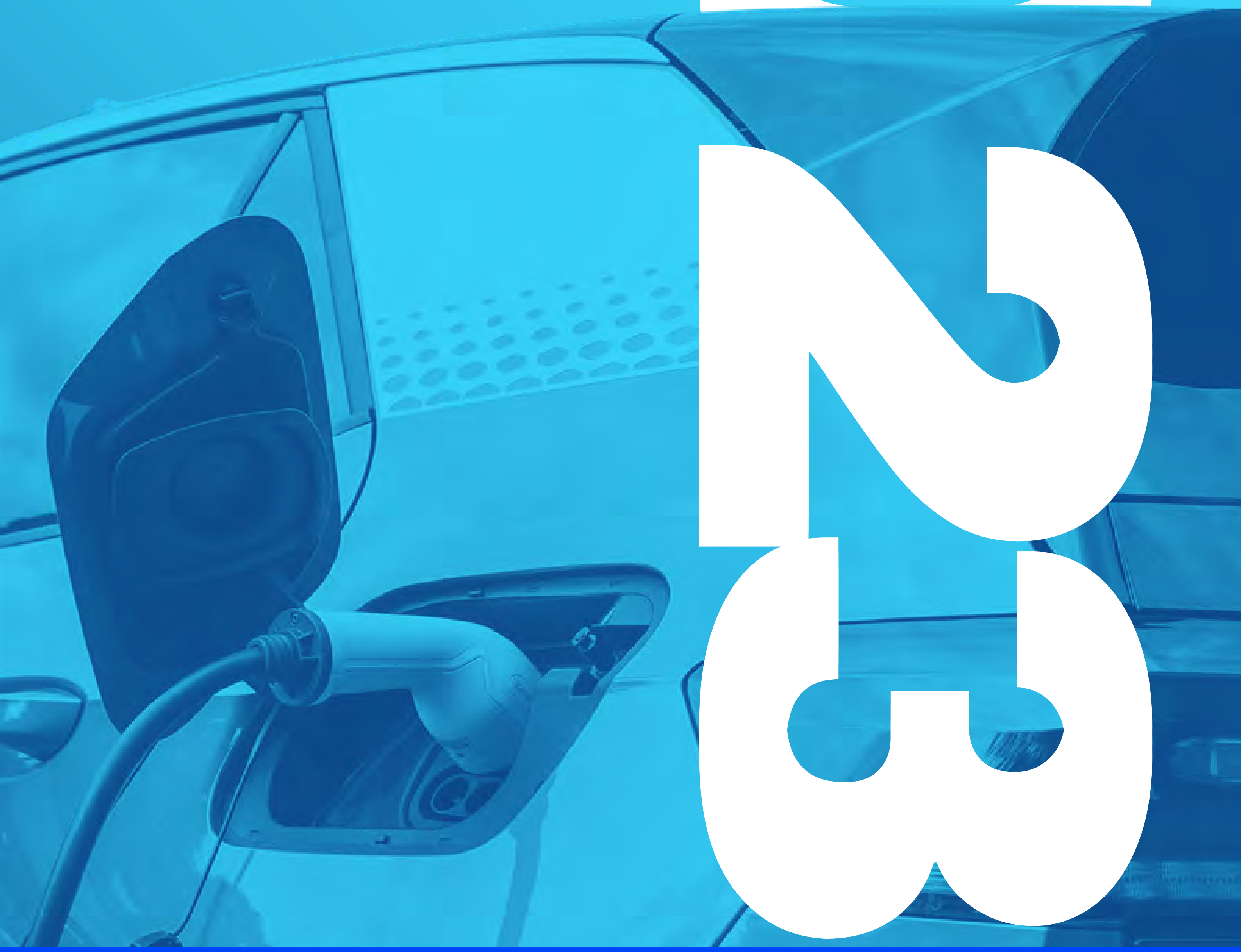
ANNUAL REPORT 2023

THE ELECTRIC DRIVE RAMPS UP



Technology Collaboration Programme

by iea

HEV TCP ANNUAL REPORT 2023

This is the 2023 Annual report for the HEV TCP – an international collaboration of 18 countries exploring cutting-edge questions in hybrid and electric vehicles. This report sets out the background to the partnership, gives updates on ongoing projects and on member countries' work, and gives a set of contact details for more information.

Implementing Agreement for Co-operation on Hybrid and Electric Vehicle Technologies and Programmes (HEV TCP) is an international membership group formed to produce and disseminate balanced, objective information about advanced electric, hybrid, and fuel cell vehicles. It enables member countries to discuss their respective needs, share key information, and learn from an ever-growing pool of experience from the development and deployment of hybrid and electric vehicles.

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INTRODUCTION

Chairperson's message

As the chairperson of the Hybrid and Electric Vehicle Technology Collaboration Programme (HEV TCP), a part of the International Energy Agency's Energy Technology Network, I have the great pleasure of introducing the 2023 Annual Report.

The work of the HEV TCP has continued to make good progress in the last year. The HEV TCP Executive Committee (ExCo) held two hybrid meetings in 2022, the first in Oslo, Norway in June and the second in Dundee, Scotland in October. The work of the various tasks also advanced, with a combination of virtual and in-person meetings and workshops.

The first ExCo meeting of 2023 was held in April in Brussels, Belgium and was hosted by the European Commission. The next ExCo meeting is planned to be held in Eskilstuna, Sweden in October 2023.

ELECTRIC VEHICLES IN 2022

The EV (BEVs and PHEVs) market continued to out-perform that of conventional light vehicles in 2022. As reported by EV-volumes.com, and as shown in Figure 1, EVs saw a sales growth of 55% in 2022, or a total of 10.5 million new EVs. This growth represents 13% of the total light vehicle market in 2022 compared to 8.3% in 2021. At the end of 2022, only 1.8% of the light vehicles in operation worldwide were EVs, or 1.3% if counting BEVs only.

The electrification of transportation is essential to meet a clear commitment to becoming carbon neutral by 2050. According to the IEA's Tracking Clean Energy Progress reports [1], electric vehicles are identified as one of the few technologies that are on track with the Net Zero Emissions by 2050 Scenario. Several governments have announced ambitious zero-emission vehicle targets and policies, supporting the 2050 commitment and automakers have announced plans to sell EVs. These actions have resulted in the encouraging performance of the EV sector observed in recent years, however, there is a need for this transition to accelerate globally in the coming years for a fully electric future to be realised.

