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DEPARTMENT OF INTERNATIONAL
AND EUROPEAN STUDIES

Postgraduate Program
"Energy: Strategy, Law, and Economics"

**Master Thesis**

# The Role of Electric Vehicles in the Geopolitics of Energy

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## Abstract

Electric vehicles (EVs) are significantly impacting global energy geopolitics by reshaping energy dependencies, trade dynamics, and the strategic priorities of the countries. As oil is diminishing the geopolitical influence of oil-rich nations, primarily in the Middle East, is reduced. On the other hand, countries with substantial reserves of lithium, cobalt, and rare earth elements, such as China, the Democratic Republic of Congo, and Chile, are gaining strategic importance.

The EV revolution is also driving technological innovation and competition. Leading economies are investing heavily in research and development in battery technology, charging infrastructure, and EV manufacturing, further reducing the geopolitical weight of fossil fuel resources. This technological race has geopolitical implications, as countries that lead in EV technology can exert considerable influence through exports and technological standards. Moreover, the rise of EVs is fostering new international collaborations and alliances. For example, the European Union is working to establish a secure and sustainable battery supply chain through partnerships with African and South American countries. Similarly, initiatives like the Belt and Road Initiative by China are aimed at securing critical mineral supplies and expanding EV markets.

The transition to EVs also brings challenges, such as potential resource nationalism, supply chain vulnerabilities, and environmental concerns related to mining and battery disposal. Addressing these challenges requires comprehensive policy frameworks and international cooperation.

## Acknowledgements

At this point, I would like to express my gratitude to all those who contributed to my academic development throughout the course of my studies.

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Anastasios Mitropetros

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# Contents

## NOMENCLATURE

EV: Electric Vehicle

BEV: Battery Electric Vehicle

AEV: All Electric Vehicle

ICE: Internal Combustion Engines

DC: Direct Current

AC: Alternate Current

BMS: Battery Management System

PHEV: Plug-in Hybrid Electric Vehicle

FCEV: Fuel Cell Electric Vehicle

FC: Fuel Cell

PEM: Proton Exchange Membrane

PCU (Power Control Unit)

HEV: Hybrid Electric Vehicles

MHEV: Mild Hybrid Electric Vehicles

BSG: Belt-driven Starter Generator

LCA: Life Cycle Assessment

REE: Rare Earths Elements

BRI: Belt and Road Initiative

WHO: World Heatlth organization

IOC: International Oil Companies

TCFD: Task Force on Climate Related Financial Disclosures

IEA: International Energy Agency

NEV: New Electric Vehicles

IRENA: International Renewable Energy Agency

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# Introduction

Electric vehicles (EVs) represent a rapidly emerging sector with significant implications for the global economy, national security, and environmental policy. As countries strive to reduce greenhouse gas emissions and tackle climate change, the transition from traditional internal combustion engine vehicles to electric vehicles is becoming increasingly critical. This shift creates new dynamics in the global energy and raw materials markets while also influencing relations between nations.

Inherently, there are tensions between trade, environmental, and industrial policies, and if governments fail to properly manage the interaction between these policies, there is a risk of conflicting objectives. These policies intersect and overlap, with governments attempting to address not only climate change but also geopolitical rivalries, the reshaping of supply chains, and technological shifts.

Efforts are being made to modify the habits and behaviors of consumers and producers, requiring the implementation of subsidies, tax reforms, and trade measures to put more electric vehicles on the roads. This is challenging on its own, but geopolitical conflicts, economic nationalism, and political polarization complicate the process even further. When we factor in the rapidly advancing technology used in the design and production of EV batteries, along with the limited and widely dispersed supply of raw materials, the complexity deepens further.

While most countries are adjusting their policies to account for geopolitics and climate policy shifts, it is the major economies—China, the EU, the US, and Japan—that are driving the process. However, no major economy, including China, is capable of producing electric vehicles entirely on its own, no matter how powerful it may be. Critical raw materials and finished goods are imported. The state-backed Chinese economy has paved the way for EV production, but its efforts may have been excessively successful, as overproduction threatens to flood domestic and global markets.

At the same time, the demands of the electrification industry are likely to drive the need for new raw materials. The World Bank (2017), for example, concludes that technologies intended to facilitate the transition to clean energy—such as wind and solar farms, hydrogen systems, and electrical power grids—are actually more material-intensive in their composition than the current traditional energy systems based on fossil fuels.

# 1. Description of Electric Vehicles

## 1.1 Definition of Electric Vehicle (EV)

EV stands for "Electric Vehicle." Electric vehicles are powered by an electric motor that draws energy from a battery, as opposed to internal combustion engines that use gasoline, diesel, or natural gas as fuel.

## 1.2 Advancements in Battery Technologies

One of the key reasons for the rising popularity of electric vehicles is the advancements in modern battery technologies. Older lead-acid batteries were heavy, offered a range of less than 100 miles, and lasted for only a few hundred complete charging cycles. In contrast, newer lithium-ion batteries provide a range of up to 300 miles and have a lifespan 10 times longer, remaining functional for approximately 2,000 full charging cycles.

## 1.3 Types of Electric Vehicles

### 1.3.1 BEV (Battery Electric Vehicle)

BEVs are also known as All-Electric Vehicles (AEVs). Electric vehicles using BEV technology operate entirely through an electric drivetrain powered by a battery. The electricity used to power the vehicle is stored in a large battery pack, which can be charged by connecting it to the power grid. Once charged, the battery pack supplies power to one or more electric motors, driving the electric vehicle. Electric motors deliver instant torque, improving acceleration and vehicle responsiveness compared to traditional Internal Combustion Engines (ICE).

#### *1.3.1.1 Operating Principles of BEVs*

The power for the electric motor is converted from DC (Direct Current) stored in the battery to AC (Alternating Current). When the accelerator is engaged, it triggers a signal to the controller, which then regulates the vehicle's speed by modifying the frequency of the AC power delivered from the inverter to the motor. The motor, linked to the wheels through a gear mechanism, driving the vehicle forward.

Most BEVs are equipped with a regenerative braking system that converts the kinetic energy generated during braking into electricity, which is returned to the battery. Additionally, BEVs feature a Battery Management System (BMS) that monitors and manages the battery's condition, including voltage, temperature, and performance, to ensure the safety and efficiency of the vehicle. The BMS also protects the battery from overcharging or excessive discharging.

***Table 1:*** *Main Parts of BEV*

| |
|---|
| Electric motor |
| Inverter |
| Battery |
| PCU |
| Drive train |

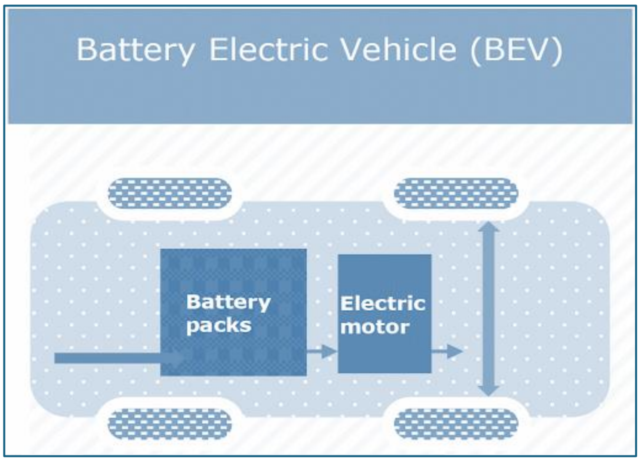


***Figure 1:*** *Schematic representation of the main components of a BEV electric vehicle*

### 1.3.2 PHEV (Plug-in Hybrid Electric Vehicle)

PHEVs, also known as hybrids, combine an internal combustion engine (ICE) with an electric motor. They can operate using either conventional fuels (such as gasoline or diesel) or alternative fuels (such as biodiesel). Additionally, they are powered by a rechargeable battery pack, which can be charged via an external power source.

PHEVs operate in two distinct modes:

1. **Electric Mode:** The vehicle is powered exclusively by the battery. The electric motor provides propulsion, with no fuel consumption or emissions during operation.

2. **Hybrid Mode:** The vehicle uses both the electric motor and the internal combustion engine in combination. The system automatically manages the transition between the two power sources to optimize energy efficiency and reduce fuel consumption.

### *1.3.2.1 Operating Principles of PHEVs*

PHEVs typically start their operation using the battery. The electric motor is utilized at low speeds, while the internal combustion engine activates when additional power is required or under other specific conditions. Similarly, when the battery is depleted, the vehicle functions as a conventional hybrid vehicle that does not require charging.

PHEVs can be charged using an external power source. During braking, the electric motor acts as a generator, capturing kinetic energy and converting it into electricity to recharge the battery (regenerative braking). The power from the internal combustion engine (ICE) is integrated with that of the electric motor, enabling the use of smaller, more efficient engines through a process known as downsizing.

***Table 2:*** *Main Parts of PHEV*

| |
|---|
| Electric motor |
| Engine |
| Inverter |
| Battery |
| Fuel |
| PCU |
| Battery charger |

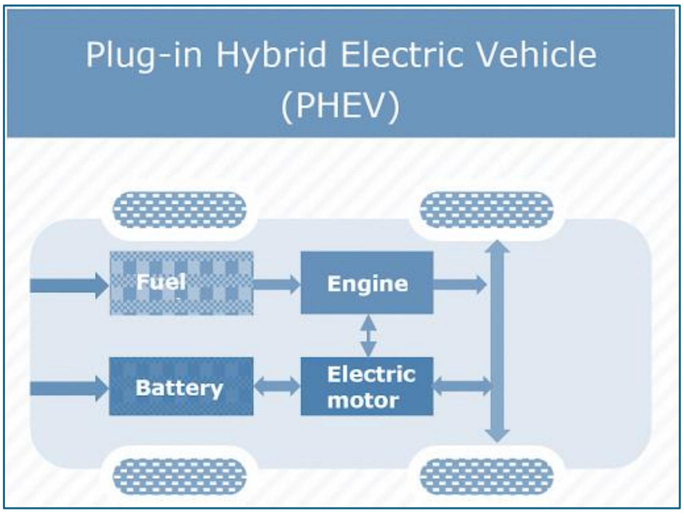


***Figure 2:*** *Schematic representation of the main components of a PHEV electric vehicle*

### 1.3.3 Fuel Cell Electric Vehicle (FCEV)

Fuel Cell Electric Vehicles (FCEVs), also referred to as Zero Emission Vehicles, represent cutting-edge electric vehicle technology. They utilize fuel cell systems to transform the chemical energy of hydrogen into electricity through a reaction with oxygen. This is an electrochemical process, not based on combustion, which means it generates no harmful emissions but only water and heat as byproducts.

By using pure hydrogen gas as fuel, FCEVs can achieve a driving range of around 450 kilometers per refill, surpassing that of many battery electric vehicles (BEVs). Moreover, they incorporate advanced features like regenerative braking to further boost energy efficiency.

#### *1.3.3.1 Operating Principles of FCEVs*

Hydrogen from the storage tanks is directed into the fuel cells where it is separated into protons ($H^+$: positively charged hydrogen ions) and electrons ($H^-$: negatively charged ions). The electrons flow through an external circuit, generating electrical energy used to power the electric motor. At the same time, the protons move through a Proton Exchange Membrane (PEM) and react with oxygen from the air and the electrons to form water, which is the only byproduct of the reaction.

