# EVs

Ecosystem, Outlook and Opportunity

*January 2022 Report*

**C2C: CHAOS TO CONFIDENCE**

*BPI Research, Consulting and Keynotes*

ANDREW BUSCH

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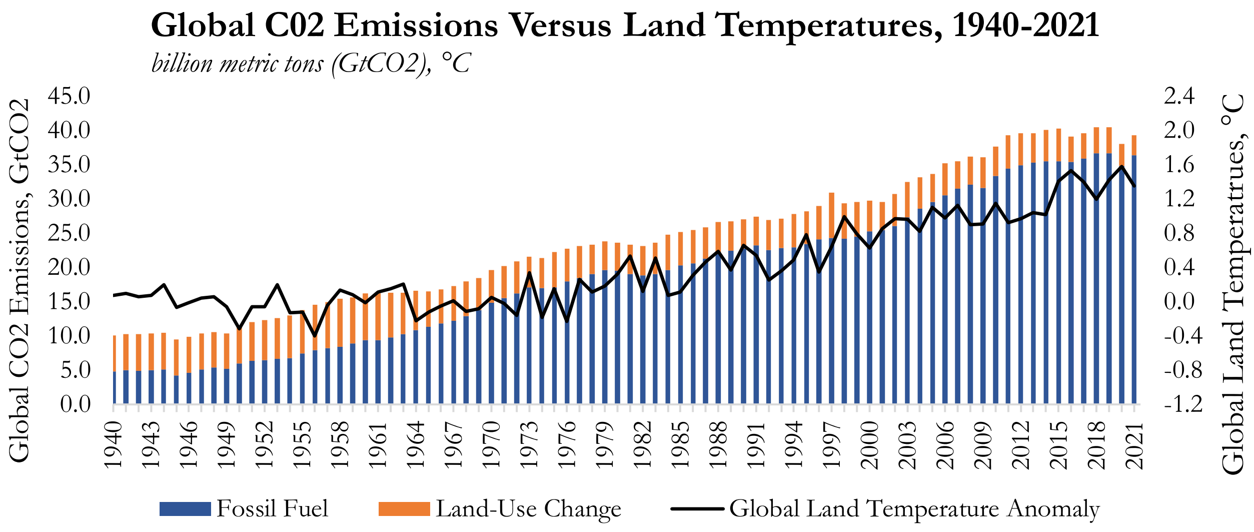
## Introduction

Over the last 200 years, the global economy has continued to evolve. From the introduction of the steam engine to electricity and now computers, new technology has changed the way we work, live, and communicate. Today, we stand on the cusp of a whole new technological shift that will bring about ground shifting societal changes in the coming decades. One of these will be linked to how we approach retooling and redesigning our economy to reduce greenhouse gas emissions. The use of fossil fuels such as oil, coal, and natural gas has brought about a significant expansion of wealth for the average human, with many more gains projected over the next 30 years. This growth does however come with a price. As a byproduct of burning these fuels, we release greenhouse gasses, most commonly CO2 and Methane. These gasses reduce the amount of the sun's heat that escapes from the atmosphere after bouncing off the surface of the earth. Over a long period, this has led to an increase in average global temperatures.

With the rise in global temperatures, new challenges have reared their head including increased extreme weather, more difficulty in agriculture, and desecration of natural habitats. To combat this, greenhouse gas emissions must be reduced, pulled out of the atmosphere or a combination of both. Many are citing the global need to have emissions at Net-Zero, where any further emission is offset through capture technology. Such a change will require a significant investment into new technologies and infrastructure. In this report, we detail some of the basic categories of growth within this trend. These include Electric Vehicles, Autonomous Vehicles, Battery Technology, Solar Energy, Hydrogen Power, as well as the changes in the Electric Grid. Lastly, we will examine current investment products that seek to take advantage of these coming changes.

This report is not meant to be exhaustive, but to act as a guide to understanding the rapid changes occurring within this exciting ecosystem. Please enjoy.

## Summary of Emissions

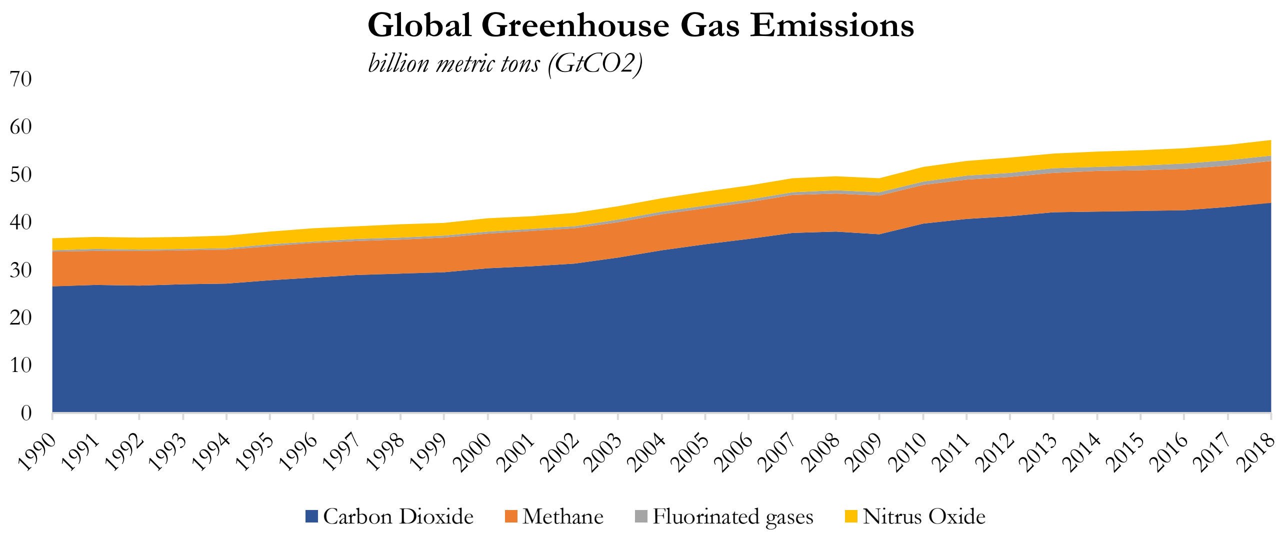



Source: Carbon Budget Project (2021) and National Oceanic and Atmospheric Administration (January 2022).

The graph above shows the evolution of historical global CO2 emissions and land temperatures. Carbon dioxide emissions have been steadily increasing since 1940 to peak in 2018 and 2019 at around 40.5 gigatons, of which 36.7 were from fossil fuel. Almost 10% of CO2 emissions were the result of land-use change and deforestation. In 2020, emissions dropped by around 6.2% to reach 38 gigatons. This reduction was a result of the slowdown in global economic activity brought about by the COVID-19 pandemic. Nevertheless, emissions rebounded in 2021 to reach almost 39.4 gigatons, almost at the 2017 level. With such a rise in emissions, global land temperature anomalies (from the 20th century average) have risen sharply to reach 1.5°C in 2020, despite a slight drop to 1.35°C in 2021.

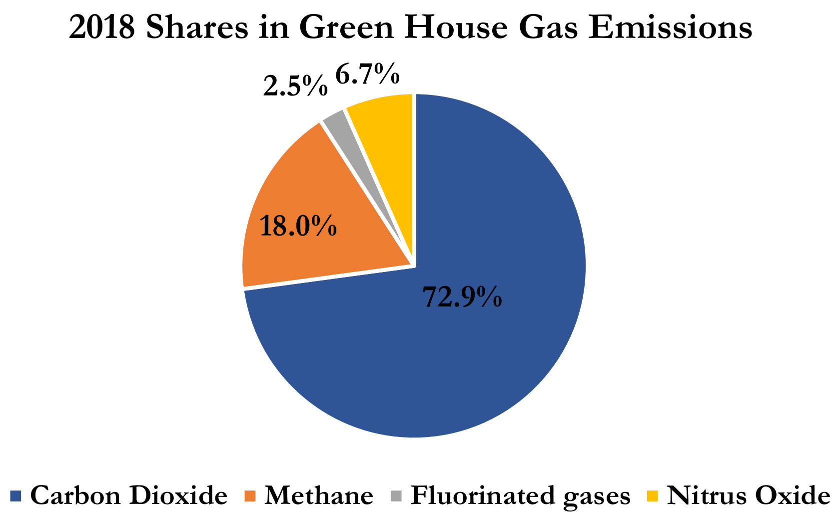
## Greenhouse Gas (GHG) Emissions

As seen in the chart below, global greenhouse gasses emitted by human activity have increased sharply over the past thirty years. GHG emissions have increased by almost 53% from 1990, reaching a total of 59.3 gigatons in 2018. There are mainly four sources of GHG emissions, carbon dioxide, methane, nitrous oxide, and fluorinated gasses. The primary source of CO2 emissions is the burning of fossil fuels. Land-use change and deforestation also contribute to CO2 emission, though to a lesser extent. Methane is produced through agricultural practices, waste management, and the use of energy. When it comes to Nitrous oxide, the use of fertilizers is the main source of emissions. Fluorinated gasses, on the other hand, are produced through industrial processes like refrigeration, and the use of consumer products such as hydrofluorocarbons and perfluorocarbons.



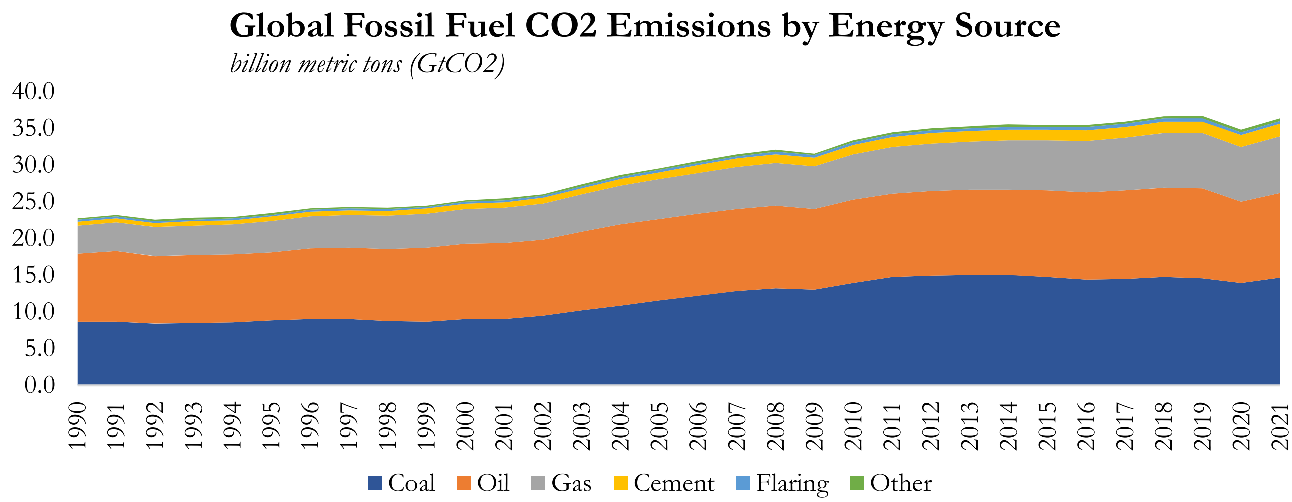

Source: Climate Watch, GHG Emissions Data

CO2 and methane gasses are the main driving factors behind global warming and climate change. As of 2018, the share of CO2 in total GHG emissions was 73%, making it the most predominant source. Methane accounted for 18%, followed by nitrous oxide, which constituted 7%.