ADMINISTRATIVE AND DELEGATE CHANGES

Since the publication of the previous annual report in May 2022, the HEV TCP welcomed the following new country delegates:

- Hamza El Jebbari, Delegate for France
- Federico Karagulian, Delegate for Italy
- Els Rutten, Delegate for Netherlands

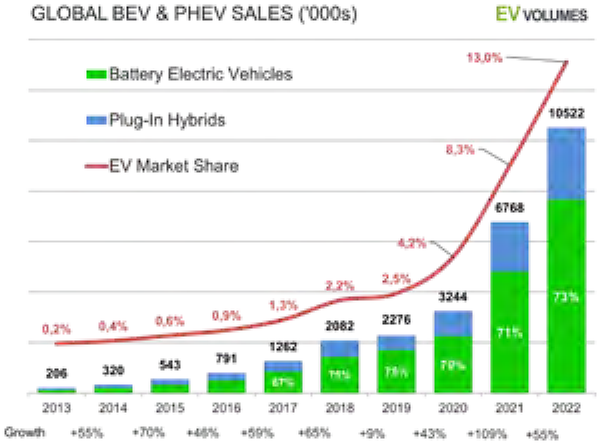


Figure 1: Global BEV & PHEV Sales [2]

- Jack de Vries, Alternate Delegate for Netherlands
- Jon Are Suul, Alternate Delegate for Norway
- Daniel Schaller, Alternate Delegate for Switzerland
- Sam Denyer, Alternate Delegate for United Kingdom
- Michael Weismiller, Delegate for United States

In 2022, the ExCo elected two new Vice Chairs: Joscelyn Terrell (UK) and Walter Mauritsch (Austria).

During the October 2022 ExCo meeting, members voted to create a new Outreach Committee with Els Rutten (Netherlands) as Chair of the committee.

As the new delegate for the United States, Michael Weismiller is the new Chair of the Technical Committee.

ACKNOWLEDGEMENTS

I would like to acknowledge the invaluable support received from Dr. James Miller (Argonne National Laboratory) as the HEV TCP Secretary and express gratitude for the generous contribution from the US Department of Energy in funding the Secretary's position.

I would like to extend my sincerest appreciation to Walter Mauritsch (Austria), Ock Taeck Lim (South Korea), and Joscelyn Terrell (UK) for their valuable assistance as Vice Chairs. I would also like to recognize the outstanding work of Gary McRae, Honorine N'Dounga, and Sofie Surraco from Urban Foresight in Task 1, as well as their excellent logistical support for the hybrid meetings.

In addition to the ExCo, the management of the TCP includes the work of three sub-committees, the Strategic Planning Group, the Technical Committee (chaired by Michael Weismiller, US DOE), and the Outreach Committee (chaired by Els Rutten, Netherlands Enterprise Agency), which count on the participation of various ExCo members. My appreciation also goes out to the Task Managers for their excellent leadership and efforts in advancing the work of their respective Tasks during the past year, as well as to all Task participants for their continued involvement.

Lastly yet importantly, I wish to thank the member country delegates and observers for their continued strong participation in ExCo meetings and other activities of the TCP.

CAROL BURELLE
Chairperson of the Executive Committee, Hybrid and Electric Vehicle Technology Collaboration Programme

[1] IEA, "Tracking Clean Energy Progress." Accessed at: https://www.iea.org/topics/tracking-clean-energy-progress.

[2] EV-Volumes, "The Electric Vehicle World Sales Database: Global EV Sales for 2022." Accessed at: https://www.ev-volumes.com/.

Executive Summary

Adoption of Electric Vehicles (EVs) experienced robust growth in 2022, despite a 3% decline in global auto sales in comparison to 2021.

For the first time, in 2022, global sales of vehicles which can be charged from the grid, i.e. battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) (10.5 million) were higher than those for non-plugin hybrid vehicles (8.4 million) [1].

A total of 10.5 million new BEVs and PHEVs were registered in 2022, increasing by 55% compared to 2021. EV sales have been generally resilient to weak auto markets, with many global regions over-performing, including North America by 78%, China by 55%, and Europe by 21%.

Nearly all EV manufacturers saw a growth in their sales in 2022, with global EV deliveries increasing year-on-year by over 55% in total. While China, Europe, and the United States remain the leading markets globally for EV sales (95% of global sales in 2022), a number of emerging markets are introducing legislation and incentive programs which are expected to ramp up adoption.

With a total of 14% of all new cars sold being electric in 2022—up from 9% in 2021 [2]—projections show that by the end of 2023, there is likely to be 40 million EVs in operation globally.

HEV TCP OVERVIEW

With a membership of 18 countries, the HEV TCP works together on joint projects (tasks) to better understand and address EV deployment challenges and provide guidance to policy makers. In 2022, these members have continued to actively participate in tasks and pursue their transport electrification agenda.

The TCP initiated two new tasks in 2022, namely:

- Task 49 on “EV Fire Safety”
- Task 50 on “Light Electric Vehicles”

In 2022, the TCP closed the following tasks:

- Task 40 on “CRM4EV: Critical Raw Materials for EVs”
- Task 41 on “Electric Freight Vehicles”

Task 34, “Batteries,” and Task 37, “Extreme Fast Charging,” have also completed their respective work programmes, and are beginning the process of submitting their final reports, which will be made available for download on the HEV TCP website at www.ieahev.org.

The TCP currently manages a total of 10 Tasks. The table overleaf provides a summary of the tasks in this report.

The HEV TCP newsletter continues to showcase policy and deployment updates from contributing member countries and tasks. Available on the HEV TCP website, the next edition of the newsletter will be released in the fall of 2023, and all contributions are welcomed.

Two hybrid ExCo meetings were held in 2022. In June 2022, members met in Oslo, Norway. Hosted by Norway, the meeting offered updates across tasks and member countries. The October 2022 meeting of the HEV TCP ExCo was held in Dundee, Scotland. With the UK as host country, the knowledge sharing day focused on policy updates from several member countries, with a very insightful update on the UK’s work on EV accessibility standards, from the Office for Zero Emission Vehicles. Due to the increased accessibility of the hybrid format, both these events were well attended.

