Enabling the Energy Transition

Industry Report and Investment Case

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

The energy transition represents a massive shift in how we produce power, moving from fossil fuels to sources that produce little or no carbon. A range of products and services are enabling this transition, including:

- Renewable Energy: Energy sources including solar, wind, geothermal, and hydroelectric power
- Energy Storage & Conversion: Offerings such as advanced lithium-ion batteries, solid-state batteries, pumped hydro and other long-duration storage solutions, 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 including smart meters, energy management systems, power controls, and light-emitting diodes (LEDs)
- Enabling Materials: Mined, manufactured, and recycled materials such as lithium, silicon carbide, gallium nitride, copper, nickel, rare earths, and waste-derived fuels

The Five Major Drivers of Clean Tech

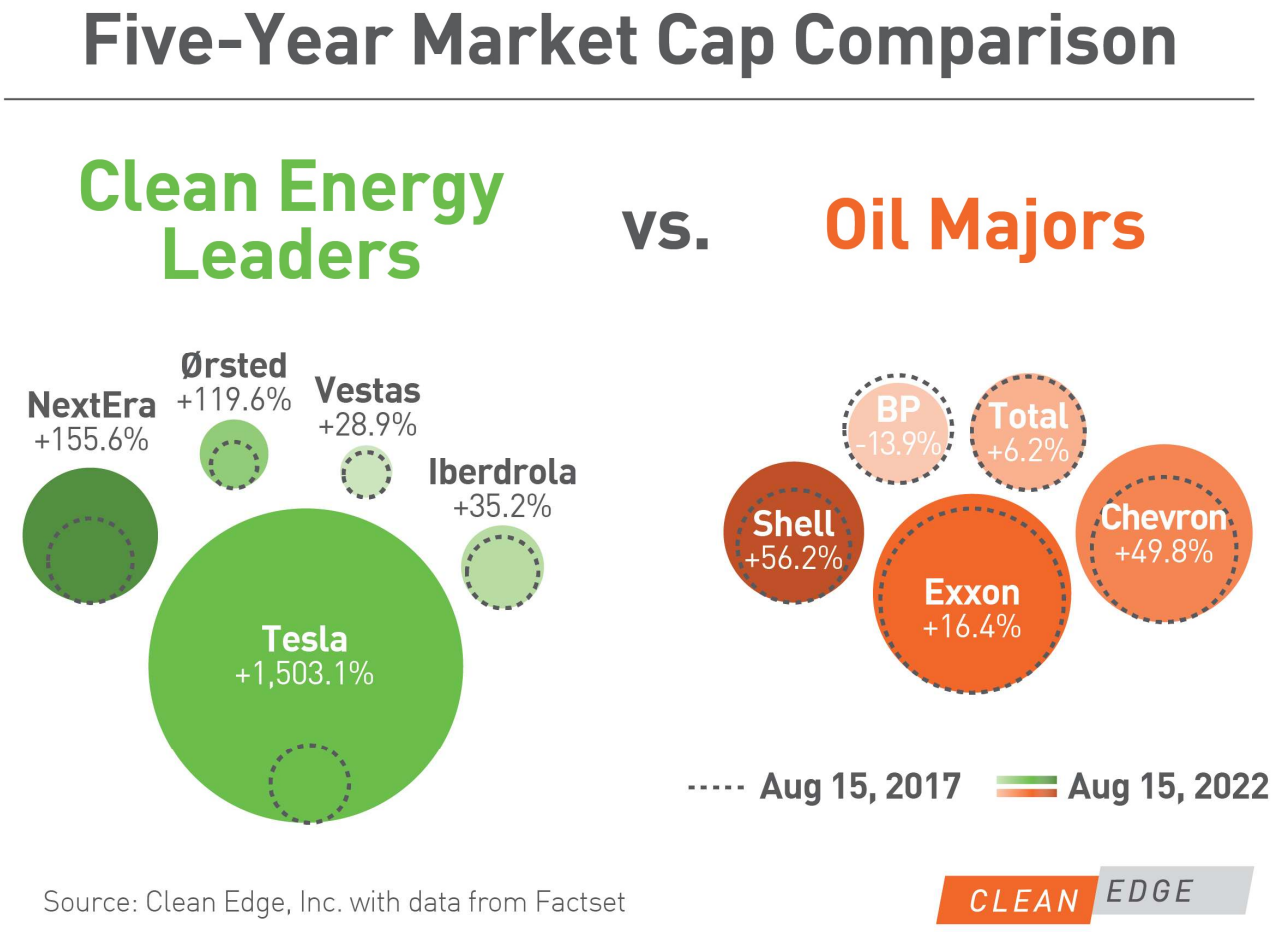
We are about halfway through the global energy transition, as businesses, utilities, consumers, and other stakeholders embrace the benefits of clean energy. The current transition period began around the turn of the 21st century and is expected to take about 50 years. At the forefront of this dramatic shift has been the rapid growth of renewable energy (primarily solar and wind), the recent rise of energy storage and electric vehicles (EVs), and the advent of smart and connected electric grids.

The key technology, capital, and policy-related developments driving this significant change include:

- Continued Decline in Costs. Since 2009, costs for solar photovoltaic (PV) energy have declined by nearly 90% per Megawatt (MW) installed, and onshore wind prices have dropped 72% in the same time frame[1]. Solar and onshore wind remain 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. These cost declines have greatly exceeded the projections in the National Renewable Energy Laboratory's 2012 Renewable Energy (RE) Futures report, which predicted that the U.S. could reach 80% renewable energy by 2050[2]. The RE

Futures Report's main scenario projected that a utility-scale solar PV system in 2050 would cost between $2,200 and $2,700 per kilowatt (kW). But by 2020, the same system cost less than half that amount, around $1,000 per kW. As electricity demand rises globally, renewable sources of power will continue to dominate new installations.

- Investment Shifts from Fossil Fuels to Clean Energy and Smart Grid. Both private and public investors are becoming cognizant of the long-term geopolitical and financial risks of fossil fuel investments and increasingly divesting from fossil fuels. At the same time, the financial benefits of renewable energy projects are driving investments in this sector. In the decade ending in 2020, average returns from renewable power investments were more than seven times higher than those from fossil fuels (422.7% compared to 59%), according to the International Energy Agency (IEA) and the Centre for Climate Finance at Imperial College Business School[3]. As of 2022, oil and gas supermajors have experienced a rebound in their valuation. Despite this, over the past five years the largest clean energy companies outpaced oil and gas, greatly increasing their market capitalization (by up to 1,500% in the case of Tesla).

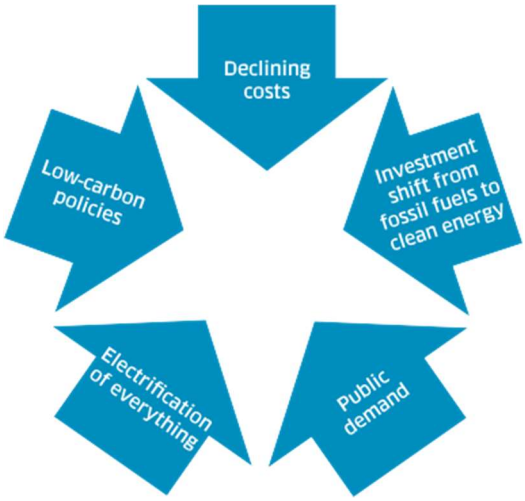


Source: Clean Edge, Inc., 2022[4]

- Infrastructure Replacement and the Electrification of Everything. With energy storage and EVs continuing to experience cost declines similar to those of renewables, the concept of "electrification of everything" is emerging. The resulting increased electrical load will require utilities to modernize grid infrastructure, driving continued investment in this sector. The move to electric heat (utilizing highly efficient electric heat pumps) is

perhaps the single largest potential driver for expanding residential electrification. Fossil fuels (mainly natural gas and heating oil) have historically provided 90% of the energy for residential space heating and 80% of the water heating in the U.S., according to the U.S. Energy Information Administration (EIA)[5]. Also underlying these trends is the digitization of energy, from smart meters to connected IoT devices, and the smart grid backbone that supports it.

- Low Carbon Policies. Globally, national governments are responding to the threats of climate change and energy security by signing commitments to reduce their carbon emissions. The 2022 Russian invasion of Ukraine, however, has had a significant impact on national energy policies and will likely result in a short-term increase in fossil-fuel-related emissions on the Continent. The European Union (EU) has stopped all Russian oil and gas imported by sea, with plans to curtail and even halt pipeline importation. The UK has followed suit, with plans to stop importing oil by the end of the year[6]. But this European shift away from Russian oil and gas has caused a temporary shift back to coal for number of countries and resulted in a frenzied search for new and reliable natural gas supplies (such as LNG from the U.S.). While this crisis-mode activity is not surprising, it is also driving new investments in energy efficiency efforts, renewables, and storage. Beyond this major and incredibly disruptive geopolitical crisis, a recent development in the U.S. could result in significant climate action. The U.S. federal government's Inflation Reduction Act of 2022 (also known as the Senate Climate Bill), passed in August, authorizes an unprecedented $369 billion to pump up investment in the solar, wind, geothermal, and battery industries while providing consumer-level incentives for EVs and heat pumps. The goal of the bill is to help meet the Biden Administration's target of halving emissions by 2030 (compared to 2005 levels)[7]. In addition to national actions, the outsized role of regional governments shouldn't be overlooked. In the U.S., for example, states are often in the driver's seat, with California (the fifth largest economy in the world), New York, and other climate leaders implementing aggressive clean-energy targets backed up by policy and financing support.