The produced electrical energy can either be stored in a lithium-ion battery or used directly to power the electric motor. Additionally, the battery can store energy recovered from the regenerative braking system. The hydrogen refueling process takes only a few minutes, compared to the charging time required for Battery Electric Vehicles (BEVs).

***Table 3:*** *Main Parts of FCEV*

| |
|---|
| Electric motor |
| Fuell Cell |
| Hydrogen Storage Tank |
| Battery & PCU (Power Control Unit) |

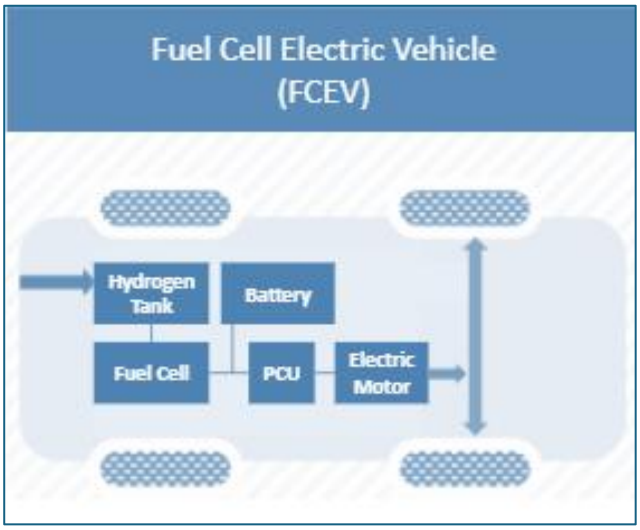


***Figure 3:*** *Schematic representation of the main components of a FCEV electric vehicle*

## 1.3.4 Hybrid Electric Vehicles (HEVs)

### *1.3.4.1 Operating Principles of HEVs*

Hybrid Electric Vehicles (HEVs) combine two types of engines—an Internal Combustion Engine (ICE) that runs on liquid or gaseous fuel (nowadays either fossil fuel or biofuel) and an electric motor—to improve fuel efficiency and reduce emissions. The HEV's batteries store electrical energy used by the electric motor and are recharged either by regenerative braking or by the internal combustion engine.

The vehicle can operate solely on the conventional engine, the electric motor, or a combination of both. This depends on speed, driving conditions, and battery charge level. An electronic controller manages the transition between the two power sources and the distribution of energy, ensuring optimal performance and fuel efficiency.

The combined use of the electric motor and the internal combustion engine reduces emissions, particularly in urban areas and during low-speed driving.

- During Normal Driving, the HEV primarily uses the internal combustion engine, while the electric motor helps improve fuel economy and reduce emissions.
- During Acceleration, the electric motor assists the internal combustion engine by providing additional power and improving performance.

***Table 4:*** *Main parts of HEV*

| |
|---|
| **Engine** |
| **Electric motor** |
| **Battery and Inverter** |
| **Fuel Tank** |
| **PCU (Power Control Unit)** |

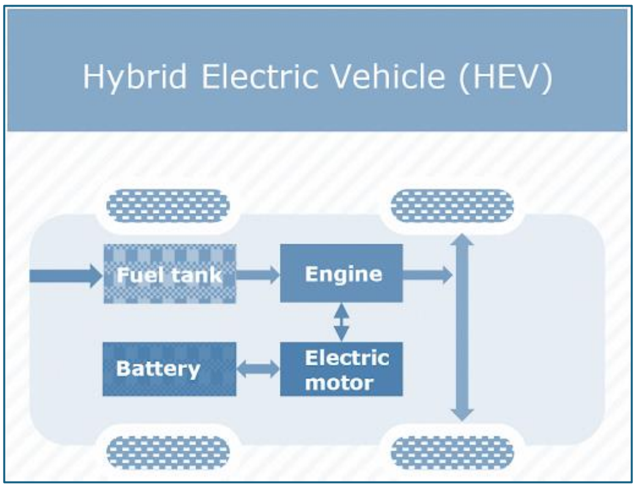


***Figure 4:*** *Schematic representation of the main components of a HEV electric vehicle*

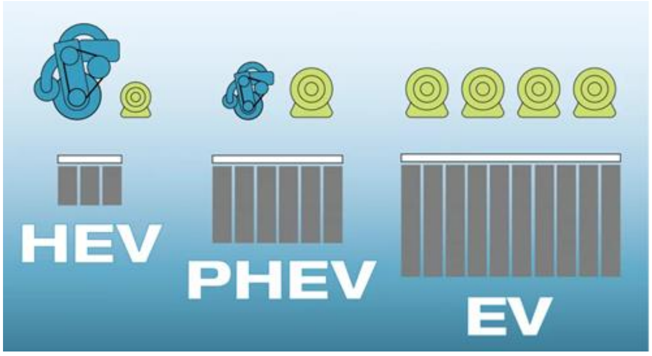


*Figure 5: Difference in the sizes of internal combustion engines, electric motors, and battery packs in HEV, PHEV, and BEV vehicles*

### 1.3.5 Mild Hybrid Electric Vehicles (MHEVs)

Mild Hybrid Electric Vehicles (MHEVs) combine an internal combustion engine (ICE) with an electric motor, offering improved fuel efficiency and reduced emissions, though they cannot operate solely on electric power.

The internal combustion engine (ICE) is the primary engine that provides power for vehicle propulsion. An electric motor/generator can assist the ICE during acceleration and recover energy during braking. MHEVs are also equipped with a small battery that stores the energy recovered during braking and supplies it to the electric motor when needed. Finally, they feature an electronic energy management system, which regulates the energy flow between the internal combustion engine, the electric motor, and the battery.

#### *1.3.5.1 Principles of Operation of MHEV*

*Acceleration:* The electric motor provides additional power, reducing the load on the internal combustion engine and improving fuel efficiency.

Deceleration and Braking: The electric motor acts as a generator, recovering the vehicle’s kinetic energy and converting it into electrical energy, which is stored in the battery.

*Start-Stop System:* The ICE shuts off when the vehicle is stationary and restarts instantly when the driver presses the accelerator. This reduces fuel consumption and emissions in urban areas with frequent stops and starts.

Low-Speed Efficiency: At low speeds or when cruising at a constant speed, the electric motor can provide support, saving fuel and lowering emissions.

***Table 5:*** *Main Parts of PHEV*

| |
|---|
| Electric motor |
| ICE: Internal Combustion Engine |
| DC/DC Converter |
| Battery 48 Volt |
| Fuel |
| CU: Control Unit |
| BSG: Belt-driven Starter Generator |

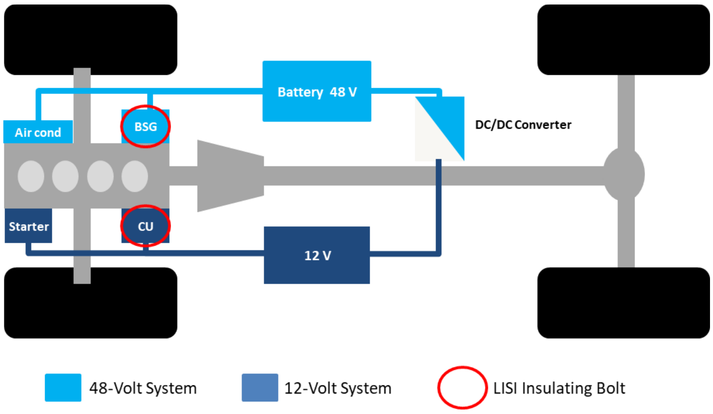


***Figure 6:*** *Schematic representation of the main components of an MHEV electric vehicle*

## 1.4 Electric Vehicle Manufacturers

**BYD Company (Build Your Dreams):**

The Chinese company BYD (OTC), standing for "Build Your Dreams," is the global leader in electric vehicle (EV) production. BYD manufactures passenger and commercial EVs, as well as mobile phone components. Its EV production volume grew by over 200% in 2022, propelling it to the top position in this sector. The company's most popular vehicle line is the Dynasty Series, named after Chinese imperial dynasties, including models like the BYD Qin, once the world's best-selling EV, and its flagship sedan, the BYD Han.

**Tesla:**

This clean energy and automobile manufacturer has become one of the world's largest companies in under two decades. By 2021, Tesla became only the sixth company to reach a market capitalization of $1 trillion. Tesla vehicles are immensely popular, breaking numerous sales records. The Model 3 was the first EV to surpass one million global sales, and in Q1 2023, the Model Y became the world's best-selling car, marking the first time an EV achieved this distinction. Tesla was founded as Tesla Motors in 2003 by Martin Eberhard and Marc Tarpenning, but it is most closely associated with CEO Elon Musk, who joined as the largest shareholder and chairman in 2004 and has served as CEO since 2008.

**Volkswagen**

Volkswagen began exploring electric vehicles (EVs) earlier than many think, starting in 1970 under Dr. Adolf Kalberlah at the company's Future Research Center. Its first EV, the Elektro Transporter, could travel 43.5 miles and took 10 hours to charge. Although the company experimented with EVs for years, it didn't fully commit to producing them for the mass market until 2017. Today, Volkswagen's ID. series includes models like the ID.3 (hatchback), ID.4 (SUV), and ID.7 (sedan).

**General Motors (GM)**

GM launched into the EV market in the 1990s with the EV1, the first modern electric car from a major automaker, offered only via lease. Despite strong user interest, GM canceled the program and scrapped most of the vehicles, doubting EV profitability. Decades later, GM is now among the world's top five EV producers, aiming to electrify all its major brands—Chevrolet, Buick, GMC, and Cadillac. The Chevrolet Bolt, once its most well-known EV, is being phased out for newer models.

**Stellantis**

Formed from the merger of Fiat Chrysler Automobiles and PSA Group, Stellantis is the newest automaker on this list. It owns brands like Jeep, Dodge, Chrysler, and Fiat. Stellantis aims for all its European sales and half of its U.S. sales to be EVs by 2030, targeting 5 million annual EV sales. In 2022, its Fiat New 500 and Peugeot e-208 were best-sellers in Italy and France.

**Hyundai Motor Group**

Ranking third globally in auto sales in 2022, Hyundai placed sixth in EV production. Its key brands include Hyundai, Kia, and luxury division Genesis. Hyundai launched its dedicated EV line, Ioniq, in 2020. The company plans to be among the top three EV manufacturers by 2030 and is investing $18 billion in South Korea's EV industry, including a $5.5 billion battery plant.

**BMW Group**

BMW's EV journey started in 1969, with its first model, the BMW 1602 Electric, showcased at the 1972 Olympics in Munich. Today, BMW's electric range includes the i4 and i7 sedans and the iX SUV. The Mini brand already offers EVs, and Rolls-Royce is preparing its debut EV, the Spectre. BMW expects electric vehicles to make up over 30% of its sales by 2025 and plans to deliver 10 million EVs by 2030.

**Geely**

A leading Chinese automaker, Geely saw its EV sales increase by over 300% in 2022. It owns global brands like Volvo and promotes EVs through its luxury brand Zeekr, Sweden-based Polestar, and the budget-friendly Geometry line. Geely Galaxy provides higher-end hybrid and electric vehicles.