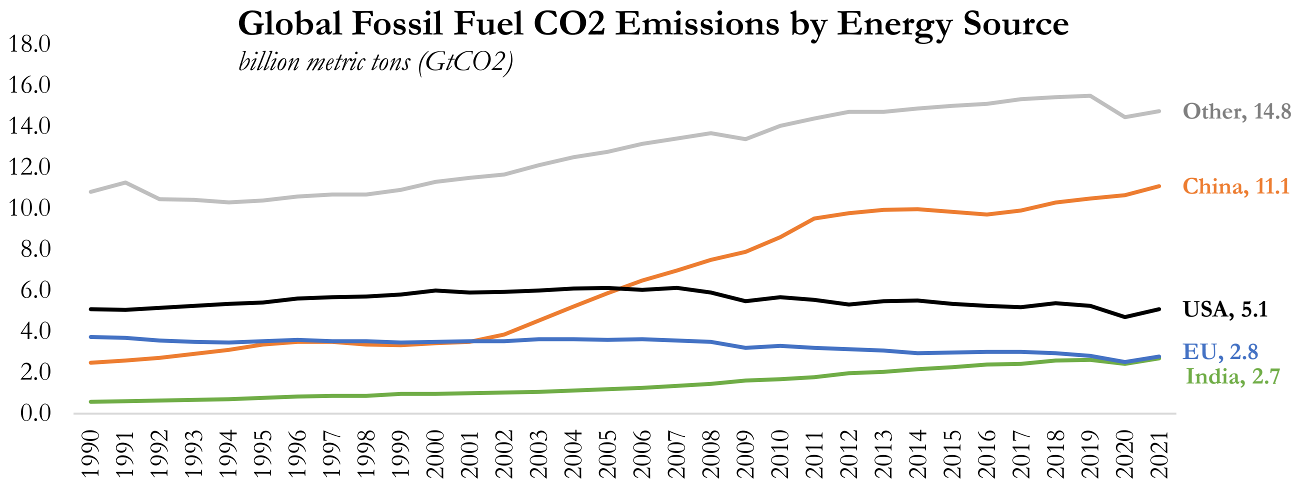

## CO2 Emissions

As seen in the chart below, fossil fuel carbon dioxide emissions have risen sharply over the past three decades. This increase has mainly been driven by the use of coal, oil, and gas for energy generation. In 1990, total annual emissions amounted to 22.7 gigatons of carbon dioxide, of which 38% were from coal, 41% from oil, and 17% from gas. Together, cement, flaring, and other sources accounted for no more than 7%. In 2021, fossil fuel CO2 emissions ballooned to 36.4 gigatons, almost 1.6 times the 1990 level. Coal still accounted for almost 40%, oil for 32%, and gas for 21%.




Source: Carbon Budget Project (2021)

This rise in emissions has been primarily due to the rise in incomes in developing countries as they transitioned from inefficient wood and biofuels predominantly used for cooking to oil, coal, and gas for electricity generation. The largest of these contributors is China which increased its carbon dioxide emissions from 2.5 gigatons in 1990 to 11.1 gigatons in 2021. This represents a CAGR of around 5% during this period. This differs from the United States whose emissions remained stable as it increased from 5.1 gigatons in 1990 to 5.4 gigatons in 2018, just to revert to 5.1 gigatons in 2021. Quite simply, the biggest driver of this stability is the adoption of natural gas-fired power plants versus coal. In fact, China accelerated to such a degree that in 2006 it surpassed the United States to become the highest individual emitter.

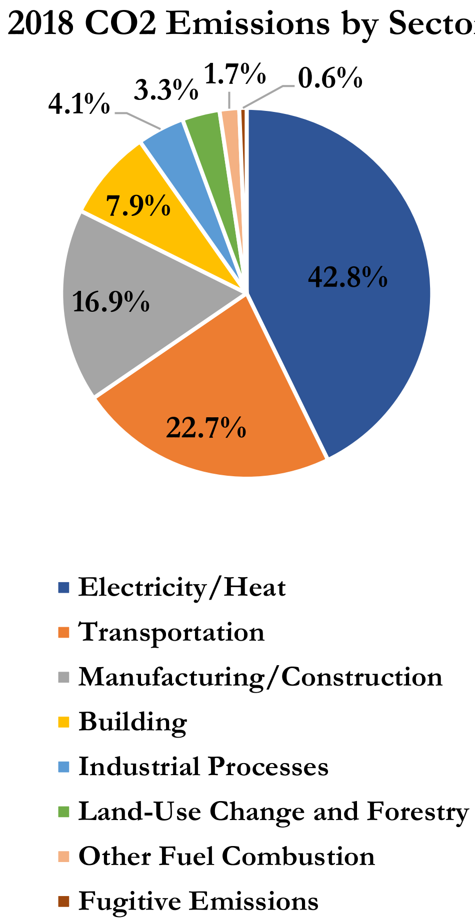



Source: Carbon Budget Project (2021)

Carbon Dioxide Emissions are the most common form of Greenhouse Gas emissions. It is released whenever a hydrocarbon undergoes a combustion reaction. This reaction introduces oxygen into long chemical chains of hydrogen and carbon. The oxygen introduced allows these long chains to break apart which releases a significant amount of energy. The byproducts of this reaction are water (H2O) and carbon dioxide (CO2). The most common forms of these hydrocarbons are through fossil fuels in the form of coal, natural gas, and oil, as well as their derivatives. These fuels have allowed for significant development of the economy due to their high-energy density, but they have permanently altered the global climate.

These fuels are used for a variety of purposes but are primarily used in electricity/heat generation as well as transportation. These two categories made up about 65% of emissions in 2018. Additionally, development and manufacturing processes contribute another 25% of annual emissions. According to the most recent data from the International Energy Agency, sectoral shares were very similar in 2019, as together, electricity/heat and transport accounted for around 66%.

To reduce annual emissions, many of these processes will have to be altered or completely replaced with alternatives. Failure to do so will likely lead to further rises in global temperatures.




Source: Climate Watch, GHG emissions data.

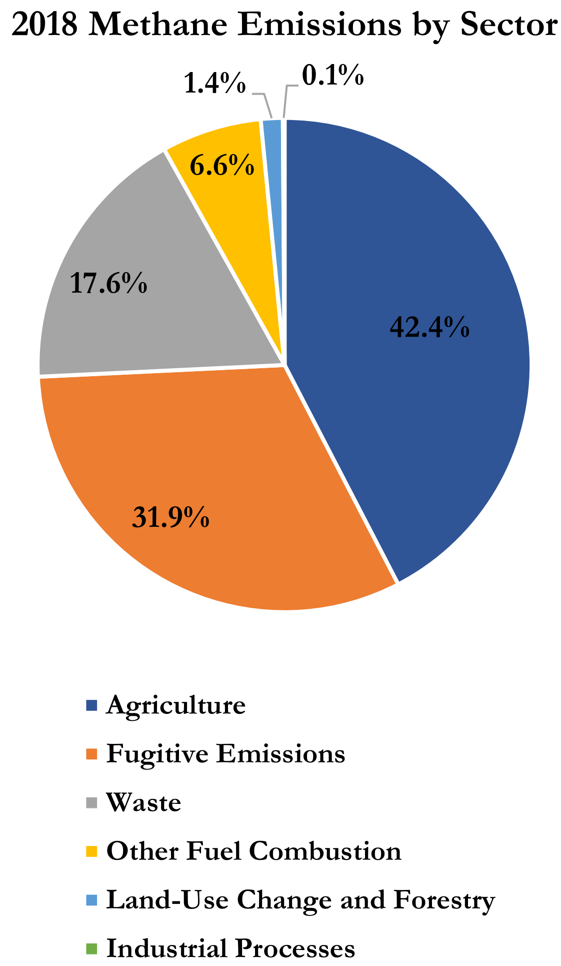
| Sector | % Of CO2 Emissions | Description |
|---|---|---|
| Electricity/Heat | 42.8% | Includes any emissions relating to the generation of electricity or heat. Main power sources include natural gas and coal. |

| | | |
|---|---|---|
| Transportation | 22.7% | Includes any vehicle-related emissions including cars, vans, trains, and airplanes. Main power sources include gasoline, diesel, and jet fuel. |
| Manufacturing/Construction | 16.9% | Relating to the production of wood, metal, and food products. |
| Building | 7.9% | Creation of structures and building. |
| Industrial Processes | 4.1% | Primarily related to the creation of cement. |
| Land-Use Change and Forestry | 3.3% | Removal of carbon sinks such as forests, cropland, and grasslands. |
| Other | 2.3% | Other emissions |

## Methane Emissions

Although similar to CO2 in that they are both greenhouse gasses that contribute to climate change, Methane has a much different profile when it comes to its sources. These are primarily from Agriculture which represents about 42% of global Methane emissions, Fugitive Emissions which represents about 32% of Methane emissions, and emissions from Waste which contain about 18% of Methane emissions. Although Methane is less prevalent than CO2 in terms of how much of it is released into the atmosphere, it has a much larger warming effect compared to CO2 on a ton for ton basis. Over a 100-year period, the EPA found that Methane has about a 25 times greater effect than CO2. This effect is particularly pronounced in the period after Methane is released since much of its warming effect over 100 years is near the beginning. The good news is that Methane lasts in the atmosphere only 13-15 years versus 250-300 years for CO2.

Although some of these emissions may be able to be reduced through the introduction of new technology to reduce fugitive emissions as well as new technologies to process waste more effectively, as the global population grows wealthier, sources such as agriculture are expected to expand as new meat production rises to meet the demand.



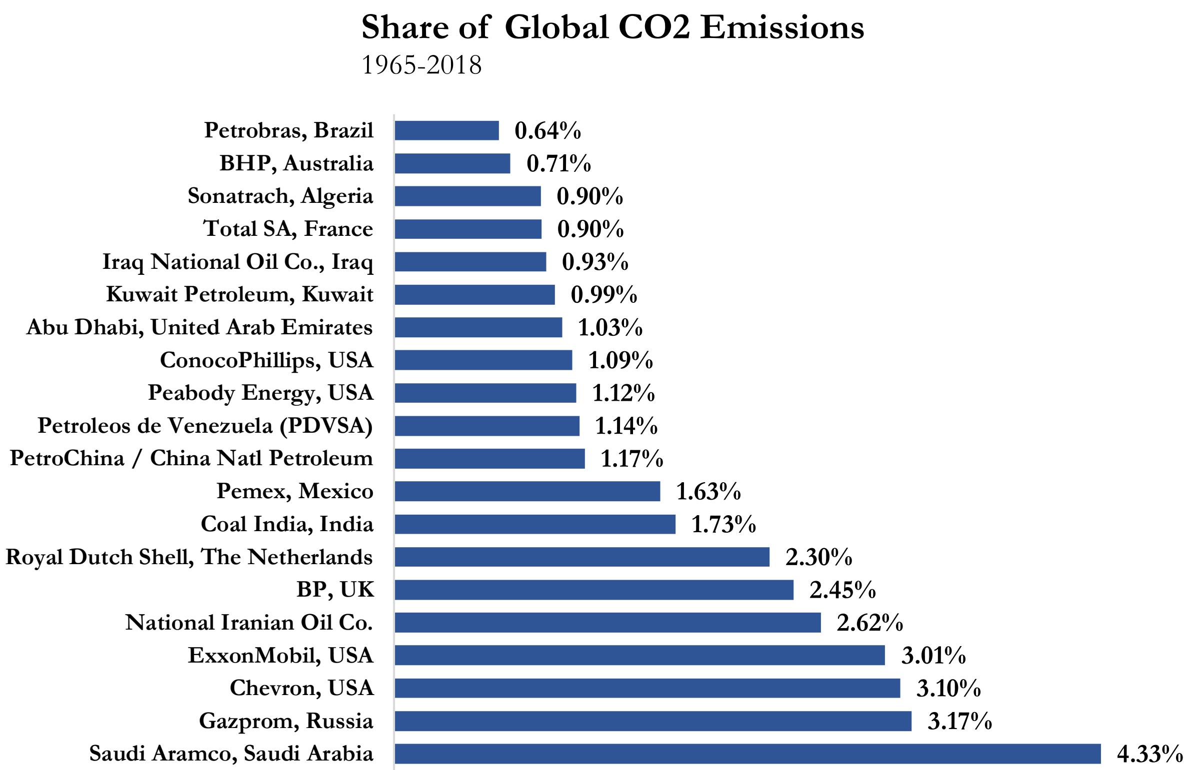

Source: Climate Watch, GHG emissions data.

| Sector | % Of Methane Emissions | Description |
|---|---|---|

| | | |
|---|---|---|
| Agriculture | 42.4% | Predominantly methane produced by aerobic and anaerobic decomposition processes in crop and livestock production. |
| Fugitive Emission | 31.9% | Related to the emissions from activities surrounding Natural Gas & Oil Systems and Coal Mining. |
| Waste | 17.6% | Emissions from wastewater treatment and landfills. |
| Other | 8.1% | Other Emissions |

## Emissions by Company

The latest data from the Climate Accountability Institute shows that only 20 companies were responsible for 35% of global CO2 emissions between 1965 and 2018. At the top came the Saudi Arabian Aramco, Russian Gazprom, USA Chevron, Exxon Mobil, and Iranian Oil Co., accounting for 4.3%, 3.17%, 3.1%, 3.0%, and 2.6% respectively. Together, those companies have contributed to a total of 493 gigatons of carbon emissions since 1965.




