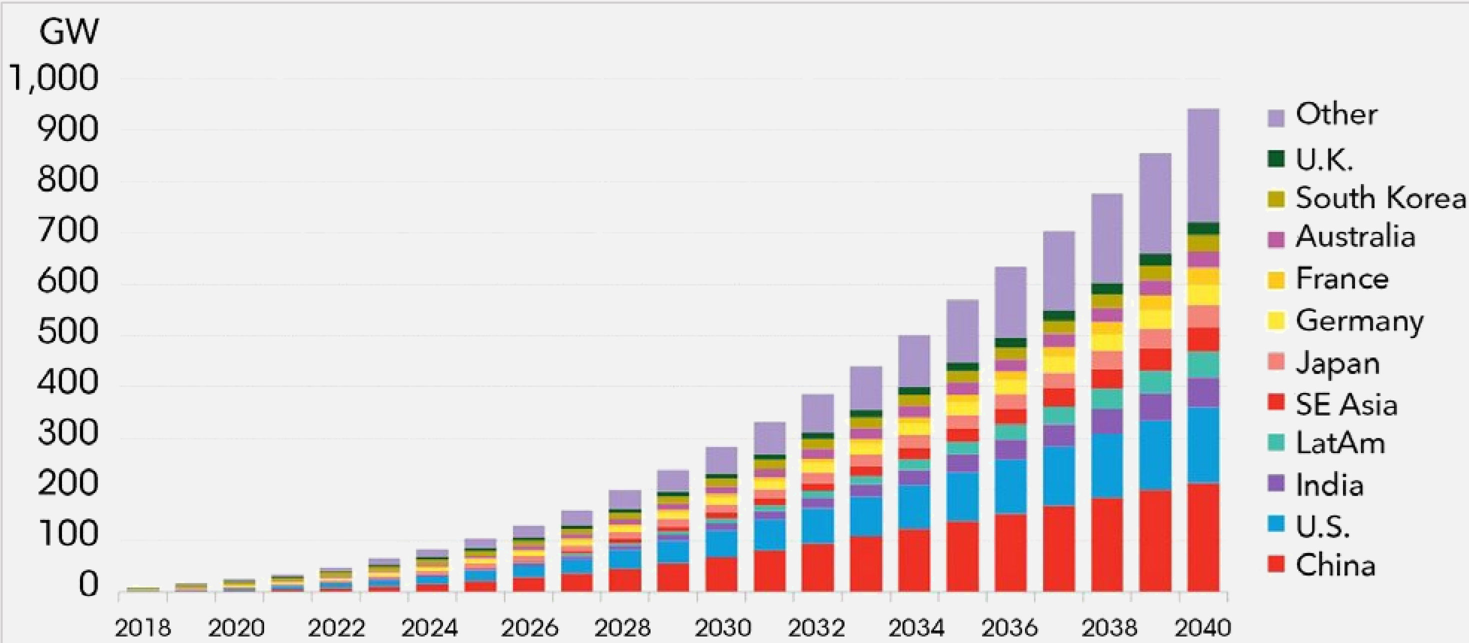
Source: McKinsey, 2018[47]

One component of grid infrastructure that has been trailing in intelligence has been the transformer, the critical equipment that helps maintain necessary power and voltage levels at the edge of the distribution grid. Transformers were not designed to accommodate the large loads of electric vehicles, and if multiple EVs are charging simultaneously at higher AC rates (known as Level 2), they can overwhelm a transformer. However, new smart transformers from companies such as ABB, Eaton, and Siemens provide greater security by protecting against cyberattacks and enhance reliability by preventing overloading from buildings and EVs. The global market for smart transformers is expected to rise from $2.21 billion in 2020 to $6.1 billion in 2027, according to research firm Market Research Future[48].

Energy Storage Technologies

Solar panels and wind turbines are intermittent energy sources, and people need electricity even on a windless, cloudy day. With an ever-increasing supply of renewable power, the next major hurdle is the storage and distribution of all this energy. Energy storage is about to experience growth rates similar to the expansion of the solar PV market over the past 15 years (when solar PV installations doubled seven times). Both the size and sale of utility energy storage projects blossomed in 2020. According to analysis from research and consulting firm Wood Mackenzie, installations of front-of-the-meter (utility-owned) energy storage projects rose 330% between Q2 and Q3 2020 – and the total capacity installed in Q3 2020 was more than five times greater than the same period in 2019[49]. The global cumulative energy storage market is expected to grow to 942 gigawatts in 2040, representing a total investment of $620 billion between 2019 and 2040, according to Bloomberg New Energy Finance[50].

Global Energy Storage Market (Projected Growth 2018-2040)



Source: Bloomberg New Energy Finance, 2018[50]

Lithium-ion batteries are the current leading technology in the energy storage market, and the deployment of existing and emerging lithium-ion batteries will remain key to the energy transition. Widespread production of these batteries has led to significant price declines, around 88% between 2010 and 2020. The price is expected to reach $100 per MWh by 2024, according to Bloomberg New Energy Finance, at which point EVs should reach price parity with their internal combustion engine counterparts[51]. However, problems remain with the technology. The batteries experience rapid deterioration over their first five years of use. Mining lithium is an environmentally damaging process that results in polluted water sources. Many countries, such as the U.S., do not currently have domestic sources of lithium due to these environmental concerns, which adds risk to the supply chain. Finally, global supplies of lithium are limited – lithium is not a renewable resource. One solution is to develop better recycling technologies for older lithium-ion batteries (from smart phones, laptops, and electric vehicles), which will stretch the existing supplies. Many, though, see promise in breakthrough energy storage technologies.

Solid-state batteries are one such technology that will enter the market in the coming decade. While many of the solid-state batteries in development do still use lithium, they have solid electrolytes, rather than liquid. This results in a battery that is more energy-dense (using less material) and has less risk of explosion than their liquid-electrolytic counterparts (meaning less air flow is required around the battery). This means the same total footprint can store more energy, more safely. The safety of energy storage is gaining attention due to high-profile fires like that which occurred in July/August 2021 while testing a Tesla Megapack at Victorian Big Battery in Australia[52]. Also in July 2021, U.S. auto safety regulators issued warnings to some 50,000 owners of Chevrolet Bolt EVs to park outside, due to potential risk of fires after charging[53]. The fire risk of lithium-ion batteries is driving development of safer storage solutions, like solid-state batteries. Other large-scale energy storage options include producing hydrogen fuel by electrolysis powered by renewables or implementing below-ground compressed air storage.