**Mercedes-Benz Group**

Mercedes-Benz is planning a full shift to EVs by 2030, depending on regional demand, but may continue selling gas vehicles where EV uptake is slow. To support this transition, it's building a global network of fast-charging stations, set to be operational by the end of the decade. Its EV lineup, the Mercedes-EQ series (launched in 2016), includes best-sellers like the EQA luxury SUV.

**Renault-Nissan-Mitsubishi Alliance**

This long-standing alliance has already spent over €10 billion on EV development and plans to invest €23 billion more. Its 2030 goals include reducing battery costs by 65% and reaching a total battery production capacity of 220 GWh.

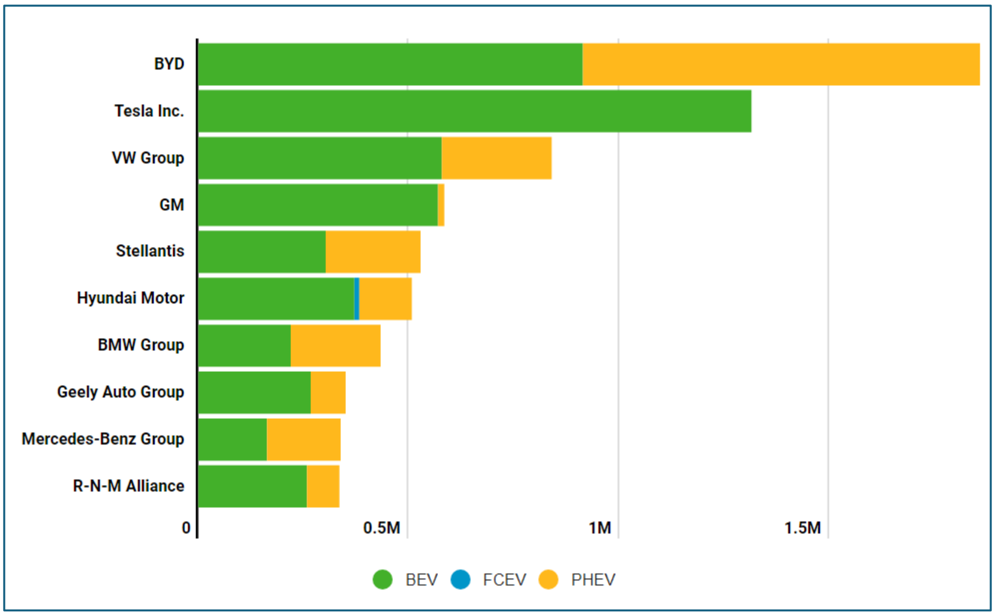


***Figure 7:*** *The largest electric vehicle manufacturers*

# 2. Raw Materials and Battery Production

Batteries constitute approximately 20-25% of the total weight of an electric vehicle and account for up to 40-60% of its cost. The key chemical elements used in battery production include graphite (C), aluminum (Al), nickel (Ni), cobalt (Co), lithium (Li), copper (Cu), and manganese (Mn). Their respective proportions are depicted in **Figure 8**.

For each of these critical raw materials, there are genuine concerns about the environmental and social impacts of mining, as well as the need to ensure that local communities benefit from the extraction activities.

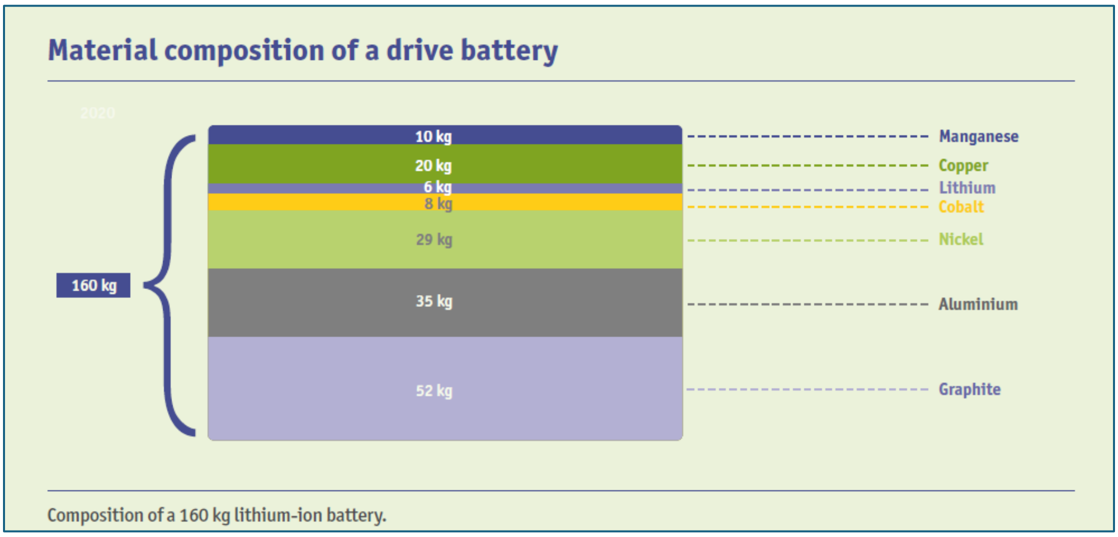


***Figure 8:*** *Composition of a typical lithium-ion battery*

The demand for metals essential to electric vehicle (EV) production is expected to grow steadily in the coming decades, primarily driven by the global shift towards electric mobility. This increased demand will, however, lead to a greater environmental footprint associated with mining activities. On a positive note, ongoing technological advancements are helping reduce the amount of raw materials needed per kilowatt-hour (kWh) of battery capacity. The use of costly and environmentally damaging elements such as cobalt, nickel, and lithium has already decreased significantly on a per-kWh basis and is projected to decline further.

To support this trend, alternative battery chemistries—such as lithium iron phosphate (LFP) batteries that do not require cobalt or nickel—are gaining traction in the market due to their lower cost and environmental benefits. Furthermore, sodium-ion batteries, which do not rely on lithium, cobalt, or nickel, were expected to begin commercial use by 2023 for specific EV applications. If these technologies succeed, they could significantly reduce the environmental burden of battery production.

In addition to battery innovations, many EV manufacturers are adopting asynchronous motors over permanent magnet motors, thus reducing the reliance on critical minerals for both motors and batteries. Within batteries, the cathode is the most chemically diverse and expensive component, playing a crucial role in performance. Nickel, in particular, is key, as higher nickel content typically enhances energy density—allowing more energy to be stored in a given volume and increasing vehicle range.

Currently, most EVs and plug-in hybrid electric vehicles (PHEVs) rely on lithium-ion batteries, although their chemical makeup differs from that of consumer electronics. The surge in lithium demand since the late 1990s has paralleled the rise of hybrid and electric vehicles, which required the development of high-energy-density rechargeable batteries. Lithium-ion batteries offer an optimal balance of energy density and power, while lithium itself—being the lightest metal—provides advantages in cost, charging speed, weight, maintenance, and lifespan. These characteristics have fueled a dramatic increase in lithium production.

Between 2015 and 2018, global lithium production rose from 31,500 to 85,000 metric tons, according to the U.S. Geological Survey (USGS). While innovations in lithium extraction and processing promise improved efficiency and lower costs, they demand substantial investment. The mining sector is, therefore, deeply interconnected with the energy storage and battery industries.

In 2020, the global lithium market stood at around 300,000 metric tons annually. Forecasts suggest that demand could rise to between 800,000 and 1,000,000 metric tons by 2030, largely depending on the pace of EV adoption. If this growth trend continues, lithium demand could potentially reach up to 3,000,000 metric tons per year by 2040, fueled further by the expansion of renewable energy storage systems.

**Albemarle Corporation**, headquartered in the United States, is the world's largest lithium producer. Albemarle's key lithium assets are distributed globally, from the vast Salar de Atacama region in Chile to the Greenbushes mine in Australia. The company also operates several processing facilities in the U.S., China, and other regions. With its production capacity, diverse portfolio of mining sites, and strong processing infrastructure, Albemarle is a powerful player in the lithium mining industry. Recent investments to expand production capacity suggest that Albemarle is positioning itself to maintain its leadership in the coming years.

**SQM**, based in Chile, is another major player in the lithium sector. The company operates in the Salar de Atacama, one of the richest lithium deposit regions globally. SQM has significantly increased its production, aiming to double output in the coming years. Despite challenges related to water usage and environmental concerns, SQM's vast lithium reserves and established market presence make it a crucial player in the lithium mining race.

**Ganfeng Lithium**, a Chinese company, is also among the world's leading lithium producers. Ganfeng operates in multiple countries and has forged strategic alliances with automakers like Tesla and BMW to secure long-term lithium supplies. Given China's strong focus on electric vehicles and renewable energy, Ganfeng is well-positioned to play a prominent role in the future of lithium mining.

**Lithium Americas Corp.**, a Canadian-based company, is developing one of the most promising lithium projects globally—the Thacker Pass project in Nevada, USA. Once operational in 2028, Thacker Pass could become one of the world's largest lithium deposits. Additionally, Lithium Americas holds a 49% stake in the Cauchari-Olaroz lithium project in Argentina, further strengthening its portfolio. If these projects deliver as expected, Lithium Americas could soon ascend to the top tier of global lithium producers.

The Australian company **Pilbara Minerals** owns the Pilgangoora Lithium-Tantalum Project, one of the largest hard-rock lithium-tantalum deposits in the world. Pilbara Minerals is expanding its production capacity and has shown strong interest in direct shipping ore (DSO) operations. Due to the high quality of its resources and its strategic location near Asian markets, Pilbara Minerals is claiming a significant position in the industry.

Lithium resources are highly concentrated in South America, particularly in Argentina (14.8 million tons), Bolivia (9 million tons—mostly untapped), and Chile (8.5 million tons). Due to their dominance, these three countries have become known as the

"Lithium Triangle." Following closely is Australia, estimated to hold 7.7 million tons of identified lithium resources, and China with 4.5 million tons.

Lastly, **cobalt** often acts as a stabilizer in NMC (Nickel-Manganese-Cobalt) batteries, improving their safety. It is crucial for supporting the cathodes in lithium-ion batteries for EVs and is almost always a byproduct of larger nickel and copper ores. This means it is not independently mined and requires significant processing to be suitable for battery use. Nearly all processing takes place in China, but there are significant ethical and production concerns surrounding cobalt mining.

In 2021, Congo supplied approximately 70% of the world's cobalt, and batteries accounted for more than 50% of this cobalt. Mines and miners often work under horrific conditions, with reports of child labor and inadequate safety standards.

The role of cobalt in increasing energy density and ensuring stability in lithium-ion batteries is undeniable. These batteries rely on the movement of lithium ions ($Li^+$) between the anode and the cobalt-containing cathode. Cobalt serves multiple important functions:

- **Increased Energy Density**: Cobalt, especially when combined with nickel, contributes to higher energy density in lithium-ion batteries. This translates into greater range and improved performance for electric vehicles.
- **Stability and Longevity**: Cobalt-based cathodes are known for their stability and long lifespan. This means that electric vehicle batteries can undergo numerous charge and discharge cycles before experiencing significant capacity degradation.
- **Voltage Stability**: Batteries containing cobalt maintain a stable voltage throughout their lifespan, which is crucial for the consistent and reliable performance of electric vehicles.
- **Fast Charging**: These batteries can handle high charging rates, reducing the time required to replenish an electric vehicle's battery.