Source: Climate Accountability Institute Data.

An earlier report by the same institute has shown that since 1998, 100 companies were responsible for almost 71% of global GHG emissions and only 25 companies were responsible for over half of the emissions. Almost 32% of those companies are publicly owned. This finding is interesting as it points out several conclusions. First, the petroleum industry is primarily responsible for the recent rise in GHG emissions. Second, we can expect climate change activists to focus on these companies to create pressure and change to their policies. Third, investors can also effect change by directing allocation to ESG investment vehicles; reducing exposure to CO2/GH emitting industries and companies; and taking an active role in board selection of the publicly traded companies to shift corporate policy towards environmental policies aligned with GHG reduction.

# Electric Vehicles (EVs)

## Introduction to EVs

Electric Vehicles (EVs) are predominantly defined as any vehicle which does not solely utilize combustion as its source of energy to propel the vehicle forward as internal combustion engine models do (ICEs). However, there are different degrees to EVs. The closest to the traditional gas car are Hybrid Electric Vehicles (HEVs) which utilize mostly gas but have some electronic components, most notably regenerative braking. Regenerative braking is when the vehicle can use some of the kinetic energy of the vehicle to charge a battery as it slows down during the braking process. Popular models include the Honda Civic Hybrid, Toyota Camry Hybrid, and Toyota Prius Hybrid. The next level up is the Plug-in Hybrid Electric Vehicle (PHEV) which runs on both electricity and gas. Its main distinguishing factor is that it can be plugged into an electricity source to charge the batteries in the car which are used to power an electric motor. Once the battery is exhausted, it can be restored through either regenerative braking, the combustion engine, or an external electricity source. Popular models include the Chevy Volt, Chrysler Pacifica Hybrid, Hyundai Sonata PHEV, and the Toyota Prius Plug-in. The final level is the Battery-Electric Vehicle (BEV). This type of vehicle is fully powered by electricity and contains no combustion engine. This is often what people think of when they hear the phrase, "Electric Car". These cars must have more batteries to effectively power the vehicle for an extended period. Popular models include the Chevy Bolt, Honda Clarity, Tesla Model S, Tesla Model X, BMW i3, and Volkswagen e-Golf.

## EVs versus combustion

Although the only main difference between BEVs and ICEs is their power source, there are many second and third-order effects associated with this change. For one, BEVs are considerably simpler vehicles compared to their combustion counterparts. Since there is no liquid fuel to manage, BEVs need fewer parts than ICEs. This reduces maintenance costs and extends their lifetime. However, since electricity is less energy-dense than gasoline, it takes longer to charge. A level 1 120-Volt charger will provide between 3 and 5 miles of range per hour. This is the slowest form of charging and is typically only recommended for PHEVs as they have much smaller batteries than BEVs. A level 2 240-volt outlet provides between 12 to 80 miles of range per hour depending on the kind of charger. These are typically installed by owners of BEVs as they allow a vehicle to be charged overnight. Lastly, level 3 is broken into DC Fast Charge and

Tesla Supercharging. These range from 400 volts to 900 volts and can provide between 3 to 20 miles of range per minute. At 15 miles per minute, a 300-mile range vehicle would be fully charged in about 20 minutes. Level 3 chargers are only used for commercial use as they are very expensive, and few residences have access to such high voltage. The refueling time in BEVs is longer than that of ICEs which can refuel in just a few minutes, but on the bright side, the technology is expected to improve in the coming decade.

Although BEVs might be more complicated to refuel, they offer significant benefits through the reduction of costs. According to a Consumer Reports Analysis (Harto, 2020), "BEVs were estimated to save consumers about 60 percent on fuel costs compared with the average vehicle of their class," On top of fuel costs the report also found, "…both BEV and PHEV drivers are saving 50 percent on their repair and maintenance costs when averaged over a typical vehicle lifetime." This reduction in costs is a clear cost-benefit for BEVs over ICEs. Additionally, these benefits are on top of comparable resale value for the vehicles when factoring in government incentive programs. These costs are also expected to fall as BEVs become standard, and repairs become more common. Although one might argue that fuel savings are reliant on high gas prices, this is not the case. One would still have about one third fewer fuel costs if the 10-year average gas price was $2.33 a gallon as it is in the EIA's low-gas-price scenario (Harto, 2020). In conclusion, although there are some drawbacks to electric vehicles, predominantly related to charging time, for many owners, BEVs represent a clear step up.

## History of EV's

Early Years: 1850 – 1900

During this period, many innovations occurred which allowed for the development of a functional electric car. The primary innovation was rechargeable electric cars in 1859. Prior to this, the batteries had to be replaced each time, and the vehicles served as little more than a parlor trick. In 1890, chemist William Morrison applied for a patent for his electric carriage. It had a top speed of 20 miles an hour and had a range of 50 miles. These were still not commercially viable and mostly served as toys for the wealthy.

On the Rise: 1900 – 1920

Electric vehicles came to be popular as they were more convenient than steam vehicles. Although steam had been useful in the past for large machinery in factories and on trains, it was not practical for personal vehicles due to its long start-up time. Gasoline vehicles did exist, but they required significant manual efforts like changing gears and requiring a hand crank to start. Additionally, they were quite noisy, and their exhaust was unpleasant. Electric vehicles did not have these issues and became popular in cities, both as taxis and for personal use. In particular, women enjoyed using them. These cars would be primarily replaced by gasoline cars due to their reduced cost as well as the introduction of the electric starter.

Oil Shocks renew interest: 1970 – 1980

In response to rising gas prices, manufacturers, as well as the government, began making investments in electric vehicles. These ventures proved unsuccessful, though, as the technology had not significantly improved. This means that the range was typically limited to 40 miles or so with a top speed of 45 miles per hour. Many of these projects were abandoned as gas prices fell back to normal levels.

Government leads the way: 1990 – 2005

Due to the introduction of legislation such as the 1990 Clean Air Act Amendment and the 1992 Energy Policy Act, as well as new emissions regulations from the California Air Resources Board, a renewed interest in the technology was born. To meet this interest, automakers adapted some of their cars to use electricity instead of gasoline. As the decade progressed, due to low gas prices and a strong economy, interest waned but government-funded research was working behind the scenes to fund new technology and innovations.

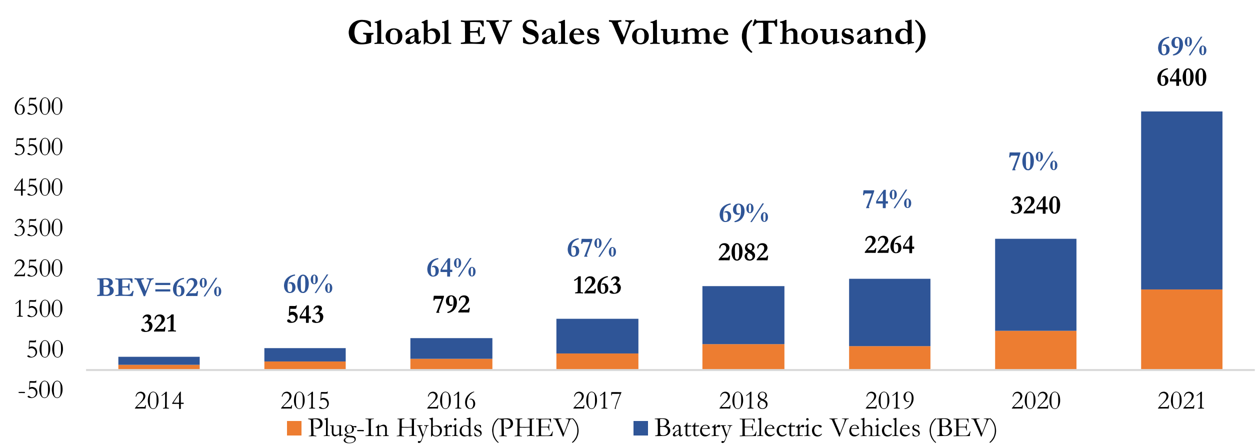
A New Age: 2005 – Present

Following the commercial success of the Prius as a new hybrid vehicle in the early 2000s, a small company known as Tesla Motors began to produce fully electric cars with a 200-mile range. Following its success, other automakers began to develop their own BEVs including the Chevy Volt and Nissan LEAF. Additionally, as battery prices continued to fall, these cars became more and more accessible to consumers. This, combined with new technology that increased the vehicles' range, allowed for a true commercialization of the product.

## What's on the horizon?

Although BEVs have a long history, much of their impact will be determined in the coming decade. As governments and institutions seek to reduce emissions on a global scale to lessen the warming effects of gasses such as methane and carbon dioxide, BEVs will become more common because they don't release carbon dioxide like ICEs. By utilizing electricity, particularly electricity generated from renewable sources, BEVs will help to reduce overall emissions or at the very least centralize them. For example, if one used a natural gas power plant to generate electricity to power 10,000 BEVs instead of having 10,000 ICEs. Both choices would lead to increased emissions, but with the powerplant, the emissions are concentrated and can be controlled through other means versus a decentralized fleet of cars that can't be controlled. Given this fact, the speed at which the fleet becomes electrified is critical to reducing overall emissions.

In 2019, 74.9 million new cars were sold worldwide. This number fell to 63.8 million in 2020 due to a contraction in demand brought about by COVID-19 and its response. As the semiconductor crisis and supply shortages persist, total sales for 2021 only grew slightly to reach an estimated 66.7 million. Just over 1.67 million of these vehicles were BEVs in 2019, representing 2.2% of new vehicle sales. This share jumped to 3.5% in 2020. Total BEV sales were forecasted at 4.42 for 2021, almost double the volume in 2020 and representing 6.7% of total car sales. PHEVs are also forecasted to double in 2021 to reach 1.98 million cars, accounting for 3% of total new car sales and 31% of Plug-In vehicle sales. Although these growth rates are impressive, there must be quick widespread adoption of this technology to effectively reduce emissions.




Source: Electric Vehicles World Sales Database

## Forecasts for the future

There are a variety of forecasts from different institutions about the number of electric vehicles on the road as well as their percent of new sales.