The Rise of Offshore Wind

As mentioned above, the price of onshore wind declined drastically over the last decade, and onshore wind is now one of the cheapest forms of energy, edged out only by solar PV. As usable land for wind farms becomes scarcer, the next generation of wind is moving offshore. The LCOE of offshore wind, while not currently as low as its onshore counterpart, is expected to decline 30-60% by 2030, according to the International Renewable Energy Agency's 2019 "Future of Wind" report[54].

Offshore wind is receiving heightened interest from governments and utilities worldwide, and plans are underway to rapidly expand the capacity. The world's largest offshore wind company, Denmark-based Ørsted, installed its 1,000th offshore wind turbine in June 2021 at the Hornsea Two development in the UK[55]. This project is due to become the world's largest offshore wind farm when it is completed in 2022, with a capacity of 1.4 GW. It may not remain the world's largest for long, though, with South Korea and the U.S. rolling out major installations of their own.

As part of its Green New Deal initiative, South Korea has plans to build an 8.2 GW offshore wind complex by 2030. This would be the largest offshore wind complex in the world, at a total price tag of approximately $43 billion[35]. In the U.S., plans are underway for 30 GW of offshore wind capacity to be installed by 2030. The Department of Energy and White House are working jointly on this endeavor, but more than $10 million of research funding comes from industry[56]. On June 11, 2021, the U.S. Department of the Interior announced its ninth offshore wind lease in the Outer Continental Shelf of the New York Bight, with the potential to supply more than 7 GW of power[57]. This is the first proposed sale for offshore wind under the Biden administration.

Offshore wind promises to provide energy, but the installations also provide a floating foothold for other technologies. Off the cost of a Belgian island, the 370 MW Norther wind farm is combining offshore wind with aquaculture, automating the cultivation of seaweed for human and animal food, biofuels, and bioplastics[58]. Project operators hope to develop this technology for use at other farms. As multi-use projects like the Norther Wind Farm become more economical, the potential for "energy islands" is vast – from solar panels and floating tidal power generators, to carbon capture and the creation of fuels like green hydrogen[59].

How Does Someone Track the Clean Energy, Smart Grid Infrastructure and Wind Energy Sectors?

Investors can track the Clean Energy, Smart Grid Infrastructure and Wind Energy Sectors through three Nasdaq Clean Edge indexes:

1. Nasdaq Clean Edge Green Energy Index™ (CELS™),
2. Nasdaq OMX Clean Edge Smart Grid Infrastructure Index™ (QGRD™), and the
3. ISE Clean Edge Global Wind Energy Index™ (GWE™).

In addition, investors can gain exposure to the indexes through the corresponding ETFs. Please see below for an overview of the respective indexes.

Nasdaq Clean Edge Green Energy Index (CELS) / Total Return (CEXX™)

The Nasdaq Clean Edge Green Energy Index is a modified market capitalization weighted index designed to track the performance of companies that are primarily manufacturers, developers, distributors and/or installers of clean energy technologies, as defined by Clean Edge. The index began on November 17, 2006, at a base value of 250.00. As of October 29, 2021, the index had 60 components. Investors can gain exposure to the index through the corresponding ETFs:

1. First Trust Nasdaq Clean Edge Green Energy Index Fund (Nasdaq: QCLN),
2. First Trust Nasdaq Clean Edge Green Energy UCITS ETF (London: QCLU), and
3. First Trust Nasdaq Clean Edge Green Energy ETF (Toronto: QCLN).

Eligibility Criteria

To be eligible for inclusion, issuers of the security must be classified, according to Clean Edge, as technology manufacturers, developers, distributors, and/or installers in one of the following sub-sectors:

- Advanced Materials (silicon, lithium, bio-based, and/or other materials and processes that enable clean-energy and low-carbon technologies);
- Energy Intelligence (conservation, efficiency, smart meters, energy management systems, LEDs, smart grid, superconductors, power controls, etc.);
- Energy Storage & Conversion (advanced batteries, power conversion, electric vehicles, hybrid drivetrains, hydrogen, fuel cells for stationary, portable, and transportation applications, etc.); and
- Renewable Electricity Generation (solar, wind, geothermal, water power, etc.).

In addition, a security must meet the following criteria:

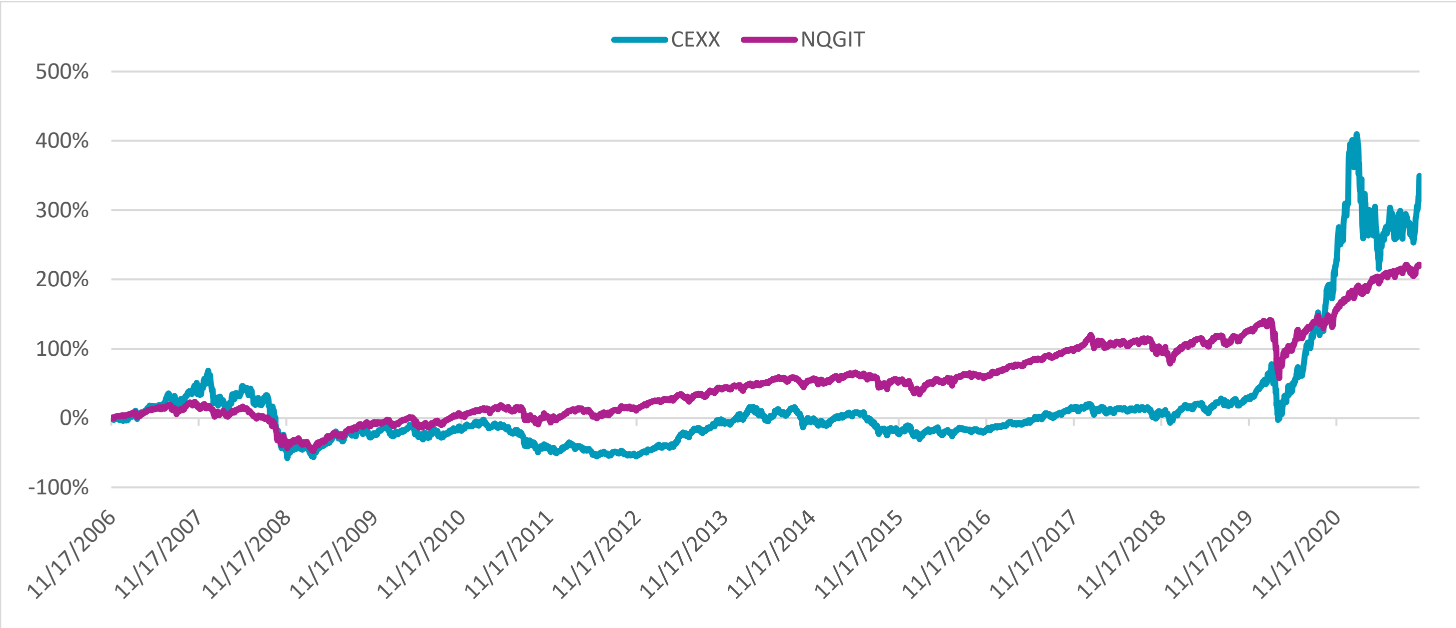
- Be listed on the Nasdaq Stock Market® (Nasdaq®), the New York Stock Exchange, NYSE American, or the CBOE Exchange;
- Have a minimum market capitalization of $150 million;
- Have a minimum average daily trading volume of 100,000 shares.