Between 2000 and 2016, cobalt consumption increased at a much higher rate (over 8% annually) than copper (2.5%) or nickel (3.9%). Despite this increase, the physical availability of cobalt has not been a major concern.

As demand for energy storage rises, particularly in the electric vehicle and renewable energy sectors, the exploration of alternative technologies that could complement or even replace lithium-ion batteries is becoming increasingly important. Several such technologies are being researched or already in use:

- **Sodium-Ion Batteries**: Sodium-ion batteries operate similarly to lithium-ion batteries but use sodium instead of lithium. Sodium is more abundant and less expensive than lithium, potentially making sodium-ion batteries a cheaper alternative. However, they have lower energy density and a shorter lifespan compared to lithium-based counterparts.
- **Solid-State Batteries**: Solid-state batteries replace the liquid or polymer electrolyte found in lithium-ion batteries with a solid, increasing battery energy density and safety. Major automakers such as Toyota and Volkswagen are investing heavily in this technology.
- **Flow Batteries**: Flow batteries store energy in liquid electrolytes, with two types separated by a membrane. They have a long lifespan and can deliver energy over extended periods, making them ideal for grid storage. Their capacity can also be easily increased by adding more electrolyte. However, their energy density is currently lower than that of lithium-ion batteries.
- **Nickel-Metal Hydride (NiMH) Batteries**: NiMH batteries are often used in hybrid vehicles. They are more durable and safer than lithium-ion batteries but have lower energy density.

The mining sector is crucial to the energy storage and battery market. From the development of electric vehicles to the implementation of renewable energy sources, the growth of these industries heavily depends on the availability of specific raw materials, most of which are obtained through mining.

While these three chemical elements (nickel, lithium, cobalt) are the most common, other raw materials are also important for the electric vehicle supply chain. Copper and graphite will be in high demand in the future. Graphite has the highest proportion in battery composition because the entire anode consists of graphite due to its relatively low cost, abundance, and long lifespan.

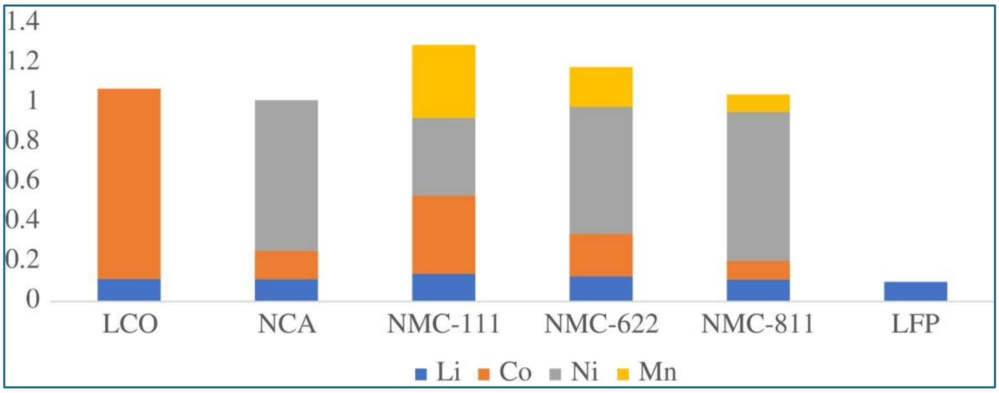


*Figure 9: Chemical composition of lithium-ion batteries in kg/kWh*

## 3. Environmental Impacts

Emissions from internal combustion engines are a primary contributor to the accumulation of greenhouse gases. Electric vehicles (EVs) play a crucial role in reducing these emissions to prevent global warming from exceeding 1.5°C but in any case it is not an easy task. The Paris Agreement brought climate change to the forefront of international policy, advocating for significant structural changes in the energy sector. Passenger and road freight transportation, overwhelmingly powered by petroleum products, account for approximately 6 gigatons (billion tons) of carbon dioxide (CO2) emissions annually. The automotive industry therefore faces a fundamental regulatory challenge to bring about a gradual transformation in emission levels. Achieving this will require massive investments to support the development of a large-scale EV market alongside the rapid decarbonization of the electricity generation industry. Electric vehicles represent a significant step toward sustainable transportation, offering a cleaner alternative. Five key environmental benefits of EVs include the following:

***a. Zero Emissions***

Electric vehicles (EVs) are renowned for their zero exhaust emissions since they lack an internal combustion engine. Unlike traditional internal combustion engine (ICE) vehicles, which burn gasoline or diesel and release harmful pollutants through their exhaust systems, EVs do not have an exhaust pipe. At the core of an EV is the lithium-ion battery, which undergoes repeated charge and discharge cycles without directly contributing to air pollution.

Life cycle assessments indicate that electric mobility has a significantly lower CO2 footprint over its entire lifespan. With the current EU electricity mix—comprising 44.6% renewable energy—an EV's $CO_2$ emissions are 66%-69% lower than those of a comparable combustion-engine car. For instance, while a diesel-powered vehicle operating under normal driving conditions in Europe emits up to 250 g $CO_2$e/km when considering its full life cycle, an EV with a 53-kilowatt-hour (kWh) battery emits only 75 g $CO_2$e/km. As a result, a typical mid-size diesel car in the "Golf" category produces approximately three times the $CO_2$e/km emissions of a comparable EV.

The $CO_2$ emissions from electric mobility primarily originate from battery production and electricity supply. Depending on the manufacturing process and battery type, between 40 and 350 kilograms of $CO_2$ are emitted per kWh of battery capacity. These emissions could be largely avoided if renewable energy sources were used for battery production. Driving-related $CO_2$ emissions, resulting from coal and natural gas used in electricity generation, can also be reduced to 1-2 g $CO_2e$/km—virtually zero—with the use of green electricity.

Currently, vehicle weights are increasing, a trend observed in EVs as well. However, this issue must be addressed in the future, as using smaller, lighter vehicles and reducing material usage through lower-capacity batteries can significantly impact emission reductions. The growing share of renewables in the electricity mix, flexible charging management, and regulatory measures in several countries—such as setting maximum $CO_2$ emission limits for batteries over their life cycle—will further reduce EV-related $CO_2$ emissions. The rapid development of new battery types and materials will also lower production-related $CO_2$ emissions in the future.

Finally, due to their high residual capacity, EV batteries can be repurposed as static energy storage units, significantly improving their ecological balance and reducing the need for manufacturing new storage batteries. Over recent years, the carbon footprint of EV batteries has dropped significantly, now being 2 to 3 times lower than previous levels.

***b. Resource Depletion Reduction***

Considering the production process, electric vehicles (EVs) are significantly less resource-intensive than traditional vehicles, offering a considerable environmental advantage. The simpler mechanics of EVs, compared to gasoline or diesel vehicles, is a key factor contributing to this resource savings.

Additionally, the batteries in EVs can be recycled, reducing the demand for new resources and minimizing waste. Promoting the widespread adoption of EVs can significantly decrease the environmental impact associated with extensive mining and the depletion of non-renewable resources.

***c. Fewer Harmful Fluids***

Electric vehicles present a major environmental benefit by eliminating the use of fossil-based products, such as lubricating oil used in gasoline and diesel vehicles.

Unlike conventional vehicles, EVs do not require various lubricants and fluids that can pose environmental hazards.
Lubricating oil, commonly found in gasoline or diesel vehicles but not in EVs, contains toxic compounds that can contaminate water sources, harming both human communities and wildlife. This emphasis on the reduced use of harmful fluids makes EVs a more environmentally friendly choice.

d. Noise Pollution Reduction

Electric vehicles play a vital role in reducing noise pollution, as electric motors operate far more quietly (reducing overall decibel levels). The significance of EVs in mitigating noise pollution extends beyond urban areas, improving environments such as residential zones and natural landscapes, and enhancing overall quality of life. As urban areas continue to grow and populations increase, the widespread use of electric vehicles becomes more important for fostering quieter, more tranquil environments.

***e. Environmentally Friendly Materials***

The significance of electric vehicles lies not only in their operational benefits but also in their use of environmentally friendly materials. While many manufacturers incorporate recycled materials into smaller components, EV manufacturers are leading the way in integrating these materials into the vehicle’s structure.

The shift toward eco-friendly materials not only reduces weight but also significantly minimizes environmental impact during production and usage. Using natural or recycled materials instead of unsustainable ones, such as metals and plastics, is a crucial step toward environmental preservation.

# 4. Geopolitics and Competition

## 4.1 Introduction to the Geopolitics of Electric Vehicles

The geopolitics of electric vehicles (EVs) pertains to their impact on international relations, economies, and state policies, as well as how countries interact and compete for control over resources, technologies, and markets. Oil has played a pivotal role in shaping geopolitics for over a century. However, the rise of EVs and the shift towards cleaner energy sources suggest that global dependence on oil may begin to decline, with both expected and unforeseen consequences.

A rapid transition from internal combustion engines to EVs could be highly disruptive, particularly in the current context of rising trade barriers and resource nationalism. The lack of preparedness among countries for a high EV penetration scenario could heighten the risk of geopolitical tensions in the future.

The 20th century was defined by a heavy reliance on fossil fuels for energy production. However, with the advent of climate change and growing concerns about sustainability, the focus has shifted towards cleaner energy forms. As a result, it has been suggested that the 21st century will be the "era of metals." In particular, there is increasing interest in lithium, which, as previously noted, is a critical component in the production of rechargeable batteries used in EVs.

Lithium reserves are highly concentrated in South America, particularly in Argentina, Bolivia, and Chile, collectively known as the "Lithium Triangle." Bolivia holds the largest untapped reserves, estimated at 21 million tons. Argentina possesses 17 million tons of reserves, while Chile accounts for 9 million tons. Australia is the fourth-largest producer, with 6.8 million tons of identified resources. China also has significant lithium resources, estimated at 4.5 million tons (Jaskula, 2020).

## 4.2 Supply Chain and Key Resources

The supply chain of electric vehicles (EVs) can be categorized into three primary stages: upstream, midstream, and downstream. Upstream involves the procurement of raw materials and components essential for vehicle production. This includes the extraction of critical minerals such as lithium and cobalt, alongside the manufacturing of core components like power batteries, electric motors, and control electronics.

Midstream focuses on the processes and activities that occur between the initial raw material production and the final assembly and delivery of vehicles to consumers. This stage is vital for ensuring the efficient operation and availability of EVs in the market. Downstream encompasses services related to charging and post-sales support. This includes charging infrastructure, vehicle financing, insurance, marketing, repair, maintenance, and ultimately, the disassembly and recycling of vehicles.

China and the EU have already identified EVs as a strategic priority and a means to reduce their exposure to volatile oil markets. Projections indicate that by 2028, China and the EU will dominate the global EV market, while the United States may lag behind China. Currently, China leads globally with an estimated 200 GWh of lithium-ion battery production capacity. Chinese companies are actively investing in mines in South America and Australia to maintain their dominant position in the downstream industries and the overall supply chain.

Meanwhile, there is a growing global push towards adopting renewable energy sources. The return of the United States to the Paris Agreement represents a significant step in this direction. Similarly, the European Green Deal has set the groundwork for other nations to follow.

The automotive sector is at the forefront of this transition. Countries like Norway and the United Kingdom have announced bans on the sale of new gasoline and diesel cars by 2025 and 2030, respectively, underscoring the rapid pace of this transformation.