IEA

The IEA has two scenarios that it forecasts for, its STEPS scenario and its SDS scenarios. The Stated Policies Scenario (STEPS) models all existing commitments by governments as well as the expected effects of other plans from industry players. The Sustainable Development Scenario (SDS) uses different assumptions which predominantly include net-zero global emissions by 2070 and global temperatures rising between 1.7 and 1.8 degrees Celsius.

| Scenario | STEPS | SDS |
|---|---|---|
| Number of BEVs sold in 2025 | 7.1 million | 11.9 million |
| Number of BEVs sold in 2030 | 14.3 million | 28.6 million |
| EV sales share in 2025 | 10.4% | 18.9% |
| EV sales share in 2030 | 17.3% | 36% |
| EV stock share in 2025 | 3.2% | 4.5% |
| EV stock share in 2030 | 7.5% | 12.8% |

BCG

Boston Consulting Group has a more optimistic view of EV penetration versus the IEA's base case. They expect EVs (both BEVs and PHEVs) to reach 15% of sales by 2025 and 34% of sales by 2030.

Deloitte

Deloitte forecasts that EVs sales will reach 11.2 million in 2025 making up 12.1% of new vehicle sales. By 2030, they expect EVs to make up 32% of new sales, reaching 31.1 million sales.

BloombergNEF

Bloomberg New Energy Finance forecasts that passenger EV sales will sharply increase by 31% from 2020 to reach 66 million in 2040. Bloomberg expects that by 2040, EVs will account for more than two-thirds of total passenger vehicle sales, with China, Europe, then the U.S. leading this transformation.

## Big players

These consist of a variety of forecasts about what the future of the EV market will look like, but it will be highly reliant on how governments act as well as how automakers adapt and respond.

| Major Players | | |
|---|---|---|
| Traditional Automake | Startups | Tesla |
| ❖ Audi<br>❖ Ford<br>❖ General Motors<br>❖ BMW<br>❖ BYD<br>❖ Mercedes-Benz<br>❖ Honda | ❖ Rivian<br>❖ Nikola<br>❖ Lucid Motors<br>❖ Lordstown Motors<br>❖ Fisker<br>❖ NIO<br>❖ Li Auto | ❖ Tesla |

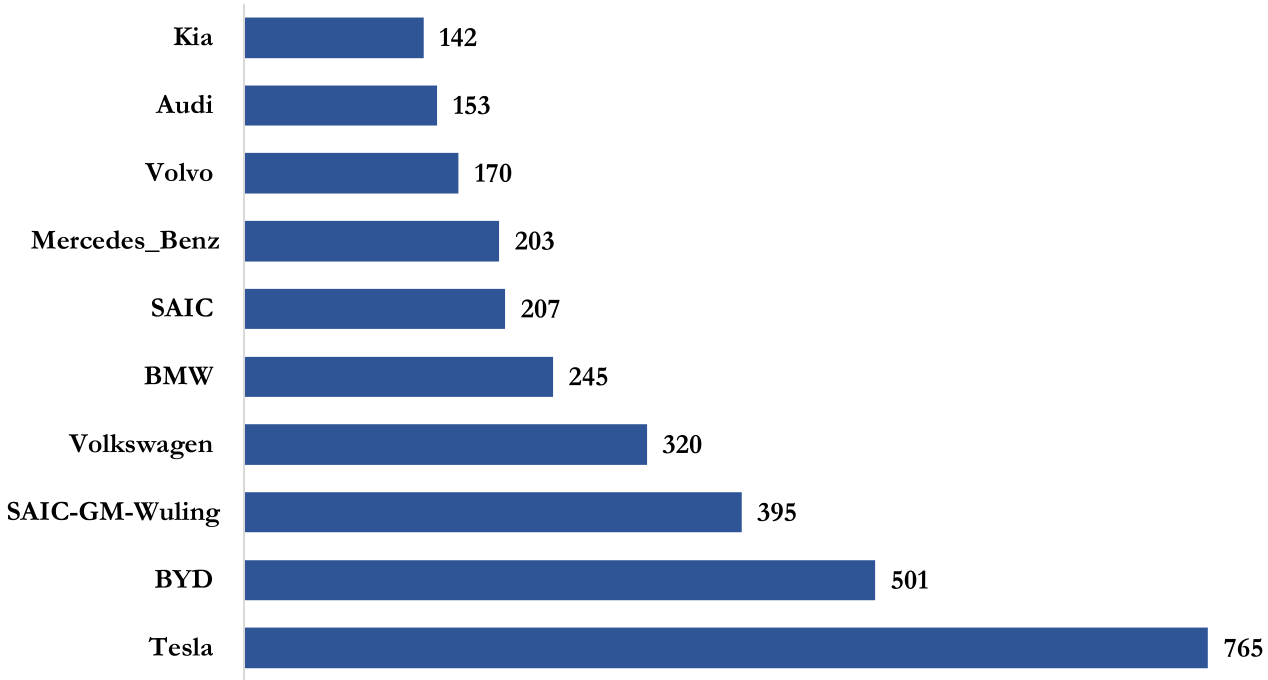
| | | |
|---|---|---|
| ❖ Kia<br>❖ SAIC<br>❖ Toyota<br>❖ Volkswagen<br>❖ Volvo | ❖ XPeng | |

Currently, EV manufacturers are split into three distinct categories: Traditional Automakers, start-ups, and Tesla. Due to the rise in popularity of EVs as well as the rapid improvement of their technology, traditional automakers have begun to enter into the space. All major automakers, both foreign and domestic, have made efforts or commitments to enter the space. These include Ford, General Motors, BMW, Mercedes-Benz, Honda, Toyota, and Volkswagen. Each of these companies has various planned or available models including both PHEVs and BEVs. The next category consists of younger companies that were founded to compete exclusively in the electric vehicle space. These include companies such as Rivian, Nikola, Lucid Motors, Lordstown Motors, Fisker, as well as foreign startups such as NIO, Li Auto, and XPeng. Lastly, Tesla stands in a category all on its own. It has kept its focus on BEVs while expanding its production capacity to reach a commercial level scale.

The chart below shows the global Plug-In vehicle sales volume for 2021 up to November, ranked by car manufacturers. Up till November 2021, total sales were at 5.6 million, up from 3.2 million for the full year of 2020. Global Sales are expected to close at 6.4 million vehicles in 2021, double the volume of the previous year. Tesla alone sold 765 thousand vehicles, obtaining first place with a share of 13.7%. Next came BYD, SAIC-GM-Wuling, and Volkswagen Group with shares of 9.0%, 7.1%, and 5.7% respectively. Together, the top-10 manufacturers accounted for just above half of the global sales

**Global EV Sales Voume by Manufacturer (Thousand)**

*January-Novemebr 2021*

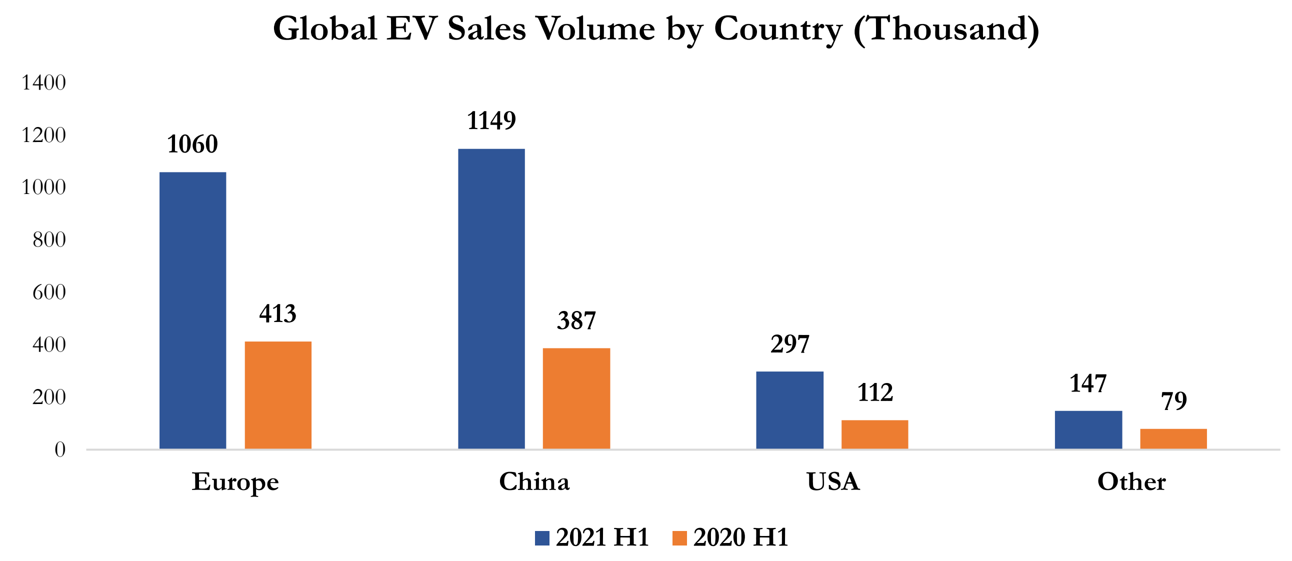



Source: InsideEVs News

## Major Countries

Almost 2.65 million new EVs (BEV + PHEV) were sold globally in the first half of 2021. Both China and Europe were the largest countries, accounting each for around 40% of global sales. Around 11% of EV sales were in the US, while all other countries accounted for 5.5%.

All regions experienced rapid growth rates in their sales volumes. Compared to the first half of 2021, sales almost tripled in Europe, China, and the US, and almost doubled in all other countries together. High growth rates were driven by both market recovery following the 2020 slump and evident market expansion.




Source: Electric Vehicles World Sales Database

## Government Action

Governments have a variety of tools at their disposal to incentivize the adoption of electric vehicles. These include tax credits for purchasers and producers, subsidies for producers and purchasers, bans on new ICEs, and a variety of others. Below are some of the recent actions and this is not intended to be exhaustive in its scope.

United States

Much of the current legislation has been inspired by California as they have implemented the strictest standards. Due to the nature of the production of EVs, the largest market tends to set the rules for the rest of the market as it is inefficient for the manufacturer to produce slightly different variations of the same car. California legislation includes a requirement that all new cars and passenger trucks by 2035 are zero-emission vehicles. Additionally, in April of 2020, the US Environmental Protection Agency and National Highway Traffic Safety Administration implemented an increase in fuel efficiency standards by 1.5 percent per year from 2021 to 2026 from the 2020 levels. This represents a decrease from the 5% annual increase under the Obama administration.

European Union

Although individual countries have set standards, the European Union has implemented broad rules that govern its entire jurisdiction. These include tightening emissions standards for vehicles by 15% between 2021 and 2025 and 37.5% between 2021 and 2030. Additionally, standards for new passenger cars are currently 95 g CO2/km which represents a 27% decline in emissions from 130 g CO2/km in 2012.

China

Due to its government structure, China has been able to enact strict legislation to achieve its goals. This includes a target of 20% share of passenger no emission vehicles by 2025. Additionally, it has increased fuel economy standards to 4.6 L/100km by 2025.

## EV Stations

The United States currently has about 43,000 public EV charging stations totaling around 120,000 charging ports which primarily consist of level 2 chargers. This compares with just over 150,000 fueling stations for ICEs. The number of chargers will need to expand massively as more and more electric vehicles enter the road. This is due to the much longer time it takes to charge an EV versus filling up an ICE. It likely does not take more than 10 minutes to fill an ICE with gasoline, but it can take up to 45 minutes to charge an EV or even longer, depending on the charger. Although the number of vehicles for every station is likely higher for EVs since consumers can also charge at home which is unavailable for ICEs, significant investment will have to be made to build out a significant charging network.