Task	Country Participants	Status	Period	Objectives
Task 01 **Information Exchange**	All	Ongoing	Jan 2022 -	Serves as a platform for information exchange among member countries.
Task 23 **Light Electric Vehicle Parking and Charging Infrastructure**	Belgium, Germany, Spain	Ongoing	2013 - 2023	Represent the interests of local governments in the standardization of Light Electric Vehicle system architectures, infrastructure, communications and interchangeable batteries.
Task 34 **Batteries**	Canada, Germany, Sweden, USA	Completed	Apr 2016 -	To encourage the sharing and dissemination of current information about battery topics of interest to the vehicle community.
Task 37 **Extreme Fast Charging***	USA	Completed	Jan 2017 -	To investigate station siting, quantify the costs of installation, document grid connection details, understand the implications of XFC on battery design, performance, and cost, and study consumer education methods and topics.
Task 38 **Marine Applications (E-Ships)**	Canada, China, Norway	Ongoing - Restarted in 2021	Oct 2017 -	To provide an overview and encourage the development and deployment of e-Ships, by building and sharing key knowledge on projects, performance, segments, and demand.
Task 40 **CRM4EV: Critical Raw Materials for EVs**	Austria, France, Germany, Netherlands, Norway, Republic of Korea, Spain, Sweden, USA, UK	Closed	Apr 2018 - 2023	To build a global representative network on the topic "Critical Materials for EVs" with stakeholders from administrations, industry, policymakers, researchers, and other relevant stakeholders representing the different value chains of the identified "in-scope" critical materials.
Task 43 **Vehicle-Grid Integration**	Belgium, Canada, Denmark, France, Germany, Ireland, Italy, the Netherlands, Republic of Korea, Spain, Switzerland, UK, USA	Ongoing	Apr 2019 -	To explore, identify, and give answers to the gaps preventing electric vehicles to be fully integrated into the electrical grid.

Task	Country Participants	Status	Period	Objectives
Task 45 **Electrified Roadways (E-Roads)**	USA, Canada, Germany, Norway, The Netherlands, Switzerland, Sweden	Ongoing	Jan 2021 -	To develop a greater global understanding and awareness of ERoads, related deployment activities, and technologies developed to advance electric mobility.
Task 46 **LCA of Electric Trucks, Buses, Two wheelers and Other Vehicles**	Austria, Canada, Germany, Republic of Korea, Spain, Switzerland, USA	Ongoing	Feb 2022 -	Analyze, discuss, and document the environmental impacts based on life cycle assessment of electric buses, trucks, two-wheelers, and other vehicles (mining, agriculture, train, etc.)
Task 47 **Zero-Carbon Freight from Port Electrification**	Norway, USA	Ongoing	Nov 2021 -	Investigate and leverage port Electrification technology deployment to enable adoption of electrified ground transportation vehicles which support port activities, with a secondary focus on grid capacity/integration methodologies to create a resilient power supply.
Task 48 **Battery Swapping**	China, Germany, Italy, Sweden	Ongoing	Nov 2021 -	Focus on creating stronger infrastructure for battery swapping technology and swapping of information.
Task 49 **EV Fire Safety**	Austria, Belgium, Italy, Norway, Republic of Korea, The Netherlands, UK	Ongoing	Jan 2023 -	Collect and share objective information on different EV fire safety related aspects to increase the overall trust in electric vehicles.
Task 50 **Light Electric Vehicles**	Germany, France, Republic of Korea	Ongoing	Jan 2023 -	Support the diffusion of Light Electric Vehicles (LEVs) in order to exploit their potential for more sustainable mobility.

*Updates available on the HEV TCP website only, and not a separate chapter in this annual report.

[1] EV-Volumes, "The Electric Vehicle World Sales Database: Global EV Sales for 2022." Accessed at: https://www.ev-volumes.com/.
[2] IEA, "Global EV Outlook 2023," Accessed at: https://www.iea.org/reports/global-ev-outlook-2023.

The IEA and its Technology Collaboration Programmes on Hybrid & Electric Vehicles

This chapter introduces the International Energy Agency (IEA) and its Technology Collaboration Programme for Cooperation on Hybrid and Electric Vehicle Technologies and Programmes (HEV TCP). In 2015, the IEA rebranded the Implementing Agreements as Technology Collaboration Programmes (TCPs).

IEA TECHNOLOGY COLLABORATION PROGRAMMES

The IEA provides a legal framework for international collaborative energy technology RD&D (Research, Development, and Deployment) groups, through multilateral technology initiatives known as Technology Collaboration Programmes (TCPs). A TCP may be created at any time, provided that at least two IEA members agree to collaborate. There are currently 39 TCPs covering fossil fuels, renewable energy, efficient energy use (in buildings, electricity, industry and transport), fusion power, and two cross-cutting TCPs dealing with technology systems modelling and women in energy. The TCP for Co-operation on Hybrid and Electric Vehicle Technologies and Programmes (HEV TCP) reports to the Working Party on Energy End-Use Technologies (EUWP). An overview of the activities of all the TCPs is available on the IEA website.

IEA TCPs embrace numerous other activities that enable policy makers and experts from IEA-member and non-member countries to share views and experiences on energy technology issues. Through published studies and workshops, these activities are designed to enhance policy approaches, improve the effectiveness of research programmes and reduce costs.

Over three decades of experience have shown that the TCPs contribute significantly to achieving faster technological progress and innovation at a lower cost. Such international co-operation helps to eliminate technological risks and duplication of effort while facilitating processes, such as harmonization of standards. Special provisions are applied to protect intellectual property rights.

The “IEA Framework for the Technology Collaboration Programme” defines the minimum set of rights and obligations of participants in IEA TCPs. Participants are welcomed from IEA member and non-member countries, the private sector, and international organisations.

Participants in TCPs fall into two categories: Contracting Parties and Sponsors.

- **Contracting Parties** may be governments of OECD member countries and non-member countries (or entities nominated by them). They can also be international organisations in which governments of OECD member and/or non-member countries participate, such as the European Commission. Contracting Parties from OECD non-member countries or international organizations are not entitled to more rights or benefits than Contracting Parties from OECD member countries.

- **Sponsors**, notably from the private sector, may be entities of either OECD member or non-member countries that have not been designated by their governments. The rights or benefits of a sponsor cannot exceed those of Contracting Parties designated by governments of OECD non-member countries, and a sponsor may not become a chair or vice-chair of a TCP.

The TCP mechanism is flexible and accommodates various forms of energy technology co-operation among participants. It can be applied at every stage in the energy technology cycle, from research, development, and demonstration through validation of technical, environmental, and economic performance and on to final market deployment. Some TCPs focus solely on information exchange and dissemination.

Financing arrangements for international co-operation through TCPs are the responsibility of each TCP. The types of TCP financing fall into three broad categories:

1. Cost-sharing, in which participants contribute to a common fund to finance the work.

2. Task-sharing, in which participants assign specific resources and personnel to carry out their share of the work.

3. Combinations of cost and task sharing (such as in the case of the HEV TCP).

In March 2008, the Transport Co-ordination Group (TCG), under the oversight of the EUWP Vice Chair for Transport, was created with the objective of strengthening collaboration among transport-related TCPs. HEV TCP actively participates in the TCG.

TECHNOLOGY COLLABORATION PROGRAMME ON HYBRID AND ELECTRIC VEHICLES

Most IEA countries have issues with urban air quality, and all IEA countries have issues with greenhouse gas emissions from automobiles and other vehicles. Today there exists a range of technologies available to address these problems - most notably hybrid and electric vehicles. There is a strong case for the existence of an IEA TCP dedicated to developing and deploying these vehicles.