## 4.3 Competition for Access to Strategic Metals and Minerals

The production of electric vehicles (EVs), as well as clean energy technology in general, relies heavily on the availability of various metals, minerals, and rare earth elements (REE). The ongoing race for critical minerals is driven by the demands of the Fourth Industrial Revolution and the push towards decarbonization in response to the climate crisis.

Several major economies have drafted critical materials lists to mitigate these risks, with the U.S. and Japan doing so in 2008, followed by the European Union in

2011. These lists are based on supply chain vulnerabilities and the economic and security implications of potential shortages.

China's rise as a global power and its Belt and Road Initiative (BRI) have heightened stakes in the competition for critical minerals. The BRI aims to connect Eurasia, Africa, and South America through an extensive trade and connectivity network, requiring significant amounts of critical minerals to support technologies like 5G and artificial intelligence. These technologies are pivotal to the next industrial revolution and depend heavily on these minerals.

In response to China's growing influence, the U.S. has taken steps to curb China's access to global markets. Measures include policies to strengthen domestic EV industries, reduce reliance on Chinese supplies, and support research and development. Key initiatives include tax incentives for consumers purchasing domestically manufactured EVs and nationwide investments in charging infrastructure to encourage broader adoption. The U.S. is also exploring alternative sources for rare earths and other critical materials required for EV batteries, focusing on recycling and domestic mining development.

Similarly, Europe is wary of China’s initiative and aims to replace foreign technology with domestic alternatives while expanding its global market presence. These actions underscore the geopolitical dimensions of the race for critical minerals. China currently dominates the upstream and midstream stages of the EV supply chain, accounting for 75% of global lithium-ion battery production and 70% of cathode capacity. Additionally, not all rare earth materials are equally valuable. Light rare earths are more abundant, while heavy rare earths are scarcer, more expensive, and more critical. Establishing a mine takes significant time and capital, often requiring at least a decade.

New technological applications have made rare earths highly sought after, to the extent that China has classified them as a strategic advantage in its industrial and economic development plans. China's national policy aims to shift away from exporting raw rare earth products to producing finished goods domestically. This strategy was evident during the rare earth crisis of 2010 when China initially reduced export quotas by 40% and then "unofficially" boycotted exports to Japan following a territorial dispute near the contested Senkaku/Diaoyu Islands in the East China Sea.

These events sent shockwaves through the international community, fueling fears of unprecedented dependence on a single supplier and concerns over geopolitical conflicts. The perceived crisis led to a sharp increase in rare earth prices and prompted simultaneous complaints to the WTO from the EU, Japan, and the U.S. in 2012, demanding consultations with China over its export restrictions on rare earths, tungsten, and molybdenum.

As the dust settled, it became evident that rare earths exemplify how resource competition may intensify in the future, particularly regarding critical minerals. Over time, the situation has grown increasingly complicated. Current trade wars have undermined the WTO's central role, heightened political rivalries, reduced scientific collaboration, and revealed a stark conflict between China and Western powers (including Japan) over economic and leadership ambitions.

These developments have spurred scholars, researchers, policymakers, and industry experts to identify other critical inputs. Cobalt and lithium, for instance, are also mined in limited geographic locations and are essential to high-tech, green economies, and defense industries.

In the case of rare earths, China maintains dominance in production and supply due to its leading processing capabilities. Enthusiasm for new discoveries has been tempered by the high costs of financing and lengthy development timelines. The only major rare earth mine outside China that the PRC has not invested in is Lynas in Australia. While the industry has made some strides toward substitution, rare earths enhance productivity and efficiency in their applications, and comparable alternatives are not readily available. Scientists are exploring ways to reduce the amount of rare earths used where possible without compromising performance. Nonetheless, China's dominance persists, and its demand for these materials is rapidly increasing. In fact, China became a net importer of many rare earth elements in 2018 for the first time since 1985. In other words, the market is tightening as China imports rare earths from abroad for downstream processing.

The largest deposits of metals and minerals required for renewable technologies are located in vulnerable states with poor governance. For example, the Democratic Republic of Congo (DRC) produces more than half of the world's cobalt and is a major copper producer. The interaction between increased demand for rare earth elements and regional instability is another potential consequence of a high-EV adoption scenario. Some analysts have flagged the risk of cobalt shortages in the early 2020s. In 2016, a Chinese mining company made the largest private investment in the DRC's history in a major copper and cobalt mining company. Other regions, including Africa's political stability, are also likely to be affected by the growing competition for rare earth access.

In 2010, the discovery of vast mineral resources in Afghanistan marked a turning point for the country. Metals such as lithium, copper, cobalt, and rare earth elements, estimated to be worth over $1 trillion, sparked hopes that Afghanistan could emerge as a significant player in the mining industry. However, over a decade later, these resources remain largely untapped. The U.S. withdrawal from Afghanistan has raised concerns about the fate of these minerals, with neighboring countries like China expressing interest in exploiting them. If developed properly, these resources could provide a much-needed boost to Afghanistan's economy and reduce its dependence on foreign aid.

The case of rare earths demonstrates that few governments have articulated, let alone implemented, a robust resource strategy. As a result, China is at least a decade ahead of its international competitors. Moreover, this explains why rare earths made headlines again in 2019 when China hinted at "weaponizing" these elements to leverage its trade dispute with the U.S.

From its side, the EU has published its lists, including rare earths and cobalt, among others, while highlighting the critical importance of lithium for battery technology. In recent years, batteries have emerged as a key strategic industry for the EU's future competitiveness in the transition to more zero- and low-emission vehicles. In this regard, the main objective of the 2018 Strategic Action Plan for Batteries is to position the EU as a leader in this field while preserving jobs. The strategy aims to empower EU citizens further, civilize international relations, and act as a responsible global player.

While Europe imports only small amounts of battery-grade lithium, primarily from Chile, increased demand could lead to supply chain vulnerabilities in lithium-ion battery production. Over 90% of Australia's lithium mineral production is shipped to China, which handles nearly 60% of global lithium processing. Furthermore, Chinese companies hold significant financial interests in foreign companies with mining rights in Australia, Chile, and Argentina. The Chinese battery giant CATL has also announced investments to develop Bolivia's lithium reserves. Acquiring stakes in mining companies and securing a strategic foothold in lithium-rich countries in Africa, Latin America, and the Asia-Pacific region is part of China's lithium supply security strategy. To achieve its ambitions, the European Union must address the transport sector, responsible for 40% of greenhouse gas emissions. Measures under consideration include multimodal mobility, automation, or balancing transportation costs with environmental impacts. Among these, road transport is considered a key activity given its significant share of EU emissions, accounting for approximately 20%.

## 4.4 Energy Security

Energy security has traditionally relied on fossil fuels, particularly oil, which has been a central factor in geopolitics for at least a century. A clear consequence of the rise of electric vehicles (EVs) and the low-carbon transition is the potential reshaping of state-to-state relations and regional dynamics. In Eurasia, a contributing factor to these shifting dynamics will be nations' investments in large-scale energy infrastructure projects, including China’s Belt and Road Initiative (BRI) and the EU’s Connectivity Strategy.

One of the most influential factors in government responses to the electrification of transport is the ongoing transformation of many of the world's largest energy companies, both private and state-owned. International Oil Companies (IOCs) are venturing into the electricity market, with some investing in EV charging infrastructure. Many of these companies have recently acquired battery storage and EV charging firms, anticipating greater growth in the electricity sector compared to oil. Energy infrastructure companies also see the expansion of EVs as an opportunity to counter declining revenues stemming from reduced energy demand and efficiency improvements. For example, Enel, which by some estimates is the world’s largest energy company, had installed nearly 50,000 EV charging points by 2018. This transition marks a significant shift in energy security paradigms, aligning with broader efforts to decarbonize economies and adapt to the evolving energy landscape. 90

## 4.5 Risk of Instability in Oil-Producing Countries

If the trend toward electrification accelerates, countries with economies heavily dependent on oil revenues are likely to see their global influence wane. This decline in international clout could also lead to internal instability, as many of these nations rely on oil sector revenues to fund social programs and subsidies for food and fuel. In a world with decreasing oil demand, countries with low production costs will hold a significant advantage. Conversely, nations with relatively high production costs, which are tied to the revenues needed to sustain competitiveness, will face vulnerabilities earlier and require strategic transition plans. Such countries include Algeria, Angola, Chad, Colombia, Ecuador, Gabon, Iraq, Kazakhstan, Libya, Nigeria, Oman, Turkmenistan, Venezuela, and Yemen.

Several Oil and Gas Companies (O&G) have been grappling with financial challenges in recent years, often relying on capital market borrowing to fund dividend payments to shareholders. Some investors are already withdrawing from fossil fuels and seeking opportunities in other sectors. This trend has led to oil and gas companies trading at low earnings multiples.

There is growing concern within the O&G sector about the sustainability of their business models in light of climate policies and physical impacts. These worries are partly driven by initiatives like the Task Force on Climate-related Financial Disclosures (TCFD). As a response, some oil companies are redirecting their investments toward the energy sector, focusing on renewable energy and electric vehicle (EV) supply chains. This shift highlights an industry-wide acknowledgment of the need for adaptation amid a global transition to more sustainable energy sources.

# 5. Future Developments and Prospects

## 5.1 Electric Vehicle (EV) Growth Forecasts

According to the International Energy Agency (IEA), global sales of electric vehicles nearly doubled in 2021 compared to 2020, reaching 6.6 million units (nearly 9% of total car sales), bringing the total number of electric cars on the road to 16.5 million. Hybrid electric vehicles (HEVs) are not included in this figure as they can operate using both gasoline engines and electric power.

True Car, a digital car marketplace, predicts that by the end of 2024, there will be more electric vehicle models available than ever before, with over 100 different models expected to be on the market. The proportion of electric cars relative to gasoline-powered vehicles is expected to gradually increase:

By 2025, electric vehicles are expected to make up as much as 20% of all new car sales. This figure could rise to 40% by 2030, and by 2040, EVs may account for nearly all new vehicle sales. Electric vehicles will need to become a priority for automakers, lawmakers, and consumers before they can fully replace gasoline vehicles.

### 5.1.2 Fleet Renewal

Fleet renewal refers to how quickly new vehicles replace older ones on the road. Due to the fact that modern gasoline cars have become more durable and longer-lasting, the transition to electric vehicles will take more time. Other factors that influence fleet renewal include urban transportation design and shared mobility services.

### 5.1.3 Automotive Manufacturers' Transitions

Automakers are working on transforming their production from conventional vehicles to fully electric vehicles, but their timelines for this transition vary. Some have committed to ending gasoline car sales by 2035, while others may need until 2045-2050 to complete the shift, unless mandated by law.

This transition will depend heavily on both technological advancements and regulatory pressures, along with consumer demand for sustainable and energy-efficient transportation options.

## 5.2 Legislation, Infrastructure, and Costs

Several U.S. states have enacted laws banning the sale of new gasoline passenger cars by 2035. If this happens at a national level, most passenger vehicles on the road by 2050 could be electric. An increase in electric vehicles means more charging infrastructure will be needed to support them.

The projected exponential growth in the adoption of electric vehicles (EVs) still faces several obstacles with consumers. Some of these challenges include ownership costs, driving habits, and range anxiety, where drivers worry about how far they can travel on a single charge.