The government has already taken steps to develop such an infrastructure. For example, the recently passed infrastructure bill allocates $7.5 billion to develop the network through a coordinated effort from the Department of Energy and the Department of Transportation. This plan is expected to increase the number of charging ports to 500,000. This will raise the number of charging points per 100,000 inhabitants from its current level of 37 to about 157 ports per 100,000 inhabitants. This would represent more than a fourfold increase and would surpass the level in the European Union of 62 charging points per 100,000 people.

# Autonomous Vehicles

Autonomous vehicles have long been theorized since the popularization of the car itself, but it is only in recent years that progress towards this has been made. Currently, a variety of companies are working to create autonomous, often called self-driving vehicles. These companies hope to create a safer and more enjoyable experience for consumers.

## Basic five levels

SAE International, formerly known as the Society of Automotive Engineers, has created a six-level system to describe autonomous vehicles. The system begins at level 0 with no self-driving capabilities and extends up to level 5 which is full self-driving.

Level 0 – No driving automation

All braking, acceleration, and steering are controlled by human drivers. Any system that may intervene is reserved for momentary action in specific situations such as emergency braking or simply serve as a warning or alert such as lane-keeping assistance, blind-spot warning, or forward-collision warning. As the lowest level, all cars are at least level 0, with many new cars having some level 0 features.

Level 1 – Driver Assistance

To achieve level 1, the vehicle must have at least one driver support system that provides steering assistance or braking and acceleration assistance. An example of such a system would be steering assistance such as lane-centering or lane-following. At level 1, the driver remains alert and ready to take control at any time.

Level 2 – Partial Driving Automation

This level is similar to level 1 except it includes both steering assistance, and braking and acceleration assistance instead of simply one or the other. This is the highest level that is currently available in commercial vehicles. The driver is required to remain prepared to take control at any time.

Level 3 – Conditional Driving Automation

Any vehicles in level 3 are in the testing phase and are not commercially available. Level 3 represents a significant jump from previous levels as it no longer simply supports the human driver with systems, but rather completely controls the vehicle. Level 3 vehicles can fully drive under specific conditions relating to traffic patterns and weather. Although the vehicle can drive itself, the driver must still be ready to take over at any time in an emergency.

Level 4 – High Driving Automation

This is similar to level 3 in capability, but no longer needs any human interaction as it can stop itself in the event of a malfunction. This car would not need an accessible steering wheel or pedal for a "driver". This would be required for driverless taxis and autonomous public transportation services. Level 4 is still limited by some conditions.

Level 5 – Full Driving Automation

As the highest level, level 5 means complete self-driving. This holds true under all conditions with no human intervention. The only human interaction required is to set a destination.

## Major Players

Given the scalability of software, it is likely that the introduction of effective and safe autonomous vehicles will lead to significant first-mover advantages. This "winner-take-all" dynamic has meant that many different companies have tried to solve these issues. These players range from small start-ups to the biggest tech companies in the world as they seek to capture some of the value of the large transportation market. Many of the companies within this space fall into three distinct categories: big technology companies, traditional automakers, and start-ups.

| Automotive | Big Tech | Start-ups |
|---|---|---|
| ❖ Cruise (GM, Honda) | ❖ Waymo (Google) | ❖ Embark |
| ❖ Argo (Ford and VW) | ❖ Apple | ❖ Pony.ai |
| ❖ Motional (Hyundai) | ❖ Mobileye (Intel) | ❖ Cortica |
| ❖ Tesla | ❖ Zoox (Amazon) | ❖ Momenta |

## Why aren't they here yet and when will they be?

Although millions of people drive every day, the need to create an effective self-driving car cannot be overstated. As a driver, one is responsible for countless variables that all must be monitored simultaneously, then one must make quick decisions in response to these variables. Because of this, it will be extraordinarily difficult to make a fully self-driving car until the industry can develop human-level Artificial Intelligence, something that is considered to be decades away.

Additionally, there are millions of possible novel scenarios that an AI would have to be able to identify and reason through that makes this an extremely difficult problem to solve. For instance, it still has to be able to identify a stop sign even if it's covered with a few leaves. The multitude of objects and their interactions create the possibility of "tail events". These "tail events" are unlikely but could lead to a collision if mishandled. It is in these situations that engineers are most concerned as these events are often novel and could leave the AI unprepared to react quickly.

Overall, until there are significant developments into general-purpose AI that can effectively match human intelligence and reasoning, full self-driving without ideal conditions will be nearly impossible.

## Who's going to win?

Putting aside the technology aspect, the question then becomes, what is this market going to look like and how is it going to change from its current state? Currently, there appear to exist two models for autonomous vehicles: direct-to-consumer and robotaxi/TaaS (transportation as service). The DTC model is quite similar to how cars are sold today. Vehicles will be purchased by consumers for their personal use whenever they please. The robotaxi/TaaS model is based on the idea that people would no longer own cars, instead ordering a car whenever they need one, like ride-sharing apps such as Uber or Lyft. This model allows the car to be used much more often, especially considering that cars are only in use about 4% of the time (Bates & Leibling, 2012). Given this reality, the robotaxi/TaaS model allows for more expensive vehicles as it would be in use much more often.

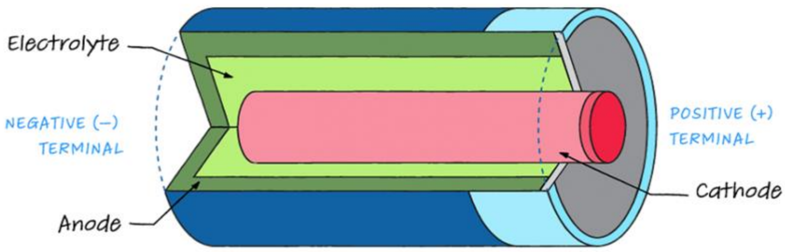
| | |
|---|---|
| Cost of vehicle | $1,000,000 |
| Average Uber Ride in large city | $ 18.40 |
| Minutes per Ride | 20 |
| Hours of Operation per day | 18 |
| Rides conducted per Day | 54 |
| Revenue per Day per Vehicle | $ 993.60 |
| Payback period in days | 1006.44 |
| Payback Period in Years | 2.88 |

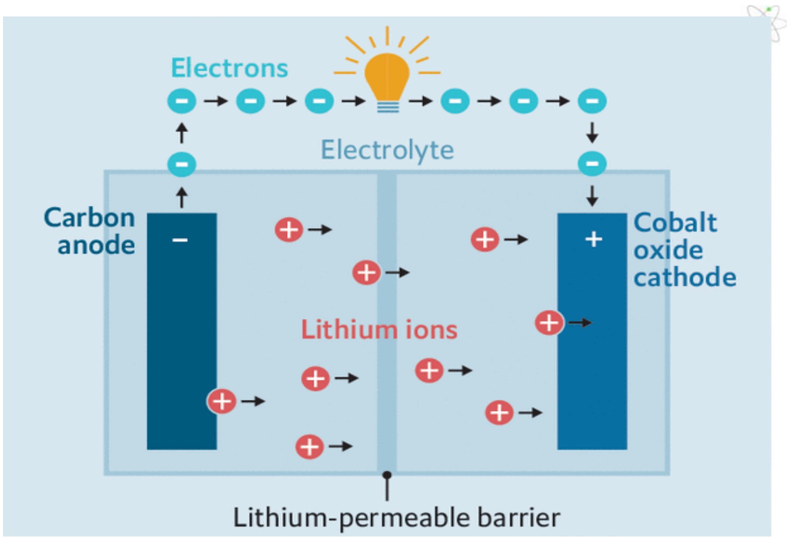
Consider the situation above of a theoretical robotaxi/TaaS. At an initial cost of $1 million per vehicle, if the car is deemed as efficient as the average uber driver and is operating for 75% of the time, then it would take less than three years to fully recoup the investment of the vehicle. As a revenue-generating asset, robotaxis/TaaS represent a much bigger market opportunity than simply selling the vehicle to the consumer directly. Thus, the companies pursuing this model have a much higher likelihood of solving this problem since the market opportunity would likely be larger. Additionally, the ability to map a specific area to help the vehicles navigate a defined area could allow for a quicker rollout of this technology.

## Batteries

### How do they work?

Although we interact with them daily, many people are unfamiliar with how batteries store and release the electrical energy needed to power everyday devices from cell phones to laptops. At a basic level, all batteries facilitate the controlled flow of electrons that can be harnessed by electrical devices to do some kind of work. The battery consists of a few main parts including the anode, the cathode, and the electrolyte. In the battery, the electrolyte reacts with the anode to build up electrons at the anode. These electrons are attracted to the positively charged cathode, but they are unable to flow through the battery to reach the cathode. Thus, when a wire connects the anode to the cathode the electrons flow which allows for the production of usable electricity.

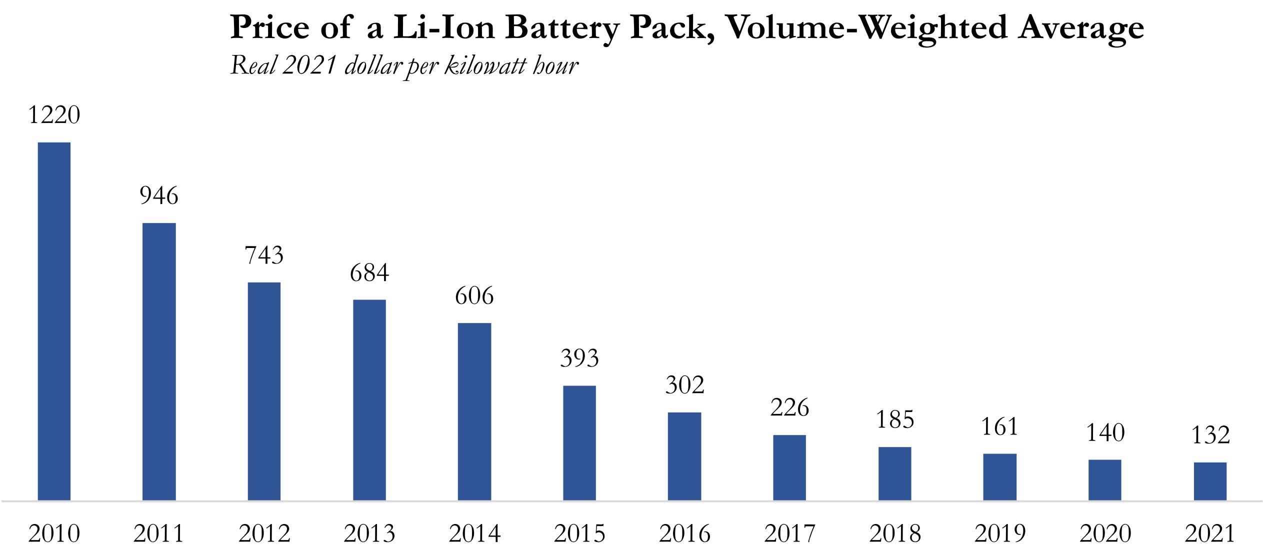



Although there are variations in batteries, all of them use the same basic principles in which some anode reacts with an electrolyte that creates a negative charge that flows towards the positively charged cathode. There are a variety of materials that have been used to create batteries including lead-acid, nickel-cadmium, nickel-metal hydride and alkaline. Nowadays, the most used battery, especially for modern devices such as cell phones, laptops and even electric vehicles is the lithium-ion battery. As the name suggests, these batteries use lithium ions to hold onto electrons until the battery is recharged which facilitates the flow of electricity.