For complete eligibility criteria, please visit the index methodology.

Performance

Below is a look at the performance of the Nasdaq Clean Edge Green Energy Total Return Index™ (CEXX) index since inception. The index generated a cumulative return of 349%, with an annualized return of 10.57% and an annualized volatility of 33.90%. The Nasdaq Global Total Return Index™ (NQGIT™), which tracks the performance of global equities covering over 98% of the entire listed market capitalization of the global equity space, generated a cumulative return of 221%, with an annualized return of 8.10% and an annualized volatility of 16.97% over the same time period.

Cumulative performance



Data from 11/17/2006 – 10/29/2021. Source: Nasdaq.

How does the index compare to competitor clean and traditional energy indexes?

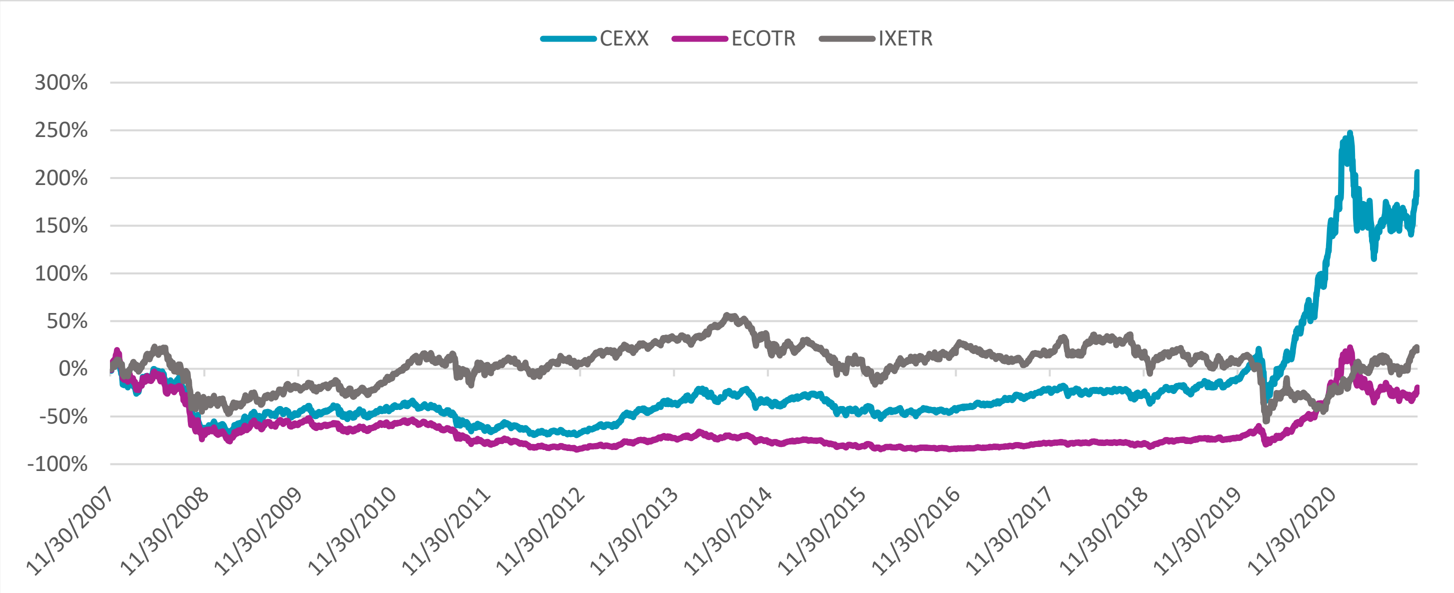
Let's start by looking at cumulative returns comparing The Nasdaq Clean Edge Green Energy Total Return Index (CEXX) to a competitor clean energy index [Wilderhill Clean Energy Index TR (ECOTR)] as well as a traditional energy index [S&P 500 Energy Select Sector Total Return Index TR (IXETR)].

Since November 30, 2007, the beginning of the ECOTR history, as can be seen in the table and chart below, Nasdaq's CEXX has significantly outperformed ECOTR as well as IXETR. The volatility profile of all three indexes is relatively similar in the mid to low 30% range despite very different return profiles. Looking at the cumulative performance chart and then at the annual performance table, can see it's apparent that CEXX had a real run the last few years. For those following the clean energy space, it shouldn't surprise to see that both CEXX and ECOTR drastically outperformed the traditional energy space as shown through IXETR in 2020 and by a good margin in 2019, as well. However, 2021 has been a different story: there has been a strong return to traditional energy. It's worth noting despite the impressive traditional energy rebound with a 57% YTD return in 2021, CEXX has had a decent year thus far at 10.7% and is outperforming ECOTR, which is down -13.7%.

