Comparison of the Chinese, European and American regulatory frameworks for the transition to a decarbonized road mobility

Provide a clear, objective assessment of the current situation of the electric vehicle industry in order to identify the root causes and draw lessons for Europe

Report written by Marc Alochet, research associate at the Management Research Center (CRG) of the École Polytechnique, under the scientific supervision of Christophe Midler, CNRS research director emeritus.

Issue date: December 11, 2023

Foreword

Environmental crises are forcing societies to make socio-economic transitions of a new kind. The last decade has clearly shown that this type of transition cannot take place within existing regulatory frameworks and markets. Indeed, it requires the simultaneous and interactive reinvention of supply and demand, creating "chicken and egg" situations that block innovation trajectories.

This research aims to analyze such a transition through the emblematic case of the transition of automotive mobility from internal combustion engine vehicles to electric vehicles.

Initially based on a questioning of European automakers faced with this transition, this research is, in our opinion, of much broader interest, given the amplitude of the systemic transitions underway: mobilization of long value chains, from raw materials used in batteries to automakers; strong interactions within heterogeneous ecosystems, in particular from energy to infrastructure; questioning, on the customer side, of mobility values and practices...

This case study is also interesting for two reasons. On the one hand, the transition is already underway, which allows to base our research on empirical data with historical depth to shed light on the dynamics of public intervention and the resulting impact on the sector.

On the other hand, given the global nature of the automotive industry, we can compare how political and administrative contexts as different as those of China, Europe and the US are contributing to the transition to electric vehicles. Beyond knowing the situation of these different actors, which is in itself an important result for a global industry, this research allows to understand the mechanisms at work in this transition to electric vehicles and to draw general guidelines for the future.

Marc Alochet and Christophe Midler

December 2023

Abstract

The electrification of mobility goes far beyond the mere conversion of thermal to electric powertrains and covers the entire lifecycle of a Plug-in Electric Vehicle (PEV). This is a systemic innovation which involves the automotive industry and related sectors such as mining, chemicals, electric powertrain and battery pack manufacturing, energy, battery waste collection and recycling. This is a very complex transition, which is challenging the balance of the traditional automotive industry at global, regional and national levels.

Through a comparative analysis – across all key stages of the EV lifecycle – of Chinese, European, and US regulations that promote the transition to decarbonized road mobility, and an assessment of the dynamics of their respective industries in implementing these regulations, this report has four main objectives.

The first is to provide a clear and objective assessment of the current situation of the Chinese, European and American automotive industries.

The second aims to identify the reasons that led to this situation and to draw lessons from them, while the third aims to summarize how European and US industries, involved in the transition to the electric mobility, have positioned themselves. The fourth summarizes the threats facing the European automotive industry during this crucial transition for its future.

Lastly, this report formulates general guidelines for achieving decarbonization targets and restoring the competitiveness of the automotive industry so important for the economy in Europe.

Table of contents

List of Sidebars v

List of Acronyms vi

1. Executive Summary 1

2. Ongoing transition context and current situation assessment 3

3. Analysis of Chinese, European and US regulations driving the transition to the decarbonized road mobility 8

   3.1. Key takeaways 9

   3.2. Chinese regulations 14

   3.3. European regulations 32

   3.4. US regulations 46

4. Comparison of the dynamics of electric mobility industrial sectors in China, Europe and the United States 54

   4.1. Key takeaways 55

   4.2. Extraction of raw materials and refining 57

   4.3. Manufacturing of battery packs, (modules), cells and main components 59

   4.4. Production of vehicles 62

   4.5. Charging network 63

   4.6. Recycling and reuse of battery critical materials 65

5. What are the main threats to the European automotive industry? 69

6. Conclusion 70

7. Appendices on the dynamics of the electric mobility industry 74

List of Sidebars

Sidebar 2-1 : Key takeaways from the ongoing transition context and current situation assessment 7
Sidebar 3-1: Key differences in the governance of the transformation of the industry between China, the U.S. and Europe 10
Sidebar 3-2 : What is “Administered Darwinism”? 11
Sidebar 3-3: Evaluation of (supra)national public financial support in China and Europe for electric mobility through 2022 and USA through 2021 12
Sidebar 3-4 : Evaluation of yearly (supra)national financial public support in China, USA and Europe for electric mobility from 2023 onwards 13
Sidebar 4-1 : What are the main strengths developed so far by automakers operating in Europe? 55
Sidebar 4-2 : Current situation of the European and US industries at each stage of the value chain 56
Sidebar 4-3 : CATL, an example of “specialized vertical integration” 62

List of Acronyms

Acronym	Significance
AFIF	Alternative Fuel Infrastructure Facility (Europe)
AFIR	Alternative Fuel Infrastructure Regulation (Europe)
BEV	Battery Electric Vehicle
CAFC	Corporate Average Fuel Consumption (China)
CAFE	Corporate Average Fuel Economy (USA and Europe)
CAM	Cathode Active Materials
CARB	California Air Resources Board (USA)
CATC	Chinese Automotive Test Cycle (China)
CEF	Connecting Europe Facility for transports (Europe)
CFI	Charging and Fueling Infrastructure Discretionary Grant Program (USA)
CRMA	Critical Raw Material Act (Europe)
DOE	Department Of Environment (USA)
EBA	European Battery Alliance (Europe)
ERMA	European Raw Materials Alliance (Europe)
EPA	Environmental Protection Agency (USA)
EPR	Extended Producer Responsibility (all regions)
FEOC	Foreign Entity Of Concern (USA)
FTA	Free Trade Agreement
ICEV	Internal Combustion Engine Vehicle
IIJA	Infrastructure Investment and Jobs Act (USA)
IPCEI	Important Project of Common European Interest (Europe)
IRA	Inflation Reduction Act (USA)
LDV	Light Duty Vehicle
LFP	Lithium Ferro Phosphate CAM
MIIT	Ministry of Industry and Information Technology of China
MOF	Ministry of Finance of China
MOST	Ministry Of Science and Technology of China
NHTSA	National Highway Traffic Safety Administration (USA)
NDRC	National Development and Reform Commission of China
NEV	New Energy Vehicle (China). At the origin, all alternative fuels. Now PHEV, BEV and FCEV
NEVI	National Electric Vehicle Infrastructure formula program (USA)
NMC	Nickel Manganese Cobalt CAM
NZIA	Net Zero Industry Act (Europe)
PEV	Plug-in Electric Vehicle, namely PHEV plus BEV
PHEV	Plug-in Hybrid Electric Vehicle
ROO	Rules Of Origin (EU-UK Trade and Cooperation Agreement)
SAFE	Safer Affordable Fuel-Efficient for vehicles (USA)
SASAC	State-owned Assets Supervision and Administration Commission of the State Council (China)
USMCA	United States-Mexico-Canada Agreement (USMCA) entered into force on July 1, 2020
WLTC	World harmonized Light-duty Test Cycle
ZEV	Zero Emission Vehicle, namely BEV, FCEV and ICEV using CO2 neutral fuel

1. Executive Summary

The electrification of mobility goes far beyond the mere conversion of thermal to electric powertrains and covers the entire lifecycle of a Plug-in Electric Vehicle (PEV). This is a very complex transition and a systemic innovation which involves the automotive industry and related sectors such as mining, chemicals, electric powertrain and battery pack manufacturing, energy, battery waste collection and recycling.

It is challenging the traditional balance of the global automotive industry. By the end of 2022, China accounted for 57% of the global share of sales, 60% of the global electric vehicle fleet, and 75% of global battery production capacity. Global players, who largely dominate ICEV technology, are now forced to catch up with Chinese electric vehicle manufacturers.

China's virtually unchallenged dominance to date is the result of a longstanding effort that began with the development of a rare earths value chain in the 1960s and the New Energy Vehicle (NEV) industry in the 1990s. It was fueled by:

- The Chinese government's strategic determination to transform the world's leading auto manufacturer into the country that dominates the global auto industry (Made in China 2025).
- A focus on BEVs since 2012.
- The promulgation of regulations to force vehicle performance improvements and increased sales year after year and the implementation of a "*Administered Darwinism*"[1] to select the national (and future global) champions who will lead the industry.
- Large and simultaneous investments (at least €110-160 billion by 2022) in all the industries involved in the PEV lifecycle, from raw material mining to battery recycling.
- Use of protectionism whenever it was necessary to help Chinese companies to overtake foreign competitors.

In the US, the current momentum, if not abruptly halted following the 2024 election results, could lead to the creation of a very active manufacturing hub for the PEV value chain before the end of this decade thanks to:

- The ambitious BEV and PHEV sales targets set at the federal level and in California[2].
- The high level of funding provided by the Infrastructure Investment and Jobs Act (IIJA) and Inflation Reduction Act (IRA) to all stages of the PEV value chain (around €10 billion per million vehicles sold per year for <u>production and clean vehicle credits alone</u> between 2023 and 2032).
- The IRA and IIJA direct and immediate incentives to locally produce the components of the battery value chain and PEVs. The IRA, which combines tax relief with domestic content, confirms the protectionist tendency of the US, mainly to the potential detriment of Europe.

At a time when European automakers are heavily dependent on the Chinese battery value chain, Europe, the target of Chinese exports of high-value PEVs, has gaps in its regulatory framework to achieve the highly ambitious goal of 100% ZEV by 2035:

- The forthcoming application of Euro 7, as originally proposed by the Commission, would divert funds from PEV development and could lead to the premature disappearance of ICEVs. The lack of compromise so far between the European institutions on future emission limits and testing procedures creates uncertainty for the industry and could jeopardise its future.
- The lack of a systemic and coordinated approach to the regulatory framework leading to vehicle electrification. Most of the key regulations affecting the PEV value chain, have been proposed or entered into force only in 2023 while "Fit for 55" was first proposed in 2021. By setting a goal without defining how to achieve it, the Commission has put the cart before the horse.
- The benchmarks used to develop and localise the battery value are not ambitious enough to compete with other regions (e.g.: at least 40% raw material processing capacity by 2030, while the IRA requires 50% in 2024 to qualify for the tax credit).

From an industry perspective, we observe that:

- All European automakers are now present at every stage of the PEV value chain and are implementing the complicated ZEV scale-up that lies ahead.
- The impetus given to the production of battery cells by European champions could be bearing fruit as we estimate a production capacity of 1.1 TWh by 2030, with European, Korean and Chinese battery manufacturers taking 44%, 27.5% and 26.8% of the market share respectively.
- The current pace of development in the European upstream battery value (materials processing and components production) chain is not sufficient to quickly reduce dependence on China.

In the very short term, the European Commission should consider developing ad hoc regulatory and financial frameworks to ensure a level playing field between different regions and to give more impetus to the electric car industry.

At the same time, member states must be prepared to continue supporting market uptake through financial and/or non-financial incentives while European automakers will need to show *organizational ambidexterity*[3] to both continue to sell profitable ICEVs and rapidly develop high-value BEVs' to compete with Chinese automakers.

---

[1] The innovation odyssey, lessons from an impossible project. Midler, C, Alochet, M, de Charentenay C, Taylor & Francis (2023)
[2] The state of California has the authority to enforce its own regulations on emissions from ICEVs and each U.S. state can choose to follow federal or California regulations. 17 states accounting for about 40% of new LDV sales plan to adopt Californian regulations
[3] Organizational ambidexterity refers to an organization's ability to compete in mature technologies and markets where efficiency, control, and incremental improvement are valued, and also to compete in new technologies and markets where flexibility, autonomy, and experimentation are required. O'Reilly III, C. A., & Tushman, M. L. (2013). Organizational ambidexterity: Past, present, and future. *Academy of management Perspectives*, *27*(4), 324-338.

2. Ongoing transition context and current situation assessment

Sales figures for passenger cars and light commercial vehicles in 2022 show a rapid and massive increase in sales of battery-electric and plug-in hybrid vehicles (PEVs[4]). At a time when, under the multiple effects of a highly uncertain geopolitical and economic context, the global market is showing a very strong downward trend, sales of PEVs have risen by 55% compared with 2021, reaching a total of around 10.5 million.

This very significant growth in sales of PEVs is very recent, as it was only in 2017 that they crossed the threshold of 1% of the market, and it was from 2020 onwards that growth accelerated sharply, with BEVs continuously accounting for over 70% of sale (see Figure 2-1).

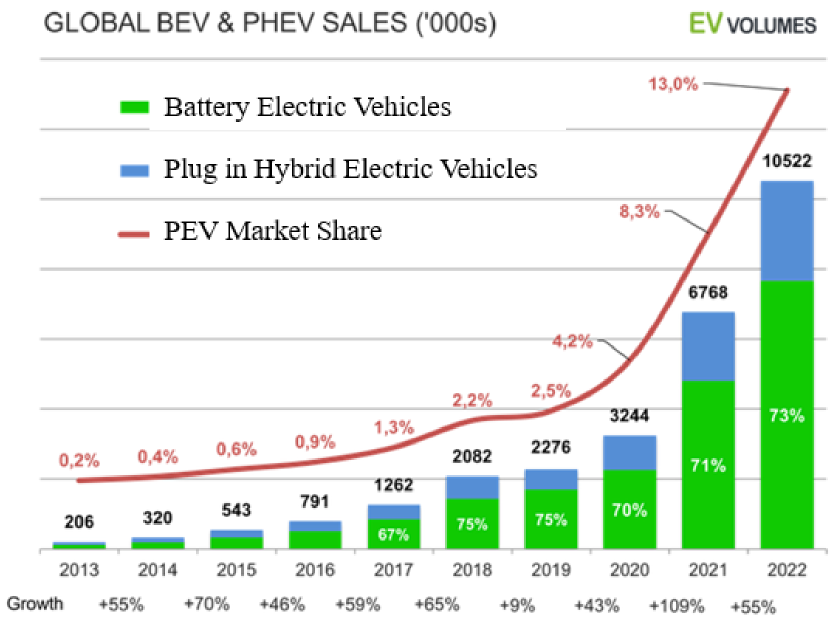


Figure 2-1: Worldwide sales of plug-in electric vehicles between 2013 and 2022
Source: https://www.ev-volumes.com/ accessed May, 5 2023 and modified by the author

This very rapid electrification of vehicles is neither the result of consumer demand nor a technological development initiated by automakers. It is a recent, growing and persistent global set of increasingly stringent environmental regulations, resulting from the 2015 Paris Agreements, that is forcing the automotive industry to move towards electrification. The European Union and the United States have committed themselves to the goal of decarbonization by 2050 and Chinese President Xi Jinping announced, at the 75th session of the United Nations General Assembly (in 2020), that China would strive to reach peak carbon emissions by 2030 at the latest, and achieve carbon neutrality by 2060.

The targets set for the ZEV deployment are consistent with these commitments:

- Europe 100% ZEVs in 2035,

- U.S. 50% and 67% BEVs and PHEVs in 2030 and 2032 respectively,
- California: 100% BEVs and PHEVs (with a minimum electric range of 50 miles under normal driving conditions) in 2035,
- China 50% BEVs and 50% PHEVs in the most densely populated areas, 40% BEVs and 60% PHEVs elsewhere in 2035.

The three main markets for electric vehicles in 2022 and in 2021, are China, Europe and the United States respectively. This finding is consistent with the fact that these three regions are already the largest automotive markets and have enacted the most proactive regulations in favor of the transition to decarbonized vehicles.

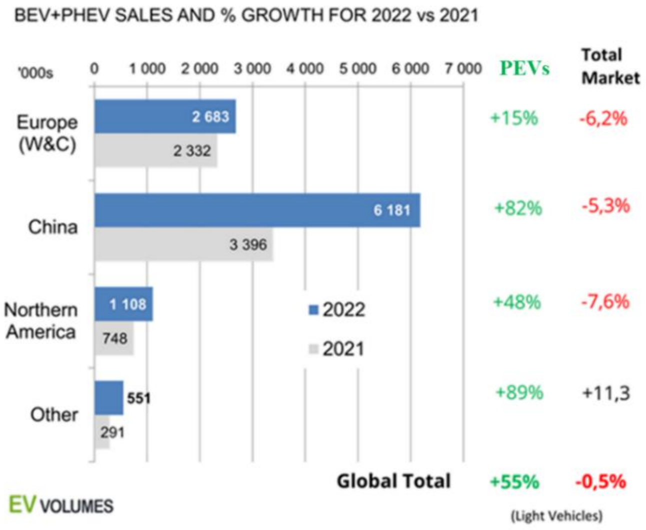


Figure 2-2: Worldwide main markets of plug-in electric vehicles in 2021 and 2022
Source: https://www.ev-volumes.com/ accessed May, 5 2023 and modified by the author

However, the industrial and economic results obtained are not the same: by the end of 2022, China accounted for 57% of sales, 60% of the global electric vehicle fleet and virtually unchallenged dominance of the electric battery value chain with 75% of global battery production capacity.

The results for H1 2023[5], show an improvement in the global market for all fuels and confirm the steady growth of PEV sales in all regions (compared to a very depressed market in H1 2022), with China leading the way with a 56% market share. Chinese automakers continue to increase their sales of PEVs with BYD, GAC and Geely Group ranking 1st, 8th and 10th respectively. In the first quarter of 2023, China surpassed Japan and Germany to become the world's largest vehicle exporter with a total of 1.069 million vehicles, of which 28% were PEVs[6], and the total number of vehicles exported from China in 2023 could reach 4.4 million in 2023, of which more than 30% will be PEVs[7].

In the Chinese market, in 2022, BYD overtook FAW-Volkswagen as the top-selling automaker with 1.86 million vehicles sold, an increase of 149% year-on-year[8], and recent results show that this situation could be confirmed in 2023[9]. In addition, in Q1 2023, 8 of the 10 NEV best sellers are Chinese NEV makers, with Tesla ranking 2nd and Smart 10th[10].

The European and American (and also Japanese and Korean) automotive industries, which largely dominate internal combustion engine technology, are now heavily dependent on the Chinese electric vehicle value chain for all stages of the PEV life cycle, with which they must catch up in terms of supply and market share (see Table 2-1, Table 2-2 and Figure 2-3).

PEVs value chain data	China	Europe	USA	Rest Of the World (ROW)
Production capacity of raw materials LI (lithium), NI (Nickel), CO (Cobalt), GR (Graphite) by capital-intensive origin of producers (% world capacity) https://lelementarium.fr/element/lithium & https://www.iea.org/reports/global-supply-chains-of-ev-batteries issued July 2022 & https://about.bnef.com/blog/localizing-clean-energy-value-chains-will-come-at-a-cost/ issued November 2022	26 / / / 80 1er world importer of LI, NI, CO	0 / / / 4	18 / / / 0	13 (Chile)/ / /16
Installed refining capacity for raw materials LI, NI, CO, GR (% worldwide capacity) https://www.iea.org/reports/global-supply-chains-of-ev-batteries issued July 2022 & https://about.bnef.com/blog/localizing-clean-energy-value-chains-will-come-at-a-cost/ issued November 2022	60 / 35 / 60 / 70	0 / 0 / 20 / 0	2 / 0 / 0 / 5	Not documented
Anode / cathode production capacity (% worldwide capacity) https://www.iea.org/reports/global-supply-chains-of-ev-batteries issued July 2022 & https://about.bnef.com/blog/localizing-clean-energy-value-chains-will-come-at-a-cost/ issued November 2022	85 / 70	0 / 0	1 / 1	11 (Japan) / 15 (Korea) + 14 (Japan)
Installed capacity of battery production in 2022 in GWh and in % https://www.visualcapitalist.com/chinas-dominance-in-battery-manufacturing/ + author's additional information	893 (72,8%)	164 (13,4%)	70 (5,7%)	100 (8,1%)
Number of companies supplying battery production systems https://www.mckinsey.com/industries/industrials-and-electronics/our-insights/unlocking-the-growth-opportunity-in-battery-manufacturing-equipment issued May 2022	31	13	11	30 (Asia-Pacific excluding China)
Number of electric vehicle manufacturers (including new entrants) having produced more than 100,000 battery electric vehicles in 2022 (Ev Volumes and automakers' information)	13 Hozon, NIO, Xiaopeng, LeapMotor	5 BMW, Mercedes, VW, Stellantis, Renault Group	4 Ford, GM, Stellantis, Tesla	2 Nissan, Hyundai / Kia
Battery recycling pretreatment capacity (% global capacity November 2022) https://rhomotion.com/battery-recycling-infographic-november-2022	80	12	2	6
Battery recycling material treatment capacity in 2022 in '000 tons China (Caixin Global), Europe (Circular Energy Storage) and USA (Own research see Table 7-11)	102	17	80	Not documented

Table 2-1: China's undisputed dominance of the plug-in electric vehicle value chain
Source: Compilation by the author of various sources explicitly mentioned for each item of information.

Data on the PEV market by the end of 2022	China	Europe	USA	ROW
Sales of PEVs in thousands of vehicles (Ev Volumes)	6 181	2 683	1 108	551
Number of electric vehicle models offered for sale – 500 models in total (Global EV Outlook 2023 IEA)	280	160	80	30 - 40
% Of sales of BEVs per model type: Small cars / Medium cars / Crossovers / Large cars / SUV (Global EV Outlook 2023 IEA)	18 / 22 / 2 /16 /42	19 / 17 / 4 / 19 / 41	6 / 12 / 0 / 22 / 60	Not documented
Public charging network Number of vehicles per charging points (EV / EVSE – EV Supply Equipment) Average power available per EV (kW / EV) https://www.iea.org/reports/global-ev-outlook-2023	8 EV/EVSE 3,5 kW/EV	13 EV/EVSE 1,2 kW/EV	24 EV/EVSE 0,8 kW/EV	World average 10 EV/EVSE 1,4 kW/EV
Stock of plug in EV in thousands of vehicles (Ev Volumes et Global EV Outlook 2023 IEA)	15,000	8,500	3,130	< 1,000

Table 2-2: China's undisputed dominance of the plug-in electric vehicle market

Source: Compilation by the author of various sources explicitly mentioned for each item of information

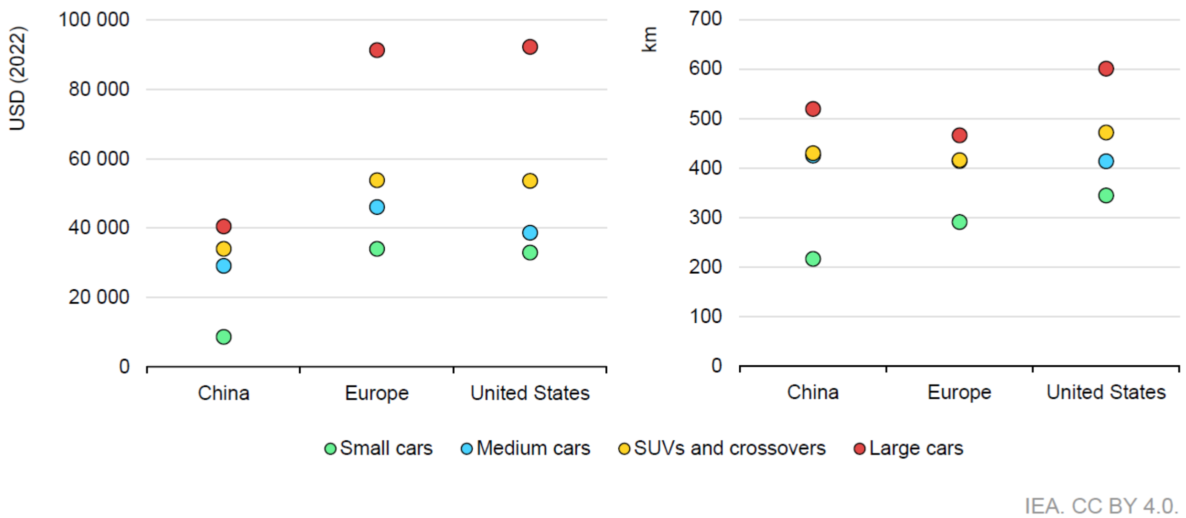


Figure 2-3: Comparison of average retail price and range of BEVs in China, Europe and USA
Source: Global EV Outlook 2023 – IEA

Figure 2-3 shows that the average retail price in China is much lower than in Europe or the United States. This is largely due to China's low labor costs and volume effect in the largest market. It is also the result of vehicles designed for specific purposes, such as small cars with a relatively short range that are suitable for urban use, such as the Wuling Hongguang Mini EV, which has a maximum selling price of less than €5,000. Meanwhile and, contrary to popular belief, the Chinese electric automotive industry is not only offering just low-cost, low-performance vehicles but also some vehicles that can successfully compete on the European market such as the MG4[11] thanks to its high performance / price ratio.

Moreover, MG, Tesla and BYD were the top brands exporting NEVs from China in the first half of the year 2023, accounting for 25.3%, 22% and 15.4%, respectively with MG and Tesla almost exclusively serving the European market[12].

Key takeaways from the ongoing transition context and current situation assessment

1. The very significant growth in sales of PEVs is a direct result of the application of a recent, growing and persistent global set of increasingly stringent environmental regulations, resulting from the 2015 Paris Agreements, that are forcing the automotive industry to move toward electrification.
2. The top main markets for PEVs in mid-2023, 2022 and 2021 are China, Europe and the United States respectively, consistent with the fact that these regions are the largest automotive markets and have enacted the most proactive regulations favoring the transition to decarbonized vehicles.
3. To date, China has a virtually undisputed dominance on the PEV value chain and market.
4. Global players, dominant in the ICEV technology, are now heavily dependent on the Chinese electric vehicle value chain for all stages of the PEV life cycle, with which they must catch up in terms of supply and market share
5. The Chinese electric automotive industry is not only offering just low-cost, low-performance vehicles but also some vehicles that can successfully compete on the European market.

Sidebar 2-1 : Key takeaways from the ongoing transition context and current situation assessment

[4] Even though sales of PHEVs are now lagging behind those of BEVs, the former remain important in terms of volume during this transition period. This is especially true as China and the US have not announced the end of the internal combustion engine in as short a timeframe as Europe.
[5] https://www.ev-volumes.com/, accessed on September 27, 2023
[6] https://carnewschina.com/2023/05/13/china-became-the-worlds-largest-vehicle-exporter-in-q1-2023-surpassing-japan/
[7] Canalys cited by CnEVPost, https://cnevpost.com/2023/06/19/china-auto-exports-to-reach-4-4-million-2023-canalys/
[8] http://epaper.chinadaily.com.cn/a/202303/29/WS64238227a310777689887b55.html
[9] https://carnewschina.com/2023/08/09/top-selling-cars-in-july-2023/
[10] http://www.eyeshenzhen.com/content/2023-04/18/content_30177679.htm
[11] https://www.jato.com/tesla-and-mg-were-the-biggest-market-share-winners-in-europe-during-h1-2023/
[12] Canalys cited by CnEVPosthttps://cnevpost.com/2023/10/25/canalys-expects-china-auto-exports-5-million-2023/

3. Analysis of Chinese, European and US regulations driving the transition to the decarbonized road mobility

The methodology of the study is to compare European, Chinese and U.S. regulations at key stages of the PEV lifecycle for passenger cars and light-duty trucks. Using a widely accepted definition of the PEV lifecycle, the vast majority of stages were selected (shown in bold in the figure below), with the exception of:

- The production of electric motors, which the world's leading automakers have mastered through in-house production and/or partnerships with non-Chinese suppliers[13] while access to rare earths is discussed in the chapter on access to raw materials.
- The use of the vehicle is limited to recovering the energy level of the battery (by whatever method), as this is a key requirement for customer acceptance of PEVs.
- We have limited the scope of recycling to high-voltage batteries, even though whole-vehicle recycling is gaining momentum in almost every region of the world.

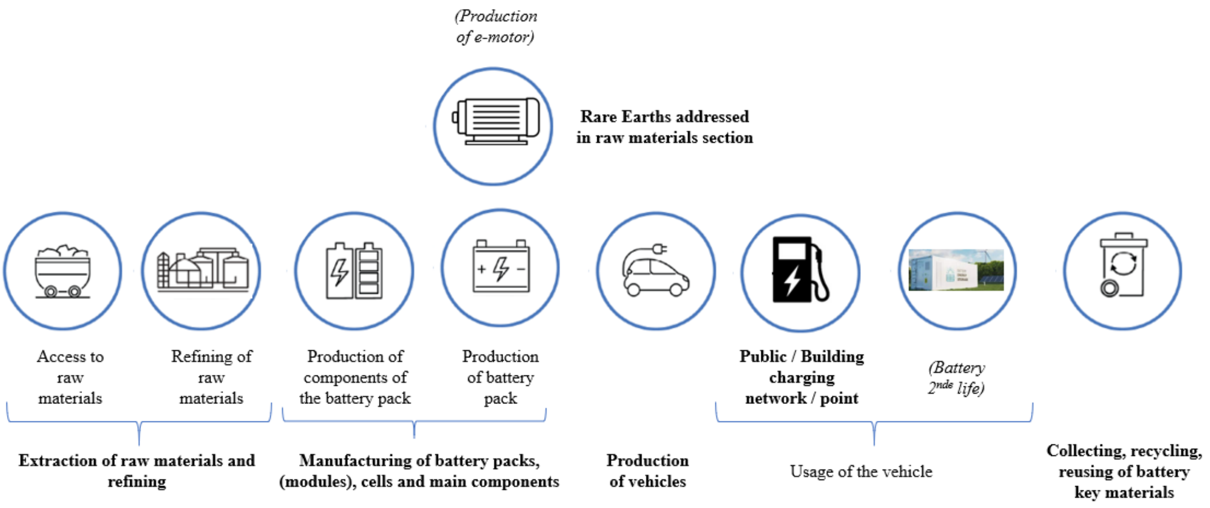


Figure 3-1: PEV life cycle stages included in the scope of the study
Source: Author's adaptation of several documents describing the life cycle of an electric vehicle.

More specifically, the study on regulations aims to:

- Clarify what they regulate (the vehicle, the charging network, etc. ....) and how they regulate (bans, threshold definition, financial support, ...).
- Summarize, for each region and for each phase of the life cycle, the amount of financial support and, if possible, by type (upfront payment, loan, subsidy, tax credit…).

Beyond a chronological and factual description of these regulations, the main objectives are to describe their dynamics in terms of direction, pace of promulgation, strength and pace of financial support.