The HEV TCP was created in 1993 to collaborate on pre-competitive research and to produce and disseminate information. HEV TCP is now in its sixth five-year term of operation that runs from March 2020 until March 2025. The 18 active Contracting Parties (member countries) as of December 2022 are Austria, Belgium, Canada, China, Denmark, Finland, France, Germany, Ireland, Italy, The Netherlands, Norway, Republic of Korea, Spain, Sweden, Switzerland, United Kingdom, and the United States.

Compared to the automotive industry and certain research institutes, HEV TCP is a relatively small organisation. Nevertheless, HEV TCP is still playing an important role by (1) focusing on a target group of national and local governments and government-supported research organizations and (2) providing a forum for different countries to co-operate in joint research and information exchange activities. More countries are invited to join the Agreement and to benefit from this international co-operation on hybrid and electric vehicles.

The work of HEV TCP is governed by the Executive Committee ("ExCo"), which consists of one member designated by each Contracting Party. Contracting Parties are either governments of IEA countries or parties designated by their respective governments. The HEV TCP ExCo meets twice a year to discuss and plan the working programme. The actual work on hybrid and electric vehicles is done through a variety of different Tasks that are focused on specific topics. Each topic is addressed in a Task, which is managed by a Task Manager (TM)—before 2011, these task forces were called Annexes. The work plan of a new Task is prepared by an interim TM, either on the OA's own initiative or on request of the ExCo, and the work plan is then submitted for approval to the HEV TCP ExCo. The Tasks that were active during 2022 are described in part B of this report. The activities associated with hybrid and electric vehicles in individual HEV TCP member countries can be found in part C.

The next three subsections briefly report on HEV TCP activities and results in the different phases of operation. The strategy for the current term of operation, and its details, are reported below in Phase 6 (2020-25).

Description and Achievements of HEV TCP Phase 2, 1999-2004

Phase 2 of the HEV TCP started in November 1999 at a time when the first hybrid vehicle – the Prius – had just been introduced to the market, and battery electric vehicles were only considered suitable only for some market niches. Although good progress had been made in battery technology; low-cost, high-performance traction batteries were not yet commercially available. Progress with fuel cell technology led to optimism about a "hydrogen economy", and car manufacturers switched their attention to fuel cells and away from battery electric vehicles.

The Tasks which ran in Phase 2 were:

- Structured information exchange and collection of statistics (Task 1).
- Hybrid vehicles (Task 7).
- Deployment strategies for hybrid, electric, and alternative fuel vehicles (Task 8).
- Clean city vehicles (Task 9).
- Electrochemical systems (Task 10).

Description and Achievements of HEV TCP Phase 3, 2004-2009

The emphasis during Phase 3 of the Agreement, from 2004 to 2009, was on collecting information on hybrid, electric, and fuel cell vehicles, with the same value-added aspects as in the previous phase. Governmental objectives of improving air quality and energy efficiency – and of reducing greenhouse gas emissions and dependence on petroleum fuel – ensured that the need continued for the HEV TCP's mission.

HEV TCP's other achievements during Phase 3 included contributing to the IEA's technology roadmap for electric and hybrid vehicles; as well as a move to interact more closely with different IAs of the International Energy Agency, which contains transportation as an item in their work programme.

The Tasks which ran in Phase 3 were:

- Information Exchange (Task 1) (The work includes country reports, census data, technical data, behavioural data, and information on non-IEA countries.)
- Electrochemical Systems (Task 10)
- Electric Bicycles, Scooters, and Lightweight Vehicles (Task 11)
- HEVs and EVs in Mass Transport and Heavy-Duty Vehicles (Task 12)
- Market Aspects of Fuel Cell Electric Vehicles (Task 13)
- Market Deployment of Electric Vehicles (Task 14)
- Plug-in Hybrid Electric Vehicles (Task 15)

Description and Achievements of HEV TCP Phase 4, 2009-2015

Interest in Hybrid and Electric Vehicles as a means to reduce energy consumption and emissions from road transport increased significantly worldwide. At the same time, many questions remain still to be answered regarding potential efficiency improvements, safety, durability, vehicle range, production potential, and the availability of raw materials for batteries, as well as issues associated with the impact on electricity grid management, standardization, the potential to introduce renewable energy in road transport, and market introduction strategies. There is a strong need for objective and complete information about these issues in order to enable balanced policy making regarding energy security, economic development and environmental protection, and the role that hybrid and electric vehicles can play.

The Tasks which ran in Phase 4 were:

- Task 17 "System Optimization and Vehicle Integration" to study how EV system configurations (including vehicle components) could be optimized for enhanced overall EV performance.

- Task 18 "EV Ecosystems" to create a roadmap of the conditions required to support market growth needed for the mass adoption of EVs in cities.

- Task 19 "Life Cycle Assessment of EVs" to explore the sustainable manufacture and recycling of EVs.

- Task 20 "Quick Charging" to discuss the impacts and potential standards for EV quick charging.

- Task 21 “Accelerated Ageing Testing for Li-ion Batteries” for collaboration on such testing efforts.
- Task 22 “E-Mobility Business Models” to understand new revenue opportunities and ways to limit costs associated with EVs, recharging infrastructure, and associated links to energy systems.
- Task 23 “Light-Electric-Vehicle Parking and Charging Infrastructure”.
- Task 24 “Economic Impact Assessment of E-Mobility”.

Description and Strategy of HEV TCP Phase 5, 2015-2020

This phase of the HEV TCP focused on producing objective information for policy and decision makers on hybrid and electric vehicle technology, projects and programmes, and their effects on energy efficiency and the environment. By general studies, assessments, demonstrations, comparative evaluations of various options of application, market studies, technology evaluations, the HEV TCP focused on being a platform for reliable information on hybrid and electric vehicles.

The Tasks which ran in Phase 5 were: into Phase 5

- Task 1: Information Exchange
- Task 10: Electrochemical Systems
- Task 21: Accelerated ageing testing for lithium-ion batteries
- Task 23: Light electric vehicle parking and charging infrastructure
- Task 24: Economic impact assessment of e-mobility
- Task 25: Plug-in Electric Vehicles
- Task 26: Wireless power transfer for electric vehicles
- Task 27: Electrification of transport logistic vehicles
- Task 28: Home grids and V2X technologies
- Task 31: Fuels and Energy Carriers for Transport
- Task 39: Interoperability of E-mobility Services
- Task 40: Critical Raw Material for Electric Vehicles (CRM4EV)
- Task 41 “Electric Freight Vehicles”, and
- Task 42 “Scaling Up EV Markets and EV City Casebook
- Task 43 “Vehicle/Grid Integration

Description and Strategy of HEV TCP Phase 6, 2020-2025

In November 2019, the IEA Committee on Energy Research and Technology (CERT) approved the sixth phase of operation for HEV TCP, which is scheduled to run from 1 March 2020 until 29 February 2025. In the strategic plan for Phase 6, the participants in HEV TCP have formulated their expectations for the time frame 2020-2025.