Index	Cumulative Return	Annualized Return	Annualized Volatility
CEXX	206.26%	8.37%	34.38%
ECOTR	-19.58%	-1.55%	35.80%
IXETR	19.30%	1.28%	32.12%

Data from 11/30/2007-10/29/2021. Source: Nasdaq, Bloomberg.

Cumulative performance vs competitors



Data from 11/30/2007-10/29/2021. Source: Nasdaq, Bloomberg.

Annual performance

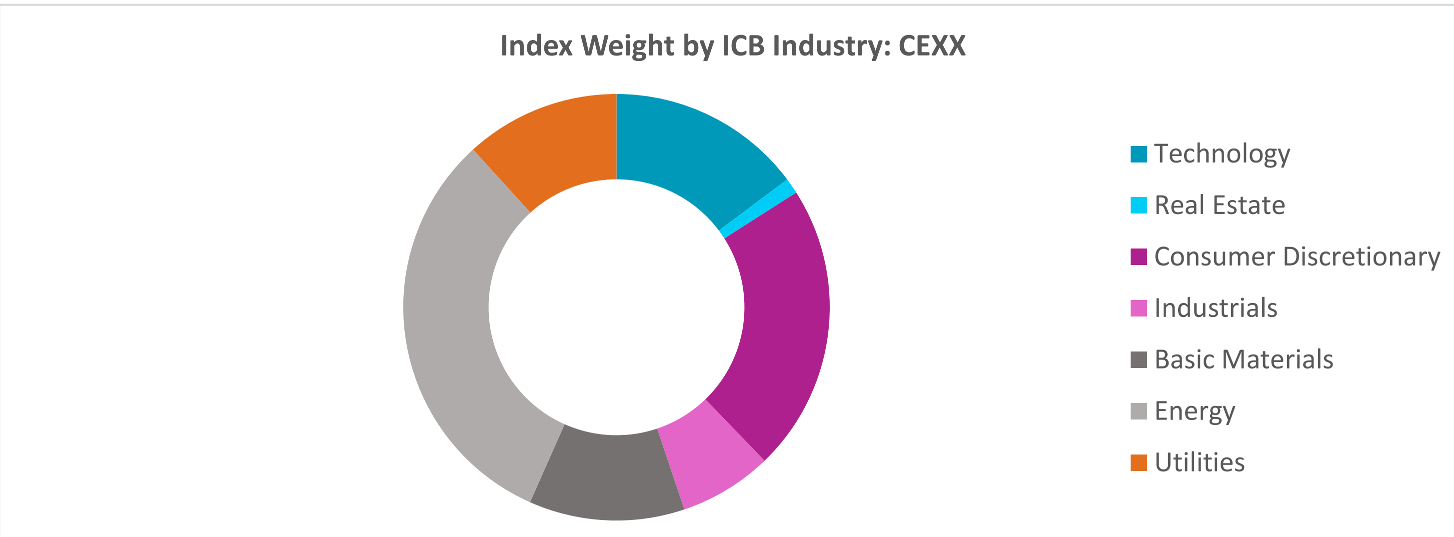
Year	CEXX	ECOTR	IXETR
2007	10.54%	16.15%	8.03%
2008	-63.44%	-69.89%	-38.71%
2009	44.72%	29.78%	21.79%
2010	2.71%	-4.76%	21.98%
2011	-40.81%	-50.43%	3.13%
2012	-1.32%	-18.11%	5.41%
2013	89.34%	58.51%	26.42%
2014	-3.13%	-16.94%	-8.47%
2015	-6.38%	-10.24%	-21.56%
2016	-2.65%	-22.00%	28.24%
2017	32.05%	39.32%	-0.86%
2018	-12.11%	-14.57%	-18.09%
2019	42.66%	59.31%	12.09%
2020	184.83%	203.78%	-32.84%
2021	10.74%	-13.69%	56.86%

Data from 11/30/2007-10/29/2021. Source: Nasdaq, Bloomberg.

CEXX ICB Industry Allocations (%)

The index currently allocates to seven of the eleven industries, with the largest weights across Energy (31.60%), Consumer Discretionary (21.82%), and Technology (14.78%).

ICB Industry	Weight (%)
Energy	31.60
Consumer Discretionary	21.82
Technology	14.78
Basic Materials	11.80
Utilities	11.75
Industrials	7.07
Real Estate	1.19



Data as of 10/29/21. Source: Nasdaq.

Top 10 Constituents

Name	Weight (%)	ICB Industry
Tesla Inc	10.38	Consumer Discretionary
Enphase Energy, Inc.	7.63	Energy
Albemarle Corporation	7.17	Basic Materials
NIO Inc. Sponsored ADR Class A	6.87	Consumer Discretionary
ON Semiconductor Corporation	5.06	Technology
Plug Power Inc.	5.03	Energy
SolarEdge Technologies, Inc.	4.20	Energy
XPeng, Inc. ADR Sponsored Class A	3.76	Consumer Discretionary
Wolfspeed Inc.	3.48	Technology
First Solar, Inc.	3.18	Energy

Data as of 10/29/21. Source: Nasdaq.

Nasdaq OMX Clean Edge Smart Grid Infrastructure Index (QGRD) / Total Return (QGDX™)

The Nasdaq OMX Clean Edge Smart Grid Infrastructure index is designed to act as a transparent and liquid benchmark for the smart grid and electric infrastructure sector. The index includes companies listed globally that are primarily engaged and involved in electric grid; electric meters, devices, and networks; energy storage and management; and enabling software used by the smart grid and electric infrastructure sector. The index began on September 22, 2009, at a base value of 250.00. As of October 29, 2021, the index had 71 components. Investors can gain exposure to the index through the corresponding ETF, which is the First Trust Nasdaq Clean Edge Smart Grid Infrastructure Index Fund (Nasdaq: GRID).