3.1. Key takeaways

In 2017, the PEV market was still in its infancy, and China's lead over Europe and the US was neither significant nor decisive, with sales of about 0.5 million, 0.3 million and 0.2 million vehicles, respectively. 2018 marks the beginning of the rise of the Chinese PEV market, and 2021 is the year of the Chinese PEV sales explosion, when just over 50% of the 6.8 million new PEV sales took place in China[14].

To analyze what has led to the current situation where China has almost unquestioned dominance in the PEV value chain, we focus sequentially on two main drivers of the ongoing transition.

First, we summarize the differences in the governance of industry transformation (Sidebar 3-1) and "Administered Darwinism" (Sidebar 3-2), coined by Alochet and Midler[15], which characterizes the specific key capabilities developed by the Chinese government to develop the new industry of electric vehicles.

Second, we summarize the amount of public financial support for electric mobility in China, Europe through 2022, and the U.S. through 2021 and from 2023 for all regions (Sidebar 3-3 and Sidebar 3-4, respectively).

Both governance of the industry transformation and financial support have contributed to shape the current state of the market and the situation of the auto industry in China, Europe, and the United States. We make it clear that China's current dominance is, of course, due in large part to significant public funding, but also to the strategic determination of the Chinese government to develop a world-leading industry and the strategies it has put in place to do so.

---

13 See Alochet, M., MacDuffie, J. P., & Midler, C. (2023). Mirroring in production? Early evidence from the scale-up of Battery Electric Vehicles (BEVs). Industrial and Corporate Change, 32(1), 61-111

14 Author's compilation of data from various sources: Ev Volumes, IEA and Statista based on national registrations.

15 Alochet, M., & Midler, C. (2021). A comparison of Chinese and European public policies on electric vehicles. Le journal de l'ecole de Paris du management, 152(6), 16-23.

China	**A longstanding commitment to shaping the future of the global automotive industry** 1. The strategic determination and the dirigisme of the Chinese government to transform the world's leading manufacturer of automobiles into the country that dominates the global automotive industry. 2. The strategy of dominating a value chain began in the 1960s with rare earths and was then successfully applied to the battery value chain. 3. The development of the NEV industry began in the 1990s and the priority given to the battery-powered electric vehicle, in 2012, has definitively set its course 4. From the outset, the Chinese government has established a regulatory framework that covers all stages of the PEV lifecycle, and has provided massive financial support for its development. 5. Chinese regulations force performance improvements and increased sales of NEVs year after year. 6. Prioritized deployment in regions with higher emissions (and higher income). 7. Continuous involvement of local authorities, be they provincial or even municipal through successive national demonstration programs. 8. An "Administered Darwinism" at the service of the selection of future national and global industry champions combined with a "whatever it takes" approach. 9. Use of protectionism.
USA	**Late but comprehensive and structured vision of the PEV value chain supported by massive funding** 1. While California has long been committed to decarbonizing transportation, the recent conflicting decisions between the Obama and Trump administrations had created policy instability at the federal level. 2. After decades of industry neglect, the Trump administration had re-established a strategic approach to raw materials through two Executive orders signed in December 2017 and September 2020, respectively. 3. The Biden administration restarted a new dynamic toward the decarbonization of road mobility through: a) High ambitions for ZEV market share (Executive Order 14307 – 05/08/2021 and EPA proposal 12/04/2023) and fuel consumption (NHTSA proposal, 28/07/2023), b) Consideration of all stages of the life cycle of PEVs, c) Direct and immediate incentives to production along the complete PEV value chain supported by a massive funding approach made possible by the passage of the IIJA (2021) and IRA (2022) regulations, d) Use of protectionism 4. Strong willingness to reduce dependence on foreign raw material supply chain by 2030 (National Blueprint for Lithium Batteries 2021–2030)
Europe	**A lack of methodology to achieve the very demanding objective of 100% ZEV in 2035** 1. A lack of a systemic and coordinated approach to building the future electric mobility industry. The Fit For 55 proposal was made in 2021 while most of the key regulations affecting the PEV value chain have been proposed or entered into force only in 2023. By setting a goal without defining how to achieve it, the Commission has put the cart before the horse. 2. Euro7 application as defined in the Commission's original proposal could divert funds from PEV development and lead to the premature disappearance of ICEVs. The lack of compromise so far between the European institutions on future emission limits and testing procedures creates uncertainty for the industry and could jeopardise its future. 3. The combination of insufficient public funding and targets that are too distant and not ambitious enough (see CRMA, NZIA and Battery Directive) means that the heavy reliance on the Chinese electric vehicle value chain may not be rebalanced quickly. 4. Underestimation of the necessary financial resources, very long delays in their implementation, absence of prioritization, heavy administrative burden 5. Fair competition "no matter what" while the US and China use protectionism.

Sidebar 3-1: Key differences in the governance of the transformation of the industry between China, the U.S. and Europe
Source: summary of author's own analysis of Chinese, US and European set of regulations and financial support

What is "Administered Darwinism"

"Administered Darwinism" characterizes the key capabilities that the Chinese government has implemented to develop the electric vehicle industry, namely the selection of national and (future global) champions to lead the industry, and the ability to pragmatically adjust the rules according to the results obtained. Combined with the "whatever it takes" approach, these are three characteristics, which we briefly summarize below, that are fundamentally different from what is usually applied in Western countries[16].

Selection of future champions

It is a combination of continually tightening the performance criteria for PEVs, consistent across many regulatory instruments and awarding subsidies and credits (CAFC and NEV credits) to the automakers that meet the standards.

- While failure to receive subsidies will sooner or later drive an automaker out of the market because its products do not meet the requirements to be competitive, failure to meet CAFC and NEV credit targets will force an automaker to buy credits from other automakers on an over-the-counter (OTC) market.
- Because the (future) champions receive a significant amount of subsidy and make a lot of money on the OTC by selling their credits, the gap between (future) champions and weak competitors quickly becomes too large to close.

Another strategy for developing future champions is to merge and restructure companies, with close ties to the Chinese government, to extend their dominance across the complete value chain. A recent example is the creation of the China Rare Earth Group, creating the world's largest producer of strategic rare earths[17].

Ability to continually and pragmatically evaluate the results of past decisions and adjust the rules accordingly

- Technology Forcing: in 2004, the "Development Policy of Auto Industry" called for the development of the NEV industry which included electric vehicles as well as other alternative fuels such as ethanol, natural gas, mixed fuels and hydrogen. In 2012, it was decided that BEV would become the strategic priority.
- Continuously and consistently tightening the criteria for obtaining subsidies since 2014 and those to earn NEV credits since 2016. On July 6, 2023, MIIT revised again the dual credit policy to award 40% fewer credits for each NEV produced, effective August 1, 2023.
- The purchase subsidies were scheduled to end at the end of 2019 to avoid artificially sustaining automakers that could not meet the technology and cost requirements. To prevent the risk of a depressed auto market, they were extended twice, until the end of 2022 and the end of 2023. Similarly, the tax credit extension, first enacted in 2014 and continuously extended since, was extended again, in 2023, through 2027.

Support the market take off "whatever it takes"

- Large and simultaneous public investments (at least €110-160 billion by 2022) in all the industries involved in the PEV lifecycle
- Additional cost of the extension of subsidies and exemption of purchase tax credit in 2023 alone: €15,5 billion.
- Huge sunk costs (not evaluated) provoked by the elimination of the weaker competitors.

Sidebar 3-2 : What is "Administered Darwinism"?
Source: Author's analysis of Chinese regulations

16 Paradoxically, it is quite close to the financing logic of Californian capitalist ventures: (i) Do not hesitate to commit to promises from the outset and accept failure, as long as it is quick; (ii) Pilot trajectories by frequently monitoring the achievement of intermediate milestones representative of learning progress and (iii)Pragmatically update support for the champions that the company has helped to create.
The innovation odyssey, lessons from an impossible project. C.Midler, M. Alochet, de Charentenay C, Taylor & Francis (2023), p 128

17 https://www.iea.org/policies/15513-sasac-announcement-on-the-establishment-of-china-rare-earth-group

	China (Tip of the iceberg[18]) Estimation by end of 2022 (€ billion)	USA Estimation by end **of 2021**[19] (€ billion)	Europe (EU27 + UK) Estimation by end of 2022 (€ billion)
Subsidies and loan guarantees for productive and R&D investments	NEV manufacturing license: 20 – 35 Direct subsidies to companies: 40 – 50	Approximately 1,3	40
Subsidies on public charging network	2,6 – 3,5		3,4
Subsidies on car purchase	29		Approximately 30
Tax credit on car purchase	20,5 – 23,5	Approximately 6,5	Approximately 2 – 3
Over-the-counter NEV credit sales between automakers	1,8 (Mostly purchased from local manufacturers and Tesla by foreign JVs)	Specific to China	Specific to China
Total	Minimum 115 – 150	Approximately 8	Approximately 75 – 80

Sidebar 3-3: Evaluation of (supra)national public financial support in China and Europe for electric mobility through 2022 and USA through 2021
Sources: Author's compilation of various sources and own estimations (refer to detailed tables in the report)

The evaluation suggested in the table above should be considered as a minimum, and we estimate that China's public financial support to date is higher than that of Europe and the United States combined in this period.

[18] The figures proposed in this report represent what can be described as "the visible tip of the iceberg" of Chinese public financial support for industry development because it is not easy to find documents provided by a Chinese public authority that present a comprehensive summary of this financial support. As mentioned in two reports, the only solution seems to analyze public disclosures of companies involved in the industry. (What Do We Know About Chinese Industrial Subsidies?", François Chimits (2023) - Mercator Institute for China Studies - http://www.cepii.fr/PDF_PUB/pb/2023/pb2023-42.pdf and Fitch Ratings cited by Nikkei Asia - https://asia.nikkei.com/Business/Business-Spotlight/Made-in-China-2025-thrives-with-subsidies-for-tech-EV-makers)

[19] Because 2022 is a transition year, with IIJA coming into effect at the end of 2021 and IRA by mid-2022, it is more reliable to consider public investment through 2021.

	Evaluation of yearly (supra)national financial public support in China, USA and Europe from 2023 onwards		
	China (Tip of the iceberg) (€ billion)	USA[20] (€ billion)	Europe (EU27 + UK) (€ billion)
Subsidies and loan guarantees for productive and R&D investments	Direct subsidies to companies: 10 – 20	5,5	Assumption of 50% dedicated to electric mobility for an amount of 18 - 20 per year of public support for the European Green Deal ➔ 9 – 10
Subsidies on public charging network	1,8 – 3,5	1,4 between 2022 and 2026	2,3 between 2023 and 2027 ➔ 0,5
Subsidies on car purchase	2,5 Extended till the end of 2023		Approximately 29
Tax credit on car production		9 in average till 2029 22,5 2030 onwards	
Tax credit on car purchase	13 in 2023 Extended till the end of 2027	15 in average till 2029 37,5 2030 onwards	Approximately 5
Over-the-counter NEV credit sales between automakers	1	Specific to China	Specific to China
Total	30 – 40	32 (till 2029) – 68 (2030 onwards)	About 45

Sidebar 3-4 : Evaluation of yearly (supra)national financial public support in China, USA and Europe for electric mobility from 2023 onwards
Sources: Author's compilation of various sources and own estimations (refer to detailed tables in the report)

Again, this comparison is between the so-called tip of the iceberg of the Chinese national authorities' financial support and the announcements of the U.S. federal government or the European Commission and some member states. However, since the U.S. and Europe are investing massively in a race against time to catch up with China, we can't think that China would have a lower level of investment than any of the other regions.

[20] When calculating the yearly financial support from federal state in the U.S., we assume average yearly sales of 3 million PEVs between 2023 and 2029 (from 1 to 7 million) and of 7,5 million PEVs between 2030 and 2032 and €3 billion for production credit and €5billion for purchase credit per year in average. In other words, from €3 billion to €21 billion for the production tax credit and from €5 billion to €35 billion for the purchase tax credit between 2023 and 2029.

3.2. Chinese regulations

In the space of a decade, China has become a major player in the automotive industry: the world's largest manufacturer of cars (2009), the largest market in terms of volume (2013), and also the world's largest producer of transport-related pollutants and CO2 (2012).

The desire to reduce vehicle emissions – the main source of air pollution – and oil dependence, as well as to promote the development of the automotive industry at a time when Chinese automakers were struggling to compete with global rivals in the ICEV market, led the Chinese government to develop a New Energy Vehicle (NEV) industry.

In less than 20 years, starting from scratch, and despite very disappointing results through 2013 (less than 60,000 NEVs sold since sales began in 2006), the Chinese State Council has systematically and continuously shaped an industry that has emerged as a global leader by 2021, with more than 50% of PEV sales taking place in China.

Before outlining the main regulations for each stage of the PEV value chain, we briefly summarize the key strategic and planning tools that have framed the construction of China's electric vehicle industry[21]:

- Successive Five-Year Plans, starting with the 8th (1990 – 1995), have shaped strategies for the economical and industrial development of this new industry.
- Strategic plans dedicated to the auto industry such as the “"The Development Plan for the Industry of Energy-Efficient Vehicle and New Energy Vehicle" (2012) and the “New Energy Automobile Industry Development Plan (2021-2035)” (2020) have constantly set ambitious sales and vehicle performance targets.
- Several technology plans, focused on electric vehicles, were initiated in the early 1990s. The 863 Program, launched by the Ministry of Science and Technology in 2001 is probably the most important one. Over the next ten years, a total of 2 billion yuan (€260 million) was allocated to support the research efforts of Chinese automakers, universities and research institutes. The research, developed in three "verticals" (hybrid, pure electric and fuel cell vehicles) and three "horizontals," namely vehicle control systems, electric motor systems, and battery/fuel cell technologies, is still guiding the development of this industry.
- Continuous involvement of local authorities, be they provincial or even municipal[22] through successive national demonstration programs: The "Ten cities with thousand vehicles" program (2009-2012) was the first large-scale program focused on the deployment of the electric mobility system in all its components. Many programs have

followed, all of which have forced the simultaneous development of the battery and NEV industries and the simultaneous deployment of vehicles and the charging network in some priority areas. In this way, they have supported the validation "at scale" of the electric mobility industrial system and facilitated NEV acceptance by end users.

Most importantly, we highlight the longstanding and strong determination of the Chinese government to shape a global leading industry by quotes from the documents listed below[23]:

- *China, now the world's leading auto manufacturer and market, must seize the opportunities offered by the development of more energy-efficient vehicles and NEVs to transform itself into a powerful country in the auto industry* (The Development Plan for the Industry of Energy-Efficient Vehicle and New Energy Vehicle, 2012).
- *Shifting the manufacturing industry "from big to strong"* (Made in China 2025, 2015).
- *Promote the development of national and international champions by supporting the merger and reorganization of the most successful companies to make them stronger and further increase the degree of industrial concentration* (New Energy Automobile Industry Development Plan (2021-2035), 2020).

Finally, we would like to emphasize that the Chinese government has given itself the means to be competent in the entire PEV value chain by drawing on scientific, technological and industrial experts. As a result, it has a strong ability to intervene at every stage, from raw material extraction to battery recycling, not only to set targets but also to prescribe how to achieve them through increasingly stringent PEV performance criteria that are consistent across numerous regulatory instruments.

3.2.1. Extraction of raw materials and refining

President Jiang Zemin declared in 1999: "*Improve the development and applications of rare earth, and change the resource advantage into economic superiority*." In fact, since the early 1990s, China has had an almost absolute monopoly on rare earths.

This advantage initially owed much to China's abundant reserves and low labor costs, which contributed to the significant loss of market share by foreign competitors in the early 2000s. It has been developed and strengthened over the years by: (i) investment in innovation in the 1960s; (ii) the start of mass production in the 1970s and, (iii) the establishment of a vertically integrated supply chain in the 1980s. By the 1990s, China had attracted foreign investment through the mandatory establishment of joint ventures to modernize its refining technologies and facilities.

To extend its domination of the rare earths industry even further, China has employed other strategies:

- Various R&D initiatives have enabled China to gradually move up the value chain, from exporting rare earth compounds and metals to intermediate products such as magnets, and then to high-tech products such as mobile phones, computers, batteries and electric motors.
- Technology transfer through direct investment, such as the acquisition of Magnequench in the mid-1990s by two Chinese companies closely tied to the government. Within a few years of the acquisition of this GM subsidiary, the Indiana plant was closed and operations and know-how were transferred to Tianjin, China, and then expanded to Singapore and Thailand.
- By appealing to protectionism, each time it was necessary to develop its own industry and overtake foreign competitors. This can take many forms, such as the Chinese state taking complete control over the development of the industry or imposing restrictions on production and exports[24].
- Promotion of international cooperation, especially in the Belt and Road regions, i.e., China-Latin America and China-Africa. The plan focuses on oil and gas, iron, copper, aluminum and other minerals, including those strategic for electric vehicles, and includes free trade agreements, loans, donations and investments in infrastructure, energy and telecommunications, up to $8 trillion, which will boost its imports of raw materials and exports of manufactured goods and services[25].
- By encouraging mergers and reorganizations of rare earth companies to extend their industrial chains further downstream. In fact, the SASAC announced the establishment of the China Rare Earth Group, creating the world's largest producer of strategic rare earth elements and strengthening the direct control of the central government[26].

This brief review of the development of China's rare earths industry [27] brings two conclusions:

1. It confirms China's dominance in rare earths materials critical to the development of electric vehicles.
2. It summarizes the strategies used to gain control of the rare earths value chain, whose application to other strategic materials for the electric vehicle has enabled China to develop its overwhelming dominance over the value chain for these materials, from mining to processing.

3.2.2. Manufacturing of battery packs, (modules), cells and main components

Since the early days of China's electric vehicle industry in the 2000s, the development of power batteries has been identified as a strategic technology for the future of this industry, one of the three "horizontals" in the 863 Program 863 which has received significant R&D funding.

Since then, the development of China's battery industry has been strongly guided and supported, at a rapid pace, by regulations as shown in the table below:

Date	Event / Objective (Google translated excerpts from sources)	Sources
2012	Setting the conditions for any company wishing to be part of the newly created NEV industry, in terms of design and production capacities as well as compliance to international quality standards. Providing ambitious targets, for a newly created industry, such as a gravimetric energy density of 180 wh/kg at the cell level in 2015	Notice on Organizing the Application for the 2012 New Energy Automobile Industry Technology Innovation Project - Public Finance Project [2012] No. 141. http://www.miit.gov.cn/n1146295/n1652858/n1652930/n3757018/c3757483/content.html
2012	Focus on the construction of power battery industry cluster areas and strive to form 2-3 leading enterprises with a production and sales scale of more than 10 billion watt-hours and key material R &D and production capabilities. There are 2-3 backbone manufacturers in the fields of positive and negative electrodes, separators, electrolytes and other key materials.	Energy Conservation and New Energy Automobile Industry Development Plan (2012-2020) Chinese State Council https://www.gov.cn/zwgk/2012-07/09/content_2179032.htm
2015	Considering the highly dispersed development level of the battery industry that limits the expansion of the overall NEV industry, standardization of the power battery industry, introduction of more stringent battery inspection standards	Automotive Power Battery Industry Standard Conditions Automotive Power Battery Industry Specification Conditions http://www.miit.gov.cn/n1146295/n1652858/n1652930/n4509627/c4511776/content.html
2016	Restricting subsidies award to only vehicles with batteries produced by the Chinese companies listed in the catalog Gradually lifted as of May 2018	'Regulations on the Standards of Automotive Power Battery Industry' catalog
2017	Improving product safety and quality Increasing battery performance Setting production capacity targets by 2020	Promote the development plan of the automotive power battery industry (NDRC) https://zfxxgk.ndrc.gov.cn/web/iteminfo.jsp?id=2737
2020	More stringent safety requirements for battery cells, modules and at the battery system level	GB 38031-2020 "Safety Requirements for Power Batteries for Electric Vehicles" https://www.miit.gov.cn/xwdt/gxdt/sjdt/art/2020/art_cdee4bda4b244dce958d2b34258268b5.html

Table 3-1 : Some key regulations driving the development of the Chinese battery industry
Source: Author's summary of an analysis of the quoted sources

The development of the battery value chain took advantage of the learning made during the development of the rare earths supply chain as the Chinese government:

- Has installed and funded technology development plans (the 863 Program has been continued for years and new plans have been launched),
- Has taken the full control of the organization and development of the industry,
- Has used protectionism to develop the battery supply chain. In 2016, at a time when Japanese and Korean battery manufacturers are far outpacing Chinese newcomers in terms of technology, MIIT introduced a regulation which restricted the awarding of subsidies to only vehicles with batteries produced by the listed Chinese companies. In parallel, thanks to high level of funding from national, regional and even local public authorities, new production capacities were launched and commissioned. Consequently, China surpassed the production capacity of both Japan and Korea probably in 2015[28]. In May 2018, when the Chinese industry had reached a “sufficient” level of maturity, the restriction was gradually lifted as the new catalog release introduced three Chinese JVs with foreign battery leaders – namely Samsung, LG ES and SKI.
- Has encouraged battery makers to develop their presence in the value chain. They have engaged in ‘specialized vertical integration’[29], actively entering related upstream and/or downstream segments within the battery supply chain to expand their business, while continuing to strengthen their capabilities with specific established assets in their original segment of the value chain (see Sidebar 4-3 for the example of CATL).
- Has provided resources through the Belt and Road Initiative to secure their supply of raw materials.

3.2.3. Production of vehicles

Automakers operating in China must comply with three regulations:

- Fuel consumption limit per model, required to be met before an ICEV can be marketed and recommended in the case of a PEV,
- Fuel consumption per automaker i.e., the Corporate Average Fuel Consumption (CAFC) which is assessed annually,
- The "dual-credit policy"[30], which is assessed annually. It is the strict implementation of the strategy announced in 2012 in "The Development Plan for the Industry of Energy-Efficient Vehicle and New Energy Vehicle": simultaneously improve the performance of ICEVs and develop a powerful NEV industry.

3.2.3.1. Model Fuel Consumption and Corporate Average Fuel Consumption

Model Fuel Consumption and CAFC regulations have been introduced in 5 successive phases since 2005, with CAFC starting in Phase III (2012).

For Model Fuel Consumption, the thresholds have been continuously tightened and the control method has been modified to adopt the World harmonized Light-duty Test Cycle (WLTC), while the scope of CAFC has been progressively extended to all fuel types as shown in Table 3-2. The maximum CAFC threshold has been drastically reduced for automakers: down 40% in 10 years, from 7 L/100 km in 2015 to 4 L/100 km in 2025 (i.e., about 95 g CO2 / km, the target set in Europe in 2020).

Regulatory phase	Regulations applicable to combustion engines for passenger cars			
	Model Fuel Consumption	Principles and objectives	CAFC	Principles and objectives
Phase I 01/01/ 2005	"Passenger Vehicle Fuel Consumption Limits". GB 19578-2004	Application to gasoline-powered passenger cars only 16 weight classes Application of the NEDC cycle	Not applicable	/
Phase II 01/01/2008		Ditto, limits reduced by 10%.	Not applicable	/
Phase III 01/01/2012		Same as Phase II	CAFC standard GB 27999-2011 Petrol cars	7 L/100 km in 2015 Target of 5 L/100 km in 2020
Phase IV 01/01/2016	"Passenger Vehicle Fuel Consumption Limits". GB 19578-2014	Ditto, with limits reduced by 20% compared with Phase II	CAFC standard GB 27999-2014 Passenger cars all fuels	CAFC threshold (L / 100 km) 2016: 6.7 2017: 6.4 2018: 6 2019: 5.5 2020: 5
Phase V 01/01/2021	"Passenger Vehicle Fuel Consumption Limits". GB 19578-2021	Results obtained on the WLTC cycle which results in a de facto tightening of 10%. Mass classes were replaced by linear regression.	CAFC standard GB 27999-2019 Passenger cars all fuels	CAFC target of 4 L / 100km in 2025

Table 3-2 Model Fuel Consumption and CAFC requirements for internal combustion passenger cars in China - 2005 - Today
Source: Author's research and information obtained from https://www.transportpolicy.net/standard/china-light-duty-fuel-consumption/

For light commercial vehicles, without going into the same level of detail, the principles of a consumption limit per model are identical and are defined in the promulgated regulations:

- GB 20997-2007, published in 2007 and applied from January 1, 2008 in phases I and II,
- GB 20997-2015, published in 2015 and applicable from January 1, 2018 (Phase III).

The Phase IV standard for light commercial vehicles is currently under development and is expected to impose more stringent standards.

The "Electric Vehicle Energy Consumption Rate Limit" regulation, (GB/T 36980-2018[31]) applicable from July 1er 2019, is the first regulation in the world to set recommended consumption thresholds (in kWh/100 km) for battery-powered vehicles based on their mass (the regulation applies to vehicles with a mass of less than 3500 kgs). The consumption was initially calculated according to the NEDC cycle (GB/T 18386-2017 standard); from October 1, 2021 (application of GB/T 18386.1-2021 standard) it is now based on CATC which uses principles similar to WLTP.

The existing recommended consumption thresholds are likely to be tightened again, as the average energy consumption of BEVs of 12.5 kWh/100 km in 2025, as set out in the New Energy Automobile Industry Development Plan (2021-2035), is already expected to be achieved[32].

3.2.3.2. NEV credit and Dual credit policy

The NEV credit, which is specific to China, is calculated for each NEV model introduced to the market according to a formula that includes criteria that have a significant impact on the vehicle's performance. The NEV credit, which can be greater than 1 (see Table 3-3), is therefore not a sales target, but a performance indicator that forces automakers to develop increasingly efficient NEVs.

The NEV credit and the Dual credit policy have been implemented in three phases:

- Phase 0 (2016 – 2018) when MIIT proposed a Temporary Management Regulation for Corporate Average Fuel Consumption (CAFC) and New-Energy Vehicle (NEV) Credits.
- Phase I (2019 - 2020) defined in the regulation "Measures for the Parallel Management of Average Fuel Consumption of Passenger Car Companies and New Energy Vehicle Credits" which concerns BEVs and PHEVs.
- Phase II (2021 - 2023) defined in the regulation "Decision on Amending the "Measures for the Parallel Management of Average Fuel Consumption of Passenger Car Companies and New Energy Vehicle Credits", which concerns BEVs, PHEVs and FEVs (Fuel Efficient Vehicle[33]).

Phase III is planned from 2024, the characteristics and criteria of which are not yet known. However, we can expect further tightening of the individual performance criteria, as well as a particular focus on range and total vehicle power consumption, the latter being a unique Chinese regulatory requirement and competitive advantage to date.

The table below shows the annual NEV credit targets and the calculation method for BEVs, by phase.

"NEV credit"	Phase I	Phase II
Annual target	2019: 10% 2020: 12%	2021: 14% 2022: 16% 2023: 18%
BEV calculation principle	Base Calculation (**BC**) = (0.012 x autonomy (**A**) + 0.8) NEV credit = BC x Energy consumption multiplier (**EC**) Capped at 6	Base Calculation (**BC**) = (0.0056 x autonomy (**A**) + 0.4) NEV credit = **BC** x Range multiplier (**CA**) x **EC** x Battery energy density multiplier (**DB**) Capped at 5,1

Table 3-3: Annual NEV credit targets and calculation method for BEVs
Source: author's analysis of cited regulations

The multiplier values applicable in Phase II are calculated according to the method described in the table below. Since most of the multipliers are less than one, only vehicles that perform better than expected can expect to receive a high NEV credit value.

Multiplier coefficient	Calculation method
Range Multiplier (**CA**) calculated according to vehicle range (**A**) expressed in km	A < 100: CA = 0 100 ≤ A < 150: CA = 0.7 150 ≤ A < 200: CA = 0.8 200 ≤ A < 300: CA = 0.9 300 ≤ A: CA = 1
Battery Density Multiplier (**DB**) calculated according to battery energy density (**ED**) expressed in WH / kg	ED < 90: DB = 0 90 ≤ ED < 105: DB = 0.8 105 ≤ ED < 125: DB = 0.9 125 ≤ ED: DB = 1
Energy consumption Multiplier (**EC**) calculated according to car target energy consumption (**Y**) - as a function of mass M - and car's measured energy consumption (**CEM**)	1.5 x CEM ≤ Y : EC = 1.5 CEM ≤ Y < 1.5 CEM : EC = CEM / Y Y < CEM: EC = 0.5

Table 3-4: Method of calculating multiplier coefficients for Phase II NEV credit for BEVs
Source: author's analysis of cited regulations

Since Phase I (in 2019), the regulation, known by the simplified name of "Dual Credit Policy", stipulates that any automaker that sells more than 30,000 locally manufactured or imported vehicles in the Chinese market must meet annually the CAFC credit and/or the NEV credit targets[34]:

- An automaker offering both ICEVs and NEVs must meet both CAFC and NEV credit targets.
- An automaker offering only NEVs must meet the NEV credit annual target and may also earn some CAFC credits, as the CAFC regulation now applies to all fuel types.

CAFC and NEV credit scores are calculated annually for each automaker (MIIT is in charge of releasing the annual CAFC and NEV credits records), and each score must be positive. If this is not the case:

- When an automaker is unable to meet its annual NEV credit targets, and (any) surpluses from previous years are insufficient to do so, it must purchase NEV credits through an Over-The-Counter market from another manufacturer.
- If an automaker is unable to meet its annual CAFC targets, it can use excess CAFC or NEV credits earned in previous years, or even transfer excess CAFC earned by its subsidiaries. If this is not enough, it must purchase NEV credit from another automaker.

Consequently, if an automaker fails to meet its targets, it is de facto strengthening a competitor by purchasing NEV credits. Penalties may apply if an automaker, with a deficit in NEV and / or CAFC credits, fails to offset its deficit by purchasing of NEV credits.

Most importantly, the "dual credit policy" is a very efficient tool for selecting local and future global champions, as shown in the table below, where the number of automakers meeting the standard is decreasing year by year and, conversely, the number of those not meeting the standard is increasing year by year.