Source: Clean Edge, Inc.

- 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 percentage of U.S. adults who favored renewable energy over fossil fuel production increased from 63% to 79%. Despite declines in 2021 and 2022, more than twice as many Americans (Democrats and Republicans alike) still prioritize clean energy[8]. At the same time, private companies are significantly increasing their efforts to become carbon neutral. More than 370 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[9].

Challenges Facing the Energy Transition

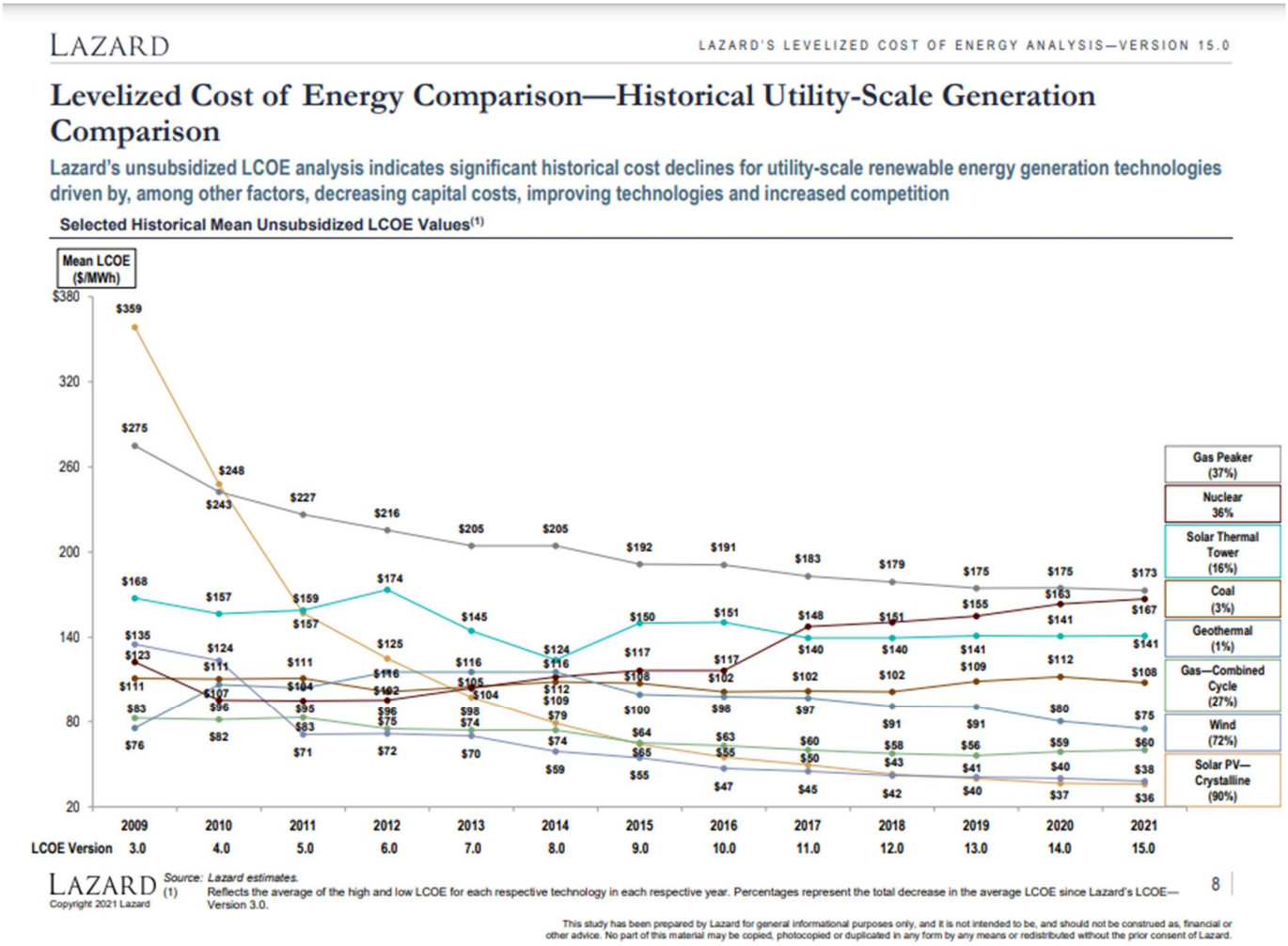
While the energy transition is bolstered by strong public support and growing economies of scale, key challenges remain in the sector. These challenges include:

- Higher Interest Rates. Renewable energy installations tend to come with high up-front costs, so low interest rates in recent years have been a boon for renewables development. But the industry has been impacted by rising interest rates in the current inflationary environment, causing more renewable projects to seek alternative funding. One solution gaining momentum is "green banks" – typically publicly-owned institutions created to help fund climate-focused projects like renewable energy installations by 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 27 green banks in 12 countries and another 20 countries actively exploring the model[10].
- Supply Chain Issues. Disruptions in the global supply chain have continued post-COVID-19, with microchips and EV battery markets being especially hard-hit. Microchips, or semiconductors, are essentially the brains behind all modern technology. In the clean energy sector, they're a required component in the manufacture of everything from LED bulbs and EVs to energy storage and heating, ventilation, and air conditioning control systems. Between the global supply chain disruptions of COVID and the war in Ukraine, manufacturers are struggling to obtain enough chips and the shortage is predicted to last into 2024[11]. As with microchips, the U.S. market (among others) is consistently falling short on the equally critical supplies of battery storage-enabling materials 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[12]. Because of this and other factors, the price of battery cells is expected to surge by 22% between 2023 and 2026[13]. To combat this threat to the domestic production of clean energy technologies, in March 2021 the U.S. Department of Energy (DOE) announced $30 million in funds for shoring up critical mineral supply chains[12]. One year later, President Biden authorized use of the Defense Production Act to strengthen U.S. manufacturing of these materials, particularly large-capacity batteries[14]. Actions for doing this include advancing recycling technologies, particularly for e-waste, and enabling a so-called Circular Economy that uses waste streams as potential resources. In 2022, the DOE announced plans to build a new refining facility, supported by $140 million from the Bipartisan Infrastructure Law, for extracting critical minerals from fossil fuel waste such as mine tailings and coal ash[15].
- 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 production is cheapest in the Southwest and Southeast. For highly populated coastal and other urban areas to reach 100% renewable targets, electricity needs to be transported from where it's cheap to where it's needed. Due to high costs and issues with siting and permitting regulations, however, transmission projects are not being completed as quickly as is needed to keep up with demand, according to research firm ScottMadden[16]. In 2021, the U.S. approved $65 billion in funding for clean energy transmission in the $550 billion Bipartisan Infrastructure Law. This money will be used to create a Grid Deployment Authority and install thousands of miles of new resilient transmission lines[17].
- Trade Issues. With recent bans on importing Russian oil and gas (see above), many countries are seeing a disruption in their energy supply. This has led some, such as Germany and the Netherlands[18], to temporarily re-fire older coal plants and/or ramp up domestic oil and gas production. Other global trade issues include the Auxin Solar tariffs case, where a small California-based solar module manufacturer petitioned the U.S. government to impose new tariffs on imported solar modules from Cambodia, Malaysia, Thailand, and Vietnam[19]. Currently about 80% of solar modules installed in U.S. solar projects come from these countries, so this would present a significant disruption to the supply chain (and the energy transition). The Biden administration announced in May 2022 that no new tariffs would be placed on solar imports for 24 months[20]. While this is welcome news to many solar developers, global trade issues will continue to influence the health of the renewable energy market.

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. Research by Lazard, a financial advisory and asset management firm which has been tracking the levelized cost of energy (LCOE) for more than a decade, shows that the LCOE for wind power dropped from $135 per megawatt hour (MWh) in 2009 to just $38 per MWh in 2021, a decline of 71.8%. Even more dramatically, utility-scale solar declined 89.9% over the same period, from $359 to $35 per MWh. As a result, 2021 marked the seventh consecutive year in which wind and solar both cost less than natural gas combined-cycle power generation. 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[1].