Eligibility Criteria

To be included in the index, a security must meet the following criteria:

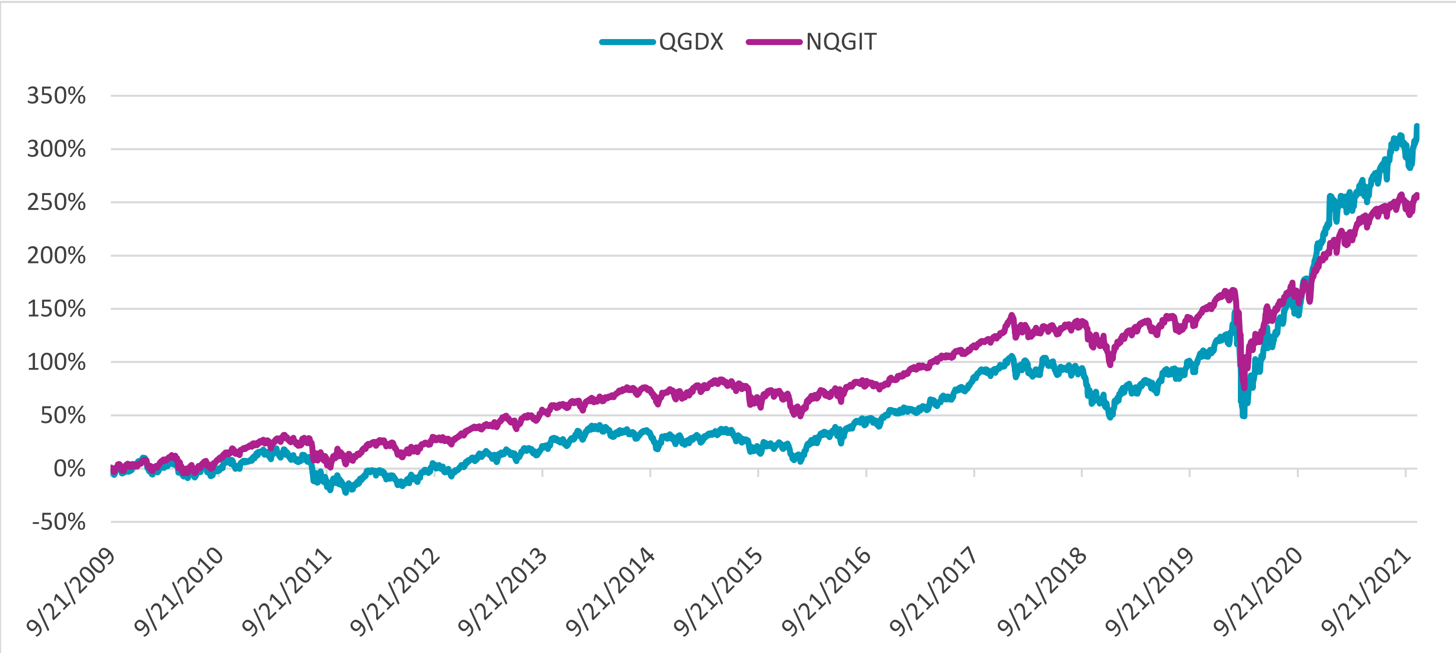
- Be classified as a smart grid, electric infrastructure, EV network, smart building, software, and/or other grid-related activities company according to Clean Edge;
- Be listed on an index-eligible global stock exchange;
- Have a minimum worldwide market capitalization of $100 million;
- Have a minimum three-month average daily dollar trading volume of $500,000; and
- A minimum free float of 20%.

For complete eligibility criteria, please visit the index methodology.

Performance

Below is a brief look at the performance of the Nasdaq OMX Clean Edge Smart Grid Infrastructure Total Index (QGDX) index since inception. The index generated a cumulative return of 321%, with an annualized return of 12.61% and an annualized volatility of 20.41%. The Nasdaq Global Total Return Index (NQGIT) generated a cumulative return of 256%, with an annualized return of 11.05% and an annualized volatility of 14.45% over the same time period. Looking at the annual performance figures, while QGDX outperformed NQGIT on and off the first decade of its existence, the relative size of underperformance caused QGDX to underperform on a cumulative basis until 2020. Over the last almost three years, the tables have turned. In 2019, 2020 and year-to-date 2021, QGDX had very strong returns and outperformed NQGIT by 17%, 34%, and 10%, respectively.

Cumulative performance



Data from 9/21/2009 – 10/29/2021. Source: Nasdaq.

Annual performance

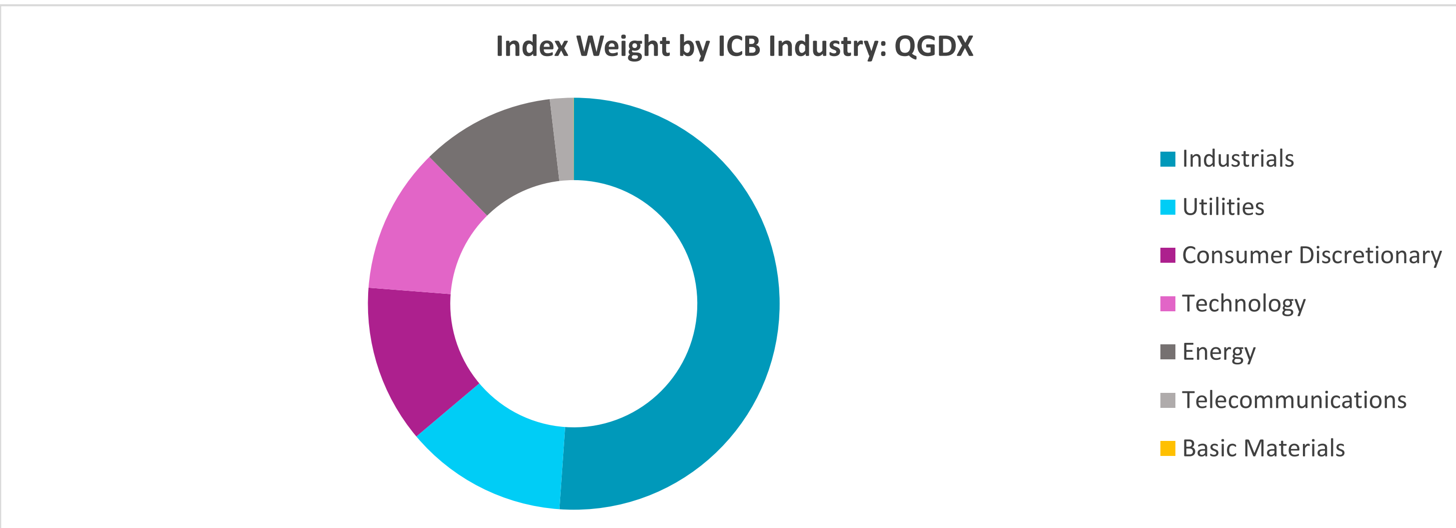
Year	QGDX	NQGIT
2009	5.94%	4.61%
2010	0.71%	15.64%
2011	-20.29%	-7.65%
2012	20.21%	18.31%
2013	26.15%	23.79%
2014	0.32%	4.49%
2015	-6.16%	-1.59%
2016	25.30%	9.02%
2017	28.83%	24.54%
2018	-21.94%	-9.72%
2019	43.90%	26.58%
2020	49.84%	16.28%
2021	27.76%	17.30%