Dual Credit Records of Nationwide Fuel Consumption and Green Energy 2016 to 2020						
Year	Nationwide Fuel Consumption: Positive Credit Score	Nationwide Fuel Consumption: Negative Credit Score	Nationwide New Energy: Positive Credit Score	Nationwide New Energy: Negative Credit Score	Number of Automobile Manufacturers Meeting the Standard	Number of Automobile Manufacturers Failing to Meet the Standard
2016	11,748,600	-1,429,900	989,500	-	80	44
2017	12,381,400	-1,689,000	1,793,200	-	74	56
2018	9,929,900	-2,951,300	4,035,300	-	66	75
2019	6,434,300	-5,107,300	4,173,300	-855,300	58	86
2020	4,367,400	-11,714,300	4,370,000	-1,065,500	44	93

Table 3-5 : Dual Credit records 2016 – 2020
Source: Ministry of Industry and Information Technology of China

If we take a closer look at the 2021 results provided by MIIT, we see that the companies that do not meet both standards are mainly JVs with foreign automakers (See Figure 3-2 below). This shows that foreign JVs must propose more high-performance PEVs and ICEVs to meet China's stringent requirements.

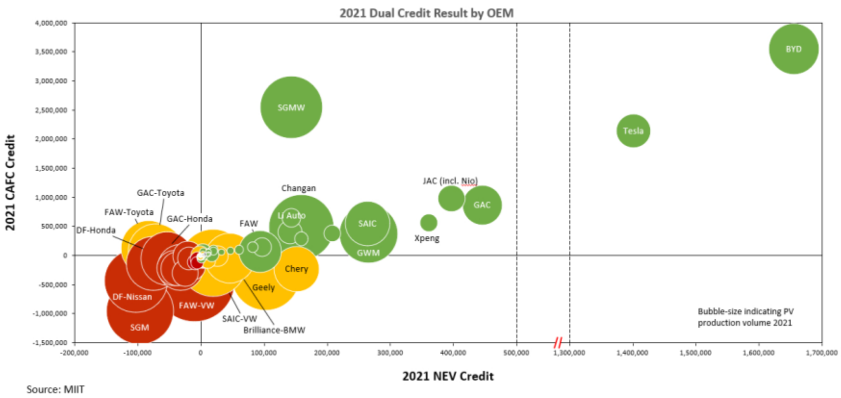


Figure 3-2 : China automakers' 2021 NEV and CAFC credit results mapping
Source: Ministry of Industry and Information Technology of China[35]

Strictly speaking, the OTC NEV credit market is not a financial support from the Chinese government to the industry. However, as the NEV credits are purchased by foreign JVs of Chinese automakers (and Tesla), it increases the financial capacity of Chinese automakers, and not just marginally. Our estimate, based on the "Annual Report on the Implementation of CAFC and NEV Management for Passenger 2022" realized by MIIT[36], is €1.8 billion by 2021 and at least €1 billion each year after 2022.

3.2.3.3. Vehicle production funding

We have attempted to assess the level of funding, said to be massive, that the government has provided to this nascent industry, all along the value chain.

The following orders of magnitude illustrate the scale of the deployment of the NEV industry (automakers only):

- Between March 2017 and March 2019, 34 "NEV production licenses" were issued by the NDRC[37] and regional DRCs, with an annual production capacity of more than 4.5 million vehicles and an initial investment of just under €20 billion as summarized in the Table 3-6 below.
- In 2019, 500 NEV manufacturers were registered in China[38], 60 of which had at least one vehicle concept, which is one of the mandatory requirements to obtain a NEV production license.

		Agreement given by			Amount of investment	
Year	Number of projects	NDRC	DRC	Yearly production capacity	RMB billion	Euros billion
2016	9	7	2	1 205,000	27,525	3,58
2017	9	8	1	875,000	22,18	2,88
2018	5		5	950,000	50,6	6,58
2019	11		11	1 530,000	52,36	6,81
Total	34	15	19	4 560,000	152,665	19,85

Table 3-6 : Summary of "NEV production license" agreements delivered by NDRC and regional DRC
Source: Author search based on production permits issued by NDRC and regional DRCs between March 2016 and March 2019

Combining these two pieces of information, 60 companies were potentially eligible for the "NEV Production License" program, resulting in a total investment of between 20 and 35 billion euros between 2016 and 2019 to support the development of automakers (incumbents or newcomers) with the capability to produce efficient NEVs.

We also found track of two instruments addressing all industries:

1. *Government industrial policy support fund* with an allocation of €2,5 billion to SAIC, €1 billion to BYD and €300 million to CATL between 2017 and 2021, totaling €3,8 billion in this period for three companies[39].
2. *Government grants and subsidies* with an allocation of €590 million to BYD between 2013 and 2017[40], and then a total allocation of €1 590 million to BYD between 2013 and 2021.

If we extend the scope of the estimate to include the top ten NEV and battery manufacturers between 2009 and 2022, we suggest that this visible part of the support could be around €40-50 billion. If we add the investment in companies eligible to "NEV Production License", the ***visible*** financial support from the Chinese government between 2009 and 2022 can be around €60-85 billion.

The "whatever it takes" approach we associate with the "Administered Darwinism" is first illustrated by the massive total amount of ***visible*** financial support at the national level, around €115-150 billion by 2022. We estimate that this could continue with an estimated financial support to the industry of €10-20 billion per year from 2023 onwards.

3.2.3.4. Purchase subsidies

Traditionally, the role of subsidies is to encourage demand by making the product more affordable to buy and/or use. The Chinese government's strategy largely follows this conventional approach, but subsidies have also been used from the outset as a means of improving vehicle performance.

In 2009, the launch of the "Ten Cities for a Thousand Vehicles" program (2009-2012) was accompanied by a financing plan in the form of purchase subsidies[41]. It applied to vehicles produced by automakers and battery manufacturers with large-scale design and production capabilities, as well as product warranty and maintenance capabilities[42]. The functional requirements are very low, but take into account the real capabilities of the nascent electric vehicle industry: a subsidy of 60,000 RMB (7,800 €) is granted for an electric vehicle with a battery of at least 15kWh (and which is not a lead-acid battery), a minimum range of 50km and can run for at least 30mns at 100km/h.

These very modest criteria are nonetheless the first step in a dynamic that has led to a gradual increase in the number of criteria taken into account in the calculation, as well as the rapid tightening of thresholds for these criteria.

Based on our own analysis of the intense regulatory activity (no less than 10 regulations enacted between 2010 and 2020), the table below shows the dynamics of the introduction of new criteria and of the tightening of the subsidy calculation method.

Date / Title of regulation	Subsidy calculation method (private vehicles)
From 13/09/2013 (Notice on continuing to promote the application and application of new energy vehicles)	Amount of subsidy = Amount Autonomy subsidy (**SA**)
From 12/02/2018 (Notice of the Four Ministries (MOF, MIIT, MOST, NDRC) on Adjusting and Perfecting the Financial Subsidy Policy for the Promotion and Application of New Energy Vehicles)	Grant amount = **SA** x **EC (**Energy Consumption multiplier**)** x **DB** (Battery Density multiplier)
From 26/03/2019 (New energy vehicle promotion subsidy program and product technical requirements)	Subsidy amount = Min **{SA**, Battery Subsidy} x **EC** x **DB**
From 23/04/2020 (Notice on improving the financial subsidy policy for the promotion and application of new energy vehicles)	Subsidy amount = Min {**SA,** Battery Subsidy} x **EC** x **DB** The sale price ≤ 300,000 RMB – 39,000€ (unless the vehicle is equipped with battery swap)

Table 3-7: Dynamics of integrating new criteria for calculating subsidies for private BEVs
Source: Author's study of various regulations

This subsidy calculation grid brings the following comments:

1. The consistency of the criteria and the method used to calculate the NEV credit and the amount of the subsidy demonstrate the coherence and determination of the Chinese strategy. The multipliers linked to the energy efficiency of the battery (**DB**) and the vehicle (**EC**), when less than 1, help to reduce the subsidy for vehicles with less than the best performance, driving them out of the market with a double penalty: poor performance and reduced (even suppressed) subsidy amount.
2. The choice of the minimum subsidy between that linked to the range of the vehicle and that linked to the size of the battery shows that the increase in range must be achieved mainly by reducing the overall consumption of the vehicle.
3. The €39,000 price cap is clearly a protectionist measure: it was aimed at Tesla, who immediately lowered the price of the Model 3. Meanwhile, NIO, which developed the "battery swap" function, continues to benefit from subsidies with an average selling price of 428,000 RMB (€55,640).[43]

Purchase subsidies were due to disappear at the end of 2019 to avoid artificially maintaining automakers unable to meet technology and cost requirements, but it was decided to extend them until the end of 2022[44]. This was to take into account the slowdown in the overall Chinese auto market, the impact of Covid-19, and the need to support NEV sales. In October 2022, the Ministry of Finance announced the continuation of the purchase subsidy until the end of 2023 and the amount of the allocation to the regions to support the market whose performance at the beginning of 2023 is significantly lower than the same period in 2022[45].

Year	Subsidy amount (billion RMB)	Subsidy unit ('000 units)	Average subsidy amount for each vehicle ('000 RMB)
2009 - 2015	33,435	Not documented	Not documented
2016	21.3	154	138
2017	37.6	455	83
2018	47.1	953	49
2019	27.4	789	35
2020	15.3	788	19
2021	23.1	1641	14
2022	21	Not documented	Not documented
2023	19	Not documented	Not documented
Total	245,235 (€ 32 billions)	4780 by the end of 2021	Not documented

Table 3-8: Amount of purchase subsidies in China between 2015 and 2023
Sources: 2016-2021 and 2023 provision = MIIT, 2009 -2015 and 2022 = Author's assessment based on different sources [46]

3.2.3.5. Purchase tax credits

Since 2014, China's Ministry of Finance has exempted the purchase of low-emission vehicles (BEVs, PHEVs and FCVs) from vehicle purchase tax. It was extended in 2017, 2020, and in 2022 until December 2023, and is expected to exempt 100 billion RMB (€13 billion) in taxes in 2023[47].

In June 2023, a further tax exemption of RMB 520 billion (€67.6 billion) in 2024-2027 was announced as part of a plan to promote the development of NEVs. Specifically, the tax exemption will be up to RMB 30,000 (€3,900) per vehicle in 2024 and 2025, and will be halved (€1,950) in 2026 and 2027[48]. The table below summarizes our assumptions and results for the tax exemption through 2023.

Year	2014 – 2020	2021	2022	2023
Sales (millions of vehicles)	5	3,4	6,2	8
Average tax exemption per vehicle (€)	1000 1625	1625	1625	1625
Calculated tax exemption per period (€ billions)	5 – 8	5,5	10	13
Cumulated tax exemption per period (€ billions)	5 - 8	10,5 – 13,5	20,5 – 23,5	33,5 – 36,5

Table 3-9 : Evaluation of the Chinese tax exemption for the purchase of NEVs
Source: Author's assessment based on figure provided by the (Chinese) State Administration of Taxation

In total, the purchase tax exemption will amount to more than €100 billion between 2014 and 2027 and is another very convincing demonstration of a "whatever it takes" strategy to develop and support the NEV market in adverse conditions.

3.2.4. Charging network

The development of an accessible public charging network is extremely important in China's most densely populated areas, which are the priority zones for the development of electric vehicles. Indeed, the development of highly urbanized residential areas on the outskirts of China's major cities poses a specific problem: it is simply impossible to install “classic” charging stations with a satisfactory level of equipment in residential areas – the target set by the Chinese government is 1:1[49] – with very dense vertical housing, comprising tens of thousands of inhabitants within a limited perimeter. This is one of the reasons, among others, for the development of the “battery swap” technology which makes it possible to recover 100% of the range by installing a charged battery in place of the discharged one, all in a time comparable to that required to fill a fuel tank.

The development of the charging network was part of the "Ten cities with thousand vehicles" program (2009-2012) from the very beginning. The intention was to avoid the lack of access to a charging station, one of the most frequently cited reasons for not buying an electric vehicle.

In 2014, the Chinese State Council issued a notice on "Accelerating the Guiding Opinions on Accelerating the Popularization and Application of New Energy Vehicles," which calls for accelerating the implementation of the charging network and the development of innovative technologies, including battery swap, which could provide a credible and adapted alternative to the classic battery (re)charging solution.

After the end of the first demonstration program, which targeted a small number of cities, the development of the charging network was made according to priorities: highly populated and polluted areas first[50], i.e., along the eastern Chinese coast in the 2013-2105 period. As shown in the figure below, three different EV and charging network deployment zones were defined for the 2016-2020 period and have been renewed for the current period.

The current pace of charging network expansion remains quite high as[51]:

- About 632,000 charging points were added in the first three months of 2023, up 28.6 percent from the same period in 2022.
- By the end of March 2023, China had more than 5.84 million charging points, up 87.9 percent year on year.

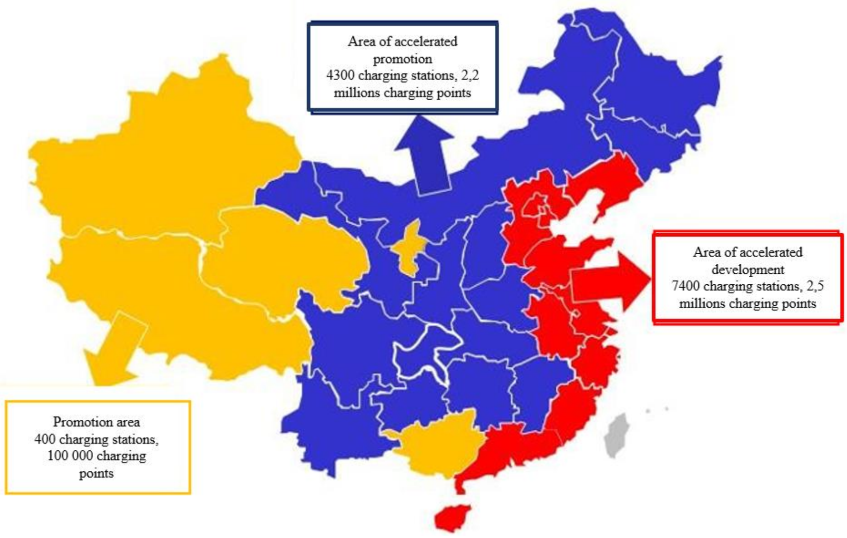


Figure 3-3 : Areas of deployment of charging network for the 2016 – 2020 period
Source: New energy vehicle charging infrastructure awards for various provinces (autonomous regions and municipalities) 2016-2020

However, the progress in charging network construction has fallen short of the planned targets. As of the end of 2022, China had a total of 13.1 million new energy vehicles, while the number of charging stations stood at 5.21 million, resulting in a nationwide vehicle-to-charger ratio of 2.5:1. This highlights a considerable gap when compared to the targeted 1:1 ratio.

The principle of incentivizing the deployment of the charging network is to provide subsidies for the installation of the network based on the number of vehicles sold: an amount was allocated for each vehicle sold up to the minimum sales threshold. The same amount was allocated for each vehicle sold above the threshold, with the total amount of subsidies capped. This principle has persisted over time and is still in use, with different values allocated per vehicle and for the total subsidy amount. The table below provides examples of the amount allocated per vehicle and the total subsidy amount in the area of accelerated development between 2016 and 2020.

Year	Area of accelerated development				
	Minimum sales threshold	Subsidy amount per vehicle (RMB)	Subvention for the sales threshold (RMB millions)	Additional maximum subvention (RMB millions)	Maximum subvention (RMB millions)
2016	30000	9000	270	120	390
2017	35000	9500	332,5	140	472,5
2018	43000	10400	447,2	160	607,2
2019	55000	11500	632,5	180	812,5
2020	70000	12600	882	200	1082
Total (RMB millions)			2564,2	800	3364,2
Total (€ millions)			333,3	104,0	437,3

Table 3-10 : Example of subvention allocated for the charging network in the area of accelerated development 2016 – 2020
Source: New energy vehicle charging infrastructure awards for various provinces (autonomous regions and municipalities) 2016-2020

Combining similar information for all regions between 2013 and 2015 (New energy vehicle charging facility reward standard 2013－2015） and between 2016 and 2020 (same source as for Table 3-10), we obtain a range of investment between €0,7 and €1,15 billion for 168 100 charging points at the end of 2020. Considering 521,000 charging points at the end of 2022, we obtain a range of investments between €2,6 and €3,5 billion by 2022. Using the same calculation method, we estimate the investment for 2023, for about 437,000 new charging points, at €1,8 - 3 billion[52].

The Chinese government is clearly at the origin of the development of the "battery swap" technology. It is mentioned as early as in 2014 in the opinions on "Accelerating the Popularization and Application of New Energy Vehicles". The "New Energy Automobile Industry Development Plan (2021-2035)", released in 2020, highlights the necessity and importance of accelerating its rollout.

In 2021, after a selection phase, the government launched a pilot project to achieve more than 1 000 battery-swapping stations and 100,000 battery-swap EVs on the road in 11 cities including 8 cities for passenger cars (Beijing, Nanjing, Wuhan, Sanya, Chongqing, Changchun, Hefei, Jinan), and 3 cities for heavy trucks (Yibin, Tangshan, Baotou).

Finally, the NDRC's document "Further Enhancing the Service Guarantee Capacity of Electric Vehicle Charging Infrastructures" in 2022, which aims to support the charging infrastructure system's goal of meeting the battery charging needs of more than 20 million electric vehicles by the end of the "14th Five-Year Plan," clearly identifies battery swap as a key technology to be developed[53].

3.2.5. Collecting, recycling and reusing battery key materials

The 2006 guideline "Automotive Product Recycling Technology Policy" requires NEV manufacturers to take responsibility for the recycling and reuse of used batteries and the "Circular Economy Promotion Law of the People's Republic of China"[54] which took effect on January 1, 2009, is, to our knowledge, the founding text dealing with the circular economy. It introduces the concept of reduction (of the use of resources and the generation of waste), reuse and recycling activities and sets incentive measures in a logic close to what was decided, about a decade ago, for the development of the NEV industry:

- Funding to support R&D, demonstration and promotion of the science and technology relating to circular economy.

- Instructions to local authorities (of provinces, autonomous regions and municipalities directly under the Central Government) to develop an independent innovation research, application demonstration and industrialization of key projects.
- Tax preferences to companies actively promoting the development and the use of circular economy.

At the beginning of 2016, NDRC promulgated the first regulation addressing the issue of battery recycling, i.e., the “Technical Policy on Recycling of Power Battery for Electric Vehicles (2015 Edition)"[55]. In continuation of the “Circular Economy Promotion Law of the People's Republic of China” and in accordance with the “Energy Saving and New Energy Vehicle Industry Development Plan (2012-2020)”, this regulation:

- Sets out a general framework for “Battery Product Coding and Tracing” policy,
- Defines non-binding targets for recycling of raw materials, namely minimum of 98% for nickel, cobalt and manganese and of 97% for nickel and rare earths.

After the first dedicated battery recycling regulation, MIIT has launched two additional regulations in 2018:

- “Interim Provisions on The Traceability Management of Power Battery Recovery and Utilization of New Energy Vehicles” which requires the installation of a comprehensive management platform to perform traceability management for the entire power battery process. Therefore, starting from 2018, a unique code had been assigned to each battery produced or imported.
- Notice on the Pilot Work of EV Power Battery Recycling which triggered a pilot program with 17 cities and regions selected, including Beijing, Shanghai and Jiangsu.

"China's 14th Five-Year Plan for Circular Economy Development" released by NDRC in mid-2021, provides more guidance on the design and operation of the battery recycling ecosystem involving all stakeholders.

Lastly, MIIT issued the “Circular of the Four Ministries on the Issuance of the Pilot Implementation Plan for the Extension of Producer Responsibility for Automotive Products” in 2021[56]. It requires automakers to play a leading role in the entire life cycle of automotive products and to establish a reverse recycling system for end-of-life vehicles (including information system for traceability) to improve the efficiency of resource use. The scope is much broader than battery recycling and is a strong incentive to develop an operational circular economy[57].

[21] Sources:
- The development of new energy vehicles for a sustainable future: A review. X.Yuan et al. – Renewable and Sustainable Energy Reviews 42 (2015) pp 298–305
- Who does what in China's new energy vehicle industry? Liu and Kokko - Energy Policy 57 (2013) pp 21–29
- Author's own research
[22] In addition to applying national policies, local governments are also pushing their own agendas in two directions: supporting local PEV market adoption (see https://theicct.org/publication/pv-chinese-cities-nev-policies-feb23/) and developing their local industry (see "The innovation odyssey, lessons from an impossible project". C.Midler, M. Alochet, de Charentenay C, Taylor & Francis (2023), p 124)
[23] All quotes are Google translations of excerpts from the documents listed.
[24] Situation and Policies of China's Rare Earth Industry.
http://english.www.gov.cn/archive/white_paper/2014/08/23/content_281474983043156.htm
[25] Biedermann, R. (2018). China's Raw Materials Diplomacy and Governance Cycle: Toward Sustainable Mining and Resource Extraction? Issues & Studies, 54(04), 1840009.
Jetin, B. (2018). 'One Belt-One Road Initiative 'and ASEAN Connectivity: Synergy Issues and Potentialities. In China's Global Rebalancing and the New Silk Road (pp. 139-150). Springer
[26] https://www.iea.org/policies/15513-sasac-announcement-on-the-establishment-of-china-rare-earth-group
[27] Author's summary of the analysis of the development of the rare earth industry in China developed in:
Barteková, Eva, and René Kemp. "Critical raw material strategies in different world regions." The United Nations University-Maastricht Economic and Social Research Institute on Innovation and Technology (UNU-MERIT) Working Papers 5 (2016).
[28] Global EV Outlook 2020, IEA
[29] Coined by Wang and al. in Wang, X., Zhao, W. and Ruet, J. (2022) 'Specialized vertical integration: the value-chain strategy of EV lithium-ion battery firms in China', Int. J. Automotive Technology and Management, Vol. 22, No. 2, pp.178–201.
[30] Introduced in 2016, the "Parallel Management Regulation for Corporate Average Fuel Consumption and New Energy Vehicle Credits for Passenger Cars" has been revised several times, most recently in 2020, and has been in force since January 1, 2021.
[31] Chinese GB standards are mandatory while GB/T standards are only recommended
[32] https://www.chinaev100.com/news/detail/1255
[33] A FEV is an ICEV that achieves a consumption result significantly below the imposed threshold
[34] This regulation is inspired by the LEV regulations first introduced in California in the mid-1990s, which required automakers to continually reduce emissions from ICEVs and phase in ZEVs.
[35] Accessed at
https://mms.businesswire.com/media/20220823005863/en/1551986/5/PR_chart.jpg?download=1&_gl=1*1tk0xbl*_ga*NDA5NDExNzY0LjE2ODQ4NDAyOTU.*_ga_ZQWF70T3FK*MTY4NDg0MDI5NS4xLjEuMTY4NDg0MDMxNy4zOC4wLjA.
[36] http://www.miiteidc.org.cn/art/2022/7/5/art_88_31014.html.
[37] The National Development and Reform Commission (NDRC) is China's national planning agency. It plays a predominant role in steering the development of Chinese industry, including authorizing the creation of industrial capacity. It has jointly promulgated the key regulations for the development of the NEV industry. The issuance of the "NEV Production License" was conditioned on the demonstration of strong capabilities in design, manufacturing and after-sales management, as well as the presentation of a prototype.
[38] Song N., Suzuki H. and Aou M., 2019, "Will Chinese EV Start-Ups Reshape the Automotive Industry?", adlittle.com,
[39]https://asia.nikkei.com/Business/Business-Spotlight/Made-in-China-2025-thrives-with-subsidies-for-tech-EV-makers
[40] https://qz.com/1579568/how-much-financial-help-does-china-give-ev-maker-byd
[41] For private vehicle purchases, the subsidies are allocated to automakers, who then deduct them from the sales price to the end customer.
[42] In the late 2000s, there were unregistered electric vehicles, Low Speed Electric Vehicles (LSEVs), assembled by companies that have improvised themselves as car manufacturers. They are all the rage outside of developed areas, because they are inexpensive and do not require a driver's license, making it possible to meet important local mobility needs. These vehicles also had very low performance in terms of speed, range and safety. As a result, the Chinese government aimed to displace LSEVs and transform the traditional automotive industry into a strategic emerging industry, the NEV industry. Chen, B., Midler, C., Ruet, J., 2018. Electric vehicle development in China: market realities and regulatory dynamics. Gérer et Comprendre, Annales des Mines 131, pp 69-79.
[43] https://www.nio.com/news/100000th-nio-vehicle-rolls-production-line
[44] http://en.caam.org.cn/Index/show/catid/23/id/1612.html
[45] http://jjs.mof.gov.cn/zxzyzf/jnjpbzzj/202211/t20221114_3851441.htm
[46] https://www.china-briefing.com/news/china-considers-extending-its-ev-subsidies-to-2023/, https://www.sixthtone.com/news/1012221
[47] http://www.chinatax.gov.cn/eng/c101269/c5181783/content.html
[48] https://www.reuters.com/business/autos-transportation/china-announces-extension-purchase-tax-break-nevs-until-2027-2023-06-21/
[49] https://www.china-briefing.com/news/electrifying-the-road-ahead-unlocking-chinas-ev-charger-industry-potential/
[50] People living in these areas of rapid economic development also benefit from higher incomes, making them potential buyers of EVs, which are more expensive than ICEVs.
[51] https://english.www.gov.cn/archive/statistics/202304/16/content_WS643b99b7c6d03ffcca6ec55b.html
[52] Figures about number of charging points available at https://www.china-briefing.com/news/electrifying-the-road-ahead-unlocking-chinas-ev-charger-industry-potential/
[53] Implementation Opinions of the National Development and Reform Commission and Other Departments on Further Enhancing the Service Guarantee Capacity of Electric Vehicle Charging Infrastructures
Development and Reform Energy Regulation. https://www.gov.cn/zhengce/zhengceku/2022-01/21/content_5669780.htm
[54] https://www.lawinfochina.com/display.aspx?id=7025&lib=law
[55] http://zfxxgk.ndrc.gov.cn/web/iteminfo.jsp?id=2389
[56] https://news.metal.com/newscontent/101501752/the-ministry-of-industry-and-information-technology-and-other-four-departments-issued-the-pilot-implementation-plan-for-the-extension-of-producer-responsibility-of-automotive-products and
https://www.miit.gov.cn/zwgk/zcwj/wjfb/zbgy/art/2021/art_41ae7b048792416ca167bde07368475f.html
[57] This section is based on the author's own research and two documents that summarize recycling technologies, policies, and ecosystem approaches:
- Scaling up reuse and recycling of electric vehicles batteries: assessing challenges and policy approaches
  https://theicct.org/wp-content/uploads/2023/02/recycling-electric-vehicle-batteries-feb-23.pdf
- International review on Recycling Ecosystem of Electric Vehicle Batteries
  https://changing-transport.org/wp-content/uploads/GIZ-Battery-Recycling-Report.pdf

3.3. European regulations

Since the 1970s, the rationale for developing the regulatory framework focused on reducing CO2 and pollutant emissions has been conceived with a certain sense of inevitability. The political institution left it to the historical actors (i.e., the automakers) to decide on the feasibility of the proposed evolution, based on the technologies they were likely to develop as a continuation of those they had already mastered. Since 1993 (Directive 93/59/EEC), successive regulations – even if they were always aimed at reducing the level of pollutant and CO2 emissions – have been drawn up in collaboration with ACEA, with a view to technological neutrality and long-term visibility[58].

In 2015, the "*High Level Group on the Competitiveness and Sustainable Growth of the Automotive Industry in the European Union"* had been mandated by the European Commission to define the conditions for Europe to have the most competitive, innovative and sustainable automotive industry by 2030 and beyond. Their report, GEAR 2030, written at the same time as the redefinition of vehicle emission targets for the post-2020 period and published in 2017[59], recognized the importance of ZEVs and ZECs (Zero Emission Capable vehicle) in achieving a sustainable automotive industry and insisted on the importance of an *"an appropriate technology neutral regulatory framework"* (Op. Cited, p 4).

But two events changed Europe's historic approach in favor of technological neutrality. First, the revelation of the discrepancies in NOX emissions between type-approved values and actual values measured in use, followed by the "Dieselgate," shifted Europe, from 2015 onward, to a strategy of technological forcing, which first led to the acceleration of the promulgation of the WLTP and RDE regulations, which were under discussion since the 2010s.

Second, the presentation of the European Green Deal in late 2019 led to the enactment of a set of regulations aimed at reducing net greenhouse gas emissions by at least 55% by 2030 compared to 1990 levels. It has accelerated the transition to decarbonize mobility with the most radical trajectory:

1. The "Fit for 55" proposal of July 14, 2021, definitively accepted on March 28, 2023, leads to the adoption of ZEVs as early as 2035 and has put an end to the technology-neutral approach, even though CO2-neutral alternative-fuel ICEVs will be authorized for sale after 2035.
2. Euro7, proposed by Commission on November 10, 2022, if passed in its initial content, could lead to the de facto elimination of ICEVs before the end of this decade. While the Council's position is to maintain the existing emission limits and testing

requirements for LDVs, the Parliament is sticking to the original proposal for passenger cars, creating uncertainty for the industry and putting its future at risk.

If we summarize the main regulations (see Table 3-11) related to the ongoing transition to electric mobility, we see both a half-full glass, as the regulatory framework now covers the entire lifecycle thanks to intense regulatory activity, and a half-empty glass, as some very important texts have only been proposed for 2023 and are still in the process of being finalized. This is the case for the CRMA, NZIA and EPIB, while the Euro7 proposal only extends to 2022.

PEV value chain stage	Regulation		
	Name or Objective	Document and/or Communication reference	Status[60]
Extraction of raw materials and refining	Critical Raw Materials Act (CRMA)	52023PC0160 COM (2023) 160 final	Proposal from the Commission on March 16, 2023 **Council and Parliament strike provisional deal on November 13, 2023**
Manufacturing of battery components, cells and packs	Net Zero Industry Act (NZIA)	52023PC0161 COM (2023) 161 final	Proposal for a regulation of the European Parliament and European Council on March 16, 2023 Parliament adopted its position on November 21, 2023 **The Council adopted its position on December 7, 2023**
Production of vehicle	Strengthening the CO2 emission performance standards	32023R0851 PE/66/2022/REV/1	Proposal presented by the Commission on 14 July 2021 Regulation (EU) 2023/851 is in force since May 9, 2023 and directly applicable
	Euro7 Proposal	52022PC0586 COM/2022 586	Proposal of the European Parliament and European Council on November 10, 2022 Council's position on emissions from cars, vans, buses and trucks on September, 25 2023 **Parliament adopted a negotiating position on November, 9 2023**
Charging network	Regulation on the deployment of alternative fuels infrastructure	32023R1804 PE/25/2023/INIT	Proposal presented by the Commission on 14 July 2021 Regulation (EU) 2023/1804 is in force since October, 12 2023 with application from April 13, 2024
	Promotion of e-mobility through buildings policy	52023DC0076 COM/2023/76 final	**Report from the Commission to the European Parliament and European Council on February 15, 2023**
Battery recycling	Battery directive *(And CRMA)*	32023R1542 PE/2/2023/REV/1	Proposal presented by the Commission on 10 December 2020 Regulation (EU) 2023/1542 is in force since August 17, 2023, with application from February 18, 2024

Table 3-11 : Summary of European regulations and proposals dealing with electric mobility
Source: Author's compilation of regulations / proposals announcements

3.3.1. Extraction of raw materials and refining

Recognizing the need for an integrated policy response at EU level to ensure sufficient access to raw materials at fair and undistorted prices, the European Commission launched the Raw Materials Initiative in 2008.