The HEV TCP ExCo considers policy/decision makers in governmental bodies at national, regional and city levels, in the automotive industry, its component suppliers and utilities as the target audience for its work. These include the HEV TCP Contracting Parties, which are representing national governments. The HEV TCP mission is defined as to advance the mass adoption of the electric drive by: supplying objective information to support decision making; facilitating international collaboration in pre-competitive research and development (R&D), demonstration and deployment projects; identifying future research areas; fostering the international exchange of information and experiences; and identifying and removing barriers.

Against this background and to fulfil its mission, the HEV TCP Executive Committee has formulated the following strategic objectives for Phase 6 (2020-2025):

- Maintain and expand its network of experts to provide meaningful contributions to technology development and policy analyses in the face of mass adoption;

- Expand focus towards electrification of other transport modes and e-mobility in a broad sense, and strengthen the research on links with future mobility systems, such as shared, connected and automated mobility;

- Strengthen its collaborations with other TCPs and other relevant research/policy groups; and

- Involve industry in its tasks to a greater extent to provide a broader network of experts and business expertise.

The existing HEV TCP working method, including meeting twice a year for information exchange and running projects in the form of Tasks, has proven to be appropriate to achieve the objectives of the Agreement, and no changes in the working method are anticipated for the sixth phase.

HEV TCP Tasks which are active at the start of Phase 6 are:

- Task 1: Information Exchange
- Task 23: Light electric vehicle parking and charging infrastructure
- Task 29: Electric, connected, and automated vehicles
- Task 30: Assessment of environmental effects of electric vehicles
- Task 32: Small electric vehicles
- Task 33: Battery electric buses
- Task 34: Batteries
- Task 35: Fuel cell electric vehicles
- Task 37: Extreme fast charging
- Task 39: Interoperability of e-mobility services
- Task 40: Critical raw materials for EVs (CRM4EV)
- Task 41: Electric freight vehicles
- Task 42: EV Cities casebook
- Task 43: Vehicle/grid integration

- Task 44: Impact of Connectivity and Automation on Electrified Vehicle Usage and Benefits
- Task 45: Electrified Roadways – eRoads
- Task 46: LCA of Electric Trucks, Buses, Two-wheelers, and Other Vehicles
- Task 47: Zero-Carbon Freight from Port Electrification
- Task 48: Battery Swapping
- Task 49: EV Fire Safety
- Task 50: Light Electric Vehicles

IEA ENGAGEMENT IN OTHER ACTIVITIES RELATED WITH ELECTRIC VEHICLES: THE ELECTRIC VEHICLE INITIATIVE

The Electric Vehicles Initiative (EVI http://www.cleanenergyministerial.org/initiative-clean-energy-ministerial/electric-vehicles-initiative and https://www.iea.org/programmes/electric-vehicles-initiative) is a multi-government policy forum established in 2009 under the Clean Energy Ministerial (CEM), a high-level global forum to promote policies and programmes that advance clean energy technology, to share lessons learned and best practices and to encourage the transition to a global clean energy economy.

The EVI is dedicated to accelerating the deployment of EVs worldwide. It brings together representatives of its member governments and partners twice per year and acts as a platform for knowledge-sharing on policies and programmes that support EV deployment. As of the end of 2022, governments currently active in the EVI include Canada, Chile, China, Finland, France, Germany, India, Japan, the Netherlands, New Zealand, Norway, Poland, Portugal, Sweden, the United Kingdom, and the United States. This group includes the largest and most rapidly growing EV markets worldwide and accounts for the vast majority of global EV sales. Canada and China are the co-leads of the initiative. The International Energy Agency serves as the EVI co-ordinator. Its EV30@30 Campaign, launched at the Eighth Clean Energy Ministerial in 2017 and subscribed by most of the EVI members, redefined the EVI ambition by setting the collective aspirational goal for all EVI members of a 30 % market share for electric vehicles in the total of all passenger cars, light commercial vehicles, buses and trucks by 2030.

The implementing actions included in the EV30@30 Campaign largely define today's EVI programme of work. These actions include:

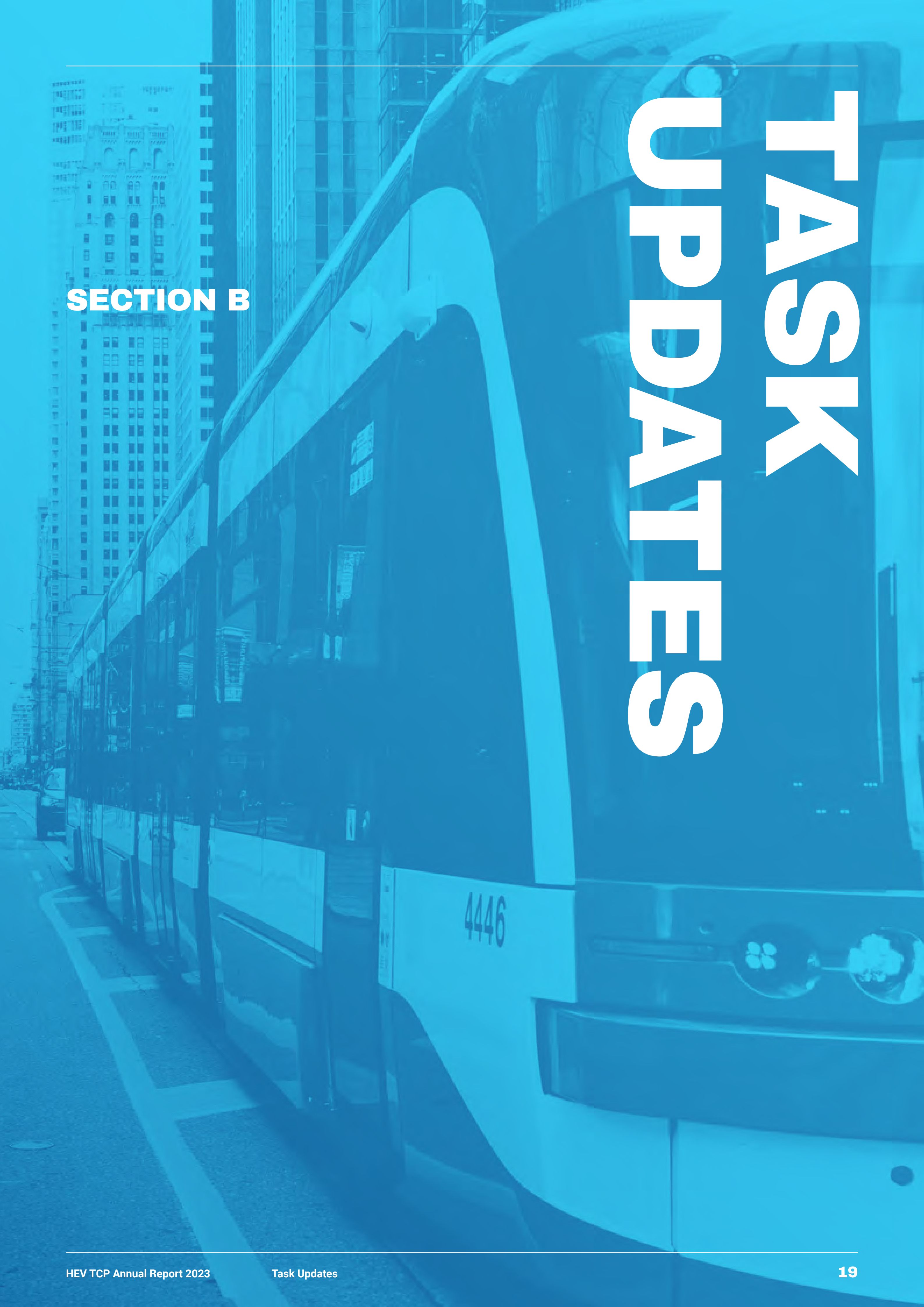
- Supporting the deployment of EV chargers and tracking progress;
- Galvanising public and private sector commitments for EV uptake in company and supplier fleets;
- Scaling up policy research, including policy efficacy analysis, information and experience sharing and capacity building;
- Supporting governments in need of policy and technical assistance through training and capacity building;
- Establishing the EVI Global Pilot City Programme (EVI-PCP), As one of the main pillars of the EV30@30 Campaign, The EVI-PCP aims to build a network of at least 100 cities over an initial period of 5 years, to work together on the promotion of electric mobility. In March 2021, EVI collaborated with the HEV TCP to release the EV City Casebook and Policy Guide (https://www.iea.org/areas-of-work/programmes-and-partnerships/evi-global-ev-pilot-city-programme).