Renewables and Conventional Comparison (2009-2021)

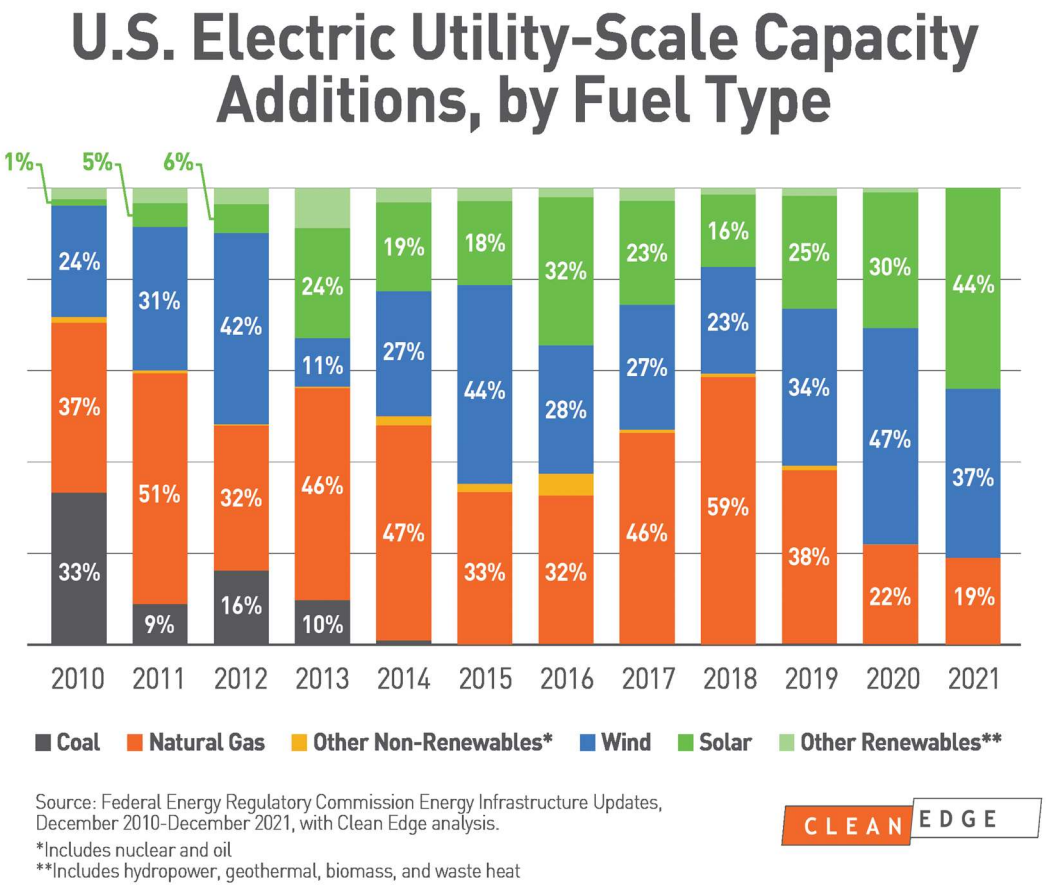


Source: Lazard, 2021[1]

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 2021, electricity generated from renewable sources (including hydropower) made up 21% of the total generation in the U.S.[21]. While global trade issues in solar have led some U.S. utilities to delay closing some existing coal plants[22], no new coal plants have been added to the U.S. grid in nearly a decade[23].

With coal generation capacity declining and demand for electricity on the rise, renewables are filling the gap. Over the past decade in the U.S., a dramatic flip has occurred in new energy installations. In 2010, about 70% of new capacity additions came from natural gas and coal. In 2021, 81% of new capacity consisted of solar and wind – and these trends are expected to accelerate[24].

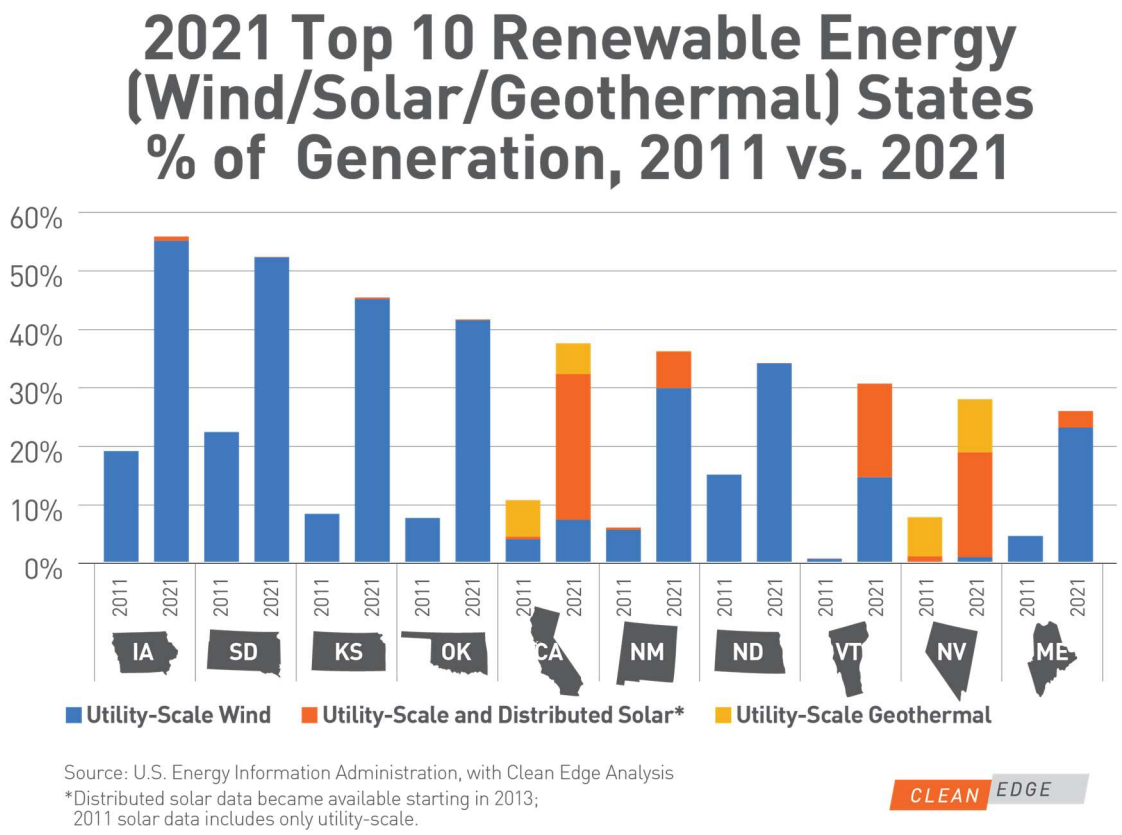
U.S. Electric Utility-Scale Capacity Additions, by Fuel Type



Source: Clean Edge, Inc., 2022[24]

At the state level, the rise in renewable energy sources is even more dramatic. A decade ago, only three states received 10% or more of their in-state electricity generation from non-hydro, utility-scale renewables (i.e. solar, wind, and geothermal). In 2021, 22 states were part of the 10% club, with eight states – Iowa, Kansas, Oklahoma, California, Vermont, New Mexico, and the Dakotas – getting 30% or more of their electricity from renewables. Iowa reached the historic milestone of generating more than half of its power from renewable sources for the second straight year, and South Dakota exceeded the 50% threshold for the first time[25].

2021 Top 10 Renewable Energy (Wind/Solar/Geothermal) States, % of Generation, 2011 vs. 2021



Source: Clean Edge, Inc., 2022[25]

The adoption of low-cost, low-carbon energy solutions also continues to rise globally. Worldwide renewable capacity (including hydro) rose by a record-breaking 295 gigawatts (GW) in 2021 despite unexpectedly high raw material costs[26]. The IEA predicts global renewables capacity will grow by another 320 GW in 2022[26]. It may come as no surprise that China leads the world in total installed renewables, topping a terawatt of renewable capacity in 2021[27]. This growth is likely to continue through 2022, with China's strong subsidies for renewable energy leading to major additions of hydropower, utility-scale PV, and onshore wind. All this feeds into China's goal for net-zero emissions by 2060[28]. Many other countries are investing heavily in renewable projects, including South Korea, India, and much of Europe.

National and corporate commitments alike will lead to continued expansion in renewable capacity through at least 2050. All this new renewable capacity means healthy growth in the renewable job market. In 2020, despite job losses due to COVID, the International Renewable Energy Agency (IRENA) and the International Labor Organization (ILO) estimated that jobs in the global renewable sector reached 12 million, up from 11.5 million in 2019[29]. These jobs continue to rise in the wake of economic recovery, with the ILO predicting a total of 24-25 million new jobs created in this sector by 2030. In the U.S., the Bureau of Labor Statistics predicts jobs in the U.S.

solar industry alone will grow 52% between 2020 and 2030, far outpacing most other industries[30]. And according to IRENA's *World Energy Transitions Outlook* report, up to 43 million energy sector jobs will be filled by renewable energy workers by 2050[31].