A Critical Raw Material (CRM) list was first established in 2011 and has been regularly updated every 3 years since then. A *critical raw material is* defined by its high economic importance and a high risk of supply without possible substitutes.

Although certain critical materials for the electric vehicle were identified as early as 2011, it was not the electric vehicle industry that justified the criticality of these materials at the time. We had to wait until the 2020 list to see lithium, cobalt and rare earths and a justification for their importance to the electric vehicle industry (Document 52020DC0474, page 5).

In 2023, the notion of strategic raw material was introduced[61] : a *strategic raw material* is characterized, in addition, by its importance for strategic fields such as renewable energies, digital, aerospace and defense technologies, by the expected growth in demand compared with current supply, and by the difficulties of increasing production. On this occasion, copper, nickel and manganese, defined as strategic materials for batteries, are added to the list.

Since the process of identifying critical and strategic materials began, their total number has risen steadily, more than doubling between 2011 and 2023. All materials required for the production of battery electric vehicles are now considered either critical or strategic as shown in table below.

Year of issue	Reference of CRM document	Total number of critical / strategic materials identified	Critical and strategic materials for battery electric vehicles
2011	52011DC0025	14	Cobalt, Graphite, Rare earths
2014	52014DC0297	20	+ Silicon
2017	52017DC0490	27	
2020	52020DC0474	30	+ Lithium
2023	Study on the Critical Raw Materials for the EU 2023	34	+ Copper, + Nickel, + Manganese[62]

Table 3-12: Dates of inclusion of critical and strategic materials for PEVs in European CRMs

Source : https://single-market-economy.ec.europa.eu/sectors/raw-materials/areas-specific-interest/critical-raw-materials_en

On the one hand, Europe has clearly identified both critical and strategic raw materials, as well as bottlenecks in the production of the main components of electric vehicles, namely the battery, the electric motor and the fuel cell, through two forward-looking studies on critical raw material requirements for the horizons 2030 and 2050[63].

On the other hand, it has launched several initiatives such as the EIP raw materials[64], the EIT raw materials[65] and the European Raw Materials Alliance[66] to bring together all the players in research and industry to launch projects aimed at contributing to sustainable supply.

What is lacking in this effort are rules that will allow Europe to reduce supply risks, a fact that was clearly recognized at the very beginning of the Communication on the Critical Raw Materials Act (CRMA), proposed on 16/03/2023: "*At present, there is no regulatory framework aimed at structurally reducing supply risks across the range of critical raw materials*".

The overall objective of the CRMA is therefore to establish a framework to ensure the Union's access to secure and sustainable supplies of critical raw materials, as shown in the table below, which summarizes the Commission's initial proposal and the provisional agreement reached between the Council and the Parliament on November 13, 2023.

Objective	Proposals
Increase EU capacity in the value chain of each strategic raw material by 2030	- Extraction capacity to cover at least 10% of annual consumption of strategic raw materials (insofar as EU reserves allow) - Processing capacity to cover at least 40% of annual consumption of strategic raw materials - Recycling capacity to cover at least 15% of annual consumption of strategic raw materials. **Increased to 25% on November 13, 2023**
Diversifying sources of supply for strategic raw materials by 2030	No single third country may account for more than 65% of annual consumption of a strategic raw material.

Table 3-13: Main provisions of the Critical Raw Material Act to secure supplies of strategic materials
Source: Analysis by the author of proposal COM/2023/160 and of the Council press release of November 13, 2023

The CRMA also aims to reduce administrative burdens and includes provisions to simplify permitting procedures for projects involving critical and/or strategic raw materials. The total duration of the permit granting process should not exceed 27 months for extraction projects and 15 months for processing and recycling projects (excluding the first step of the environmental impact assessment conducted by the promoter of the project).

Given the current average lead time of fifteen years, the high level of financing and the environmental risks involved in starting a new mining activity, Europe is also focusing on establishing free trade agreements with third countries for the supply of raw materials.

Two strategic partnerships on raw materials have been adopted, one with Canada in June 2021 and one with Ukraine in July 2021, aiming at a closer integration of raw materials and battery value chains. The Commission will continue to explore ways to enhance cooperation with other trading partners, including Norway and countries in Latin America and Africa, as well as the Western Balkans and Greenland[67].

3.3.2. Manufacturing of battery packs, (modules), cells and main components

To address the expected massive deployment of electric vehicles and the need to overcome the lack of mass production capacity and European companies capable of exploiting it, the Commission launched the European Battery Alliance (EBA) project at the end of 2017[68]. This program aims to develop an innovative, competitive, and sustainable European battery value chain.

This was followed in 2018 by the definition of six strategic priorities, including securing access to raw materials, supporting European battery manufacturing through investment, accelerating R&D plans and developing a skilled workforce.

In addition, the Net Zero Industry Act (NZIA proposed on 16/03/2023, COM/2023 161 final) sets targets for the localization of the battery value chain:

- 40 % of components manufacturing by 2030,
- Almost 90% of the Union's battery annual demand being met by the Union's battery manufacturers, translating into a Union manufacturing capacity of at least 550 GWh in 2030.

The Parliament has adopted its position on the NZIA proposal[69], and among the suggestions made, there are three important amendments in favor of the industrialization of the battery value chain (also applicable to other net-zero technology value chains) in Europe:

- The extension of the scope of the draft legislation to the entire supply chain, including components, materials and machines for the production of net-zero technologies, which is a gap in the Commission's original proposal,
- The definition of two project classifications: net-zero technology manufacturing projects and net-zero strategic projects, coupled with the streamlining of the permitting process by establishing a timeline of 9 to 12 months for regular projects and 6 to 9 months for strategic projects to be approved.
- The creation of "Net Zero Industry Valleys" initiatives and the acceleration of the permitting process by delegating portions of the environmental assessment evidence gathering to member states.

The Council's position, published on 7 December 2023[70], supports the main objectives of the NZIA as well as the Parliament's proposals, but makes several improvements, such as broadening the scope, clarifying the rules on licensing procedures, market access and public procurement, and promoting skills, research and innovation.

The EU-UK Trade and Cooperation Agreement, entered into force on May 1, 2021, includes rules of origin (ROO) provisions for batteries and PEVs that are deliberately designed to increase the localization of the value chain. For the period ending December 31, 2023, the maximum value of non-originating materials should be less than 70% for battery cells (modules) and packs and 60% for PEVs. Considering that, due to unforeseen circumstances, the implementation of the battery value chain has not reached the expected level, the Commission proposed to the Council a one-off extension of the current rules until 31 December 2026, where the maximum value of non-originating materials should be less than 40% for battery packs, 50% for battery cells and 55% for PEVs[71]. The strongest constraint for the industry is the localisation of the production of active cathode materials in EU and UK[72].

According to the European Battery Alliance, investment (total public and private funding) in the battery value chain will exceed €180 billion by 2022, including at least €20 billion of public funding through the IPCEI framework, the EIB and research funding (notably Batt4EU)[73]. The total amount of (public + private) investment needed to create a self-sufficient battery industry by 2030 is estimated at around 500 billion euros[74], or an average of €40 billion per year between 2023 and 2030. If we consider the funding received by ACC through the IPCEI on batteries for the installation of the pilot line and two gigafactories[75], we obtain a ratio of 25% public funding (total of all subsidies) and 75% private funding on average. As a result, we maintain the figures of 45 billion euros until the end of 2022 and 10 billion euros per year between 2023 and 2030 of public funding for the development of the European battery value chain.

3.3.3. Production of vehicles

European automakers have to meet two regulatory emissions targets:

- One for CO2 emissions, commonly known as CAFE, where non-compliance leads to the application of a penalty calculated annually on the average emissions of the vehicles sold. From 2019, this is calculated by multiplying the number of grams over the target by the number of vehicles sold and the amount of the penalty for one gram, i.e., €95.
- The second one is for emissions of other pollutants[76], compliance with which is mandatory for each new type of vehicle placed on the market[77].

3.3.3.1. CO2 emissions regulations

The first European regulation on CO2 (443/2009/EC) set an emissions target (calculated for each manufacturer as the average emissions of all vehicles sold over one year) of 130 g CO2/km in 2015, and proposed a target of 95 g CO2/km in 2020. The figure below summarizes the targets set by successive regulations for passenger cars between 2009 and 2023, and for commercial vehicles between 2011 and 2023.

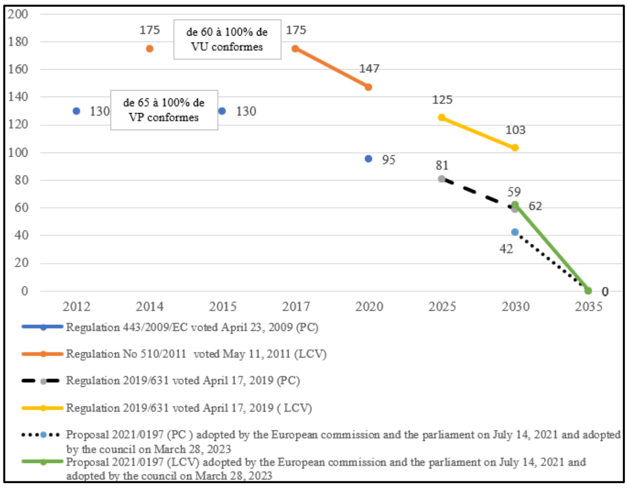


Figure 3-4: C02 targets for cars and trucks in Europe 2012 - 2035
Source: Author's analysis of cited regulations

The regulation EU 2023/851, adopted by the council on March 28, 2023 has validated the target of 100% ZEVs by 2035 and also modified the support mechanisms to obtain credits expressed in g CO2 / km:

- The "super credit" for vehicles emitting less than 50 g CO2 / km existing since 2012 will be discontinued from 2023 and replaced by a regulatory incentive mechanism for Zero and Low Emission Vehicle.
- The innovative technology package initially set at 7 g CO2 / km per automaker (EU 333/214) in 2014 and is as follows: 7 g CO2/km until 2024;6 g CO2/km from 2025 until 2029;4 g CO2/km from 2030 until and including 2034.

3.3.3.2. Regulations on pollutant emissions

Directive 70/220/EEC aimed to harmonize the different regulations of the Member States with regard to pollutant emissions. It therefore defined a series of maximum emission limits for certain pollutants and stipulated that any new vehicle model which met these criteria could not be refused European or national type-approval. Directive 91/441/EEC (Euro1) requires all Member States to grant type-approval from July 1, 1992 to any new vehicle model that meets the emission requirements it defines.

Successive regulations for passenger cars and light commercial vehicles (from Euro1 in 1992 to Euro6e currently in force for new type approvals from September 2023 and applicable to all vehicle types one year later) have systematically and significantly reduced the maximum limits for pollutants, as shown in the figure below using NOx as an example.

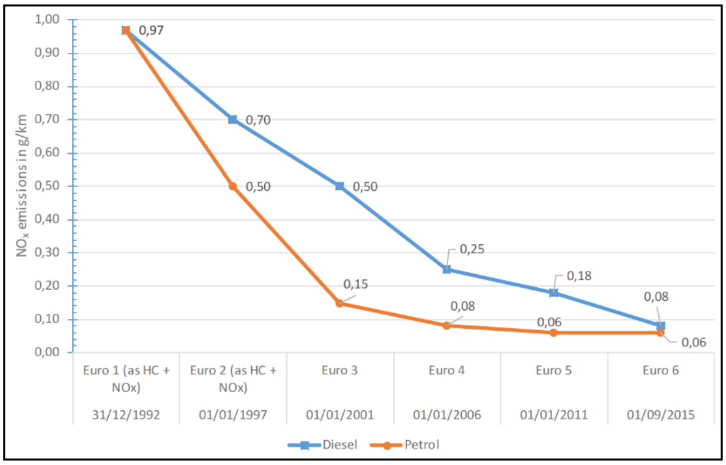


Figure 3-5: Changes in the maximum NOx threshold for diesel and gasoline passenger cars (in %)
Source: ECA analysis based on European directives cited above in "The EU's response to the "dieselgate" scandal"

Despite these very strict regulations, significant discrepancies were found between the theoretical NOx emissions of diesel vehicles, measured during tests to obtain regulatory compliance, and actual emissions during use[78]. In the context of the "Dieselgate" scandal, revealed in 2015, the Commission accelerated initiatives already underway to reduce this gap, leading to the addition of two complementary measures to the existing schemes:

1. Worldwide Harmonized Light Vehicles Test Procedure (WLTP), applied since September 2017 for new models, aims to define a driving cycle applied for homologation tests that is as representative as possible of real-life conditions.
2. Real Driving Emissions test procedure (RDE), applied to all vehicles from September 2019, supplements type-approval test measurements with measurements under real driving conditions to check that NOx and particulate emissions remain within acceptable limits.

Finally, on November 10, 2022, the Commission published its final proposal for a regulation limiting pollutant emissions (Euro7 - COM/2022 586) which, for the first time, should apply, to all new vehicles (cars, LCVs, buses, trucks), regardless of fuel type (gasoline, diesel, electric or alternative).

The key points of the current proposal for cars and LCVs are summarized in Table 3-14. It would apply at the earliest to new cars and LCVs sold from 1, January 2025 and to new buses and trucks sold from 1, January 2027, but this proposal is still under discussion as:

- On September 25, 2023, the Council took position to maintain existing provisions for vehicle testing and emissions[79],
- On November 9, 2023, the Parliament confirmed the dispositions for passenger cars and proposed to introduce an additional breakdown of emissions into three categories for LCVs based on their weight [80].

Objective	Proposal
Better control of air pollutant emissions from all new vehicles	Extension of the range of driving conditions to better reflect the conditions that vehicles may encounter across Europe
Pollutant emissions from internal combustion vehicles	Minus 35% total NOx emissions Minus 13% total particulate emissions
Maximum limit for PM (10) emissions linked to brake wear	7 mg / km until 2034 3 mg / km from January 1, 2035
Maximum limit for PM (10) emissions linked to tire wear	To be defined (in mg / km)
Battery life	The battery must retain a storage capacity of 80% of its original value after five years or 100,000 km (whichever comes first) and 70% after eight years or 160,000 km (whichever comes first)
Extension of compliance	Cars and vans will be checked for compliance until they reach 200,000 kilometers and 10 years of age. This doubles the existing durability requirements under Euro 6/VI rules (100,000 kilometers and 5 years)

Table 3-14: Euro7 main proposals for cars and LCVs
Source: Author's analysis of the EC proposal (Euro7 - COM/2022 586)

3.3.3.3. Purchase subsidies and tax credit

For purchase and use subsidies and tax credits, the assessment of financial support was mainly based on ACEA's list of "Tax Benefits and Purchase Incentives" in the 27 (28) Member States of the European Union.

Assessments, based on the yearly sales of PEVs per country (between 2018 and 2022 with market assumptions for 2023), are made for France, Germany, Italy, Spain and the United Kingdom (G5 countries), given that these countries are the largest automotive markets and represent a large majority of PEV registrations. A multiplier of 1.2[81] was applied to assess the total amount of financial support provided by these two instruments in Europe (EU 27 + UK) and other sources of information were necessary to obtain a more detailed understanding of the calculation methodology for purchase subsidies and tax credits per country[82].

	2018	2019	2020	2021	2022	2023 (est.)
Total amount of tax credit (G5)	71	121	287	563	911	1952
Total amount of tax credit EU27 + UK (G5*1,2)	85	145	344	676	1093	2343
Cumulated Tax credit amount EU27 + UK	85	230	574	1250	2343	4685
Total amount of BEV PHEV subsidies (G5)	731	1233	4925	8212	9166	24268
Total amount of BEV PHEV subsidies EU27 + UK (G5*1,2)	878	1480	5910	9855	10999	29122
Cumulated subsidies amount EU27 + UK	878	2358	8268	18123	29122	58244
Cumulated subsidies and tax credit EU27 + UK	963	2587	8842	19372	31464	62929

Table 3-15 : Yearly and Cumulated Amount of purchase subsidies and tax credits in EU27 + UK (in € million)
Source: Author's own research based on yearly sales of PEVs and methodologies for calculation

3.3.4. Charging networks

In 2001, the European Commission clearly stated its intentions regarding the transport system: "A modern transport system must be sustainable from an economic and social point of view, as well as from an environmental point of view"[83] .

Since 2011, heavy dependence on imported oil and the desire to reduce CO2 and other pollutant emissions have led the European Commission to promote the development of alternative fuels[84]. The introduction of regulations applies to the distribution networks of identified alternative fuels and covers both public networks and the installation of charge points in residential and non-residential buildings.

In 2013, the "Clean Power for Transport: A European alternative fuels strategy" – COM (2013) 17 final – listed all alternative fuels by name and clearly identified their potential areas of application. At the time, biofuels appeared to be an almost universal solution, as their scope covered all modes of transport and allowed them to be used even over long distances; indeed, in 2011 they accounted for 4.7% of all fuels consumed in Europe (source: Directive 2014/94/EU).

In 2014, the Alternative Fuel Infrastructure Regulation (AFIR) directive was published, setting a target of 1 charging point for every 10 alternative fuel vehicles (COM (2013) 17 final). It was amended in 2017 and 2020 until the recent adoption of Regulation (EU) 2023/1804 entered into force on 12 October 2023, whose main deployment targets are summarized below.

TEN-T core road network	TEN-T comprehensive road network
Publicly accessible recharging pools with a maximum distance of 60 km between them: by 31 December 2025, at least 400 kW of power output, at least one recharging point with an individual power output of at least 150 kW; by 31 December 2027, at least 400 kW of power output, at least two recharging points with an individual power output of at least 150 kW;	Publicly accessible recharging pools with a maximum distance of 60 km between them: by 31 December 2027, along at least 50 % of the length of the TEN-T comprehensive road network, at least 300 kW of output and at least one recharging point with an individual power output of at least 150 kW; by 31 December 2030, each recharging pool offers a power output of at least 300 kW and includes at least one recharging point with an individual power output of at least 150 kW; by 31 December 2035, each recharging pool offers a power output of at least 600 kW and includes at least two recharging points with an individual power output of at least 150 kW.
Hydrogen refueling infrastructures capable of serving both cars and trucks are to be deployed from 2030 at all urban hubs and every 200 km on the TEN-T network.	

Table 3-16: Electric vehicle charging network deployment targets according to AFIR Regulation (EU) 2023/1804
Source: Author's analysis of quoted document

For buildings, the first requirements for charging points or pre-wiring for new or substantially renovated residential and non-residential buildings come into force in 2018, and the latest proposal in 2023 (COM/2023/76 final) proposes to strengthen them as shown in the table below.

Regulations Equipment threshold (number of parking spaces)	**30/05/2018** Directive (EU) 2018/844 2018 Document 32018L0844	**15/02/2023** Promotion of e-mobility through buildings policy Document 52023DC0076
For a new non-residential building or one undergoing major renovation	>= 10 Preparatory wiring work for each parking space	>= 5 Pre-wiring for each parking space Upon delivery of the new or renovated building
For a new office building or one undergoing major renovation	Not applicable	>= 5 At least 1 charging point for every two parking spaces Upon delivery of the new or renovated building
For all non-residential buildings	Not applicable	>= 20 At least 1 charging point per 10 parking places by 2027
For any building owned or used by a public authority	Not applicable	None 50% of spaces pre-wired by 2033
For a new residential building or one undergoing major renovation	>= 10 Preparatory wiring work for each parking space	>= 3 Pre-wiring for each parking space On delivery date of the new or renovated building

Table 3-17: Comparison of charge point and pre-wiring installation requirements for new and substantially renovated residential and non-residential buildings
Source: Analysis by the author of quoted documents

The Connecting Europe Facility (CEF) for Transport is the financial instrument for the implementation of the European transport infrastructure policy for all modes of transport (land, air and sea). In terms of the charging network, the priority is the completion of the core network by 2030, structured around nine multimodal core network corridors.

Two successive programs have been funded through the CEF with 23 billion euros between 2014 and 2020[85] then 25.8 billion euros for the current program (2021 - 2027)[86]. Under the previous program, we estimate that 250 million euros were allocated to charging network projects. For the current program, AFIF is the permanent funding instrument to support innovation and improvement of European alternative fuel infrastructure along the TEN-T network, with 1.575 billion euros from the CEF Transport budget until 2027. Under the current program, 578 million euros have been allocated until the end of 2022[87], which makes a total of 828 million euros between 2014 and 2022 and leaves about 1 billion until the end of 2027.

In addition to the programs financed through the CEF, there are national initiatives listed below for the G5 countries.

Country	Plan	Allocated funding (€ million)	Application period
France (https://advenir.mobi/)	Advenir	320	2016 - 2025
Germany https://nationale-leitstelle.de/en/foerdern/	"Local charging infrastructure"	500	2021 – 2025
Italy https://www.eltis.org/in-brief/news/italy-install-21-000-electric-vehicle-charging-stations-2026	National Recovery and Resilience Plan	700	2023 - 2026
Spain https://www.miteco.gob.es/es/prensa/210413npcminrdmovesiii_tcm30-524996.pdf	MOVES	200[88]	Ending in 2023
UK https://www.gov.uk/government/news/56-million-of-public-and-industry-funding-electrifies-chargepoint-plans-across-the-country	Many different programs	65,5 including 45,6 of public funding	2026
Total		1 800	

Table 3-18 : G5 funding for charging infrastructure
Source: Author's own research

Taking into account the very recent increase in investment in the charging network, we estimate that, of the €1,800 million in funding provided by the G5 countries, €500 million has been allocated by 2022 and €1,300 million by 2026.

3.3.5. Collecting, recycling and reusing battery key materials

Directive 2006/66/EC established rules for all types of batteries/accumulators applicable in all Member States, dealing with the placing on the market of products containing hazardous substances and their collection, treatment, recycling and disposal. This Directive has been regularly amended and the latest version has been in force since July 4, 2018.

The proposal to modernize the Battery Directive (COM/2020/798 final) was published on December 10, 2020, and the European Parliament issued its report (A9-0031/2022) on the legislative proposal on February 22, 2022. Following an agreement between representatives of the three institutions (Commission, Council, Parliament) in early 2023, the final act was signed by the co-legislators on July 12, and EU Regulation 2023 / 1542 entered into force on August 17, 2023, with application from February 18, 2024.

The regulation introduces information and labeling requirements for all types of batteries, and the table below focuses on the main provisions addressing electric vehicle batteries, which become a specific category of battery (EV battery) and are defined as having a capacity >= 2 kWh and weighing more than 25 kg.

This regulation is a starting point rather than a finished package, as important delegated acts will need to be adopted in the coming years to specify certain key methodologies, such as the calculation of a battery's carbon footprint or recycled content. In addition, we emphasize that some requirements are rather distant and do not encourage the rapid reuse of recycled materials.

<table>
<tr><th>Objective</th><th colspan="2">Dispositions</th></tr>
<tr><td>Collection rate</td><td colspan="2">Producer responsibility to provide a 100% collection system for waste batteries regardless of their origin.</td></tr>
<tr><td>Carbon footprint over the total lifecycle from mining to recycling
Calculated in kg of CO2 equivalent per kWh of energy supplied</td><td colspan="2"><u>The Commission shall, for the EV battery category, adopt delegated acts:</u>
By 18 February 2024, to define the methodology for the calculation and verification of the carbon footprint
By 18 February 2025, to define the carbon footprint performance classes
By 18 August 2026, to determine the maximum life cycle carbon footprint threshold
<u>Per battery model and per manufacturing plant, battery producer must</u>
By 18 February 2025 or 12 months after the date of entry into force, whichever is the latest, provide the carbon footprint declaration
By 18 August 2026 or 18 months after the date of the adoption of the delegation act, whichever is the latest, declare the carbon footprint performance class
By 18 February 2028 or 18 months after the date of the adoption of the delegation act, whichever is the latest, comply to maximum life cycle carbon footprint threshold</td></tr>
<tr><td>Overall Recycling efficiency (all battery materials)</td><td>By January 1, 2025 at the latest, a recycling yield of at least 65% by average weight</td><td>By January 1, 2030 at the latest, a recycling yield of at least 70% by average weight</td></tr>
<tr><td>Recovery rates</td><td>As of January 1, 2027, 90% for cobalt, copper, and nickel and 50% for lithium.</td><td>As of January 1, 2031 95% for cobalt, copper, and nickel and 80% for lithium.</td></tr>
<tr><td rowspan="2">Recycled materials content in batteries</td><td colspan="2"><u>The Commission shall, for the EV battery category, adopt delegated acts:</u>
By 18 August 2026, to define the methodology for the calculation and verification of the percentage share of cobalt, lithium, nickel (and lead) present in active materials and that has been recovered from battery</td></tr>
<tr><td>From 18 August 2031, a battery must contain at least 16% cobalt, 6% lithium, 6% nickel and 85% lead from the recycling process.</td><td>From 18 August 2036, a battery must contain at least 26% cobalt, 12% lithium, 15% nickel and 85% lead from the recycling process.</td></tr>
<tr><td>Electrochemical performance and durability requirements</td><td colspan="2">No later than 12 months after the regulation comes into force, mandatory declaration of electrochemical performance and durability parameters
By December 31, 2024, definition of minimum thresholds for electrochemical performance and durability parameters
On January 1er 2026, obligation to reach minimum thresholds</td></tr>
<tr><td>"Supply chain due diligence”</td><td colspan="2">Mandatory no later than 12 months after regulations come into force</td></tr>
</table>

Table 3-19: Requirements for electric vehicle batteries according to EU Regulation 2023 / 1542
Source: analysis of the proposal by the author

Finally, we also mention the recent proposal of the European Commission of July 13, 2023 to improve the circularity of the automotive sector[89]. While the scope is much broader than the battery value chain, this proposal takes into account the upcoming growing consumption of raw materials by the automotive industry and aims to maximize their recovery and reuse.

58 The proposal (COM/2007 856 final) also proposed longer-term targets: 125 g CO2/km in 2015, 95 g CO2/km in 2020 and, if possible, 70 g CO2/km in 2025.
59 Available at: https://ec.europa.eu/docsroom/documents/26081
60 In short, the Commission proposes a new regulation to which both the Parliament and the Council can propose changes and amendments. The process leads to a trilogue where the Commission, Parliament and Council reach an agreement before a formal vote and entry into force.

61 Supply chain analysis and material demand forecast in strategic technologies and sectors in the EU - A foresight study
62 The Council and Parliament provisional deal sets synthetic graphite to be a strategic raw material during a period of three years, until the Commission makes the next revision of the list. https://www.consilium.europa.eu/en/press/press-releases/2023/11/13/council-and-parliament-strike-provisional-deal-to-reinforce-the-supply-of-critical-raw-materials/
63 see for instance Critical Raw Materials for Strategic Technologies and Sectors in the EU, A Foresight Study, p23. https://op.europa.eu/en/publication-detail/-/publication/9e17a3c2-c48f-11ed-a05c-01aa75ed71a1/language-en
64 https://single-market-economy.ec.europa.eu/sectors/raw-materials/eip_en
65 https://eitrawmaterials.eu/about-us/
66 https://single-market-economy.ec.europa.eu/industry/strategy/industrial-alliances/european-raw-materials-alliance_en
67 https://ec.europa.eu/commission/presscorner/detail/en/qanda_22_1257
68 https://single-market-economy.ec.europa.eu/industry/strategy/industrial-alliances/european-battery-alliance_en
69 https://www.europarl.europa.eu/news/en/press-room/20231117IPR12205/meps-back-plans-to-boost-europe-s-net-zero-technology-production
70 https://www.consilium.europa.eu/en/press/press-releases/2023/12/07/net-zero-industry-act-council-adopts-position-to-boost-technologies-for-the-green-transition/
71 See p 1100 and 1101, document accessible at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.L_.2021.149.01.0010.01.ENG&toc=OJ%3AL%3A2021%3A149%3ATOC
72 https://www.vda.de/en/press/press-releases/2023/230519_PM_Brexit-rules-VDA-President-Hildegard-Mueller-on-rules-of-origin-for-e-cars
73 T&E - A European response to IRA
74 https://ec.europa.eu/commission/presscorner/detail/en/qanda_22_1257
75 https://www.concertation-acc-batteries.fr/le-calendrier-et-le-financement
76 CO, THC, NMHC, NOX and mass, number of airborne particles
77 Since 1 July 1992, it has been an integral part of the certificate of conformity required by Directive 70/156/EEC.
78 Weiss, M., Bonnel, P., Hummel, R., Manfredi, U., Colombo, R., Lanappe, G., Le Lijour, P., & Sculati, M. (2011). Analyzing on-road Emissions of Light-duty Vehicles with Portable Emission Measurement Systems (PEMS) (Technical Report EUR 24697 EN). European Commission. https://publications.jrc.ec.europa.eu/repository/handle/JRC62639
79 https://www.consilium.europa.eu/en/press/press-releases/2023/09/25/euro-7-council-adopts-position-on-emissions-from-cars-vans-buses-and-trucks/
80 https://www.europarl.europa.eu/news/en/press-room/20231106IPR09026/euro-7-meps-support-new-rules-to-cut-down-pollutant-emissions
81 According to EvVolumes, 2 332 000 BEVs + PHVs were sold in Europe while, according to the author's own research 1 944 000 were sold in the G5 countries, giving a ratio value of 1,2
82 France:
https://www.avere-france.org/, https://blog.evbox.com/fr-fr/aides-voiture-electrique-France
https://guichetcartegrise.com/blog/prix-de-la-carte-grise-en-2020-une-evolution-a-lavantage-de-lelectrique
Germany:
https://cleantechnica.com/2023/01/20/31-of-new-vehicle-sales-plugin-sales-in-germany-in-2022/
https://theicct.org/germanys-vehicle-tax-system-small-steps-towards-future-proof-incentives-for-low-emission-vehicles/
Italy:
https://www.trade.gov/market-intelligence/italy-automotive-electric-vehicles
https://www.hivepower.tech/blog/electric-vehicles-in-italy-what-you-should-know
https://cleantechnica.com/2023/03/11/italys-bev-market-down-26-6-in-2022-will-tesla-come-to-the-rescue/
https://www.agenziaentrate.gov.it/portale/web/english/nse/services/vehicle-tax
Spain:
https://aedive.es/, https://cleantechnica.com/files/2021/08/Spain-Plugin-Electric-Vehicle-Share-Year-by-Year-.png
https://n26.com/en-es/blog/road-tax
UK:
https://www.zap-map.com/ev-stats/ev-market/, https://www.electrive.com/2021/12/15/uk-lowers-ev-subsidies-again/
https://www.gov.uk/vehicle-tax-rate-tables, https://www.joinbonnet.com/post/ev-grants-incentives-uk
83 White Paper - European transport policy for 2010: time to decide (Document 52001DC0370)
84 White Paper "Roadmap to a Single European Transport Area - Towards a competitive and resource efficient transport system".
85 https://wayback.archive-it.org/12090/20221222155224/https://ec.europa.eu/inea/en/connecting-europe-facility/cef-transport
86 https://cinea.ec.europa.eu/programmes/connecting-europe-facility/transport-infrastructure_en
87 https://cinea.ec.europa.eu/system/files/2023-09/2023_09_CEF_Transport_factsheet_AFIF_FINAL.pdf
88 The whole program encompasses purchase of PEVs and funding for charging infrastructure for €400 million. We assume that 50% is dedicated for charging infrastructure
89 https://ec.europa.eu/commission/presscorner/detail/en/ip_23_3819

3.4. US regulations

The conflicting decisions between the Obama and Trump administrations are probably one of the main reasons why the US electric vehicle industry currently lags behind China and Europe, despite Tesla's amazing momentum. The very low level of public investment through 2021, compared to China and Europe, with only about €8 billion dedicated to the PEV value chain, underscores this lack of support for the electric mobility industry in recent years.