Data from 9/21/2009 – 10/29/2021. Source: Nasdaq.

QGDX ICB Industry Allocations (%)

The index currently allocates to seven of the eleven industries, with the largest weights across Industrials (51.11%), Utilities (12.74%), and Consumer Discretionary (12.38%).

ICB Industry	Weight (%)
Industrials	51.11
Utilities	12.74
Consumer Discretionary	12.39
Technology	11.39
Energy	10.51
Telecommunications	1.84
Basic Materials	0.02



Data as of 10/29/21. Source: Nasdaq.

Top 10 Constituents

Name	Weight (%)	ICB Industry
Aptiv Plc.	8.81	Consumer Discretionary
Johnson Controls International plc.	7.61	Industrials
Eaton Corp. Plc.	7.59	Industrials
Schneider Electric SE	7.48	Industrials
ABB Ltd.	6.94	Industrials
Enphase Energy Inc.	5.17	Energy
SolarEdge Technologies, Inc.	4.75	Energy
Quanta Services Inc.	4.61	Industrials
Prysmian S.p.A.	3.78	Industrials
Terna S.p.A.	3.66	Utilities

Data as of 10/29/21. Source: Nasdaq.

ISE Clean Edge Global Wind Energy Index (GWE) / Total Return (GWETR™)

The ISE Clean Edge Global Wind Energy Index (GWE) is designed to track the performance of companies listed globally that are primarily engaged and involved in the wind energy industry based on analysis of the products and services offered by those companies (including both pure play companies focused on the wind energy sector and diversified multinationals with wind energy sector exposure). The Index was launched on December 16, 2005, at a base value of 100.00. As of October 29, 2021, the index had 48 components. The ETF that tracks the index is the First Trust ISE Clean Edge Global Wind Energy Index Fund (NYSE: FAN).

Eligibility Criteria

To be included in the index, a security must meet the following criteria:

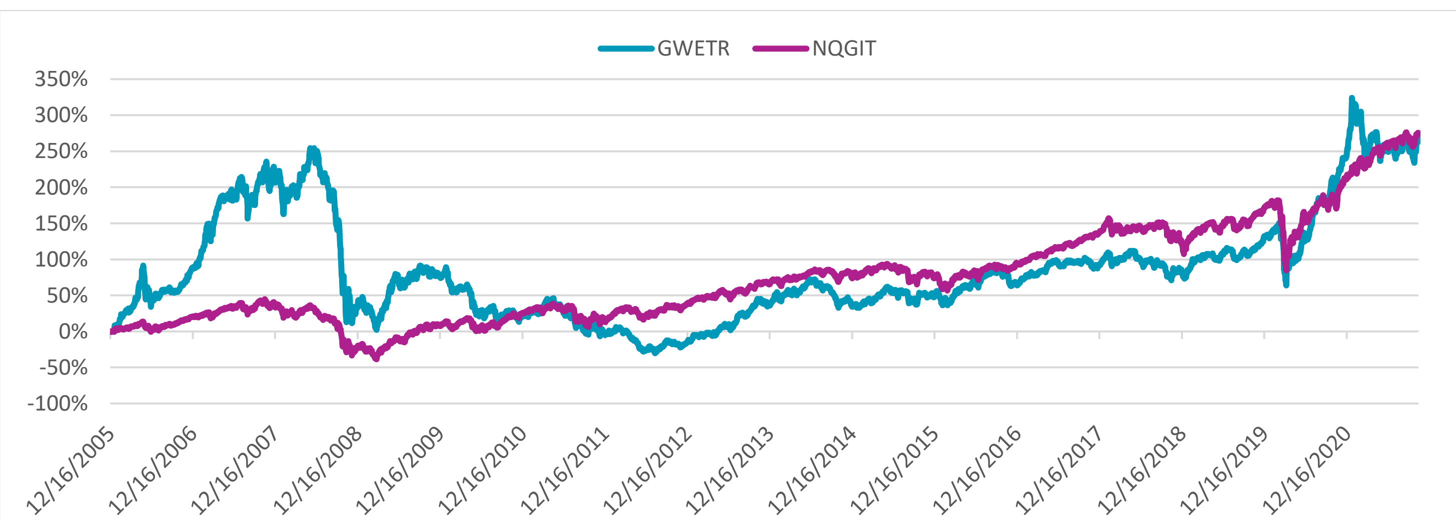
- Be actively engaged in some aspect of the wind energy industry such as the development or management of a wind farm, the production or distribution of electricity generated by wind power, or involvement in the design, manufacture or distribution of machinery or materials designed specifically for the Industry according to Clean Edge;
- Be listed on an index-eligible global stock exchange;
- Have a minimum worldwide market capitalization of $100 million;
- Have a minimum three-month average daily dollar trading volume of $500,000; and
- A minimum free float of 25%.

For complete eligibility criteria, please visit the index methodology.

Performance

Below is a chart of the cumulative performance for the ISE Clean Edge Global Wind Energy Total Return Index (GWETR) since inception. The index generated a cumulative return of 266%, with an annualized return of 8.51% and an annualized volatility of 22.98%. The Nasdaq Global Total Return Index (NQGIT) generated a cumulative return of 275%, with an annualized return of 8.68% and an annualized volatility of 16.49% over the same time period. From the GWETR low point (on a cumulative basis since inception that occurred) on July 25, 2012, through October 29, 2021, GWETR had a cumulative return of 425%, more than double the 208% of NQGIT.