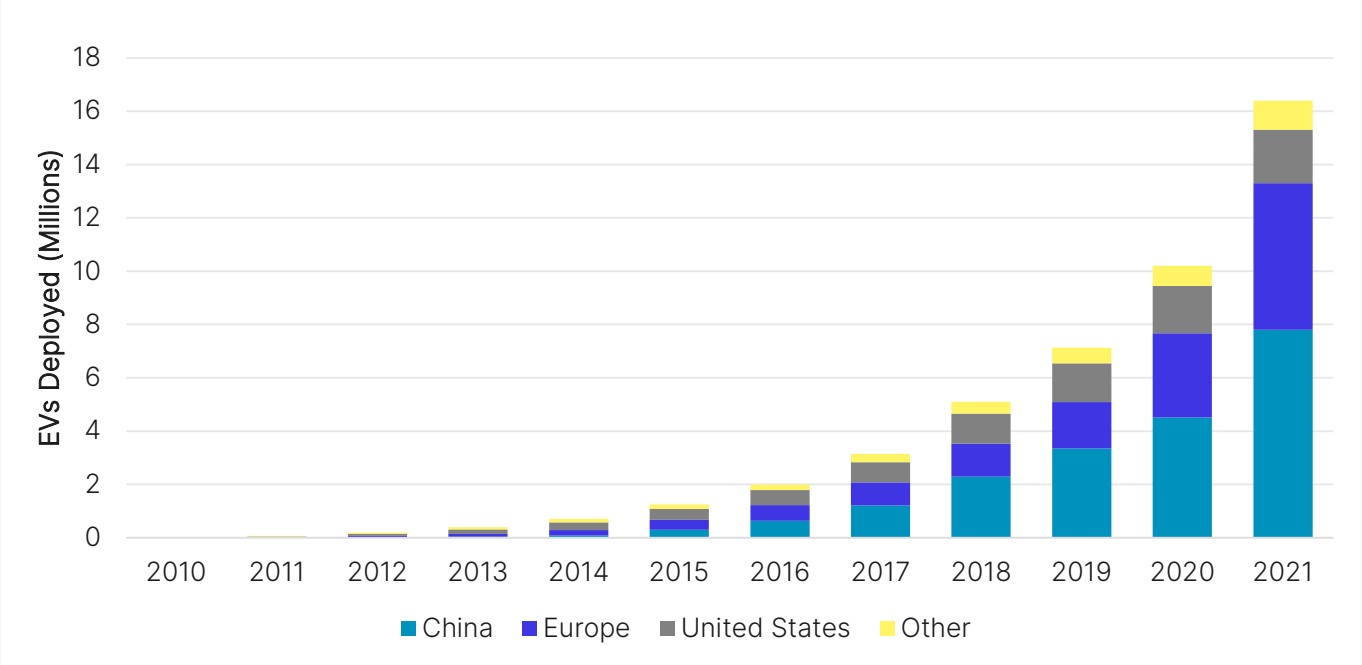
Smart Grid Infrastructure

With the ongoing renewable energy transition, the electric grid is experiencing a technological renaissance. This emerging, more modernized grid, based on advances in big data, artificial intelligence, distributed networks, and other technologies, is enabling significant progress in digitization of the grid. Smart meters, which can be used to manage aggregated demand from residential and commercial buildings, 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 is expected to reach 80% by 2025. In Europe, France, Spain, and the Netherlands all hit the EU's goal of 80% penetration in 2020[32]. These devices, communicating via 5G and LTE networks, will improve service reliability by optimizing usage in real time while also reducing costs.

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 renewables generation. HVDC power lines lose significantly less energy than traditional power lines, particularly over distances greater than 300 miles. They also allow for rapid change in the direction of energy flow – so renewables can more easily be hooked into the grid. Several long distance HVDC transmission projects have been completed, such as a line connecting Spain and France, the most powerful HVDC line in the world[33]. Many others are underway, with annual deployment of HVDC lines expected to reach nearly 11,200 miles by 2030, according to research from Global Market Insights[34].

While HVDC enables more efficient transmission, the rapid growth of EVs and energy storage is poised to dramatically rewire the electric grid. In 2021, global sales of EVs soared 61% from 2020, topping 16.5 million EVs on the road. A huge part of this growth comes from China, but in the final quarter of 2021, EV sales in Europe supplanted diesel-powered vehicle sales for the first time ever[35]. According to the IEA, annual sales of EVs in the U.S. more than doubled (114% growth) in 2021[35].

Electric Vehicle Deployment, 2010-2021



Source: International Energy Agency, 2022[35]
*Totals include battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs). Does not include conventional hybrids.

As consumer demand for EVs increases, both major auto manufacturers and new startups are positioning themselves to compete in this new electrified world. 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 to safeguard future revenue. And many utilities are developing or have applied for permits to develop a backbone of charging locations to better serve customers in their service territories.

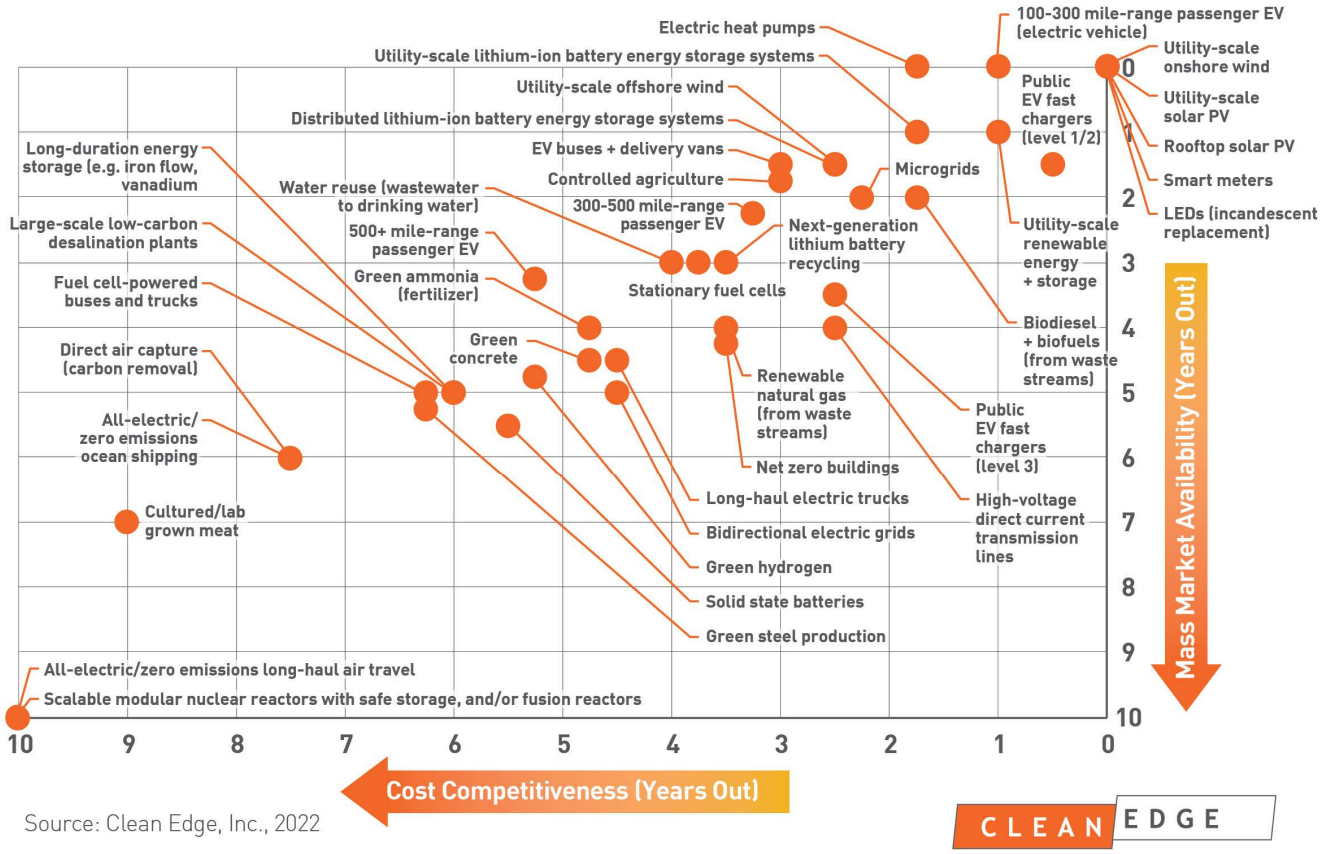
While charging EVs will increase electricity demand, it's not expected to exceed utility capacity, reaching just 5% of total electricity demand by 2030, according to McKinsey & Company[36]. In fact, integrating EVs provides grid operators with a somewhat flexible load that can absorb excess capacity 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 utilities directly to EVs' telematics systems. Vehicle-grid integration services, including advanced energy storage, will become even more critical when there are tens of millions of EVs plugging in.

With an ever-increasing supply of renewable power coupled with high demand from electrified transportation, the next major hurdle is the storage and distribution of all this clean energy. Lithium-ion batteries are the current leading technology in the energy storage market, and the deployment of existing and emerging lithium-ion battery technologies will remain key to the energy transition. The widespread production of these batteries has led to dramatic price declines of around 88% between 2010 and 2020. Recent spikes in the costs of lithium carbonate, however, have dimmed hopes that the price of lithium-ion batteries will reach $100 per kilowatt-hour by 2023[37]. One solution is to develop better recycling technologies for older lithium-ion batteries (from smart phones, laptops, and EVs, for example), which could dramatically stretch existing supplies in a virtual circular loop.

Solid-state batteries are one such technology that will enter the market in the coming years. 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. This means the same total footprint can store more energy, more safely. Indeed, the fire risk of lithium-ion batteries, which have caused concern in scaled deployment, is driving the development of safer storage solutions including not only solid-state batteries but also better thermal barriers and encasements for traditional lithium-ion chemistries. Other large-scale long-duration energy storage solutions include pumped hydro, flow batteries, below-ground compressed air storage, and other emerging options.

Tech Maturation Model

The energy transition relies on massive scaling up of many varied technologies, which range in their technological maturity. The Clean Edge Tech Maturation Model, shown below, is a tool for investors, governments, and other stakeholders to assess the market availability and cost competitiveness of these technologies over the next 10 years.