Type of financial support	Upfront payment (in € billion)	Loans (in € billion)	Purchase subsidies (in € billion)	Operation tax credit (in € billion)	Purchase credit (in € billion)
Extraction of raw materials and refining	0,025 for R&D programs	/	/	/	/
Battery value chain	/	1,45 for Nissan North America battery plant	/	< 2% of the initial allocation (2,3)	/
Production of vehicles	/	/	/	/	< 6,5 between 2008 and 2021
Charging network	/	/	/	/	/
Total	Approximately 1,5		/	Approximately 6,5	

Table 3-20 : Funding in the US battery value chain through 2021

Source: Author's synthesis based on https://www.csis.org/analysis/united-states-industrial-strategy-battery-supply-chain & https://www.energy.gov/articles/energy-department-announces-battery-recycling-prize-and-battery-recycling-rd-center

The Biden Administration was able to advance an agenda more favorable to the decarbonization of road mobility and secure funding through 2032 through two very important pieces of legislation passed by the US Congress (which are part of an agenda that goes beyond the transition to low-carbon mobility):

1) "Infrastructure Investment and Jobs Act" (IIJA) or "Bipartisan Infrastructure Law" (BIL) - Public Law No 117-58 passed on November 15, 2021.
2) Inflation Reduction Act (IRA) - Public Law No 117-169 passed on August 16, 2022.

An important marker, continuing the direction of the previous administration, is the localization of the industry in the United States. The DOE's National Blueprint for Lithium Batteries 2021-2030[90], which recognizes that the U.S. has very limited resources of nickel and cobalt, sets ambitious goals to develop and produce cobalt- and nickel-free active materials at scale by 2030 and to suppress (at least significantly reduce) foreign supply chain dependence.

This direction is also very evident in the rules for awarding a project set forth in the IIJA, which state that a project will be assigned in priority to an entity that:

1. Is located and operates in the USA;
2. Is owned by a US entity;
3. Deploys US-owned intellectual property and content;

4. Represents consortia or industrial partnerships;
5. Will not use and/or export battery material from/to a Foreign Entity Of Concern.

3.4.1. Extraction of raw materials and refining

In the 1950s, the U.S. had a strong position in rare earths and other minerals that are now considered critical to the battery value chain. Some companies, such as Molycorp, were strong in producing and processing rare earths, and Magnequench, a subsidiary of GM, supplied magnets for its auto plants. The latter was sold in 1995 to a Sino-American consortium with the approval of President Clinton, who said there was no evidence that it could threaten American security, and in 2003 all Magnequench activities were transferred to China.

Both the Clinton (1993-2001) and Bush (2001-2009) administrations continued the decline of this industry by closing the US Bureau of Mines, selling off defense stockpiles, or closing the Rare Earth Information Center.

The wake-up call came in 2010, when US Secretary of State Hillary Clinton discovered that China not only controlled 97% of the world's production of rare earths, but was prepared to use them for geopolitical purposes against Japan in the Senkoku Island dispute. However, the Obama presidency's record on this industry remains modest.

The policy shift came with the Trump presidency (2017-2021). Executive Order 13817 was signed in December 2017, with the goal of creating an inventory of critical minerals on US soil and streamlining the mining leasing and permitting process. A list of critical minerals was released in 2018 and funding was provided for scientific research in mining and metal refining.

In September 2020, President Trump signed the Executive Order 13953 to respond to the threat to the domestic supply chain due to heavy reliance on critical materials sourced from “Foreign Adversaries”, a clear reference to China, with which the Trump presidency has been engaged in a worsening trade dispute. The aim is to bring mining activities back to the United States, reducing dependence on imports and creating jobs that can no longer be outsourced. In addition, partnerships with Greenland and resource-rich allies (Canada, Mexico, Australia) are being strengthened through agreements. This set of policies is clearly aimed at reducing China's control over critical minerals[91].

The Biden presidency's actions to decarbonize road mobility build on some of the strategies already implemented by the Trump administration in three directions:

- The exclusion of FEOCs[92] from the supply chain. The IRA prohibits the allocation of tax credits (under SEC. 13401, Clean Credit Vehicle) for PEVs that have a battery manufactured or assembled by a FEOC after December 31, 2023 onwards, or that contain "any" critical minerals "mined, processed, or recycled" by a FEOC after December 31, 2024. The U.S. has again limited the share of Chinese companies in the battery supply chain, as companies will soon have to ensure that their batteries do not contain any mineral or component from a company that is at least 25% owned by a China-related entity[93].

- The management of critical materials with two lists published in 2022 and 2023. The latter presents criticality matrices and, in the mid-term vision (2025 - 2035), all raw materials associated with PEVs are considered critical, both in terms of energy importance and supply chain risks[94].
- The development of partnerships with the creation, in June 2022, of the Minerals Security Partnership, an ambitious new initiative to strengthen critical minerals supply chains. This US-led initiative includes 13 countries and the European Commission which are jointly developing projects along the entire value chain, with 11 projects in upstream mining and mineral extraction, 4 projects in midstream mineral processing, and 2 projects in recycling and recovery[95].

The main difference is that while strengthening US defense remains a key factor, the development of PEVs throughout the value chain now occupies an important place as evidenced by the raw materials programs funded by the IIJA and IRA.

Law	Section	Program name	Funding		Program duration
			Type	Amount ($ billion)	
IIJA	40205.	Rare earths elements demonstration facility	Grant	0,14	2022
	40207.	Battery Material Processing Grant Program		3 per year	2022 - 2026
	40210.	Critical minerals mining and recycling research		0,4	2021 - 2024
	41003.	National Geological And Geophysical Data Preservation Program		0,024	2022 - 2025
		Rare Earth Mineral Security		0,10	2022 - 2026
		Critical Material Innovation, Efficiency, And Alternatives		0,6	2022 - 2025
		Critical Material Supply Chain Research Facility		0,075	2022 – 2023
Total Funding IIJA				1,4 plus 3 per year	2021 – 2026
IRA	50141.	Funding for Department Of Energy Loan Programs Office Applicable to the processing, manufacturing and recycling of critical minerals	Loan	Up to 3,6 giving access to maximum loan of 40 all projects	2023 - 2026

Table 3-21 : Public funding allocated to raw materials programs through IIJA and IRA in the period 2021 – 2026

Source: Author's analysis of IIJA and IRA documents

The funds made available through the IIJA are being put to very rapid use, with $2.8 billion in grants awarded in 2022 to approximately 20 companies for the construction of lithium refineries and graphite production facilities, and a new funding opportunity of up to $3.5 billion announced on November 15, 2023 [96].

3.4.2. Manufacturing of battery packs, (modules), cells and main components

To address the lack of mass production capacity in North America, an active regulatory activity has taken place: of 40 regulations related to "battery policies and incentives" for electric vehicles, 34 have been issued or amended at the federal level by the DOE. Most strikingly, as of July 10, 2023, 22 regulations have been issued under the Biden administration in about two and a half years, demonstrating a flurry of regulatory activity to support the development of the battery value chain not seen under the previous administrations[97].

The IRA amended the Clean Vehicle Credit to add battery requirements effective January 1, 2023. To be eligible, a vehicle must meet local sourcing requirements for the extraction, processing, and recycling of critical minerals and the manufacturing and assembly of battery components. Vehicles that meet the critical mineral requirements are eligible for a maximum tax credit of $3,750, those that meet the battery component requirements are eligible for a maximum tax credit of $3,750, making a maximum total tax credit of up to $7,500, subject to local manufacturing thresholds for each requirement that are tightened each year (see Table 3-22 below).

<table>
<tr><th rowspan="2">Law</th><th rowspan="2">Section</th><th rowspan="2">Program name</th><th colspan="2">Funding</th><th rowspan="2">Program duration</th></tr>
<tr><th>Type</th><th>Amount
($ billion)</th></tr>
<tr><td>IIJA</td><td>SEC. 40207.</td><td>Battery Manufacturing and Recycling Grant Program</td><td>Grant</td><td>3 per year</td><td>2022 – 2026</td></tr>
<tr><td rowspan="2">IRA</td><td>SEC. 13502. Advanced manufacturing Production Credit</td><td>10% of the production cost of critical minerals,
10% of the cost of active materials for battery electrodes,
$35 / kWh for battery cell production
$10 / kWh for the production of battery modules (or $45/kWh for the production of battery packs with a different architecture)</td><td>Production tax credit</td><td>3,26 per year per million vehicles sold[98]</td><td rowspan="2">2023 – 2032</td></tr>
<tr><td>SEC. 13401.[99] Clean Credit Vehicle</td><td>3,750 for critical minerals (minimum local content threshold from 40% in 2023 to 80% between 2027 to 2032)
$3,750 for the battery (minimum local content threshold from 50% in 2023, to 100% between 2029 and 2032)</td><td>Purchase tax credit</td><td>6 per year per million vehicles sold (considering 80% of localization in average)</td></tr>
</table>

Table 3-22: Production and Purchase funding allocated to the battery value chain through IIJA and IRA (2023 – 2032)
Source: Author's analysis of IIJA and IRA documents and own estimation of annual allocated funding

To qualify for the rebates, batteries must be produced and assembled in Canada, Mexico or the USA, where the United States-Mexico-Canada Agreement (USMCA), the new trade agreement, allows for an integrated flow of components[100].

3.4.3. Production of vehicles

In California, the political will to combat air pollution was forged in the 1940s, when the Los Angeles area was plagued by smog. Since then, California has pioneered regulations such as those to reduce pollutant emissions in the late 1960s and the first-ever technology-forcing program for zero-emission vehicles (ZEV) in the 1990s. Because of its vehicle regulations, which precede the federal Clean Air Act (CAA) of 1970, and its particularly severe motor vehicle-related air quality problems, the state of California has the authority to enforce its own regulations on emissions from internal combustion engine vehicles, and each US state can choose to follow federal or California regulations[101].

As of May 13, 2022, 17 states, accounting for more than 40% of new LDV sales in the United States, have adopted or plan to adopt some or all Californian regulations[102]. The other states follow the federal regulations which encompass the CAFE (Corporate Average Fuel Economy standards), introduced by the US Congress in 1975[103], and one aiming at reducing GHG emissions introduced under the Clean Air Act in 2011.

The latest Californian regulation, i.e., Advanced Clean Cars II rule, adopted in August 2022[104], defines the trajectory to achieve 100% of sales of ZEVs and PHEVs (with a minimum electric range of 50 miles under normal driving conditions) by 2035.

If California's decision is a continuation of its longstanding air quality fight, the Trump administration had issued the Safer Affordable Fuel-Efficient (SAFE) vehicles rule in 2020, which severely slowed any progress in reducing pollutants and greenhouse gas emissions from ICEVs. CAFE was then set to increase at a rate of 1.5% per year through model year 2026, compared to the previous standards issued in 2012, which required annual increases of approximately 5%[105]. The latest NHTSA proposal, dated July 28, 2023, for fuel economy standard includes a 2% per year improvement in fuel efficiency for passenger cars, and a 4% per year improvement for light trucks, beginning in model year 2027 and ramping up through model year 2032, potentially reaching an average fleet fuel economy of 58 miles per gallon by 2032[106].

Both Executive Order 14037, issued by President Biden in August 2021, which calls for 50 percent zero-emission vehicles in all new car and light truck sales by 2030, and the latest EPA proposal (on 12/04/2023) which sets an even more ambitious target of 66.7% in 2032[107], confirm the current administration's commitment to electrification. They provide a more stable playing field for the US automotive industry and have boosted sales in the United States which have tripled since President Biden took office.

Once again, this political commitment is matched by funding from IRA, as shown in the table below.

IRA Section	Program name	Allocated funding ($ billion)	Program duration
SEC. 13501.	Extension of the Advanced Energy Project Credit for components, energy systems and vehicles manufacturing	10	2023 – 2032
SEC. 50142.	Advanced Technology Vehicle (ATV) Manufacturing Loan Program. Production of ATV components, qualified ATVs, of alternative fuels infrastructure	Up to 3 giving access to 25 in loans	2023 - 2028
SEC. 50143.	Electric Vehicle (EV) and Fuel Cell Electric Vehicle (FCEV) Manufacturing Loans Production of HEV, PHEV, BEV & FCEV as well as components	2	2023 - 2032

Table 3-23: Loans and tax credits allocated to PEV manufacturing through IRA in the period 2023 – 2032
Source: Author's analysis of IRA document

3.4.4. Charging network

In 2015, the Obama administration passed the Fixing America's Surface Transportation Act, which provided $305 billion in federal assistance between 2016 and 2020 for the development of critical highway infrastructure projects. It also amended Chapter 1 of Title 23 of the United States Code[108], which governs federal assistance for the development of a national highway system, to include Section 151. The latter requires the deployment of national vehicle charging networks for alternative fuels such as electricity, hydrogen, propane and natural gas.

The IIJA, SEC. 40431., follows up on these provisions and establishes two programs to develop a network of 500,000 public chargers by 2030:

1. National Electric Vehicle Infrastructure (NEVI) Formula Program with $5 billion (€4,5 billion) between 2022 and 2026 to develop a national public electric vehicle charging network, 80% of which will be funded by the federal government.
2. Charging and Fueling Infrastructure (CFI) Discretionary Grant Program with $2.5 billion (€2,3 billion) between 2022 and 2026 for the development of local public electric vehicle charging networks.

Additional regulatory actions have been taken quickly to enable rapid implementation of the programs, such as draft specifications for chargers in NEVI projects in June 2022 or, in February 2023, FHWA established a Build America, Buy America (BABA) implementation plan by publishing a temporary public interest waiver of Buy America requirements for steel, iron, manufactured products, and construction materials in electric vehicle (EV) chargers. This short-term, temporary waiver was structured to enable EV charger acquisition and installation to immediately proceed while also ensuring the application of Buy America to EV chargers by the phasing out of the waiver over time[109].

California, which leads the electric vehicle sales in USA and already has more than 80,000 charging stations (electric/H2) by the end of 2022, announced a $3 billion program for 90,000 new electric vehicle chargers, keeping the state on track to meet its goal of installing 250,000 chargers by 2025[110] .

3.4.5. Collecting, recycling and reusing battery key materials

There are currently no regulations setting mandatory targets for battery recycling and the reuse of raw materials within a given timeframe. However, the National Blueprint for Lithium Batteries 2021–2030 identifies recycling batteries as a key priority (Goal N°4) and sets an objective of 90% recycling rate of PEV batteries by 2030.

So far, the most significant regulatory impact on battery recycling is related to IRA, SEC. 13401. dedicated to the Clean Vehicle Credit, where it is stated that a critical raw material to qualify for the "critical mineral requirements" must be:

- extracted or processed in the United States, or in any country with which the United States has a free trade agreement in effect, or
- recycled in North America (whatever the origin).

The qualification of recycled material in North America for the "critical mineral requirements" incentivises immediate action from the industry to develop recycling factories as pointed out by Reuters[111]. It also opens the door to situations where the loopholes in the regulation are demonstrated, such as the case of LG CHEM and Huayou Group, who have partnered to produce LFP cathode materials in a Moroccan plant. The CAM will be supplied to the North American market and will be subsidized by IRA as Morocco is a signatory to the US FTA. Consequently, LG Chem and Huayou Group have to adjust their share in accordance with the Foreign Entity of Concern (FEOC) regulations of the IRA[112].

Lastly, R&D and demonstration plans for recycling are encouraged. In addition to IIJA access to grants (SEC. 40207, see Table 3-21) for an amount of $3 billion for both manufacturing and recycling, we list a complementary amount of $0,3 billion.

IIJA Section	Program name	Allocated funding ($ billion)	Program duration
SEC. 40207. Battery Processing and Manufacturing	Lithium-ion Battery Recycling Prize Competition	0,01	2022
	Battery Recycling Research, Development, and Demonstration Grants	0,06	2022 – 2026
SEC. 4028.	Electric drive vehicle recycling and second life application program	0,2	2022 – 2026
Total		0,3	2022 - 2026

Table 3-24 : Grants allocated to battery recycling programs through IIJA in the period 2021 – 2026
Source: Author's analysis of IIJA document

[90] https://www.energy.gov/sites/default/files/2021-06/FCAB%20National%20Blueprint%20Lithium%20Batteries%200621_0.pdf
[91] Author's summary of the situation of raw materials industries in the U.S. developed in:
Barteková, Eva, and René Kemp. "Critical raw material strategies in different world regions." The United Nations University-Maastricht Economic and Social Research Institute on Innovation and Technology (UNU-MERIT) Working Papers 5 (2016).
Jetin Bruno. "Electric batteries and critical materials dependency: a geopolitical analysis of the USA and the European Union." Forthcoming International Journal of Automotive Technology and Management (2023)
[92] See https://www.federalregister.gov/documents/2023/12/04/2023-26479/interpretation-of-foreign-entity-of-concern
[93] https://source.benchmarkminerals.com/article/us-moves-to-cut-china-from-its-battery-supply-chain?mc_cid=e9bdd3acc7&mc_eid=d9a36e1126
[94] See Medium-term (2025–2035) criticality matrix, https://www.energy.gov/cmm/what-are-critical-materials-and-critical-minerals
95 USA, Australia, Canada, Finland, France, Germany, India, Italy, Japan, the Republic of Korea, Norway, Sweden, the United Kingdom, and the European Union represented by the Commission. https://www.state.gov/joint-statement-on-the-minerals-security-partnership-announce-support-for-mining-processing-and-recycling-projects/
[96]https://www.energy.gov/mesc/bipartisan-infrastructure-law-battery-materials-processing-and-battery-manufacturing-recycling
https://www.energy.gov/articles/biden-harris-administration-announces-35-billion-strengthen-domestic-battery-manufacturing
[97] Authors' calculations based on data extracted from department of energy website. Https://www.energy.gov/eere/vehicles/battery-policies-and-incentives-search#/?jurisdiction=US
[98] Assumptions: 18% of small cars with a battery size of 60 kWh, 60% SUVs with a battery size of 70-75kWh (72,5 in average), 22% of large cars with a battery size of 75 – 90 kWh (82,5kWh in average). Based on data issued from Global EV Outlook 2023 IEA
[99] Given the huge impact of the Clean Credit Vehicle (purchase tax credit) on the future of the battery value chain, we have included the table summarizing the allocated funds in this section rather than in the Vehicle Emissions section.
[100] https://ustr.gov/trade-agreements/free-trade-agreements/united-states-mexico-canada-agreement
[101] The Trump administration suppressed California's authority to enforce its own law in 2019, which the Biden administration restored in March 2022. https://www.epa.gov/newsreleases/epa-restores-californias-authority-enforce-greenhouse-gas-emission-standards-cars-and
[102] https://ww2.arb.ca.gov/resources/documents/states-have-adopted-californias-vehicle-standards-under-section-177-federal
[103] The CAFE, result of a harmonic calculation across all vehicles sold of different models (each having its own fuel efficiency target depending on its footprint) by an automaker, contributes because increased miles per gallon implies lower pollutants emissions (all other things being equal).
[104] https://ww2.arb.ca.gov/news/california-moves-accelerate-100-new-zero-emission-vehicle-sales-2035
[105] https://www.nhtsa.gov/press-releases/us-dot-and-epa-put-safety-and-american-families-first-final-rule-fuel-economy
[106] https://www.nhtsa.gov/press-releases/usdot-proposal-updated-cafe-hdpuv-standards
[107] https://www.epa.gov/regulations-emissions-vehicles-and-engines/proposed-rule-multi-pollutant-emissions-standards-model
[108] Introduced in 1958
[109] Document available at https://www.federalregister.gov/documents/2023/02/21/2023-03498/waiver-of-buy-america-requirements-for-electric-vehicle-chargers
[110] https://www.gov.ca.gov/2022/12/14/charging-ahead-california-doubling-the-number-of-ev-chargers-in-the-state-with-3-billion-investment/
[111] https://www.reuters.com/business/autos-transportation/dead-ev-batteries-turn-gold-with-us-incentives-2023-07-21/
[112] https://www.lgchem.com/company/information-center/press-release/news-detail-9365?lang=en_GLOBAL

4. Comparison of the dynamics of electric mobility industrial sectors in China, Europe and the United States

The comparative analysis of the dynamics of electric mobility industrial sectors in China, Europe and the USA is based on the same critical stages of the PEV's lifecycle (see Figure 3-1) and also covers passenger cars and light-duty trucks. The goal is to assess whether and how regulations enacted in each of the three regions affect the dynamics of the electric vehicle industry at the local and global levels.

For each stage of the PEV lifecycle, we provide figures and trends on the development of industrial capacity in China, Europe and the USA up to 2030, and 2035 where possible. To do this, we track the initiatives of all the major companies operating in a given region, with a particular focus on automakers (without claiming to be exhaustive of the initiatives of all the automakers we observe).

Beyond the geographical location of these industrial capacities, we also try to identify the origin of the capital involved in order to show how the technological and industrial dependence of Europe and the US on China's electric automobile industry is evolving.

4.1. Key takeaways

As China's electric vehicle industry continues to develop, we summarize below the strengths acquired by automakers operating in Europe and the situation of the European and US industries at each stage of the PEV value chain (except for the vehicle production stage which is sufficiently covered in the summary of strengths developed by automakers).

What are the main strengths developed so far by automakers operating in Europe?

Automakers have leveraged their integrator capacities – "know more than they make"[113], mastery of manufacturing and logistics systems, and being legally accountable to customers and governments for meeting regulatory requirements for safety, quality assurance and environmental performance[114] – to manage the technological transition from ICEVs to PEVs. Consequently:

1. They are proposing a comprehensive portfolio of PEVS and have committed to having a full range of ZEVs by 2035, and for some even sooner.
2. They have started to develop a direct supply of raw materials (although not covering 100% of demand) and some also have supply contracts for battery cell components.
3. They have mostly secured their supply of battery cells and have contributed to the development of the European battery industry.
4. They invest in future technologies such as solid-state batteries[115].
5. They have established an industrial organization for the production of electric drive systems, assembly of battery packs and PEVs by using and improving their existing assets (and developing new facilities when required).
6. They contribute, either directly or through consortia, to the development of the charging networks, with particular emphasis on the installation of high-power chargers for long-distance travel.
7. They have entered into agreements with specialized companies to develop battery recycling capacities.

In short, they are now present at every stage of the PEV value chain and are implementing the complex and complicated ZEV scale-up that lies ahead.

Sidebar 4-1 : What are the main strengths developed so far by automakers operating in Europe?
Source: Author's own analysis based on information collected on the development of the European electric automotive industry

[113] "…multitechnology firms need to have knowledge in excess of what they need for what they make, to cope with imbalances caused by uneven rates of development in the technologies on which they rely and with unpredictable product-level interdependences". Brusoni, S., Prencipe, A., & Pavitt, K. (2001). Knowledge specialization, organizational coupling, and the boundaries of the firm: why do firms know more than they make? Administrative science quarterly, 46(4), 597-621.

[114] Jacobides, M. G., & MacDuffie, J. P. (2013). How to drive value your way. Harvard Business Review, 91(7), 92-100.
Jacobides, M. G., MacDuffie, J. P., & Tae, C. J. (2016). Agency, structure, and the dominance of OEMs: Change and stability in the automotive sector. Strategic Management Journal, 37(9), 1942-1967.

[115] https://www.spglobal.com/mobility/en/research-analysis/fuel-for-thought-what-can-oems-do-to-ensure-a-robust.html

PEV value chain stage	Key takeaways
Extraction of raw materials and refining	In the context of a potential raw material shortage by 2030, due to failure to anticipate mining projects: • Projected raw materials extraction capacity in both the US and Europe is insufficient to meet local demand by 2030. • Both regions will have to consider signing free trade agreements with third countries to secure their supplies or developing alternative technologies that will make them less dependent on the producing countries of (refined) raw materials and may enable them to reduce the risk of raw material shortages. • Materials refining capacity is also insufficient to meet local demand by 2030 in both the US and Europe, although the project momentum is much higher than for access to raw materials, with the US ahead of Europe. • Global automakers have secured the supply of a percentage of their (refined) raw material requirements through either procurement contracts or direct investment agreements, mostly with non-Chinese companies. They are motivated to do so in order to secure their supply, reduce costs, reduce dependence on Chinese companies, and to qualify for IRA requirements as well as future ROO and battery CO2 footprint requirements in Europe.
Production of battery components, cells (modules) and packs	• In Europe, our study shows that installed cathode and anode production capacity will only meet 64% and 18% of demand respectively in 2030. Neither the CRMA's low target of 40% material processing in Europe nor the lack of financial incentives encourage the localisation of this production capacity, even though it is crucial to meet future ROO (which impose a rate of CAM localisation) and battery CO2 footprint targets. • We also show similar results in the United States even if the gap to close is lower than in Europe. • Battery cell production in Europe is expected to increase from 233.5 GWh in 2023 to 1086.5 GWh in 2030, while in the U.S. it is expected to increase from 146.5 GWh to 970.5 GWh over the same period. • By 2030, battery cell production in Europe and the U.S. should be realized by Korean battery manufacturers for 40,8%, European battery manufacturers for 30,5% and Chinese battery manufacturers for 19,3%. It shows the need to mitigate sourcing to achieve the production target, a certain success of the emergence of European champions and an overall dominance of Korean battery makers in the U.S. • Regulations pushing for the adoption of PEVs in a short timeframe have provoked this rapid growth in battery production capacity in both regions while IRA has obviously accelerated the emergence of projects in USCMA countries.
Vehicle production	Refer to Sidebar 4-1
Charging network	• A rapid convergence on charging connectors standards would facilitate a less expensive and quicker development of charging network. • The main issue for the rapid deployment of public battery charging networks (including fast charging stations along high traffic and/or high-speed roads) is the level of incentives provided by public authorities. • While China is pushing hard for battery swap technology, Stellantis is the first global player to announce a future application in Europe (Free2move in Madrid, Spain in 2024)
Battery recycling	• While recycling requires a large volume of batteries to be recycled in order to be an efficient and economically viable industry, which is likely to take another decade, the industry take off will benefit from production waste which is typically quite high in the start-up phase (10- 30%). • The pace of development seems to favor the US as the IRA provides direct and "immediate" incentives from IRA to produce recycled materials, while in Europe, it is determined by the more distant attainment of material recycling and reuse thresholds defined by the battery directive and CRMA.

Sidebar 4-2 : Current situation of the European and US industries at each stage of the value chain

Source: Synthesis of the author's analysis for each stage of the value chain

4.2. Extraction of raw materials and refining

The quantity of raw materials and number of industrial facilities needed for battery production to meet decarbonization targets by 2035 is expected to grow impressively, as shown in the figure below.

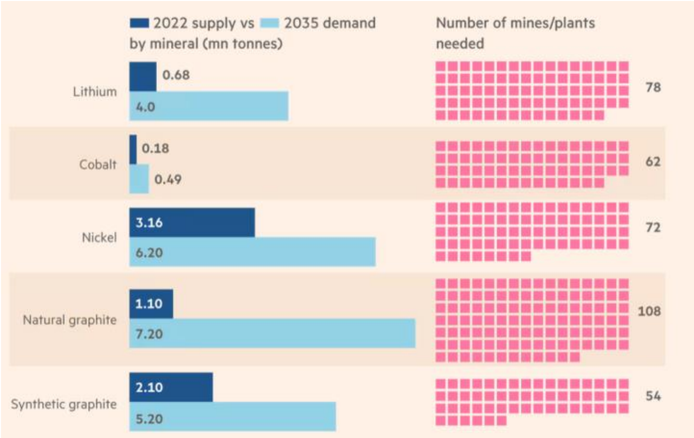


Figure 4-1 : Growth of needs of raw materials to 2035 per raw material
Source: Benchmark Mineral Intelligence, figure design by Financial Times[116]

While China has full control on the graphite value chain and is the world first importer of lithium, nickel and cobalt, Europe and the United States share the same situation. Both regions have some resources[117] of lithium[118], relatively low resources of cobalt, nickel, manganese and rare earths, although a large deposit of rare earths has been identified very recently in Sweden.[119] In addition, their existing and planned facilities to extract what they have (mining or other technologies) are insufficient to meet their immediate needs for the battery value chain.