Although the total cost of ownership for an electric vehicle is lower than that of a conventional car, the purchase price for an EV in 2021 was about $10,000 higher than the average for conventional vehicles. The installation of home charging stations, battery replacement, and insurance for EVs can also be costly. Ultimately, EV adoption will increase when the purchase and maintenance costs align with those of conventional vehicles.

As more companies and employees embrace remote work, future driving habits and car purchasing decisions could be affected. People who drive less might be less likely to replace an older vehicle and invest in an electric option.

Range anxiety refers to the concern people have about an electric vehicle running out of power and leaving them stranded. This anxiety could decrease as more charging stations become available. It will also be alleviated as batteries become more powerful, and as drivers realize that they typically do not drive long enough distances for range to become a significant issue. If the industry can address these challenges quickly and decisively, the rate of EV adoption could exceed expert predictions.

## 5.3 Geopolitical Reshaping

Despite its economic promises, a rapid transition to electric vehicles (EVs) will have significant geopolitical implications across several key areas. In all scenarios, electric vehicles could act as a catalyst for greater collaboration or a source of conflict.

### 5.3.1 International Trade

Regarding international trade, the integration of global markets into electric vehicles may intensify trade tensions due to the potential disruption of existing industries, particularly in the European Union (EU), the United States, and Japan, where car manufacturing is a significant source of jobs and economic development. Countries that lag behind in the EV and battery sectors might respond by imposing tariffs and other trade barriers, echoing the trade disputes that have emerged in recent years over solar panels. On the other hand, the cost of electric vehicles must quickly decrease for them to realize their full development potential, ensuring a transportation sector aligned with the Paris Climate Agreement. This requires deepening global supply chains and integrating regulatory frameworks and markets to achieve economies of scale. This interdependence is also a priority for achieving climate security goals, including greater international cooperation and climate risk management.

The actual scaling up of electric vehicles means a significant role for policy in supporting innovation and resource efficiency, including better recycling of their materials. The growing demand for EVs could lead to an increase in the trade of vehicles, highly efficient batteries, and other components. Achieving these results will require countries to take steps to eliminate trade barriers for electric vehicles and their components. The benefits from EV trade could be substantial: the global electric vehicle market was about \$120 billion in 2017 and is expected to reach \$567 billion by 2025, growing at a compound annual growth rate (CAGR) of 22%.

A second way in which EVs could impact international trade is through exacerbating trade tensions due to the potential disruption of existing industries, particularly in the EU, the US, and Japan. Job losses could reach up to 3 million, or 25%

in major exporting countries (US, EU, Japan), without retraining programs, due to the extensive internal combustion engine supply chain.

Moreover, electric vehicles could lead to tensions regarding the use of state subsidies to support domestic industries, as well as rules on access to technology and intellectual property rights. If countries with deep-rooted interests and legacy in the car industry struggle to create and adopt the best electric vehicle technologies, this could lead governments to increase, rather than reduce, trade barriers. These developments occur amid growing threats to multilateralism and the World Trade Organization (WTO).

Chinese electric vehicle manufacturers are still planning to sell new models in the United States. Notably, Japan does not impose tariffs on either internal combustion engine vehicles or electric vehicles. Some developing countries have committed to reducing tariffs on hybrid or electric vehicles as part of their national contributions to the Paris Agreement.

The current geopolitical environment increases the risk that major car-producing countries will decide to pursue electric vehicles on their own. In this scenario, countries would not invest in electric vehicles to take a leadership role in an expanding global market but to gain a strategic advantage in terms of reduced dependence on imported vehicles or energy. This scenario could lead to market fragmentation, with each region having different technologies and standards, resulting in fewer overall electric cars, fewer jobs, and less impact on emissions. It could also negatively affect cooperation on other issues, such as energy security or access to resources.

### 5.3.2 Energy Security

As electric mobility advances and reduces global oil consumption, oil-producing nations—many of which are located in politically unstable regions—may face significant declines in public revenue. This shift could have broader implications, potentially altering the geopolitical relationships between energy-producing and energy-consuming countries, including the balance of power between the United States and China. In anticipation of these changes, China designated New Energy

Vehicles (NEVs) as a “strategic emerging industry” as early as 2010. Its investments in EVs reflect not only an ambition to dominate a new technological frontier but also a strategic effort to lessen reliance on the United States for securing global oil supplies.

### 5.3.3 Access to Resources

Without significant technological breakthroughs, electric vehicles will increase the demand for cobalt, nickel, lithium, and other strategic minerals. Access to these resources could become, much like oil, a form of "energy statecraft." Just as control over choke points in the oil supply has long been recognized as a vulnerability for oil-importing nations, including China, China has in turn recognized the increasing demand for minerals required for clean energy technologies as a geopolitical opportunity. Some of the largest reserves of raw materials needed for lithium-ion battery production are located in fragile countries with poor governance records, such as the Democratic Republic of the Congo, which hosts the majority of the world’s cobalt. Without a coordinated effort to build capacity in these countries, the risk of instability and conflict could rise.

Finally, electric vehicles will have cascading impacts with complex geopolitical and potentially even humanitarian consequences that are difficult to predict. The adoption of electric vehicles could eliminate up to $19 trillion in revenues from the oil industry by 2040. This represents a risk not only for oil-producing states but also for global institutional investors, including pension funds, which means it also poses an economic risk to consumers.

# 6. Geopolitical and Economic Impacts on the Global Electric Vehicle (EV) Market

## 6.1 U.S.-China Trade War and Its Impact on the EV

The U.S.-China trade war has had profound implications for the global electric vehicle (EV) supply chain and the broader geopolitical landscape. Two of the world's largest economies, the United States and China are engaged in an ongoing economic and technological rivalry that significantly influences key industries, including the production and distribution of EVs. Given the interdependent nature of global supply chains, any disruption in trade relations between these two economic powerhouses affects not only automakers but also consumers, governments, and the renewable energy transition.

At the core of the EV supply chain is the reliance on critical minerals, such as lithium, cobalt, nickel, and rare earth elements, which are essential for battery production. China dominates the processing and refinement of these minerals, controlling a significant share of the global supply. The United States, on the other hand, is heavily dependent on imports for these materials, making the EV sector particularly vulnerable to trade restrictions, tariffs, and geopolitical tensions. As trade relations between the two countries deteriorate, the risk of supply shortages and price volatility increases, raising concerns about the stability and competitiveness of the U.S. EV market.

One of the most significant aspects of the trade war has been the imposition of tariffs on key industrial goods, including automotive components and battery materials. In response to U.S. tariffs on Chinese goods, China has threatened and, in some cases, implemented countermeasures, including potential export restrictions on rare earth elements. Such a move would have far-reaching consequences, as these materials are essential for the production of EV motors and other high-tech applications. If China were to limit the export of rare earth elements to the United States, American automakers would face supply shortages and increased costs, potentially slowing EV adoption and undermining efforts to transition away from fossil fuel dependence. This move has raised concerns about supply chain stability and increased costs for U.S. and European automakers.

The trade war has also influenced investment decisions in the EV sector. In an effort to reduce reliance on Chinese suppliers the Biden administration introduced the Inflation Reduction Act (IRA) in 2022. This legislation provides tax incentives for EVs but only if their batteries are produced in North America or sourced from U.S. allies. As a result, automakers like Tesla, GM, and Ford are investing in domestic battery However, developing domestic alternatives requires significant investment and time, leaving the U.S. EV industry vulnerable to supply chain disruptions in the short term.

China, in turn, has used the trade war as an opportunity to strengthen its own EV industry and expand its influence in global markets. Chinese automakers, such as BYD and NIO, have benefited from strong government support and access to key raw materials, allowing them to compete aggressively in both domestic and international markets. While U.S. tariffs have sought to limit China's EV exports, Chinese manufacturers have increasingly targeted markets in Europe, Latin America, and Africa, where demand for affordable electric vehicles is growing. This shift has geopolitical implications, as China's dominance in EV production allows it to forge strategic partnerships with countries seeking to accelerate their clean energy transitions.

Another major geopolitical consequence of the U.S.-China trade war is the fragmentation of global supply chains. Instead of a single, integrated EV market, trade barriers have encouraged the development of regional supply networks, with the U.S. and its allies attempting to reduce dependence on China while China strengthens its position in alternative markets. This shift has the potential to reshape the balance of power in the global automotive industry, as new alliances and trade agreements emerge to support EV production outside of China's sphere of influence. For instance, the U.S. has sought to deepen partnerships with Canada, Australia, and countries in South America to secure a more stable supply of lithium and other key materials.

Beyond the direct economic consequences, the trade war has also influenced technological innovation and competition in the EV sector. As access to Chinese supply chains becomes more uncertain, American automakers have accelerated research and development efforts to reduce reliance on scarce materials. Solid-state battery technology, alternative battery chemistries, and recycling initiatives have gained traction as potential solutions to the vulnerabilities exposed by the trade conflict. While these advancements hold promise for the long-term resilience of the U.S. EV industry, they require substantial investment and may not be widely available in the near future.

The geopolitical implications of the U.S.-China trade war extend beyond the EV sector, affecting broader diplomatic and strategic considerations. As the United States seeks to counter China’s influence in global supply chains, the competition over resources and technological leadership is likely to intensify. The trade dispute has also contributed to a broader decoupling of the two economies, raising concerns about long-term economic stability and cooperation in addressing global challenges such as climate change. Given the central role that electric vehicles play in reducing carbon emissions, a prolonged trade conflict that hinders EV adoption could have serious consequences for global efforts to combat climate change.

In 2025, the U.S.-China trade tensions continue to impact the electric vehicle (EV) industry, with tariffs playing a central role in shaping market dynamics. The United States has reinforced its trade policies by maintaining a 100% tariff on imported Chinese EVs, a move designed to protect domestic manufacturers from what is perceived as unfair competition. This decision stems from concerns that Chinese automakers, heavily supported by government subsidies, are flooding the market with competitively priced EVs, putting American companies at a disadvantage. The tariff aims to limit China's growing influence in the global EV sector and encourage the development of domestic production capacity in the U.S.

In response to these U.S. trade policies, China has implemented additional tariffs on American-made vehicles. Specifically, Beijing has introduced a new 10% duty on vehicles with engines larger than 2.5 liters, adding to the existing 15% tariff. While this measure primarily targets traditional internal combustion engine (ICE) vehicles, it reflects the broader economic tensions between the two nations. The additional tariff increases costs for American automakers exporting to China, making it more challenging for brands like Tesla and General Motors to maintain a competitive position in the Chinese market, which remains one of the largest and most lucrative for EVs.

Chinese EV manufacturers, particularly BYD, have responded strategically to these trade barriers. Rather than relying on exports to the United States, BYD has shifted its focus to expanding its global presence in alternative markets. The company has announced plans to double its overseas sales to 800,000 units by the end of 2025, targeting regions such as Britain, Latin America, and Southeast Asia. To circumvent tariffs and reduce operational costs, BYD is also exploring the establishment of local assembly plants in these markets. This approach allows the company to maintain competitive pricing and avoid trade restrictions that could hinder its growth.

In conclusion, the U.S.-China trade war has significantly disrupted the electric vehicle industry, introducing economic and geopolitical uncertainties that influence global supply chains, investment strategies, and technological advancements. The global shift toward sustainable transportation depends not only on technological advancements but also on the ability of nations to navigate complex economic and political relationships while ensuring stable access to critical raw materials and components.