To date, the EVI has developed analytical outputs that include the Global EV Outlook series with annual editions since 2015. The EVI has also successfully engaged private sector stakeholders in roundtables in Paris in 2010, in Stuttgart in 2012, at the annual COP meetings since 2015 and at the 2019 Paris Peace Forum to discuss the roles of industry and government in EV development as well as the opportunities and challenges ahead for EVs. In addition, other publications such as the EV Cities Casebook and Policy Guide (a joint collaboration between the EVI and the HEV TCP) highlights inspiring examples and policy recommendations from cities which have taken actions to accelerate mass adoption of EVs, with the latest release in 2021. Finally, the GEF funded Global E-Mobility Programme was launched at COP26 with the aim to support low and middle income countries with a shift to electric mobility. The United Nations Environment Programme (UNEP) is coordinating the implementation of the programme which includes both global thematic working groups, regional investments platforms and almost 30 country projects (with technical support and pilot projects). The work will be carried out over five years and many activities will be co-branded with the EVI, which is co-funding the work through the financial support to IEA as the coordinator. The programme also includes a tracking and monitoring framework which builds on the data collection prepared for the Global EV Outlook. Several international organisations are involved in the implementation of the programme, including the Asian Development Bank, European Bank for Reconstruction and Development (EBRD), Centro de Mario Molina and UNEP.

For the development of EVI activities, the IEA secretariat cooperates with the IEA Technology Collaboration Programmes on Advanced Fuel Cells (AFC) and Hybrid and Electric Vehicle Technologies and Programmes (HEV TCP). Other partners include: Argonne National Laboratory (ANL); C40; ClimateWorks Australia; ClimateWorks Foundation; Electrification Coalition; European Association for Electromobility (AVERE); Forum for Reforms, Entrepreneurship and Sustainability (FORES) in Sweden; Global Environment Facility; GreenTech Malaysia; International Council for Clean Transportation (which hosts the secretariat of the International Zero-Emission Vehicle Alliance); International Electrotechnical Commission (IEC); International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE); International Renewable Energy Agency (IRENA); Hewlett Foundation; King Mongkut's University of Technology Thonburi (Thailand); Lawrence Berkeley National Laboratory; Mission 2020; Natural Resources Defence Council (NRDC); National Renewable Energy Laboratory (NREL) of the United States; Nordic Energy Research; Partnership on Sustainable, Low Carbon Transport (SloCaT); REN21; Rocky Mountain Institute (RMI); Swedish Energy Agency; The Climate Group; the United Nations Environment (UN Environment); the United Nations Human Settlements Programme (UN Habitat); the United Nations Industrial Development Organization (UNIDO); World Resources Institute (WRI) and Urban Foresight.

The HEV TCP and the EVI worked together on annual data collection, and several HEV members support the development of analytical activities in the IEA, with direct implications for the EVI deliverables, starting from the Global EV Outlook.

Key examples include the close cooperation established between the IEA and the Argonne National Laboratory on battery cost and the assessment of the greenhouse gas emissions resulting from battery manufacturing. This allows better alignment of HEV TCP and EVI data analysis and messages throughout their respective publications.



SECTION B

TASK UPDATES

01 Information Exchange

Task 01 Task Manager

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STATUS
Ongoing

Task 01 began in the first phase of HEV TCP in 1993, and continues as the main forum and portal for news and results to the wider community of the International Energy Agency (IEA).

As a platform for information exchange between member countries, Task 01 aims to collect, analyze, and disseminate information on hybrid, electric, and fuel cell vehicles, and their related activities from member and non-member countries. The Task operates across the HEV TCP projects and topics, from research and technology development, commercialization and marketing, regulation and standards, to awareness raising measures. Any member country of the HEV TCP can automatically participate in Task 01, free of charge—with each country designating an agency or non-governmental organization as its Task 1 expert delegate.

The Task 01 Task Managers are responsible for coordinating and leading the biannual experts' meetings, compiling the minutes of these meetings, maintaining the HEV TCP website, and editing and supervising the production of HEV TCP publications including the newsletter and the ExCo annual report. The Task Managers also act as liaison to the other Task Managers, the ExCo Chair (together with the Secretary-General), and the IEA Desk Officer. Urban Foresight (United Kingdom) has been responsible for Task 01 since 2020.

The HEV TCP's Phase 6, running from 2020 to 2025, states that the HEV TCP "will aim to communicate and engage with key influencers of technology acceptance and deployment […] The main communication vehicles will remain the same (public website, HEV TCP annual reports, workshop reports, and Task final reports), with additional journal articles and conference papers."