This situation echoes the opinion of Caspar Rawles, Chief Data Officer of Benchmark Mineral Intelligence, quoted by the Guardian[120], when he estimates that "In the medium and even the long term, lithium is probably going to be the limiting factor on the rate that the battery industry can scale." The problem, as he points out, is not a lack of resources (at least not in the 2030-2035 timeframe), but a lack of anticipation in getting mining projects off the ground.

Indeed, in Europe, most of the ongoing lithium extraction (refining) projects are still in the process of obtaining all the necessary permits to start production. At the earliest, production could take place in 2025 for 3 of the 8 projects observed with an output of 49,000 tons of lithium hydroxide per year (see Table 7-1). In addition, the company Euro Battery minerals is exploring different extraction projects concerning cobalt, nickel and rare earths in Sweden, Finland and Spain[121]. So far, all the ongoing projects are operated by non-Chinese companies.

In the U.S., there are 6 active mines for the strategic raw materials needed for electric mobility (1 for lithium, 3 for cobalt and 2 for nickel), with 8 projects planned by 2028 and 16 still unplanned[122].

As shown in Table 2-1, China also has a very important part of the refining industry, while the EU27 countries, with the exception of cobalt with 16% of the world's processing capacity, have a very low processing capacity for the strategic raw materials needed in the battery value chain. The same observation applies to the US.

According to the “Cobalt Market Report 2022”, the pipeline of likely European projects to develop cobalt mining and especially refining capacity is clearly insufficient to meet the growth in demand spurred by the increase in sales of PEVs[123]. The situation is similar for nickel and manganese.

In the USA, the report “: The EV transition: Key market and supply chain enablers” (Opus already cited) lists 7 processing capacities in activity, 9 planned and 8 announced whose start of operation is not yet scheduled. Some of the planned and announced projects are integrated in the first set of projects funded by the IIJA to expand domestic production of battery components. The projects related to Material separation and processing (in Table 4-1 below) received $1,6 billion in federal funding, which will be matched by the recipients to leverage a total of $5,27 billion.

Stage of the value chain	Federal funding ($ million)	Recipient funding ($million)	Total funding ($ million)
Material separation and processing	1595,1	3673,1	5268,2
Component Manufacturing	1161,8	2787,5	3949,3
Recycling	75	107,5	182,5
Total	2832	6568,1	9400,1

Table 4-1 : US federal and recipient funding for Battery Materials Processing and Battery Manufacturing projects
Source: Author's extraction of data addressing key project characteristics [124]

While automakers typically don’t manage the value chain along its entire depth, Table 7-2 shows that they have entered into either procurement contracts or direct investment agreements with raw material mining or refining companies to address the above issues. It also shows that some of them have secured sourcing of battery cells components such as electrodes or separators. Global players seek direct access to raw material miners and/or refiners, through long-term sourcing agreements or direct investment, and localise their battery value chain as much as possible in order to:

1. Avoid shortages of raw materials and/or battery components.
2. Rebalance their supply chain to avoid over-dependence on the Chinese companies that currently dominate the market.
3. Minimize the impact of raw material price volatility, exacerbated by the complex geopolitical context.

4. Qualify for IRA requirements in the U.S. and prepare for future ROO and CO2 footprint requirements in Europe.
5. Have a better control over the conditions of raw materials extraction / mining, as most of them have joined some initiatives for more responsible and sustainable mining such as, for example, the "Initiative for Responsible Mining Assurance"[125].

4.3. Manufacturing of battery packs, (modules), cells and main components

China has a virtual monopoly in cathode and anode production, while anode and cathode production capacity in both Europe and the US is close to zero in 2022. In this context, Umicore estimates that by 2030, growth in the United States should be sufficient to meet demand, while the shortfall in Europe should be very substantial[126].

Our analysis of the situation confirms the strong momentum in the launch and financing of projects in the US (see Table 4-1 line Component Manufacturing) although there is a risk that this may not be sufficient to meet demand, as our assessment of battery production capacity in the US appears to be higher than the benchmark used. In Europe, we estimate that the maximum planned production capacity of CAM should be sufficient to produce only about 700 GWh-equivalent of batteries. Both our analysis – only about 200 GWh-equivalent of batteries by 2030 (see Table 7-3) – and Benchmark Minerals analysis[127] show an important deficit in anode production capacity. This European electrode production deficit could be problematic for meeting future ROOs that impose a CAM localisation rate and C02 footprint targets for battery production.

The different liquid ion chemistries (NMC, NCA, LFP but also HLM[128], Sodium-ion[129], ...) have different advantages and disadvantages in terms of cost, safety, energy density and durability. Depending on their product strategy, automakers could decide to switch from one chemistry to another, and estimates of global production capacity by 2030 show the emergence of chemistries other than NMC[130]. It could lead to the modification of some existing production capacities, as certain transitions from one chemistry to another cannot be performed on the same equipment[131]. In addition, the confirmation of the industrial viability of solid-state technology could also lead to the creation of new production capacity. Both would increase the already high level of investment and could increase the latent risk of global production overcapacity.

The PEV battery market is currently dominated by China, which has 893 GWh of installed capacity, accounting for 77% of a global manufacturing capacity of approximately 1200 GWh by the end of 2022[132]. This rapid progress of Chinese companies' market shares is illustrated by the rapid evolution in the hierarchy of top-selling battery companies (source SNE research[133]):

- In 2020, CATL is already the market leader with a 24.2% share, closely followed by LGES and Panasonic with 22.6% and 19.2%, respectively. Samsung SDI, SK Innovation, and BYD were far behind with 5.8%, 5.5%, and 5.4% market share, respectively.
- In the first half of 2023, CATL is the leader of a market totaling more than 300 GWH, with a share of 36.8%, followed by BYD and LGES with 15.7% and 14.5%, respectively. Other suppliers, including Panasonic, fall below 10% market share, while Chinese newcomers enter the top 10. However, LGES has the #1 production capacity outside of China.

This description of the evolution of the market shares of the various companies confirms the growing stranglehold of Chinese battery cell manufacturers including CATL as a global champion supplying numerous automakers, both Chinese and global.

The dynamics, revealed by our analysis of current and future battery cells production capacity, show that, by 2030, Europe and the U.S. should total 2 TWh with 1,09 TWh and 0,97 TWh respectively. By 2030, the breakdown of cell manufacturing capacity by country of origin in Europe and the USCMA countries, summarized in the table below, shows that:

- European battery manufacturers should show significant growth in Europe,
- Korean battery manufacturers should take the lion's share in the USCMA countries,
- Chinese battery manufacturers would account for more than 19% of the market share in Europe plus the USCMA countries.

Country of origin of battery cells manufacturers	Europe capacity of production (in GWh)	USCMA capacity of production (in GWh)	Europe + USCMA capacity of production (in GWh)	% Of Europe + USCMA capacity of production
Korea	277,5	560,5	838	40,8
Europe (ACC, Northvolt, Power&Co, Verkor, Inobat, FAAM)	478 **See footnote[134] for assessment methodology**	150	728	30,5
China	291	105	396	19,3
Japan (Panasonic)	0	155	155	7,6
Tata Motors	40	0	40	1,8
Total	1086,5	970,5	2057	100

Table 4-2 : Europe (EU27, CH, UK, Norway, Turkey) and USCMA countries battery cells capacity production by country of origin of battery cells manufacturers by 2030

Source: For Europe, see Table 7-4 for list of projects and Table 7-5 for synthesis and for the USCMA countries see Table 7-6 for list of projects and Table 7-7 for synthesis

LGES could become the largest battery cell manufacturer in the USCMA countries with an estimated production capacity of about 287 GWh by 2030 (29,6% of the total production capacity). The company is expanding its battery value chain in North America, demonstrating its intention to establish a strong manufacturing base in the U.S. and take advantage of the IRA production tax credits[135].

Considering that Korean and Japanese battery manufacturers have recently announced their intention to increase their production capacity in the Asia-Pacific region (see Table 7-8), we estimate a global production capacity about 6.3TWh by 2030, divided into four groups by country (region) of origin: Chinese battery manufacturers with about 4,1TWh, Korean and Japanese battery manufacturers with 1.5TWh, European battery manufacturers with about 0.63TWh and others.

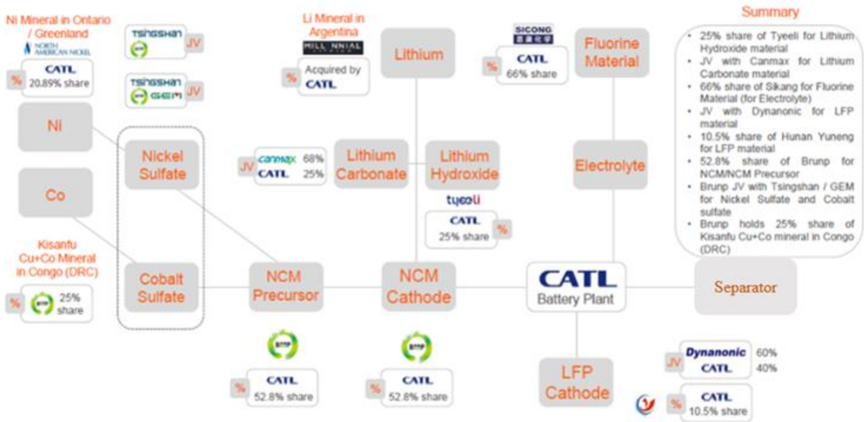
Country of origin of battery makers	Capacity of Production by 2030 (in GWh and % of total production)					
	China[136]	Europe	USCMA countries	Korea and Japan	ROW	total
China	3675	291	105			4071 (64,9%)
Korea and Japan	300	277,5	715	100	100	1492,5 (23,8%)
EU27, CH, UK, Norway, Turkey		478	150			628 (10%)
Others		40			40	80 (1,3%)
Total	3975	1086,5	970,5	100	140	6272

Table 4-3 : Global battery cells manufacturing by capacity and breakdown by country of origin
Source: Author's analysis of public announcements by companies summarized in tables listed above and global overview provided by S&P Global

The distribution of production is likely to change by 2035, with the potential realization of capacity announcements in Europe and in USCMA countries, leading to an increase in production capacity in all regions considered, and the emergence of production capacity in other regions (Asia-Pacific, South America) or countries such as India. However, we estimate that Chinese battery manufacturers are likely to maintain a market share of over 50% at that time, thanks to their huge installed capacity in China, fueled by a domestic market that is not yet saturated with PEVs.

The Chinese government promotes the development of national and international champions by supporting the merger and reorganization of the most successful companies to make them stronger and further increase the degree of industrial concentration. Sidebar 4-3 below provides the emblematic example of CATL to illustrate the "specialized vertical strategy" in which a company expands up and down from its original core business.

Development in the upstream value chain



Core business development and extension

CTP and CTC technologies (https://www.catl.com/en/research/technology/)

CATL's First Sodium-ion Battery to Power Chery EV Models (https://www.catl.com/en/news/6013.html)

Contemporary Amperex Intelligence Technology (Shanghai) Limited (CAIT-SH), a wholly-owned subsidiary of CATL to build the CATL Integrated Intelligent Chassis (CIIC) Production (https://www.catl.com/en/news/5993.html)

(Some among many signed) Agreements with Chinese automakers: BAIC (https://www.catl.com/en/news/6008.html), NIO (https://www.catl.com/en/news/5992.html), Changan Automobile (https://www.catl.com/en/news/1049.html) and Geely – Zeekr (https://www.catl.com/en/news/1048.html)

Development in the downstream value chain

Battery swap technology and network (https://www.catl.com/en/news/856.html) via a fully owned subsidiary Contemporary Amperex Energy Service Technology Ltd. (CAES), https://www.catl.com/en/news/6027.html

Battery recycling and utilization for the development of a circular economy via a subsidiary, Brunp owned at 65%, in China (https://www.catl.com/en/solution/recycling/) but also in Europe and the USA (https://www.electrive.com/2023/06/30/catl-plans-recycling-sites-in-europe-and-north-america/)

Sidebar 4-3 : CATL, an example of "specialized vertical integration"
Source: Author's own research and compilation of listed sources

4.4. Production of vehicles

This sub section summarizes the key findings of a recent study[137], updated at the end of 2021, assessing the strategic choices of 19 automakers (including 14 incumbents, 11 global players plus three Chinese automakers, and five new all-EV automakers, two from USA and three from China) with respect to manufacturing (make), purchasing (buy), or joining forces (ally) to produce BEVs, for both the assembly plant and the sourcing of the two main systems, namely the HV battery and electric powertrain.

We found that, at that time, incumbents were producing BEVs in their assembly plants alongside conventional ICEVs, and new entrants with plants dedicated entirely to BEVs were using essentially the same production process. The main reasons for doing so were to leverage existing assets, processes and competencies, provide volume flexibility (for incumbent automakers), and learn how to manage the mass production of electric vehicles.

To the best of our knowledge, this general situation, made possible by the high level of manufacturing expertise accumulated by the incumbent automakers over more than a century, has not changed since then. This is consistent with the need to achieve a design that can be mass-produced at low cost, and demonstrates that automakers have the technological capability to mass-produce BEVs and PHEVs today, and ZEVs in the near future.

For the battery pack system, we found that 68% of automakers have a make battery pack capability (13/19) in their main markets, while 32% of them choose to ally either with battery manufacturers or other automakers (6/19). In China, some global players were in a buy situation to take advantage of localization pricing opportunities, while the observed Chinese newcomers, with the exception of BYD, were in a buy or ally situation. While there are still a few alliances between automakers for developing BEVs (e.g., Ford and VW or GM and Honda), the results of this report on battery cell manufacturing (see Table 7-4 and Table 7-6) show that all global players now have contracts or alliances (or even licensing agreements) with battery manufacturers that supply battery cells (sometimes modules), while they have installed or are installing battery pack plants near their vehicle assembly plants or even on site in Europe and the US.

For the electric powertrain system, we found that roughly the same percentage have a make (or ally to make) e-motor capability in their main market, while the situation was slightly different in China, where some global players and 3 out of 5 of the Chinese newcomers were in a buy situation.

The study concludes that this observed situation could be permanent, at least until the global industry reaches a period of stabilization, which is still a long way off, especially for the battery value chain.

4.5. Charging network

The ability to quickly recover a high level of energy stored in the battery is critical to achieving mass adoption of PEVs and is actually a pain point in all regions. The most common solution is to charge the battery, which can be done at home, in a private charging area (e.g., in a company or supermarket parking lot) or via access to a public charging point.

By the end of 2021, China had about 1,140,000 public chargers available and is expected to have 8,600,000 publicly available chargers by 2030. The rapid development of the PEV market has triggered the emergence of a dedicated industry of charging stations and of charging network operators with a strong dominance of Chinese companies, which account for about 94% of China's public charging stations[138]. However, the rapid expansion of the charging network, required to meet the targets set by the Chinese government, is paving the way for a number of initiatives, mainly by global oil and gas companies (BP, Shell and Total Energies), in China.

In Europe, by the end of 2022, there are already 530,000 public charging points (including 70,000 fast chargers)[139] and this number should be multiplied by 20 to reach the 10,400,000 public charging points expected by 2035[140].

Many companies from different industries as well as specialized newcomers have entered the European PEV charging market. While European companies such as ABB, Siemens, EVbox, Webasto, Wallbox, Schneider Electric or Efacec, to name a few, supply AC/DC chargers and managing software for public networks (as well as home solutions for some of them), we have focused on the main European players involved as charging network operators, whether they are incumbent companies from the oil and gas, automotive and energy industries, or newcomers. Table 7-9 lists some of the major PEV charging operators in Europe and shows the continued momentum in deployment driven by these companies, including automakers which have a strong focus on fast chargers. Tesla with around 10,000 fast chargers is the main non-European charging network operator in Europe.

By the end of 2022, there are already 114,000 public charging points operated in the USA and this is expected to increase sharply to 1,200,000 by 2030[141]. Charger manufacturing plants in the US are listed in the report "The EV transition: Key market and supply chain enablers" (Opus cited above, p. 23). They are operated by American companies, including Tesla, or European companies such as WallBox, EVbox, and most notably Siemens. Following Tesla's strategy, automakers are also committed to deploying fast or ultra-fast charging networks, with BMW Group, General Motors, Honda, Hyundai / Kia, Mercedes-Benz Group and Stellantis NV aiming to install 30,000 high-power charging points in urban and highway locations starting in the summer of 2024[142].

The existence of different charging standards and different types of EV charging connectors in different regions[143] creates a need for convergence to avoid market fragmentation and the proliferation of solutions developed by automakers to allow their customers free access to different charging networks. In particular, many automakers have recently announced their decision to adopt the Tesla connector in the U.S. to gain access to Tesla fast charging network, while the de facto standard promoted in the U.S. and Europe is Combined Charging System[144].

We conclude that the main issue for the rapid deployment of public battery charging networks (including fast charging stations along high traffic and/or high-speed roads) is the level of incentives provided by public authorities. Further standardization of connectors would also contribute to rapid deployment but may be difficult in the short term. This observation applies to all three regions.

On the other side, China is strongly promoting, through successive regulations the development of the battery swap technology. It aims at accelerating PEV adoption as it appears to be a good solution to quickly recover a high level of battery capacity and reduce the acquisition cost as the business model includes leasing the battery. Collectively, all of the Chinese companies involved in battery swap technology and networks, such as NIO, Aulton New Energy Automotive, Sinopec, and CATL, to name a few, have pledged to build as many as 26,000 stations by 2025[145].

A May 2022 report by the Mercator Institute for China Studies suggests that the battery-swapping bet could isolate China's electric car industry because of global players' strategy against battery swapping and other drawbacks of the technology. They conclude that it is unlikely that battery swapping will ever replace charging in any country, including China, and that the current push is likely to result in the coexistence of both technologies[146].

Stellantis has very recently announced the signature of a binding agreement with Ample to establish a partnership in battery-swapping technology. The initial program is planned to begin in Madrid, Spain in 2024 using a fleet of 100 Fiat 500e's within Stellantis' Free2move car sharing service[147].

4.6. Recycling and reuse of battery critical materials

In a context where there is a high risk of raw material shortages for the automotive industry and a high interest in the development of a circular economy for society, the figure below shows the decisive advantage of recycling over more traditional processes such as mining or extraction from brine.

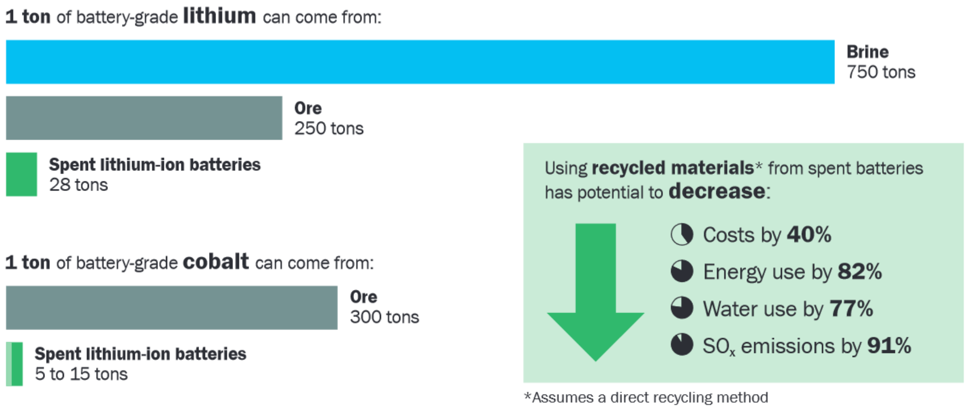


Figure 4-2 : Benefits of recycling versus mining or brine extraction
Source: (US) National Blueprint for lithium batteries 2021 – 2030, (Opus cited, p21)

While the volume of PEV batteries available for recycling, i.e., at the end of their life in vehicles or after a second life where they can be used as storage capacity, is expected to increase twelvefold from about 11.3 GWh of batteries in 2022 to 138 GWh in 2030[148], the situation is different in the three regions of the world we observe.

Already the world's largest battery producer, the development of a battery recycling industry is critical for China to maintain its dominance in the value chain and secure its own supply. As a result, China, which is far ahead of other regions in PEV adoption, is also far ahead in battery recycling, with 80% of battery pre-treatment recycling capacity and about 50% of material recovery capacity at 102,000 tons in 2022.

The growth of material recovery capacity is very fast as approximately 115,000 tons were recycled in the first five months of 2023, representing a full-year increase of approximately 270% year-over-year if the trend continues. In line with Chinese regulations to develop a battery recycling ecosystem, there are now more than 10,000 battery collection points and 84 designated Chinese companies that meet battery recycling industry standards[149]. In addition, some global players are also entering the Chinese battery recycling market, such as Mercedes in cooperation with CATL[150], or LG ES and BMW, which have signed cooperation agreements with the Chinese company Huayou Cobalt[151].

In Europe and the USA, the development of more efficient and sustainable technologies for the production of battery grade materials from waste is funded by the IIJA in the US and by European funding instruments (Horizon Europe, ...) or at Member State level in Europe (IPCEI, …).

The challenge, therefore, is to develop the industry at a time when there is not yet a sufficient volume of used batteries from PEVs to be recycled. Here, the opportunity is to use manufacturing waste, which will provide the majority of materials to be recycled over the next decade[152]. This is even more the case in Europe where used PEV batteries or manufacturing scraps are currently shredded into black-mass (mixtures of valuable metals including lithium, manganese, cobalt and nickel) and shipped to China for recycling[153], when they could be processed locally.

According to calculations by the Fraunhofer Institute for Systems and Innovation, the European industry will need to increase its capacity by more than 30% per year until 2040 and adapt it to PEVs battery characteristics, representing an investment of around €9 billion[154]. Its development is strongly guided by the provisions of the Battery Regulation (EU 2023/1542) on the recovery of cobalt, copper, lead, lithium and nickel end-of-life materials by 2027 and their reuse by 2031 at the latest (8 years after the entry in force of the regulation). Our analysis of the announced projects shows that the actual capacity to treat used batteries to produce battery grade materials per year should increase from 17,000 tons in 2022 to at least 500,000 tons in 2027 (see Table 7-10).

Although the "National Blueprint for Lithium Batteries 2021–2030" sets an ambition of 90% of battery recycling by 2030, there is no, so far, US regulation setting mandatory thresholds for the use of recycled materials in battery manufacturing, as there is in Europe. However, the IRA clause, which automatically qualifies EV battery materials recycled in the U.S. as American-made for subsidies regardless of their origin, has sparked a dynamic in the U.S. recycling industry. A recycling capacity of treatment of 80,000 tons of used batteries (to produce black-mass and battery grade material) is already operational and should increase to about 670,000 tons to produce battery grade materials by 2026 (see Table 7-11).

Automakers in both regions have either organized waste collection of used batteries with some specialists or have entered into cooperation with other players in the recycling business to develop a complete recycling ecosystem see Table 7-11). As the IEA states that policies can play a pivotal role in scaling up recycling[155], European regulators should play an important role in creating the conditions for this new industry to develop ecosystems involving all stakeholders at a pace "consistent with the growth of the industry" and to achieve technological leadership.

---

[116] Mineral Commodity Summaries 2023, accessed at https://www.ft.com/content/a8e0f1bb-f69a-4a77-b762-02f957e47f5c

[117] In short, resources are the total amount of minerals present in a country and consist of known reserves – the amount of mineral product that can be extracted economically – and other deposits that may become additional reserves or remain undeveloped deposits.

[118] Combining reports from the US Geological Survey (https://pubs.usgs.gov/periodicals/mcs2023/mcs2023.pdf) and from BRGM for France (Ressources métropolitaines en lithium et analyse du potentiel par méthodes de prédictivité, 2018Bureau de Recherches Géologiques et Minières, report BRGM/RP-68321-FR, http://infoterre.brgm.fr/rapports/RP-68321-FR.pdf), Europe and the US account for about 7% and 12%, respectively of the world lithium resources estimated at about 98 million tons

[119] https://lkab.com/en/press/europes-largest-deposit-of-rare-earth-metals-is-located-in-the-kiruna-area/

[120] https://www.theguardian.com/business/2023/dec/04/europe-miles-behind-race-raw-materials-electric-car-batteries-lithium-cobalt-nickel

[121] https://eurobatteryminerals.com/en/projects/

[122] Tom Taylor and Noah Gabriel, November 2022. Atlas Public Policy accessible at https://atlaspolicy.com/wp-content/uploads/2022/12/2022-EV-Transition-Key-Market-and-Supply-Chain-Enablers.pdf

[123] See figure 2, p8 of the "Cobalt Market Report 2022", issued in May 2023 and accessible at https://www.cobaltinstitute.org/wp-content/uploads/2023/05/Cobalt-Market-Report-2022_final-1.pdf
[124] Accessed at https://www.energy.gov/sites/default/files/2022-11/DOE%20BIL%20Battery%20FOA-2678%20Selectee%20Fact%20Sheets.pdf
[125] https://responsiblemining.net/
[126] : Umicore assessment of North American and European CAM market supply/demand balance to 2030. Source: https://www.umicore.com/storage/group/investor-presentation-february-2023-website.pdf
[127] https://source.benchmarkminerals.com/article/europes-looming-battery-anode-shortage?mc_cid=d3871583f3&mc_eid=d9a36e1126
[128] https://www.electrive.com/2023/02/14/umicore-to-bring-hlm-batteries-to-market-in-2026/
[129] https://source.benchmarkminerals.com/article/sodium-ion-batteries-advance-with-byd-northvolt-plans-but-supply-chain-challenges-loom?mc_cid=d1855d9d18&mc_eid=d9a36e1126
[130] https://www.isi.fraunhofer.de/en/blog/themen/batterie-update/globale-batterieproduktion-analyse-standorte-mengen-zellen-lfp-nmc-nca-kathoden.html
[131] For example, it is possible to produce LFP chemistry on a line originally designed for NMC production, but it is not possible to produce NMC on a line originally designed and optimized for LFP production without modifying the equipment.
[132] https://www.visualcapitalist.com/chinas-dominance-in-battery-manufacturing/
[133] 2020 situation accessed at https://www.kedglobal.com/batteries/newsView/ked202101290006
2023 situation accessed at https://cnevpost.com/2023/08/04/global-ev-battery-market-share-in-h1-2023/
[134] In addition, there is a very significant potential for additional announced capacity of more than 470 GWh by 2030, with 55 GWh announced by Chinese companies and more than 415 GWh proposed by European new entrants such as Italvolt, Innobat, Morrow batteries, Freyr, West Midlands Gigafactory, to name but a few. We have calculated European production capacity by selecting projects with announced automotive customers for liquid lithium-ion technology (there are at least three projects for solid-state technology that have not yet been validated by automakers).
[135] https://news.lgensol.com/company-news/press-releases/page/4/
[136] https://www.spglobal.com/marketintelligence/en/news-insights/research/lithium-ion-battery-capacity-to-grow-steadily-to-2030
[137] All the results quoted are based on Alochet, M., MacDuffie, J. P., & Midler, C. (2023). Mirroring in production? Early evidence from the scale-up of Battery Electric Vehicles (BEVs). Industrial and Corporate Change, 32(1), 61-111. Additional data are explicitly mentioned.
[138] Data from China Electric Vehicle Charging Infrastructure Promotion Alliance Accessed at https://www.china-briefing.com/news/electrifying-the-road-ahead-unlocking-chinas-ev-charger-industry-potential/
[139] Global EV outlook 2023
[140] https://www.siemens-advanta.com/all-electric-2035
[141] https://www.nrel.gov/news/program/2023/building-the-2030-national-charging-network.html
[142] https://www.stellantis.com/en/news/press-releases/2023/july/seven-automakers-unite-to-create-a-leading-high-powered-charging-network-across-north-america
[143] https://www.transportation.gov/rural/ev/toolkit/ev-basics/charging-speeds and https://www.makeuseof.com/ev-charging-connectors-region-differences/
[144] https://www.cnet.com/roadshow/news/teslas-ev-charger-is-on-track-to-be-the-industry-standard-but-the-road-ahead-is-bumpy/
[145] Bloomberg report cited by Protocol. https://www.protocol.com/climate/electric-vehicle-battery-swap-china
[146] https://merics.org/en/comment/beijings-battery-swapping-bet-could-isolate-chinas-electric-car-industry
[147] https://www.stellantis.com/en/news/press-releases/2023/december/stellantis-and-ample-establish-partnership-to-leverage-ample-s-modular-battery-swapping-technology-for-use-in-stellantis-electric-vehicles
[148] Circular Energy Storage, cited by Reuters https://www.reuters.com/business/autos-transportation/dead-ev-batteries-turn-gold-with-us-incentives-2023-07-21/
[149] Xin Guobin, a vice minister from MIIT cited by Caixin Global. https://www.caixinglobal.com/2023-06-22/ev-battery-recycling-accelerates-in-china-with-strong-state-support-102068324.html
[150] https://www.autonews.com/china/mercedes-benz-launches-battery-recycling-catl-2-other-chinese-companies
[151] https://source.benchmarkminerals.com/article/bmw-teams-up-with-huayou-to-recycle-batteries and https://en.huayou.com/news/751.html
[152] Umicore, Investor's presentation February 2023. https://www.umicore.com/storage/group/investor-presentation-february-2023-website.pdf
[153] https://www.reuters.com/business/autos-transportation/dead-ev-batteries-turn-gold-with-us-incentives-2023-07-21/
[154] Author's summary and adaptation of information available at https://www.isi.fraunhofer.de/en/blog/themen/batterie-update/recycling-lithium-ionen-batterien-europa-starke-zunahme-2030-2040.html and https://www.isi.fraunhofer.de/content/dam/isi/dokumente/cct/2021/VDMA_Kurzstudie_Batterierecycling.pdf
[155] https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions

5. What are the main threats to the European automotive industry?

We are only at the beginning of vehicle mass electrification, as the European Green Deal refers to an estimated 13 million zero- and low-emission vehicles on European roads by 2025. The Commission also sets a milestone of at least 30 million ZEVs by 2030 and a largely ZEV fleet by 2050, a significant increase on the approximately 8.5 million PEVs registered in Europe by the end of 2022.