Source: Clean Edge, Inc., 2022[38]

Green Hydrogen and Green Fuels Power Heavy Industry

While the global electricity market is showing a remarkable shift to low-carbon energy, heavy industry has consistently lagged behind in carbon reduction goals. Intense energy and high heat demand in sectors like concrete, ammonia production, and steel have made these industries difficult to electrify. Green hydrogen and green fuels are likely pathways for decarbonizing heavy industry (though there are some companies also working on direct electrification solutions). Green hydrogen and green fuels are relatively nascent technologies but are gaining momentum and investment as more companies include these fuels in their carbon reduction goals.

While hydrogen is a clean-burning fuel (creating only water as a by-product), producing it can be a dirty process. Most hydrogen currently comes from fossil fuels, with 79% of hydrogen produced in 2020 coming from fossil fuel-powered (primarily natural gas) production plants. Almost all other hydrogen was produced as a by-product of refining gasoline. Only 0.03% of hydrogen in 2020 was produced through electrolysis[39]. To be considered "green hydrogen", this process must be powered through renewables. While production of green hydrogen is slated to ramp up dramatically, with 350 new electrolysis projects planned or underway worldwide, total expected production is only 5 million metric tons of hydrogen by 2030. To achieve net-zero goals, electrolyzers must ramp up to produce 50 times that amount – 250 million metric tons – annually by 2050, according to the IEA[39]. As solar and wind capacity continues to rise, hydrogen production can serve to store excess energy, particularly in the case of offshore wind farms.

The synergies between green hydrogen and other green fuels are numerous, with many of the same players seen in production of both. A common use case for hydrogen is ammonia production. Ammonia is used in a variety of processes, but around 80% of the annual 200 million tons produced annually goes into chemical fertilizers[40]. But ammonia is energy-dense, making it attractive as fuel for long-distance transportation such as shipping. Ammonia is composed of nitrogen and hydrogen, with green ammonia being produced from green hydrogen. Rising prices for natural gas are expected to make green ammonia more cost-effective, increasing demand[40]. Another green fuel alternative is renewably produced methane. Biogas and renewable natural gas (RNG), produced from anaerobic digestion of dairy and agricultural waste or through landfill capture (both forms of methane capture), are becoming more common. A growing number of established and emerging companies are already distributing RNG, primarily for use in heavy-duty trucking[40].

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 IRENA's 2019 "Future of Wind" report[41].

Offshore wind is receiving heightened interest from governments and utilities worldwide, and plans are underway to rapidly expand capacity. The world's largest offshore wind developer, Denmark-based Ørsted, installed its 1,000th offshore wind turbine in June 2021 at the Hornsea Two wind farm in the UK[42]. Going online in December 2021, Hornsea Two is the world's largest offshore wind farm with a capacity of 1.32 GW[43].

As part of its Green New Deal initiative, South Korea has plans to expand its offshore wind capacity to 12 GW by 2030, investing $7.7 billion by 2025[44]. In the U.S., the Biden administration has announced a goal of 30 GW of offshore wind capacity to be installed by 2030. The Department of Energy and the White House are working jointly on this endeavor, but more than $10 million of research funding comes from industry[45]. Since this initiative was announced in 2021, governors from East Coast states have made commitments to procure almost 40 GW of offshore wind capacity as part of a Federal-State Offshore Wind Implementation Partnership[46].

Offshore wind provides clean energy, but the installations also provide a foothold for other technologies. Off the coast of a Belgian island, Dutch utility Eneco's 370 MW Norther wind farm is combining offshore wind with aquaculture, powering the cultivation of seaweed for human and animal food, biofuels, and bioplastics[47]. Project operators hope to develop this technology for use at other farms. As multi-use projects like Norther 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[48].

A 7-Point Energy Transition Action Plan

We estimate that the world is approximately halfway through the modern energy transition (2000—2050). If companies, governments, and individuals are going to meet their net-zero and carbon-reduction targets by mid-century, then how and where we focus our collective actions will matter. Targeted technology, policy, and capital innovations must be deployed *at scale* to meet the challenges of this monumental shift. We offer up Clean Edge's 7-Point Energy Transition Action Plan as one possible pathway to ensure the viability and success of the clean-energy transition.

1. FOCUS ON EFFICIENCY FIRST

Pursue energy efficiency's low-hanging fruit for the most bang-for-your-buck, including LEDs, insulation materials, building controls, and energy management systems.

2. SCALE UP WIND & SOLAR MASSIVELY

Support aggressive global deployment of solar and wind power, utility scale and distributed, to reach 100% zero-carbon emission electric grids.

3. PAIR RENEWABLES WITH STORAGE AT SCALE

Deploy storage at scale to enable 100%, 24/7 renewable power. Focus on both utility-scale and distributed storage, using electrochemical batteries (lithium-ion, solid-state, flow, etc.) and mechanical energy storage (pumped hydro, compressed air, etc.).

4. ELECTRIFY HEATING & VEHICLES ASAP

Although we often hear the demand to "electrify everything," we recommend focusing on two high-impact areas: passenger vehicles (two-, three-, and four-wheelers) and heating and cooling systems for homes and buildings (via adoption of electric heat pumps).

5. MODERNIZE TRANSMISSION & DISTRIBUTION GRIDS

Build out a range of electricity grid modernization efforts including digitization, smart meters and devices, bi-directional meters and charging, smart substations, and high-voltage, direct current transmission lines. A modern 21st century grid is critical to enable the clean-energy transition.

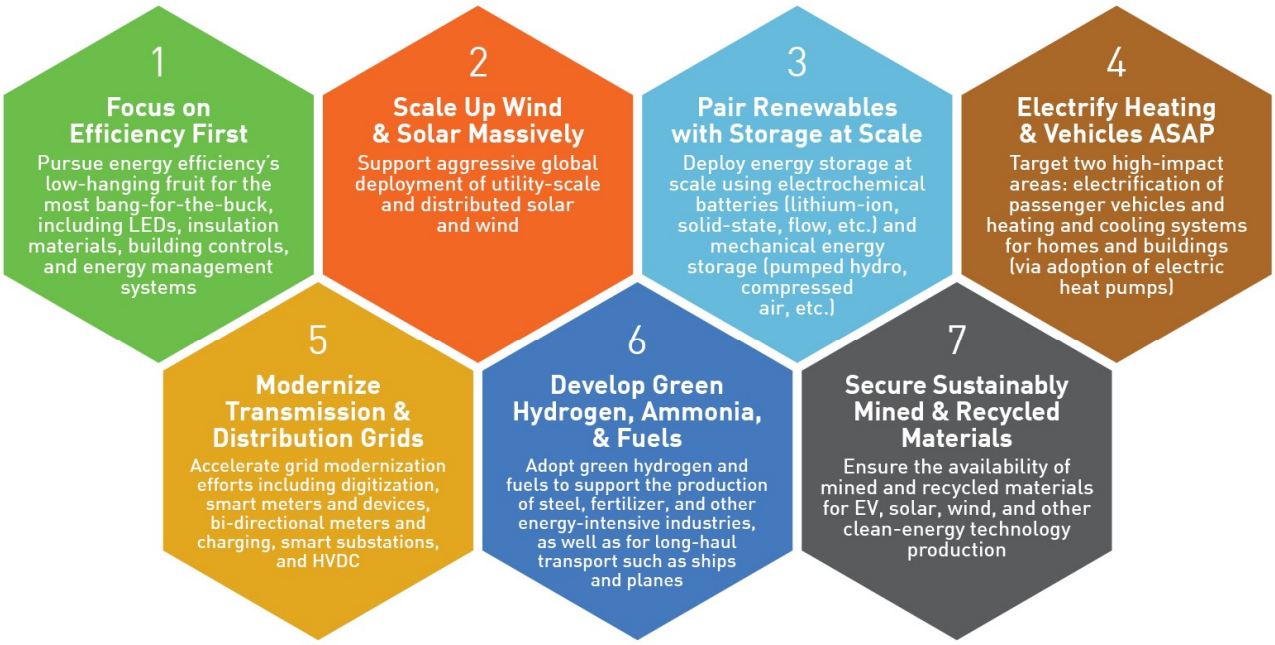
6. DEVELOP GREEN HYDROGEN, AMMONIA, AND FUELS

Decarbonizing heavy industry will not be easy and will require green fuels above and beyond electrification. We recommend the adoption of green hydrogen and fuels to support the production of steel, fertilizer, and other energy-intensive industries, as well as for long-haul transport such as trucking, marine shipping, and air travel.

7. SECURE SUSTAINABLY MINED AND RECYCLED MATERIALS

Ensure the availability of mined and recycled materials for EV, solar, wind, and other clean-energy technology production. The future of energy depends on secure and reliable supplies of sustainably mined or recycled materials (lithium, rare earths, silicon, nickel, etc.) rather than the extraction of fossil fuels (coal, oil, gas).

The Clean Edge 7-Point Energy Transition Action Plan



Source: Clean Edge, Inc., 2022[49]

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. It is reconstituted semi-annually in March and September and is rebalanced quarterly in March, June, September, and December. The index began on November 17, 2006, at a base value of 250.00. As of July 29, 2022, the index had 65 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),
3. First Trust Nasdaq Clean Edge Green Energy ETF (Toronto: QCLN), and
4. Samsung KODEX US Clean Energy Nasdaq ETF (South Korea: 419420)

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.).
- A security must also have a demonstrated ability to capture the potential of the clean-energy sector by receiving a majority (50% or more) of its revenue from clean-energy and low-carbon activities, or, in the case where a constituent has multiple business units and revenue streams, have substantial exposure to the clean-energy and low-carbon sector, as determined by Clean Edge.