Cumulative performance

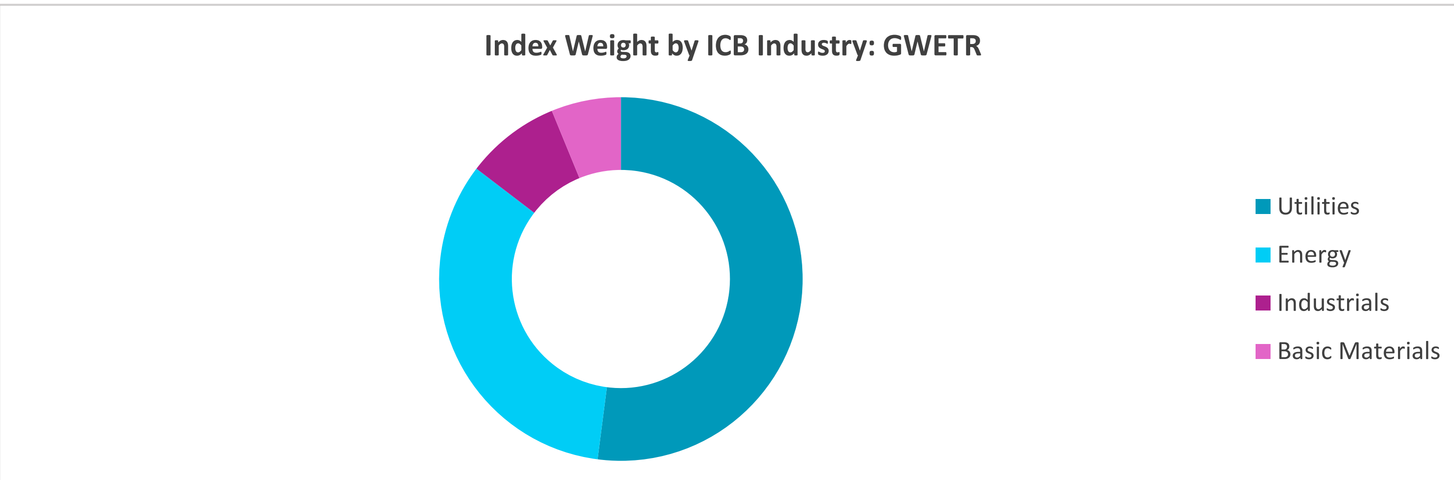


Data from 12/16/2005 – 10/29/2021. Source: Nasdaq.

GWETR ICB Industry Allocations (%)

The index currently allocates to four of the eleven industries, with the largest weights across Utilities (52.05%), Energy (33.33%), and Industrials (8.42%).

ICB Industry	Weight (%)
Utilities	52.05
Energy	33.33
Industrials	8.42
Basic Materials	6.20



Data as of 10/29/21. Source: Nasdaq.

Top 10 Constituents

Name	Weight (%)	ICB Industry
Vestas Wind Systems A/S	8.59	Energy
China Longyuan Power Group Corp. Ltd. Class H	7.54	Energy
Orsted	7.21	Utilities
Northland Power Inc.	6.62	Utilities
Siemens Gamesa Renewable Energy, S.A.	6.00	Energy
EDP Renovaveis Br	4.30	Utilities
Boralex Inc. Class A	2.94	Utilities
Nordex	2.41	Energy
Innergex Renewab Rg	2.33	Utilities
EDP-Energias Rg	2.07	Utilities

Data as of 10/29/21. Source: Nasdaq.

Conclusion

In this research piece we discussed how, over the past decade, clean energy has gone from niche to mainstream and covers a wide range of products and services. And while it's hard to pinpoint the exact time span of the energy transition, we believe that we are approximately 25 years into a 50-year transition cycle from fossil fuels to clean-energy sources. As we outlined in this report, the following developments are at the forefront of this massive shift:

- Clean energy, in many regions, is now the lowest cost option for new power generation (less expensive than fossil fuels and nuclear, and attracting an increasing share of capacity additions)
- Energy storage and EVs are not far behind in terms of cost reduction, now following growth trajectories similar to solar and wind over the past decade
- Corporate, investor, and government commitments to net-zero are being driven by both pure economics and a growing awareness of the need to aggressively address climate change
- Smart grid infrastructure is the great enabler of a 21st century electric grid and supports the convergence of renewable energy, EVs, IoT grid devices, smart transformers, and energy storage

These and other developments create unique opportunities of which investors should be aware.

Investors can track the Clean Energy, Smart Grid Infrastructure and Wind Energy Sectors through three Nasdaq Clean Edge indexes:

1. Nasdaq Clean Edge Green Energy Index (CELS),
2. Nasdaq OMX Clean Edge Smart Grid Infrastructure Index (QGRD), and the
3. ISE Clean Edge Global Wind Energy Index (GWE).

In addition, investors can gain exposure to the indexes through the corresponding ETFs. The following lists each of the respective ETF names, followed by the exchange the ETF listed on, the ETF ticker, and the index ticker that each ETF tracks.

- First Trust Nasdaq Clean Edge Green Energy Index Fund (Nasdaq: QCLN) (Index: CELS),
- First Trust Nasdaq Clean Edge Green Energy UCITS ETF (London: QCLU) (Index: CELS),
- First Trust Nasdaq Clean Edge Green Energy ETF (Toronto: QCLN) (Index: CELS),
- First Trust Nasdaq Clean Edge Smart Grid Infrastructure Index Fund (Nasdaq: GRID) (Index: QGRD), and
- First Trust ISE Clean Edge Global Wind Energy Index Fund (NYSE: FAN) (Index: GWE).