## Cost Reduction

Although first developed in 1991, lithium-ion batteries have benefited from significant cost reductions both due to innovations in their manufacturing process as well as the increase in the scale of their production. This has led to a reduction of costs from $1,220 per kilowatt-hour in 2010 to $132 in 2021 according to BloombergNEF. This represents an 88.1% decrease in costs over this period with an average annual decrease in prices of ~18% over the period from 2010 to 2021.




Source: BloombergNEF

Although the reductions in cost have been significant, at current levels, BEVs were not cost-competitive when compared with ICEs before the inclusion of subsidies or cost benefits from fuel, insurance, and maintenance. This level is forecasted to be about $100/kWh to truly make these vehicles competitive. Below, there is a chart detailing possible scenarios for battery cost reductions. The bull case uses the historical average for the period from 2010 to 2021 of ~18%. The base case takes the average of the last three periods and the bear case adds a 3.5% hurdle to this base case assuming unforeseen barriers. In all of these cases, this $100/kWh level is reached by 2026 signaling cost competitiveness for BEVs by this time.

| | Bull | Base | Bear |
|---|---|---|---|
| Cost Reduction | 18% | 11% | 7.5% |
| 2021 | 132 | 132 | 132 |
| 2026 | 49 | 75 | 89 |
| 2030 | 22 | 48 | 65 |

## New Technology

Although the lithium-ion battery has proven effective as an all-purpose battery, there are a variety of variations as well as entirely different kinds of batteries that will hopefully allow for increased power density, longevity, and safety.

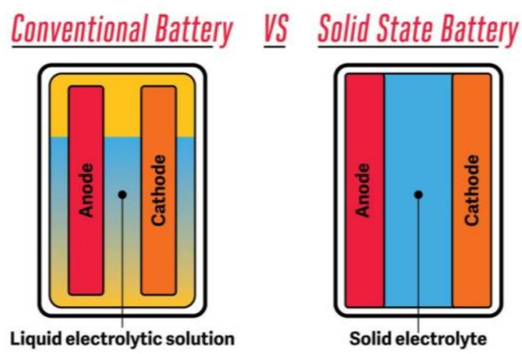
### Variations on Lithium-Ion

These batteries include changing either the materials or the structures within the batteries to increase power density. One such example is the utilization of silicon for the anode which could massively increase energy storage capability, but current prototypes have a very short lifespan due to warping in the silicon anode when lithium ions are released which results in the anode breaking down. Another option is to replace the graphite anode with a graphene anode. Although similar, graphene is only one atom thick and would allow for much more efficient intercalation of the lithium ions, but the rapid insertion of lithium ions into the graphene required for charging results in the anode breaking down. Lastly, one out of the box suggestion is to simply use the oxygen in the air as the cathode which would allow for up to ten times more energy density versus current lithium-ion batteries. This however remains a difficult task as lithium is extremely reactive and keeping it stable while exposed to air is difficult.

### Replacement of Lithium

In addition to variations on the current model, there exist a variety of alternative materials that could result in a better battery. For example, a sodium-ion battery operates very similarly to a lithium-ion but uses sodium since it's cheaper and easier to source. These are especially useful for large batteries used by solar and wind farms as they require more regular maintenance. Conversely, an aluminum alloy that reacts with the air may be able to compete with lithium-ion batteries directly if an alloy could be found that doesn't degrade, but these are much further on the horizon.

### Solid-State Batteries



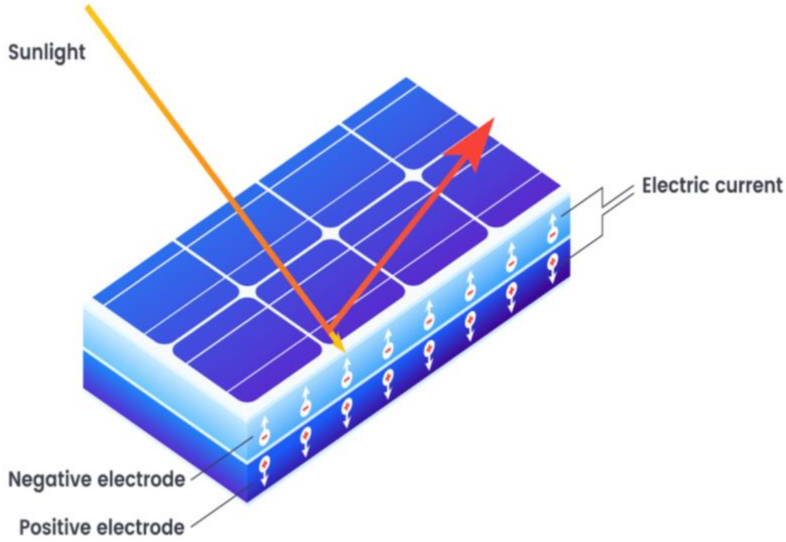

Although there are variations in all of the batteries described above, these technologies focus on changing either the anode or the cathode. This differs from solid-state batteries which instead focus on the electrolyte that the lithium ions pass through. Traditionally, the electrolyte is in a liquid form, but if a solid-state can become mass-produced, it could massively increase energy density. This is because a solid electrolyte takes up much less space than a liquid one which means more batteries could be packed into the same space. Additionally, these batteries would last much longer and charge quicker. Such improvements would push BEVs into a class of their own in terms of range, reliability, and convenience. Additionally, the application of such energy-dense batteries to power generation, particularly renewable sources, would allow for a significant improvement in the energy storage space.

# Solar

Although growing, solar energy remains a small part of the energy generations portfolio in the US and around. According to the US energy department, 2.3% of the electricity produced in 2020 was through solar energy, but it represented 43% of the new capacity addition which is the highest percentage in history and a huge step up from the 4% share it held in 2010. At 10.8 billion dollars, solar represents a small portion of the current energy industry but is expected to grow significantly. Overall, solar represents a significant opportunity in the coming decades as costs continue to fall and governments seek alternatives to fossil fuels.

## How It Works

There are two main kinds of solar energy: Photovoltaic (PV) and Concentrated Solar. Photovoltaic is the most common and makes up about 97% of the revenue of the industry. These cells work by creating two layers of silicon, one positively charged, and one negatively charged. When photons from the sun hit the top layer of the semiconductor (typically made of silicon), it knocks an electron off of the silicon. This electron then moves along the electrical field created so it can be captured and combined with other electrons to create a current. The combination of many electrons being knocked out of the silicon is what creates electricity. This differs from other forms of generation which use some kind of fuel to do work that turns a turbine.

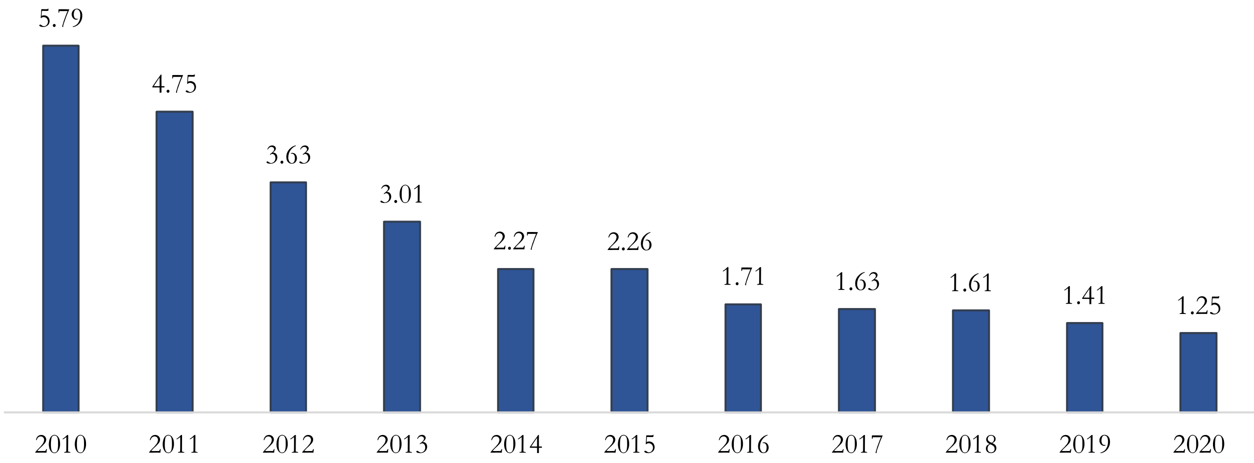



Alternatively, Concentrated Solar uses a mirror to focus solar energy onto a particular spot. This spot usually contains some kind of liquid that holds heat well such as a sodium mixture or petroleum derivative. Once the liquid heats up enough, it is transferred into a heat disperser where it heats water into steam which then turns a turbine to generate electricity. Both the liquid and the water are recycled back into the system to be used again. These used to be more popular amongst utilities, but the massive decrease in costs for PV cells have made them less common.

## Costs and avenues for growth

Over the last decade, solar panels have become significantly more cost-competitive. This has been primarily due to advancements in technology, economies of scale, and government investment. In 2010, it cost $5.79 on average per watt to install a PV system. By 2020, this number fell 78% to a cost of $1.25. This is significantly more than the 32% drop in natural gas over the same period.

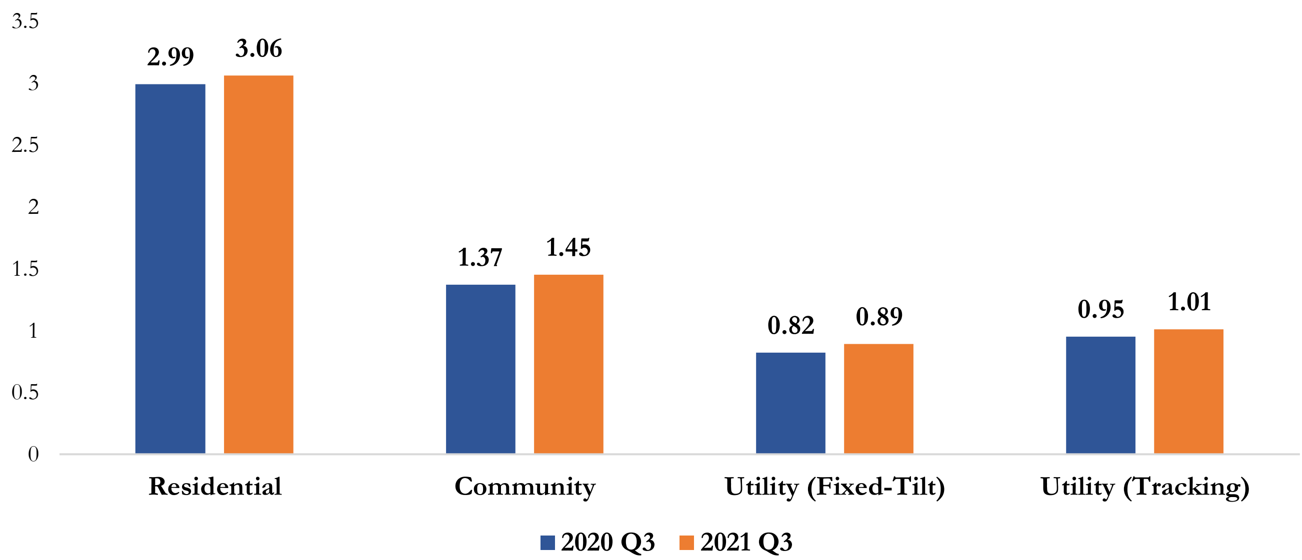
**U.S. Solar PV Price Declines, 2010-2020**
*Blended-Average PV System Price ($/Watt)*