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.

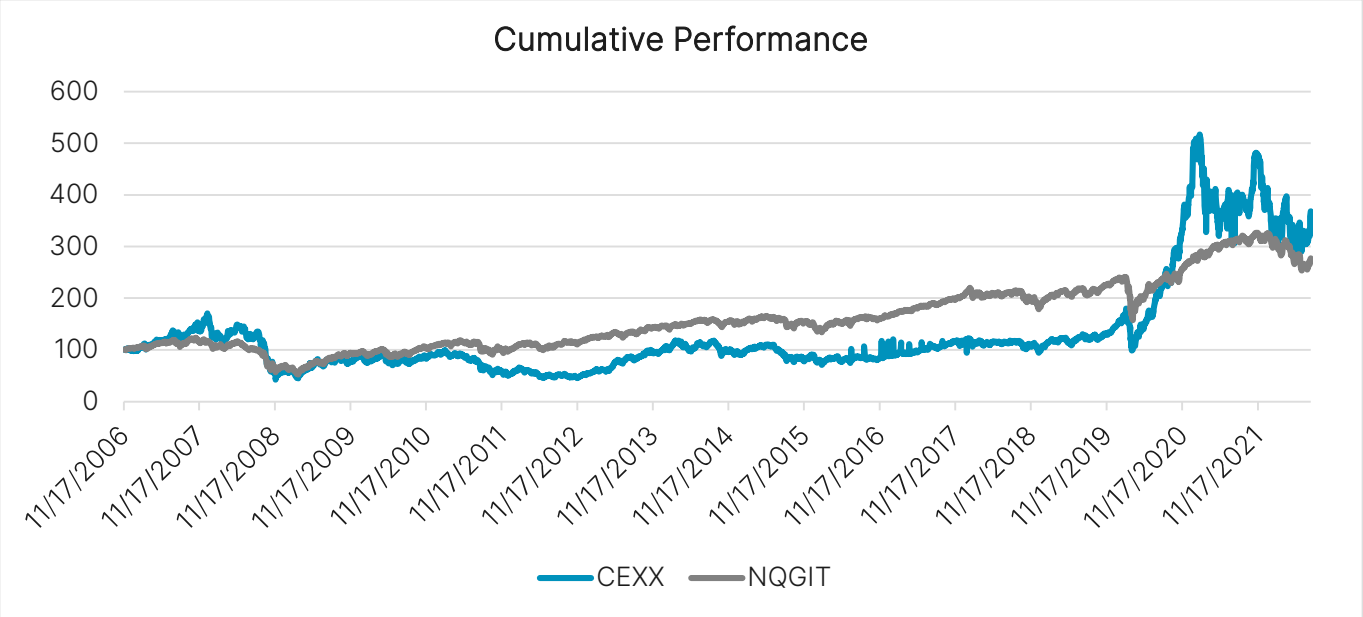
For complete eligibility criteria, please visit the index methodology.

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 268.24%, with an annualized return of 8.57% and an annualized volatility of 34.84%. 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 177.41%, with an annualized return of 6.58% and an annualized volatility of 16.86% over the same time period.

Cumulative performance



Data from 11/17/2006 – 7/29/2022. Source: Nasdaq.

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

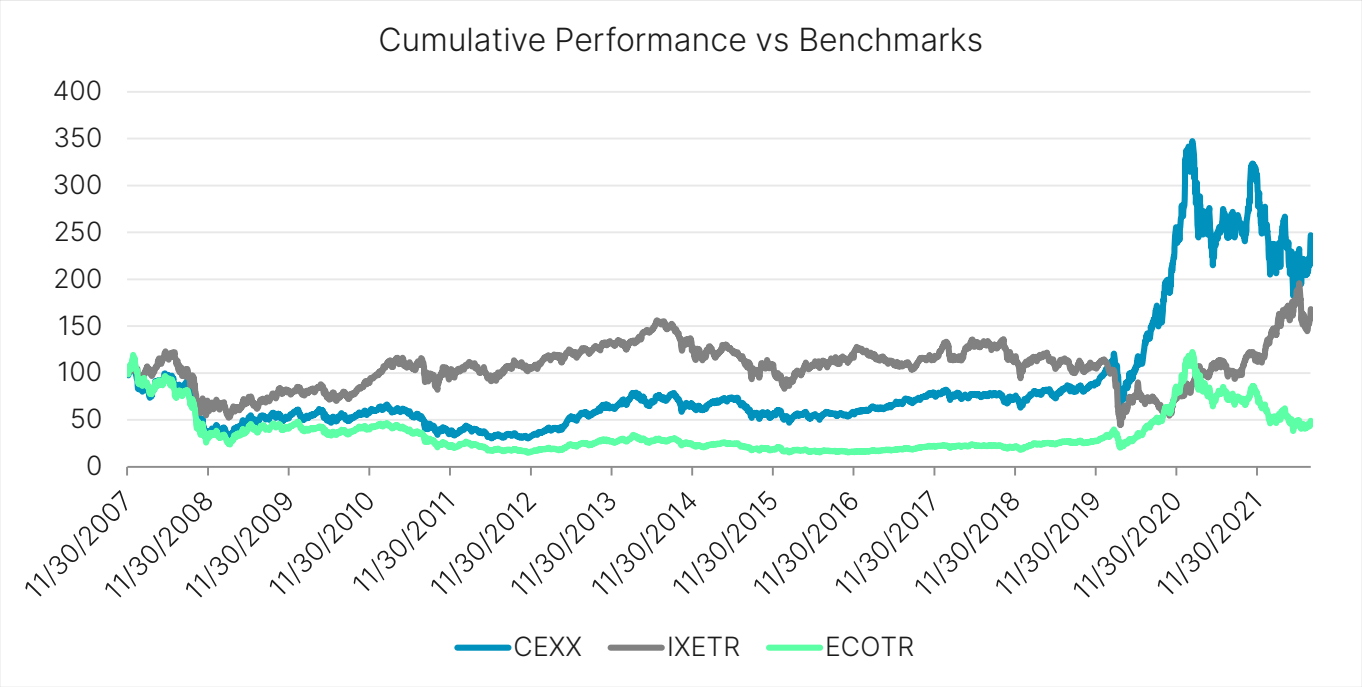
Let's start by looking at cumulative returns by comparing the Nasdaq Clean Edge Green Energy Total Return Index (CEXX) to a competitor clean energy index [Wilderhill Clean Energy Index TR (ECOTR)] as well as a traditional energy index [S&P 500 Energy Select Sector Total Return Index TR (IXETR)].

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, one can see it's apparent that CEXX had a real run between 2020 and 2021 and has pulled back over the last 12 months. For those following the clean energy space, it shouldn't be a 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, the last few years have 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 44% YTD return in 2022, CEXX has fallen just -8%, outperforming ECOTR by 14.02%.

Index	Cumulative Return	Annualized Return	Annualized Volatility
CEXX	147.27%	6.36%	35.34%
ECOTR	-49.40%	-4.54%	37.06%
IXETR	68.48%	3.62%	32.25%

Data from 11/30/2007-7/29/2022. Source: Nasdaq, Bloomberg.

Cumulative performance vs competitors



Data from 11/30/2007-7/29/2022. 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%

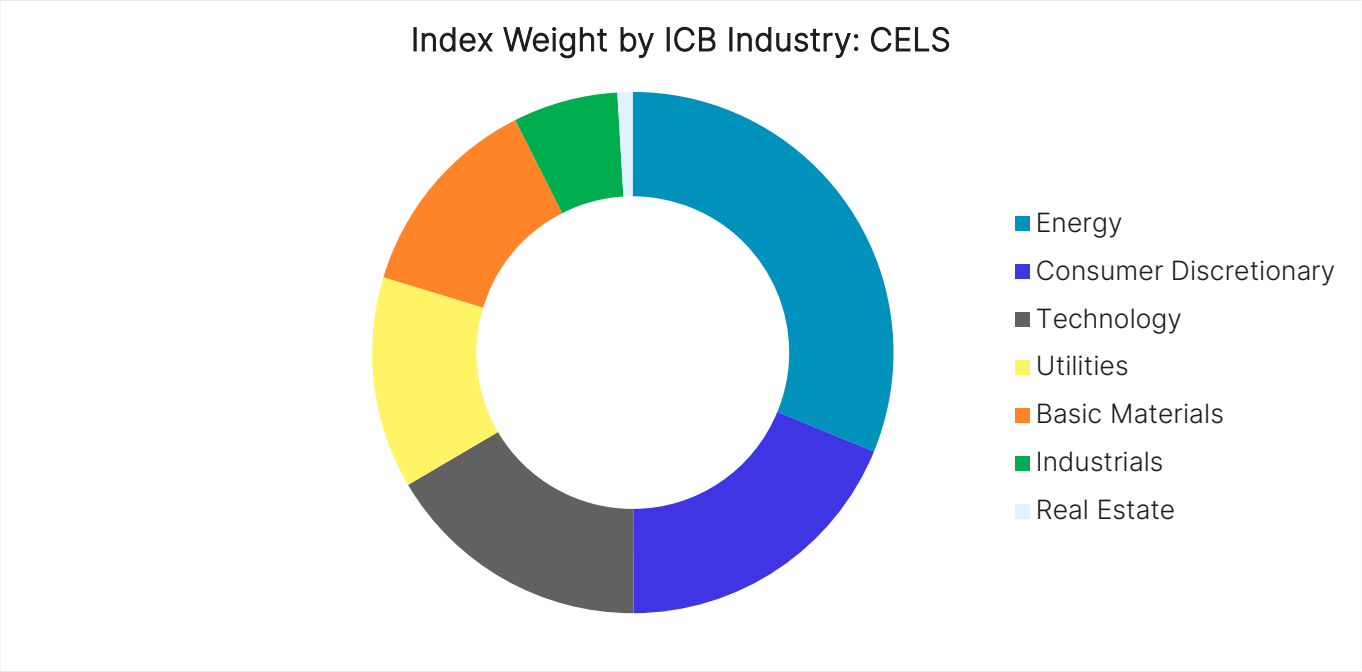
2019	42.66%	59.31%	12.09%
2020	184.83%	203.78%	-32.84%
2021	-2.64%	-30.21%	53.43%
YTD 2022*	-8.17%	-22.19%	44.32%

*Data from 11/30/2007-7/29/2022. Source: Nasdaq, Bloomberg.