## 6.2. Inflation and Rising EV Production Costs

### 6.2.1 Rising Energy and Material Costs

The electric vehicle (EV) industry has faced significant challenges in recent years, driven in large part by rising energy and material costs, which have been exacerbated by geopolitical events such as Russia's invasion of Ukraine. The ongoing conflict has disrupted global supply chains, particularly in the energy and raw material sectors, with ripple effects felt throughout industries reliant on these inputs, including the EV sector. The consequences of these disruptions are multifaceted, influencing both the cost structure of EV production and the broader economic environment in which the industry operates.

One of the most direct impacts of the geopolitical tensions is the sharp increase in energy costs, particularly in Europe, which has traditionally relied on Russian natural gas supplies. The disruption of these supplies following Russia's invasion has led to higher electricity prices across the continent. As electricity prices surged, manufacturers faced increased operational costs, particularly for energy-intensive processes such as battery production. Battery manufacturing is crucial to the EV industry, as batteries are the most expensive component of an electric vehicle. The rising energy costs have increased the production costs of batteries, subsequently driving up the overall cost of electric vehicles. These higher production costs are particularly problematic for automakers striving to meet consumer demand for more affordable EV options while also addressing the increasing competition in the EV market.

In addition to energy costs, material costs, particularly for the raw materials essential for battery production, have experienced significant fluctuations. Materials such as lithium, nickel, cobalt, and rare earth metals are integral to the production of EV batteries. These materials have seen dramatic price increases in recent years, driven by a combination of supply chain disruptions, rising demand, and geopolitical factors. While lithium prices, for example, saw a peak in 2022, they have since shown some volatility, with demand expected to continue fluctuating based on the broader dynamics of the EV market. Despite the recent decline in lithium prices, the cost of these materials remains a significant concern for the EV industry. The price volatility of key materials is not only impacting battery manufacturers but is also creating uncertainty for automakers, who are now faced with the challenge of managing these fluctuating costs while maintaining profitability and competitive pricing.

The impact of rising material costs is further compounded by the competition for access to these critical resources. As global demand for electric vehicles continues to rise, the demand for these materials is expected to increase as well. Many automakers are looking to secure long-term contracts and establish partnerships with mining companies to ensure stable access to these materials, but such arrangements are often costly and complex. In some cases, automakers may be forced to pass these increased costs onto consumers, further driving up the cost of EVs and potentially slowing adoption rates.

The rising energy and material costs are also affecting the broader EV ecosystem, including the development of infrastructure such as charging stations. The cost of electricity, coupled with material price increases, impacts the affordability and feasibility of expanding EV charging networks, which are essential for supporting the widespread adoption of electric vehicles. In regions heavily impacted by rising energy costs, the growth of charging infrastructure may be slowed as local governments and private companies reassess their investment strategies in the face of higher operational costs.

In recent years, the electric vehicle (EV) industry has seen a notable shift towards the use of lithium iron phosphate (LFP) batteries, driven primarily by the need to reduce production costs and enhance vehicle affordability. Unlike traditional battery technologies, such as nickel cobalt aluminum (NCA) and nickel manganese cobalt (NMC), LFP batteries utilize a more abundant and cost-effective material, which helps lower the overall manufacturing costs of EVs. The use of LFP batteries eliminates the reliance on expensive and ethically problematic materials like cobalt, which has been a significant concern in the automotive industry due to its environmental impact and mining conditions. This shift not only addresses the demand for more affordable EV options but also aligns with sustainability goals, as LFP batteries are seen as a more environmentally friendly alternative.

Several major automakers have adopted LFP technology in their electric vehicles to cater to a broader market. Tesla, for example, has incorporated LFP batteries in some of its Model 3 variants, offering a lower-priced option that remains competitive in terms of performance and range. Other automakers such as Ford and Volkswagen have followed suit by introducing LFP-equipped versions of their popular EVs, including the Mustang Mach-E. This adoption is driven by the desire to increase accessibility to electric vehicles by reducing the upfront cost for consumers, which is often a significant barrier to widespread EV adoption.

To mitigate these challenges, automakers and policymakers alike are exploring strategies to reduce energy consumption and improve the efficiency of battery production. Innovations in battery technology, such as the shift toward alternative battery chemistries like Lithium Iron Phosphate (LFP) batteries, may help reduce dependence on more expensive or scarce materials like cobalt and nickel. Additionally, there is growing interest in developing more sustainable and cost-effective methods for sourcing and recycling critical raw materials. However, the transition to these new technologies and practices will take time, and the industry will likely continue to face pressure from rising energy and material costs in the near term.

The transition to LFP batteries marks a significant milestone in the evolution of the electric vehicle industry. By offering a cost-effective, safer, and longer-lasting alternative to traditional battery technologies, LFP batteries address key challenges faced by automakers and consumers alike. While the lower energy density of LFP batteries remains a consideration, ongoing developments in battery technology are expected to mitigate these concerns. As the global demand for electric vehicles continues to grow, LFP batteries are poised to play a crucial role in accelerating the widespread adoption of sustainable transportation solutions. Chinese companies like BYD and CATL are leading in LFP battery production, which is giving them a competitive edge over Western automakers.

In conclusion, rising energy and material costs pose significant challenges to the electric vehicle industry, driving up production costs and creating uncertainty for both manufacturers and consumers. The geopolitical events, particularly Russia's invasion of Ukraine, have exacerbated these challenges by disrupting energy supplies and materials markets, affecting not only the cost of EVs but also the broader efforts to scale up production and infrastructure. While the industry is exploring alternative technologies and solutions to address these issues, the short-term outlook remains complex, and stakeholders will need to navigate these rising costs carefully to ensure the continued growth and sustainability of the EV sector.

### 6.2.2 Higher Interest Rates and Financing Costs

The rise in interest rates up to 2023 and the subsequent increase in financing costs have become significant factors influencing the electric vehicle (EV) market, impacting both manufacturers and consumers. In response to rising inflation, central banks, such as the U.S. Federal Reserve and the European Central Bank, have implemented a series of interest rate hikes. These measures, aimed at curbing inflationary pressures, have had a direct effect on the cost of borrowing, making it more expensive for both businesses and consumers to finance purchases, including the acquisition of electric vehicles.

For automakers, higher interest rates translate into increased costs for financing new EV infrastructure projects, such as the construction of battery factories and charging networks. Developing the necessary infrastructure to support the widespread adoption of electric vehicles requires significant investment. The rising costs of financing these projects, driven by higher interest rates, have made it more challenging for manufacturers to expand their EV production capacity and establish the requisite charging networks. As a result, automakers may face delays in meeting their production targets or expanding EV offerings to meet growing demand, ultimately impacting their ability to capture market share in the increasingly competitive EV sector.

For consumers, the effects of higher interest rates are perhaps even more pronounced. Many potential EV buyers rely on financing to make the purchase, whether through loans, leases, or other credit options. The rising interest rates have made borrowing more expensive, increasing monthly payments for those seeking to finance their vehicle purchases. As the cost of credit increases, consumers face higher overall vehicle prices, which may lead some to reconsider or delay their EV purchase decisions. This is particularly true for individuals with lower credit scores or those seeking to secure financing for higher-priced EV models, which tend to have larger loan amounts and longer repayment periods.

In addition to the increased financing costs, consumers are also contending with higher overall costs for goods and services, which reduces disposable income. The persistent global supply chain disruptions, exacerbated by geopolitical events such as the COVID-19 pandemic and Russia's invasion of Ukraine, have contributed to the rising costs of manufacturing materials, including raw materials for EV production. As a result, automakers have been forced to adjust their pricing, pushing EVs further out of reach for budget-conscious buyers.

In conclusion, the combination of economic uncertainty, rising financing costs, and increased living expenses has led to a postponement of electric vehicle purchases by many consumers. While the long-term benefits of owning an EV, including savings on fuel and lower maintenance costs, remain attractive, the current economic conditions are making it harder for consumers to commit to such purchases. Automakers will need to carefully navigate these challenges by offering more affordable options and flexible financing plans to retain consumer interest and foster continued growth in the electric vehicle market.

## 6.3 The War in Ukraine and Its Impact on the EV Industry

The ongoing war in Ukraine has had profound implications for the global economy, with notable consequences for several industries, including the electric vehicle (EV) sector. The conflict, which began in early 2022, has caused significant disruptions in supply chains, particularly in relation to critical raw materials and energy resources vital for the production of electric vehicles. This war has not only affected the geopolitical landscape but also accelerated the challenges and complexities faced by the EV industry in securing the necessary resources for continued growth and innovation.

One of the most immediate impacts of the war on the EV industry has been the disruption of supply chains for key materials used in the production of electric vehicles, such as lithium, cobalt, nickel, and palladium. These materials are crucial for the manufacturing of batteries, which are at the core of electric vehicle technology. Ukraine itself is known to have substantial reserves of critical minerals, including lithium and nickel, which are in high demand as the world transitions toward clean energy. The Russian invasion has caused significant damage to Ukrainian mining infrastructure, thus reducing the global supply of these vital minerals.

Moreover, the war has led to heightened tensions in the international market, with the imposition of sanctions on Russia, a major global supplier of nickel and palladium, further exacerbating the challenges facing the EV sector. These sanctions have created volatility in metal prices, which in turn has led to increased production costs for electric vehicles. As a result, many automakers have faced rising costs for manufacturing EVs, which has been passed on to consumers in the form of higher prices for electric vehicles, further slowing the pace of adoption among consumers who are already grappling with inflationary pressures and economic uncertainty.

Another significant consequence of the war has been its effect on energy prices, particularly oil and natural gas. While the EV industry has long been seen as part of the solution to reducing dependence on fossil fuels, the sharp increase in global energy prices has heightened the urgency of transitioning to renewable energy. This shift in focus has made it more difficult for some governments to invest in the infrastructure needed to support the EV transition. In the European Union, for example, the rising cost of energy has prompted calls for a more balanced approach to energy security, which may delay or alter the implementation of policies designed to promote EV adoption and the development of supporting infrastructure such as charging stations.

In conclusion, the war in Ukraine has significantly impacted the EV industry in various ways. The disruption of supply chains for critical raw materials, the volatility of energy prices, and the shifting geopolitical dynamics have all posed significant challenges to the growth of the electric vehicle sector. However, these challenges have also highlighted the importance of transitioning to cleaner and more sustainable energy sources, underscoring the need for continued investment in the EV industry. The full impact of the war on the electric vehicle sector is yet to be seen, but it is clear that the ongoing conflict will play a pivotal role in shaping the future of the global automotive market and the broader clean energy transition.

### 6.3.1 Acceleration of Renewable Energy and EV Adoption in Europe

The energy crisis in Europe, triggered by Russia's invasion of Ukraine and the subsequent disruption of Russian gas supplies, has had profound implications for the region's energy strategy and transportation sector. Europe's heavy reliance on Russian gas for both domestic energy consumption and industrial needs made the region particularly vulnerable when Moscow cut off gas supplies. This crisis underscored the urgent need for Europe to accelerate its transition to more sustainable and secure energy sources. As a result, European Union (EU) nations have intensified their investments in renewable energy, including wind, solar, and nuclear power, as part of a broader strategy to reduce reliance on external energy imports and to meet climate goals.