COMMUNICATION OBJECTIVES

- Produce objective information for policy and decision-makers
- Dissmeniate information produced by HEV TCP to the IEA community, national governments, industries, and other organisations
- Collaborate on pre-competitive research
- Collaborate with other IEA Technology Collaboration Programmes and groups outside the IEA
- Provide a platform for reliable informations

UPDATES FROM 2022

In 2022, Task 01 helped coordinate the running of ExCo 55 and ExCo 56, which were both held in a hybrid format. As part of both ExCo 55 held in Oslo, Norway and ExCo 56 held in Dundee, Scotland, Task 01 organized and ran the Knowledge Sharing Workshop, which offered updates from member countries and host country organizations.

The Task 01 Task Managers continue to manage HEV TCP's public website and internal Members' Sharepoint site, the latter of which is used to organize and maintain a database of up-to-date information and resources for members.

A leading focus over this past year was the updating of HEV TCP templates for data collection and reporting. Working with the Chair and Secretary. this is in effort to help ensure consistent branding and updated design across all HEV TCP publications.

As was the case in previous years, Task 01 is committed to continuing to grow HEV TCP's presence on social media, through regular information sharing via the LinkedIn and Twitter profiles.

Task 01 continues to publish newsletters with regular updates on HEV TCP work and updates from ExCos, and welcomes any contributions from HEV TCP members for future issues.

23 Light-Electric-Vehicle Parking & Charging Infrastructure

Task 23 Task Manager

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STATUS
Ongoing

COUNTRIES
Spain
Germany
Belgium
Turkey

Task 23 is led by the objective of representing the interests of local governments in the standardization of Light Electric Vehicle system architectures, infrastructure, communications and interchangeable batteries.

This is expected to be achieved through following the IEC TS 61851-3-1/2/4/5/6 & 7, as well as other related IEC/ISO, CEN/CENELEC Standardization projects. In terms of standardization, the key objective is to ensure that there are no gaps within the technical infrastructure defined by IEC and ISO standards. In 2016, EN 50604-1 was published, the first battery safety standard from the European standardization body CENELEC specifically designed for LEV battery safety during all anticipated usage scenarios. This set the lead globally and was followed by ISO 18243. These standards serve as a good starting point for international GTRs (Governmental Technical Regulations) in defining that Pedelecs may be considered equivalent to cycles, according to the UN vehicle definitions, which are the reference for all national traffic related legislation.

In 2021, Task 23 started to cooperate with the EU Project CleanMobileEnergy within the Interreg North-West-Europe program. Members of this project are from Ireland, UK, France, Luxembourg and Germany. Task 23's key findings and accomplishments from recent years have been trialed in so called 'City-Pilots' in Baden-Württemberg Stuttgart and Schwäbisch Gmünd.

Across its activities, Task 23 looks to exemplify how the outlook for LEVs is remarkable, as they have the potential to replace more and more fossil fuel powered two-wheelers and, in many cases, cars and vans as well. Drivers for this growth are high convenience and easy local energy supply by renewable energy—especially in rural areas where gasoline supply is not so simple to organize and usually very costly. This is especially important in countries with no domestic fossil energy sources, where there is high dependency on imported fossil energy. Importantly, governments do recognize the commercial benefits of switching between expensive imports and locally-produced renewable energy to cover LEV energy needs.

ACTIVITIES IN 2022

Due to activity of the Netherlands, and the political pressure of the alternative references to battery safety in the Pedelec (EPAC/Electrically Power Assisted Cycle) Standard of the EU, the EN 15194 was removed, meaning that after the end of the transition period in Summer 2024, only Pedelecs that have batteries that conform with EN 50604-1 and its safe charging interface will be legal to be sold since the EN 15194 is the mandatory CE conformity reference standards. This means that when EN 50604-1 is harmonized (i.e. listed in the Official Journal as meeting the essential safety requirements of the relevant directives of the EU) it will not only define the technical state of the art, it will be almost essential for manufacturers to comply with it.

In the EN 50604-1 + AMD1, the safe charging is addressed through reference to the IEC TS 61851-3-4 / EN 61851-3-4 and the EV supply equipment according to IEC TS 61851-3-1/EN 61851-3-1, which was 100% positive voted on September 2, 2022. Thanks to these harmonized standards, which have been established during the Task 23 activity since 2013, easy infrastructure interconnection will be enabled down the road and public tenders which are open for strong competition. And best of all, it is possible to invest money into LEV parking and charging infrastructure which will still be fully useful potentially 40 years down the road for the next generation.

23 events have been used for the dissemination of Task 23's intermediate results. The numerous interactions with local governments, traffic and city planners, the infrastructure and vehicle industry, and political leaders have helped sharpen the concept and structural approach. Events have been held in Germany, Netherlands and Norway. As a result, two federal States of Germany (Lower-Saxony and Thuringia) with each one area (Hannover and Schwarzatal Region) have been encouraged to create the first tenders to finally achieve the goal of Task 23 and help establish a tender blueprint to be copied by other regional and city governments for easy, legally safe and effective tendering processes.

To enable the operation on a long-term basis, and coordinate continuously between the public and private stakeholders—consideration has focused on establishing a foundation organization which would run the operation of the stations and vehicle fleets.

Figure 1: Globally first fully Implemented interface using the charge and lock cable interface according to IEC TS 61851-3-1. The cable is fixed on the vehicle and the socket is located on the infrastructure. This architecture supports a long infrastructure maintenance lifetime and does allow the vehicle manufacturer to individually choose how to integrate the cable into the vehicle. It also gives most flexibility on vehicle types to be parked and charged.

Figure 2: For fast transition of car-centric streets into LEV-friendly ecosystems, an off-grid pop-up mobility station was developed, which is easy to place anywhere on a car parking space and transform immediately into a LEV parking and charging mobility station, which can cater sharing vehicles and private vehicles of all kinds.