CELS ICB Industry Allocations (%)

The index is currently allocated to seven of the 11 industries, with the largest weights across Energy (31.20%), Consumer Discretionary (18.75%), and Technology (16.58%).

ICB Industry	Weight (%)
Energy	31.20
Consumer Discretionary	18.75
Technology	16.58
Utilities	13.13
Basic Materials	12.89
Industrials	6.49
Real Estate	0.95



Data as of 7/29/22. Source: Nasdaq.

Top 10 Constituents

Name	Weight (%)	ICB Industry

Enphase Energy, Inc.	10.88	Energy
Tesla, Inc.	8.38	Consumer Discretionary
ON Semiconductor Corporation	7.85	Technology
NIO Inc. Sponsored ADR Class A	7.45	Consumer Discretionary
Albemarle Corp	6.69	Basic Materials
SolarEdge Technologies, Inc.	4.71	Energy
Plug Power, Inc.	3.61	Energy
First Solar, Inc.	3.09	Energy
Brookfield Renewable Partner	3.04	Utilities
Wolfspeed Inc.	3.01	Technology

Data as of 7/29/22. 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; connected mobility; and enabling software used by the smart grid and electric infrastructure sector (including both pure play companies focused on the smart grid sector and diversified multinationals with smart grid sector exposure). It is reconstituted semi-annually in March and September and is rebalanced quarterly in March, June, September, and December. The index began on September 22, 2009, at a base value of 250.00. As of July 29, 2022, the index had 78 components. Investors can gain exposure to the index through the corresponding ETFs:

1. First Trust Nasdaq Clean Edge Smart Grid Infrastructure Index Fund (Nasdaq: GRID)
2. First Trust Nasdaq Clean Edge Smart Grid Infrastructure UCITS ETF (London: GRID)

Eligibility Criteria

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

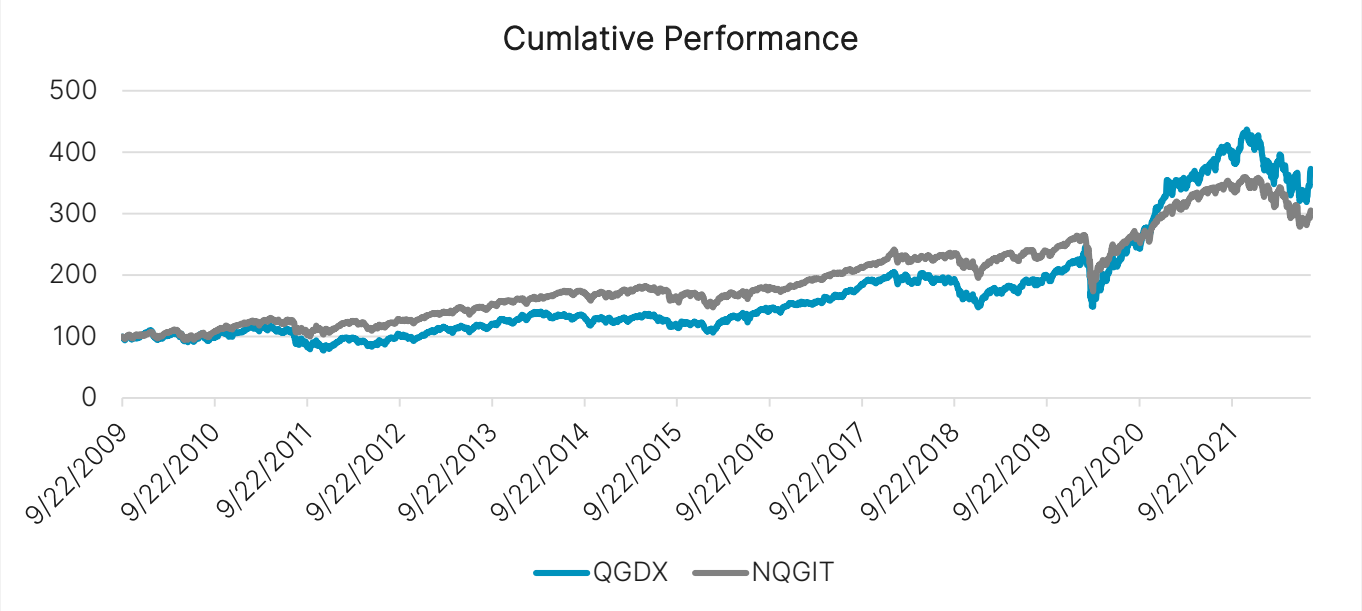
- Be classified as a smart grid, electric infrastructure, EV network, smart building, software, and/or other grid-related activities company according to Clean Edge;
- Be listed on an index-eligible global stock exchange;
- Have a minimum worldwide market capitalization of $100 million;
- Have a minimum 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 273.05%, with an annualized return of 10.52% and an annualized volatility of 20.51%. The Nasdaq Global Total Return Index (NQGIT) generated a cumulative return of 204.85%, with an annualized return of 8.81% and an annualized volatility of 14.66% 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. Since 2019, QGDX has had very strong returns and on average, has outperformed NQGIT by 16%.

Cumulative performance



Data from 9/21/2009 – 7/29/2022. 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%

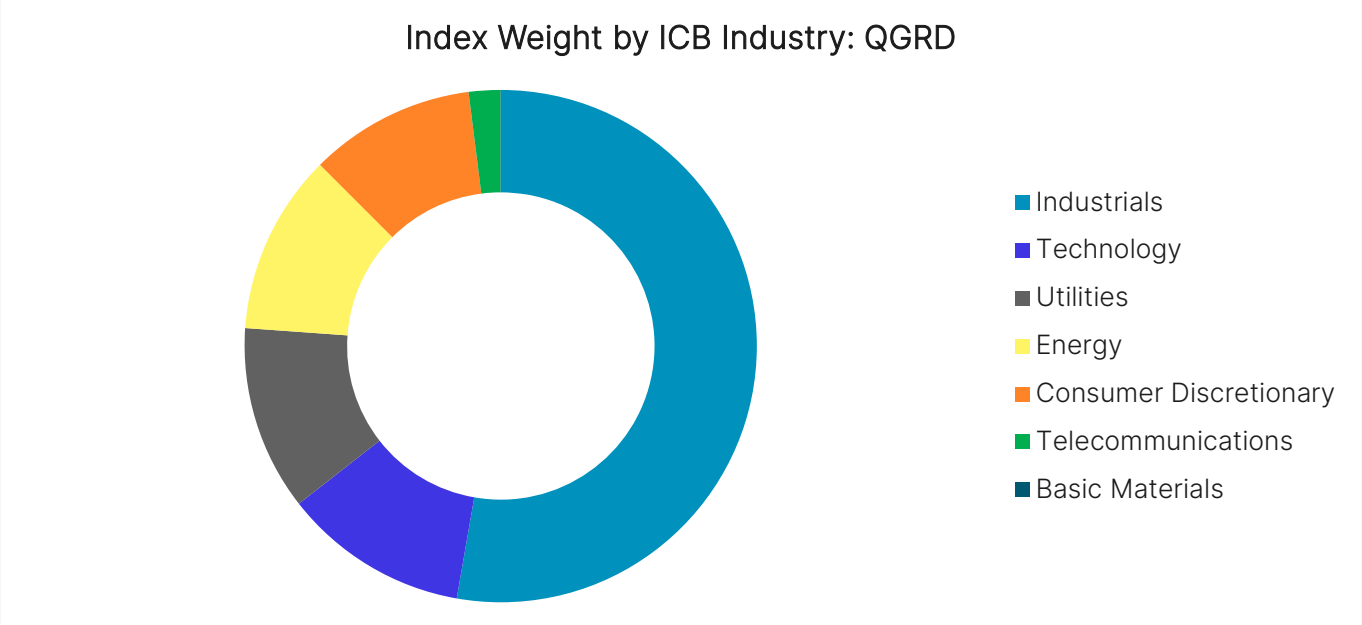
2019	43.90%	26.58%
2020	49.84%	16.28%
2021	29.34%	18.64%
2022	-12.19%	-14.39%

Data from 9/21/2009 – 7/29/2022. Source: Nasdaq.