One of the most significant shifts resulting from this energy crisis has been the accelerated pace of renewable energy investments across the EU. With the cessation of Russian gas supplies, Europe has faced an urgent imperative to diversify its energy sources and reduce its vulnerability to geopolitical shocks. As a result, EU countries have increasingly prioritized the development of renewable energy infrastructure. Wind and solar power have seen a surge in investment, given their potential for scalable and low-cost energy production. Furthermore, nuclear energy, once considered a contentious source of power in many European countries, has seen renewed interest as a reliable, low-carbon energy source capable of providing baseload power. These efforts are not only aimed at energy security but also at decarbonizing the energy sector, which is a key component of the EU's broader climate strategy to achieve carbon neutrality by 2050.

This shift toward renewable energy sources has also had a direct impact on the transportation sector, particularly the adoption of electric vehicles (EVs). Prior to the energy crisis, Europe had already been making strides toward the adoption of EVs as part of its long-term goal to reduce carbon emissions from the transportation sector. However, the energy crisis has given additional impetus to the transition away from fossil fuels, and EU nations have made the rapid adoption of EVs a priority. Reducing reliance on oil imports, particularly from unstable or geopolitically contentious regions, has become a key focus for European policymakers. By encouraging the adoption of EVs, the EU aims not only to address energy security concerns but also to reduce the environmental impact of the transportation sector, which is one of the largest contributors to greenhouse gas emissions in Europe.

The accelerated push for EVs is also supported by a range of policy measures, including subsidies, tax incentives, and regulations aimed at reducing the carbon footprint of new vehicles. The European Green Deal, which outlines the EU's roadmap for achieving carbon neutrality, has set ambitious targets for the transportation sector, including a significant increase in the share of EVs in new vehicle sales. Moreover, EU nations have increasingly invested in EV infrastructure, such as charging stations, to ensure that the adoption of electric vehicles is supported by the necessary infrastructure for everyday use. This infrastructure expansion is crucial to addressing one of the key barriers to EV adoption: range anxiety, or the fear that drivers will not be able to find a charging station when needed.

Additionally, the transition to EVs has been seen as an opportunity to boost local economies and create jobs, particularly in the renewable energy and automotive sectors. By fostering innovation in battery technologies, renewable energy generation, and clean transportation infrastructure, European countries have positioned themselves as leaders in the green economy, attracting investment and promoting technological advancements that will help drive further adoption of EVs.

However, the shift toward renewable energy and EV adoption is not without challenges. The transition to renewable energy requires significant upfront investments in infrastructure and technological development, particularly in the areas of energy storage and grid modernization. While wind and solar energy have become increasingly cost-competitive, their intermittency still presents challenges for grid reliability, necessitating further investments in energy storage technologies such as batteries and pumped hydro storage. Furthermore, the rapid growth of the EV market requires a corresponding increase in the availability of raw materials such as lithium, cobalt, and nickel, which are essential for battery production. The demand for these materials has surged, leading to concerns over supply chain sustainability and the environmental impact of mining practices.

In conclusion, the energy crisis resulting from Russia's invasion of Ukraine has been a turning point for Europe, accelerating the transition to renewable energy and electric vehicles. With the EU facing an urgent need to reduce dependence on Russian energy imports, investments in wind, solar, and nuclear power have been ramped up, and the adoption of electric vehicles has been prioritized. These changes are not only aimed at ensuring energy security but also at reducing the carbon footprint of the transportation sector and achieving the EU's climate goals. While challenges remain, particularly in terms of energy storage and the supply of critical materials for EV batteries, Europe’s response to the crisis has reinforced its commitment to a sustainable and secure energy future. The future of the EV industry in Europe is likely to be shaped by ongoing investments in renewable energy, infrastructure, and technological innovation, with long-term implications for both energy policy and the global automotive market.

## 6.4. The Israel-Gaza War and Middle Eastern Instability

Although the war between Israel and Hamas in Gaza does not directly impact EV manufacturing, broader Middle Eastern instability has several indirect effects on the market. The Israel-Gaza war, coupled with broader Middle Eastern instability, has far-reaching implications not only for regional politics but also for global economic sectors, including the electric vehicle (EV) industry. The conflict, which has endured for decades and flared up in various forms, continues to shape the geopolitical landscape of the Middle East. While its direct effects on the EV industry may not be as immediately apparent as those of other global crises, the interconnectedness of global energy markets, mineral supply chains, and international trade means that this ongoing instability does indeed intersect with the geopolitics of electric vehicles.

One of the key aspects of the relationship between the Israel-Gaza conflict and the EV industry lies in the broader instability of the Middle East, particularly in relation to energy markets. The Middle East has long been a critical region for global oil and gas production, with countries like Saudi Arabia, Iran, and Iraq serving as major suppliers. Although the world's transition to renewable energy and electric vehicles reduces the overall reliance on fossil fuels, the oil market remains a critical component of the global economy. Any escalation in conflict or disruption in the Middle East has the potential to send shockwaves through oil markets, thereby affecting global energy prices, including those of natural gas, which is used in power generation. Such fluctuations in energy prices can indirectly impact the EV industry, particularly in terms of the competitive landscape between electric vehicles and traditional internal combustion engine (ICE) vehicles.

For example, higher oil prices, often a result of Middle Eastern instability, can make electric vehicles more attractive as consumers seek alternatives to rising fuel costs. In contrast, the political volatility in the region can also slow the pace of renewable energy development or disrupt supply chains for critical minerals and raw materials needed for the production of EVs. This can create a delicate balancing act for governments and industries seeking to transition to clean energy, as they must navigate the pressures of energy security while simultaneously pushing for cleaner alternatives like electric vehicles.

# 7. Conclusion - Discussion

As with any transition, there will inevitably be challenges along the way, but the shift to electric vehicles (EVs) can be managed either positively or negatively. With greater attention from the international community, EVs can enhance energy security, improve air quality, reduce climate risks, and strengthen rule-based international cooperation.

The review of relevant trends and available forecasts suggests that EVs are highly likely to account for a growing share of car sales in the coming decades, across nearly every scenario. Given technological trends like digitization, governments' increasing awareness of the need to manage climate change risks and air pollution, and changing consumer preferences, there is reason to believe that the electrification of the transport sector could happen more quickly than most traditional stakeholders predict. History shows that rapid energy or technological transitions can be highly disruptive, and the level of interconnectedness in the global economy today only amplifies these risks.

The rapid global adoption of electric vehicles would have extensive impacts, stretching across trade, security, the economy, and society. There would be implications for global supply chains, including car markets and the availability of rare earths and other resources. Secondary and tertiary effects would also likely arise from declining revenues and taxes in oil-producing countries. With increased electrification comes greater interconnectedness and possibly interdependence. Control over electricity grids and storage capacity could become more important than controlling fossil fuel resources, but it would also introduce new cyber risks.

Changes in national energy strategies, private sector investments, and the recognition of climate risks—especially in the financial sector—are already influencing the foreign policies of the world's major powers. The EU's Global Strategy and its increasing focus on strengthening resilience in its neighborhood have been heavily impacted by the need to address several vulnerable states at its borders, which are at risk of instability as oil revenues decline and instability rises. China shares similar concerns regarding Russia, which depends on fossil fuels for half of its exports. If oil loses its strategic significance, it is likely that battery production will rise in importance, though countries are already preparing for this scenario. China supports EVs not only to address energy security but also to dominate technology markets and strengthen diplomatic relations with countries that have clean energy goals. France and Germany both have plans to boost battery production for EVs, largely in response to the market dominance of Asian battery companies. It’s important to note that in both scenarios, China and the EU will hold the largest share of the EV market by 2030, despite the historical leadership of the US in battery innovation.

Other forecasts suggest that Europe will surpass the United States as the second-largest EV market in the 2020s. A world where batteries replace oil as the main geopolitical driver, but where the US falls behind China and the EU in this market, would look very different.

If demand were to rise significantly in a high EV usage scenario, two potential geopolitical impacts are worth considering. First, access to these materials could be used, much like oil, for energy "diplomacy." Just as control over oil supply chokepoints has long been recognized as a vulnerability for oil-importing nations, including China, China has recognized the increasing demand for the metals and minerals required for clean energy technologies as a similar geopolitical opportunity.

It remains to be seen whether rare earth elements and other minerals will hold the same level of geopolitical influence as oil has for decades. Most of the rare gases and other elements used in clean technologies are not truly "rare," but are considered difficult to produce. The market operates cyclically—meaning when demand rises, investment increases, which ultimately leads to an increased supply. A recent analysis by the International Renewable Energy Agency (IRENA) underscores the reasons to believe that it will be harder to use minerals for political leverage—such as ongoing efforts to produce cobalt-free batteries and the opportunities presented by recycling to boost the supply of these elements. Historical experience with resource competition and the vulnerabilities of producing countries suggests that this issue needs to be approached carefully and requires states to invest in international cooperation around governance and institutional frameworks for mining and exporting resources.

According to Aurora Energy Research, the adoption of electric vehicles could eliminate $19 trillion from the oil industry by 2040. Such a loss in revenue would also mean reduced tax income for governments dependent on the oil industry. This would impact institutional investors and pension funds and, ultimately, could have human security implications if not properly managed. Only 5% of pension funds in the UK have a climate change policy despite being exposed to both physical and transition risks related to climate change. Moreover, these need not necessarily be immediate impacts—even the perception of future risks could lead to economic shocks. One study has shown that without measures to limit global temperature increases to 2°C, a typical pension fund could incur losses of 25% within five years after an economic shock.

The market capitalization of oil and gas companies remains significant, close to $4.65 trillion, and is widely held by institutional and other investors. However, there are signs this is changing: The Norwegian Sovereign Wealth Fund, the largest in the world, recently announced it would stop investing in oil and gas exploration to reduce its exposure to oil prices. This follows other commitments by development funds to end investments in fossil fuel extraction. Around a thousand institutional investors, with a combined value of $6 trillion, have committed to withdrawing their investments from fossil fuels. These moves, combined with other structural changes, including rising competition from National Energy Companies, create potential risks of abandonment for oil companies, leading to significant value losses for private and public investors. This corresponds to public policy concerns about economic instability.

In conclusion, a combination of economic factors, supply chain issues, market dynamics, strategic priorities, and technological parameters are influencing major car manufacturers to moderate their EV production plans and pushing them to develop internal combustion engines that run on natural gas or hydrogen to meet different market needs and conditions.

The electric vehicle market is increasingly shaped by geopolitical and economic factors. While trade wars, inflation, and global conflicts pose short-term challenges, they may ultimately accelerate the transition to EVs due to:

- The push for energy independence (reducing reliance on fossil fuels)
- The development of regional battery supply chains in the U.S. and Europe
- The shift to alternative battery technologies (LFP) to reduce costs

In conclusion, while the EV industry faces significant headwinds due to geopolitical uncertainties, the long-term outlook remains positive. With continued government support, technological innovation, and strategic adjustments by automakers, the shift to electric vehicles will likely accelerate in the coming years. However, the path forward will require careful management of supply chain risks, market volatility, and economic pressures to ensure the successful and equitable adoption of electric vehicles worldwide. As the global demand for cleaner, more sustainable transportation grows, the evolving geopolitical landscape will continue to shape the trajectory of the EV market, making adaptability and resilience key to its future success.

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