Source: SEIA/Wood Mackenzie Power & Renewables U.S. Solar Market Insight

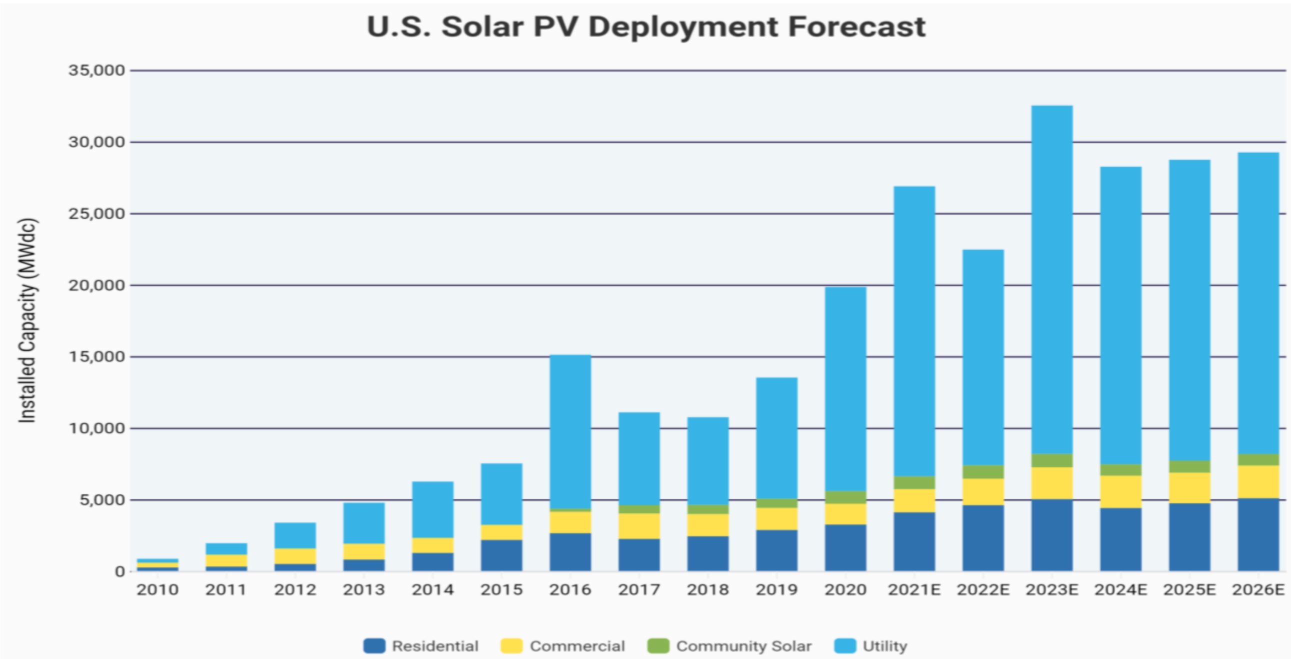
Nevertheless, recent estimates have shown installation costs increasing across all market segments in 2021 because of the global supply chain crisis brought about by the COVID-19 pandemic and the trade restrictions on Xinjiang. PV prices have increased in the second and third quarters of 2021 compared to 2020. Residential PV prices increased by 2% during the third quarter, compared to an increase of 6% for community PV, 9% for utility (fixed-tilt) PV, and 6% for utility (tracking) PV. In all market segments, except for the residential market, price increases marked the highest year-over-year growths since 2014. It is expected that prices will revert to their decreasing trend once the supply chain crisis resolves.

**U.S. Solar PV Price Increases, 2021 Q3**
*Price ($/Watt)*




Source: SEIA/Wood Mackenzie Power & Renewables U.S. Solar Market Insight

With a decrease in prices, the adoption of solar has increased significantly, going from ~850-megawatt installations in 2010 to over 19,000 in 2020. As these trends continue, solar will begin to take up more of the energy mix. Over the following 10 years, it is forecasted that over 348,000 megawatts will be installed, three times more than the 2020 level. This is especially true given its cost competitiveness with fossil fuels. According to a report by Lazard, the lifetime costs of power (including subsidies) are $31 per megawatt-hour for solar, which compares to $41 for coal and $28 for natural gas. As costs continue to fall, solar will become the low-cost decision for electricity capacity as well as being the sustainable choice.



Source: SEIA/Wood Mackenzie Power & Renewables U.S. Solar Market Insight

In addition to cost, solar is likely to succeed due to government action and corporate commitments. 30 states have passed legislation requiring the utility market to have a certain percentage of the electricity they sell to come from renewable sources by a certain time. These rules vary from state to state but having complete renewables by 2045 is common. These laws will create significant tailwinds as the utility market must invest in solar to meet these goals. Additionally, companies including Amazon, Apple and Google have made commitments to use renewables as well. Overall, the commitments made by both the private and the public sector combined with lower costs indicate that solar will grow well into the future.

## Solar Power Generation Industry?

Solar energy is dominated by large-scale companies using vast amounts of land to generate solar power which they then sell into the power grid. There are consumer solar panels, such as ones that would be installed on a rooftop for a single home, but these account for only about 30% of the market. The majority of solar panels are on Solar Farms as they are cheaper to install and maintain on a per megawatt basis due to economies of scale. These producers are either directly owned by utilities or otherwise are classified as Independent Power Producers (IPPs) which sell power into the market. These are known as Power Purchase Agreements which consist of the producer selling to a customer at a fixed price over a period. They are most commonly done with utilities as opposed to consumers since the utility market has a much larger customer base. Additionally, these agreements allow for the utility market to meet the renewable standards set by the state.

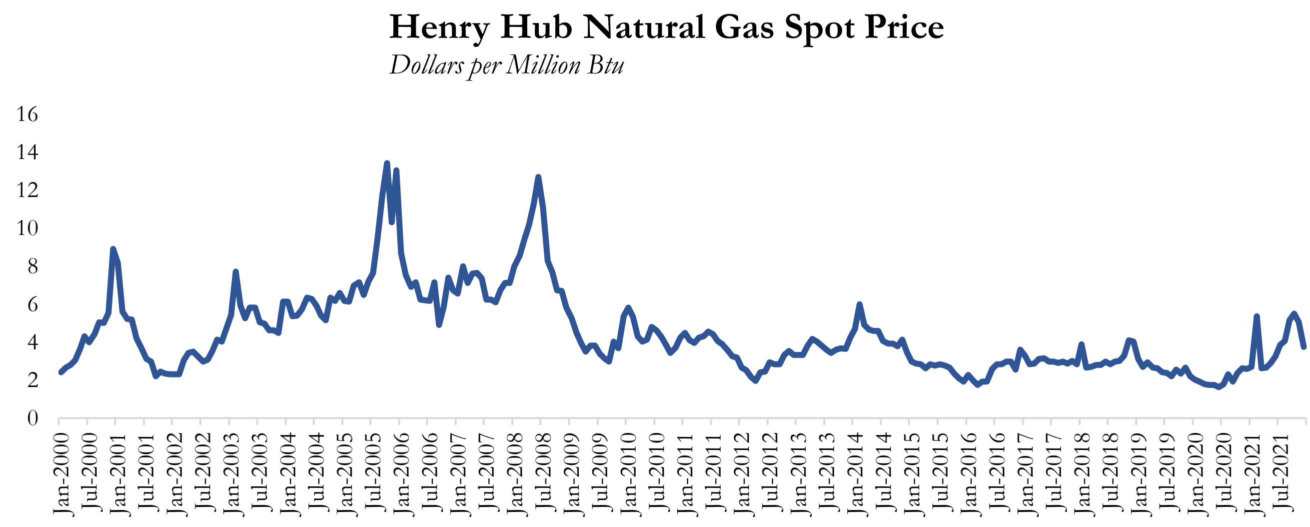
## Potential pitfalls

### Soft costs

According to the Office of Energy Efficiency & Renewable Energy, soft costs are defined as, "the non-hardware costs associated with going solar. These costs include permitting, financing, and installing solar, as well as the expense solar companies incur to acquire new customers, pay suppliers, and cover their bottom line." Soft costs can lead to significant costs for producers, this is especially true if state or local governments do not have programs that help to facilitate installation. Often, electricity-generating machinery is highly regulated, and the ability to acquire permits for installation is key to keeping costs low. Additionally, if residents are connecting to the grid directly, they must have inspections and labor to facilitate that connection. Soft costs are the primary reason why utility-scale solar is more efficient to add capacity to the grid compared to rooftop solar.

### Natural Gas Prices

Although solar has proven to be more cost-effective than coal, it still faces competition from natural gas power plants in terms of the marginal production of electricity coming from existing plants. This marginal production cost is primarily influenced by natural gas prices. If prices stay low over the coming decade, then it could take longer for these plants to be retired which would be a hindrance for solar. In the US, from the period of 2005 through 2009, monthly Henry Hub natural gas spot prices averaged $7.07 versus $3.26 from 2010 through the end of 2021. If prices continue to fall then it could lead to more investment into the natural gas sector over solar.




Source: US Energy Information Administration

## Battery Storage

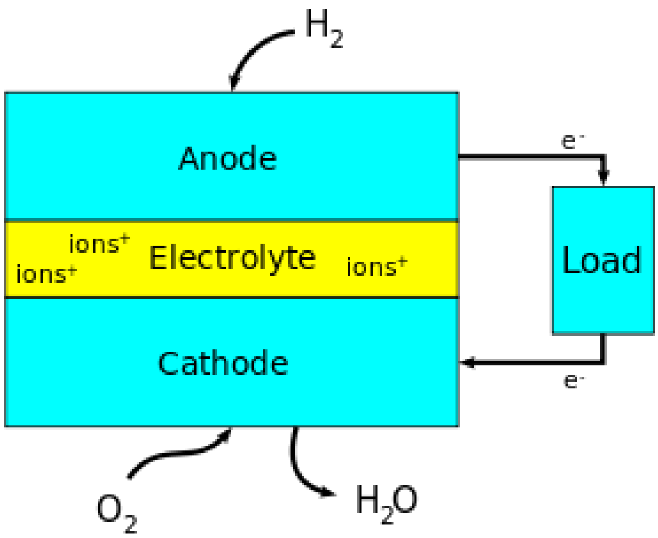
Unlike fossil fuels, solar energy can't be generated at all times, particularly at night. Thus, if it is going to be used at a widespread scale, it must include some sort of battery storage mechanism which allows it to store excess energy to be used later. As mentioned above, the decreasing cost of lithium-ion batteries will lead to cheaper and more widespread battery storage. However, this represents an added cost for solar which would make it less competitive. Solar will likely have to be paired with some baseload such as nuclear or natural gas until the cost falls enough to make it more cost-competitive.

## Hydrogen

Hydrogen, specifically hydrogen fuel cells, represent an opportunity for growth as the economy shifts away from fossil fuels. This is because hydrogen is a fuel source that does not produce emissions when it is used up. This means that it does not contribute to greenhouse gas emissions and thus climate change. Although it remains in its infancy, it is expected to grow significantly in the coming decades.

### How it works

The most common way for hydrogen to be utilized is through the hydrogen fuel cell. These cells take in hydrogen stored in a tank as well as oxygen from the air to generate electricity that can run an electric motor. This is the science behind hydrogen vehicles. The main components of the fuel cell are the anode, the cathode, and the electrolyte. The anode, often made of platinum, oxidizes the hydrogen. This separates the electron from the proton in the hydrogen. The proton, also known as a hydrogen ion, then passes through the electrolyte. This electrolyte only allows positively charged particles to pass through it. The negatively charged electron is instead routed through wiring to create an electric current to power a motor. In the cathode, oxygen from the air is combined with hydrogen ions and the used electron to create water. Thus, the fuel cell uses hydrogen from its storage tank and oxygen from the air to create electricity, with the only byproduct being water.