[1] https://www.lazard.com/media/451419/lazards-levelized-cost-of-energy-version-140.pdf

[2] https://iea.blob.core.windows.net/assets/ef1d6b50-66a6-478c-990e-ee227e2dd89b/Clean_Energy_Investing_-_Global_Comparison_of_Investment_Returns.pdf

[3] https://cleanedge.com/data-dive-charts/Market-Cap-Comparison-Clean-Energy-vs-Oil

[4] https://www.eia.gov/consumption/residential/data/2015/c&e/pdf/ce4.1.pdf

[5] https://www.bbc.com/news/world-59137828

[6] https://www.pewresearch.org/science/2021/05/26/climate-energy-and-environmental-policy/

[7] https://www.there100.org/re100-members

[8] https://www.nrdc.org/sites/default/files/state-green-banks-2020-report.pdf

[9] https://time.com/6075425/semiconductor-chip-shortage/

[10] https://www.energy.gov/articles/doe-announces-30-million-research-secure-domestic-supply-chain-critical-elements-and

[11] https://www.scottmadden.com/news/study-on-transmission-as-the-solution-for-the-integration-of-renewables-and-resilience-by-scottmadden-for-wires/

[12] https://www.whitehouse.gov/briefing-room/statements-releases/2021/11/08/fact-sheet-the-bipartisan-infrastructure-deal-boosts-clean-energy-jobs-strengthens-resilience-and-advances-environmental-justice/

[13] https://www.iea.org/reports/renewables-2020?mode=overview

[14] https://www.iea.org/reports/net-zero-by-2050

[15] https://www.greenbiz.com/article/7-days-may-climate-finance-week-when-everything-changed

[16] https://www.wsj.com/articles/banks-arctic-financing-retreat-rattles-oil-industry-11602157853

[17] https://www.bloomberg.com/news/articles/2021-06-04/what-a-dutch-court-ruling-means-for-shell-and-big-oil-quicktake

[18] https://www.reuters.com/business/energy/chevron-shareholders-approve-proposal-cut-customer-emissions-2021-05-26/

[19] https://www.nytimes.com/2021/06/09/business/exxon-mobil-engine-no1-activist.html

[20] https://www.lazard.com/media/451419/lazards-levelized-cost-of-energy-version-140.pdf

[21] https://cleanedge.com/data-dive-charts/Solar-Wind-and-Storage-Cost-Declines-vs-Installed-CapacityDemand

[22] https://www.eia.gov/outlooks/aeo/pdf/04%20AEO2021%20Electricity.pdf

[23] https://www.eia.gov/todayinenergy/detail.php?id=44976

[24] https://cleanedge.com/data-dive-charts/New-Energy-Capacity-in-the-US

[25] https://www.eia.gov/electricity/data/state/

[26] https://cleanedge.com/data-dive-charts/Top-10-Renewable-Energy-States-of-Generation

[27] https://www.iea.org/reports/renewable-energy-market-update-2021/renewable-electricity

[28] https://www.irena.org/Statistics/View-Data-by-Topic/Capacity-and-Generation/Country-Rankings

[29] https://www.iea.org/articles/renewables-2020-data-explorer?mode=market&region=China&product=PV

[30] https://www.bloomberg.com/news/articles/2021-07-12/a-bout-of-deals-could-follow-china-s-record-wind-boom-ceo-says

[31] https://cleantechnica.com/2020/12/20/european-union-approves-worlds-largest-green-stimulus/

[32] https://www.bloomberg.com/news/articles/2021-07-14/the-seven-elements-of-the-eu-green-deal-you-should-care-about

[33] https://cleantechnica.com/2020/12/20/european-union-approves-worlds-largest-green-stimulus/

[34] https://www.iea.org/data-and-statistics/charts/global-average-annual-net-capacity-additions-by-type-2010-2040

[35] https://www.powermag.com/benefits-of-high-voltage-direct-current-transmission-systems/

[36] https://www.renewableenergyworld.com/wind-power/hvdc-the-key-to-revolutionizing-the-renewable-energy-grid/#gref

[37] https://www.forbes.com/sites/jamesellsmoor/2019/04/27/meet-5-companies-spearheading-blockchain-for-renewable-energy/?sh=a5c283f2ae2a

[38] https://cbeci.org/cbeci/comparisons

[39] https://techcrunch.com/2021/03/21/the-debate-about-cryptocurrency-and-energy-consumption/

[40] https://www.greentechmedia.com/articles/read/wood-mackenzie-world-will-invest-30b-in-smart-meters-through-2025

[41] https://www.marketsandmarkets.com/Market-Reports/iot-utility-market-116054824.html

[42] https://cleanedge.com/data-dive-charts/Clean-Edge-Tech-Maturation-Model

[43] https://www.ev-volumes.com/

[44] https://www.canalys.com/global-ev-outlook-report

[45] https://www.iea.org/data-and-statistics/charts/global-electric-passenger-car-stock-2010-2020

[46] https://media.ford.com/content/fordmedia/fna/us/en/news/2021/05/19/all-electric-ford-f-150-lightning.html

[47] https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/the-potential-impact-of-electric-vehicles-on-global-energy-systems#

[48] https://www.marketresearchfuture.com/reports/smart-transformers-market-6014

[49] https://www.cesa.org/wp-content/uploads/ESTAP-webinar-2-25-21-slides.pdf

[50] https://about.bnef.com/blog/energy-storage-620-billion-investment-opportunity-2040/

[51] https://www.washingtonpost.com/business/energy/why-batteries-are-the-key-to-bidens-green-dreams/2021/06/30/0e854ed2-d975-11eb-8c87-ad6f27918c78_story.html

[52] https://www.bloomberg.com/news/articles/2021-08-02/a-tesla-big-battery-in-australia-is-burning-for-a-fourth-day

[53] https://www.reuters.com/business/autos-transportation/gm-says-some-chevy-bolt-ev-owners-should-park-outside-after-two-fires-2021-07-14/

[54] https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Oct/IRENA_Future_of_wind_2019.pdf

[55] https://www.oedigital.com/news/488732-millennial-milestone-rsted-installs-1000th-offshore-wind-turbine-in-uk#.YNZRF9KVZfQ.twitter

[56] https://cleantechnica.com/2021/06/13/offshore-wind-power-a-centerpiece-of-us-department-of-energys-power-plans/

[57] https://www.boem.gov/renewable-energy/state-activities/new-york-bight

[58] https://www.power-technology.com/features/offshore-wind-farm-seaweed-wier-north-sea-farmers-aquaculture-farming/

[59] https://www.forbes.com/sites/jeffmcmahon/2021/06/23/us-agency-sees-greater-potential-for-european-style-energy-islands/?sh=1d84ae109f92