Leaving aside the state of the industry and the market at the end of the current crisis triggered by Covid-19 and the war in Ukraine[156], as well as the inherently complex functioning of a political and economic union of 27 member states, we identify the following main challenges to the European automotive industry:

1. The weight-based CO2 target system has favored heavy vehicles, which have become heavier every year. As a result, it has created the so-called "upmarket drift"[157], in which price, mass, and engine power have grown simultaneously in a *seemingly* never-ending race while CO2 emissions per unit produced have not decreased as much as expected[158]. All other things being equal, a PEV is intrinsically heavier and consumes more strategic raw materials than an ICEV. Following the trend of increasing vehicle mass and offering a high-capacity battery would not go in the direction of minimizing PEVs' CO2 production footprint. Likewise, continuing to offer PEVs with high air resistance – SUVs and large cars dominate the electric market in 2022[159]–, would not improve their energy efficiency. This last point is especially true as Chinese regulations aim to reduce the energy consumption of PEVs giving them a competitive advantage over global players' vehicles.
2. Failure to anticipate lithium mining projects could lead to potential shortages and be the limiting factor in battery scale-up by 2030 on a global scale[160]. Cobalt and nickel are also at least at risk.
3. A faster pace of development of the battery value chain for raw material refining, battery component production, and of the battery recycling chain in USCMA countries than in Europe. It is strongly and pragmatically incentivised by the IRA and the IIJA, which contribute to North American countries' aspirations of investments in the PEV value chain.
4. Lack of a European mass production industry along the battery value chain from raw material refining to battery recycling. Neither the "low" CRMA, NZIA and Battery

Directive thresholds to be reached by 2030 (much later than in the US) nor the lack of financial incentives provide a strong stimulus for rapid localisation of the battery value chain, putting at risk the achievement of ROO targets by the end of 2026[161] and CO2 footprint targets in the long term.

5. The ramp up of new gigafactories by new European entrants, which is already a complicated phase with scrap rates between 10% and 30%[162], could take longer than expected as these new entrants need to acquire skills that are mainly controlled by Asian specialists. This is especially true given that most of the ramp-up phases could occur between 2024 and 2026.
6. Europe is already a net importer of PEVs and Li-Ion batteries[163] and is the target market for Chinese PEVs exports. There is a risk of a rapid and massive penetration in Europe by Chinese BEVs, whose prices are lower than those of European BEVs, which are already too expensive for the vast majority of consumers[164]. This is especially true in Central and Eastern European countries, where price is important[165]. The forthcoming application of Euro 7, if maintained in its original proposal by the Commission, could lead to the premature disappearance of ICEVs, further complicating the task of European automakers.
7. A market open to subsidies for North American vehicles that have already benefited from production subsidies in their country of manufacture, thus distorting competition.
8. Member States reducing too quickly (or even stopping) financial support for the purchase of PEVs for market introduction, when one of the lessons learned from China is the need for continuous and massive financial support for end customers.
9. A potential decline in European automakers' sales in China. Chinese automakers will dominate the domestic market and the market share of foreign competitors will gradually decline.
10. A potential decline in exports of European vehicles to the US (effect of IRA) and China (same reason as above), which are the first and third importers by value and the second and fourth importers by volume in 2022[166], respectively.

6. Conclusion

If we were to stop the clock now, we would probably conclude that China has definitely shaped the future of the global electric automotive industry. The undisputed dominance in the global PEV value chain and the PEV market that we observed in 2022 is confirmed by the sales figures[167] or the market share of Chinese battery manufacturers[168] in H1 2023.

China is continuing its NEV industry development plan, with the extension of purchase subsidies in 2023 – and likely 2024[169]–, the announcement of tax exemptions until 2027, and new regulations for CAFC and NEV credits expected in early 2024. Assuming China has the capacity to pursuing its "whatever it takes" strategy to support market uptake and industry development, it would be well on its way to achieving its ultimate goal of leading the global automotive industry for all fuels.

The situation is very complex for Europe, because China is not only a fierce competitor in the race to decarbonize the automotive industry, but also a strong innovation hub for automotive technologies and home to battery suppliers that are currently enabling European automakers' development in China and the rapid growth of PEV sales in Europe.

However, the future of the automotive industry is far from written, and both the United States and Europe have cards to play.

The momentum created by the state of California (and the other states that have decided to follow its lead) and the ambitious ZEV sales targets set by President Biden, as well as the IIJA and IRA are the real catalysts for the current acceleration of the electric vehicle industry in North America. This is largely due to the comprehensive and immediate funding of each stage of the PEV value chain which boosts the development of all the industries involved in the transition. Since the focus to date has been much more on high-paying jobs, energy independence and national security than on developing US global champions in battery cell manufacturing[170], this plan is likely to be a great success, as recent figures show that North America is attracting massive investment[171].

North America, aided by low energy prices, some from renewable sources, could become, before the end of this decade, a powerful PEV manufacturing hub mainly localised in the US, with Canada and Mexico taking advantage of the context to strengthen their own automotive industries as much as possible. The main risk that could jeopardise the development of the US electric mobility industry is the return of a Republican administration that would again lower ZEV sales thresholds and slow the pace of its development by reducing or even diverting funding to other priorities. Donald Trump's violent diatribe against PEVs during his recent visit to striking auto workers in Michigan on September 27, 2023 leaves little doubt about his future intentions should he be re-elected President[172].

From an industry perspective, at the European level, automakers are now present at each stage of the value chain through direct investment or cooperation and are implementing the forthcoming ramp-up of ZEVs. They must now focus on delivering more affordable and performant PEVs to support the market take off and counter the more efficient offerings from Chinese manufacturers. Efforts to develop battery cell manufacturing at scale seem to be bearing fruit, but this is not the case for the upstream battery value chain, which is still heavily dependent on Chinese suppliers.

From a strategic perspective, Europe is in a half-full, half-empty glass situation, with a regulatory framework now covering all stages of the PEV life cycle, but also in the process of finalizing some key regulations such as CRMA, NZIA, EPIB and Euro 7, due to intense regulatory activity at the end of 2023.

In addition, Europe is sticking to fair competition "no matter what" while the US and China use protectionism. All European automakers are global players and have an interest in smooth trade across regions that doesn't require protectionism. But, the absence of measures enabling the European electric mobility industry to develop without having to suffer the effects of protectionism in other regions is a handicap for the industry.

At the global level, the already tense relationship between China, the US and Europe could deteriorate further, leading to an all-out trade war that could destabilize the entire auto industry. The Chinese government's decision to restrict graphite exports[173], effective December 1, 2023, follows those already in place for gallium and germanium. It is a concrete response to US restrictions on chip exports to China and limits on Chinese companies' share of the battery supply chain, as well as the EU's anti-subsidy investigation into electric vehicle imports from China.

Given the situation and the challenges facing the industry, it may be possible for European automakers to catch up with Chinese competitors by the end of the decade if decisive action is taken in the next 18 months. Consequently, in the very short term, the European Commission should consider a holistic approach to develop ad-hoc regulatory and financial frameworks to:

1. Provide a degree of symmetry and a level playing field between the different regions when China and the U.S. use protectionism.
2. Rapidly secure the supply of raw materials where there are insufficient local resources to meet the short/medium-term demand. In addition, incentivise alternative technologies to reduce dependence on countries producing (refined) raw materials and mitigate the risk of raw material shortages.
3. Accelerate the localization of raw material processing and battery cell component production, where Europe is lagging behind China and where too low a level could

jeopardise both the achievement of the ROO requirements by the end of 2026 and the CO2 footprint targets for batteries in the long term.

4. Support the rapid development of accessible and economically viable BEVs where there is a high risk of rapid and massive penetration by Chinese BEVs with a better price / performance ratio.
5. Accelerate the development of the public charging networks with fast chargers to accelerate mass adoption and enable the development of a credible alternative to high battery capacity vehicles.
6. Support the development of large-scale, multi-stakeholder battery recycling ecosystems, as there is strong potential for technological and economic development for a circular economy.
7. Accelerate the development of breakthrough battery technologies to gain a competitive advantage over other regions.

At the same time, member states must be prepared to continue supporting market uptake through financial and/or non-financial incentives while European automakers will need to show *organizational ambidexterity* to both continue to sell profitable ICEVs and rapidly improve BEVs' performance to compete with Chinese automakers.

---

156 The author makes it clear that the main impact of the war in Ukraine is on the Ukrainian population.
157 Heavier, faster and less affordable cars - The consequence of EU regulations for car emissions. T.Pardi, ETUI report 2022.07
158 ACEA pocket Guide 2023-2024, p84. https://www.acea.auto/publication/the-automobile-industry-pocket-guide-2023-2024/
159 Global EV Outlook 2023, p10
160 Caspar Rawles, Benchmark's chief data officer quoted by the Guardian. https://www.theguardian.com/business/2023/dec/04/europe-miles-behind-race-raw-materials-electric-car-batteries-lithium-cobalt-nickel and https://www.nytimes.com/2023/07/02/business/lithium-mining-automakers-electric-vehicles.html
161 The EU-UK Trade and Cooperation Agreement, which entered into force on May 1, 2021, includes rules of origin (ROO) for batteries and PEVs. Considering that, due to unforeseen circumstances, the implementation of the battery value chain has not reached the expected level by 31 December 2023, the Commission has proposed to the Council a one-off extension of the current rules until 31 December 2026. If adopted by the Council, this proposal would avoid the 10% tariff on PEVs, which is expected to cost nearly €4.3 billion over the three-year period between 2024 and 2026, weakening the EU car industry at a time when it needs to focus on delivering high-performance PEVs.
162 https://www.adlittle.com/id-en/insights/viewpoints/european-battery-recycling-emerging-cross-industry-convergence
163 Global EV Outlook 2023, p106
164 https://www.autoactu.com/documents/telecharger/etude-jato-sur-les-prix-des-voitures-chinoises
165 https://www.forbes.com/sites/neilwinton/2023/05/18/europe-weakens-its-own-auto-industry-as-china-salesaccelerate/?sh=41454264bcf1
166 https://www.acea.auto/publication/the-automobile-industry-pocket-guide-2023-2024/
167 https://www.ev-volumes.com/
168 SNE research cited by CnEVPost - https://cnevpost.com/2023/08/04/global-ev-battery-market-share-in-h1-2023/
169 The subsidies have already been extended twice and are part of the Chinese government's efforts to support the market take-off. Given that the extension of subsidies is usually announced within a year, the author hypothesizes that another extension will be announced in 2024.
170 Only one newcomer identified in the production of battery cells, namely Statevolt, https://statevolt.com/
171 https://www.atlasevhub.com/data_story/210-billion-of-announced-investments-in-electric-vehicle-manufacturing-headed-for-the-u-s/
172 https://www.reuters.com/world/us/trump-skips-debate-woo-blue-collar-workers-michigan-2023-09-27/
173 However, it may also happen that, similar to the gallium and germanium controls, China is implementing new licensing requirements but continues to facilitate exports under a presumption of permit approval (https://www.csis.org/analysis/chinas-new-graphite-restrictions). The existence of Chinese overcapacity for the production of graphite anodes is probably one of the main reasons for doing so (https://source.benchmarkminerals.com/article/in-charts-why-decoupling-from-chinas-anode-market-could-be-difficult-for-the-west?mc_cid=b3fbca6cc2&mc_eid=d9a36e1126).

7. Appendices on the dynamics of the electric mobility industry

Company	Location (Country of origin of company if different from country of location)	Capacity of production (Ktons of Lithium hydroxide per year) Duration Project status	Source
European Lithium	Austria	10 Expected to start in Q1 2025, duration about 20 years Ongoing definitive feasibility study	https://europeanlithium.com/wolfsberg-lithium-project/
European Metals Holdings 49% - CEZ 51%	Czechia (EMH, Australian and UK listed company CEZ Czech public company in energy)	30 Starting date to be determined, duration about 25 years On-going Environmental Impact Assessment	https://www.europeanmet.com/cinovec-project-overview/
Imerys	France	34 Expected to start in 2028 duration about 25 years	https://emili.imerys.com/calendrier-du-projet-dextraction-de-lithium-beauvoir
Infinity Lithium Corporation	Spain (Australian company)	19,5 Starting date to be determined, duration about 26 years Ongoing Exploitation Concession Application process	https://www.businessnews.com.au/article/Infinity-continues-forward-moves-at-Spanish-lithium-project?utm_source=Business+News+Mailing+List&utm_campaign=5beeea5789-dba&utm_medium=email&utm_term=0_e5391356e5-5beeea5789-290077586
Sibanye Keliber	Finland (South African company)	15 Expected to start in 2025, duration at least 16 years, Proposed mining and processing activities are authorized by local agency	https://www.sibanyestillwater.com/business/europe/keliber/ https://investingnews.com/lithium-mining-projects-europe/ https://www.sibanyestillwater.com/keliber-news/2023/sibanye-stillwater-provides-update-on-environmental-permits-for-the-keliber-lithium-project/
Savannah Resources	Portugal (English company)	Environmental License expected in 2024	https://www.savannahresources.com/project/environmental-impact-assessment/
Vulcan Energy Resources	Germany	24 for the 1st round expected to start in 2025 Definitive Feasibility Study stage for round 1	https://v-er.eu/ https://www.investi.com.au/api/announcements/vul/e617fca6-6d4.pdf
Zinnwald Lithium	Germany	12 Starting date to be determined On-going Environmental Impact Assessment	https://www.zinnwaldlithium.com/projects/zinnwald-lithium-project/

Table 7-1 : Lithium extraction and processing projects in Europe

Automaker	Company	Nature of supply	Location of production	Source
BMW	Ganfeng Lithium Co., Ltd (China)	Lithium	Mines in Australia	https://www.bmwgroup.com/en/company/news.html#ace-297947972
	Managem (Morocco)	Cobalt	Mining in Morocco (Remaining 80% in Australia)	https://www.press.bmwgroup.com/france/article/detail/T0310910FR/approvisionnement-en-mati%C3%A8res-premi%C3%A8res-pour-les-cellules-de-batterie:-bmw-group-s-approvisionne-en-cobalt-durable-au-maroc-pour-une-valeur-d-environ-100-millions-d-euros?language=fr
	European Lithium (Autralia)	Lithium	Wolfsberg Lithium project in Austria.	https://stockhead.com.au/resources/european-lithium-nabs-binding-offtake-agreement-with-bmw/
	Livent (USA)	Lithium	Responsible extraction of lithium in Argentina	https://www.press.bmwgroup.com/usa/article/detail/T0328874EN_US/bmw-group-steps-up-sustainable-sourcing-of-lithium-for-battery-cell-production-to-ensure-rapid-e-mobility-expansion?language=en_US
Mercedes Benz	Rock Tech Lithium Inc. (Germany - Canada)	Lithium hydroxyde	Mining in Ontario (Canada) Refining in Guben (Germany)	https://media.mercedes-benz.com/article/980f313c-6e81-4de3-9cc0-f091ba7c6c40
	Sila (USA)	High-Silicon Anode	To be available by mid (current) decade	https://group.mercedes-benz.com/company/news/mercedes-benz-and-sila.html
Ford	Ioneer Ltd's (USA)	Lithium hydroxide	Mining in Nevada	https://www.reuters.com/business/autos-transportation/ford-buy-lithium-ioneer-american-ev-battery-plant-2022-07-21/
	Compass Minerals (USA)	Lithium hydroxide	Solar evaporation facility in Utah	https://www.compassminerals.com/info/news/compass-minerals-and-ford-motor-company-sign-non-binding-agreement-for-the-supply-of-battery-grade-lithium/
	Nemaska (Canada)	Lithium hydroxide	Mining and production Quebec	https://nemaskalithium.com/en/ford-and-nemaska-lithium-enter-long-term-lithium-hydroxide-supply-agreement/
	Albemarle (USA)	Lithium hydroxide	lithium hydroxide domestically produced in the U.S. or originating in a country with a U.S. FTA.	ttps://www.albemarle.com/news/albemarle-establishes-strategic-agreement-with-ford-motor-company#_ga=2.218155674.280557114.1690579032-1248178279.1690579032
	SK On and EcoPro BM	Cathode	New plant to be built in Quebec	https://www.bloomberg.com/news/articles/2022-11-04/ford-in-talks-with-korean-firms-to-build-cathode-plant-in-quebec
GM	Lithium Americas Corp. (USA)	Lithium	Mining in Nevada	https://news.gm.com/newsroom.detail.html/Pages/news/us/en/2023/jan/0131-lithium.html
	Element 25 GM provide US$85 million loan	Manganese sulfate	Plant to be built in Louisiana	https://news.gm.com/newsroom.detail.html/Pages/news/us/en/2023/jun/0626-supplychain.html
	Vale Canada Limited (Canada)	Nickel sulfate	Production plant in Quebec	https://news.gm.com/newsroom.detail.html/Pages/news/us/en/2022/nov/1117-vale.html
	Microvast Holdings, Inc.	Battery separator	New plant to be built in USA	https://news.gm.com/newsroom.detail.html/Pages/news/us/en/2022/nov/1102-microvast.html
	POSCO Future M	Cathode active material	Becancour, Quebec	https://www.automotivedive.com/news/general-motors-1b-ev-batteries-investment/652193/
Honda	Hanwa Co., Ltd (Japan)	Procurement of essential metals	Not defined in the press release	https://global.honda/newsroom/news/2022/c220906eng.html

		necessary for batteries such as nickel, cobalt and lithium		
	POSCO Future M	Exploration of cooperation	Anode and cathode materials	https://www.greencarcongress.com/2023/04/20230412-posco.html
Hyundai / Kia	Arafura (Australia)	Rare Earths	Mining in Autralia	https://www.arultd.com/wp-content/uploads/2023/04/202304_Fact-Sheet_NOLANS-PROJECT_reduced.pdf
	Korea zinc	Sourcing and processing of nickel	“Countries that meet IRA requirements”	https://www.hyundai.com/worldwide/en/company/newsroom/hyundai-motor-group-partners-with-korea-zinc-on-value-chain-for-ev-business-0000017077
Nissan				
Renault Group	Terrafame (Finland)	Nickel sulphate	Bioleaching-based production process in Finland	https://media.renaultgroup.com/renault-group-to-partner-with-terrafame-for-sustainable-nickel-supply/?lang=eng
	Managem (Morocco)	Cobalt	Mining in Morocco Refining in Guemassa industrial complex	https://media.renaultgroup.com/renault-group-and-managem-group-sign-an-agreement-for-a-sustainable-supply-of-moroccan-cobalt/
	Vulcan Energy (Australia)	Lithium	Germany	https://media.renaultgroup.com/renault-group-signe-un-accord-avec-vulcan-energy-pour-un-approvisionnement-decarbone-et-europeen-en-lithium/?lang=fra
Stellantis	Element25 (Australia)	Manganese sulphate monohydrate	New plant to be built in USA	https://www.stellantis.com/en/news/press-releases/2023/january/stellantis-signs-binding-agreement-with-element-25-limited-for-manganese-sulphate-supply-for-electric-vehicle-batteries
	Controlled Thermal Resources Ltd. (USA)	Lithium	Process lithium from geothermal brines in California	https://www.stellantis.com/en/news/press-releases/2022/june/stellantis-secures-low-emissions-lithium-supply-for-north-american-electric-vehicle-production-from-controlled-thermal-resources
	NioCorp (USA)	Rare Earths	Elk Creek Critical Minerals Project Nebraska	https://www.stellantis.com/en/news/press-releases/2023/july/stellantis-and-niocorp-sign-rare-earth-offtake-term-sheet-in-support-of-stellantis-commitment-to-reaching-carbon-net-zero-by-2038
	Vulcan Energy (Australia)	Lithium	Germany	https://www.stellantis.com/en/news/press-releases/2021/november/stellantis-signs-lithium-supply-agreement-with-vulcan-energy
	Alliance Nickel (Australia) Supply contract and investment	Battery-grade nickel and cobalt sulphate (World supply)	Western Australia	ttps://www.stellantis.com/en/news/press-releases/2023/april/stellantis-signs-offtake-agreement-and-invests-in-alliance-nickel-for-battery-grade-nickel-and-cobalt-sulphate
	Kuniko (Norway) Supply contract and investment	Low Carbon Nickel and Cobalt Sulphate	Norway	https://www.stellantis.com/en/news/press-releases/2023/june/stellantis-signs-offtake-terms-and-invests-in-kuniko-for-supply-of-norwegian-low-carbon-nickel-and-cobalt-sulphate
	Mc Ewen Mining (Canada) Investment	Copper (World supply)	Argentina	https://www.stellantis.com/en/news/press-releases/2023/february/stellantis-announces-strategic-copper-investment-in-argentina-reinforcing-commitment-to-reaching-carbon-net-zero-by-2038
	ACG Electric Metals – Investment	Nickel, Copper	Brazil	https://batteriesnews.com/glencore-automakers-stellantis-volkswagen-back-1-billion-nickel-copper-spac-deal-in-brazil/

VW (PowerCo[174])	Vulcan Energy (Australia)	Lithium	Germany	https://www.volkswagenag.com/en/news/2021/12/volkswagen-enters-into-strategic-partnerships-for-the-industrial.html
	ACG Electric Metals – Supply contract	Nickel, Copper	Brazil	https://batteriesnews.com/glencore-automakers-stellantis-volkswagen-back-1-billion-nickel-copper-spac-deal-in-brazil/
	Umicore	Cathodes (and components)	Belgium	https://www.volkswagenag.com/en/news/2022/09/powerco-and-umicore-establish-joint-venture-for-european-battery.html#
VW China	Joint Venture with Huayou (China) and Tsingshan (China)	Nickel and cobalt raw materials	Indonesia	https://volkswagengroupchina.com.cn/en/news/Detail?ArticleID=705E75C6C4484A959C116B0A95196585
Nissan				
Tesla	List of direct suppliers from different countries for lithium, cobalt, nickel			https://electrek.co/2022/05/06/tesla-list-battery-material-suppliers-long-term-nickel-deal-vale/
JV Toyota Panasonic	Ioneer LTD's Rhyolite Ridge mining project.	Lithium hydroxide	Mining in Nevada	https://electrek.co/2022/08/01/toyota-panasonic-buying-us-lithium-boosts-ev-capacity/
	BASF TODA Battery Materials	Cathode Active Materials (CAM)	Onoda (Japan)	https://catalysts.basf.com/news/basf-selected-as-strategic-supplier-of-cathode-active-materials-to-prime-planet-energy-solutions-ppes-in-japan
Toyota Tsusho	Orocobre (Australia)	Lithium	Mining in Argentina	https://www.toyota-tsusho.com/english/press/detail/180116_004099.html

Table 7-2 : Global direct sourcing of strategic raw materials and battery cells components by global automakers
Source: Author's search of automaker's corporate news section and/or Google search of "raw materials suppliers for a given automaker"

Company	Investment (€ billion)	Nature of Supply	Capacity in equivalent GWh of battery[175]	Source
JV Umicore PowerCo (Location to be defined)	3	CAM & pCAM Production to start in 2025	160 at the end of the decade	https://www.umicore.com/en/newsroom/news/umicore-and-powerco-get-official-go-to-start-joint-venture-for-eu-battery-materials-production/
Umicore (Nysa plant in Poland)		CAM	20 by the end of 2023 40 by the end of 2024 200 by the end of the decade	https://www.umicore.com/en/newsroom/umicore-accelerates-european-e-mobility-with-nysa-gigafactory/
BASF (Schwarzheide in Germany)		CAM	20 by the end of 2024	https://catalysts.basf.com/industries/automotive-transportation/battery-materials/global-footprint/european-battery-materials-investment
BASF (Harjavalta in Finland)		pCAM	20 by the end of 2024	
JV Orano XTC New Energy group (Dunkerque France)	1,5	pCAM & CAM Production to start in 2026	10% of market need by 2030 for each product	ttps://www.orano.group/en/news/news-group/2023/may/orano-and-xtc-new-energy-join-forces-to-manufacture-battery-components-for-electric-vehicles-in-france https://www.orano.group/en/nuclear-expertise/valuation-of-strategic-metals/recycling-of-electric-vehicle-batteries-launch-of-a-new-industrial-pilot
JV Finnish Minerals Group 30% and Beijing Easpring 70% (Kotka Finland)	1	CAM	37,5 (750,000 vehicles at full scale)	https://www.mineralsgroup.fi/topical/news/finnish-minerals-group-and-beijing-easpring-to-establish-a-jv-company-to-advance-the-cam-plant-project-in-kotka.html
JV Finnish Minerals Group 40% and CNGR Advanced Material 60% (Hamina Finland)		pCAM		https://www.mineralsgroup.fi/business/cngr-finland.html
Partnership Freyr / Finnish Minerals Group (Vaasa Finland)		CAM	2 options 12,8 (20,000 tons) 38,4 (60,000 tons)	https://www.mineralsgroup.fi/business/vaasa-lfp-cam-project.html
Altris (Sandviken Sweden)		Innovative CAM material	1	https://www.altris.se/news/altris-to-manufacture-ground-breaking-cathode-material-in-sandviken-sweden
Northvolt (Borlänge, Sweden)		CAM	100	https://northvolt.com/articles/northvolt-to-transform-closed-paper-mill-in-sweden-into-new-gigafactory/
Total CAM production		CAM	By 2030 maximum capacity 700	/
Vianode, (Elkem, Hydro and Altor) (Herøya Norway).	0,36 (1st step)	Anode materials	1 by 2024 100 by 2030	https://www.vianode.com/news/article/?itemid=E2BA6D45A672505A
Shanghai Putailai New Energy Technology (Timrå Sweden)	1,32	Anode materials	32 (50,000 tons) by 2025 64 (100,000 tons) by early 2027	https://www.yicaiglobal.com/news/20230405-03-ptl-slips-on-plan-to-invest-up-to-usd15-billion-to-build-lithium-ion-anode-material-base-in-sweden
Total Anode materials production		Anode materials	200 by 2030	

Table 7-3 : Battery materials processing projects in Europe
Source: Author's analysis of the mentioned sources

Company (Origin of Shareholders)	Customers	Investment (€ billion)	Capacity of production GWH Current	2030	Location of production	Source
ACC (France / Germany)	Stellantis, Mercedes	7,5	13,4 (2024 Fr)	40 40 40	Douvrin (France) Kaiserslautern (Germany) Termoli (Italy)	https://www.acc-emotion.com/fr/a-propos-d-acc https://www.acc-emotion.com/stories/acc-announces-opening-3rd-gigafactory-termoli-italy
AESC Envision (China / Japan)	Renault Group, Nissan + Others	2,6 2 3,8	2 (UK) 9 (2024 Fr)	25 24 50	Sunderland (UK) Douai (France) Extramadura (Spain)	https://www.aesc-group.com/en/network.html https://global.nissannews.com/en/releases/release-10e81128ff45380ddab0a113f800e7fe-210701-03-e https://media.renaultgroup.com/renault-group-places-france-at-the-heart-of-its-industrial-strategy-for-ev-batteries/ https://www.electrive.com/2022/07/19/envision-aesc-is-building-another-battery-plant-in-spain/
Basquevolt	*Unknown (Solid State batteries)*	*0,7*	*/*	*10*	*Vitoria (Spain, starts in 2027)*	*https://basquevolt.com/en/news/news/basquevolt-basque-solid-state-battery-initiative-stars-up-produce-10gwh-2027*
CALB (China)	*Unknown*		*/*	*15*	*Sines Industrial and Logistics Zone (Portugal)*	*https://www.clbrief.com/chinas-calb-lithium-battery-factory-in-portugal-in-peril/*
CATL (China)	BMW, Mercedes Benz Stellantis, VW, Tesla	7,34	/	100	Debrecen (Hungary)	https://www.catl.com/en/news/983.html https://group.mercedes-benz.com/innovation/digitalisation/industry-4-0/article-2.html
			14	24	Erfurt (Germany)	https://www.catl.com/en/news/921.html
EVE Power (China)	BMW	1,4	/	28	Debrecen (Hungary, starts in 2026)	https://hipa.hu/news/eve-power-teams-up-with-bmw-in-debrecen-to-supply-ifactory-next-door/
ElevenES	*LFP technology, samples under testing process by customer*		*/*	*48*	*Subotica (Serbia, 8GWh in 2026 + 40 GWh in 2027)*	*https://elevenes.com/en/news/elevenes-opens-europe-s-first-lfp-battery-cell-manufacturing-facility*
Elinor Batteries	*Production of A sample for evaluation by customers*	*0,9*	*/*	*40*	*Trondheim, Norway (to start Q2 2026).*	*https://www.elinorbatteries.com/articles/first-step-towards-our-gigafactory*
FAAM (Italy)	LFP technology Electric bus and ICEV ➔ EV transformation	0,5	0,35	8	Teverola (Italy	https://faam.com/index.php/en/2023/07/04/unicredit-zes-e-gigafactory/
Finnish Minerals Group	*Unknown*	*2,7 to 40*		*27 to 40*	*(MoU) with a potential partner for a cell production plant project. Kotka (Finland)*	*https://www.mineralsgroup.fi/topical/news/finnish-minerals-group-to-prepare-for-cell-production-plants-eia-procedure.html*
Freyr (Ongoing localization in the US)	*ESS (JV with Nidec)*[176]		*/*	*43 (12 for JV with Nidec)*	*Giga Artic Mo i Rana (Norway, starts in 2025)*	*https://www.freyrbattery.com/news/freyr-battery-and-nidec-corporation-complete-formation-of-joint-venture* *https://www.freyrbattery.com/news/freyr-battery-signs-first-e-mobility-offtake-agreement-with-impact-clean-power-technology-to-supply-up-to-14-gwh-of-lfp-cells*
	Unknown		*/*	*45*	*Vaasa (Finland)*	*https://www.freyrbattery.com/news/freyr-battery-begins-preparatory-work-in-vaasa-finland*