### How is it made?

Although it emits no greenhouse gasses when burned or run through a fuel cell, the process of creating hydrogen fuel can create emissions. The amount of emissions is dependent on how the fuel is produced, with the three main production methods creating gray, blue, and green hydrogen.

#### Gray

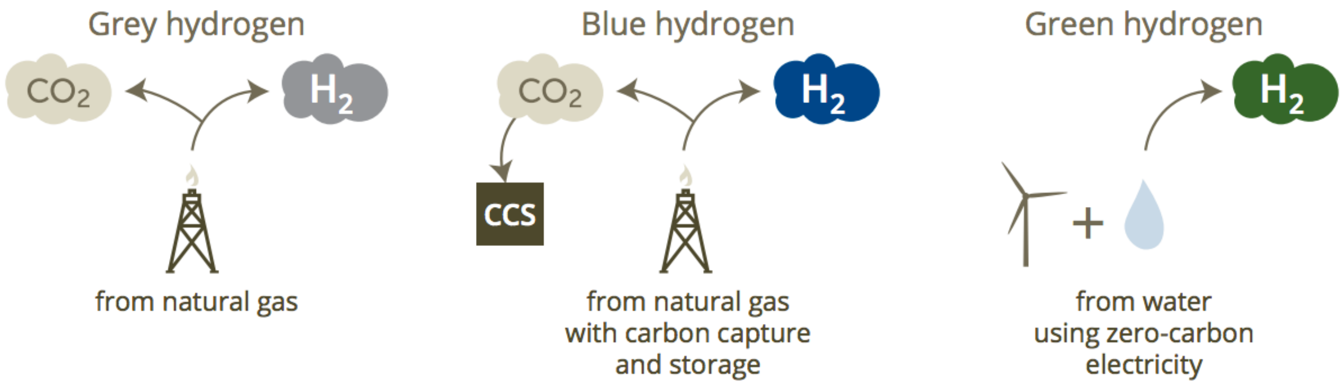
Gray (or grey) hydrogen is created through a process of separating hydrogen from methane, the most common part of natural gas. This process consists of utilizing a catalyst at high temperatures to include a chemical reaction in the methane. As the hydrogen is separated and stored, the leftover carbon binds with oxygen molecules to create carbon monoxide or carbon dioxide which is then released into the atmosphere. This method is cheap but produces between 9 to 12 kilograms of carbon dioxide for every kilogram of hydrogen, according to the IEA. Over 90% of hydrogen currently produced is gray hydrogen.

#### Blue

Blue hydrogen is created using the same process as gray hydrogen, but the carbon dioxide produced is sequestered underground rather than being released into the atmosphere. According to the IEA, this reduces the amount of carbon dioxide released to between 1 and 4 kilograms per kilogram of hydrogen fuel. Although an improvement, this method of production still releases emissions and is thus not fully considered "clean energy".

### Green

Green hydrogen is produced through the electrolysis of water instead of using methane. In this process, electricity is run through water to separate hydrogen from oxygen. If the electricity used to create this hydrogen is from a renewable source such as wind or solar then its production would have no emissions associated with it. Currently, less than 2% of hydrogen is green hydrogen according to the IEA.




## Hurdles

Although hydrogen represents a promising energy source, it faces immense roadblocks that prevent it from being fully adopted. These primarily include the need for the creation of a refueling network, storage issues, costs.

### Refueling Network

As a new fuel, hydrogen lacks the infrastructure required to sustain a robust hydrogen fleet. As of January 2021, there were 45 public hydrogen fueling stations in the United States with 43 of them being located in California. If hydrogen is going to become more widely adopted for cars and trucks, then a more robust network must be created. However, hydrogen fuel does not have to be exclusively used in cars. It may be better applied to other modes of transportation as a replacement for fossil fuels such as within trains or airplanes that may find battery technology to be impractical. These more specialized forms of transportation would not need as widespread of a network which would allow for a faster rollout. Regardless, significant investment will need to be made in this space if it is going to compete with fossil fuel-powered vehicles.

### Storage

As a gas, hydrogen has specific needs when it comes to storage that liquid fuels do not. In particular, it is prone to leakage which can mean that small leaks can lead to large losses. Additionally, it is significantly less energy-dense than gasoline. This means that it requires much more volume to store the same amount of energy which adds to difficulties of storage. New technology will have to be developed to make storage more efficient and reduce leakage if hydrogen is going to be used on a large scale.

### Costs

Currently, hydrogen fuel is too expensive to be a viable alternative to fossil fuels, but this is expected to change in the next decade. S&P Global estimates that producing hydrogen from renewables will need to fall over 50% to between $2 and $2.50 by 2030 to become a viable alternative to conventional fuels. Failure for this cost to come down effectively will prevent hydrogen from becoming truly viable as a fuel source, regardless of its applications to transportation.

## The Power Grid

As the electrification of the economy continues over the coming decades, the power grid will have to be upgraded and repaired to meet this shift in demand preferences. In particular, as the electricity generation portfolio shifts towards renewables such as wind and solar, the infrastructure to facilitate these changes must be introduced. This is primarily in the form of long-distance transmission lines. Since wind and solar are highly dependent on location to maximize efficiency, they require this power to be transferred over long distances to where it will be consumed. This typically means transferring power from the Midwest region where wind turbines are most efficient to the coasts. Such an undertaking will require significant investments to effectively implement. In a report outlining possible net-zero scenarios, researchers at Princeton found that transmission capacity will need to triple by 2050 if the grid is to be effectively transitioned to renewables.

### The Basics of Transmission

High-voltage Transmission lines are used to efficiently transmit electricity over long distances. This is due to how electricity interacts with its conductor. Power Loss (P), the amount of energy lost to heat as electricity is transported, is a function of Current (I) and Voltage (V) as seen below:

$P = I * V$

To reduce this power loss, one first has to use Ohm's Law which shows that

$V = I * R$

where R is the resistance of the wire. If we substitute V, we find that

$P = I^2 * R$

To minimize P, we can either reduce the resistance of the conductor (R) or decrease the current (I). However, if we refer to the equation, it's quite clear that reducing current is more effective since current is squared. This means that if we cut current in half, power loss would become just 25% of what it was previously versus only falling by 50% if we cut resistance in half. Now, referring back to Ohm's Law, we find that the only way to decrease the current without adjusting the resistance is to increase the voltage. This basic principle is the reason transmission lines run at such high voltages. High voltage does present dangers, but careful design of the transmission towers helps to mitigate risks of damage to individuals or vehicles.

### Barriers to development

Although this infrastructure would require a significant monetary investment to the tune of tens of billions of dollars, the real limitations come from the patchwork of regulations that govern such projects. Utilities must satisfy regulators at local, state, and federal levels in addition to the residents of the surrounding areas of development. In this case, the government will have to make commitments to reduce these burdens to allow for productive investment in this space. Failure to streamline the system will cause projects to be delayed and reduce overall grid health.

## Investment opportunities

### iShare Global Clean Energy ETF – Tracks the S&P Global Clean Energy Index

Tracks the S&P Global Clean Energy Index, an index of about 100 companies in global clean energy-related businesses from both developed and emerging markets. It has an expense ratio of 0.42%. It currently has about $5.6 billion in assets.

Top 5 holdings

1. Vestas Wind Systems (VWS) – 8.16%
2. Enphase Energy (ENPH) – 6.67%
3. Consolidated Energy (ED) – 6.38%
4. Orsted (ORSTED) – 6.2%
5. Solaredge Technologies (SEDG) – 4.54%

| ERTH | 1y | 3y | 5y | 10y |
|---|---|---|---|---|
| Toal Return (%) | 0.3% | 35.2% | 25.1% | na |

### Invesco MSCI Sustainable Future ETF

Tracks the MSCI Global Environment Select Index which consists of companies that focus on offering products or services that contribute to a more environmentally sustainable economy. It is exposed to six different environmental themes: alternative energy, energy efficiency, green building, sustainable water, pollution prevention and control, and sustainable agriculture. It has an expense ratio of 0.55% and has about $415 million in assets.

Top 5 holdings

| ICLN | 1y | 3y | 5y | 10y |
|---|---|---|---|---|
| Toal Return (%) | -23.8% | 38.3% | 23.8% | 11.9% |

1. Vestas Wind Systems (VWS) – 4.46%
2. Central Japan Railway (9022 JP) – 3.87%
3. Kingspan Group (KSP) – 3.16%
4. Contemporary Amperex Technology (300750 C2) – 2.53%
5. Alstom SA (ALO FP) – 2.28%

### Shelton Green Alpha Fund

Focuses on investing in companies in the Green Economy that have an above-average growth potential and are reasonably valued. It has an expense ratio of 1.16% and has $331 million in assets.

Top 5 Holdings

| NEXTX | 1y | 3y | 5y | 10y |
|---|---|---|---|---|
| Toal Return (%) | 2.7% | 46.7% | 27.1% | na |

1. Tesla (TSLA) – 4.88%
2. Moderna (MRNA) – 3.91%
3. JinkoSolar Holding Co (JKS) – 4.23%
4. Taiwan Semiconductor Manufacturing Co Ltd (TSM) – 3.91%
5. BrookField Renewable Corp (BEPC) – 3.91%

### Global X Lithium & Battery ETF

Seeks to track the Solactive Global Lithium Index which includes companies active in the exploration and/or mining of Lithium as well as the production of Lithium Batteries. It has an expense ratio of 0.75% and about $5.5 billion in assets.

Top 5 Holdings

1. Albemarle Corp (ALB) – 10.77%

2. Tesla (TSLA) – 5.98%
3. TDK Corp (TTDKY) – 5.62%
4. Eve Energy Co (300014) – 5.26%
5. Contemporary A (300750) – 4.98%

| LIT | 1y | 3y | 5y | 10y |
|---|---|---|---|---|
| Toal Return (%) | 37.4% | 47.4% | 30.3% | 13.0% |

### Global X Autonomous & Electric Vehicles ETF

Tracks the Solactive Autonomous & Electric Vehicles Index which is composed of companies that are active in the electric vehicles and autonomous driving segments. It has an expense ratio of 0.68% and $1.4 billion in assets.

Top 5 Holdings

1. Tesla (TSLA) – 4.44%
2. Nvidia (NVDA) – 4.06%
3. Qualcomm (QCOM) – 3.3%
4. Microsoft (MSFT) – 3.27%
5. Apple (AAPL) – 3.26%

| DRIV | 1y | 3y | 5y | 10y |
|---|---|---|---|---|
| Toal Return (%) | 28.0% | 38.5% | na | na |

### Alternatives

In addition to publicly traded companies, there are a variety of platforms and investment vehicles to invest in companies trying to take advantage of this evolving space. These opportunities range from traditional Venture Capital to established Private Equity to innovative crowdfunding platforms. Some examples of Venture Capital groups include Clean Energy Venture Group (CEVG), Clean Energy Ventures, and Energy Impact Partners. Platforms such as Start Engine, WeFunder, and Republic allow for nonaccredited investors to engage in angel investments for early-stage companies. Overall, there are a variety of ways to invest in new companies in this space with a variety of growth profiles and risks.

## Quick Summary

Stating the obvious, the next decade will likely consist of significant changes as new technology emerges and existing investments begin to show their value. Changes in how we generate electricity as well as how we use and store it will be pivotal to how we live our lives and impact our planet. Although these trends appear to be on an upward trajectory, there are many ways they could evolve. Is there a new technology being developed that could radically change the need for EVs? Of course. The present rate of change will be the slowest we'll experience in this sector. It will only evolve faster and faster as the flow of money generates rapid advances. This requires remaining informationally vigilant and diversified in your holdings as keys to taking advantage of these opportunities.

## Works Consulted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