QGRD ICB Industry Allocations (%)

The index currently allocates to seven of the 11 industries, with the largest weights across Industrials (52.76%), Technology (11.70%), and Utilities (11.67%).

ICB Industry	Weight (%)
Industrials	52.76
Technology	11.70
Utilities	11.67
Energy	11.40
Consumer Discretionary	10.46
Telecommunications	2.00
Basic Materials	0.02



Data as of 7/29/22. Source: Nasdaq.

Top 10 Constituents

Name	Weight (%)	ICB Industry
Eaton Corp.	8.29	Industrials
Schneider Electric SE	7.68	Industrials
Johnson Controls International	7.66	Industrials
Aptiv PLC	7.65	Consumer Discretionary
ABB Ltd.	7.63	Industrials
Enphase Energy Inc.	5.91	Energy
SolarEdge Technologies, Inc.	5.11	Energy
Quanta Services Inc.	4.51	Industrials
Samsung SDI Co.	3.65	Technology
Terna S.p.A.	3.49	Utilities

Data as of 7/29/22. 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). It is reconstituted and rebalanced semi-annually in March and September. The Index was launched on December 16, 2005, at a base value of 100.00. As of July 29, 2022, the index had 52 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%.

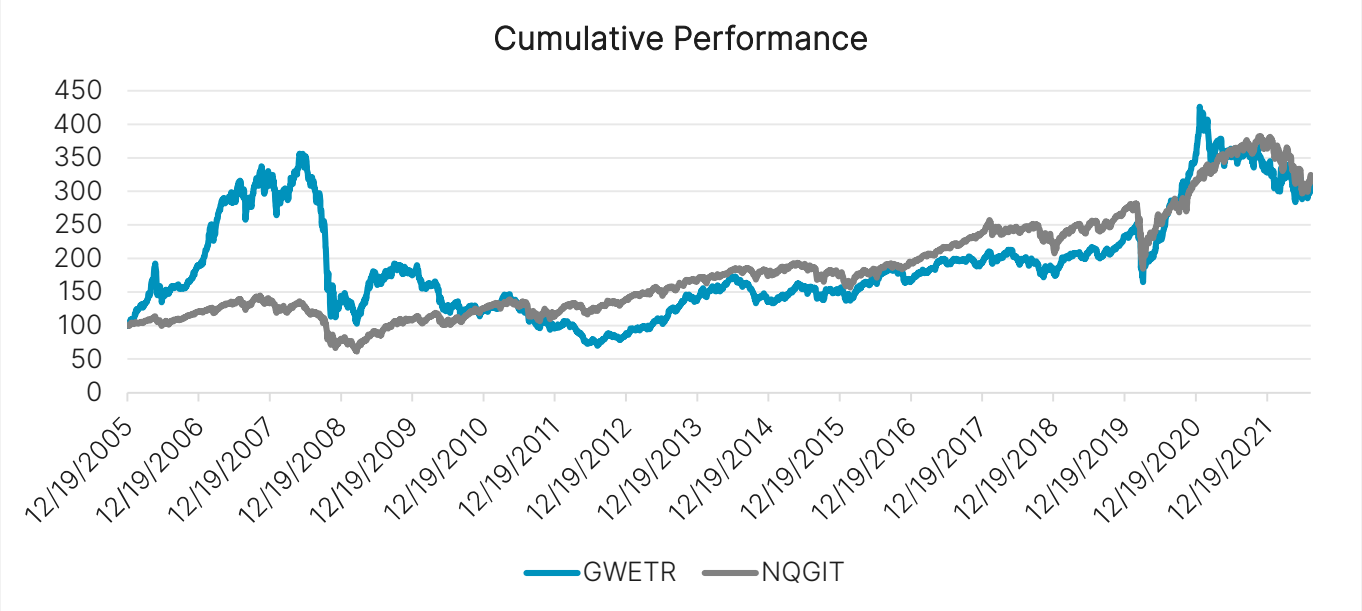
For complete eligibility criteria, please visit the index methodology.

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 213.78%, with an annualized return of 7.12%

and an annualized volatility of 22.97%. The Nasdaq Global Total Return Index (NQGIT) generated a cumulative return of 224.55%, with an annualized return of 7.19% and an annualized volatility of 16.57% over the same time period. From the GWETR low-point (on a cumulative basis since inception that occurred) on July 25, 2012, through July 29, 2022, GWETR had a cumulative return of 348%, more than double the 167% of NQGIT.

Cumulative performance

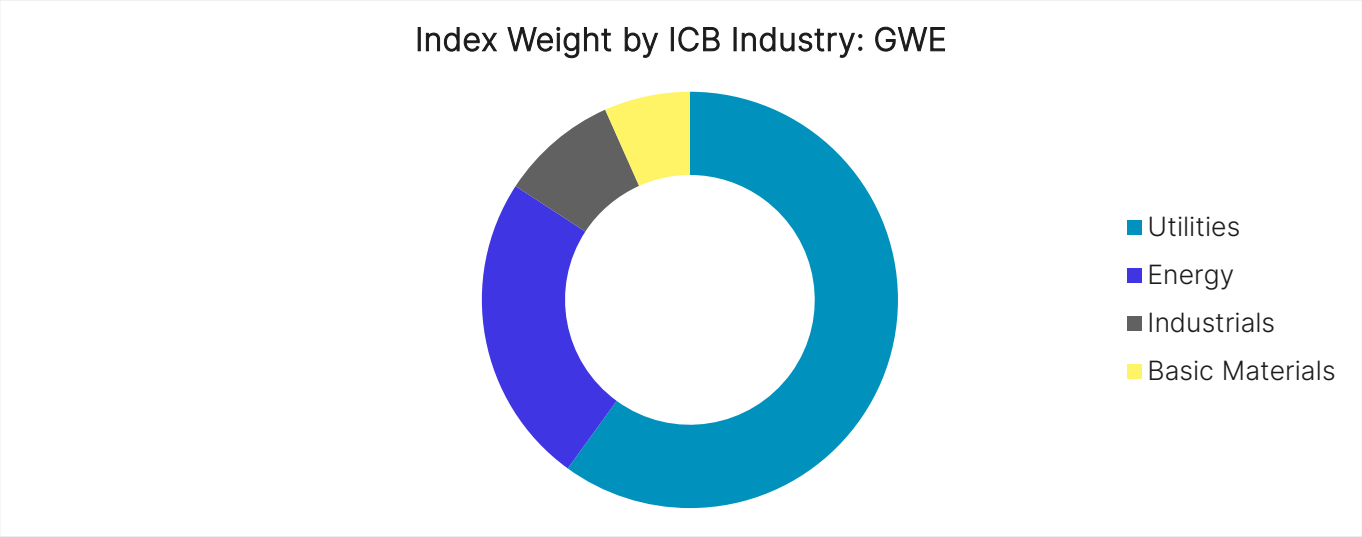


Data from 12/16/2005 – 7/29/2022. Source: Nasdaq.

GWE ICB Industry Allocations (%)

The index currently allocates to four of the 11 industries, with the largest weights across Utilities (59.98%), Energy (24.22%), and Industrials (9.13%).

ICB Industry	Weight (%)
Utilities	59.98
Energy	24.22
Industrials	9.13
Basic Materials	6.67



Data as of 7/29/22. Source: Nasdaq.

Top 10 Constituents

Name	Weight (%)	ICB Industry
Northland Power	7.89	Utilities
Orsted	7.78	Utilities
EDP Renovaveis Br	7.06	Utilities
Vestas Wind	6.90	Energy
CN Longhuan Power	5.79	Energy
Boralex Inc. Class A	3.89	Utilities
Siemens Gamesa Renewable Energy, S.A.	3.43	Energy
Innergex Renewab Rg	3.39	Utilities
Duke Energy	2.39	Utilities
Nextera Energy	2.36	Utilities

Data as of 7/29/22. 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 halfway through 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:

- Continued lower costs. 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

- Globally, national governments are responding to the threats of climate change and energy security by signing commitments to reduce their carbon emissions. In the U.S., the federal government's recently passed Inflation Reduction Act of 2022 (also known as the Senate Climate Bill), authorizes an unprecedented $369 billion to pump up investment in the solar, wind, geothermal, and battery industries while providing consumer-level incentives for EVs and heat pumps. The goal of the bill is to help meet the Biden administration's emissions reduction targets (halving 2005 levels by 2030)
- 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
- Green hydrogen and green fuels are relatively nascent technologies but are gaining momentum and investment as more companies include these fuels in their carbon reduction goals
- Offshore wind is receiving heightened interest from governments and utilities worldwide, and plans are underway to rapidly expand capacity. 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

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),
- Samsung KODEX US Clean Energy Nasdaq ETF (South Korea: 419420) (Index: CELS),
- First Trust Nasdaq Clean Edge Smart Grid Infrastructure Index Fund (Nasdaq: GRID) (Index: QGRD),
- First Trust Nasdaq Clean Edge Smart Grid Infrastructure UCITS ETF (London: GRID) (Index: QGRD), and
- First Trust ISE Clean Edge Global Wind Energy Index Fund (NYSE: FAN) (Index: GWE).

Sources: Nasdaq Global Indexes, Bloomberg, FactSet.

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