InoBat (Slovakia)	Supply agreement with Impact[177]		/	10 (4 for Impact)	Voderady, (Slovakia, starts in 2024)	https://www.inobat.eu/newsroom/inobat-provides-operational-update-following-significant-2022-progress/ https://www.electrive.com/2022/04/06/inobat-to-build-battery-gigafactory-in-western-europe/
	Unknown		/	*4 - 32*	*MOU gigafactory in Serbia, starts in 2025*	*https://www.inobat.eu/newsroom/inobat-signs-declarations-of-intent-with-the-republic-of-serbia-for-the-construction-of-a-new-ev-battery-gigafactory/*
	Unknown		/		*MOU gifactory in Valladolid, Spain*	*https://www.inobat.eu/newsroom/inobat-auto-signs-declarations-of-intent-with-spain-for-construction-of-new-ev-battery-manufacturing-plant/*
JV Inobat Gotion	*Not mentioned in the press release*		/	*40*	*European Union country*	*https://www.inobat.eu/newsroom/inobat-and-gotion-sign-mou-to-develop-joint-venture-ev-battery-cells-and-packs-in-cee/*
ItalVolt (Italy)	*License Store Dot extreme fast charging technology[178]*	*3*	/	*45 (no capacity announced for StoreDot offtake of cells)*	*Termini Imerese (Sicily)*	*https://www.italvolt.com/#about https://www.italvolt.com/italvolt-and-politecnico-di-milano-unveil-new-plan-to-up-skill-the-automotive-workforce-at-termini-imerese/ https://www.italvolt.com/italvolt-enters-strategic-collaboration-with-storedot-for-extreme-fast-charging-lithium-ion-battery-technology/ https://www.reuters.com/technology/italvolt-license-battery-technology-israels-storedot-2023-01-16/*
LGES (Korea)	Renault Group + Ford + tesla	0,29 + 2	70	115	Wroclaw (Poland)	https://lgensol.pl/en/about-us/ https://www.electrive.com/2021/06/28/renault-confirms-battery-deals-with-aesc-and-verkor/
JV LG ES Ford Koç Holding	Ford		/	25	Başkent (Turkey)	https://news.lgensol.com/company-news/press-releases/1520/
Morrow batteries (Norway)	*ESS[179]*		/	*43 (7GWH by 2030 for ESS applications)*	*Arendal (Norway, starts in 2028,)*	*https://www.morrowbatteries.com/about-us*
Northvolt (Sweden)	BMW, VW group	2,7	40	60	Skellefteå, (extension of production starts in 2024)	https://northvolt.com/articles/northvolt-equity-june2021/
		4	/	60	Heide (Germany, starts in late 2025)	https://northvolt.com/articles/northvolt-drei/
	Volvo Cars and Polestar	2,52	/	50	Gothenburg (Sweden, starts in 2025)	https://northvolt.com/articles/northvolt-volvo-gigafactory/
Power Co (Germany)	VW Group	2	/	60	Salzgitter (Germany from 2025 onwards)	https://www.volkswagen-newsroom.com/en/press-releases/ground-breaking-in-salzgitter-volkswagen-enters-global-battery-business-with-powerco-8050
		3	/	40 (60)	Valencia (Spain from 2026 onwards)	https://www.volkswagen-newsroom.com/en/press-releases/gigafactory-valencia-powerco-gives-starting-signal-for-construction-of-second-cell-factory-15641
Prologium (Taiwan)	*Automotive Solid-State cells MOU with ACC*	*5,2*	/	*48*	*Dunkerque (France)*	*https://prologium.com/prologium-announces-e5-2b-gigafactory-in-dunkirk-france-and-greets-french-president-emmanuel-macron/ https://www.acc-emotion.com/stories/acc-prologium-partner-accelerate-development-solid-state-ev-battery*
Samsung SDI (Korea)	BMW, VW, Stellantis	2,5	40	90	Göd (Hungary)	https://www.kedglobal.com/batteries/newsView/ked202303020024
SK innovation (Korea)	VW, Mercedes	2,3	17,5	47,5	Konarom + other location for new plant (Hungary)	https://www.kedglobal.com/batteries/newsView/ked202101290006

Sunwoda (China)	*Not mentioned in the press release*		/	*Not announced*	*Nyíregyháza (Hungary)*	*https://hipa.hu/news/yet-another-leading-battery-manufacturer-chooses-hungary-as-investment-location/*
Svolt (China)	Stellantis ?		/	16	Lauchhammer (starts early 2025)	https://svolt-eu.com/en/svolt-builds-additional-battery-cell-factory-in-brandenburg-germany-for-european-market/ https://www.electrive.com/2022/09/10/svolt-confirms-2nd-battery-cell-plant-in-germany/
		2	/	24	Überherrn (Germany, start delayed to 2024)	https://www.svolt.cn/en/about_newdal.php?tab=about&VID=152
Swiss Clean Battery	*Solid State samples under testing process*	*0,4 to 2*	/	*1,7 to 7,6*	*Frauenfeld, Switzerland (starts 2025)*	*https://www.swisscleanbattery.ch/en/press/20Minuten_20230727_EN.php https://www.ns-businesshub.com/transport/swiss-clean-battery-solid-state-batteries-gigafactory/*
Tata Sons (India)	JLR, Tata Motors	4,7	/	40	UK to start in 2026	https://www.tata.com/newsroom/business/battery-gigafactory-uk
Tesla[180]	Tesla		(50)	(100)	Grünheide (Germany)	https://www.reuters.com/business/autos-transportation/tesla-requests-approval-revamp-german-plant-application-documents-2023-07-19/
Verkor (France)	Renault Group	2,5	/	50	Dunkerque (France)	https://media.renaultgroup.com/renault-group-places-france-at-the-heart-of-its-industrial-strategy-for-ev-batteries/
West Midlands Gigafactory (Local)Public Private Partnership	*Not mentioned in the press release*	*2,9*	/	*60*	*Coventry UK*	*https://ukgigafactory.com/news/2022/5/2/west-midlands-gigafactory-the-largest-in-the-uk-to-secure-the-british-automotive-industrys-long-term-electric-future*
Total potential projects			/	471,6		
Total projects		60,4	183,5	1086,5		
Grand Total			183,5	1558,1		

Table 7-4: Battery cells production capacity in Europe (EU27, UK, Norway and Turkey), current and projected situations (plant capacity > 5GWh)

Source: Author's analysis of the cited websites

Battery cell manufacturer country of origin	Current manufacturing capacity (GWh)	Total manufacturing capacity by 2030 (GWh)	% Of battery cell manufacturing capacity by 2030	Potential additional manufacturing capacity by 2030 (GWh)
Korea	127,5	277,5	27,5	0
India	0	40	3,7	
China	16	291	26,8	55
Europe	40	478	44	416,6
Total	183,5	1086,5	100	471,6

Table 7-5 : Europe (EU27, CH, UK, Norway, Turkey) current and expected battery cells manufacturing capacity by country of origin of battery cell makers

Company (Origin of Shareholders)	Customers	Investment ($ billion)	Capacity of production GWH		Location of production	Source
			Current	2030		
AESC (China / Japan)	BMW Nissan Mercedes	0,8	/	30	Florence (South Carolina, starts in 2026)	https://www.bmwgroup-werke.com/spartanburg/en/news/2023/BMW-Group-Breaks-Ground-on-New-High-Voltage-Battery-Assembly-Factory-in-South-Carolina1.html ttps://us.aesc-group.com/envision-aescs-investment-in-30gwh-south-carolina-gigafactory-creates-1170-new-jobs-and-cements-the-states-reputation-as-an-automotive-hub/
			/	30	Bowling Green (Kentucky, starts in 2027)	https://www.wbko.com/2022/08/30/envision-aesc-breaks-ground-bowling-green/
			3	10	Smyrna (Tennessee)	https://insideevs.com/news/618462/us-envision-aesc-70gwh-battery-manufacturing/
Freyr (Norway)	*ESS storage*	*(1,7)*	*/*	*(34)*	*Coweta County, Georgia*	*https://www.freyrbattery.com/extra-pages/facilities/giga-factory-usa*
LG ES (Korea)	Lucid Air + others US EV makers	Total around 10	5	25	Holland (Michigan, start in 2025)	https://news.lgensol.com/company-news/supplementary-stories/681/
			/	27	Queen Creek (Arizona, start in 2025)	https://news.lgensol.com/company-news/press-releases/1613/
Ultium Cells, JV LGES (50%) GM (50%)	GM (and Honda[181])	7,5	40 35	50 40 35	Michigan (starts late 2024), Ohio (starts in 2022), Tennessee (starts in 2022)	https://www.gm.com/stories/manufacturing-ultium-evs-trucks https://insideevs.com/news/590979/ultium-cells-steel-building-structure-tennessee/
JV Samsung SDI GM	GM	3	/	30	Production to start in 2026	https://www.samsungsdi.com/sdi-news/3162.html?idx=3162
JV LGES (51%) Honda (49%)	Honda	3,5	/	40	Jeffersonville (Ohio, start in 2025)	https://global.honda/newsroom/news/2023/c230113beng.html
JV LGES (50%) Hyundai (50%)	Hyundai / Kia	4,3	/	30	Savannah (Georgia, start in 2025))	https://www.hyundai.com/worldwide/en/company/newsroom/-0000017038
JV LGES Stellantis	Stellantis	3,75	/	40	Windsor (Ontario, start in 2024)	https://www.stellantis.com/en/news/press-releases/2022/march/stellantis-and-lg-energy-solution-to-invest-over-5-billion-cad-in-joint-venture-for-first-large-scale-lithium-Ion-battery-production-plant-in-canada
Northvolt	VW and others	5,3	/	60	Quebec, starts in 2026	https://northvolt.com/manufacturing/six/ https://cleantechnica.com/2023/06/30/northvolt-close-to-choosing-site-near-montreal-for-5-3-billion-green-battery-factory/
StarPlus Energy JV Stellantis / Samsung SDI	Stellantis		/	33 34	Indiana 1st plant 2025 2nd plant 2027	https://www.stellantis.com/en/news/press-releases/2023/july/stellantis-samsung-sdi-announce-plans-to-build-second-starplus-energy-gigafactory-in-the-united-states
JV SK on (50%) Hyundai (50%)	Hyundai / Kia	5	/	35	Bartow County (Georgia, start in 2025)	https://www.hyundai.com/worldwide/en/company/newsroom/hyundai-motor-group-and-sk-on-to-establish-ev-battery-cell-production-joint-venture-in-us-0000017016
Blue Oval SK JV Ford 50% – SK Innovation 50%	Ford	11	/	40 80	Tennessee Kentucky (Start in 2025)	https://blueovalsk.com/
Ford (LFP tech. licensed by CATL)	Ford	3,5	/	35	Marshall (Michigan, starts in 2026)	https://media.ford.com/content/fordmedia/fna/us/en/news/2023/02/13/ford-taps-michigan-for-new-lfp-battery-plant--new-battery-chemis.html

Statevolt (US newcomer)	*Not announced*	*4*	*/*	*54*	*Imperial Valley (California, to start in 2025)*	*https://statevolt.com/2022/04/19/lars-carlstrom-announces-launch-of-statevolt-to-develop-54gwh-gigafactory-in-california/*
Toyota ?	Toyota	3,8 2,1 (+ 1,7 announced in 2021)	5	25[182]	New Liberty location (North Carolina, start in 2025)	https://pressroom.toyota.com/toyota-ramps-up-commitment-to-electrification-with-u-s-bev-production-and-additional-battery-plant-investment/ https://global.toyota/en/newsroom/corporate/37964997.html
Tesla Panasonic supply contract	Tesla	6,2 + 3,6	37	100	Gigafactory Sparks, Nevada	https://www.tesla.com/blog/continuing-our-investment-nevada
Panasonic	Not announced (Rivian, Tesla)	4	/	30	De Soto (Kansas, start in 2025)	https://na.panasonic.com/us/news/panasonic-awards-turner-yates-contract-build-ev-battery-plant
SK On	Ford	2,6	21,5	21,5	Jackson County (Georgia)	https://skinnonews.com/global/archives/4900
VW Power CO	VW (+ others ?)	4,8	/	90	London (Ontario, to start by 2027)	https://www.volkswagen-newsroom.com/en/press-releases/volkswagen-and-powerco-se-will-build-their-largest-cell-factory-to-date-in-canada-15781
?	BMW	?		?	new battery cell factory to be built in Mexico	https://www.bmwgroup.com/en/company/news.html#ace-142573040
Total potential projects		5,7		88		
Total projects		86,3	146,5	970,5		
Grand Total		92	146,5	1058,5		

Table 7-6: Battery cells production capacity In USCMA countries, current and projected situations. Source: Author's synthesis of the cited websites

Battery cell manufacturer country of origin	Current manufacturing capacity (GWh)	Total manufacturing capacity by 2030 (GWh)	% Of battery cell manufacturing capacity by 2030	Potential additional manufacturing capacity by 2030 (GWh)
Korea	101,5	560,5	57,8	0
Japan	42	155	16	0
China	3	105	10,8	0
Europe	0	150	15,4	34
USA	0	0	0	54
Total	146,5	970,5	100	88

Table 7-7 : USCMA current and expected battery cells manufacturing capacity by country of origin of battery cell makers

Battery maker	Capacity (in GWh)	Date of start of production	Country	Source
SK ON	20	2028	Korea	https://www.just-auto.com/news/sk-on-to-build-third-battery-plant-in-south-korea/
	200	2025	China	https://www.reuters.com/business/retail-consumer/sk-innovation-invest-1-bln-new-battery-factory-china-2021-09-01/
LG ES	145	2023	China	https://news.lgensol.com/company-overview/fast-facts/ https://pulsenews.co.kr/view.php?sc=30800028&year=2023&no=197123
	33	2025	Ochang, Korea	
	12	2025	Karawang, Indonesia	
Samsung SDI	8-12	2025	Serembam, Malaysia	https://www.samsungsdi.com/sdi-news/2840.html?pageIndex=3&idx=2840&searchCondition=0&searchKeyword= https://www.electrive.com/2022/06/30/samsung-sdi-to-build-4680-pilot-line-in-cheonan/
Panasonic[183]	29	2031	Japan	https://www.reuters.com/business/autos-transportation/panasonic-needs-four-more-ev-battery-plants-meet-capacity-target-executive-says-2023-07-03/
Prime Planet Energy & Solutions JV Toyota Panasonic	11	2024	Himeji, Hyogo Japan	https://www.p2enesol.com/en/news/
	< 1	2022	Dalian, Liaoning, China	https://www.p2enesol.com/wp-content/uploads/2021/05/20210519_NR_EnhanceProduntion_EN.pdf https://www.electrive.com/2022/02/17/prime-planet-to-build-third-battery-plant-in-china/

Table 7-8 : Production capacity of Japanese and Korean battery manufacturers in the Asia region until 2031

Source: Author's synthesis of the information provided in the cited websites

Industry of origin	Company name	Ambitions	Source(s) of information
Oil and Gas	Shell	500 000 charge points by 2025 and 2 500 000 by 2030 worldwide Agreement with BYD for preferential access to charging services to cars 'owners Agreement with Volkswagen to deploy an innovative charging solution	https://shellrecharge.com/en-us/solutions/news/ev-charging-solutions-leader-greenlots-to-become-shell-recharge-solutions https://www.shell.com/energy-and-innovation/mobility/mobility-news/byd-and-shell-partner-on-charging-for-100000-electric-vehicle-customers.html https://www.volkswagen-newsroom.com/en/press-releases/shell-and-volkswagen-push-ahead-the-expansion-of-charging-infrastructure-opening-of-the-first-innovative-flexpole-charging-station-15912
	Total Energies	150 000 charging points in cities and urban areas plus high power charging every 150 kms on the European motorways network station by 2025	https://totalenergies.com/infographics/totalenergies-and-electric-mobility
	BP	Increase the number of charging points from 22 000 to over 100,000 by 2030 worldwide, around 90% rapid or ultra-fast Agreement with Volkswagen up to 8,000 new charge points across Germany, UK and other European countries by end 2024.	https://www.bp.com/en_us/united-states/home/news/press-releases/bp-plans-to-invest-1-billion-in-ev-charging-across-us-by-2030-helping-to-meet-demand-from-hertzs-expanding-ev-rentals.html https://www.bp.com/en/global/corporate/news-and-insights/press-releases/volkswagen-group-and-bp-launch-strategic-partnership-to-rapidly-roll-out-ev-fast-charging-in-europe.html
	ENI	Increase the number of charging points from 13 000 charging points (as of February 2023), mainly in Italy to 30 000 charging points in Europe by 2026	https://eniplenitude.com/about/e-mobility
Automotive	Bridgestone (Partnership with EVBox)	3,500 new AC and DC charging ports across Bridgestone's European retail and service network, including leading brands like Speedy and First Stop	https://news.evbox.com/en-WW/202085-evbox-bridgestone-emia-and-tsg-partner-to-enhance-ev-charging-infrastructure-in-europe
	VW	Elli charging network (subsidiary of Volkswagen Group Technology) with over 500 000 charging points (for VW group car's users) 10 000 High Power Charging point by the end of 2023 in Europe and a global target of 45 000 by the end of 2025	https://www.volkswagen-newsroom.com/en/press-releases/shell-and-volkswagen-push-ahead-the-expansion-of-charging-infrastructure-opening-of-the-first-innovative-flexpole-charging-station-15912
	Renault	By mid-2024, the network will have 200 stations in Europe, accessible to all BEV drivers, with 6 ultra-fast charging points of up to 400 kW	https://media.mobilize.com/mobilize-fast-charge-le-nouveau-reseau-de-recharge-ultrarapide-en-europe/?lang=fra
Energy companies	Iderdrola	Increase the number of charging points from 2,500 (in 2021) to 110 000 high-efficiency charging points by 2025 in Spain and Portugal Agreement with Volkswagen to create a public charging infrastructure network.	https://www.iberdrolaespana.com/sustainability/electric-car-charging-point-plan-spain https://www.iberdrola.com/press-room/news/detail/iberdrola-volkswagen-seat-strengthen-their-partnership-accelerate-electrification-spain
	EnBW	2,500 fast charging locations across Germany by 2025	https://www.enbw.com/company/press/europe-s-largest-public-fast-charging-park-under-construction-1.html
	Izivia (EDF subsidiary)	5000 charging points in France	https://izivia.com/
	Engie Vianeo	12000 charging points in France including 4500 fast chargers	https://www.avem.fr/2023/06/19/bornes-de-recharge-engie-lance-sa-marque-et-annonce-un-deploiement/#
Newcomers	Ewiwa JV VW Enel	Build by 2025 an Italian network of over 3000 high-voltage (up to 350 kW) charging stations	https://ewiva.com/en/
	Ionity	From 1500 to about 7000 high-powered charging infrastructure along highways in 24 European countries by 2025	https://ionity.eu/en/weareonit

	JV BMW Group, Ford Motor Company, Hyundai Motor Group, Mercedes Benz AG and Volkswagen Group with Audi and Porsche		
	Allego	+ 34 000 public charging points in Europe	https://www.allego.eu/
	Powerdot	About 10 000 charging points at retailers' parking lots	https://www.powerdot.eu/en/

Table 7-9 : Some key European PEV charging operators
Source: Author's synthesis of the information provided in the cited websites

Company		Project			
Industry of origin	Name (country of origin)	Year / Operational	Type of material	‘000 Tons of materials per year - location	Source(s) of information
Specialists	Stena Recycling (Sweden)	2023	Battery Grade Material	Recycle 10 of batteries (Halmstad – Sweden)	https://www.stenarecycling.com/news-insights/newsroom/2022/the-swedish-energy-agency-supports-stena-recyclings-major-investment-in-battery-recycling/
	Fortum (Finland)	2023	Pre-treatment facility	Treatment of 3 of batteries (Kirchardt Germany)	https://www.fortum.com/media/2023/03/fortum-battery-recycling-receives-permit-start-battery-recycling-operations-germany
		?	Black-Mass	Treatment of 5 of batteries (Ikaalinen, Finland)	https://www.fortum.com/media/2023/09/fortum-battery-recycling-awarded-grant-45-million-euros-expand-its-mechanical-processing-capacity
		?	Battery Grade Material	(Harjavalta Finland)	https://www.fortum.com/media/2023/04/fortum-battery-recycling-opens-europes-largest-closed-loop-hydrometallurgical-battery-recycling-facility-finland
	Li Cycle Spoke (Canada)	2023	Black-Mass	Up to 30 (Magdebourg, Germany)	https://li-cycle.com/press-releases/li-cycle-starts-operations-at-its-first-european-lithium-ion-battery-recycling-facility/
	Glencore Li Cycle (USA)	2027	Battery Grade Material	Processing 50 to 70 of Black-Mass (Portovesme Italy)	https://www.glencore.com/media-and-insights/news/glencore-and-li-cycle-announce-joint-study-to-develop-a-european-recycling-hub
	Umicore (Belgium)	2026	Battery Grade Material	Recycle 150 of batteries (Location to be precised)	https://www.umicore.com/en/newsroom/umicore-battery-recycling/
	Suez / Eramet (France)	2025	Black-Mass	Recycle 50 of batteries (Dunkerque France)	https://www.suez.com/en/news/press-releases/eramet-and-suez-choose-dunkirk-electric-vehicle-battery-recycling-plant
		2027	Battery Grade Material	? (Dunkerque France)	
Battery makers	Northvolt (Sweden)	starting in 2023	Battery Grade Material	Up to 150 (Skellefteå, Sweden)	https://northvolt.com/articles/recycled-battery/
	Hydrovolt (JV Hydro Northvolt)	2023 2025 2030	Battery Grade Material	12 70 300 (Fredrikstad, Norway)	https://hydrovolt.com/europes-largest-electric-vehicle-battery-recycling-plant-begins-operations/
	ACC (France)	Agreement with Umicore to use its technology in Nersac pilot plant (France) before future extension			https://www.umicore.com/en/newsroom/news/new-generation-li-ion-battery-recycling-technologies-and-announces-award-with-acc/#english
	Mecaware / Verkor (France)	2024 2026	Battery Grade Material	Treatment of production scraps < 0,1 Grenoble France	https://www.ecologie.gouv.fr/france-2030-annonce-des-laureats-recyclage-des-batteries-lappel-projets-recyclage-recyclabilite-et

				6 – 8 (Dunkerque France)	
Automakers	BMW				
	Ford				
	Honda	Agreement with SNAM for Lithium and cobalt recycling			https://www.honda.co.uk/engineroom/world/hybrid-and-ev-battery-recycling-SNAM/
	Hyundai Kia				
	Mercedes Benz	Pilot Plant in Kuppenheim 2,5 by 2024			https://media.mercedes-benz.com/article/3af10452-84b2-4cfc-b5f4-7b5589881c84
	Nissan	One plant in Europe by the end of 2025			https://news.metal.com/newscontent/101696082/nissan-will-build-battery-recycling-plants-in-europe-and-the-united-states-before-fiscal-year-2026
	Renault Group Veolia Solvay	2023 2028	Battery grade material	Treatment of used batteries 10 40 (Metz – France)	https://www.ecologie.gouv.fr/france-2030-annonce-des-laureats-recyclage-des-batteries-lappel-projets-recyclage-recyclabilite-et
	JV Stellantis Orano	2026	Battery grade material	New Orano plant (Dunkerque France)	https://www.stellantis.com/en/news/press-releases/2023/october/stellantis-and-orano-enter-electric-vehicle-battery-recycling-agreement
	Valmet Fortum Cooperation	Production scraps			https://www.fortum.com/media/2021/08/fortum-and-valmet-automotive-co-operate-sustainable-recycling-battery-materials
	VW	Salzgitter pilot plant up to 1,5			https://www.recyclingtoday.com/news/volkswagen-opens-ev-battery-recycling-plant-germany/
	Volvo				

Table 7-10 : Some European projects in the battery recycling industry
Source: Author's synthesis of the information provided in the cited websites

Company		Project			Source(s) of information
Industry of origin	Name (country of origin)	Year / Operational	Type of material	'000 Tons of materials per year - location	
Recycling specialists	Interco (USA)	Operational	Battery grade material	24 Illinois	Tom Taylor and Noah Gabriel, November 2022. Atlas Public Policy accessible at https://atlaspolicy.com/wp-content/uploads/2022/12/2022-EV-Transition-Key-Market-and-Supply-Chain-Enablers.pdf
	Li Cycle (Canada)	Operational	Black-Mass	10 Alabama 5 New York 10 Arizona	https://li-cycle.com/press-releases/li-cycle-starts-operations-at-its-first-european-lithium-ion-battery-recycling-facility/ https://atlaspolicy.com/wp-content/uploads/2022/12/2022-EV-Transition-Key-Market-and-Supply-Chain-Enablers.pdf
		2023	Black-Mass Battery grade material	15 Ontario 35 New York	
	Cirba (USA) [184]	Operational Capacity extension?	Battery grade material	? Ohio 23,5 Ohio	https://www.cirbasolutions.com/cirba-solutions-expands-ohio-lithium-ion-processing-facility/
		2023	Battery grade material	5,9 Arizona	https://www.cirbasolutions.com/new-lithium-ion-battery-recycling-facility-in-eloy-az-announced/
		Late 2024	Battery grade material	59 South Carolina	https://www.cirbasolutions.com/world-class-ev-battery-materials-facility-in-south-carolina/
	SungEel HiTech[185] (Korea)	2025	Battery grade material	12 Indiana	https://www.thelec.net/news/articleView.html?idxno=4628 https://alphabiz.co.kr/news/view/1065540461916230
		2024	Battery grade material	50 Georgia	https://www.georgia.org/press-release/korean-lithium-ion-battery-recycler-sungeel-hitech-build-first-us-recycling-facility
	Ascend elements (USA)	Operational	Battery grade material	30 Georgia	https://www.electrive.com/2023/03/31/us-ascend-elements-opens-battery-recycling-plant-in-georgia/
		2026	Battery grade material	150 Kentucky	https://ascendelements.com/ascend-elements-secures-300-million-in-funding/
	Redwood (USA)[186]	Operational Late 2024	Battery grade material	? Nevada 155 Nevada	https://www.enr.com/articles/55900-nevada-ev-battery-material-plant-expands-with-2b-us-loan
		Late 2024	Battery grade material	155 South Carolina	https://www.redwoodmaterials.com/news/announcing-redwood-south-carolina/
	ABTC (USA)		Battery grade material	Pilot plant Nevada	https://americanbatterytechnology.com/press-release/american-battery-technology-company-selected-for-10m-additional-us-doe-grant-to-commercialize-nextgen-battery-recycling-technologies-for-vulnerable-domestic-battery-markets/
Battery makers	AESC	Partnership with Redwood Materials			https://www.electrive.com/2021/02/25/redwood-launches-battery-recycling-with-envision-aesc/
	LG ES (Ultium LLC)	Partnership with Li Cycle			https://inside.lgensol.com/en/2022/08/lg-energy-solutions-battery-strategy-for-the-future-reuse-recycle/
	Samsung SDI				
	SK innovation	Partnership with Ascend elements			https://www.energy-storage.news/us-battery-scrap-recycling-deal-for-sk-basf-building-cathode-materials-and-recycling-plant-in-canada/
	Panasonic	Partnership with Redwood Materials			https://www.electrive.com/2021/02/25/redwood-launches-battery-recycling-with-envision-aesc/

Automakers	BMW		
	Ford Motors	Partnership with Redwood Materials	https://www.redwoodmaterials.com/news/redwood-materials-and-ford-motor-company-announce-strategic-relationship/
	GM	Strategic investment in Lithion	https://pressroom.gm.com/gmbx/us/en/pressroom/home/news.detail.html/Pages/news/us/en/2022/sep/0922-lithion.html
	Honda	Partnership with Ascend elements	https://global.honda/newsroom/news/2023/c230227aeng.html
	Honda	Partnership with Cirba	https://www.cirbasolutions.com/cirba-solutions-announces-agreement-with-honda/
	Hyundai	Lithion recycling in Canada	https://www.electrive.com/2021/03/13/hyundai-canada-and-lithion-recycling-partner-up-for-ev-battery-recycling-in-canada/
	Mercedes Benz	plan to establish a closed material loop for battery recycling	https://group.mercedes-benz.com/documents/company/advocacy/mercedes-benz-ea-position-paper-circular-economy.pdf
	Nissan	One plant in the US by the end of 2025	https://news.metal.com/newscontent/101696082/nissan-will-build-battery-recycling-plants-in-europe-and-the-united-states-before-fiscal-year-2026
	Stellantis		
	Tesla		
	Toyota	Partnership with Redwood Materials	https://www.redwoodmaterials.com/news/redwood-materials-and-toyota-collaboration/
	VW		https://media.vw.com/en-us/releases/1695 https://www.redwoodmaterials.com/news/redwood-and-volkswagen-partnership/
	Volvo		https://www.reuters.com/business/autos-transportation/ford-volvo-join-redwood-ev-battery-recycling-push-california-2022-02-17/ https://www.redwoodmaterials.com/news/electric-vehicle-and-hybrid-battery-recycling-california/

Table 7-11 : Some USCMA countries' projects in the battery recycling industry
Source: Author's synthesis of the information provided in the cited websites

[174] PowerCo is the European company established by VW to consolidate activities along the complete value chain for batteries (https://www.powerco.de/#)
[175] Conversion between Ton of CAM, GWh and number of vehicles. 1 vehicle with a battery of 50KWh, 10,000 tons of CAM = 6,4 GWH = 128,000 vehicles
[176] https://www.nidec-industrial.com/freyr-battery-and-nidec-corporation-complete-formation-of-joint-venture/
[177] https://www.inobat.eu/newsroom/inobat-and-impact-clean-power-technology-sign-customer-agreement-for-the-development-and-supply-of-battery-cells/
[178] Potential customers could be Store Dot investors such as Mercedes Benz and Volvo, see https://www.store-dot.com/
[179] https://news.morrowbatteries.com/pressreleases/morrow-batteries-nordic-batteries-and-eldrift-join-forces-to-build-norwegian-battery-supply-chain-3269092
[180] As a reminder, Tesla needs already counted in Korean and Chinese battery cell makers capacity of production
[181] Honda and GM have set an agreement for the development of Honda BEVs on the Ultium platform developed by GM. https://global.honda/newsroom/news/2020/c200403eng.html and https://global.honda/newsroom/news/2022/c220405eng.html
[182] Author's estimate based on a global capacity increase of 40 GWh, with investment split almost equally between Japan and the United States.
[183] Moving from 50 to 200 with about 160 in USA and including PPES
[184] Ohio Plant supplies 200,000 vehicles with a battery of 75 kWH = 15 GWh = about 23,500 tons of CAM. Arizona plant supplies 50,000 vehicles = about 5,900 tons, South Carolina supplies 500, 000 vehicles = 59,000 tons
[185] Indiana plant supplies 100,000 vehicles with a battery of 75 kWH = 7,5 GWh = about 12 (11,750) tons of CAM
[186] South Carolina plant supplies 100 GWh equivalent in CAM and anode materials = about 155 tons. Same calculation for the Nevada plant which has the same target of 100 GWh equivalent