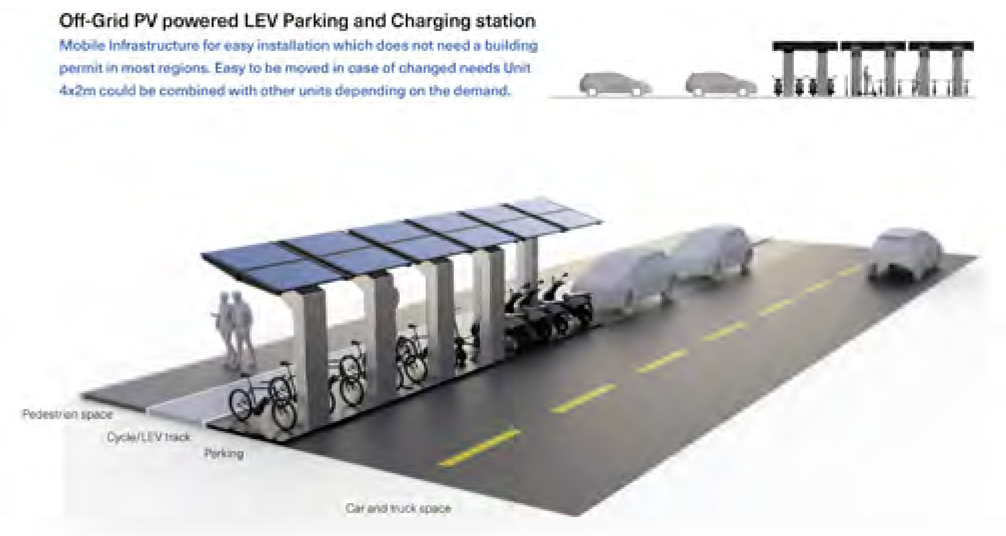

Figure 3: 2 Car parking lots (5x2m each) can be converted with three elements to 12 LEV packing and charging spaces. If demand changes, these stations can be easily relocated with minimal costs and labor effort.

Figure 4: The 1.6-ton pop-up mobility station can be picked up without a crane, just with simple mechanical devices with one person, and placed on a car trailer within 10 minutes. It can be hauled by a larger car or a van. 12 stations can be placed semi-assembled in a standard truck trailer or a train wagon for the first trip between the factory and the application area.

Figure 5: May 30th, 2022, visit of President of the Federal Council of Germany and Minister President of the federal state of Thuringia Mr. Bodo Ramelow visited EnergyBus headquarters at Tanna to inform himself on the status of the standardization and trial implementation of LEV infrastructure. He came together with the Minister of Transport of the State of Thuringia Mrs. Suzanna Karawanskij.

Figure 6: Showcasing of the LEV ecosystem solution to local politicians and decision makers of the Schwarzatal region in the heart of Thuringia, where mobility mostly depends on personal car usage. The aim is to create a network of LEVs in public transport to compete with cars in terms of convenience and time.

Figure 7: Trial days at Schwarzatal Thuringia with local citizens. The reaction was overwhelmingly positive towards alternative options available beyond the limits to personal car ownership, which are considered by many as significant cost burdens and time-consuming transport mode for households with children.

Figure 8: Minister President of the federal state Lower Saxony, Mr. Stephan Weil, and the Mayor of Steyerberg, Mr. Marcus Meyer, at the Pop Up Mobility station of Task 23 while visiting the City of Steyerberg.

Figure 9: Showcase in front of the Townhall of the City of Hannover on the day of the City Council traffic working group's meeting.

Figure 10: Meeting with the mayor of Hannover, Mr. Belit Onay, at the Pop Up Mobility Station, proposing how to potentially replace 30,000 car parking lots within the city of Hannover with LEV parking infrastructure within the next 7 years.

Figure 11: Trial set up at Hannover South on how a car parking lot conversion could look and general reactions of local citizens.

Figure 12: Intermediate Report on Task 23 presentation at EVS35 Oslo by Hannes Neupert, as well as welcoming many international guests like the Minister of Transport of the county of Baden-Württemberg, Mr. Winfried Herrmann. The Pop Up Mobility station was also on display during 2022 conference and exhibition.

NEXT STEPS

The Pilot regions will create an initial call for parties interested in the tender for bidding for: A) the parking and charging infrastructure elements, B) for vehicles to be interoperable with the parking and charging infrastructure and C) for the operating software. At this initial meeting, the targets of the mobility concept of the Pilot region will be presented, as well as the functional boundaries and minimum requirements which need to be met. Within a three-month period, the manufacturers and interested parties will have the chance to come up with proposals which match the boundary conditions and present these in a conference style to the pilot region as well as all other parties. These inputs will be taken into consideration for the final tender text to be frozen after this workshop. The iterative approach will be continued to secure wide industry participation.

Equal to the 2012 Task 11 final cumulative publication—which was executed as a joint handbook between the Task 11 and the EU Project GoPedelec, as was part of the EU Intelligent Energy Program—a handbook will be published to be a reference resource for industry players and local governments when it comes to LEV parking and charging infrastructure. This handbook will place emphasis on the creation of tendering processes for the establishment of infrastructure and LEV-led mobility ecosystems.

34 Batteries

Task 34 Task Manager

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STATUS
Ongoing

COUNTRIES
Canada
Germany
Sweden

Task 34 deals with topics related to the chemistry and performance of electrochemical energy storage devices of interest to those working on electric drive vehicles.

Electric vehicles are important because they reduce our reliance on petroleum, thereby increasing economic security, and providing an opportunity to improve air quality with increased fuel economy while reducing, or eliminating, tail-pipe emissions. Since batteries account for a significant part of the total cost of electric vehicles (EVs); R&D continues worldwide to develop abuse-tolerant and affordable batteries with higher energy density–i.e. batteries that would cost less, weigh less, last longer, avoid range anxiety, and lead to a widespread electrification of the transportation sector.

The goal of Task 34 is to encourage the sharing and dissemination of current information about battery topics of interest to the vehicle community. The primary focus of this task is on collecting and reporting information on the state-of-the-art EV battery performance and cost, and on R&D being conducted worldwide through country-to-country information exchange and public meetings.

UPDATES FROM 2022

Lithium Metal Battery Technology

BACKGROUND

Lithium metal batteries offer the potential for significant increases in energy density that could enable large-scale adoption of electric vehicles. However, it is not yet possible to build high-energy density lithium metal batteries with long lifetimes (>1,000 cycles) due to the reactivity of lithium metal with electrolytes. If specific failure mechanisms of lithium metal batteries can be identified, this will help efforts to potentially increase the lifetime of those batteries.

ELECTROLYTES FOR LI-METAL ANODES VIA SOLVATION-PROTECTION STRATEGY (ANL)

The development of a stable electrolyte system is crucial to the use of lithium metal batteries. Researchers at ANL have developed a new "solvation-protection" strategy to stabilize lithium metal anodes. Fluoroethylene carbonate (FEC) was introduced into the difluoroethylene carbonate/fluoroethyl methyl carbonate (DFEC/FEMC) electrolyte system to serve as a solvation protection agent. Although DFEC enables stable cycling of a Li metal anode, a Li||NMC811 cell with DFEC/FEMC electrolyte (and no FEC) displays inferior cycling performance because of lithium complexes solvated solely by FEMC. Due to the relatively high solvating power of FEC, the solution structures of lithium complexes can be altered. The FEC/DFEC/FEMC electrolyte not only maintains the beneficial effect of DFEC in forming a robust SEI on the Li, but also confers outstanding anodic stability provided by FEMC, evidenced by the stable cycling of Li||NMC cells (Figure 1).

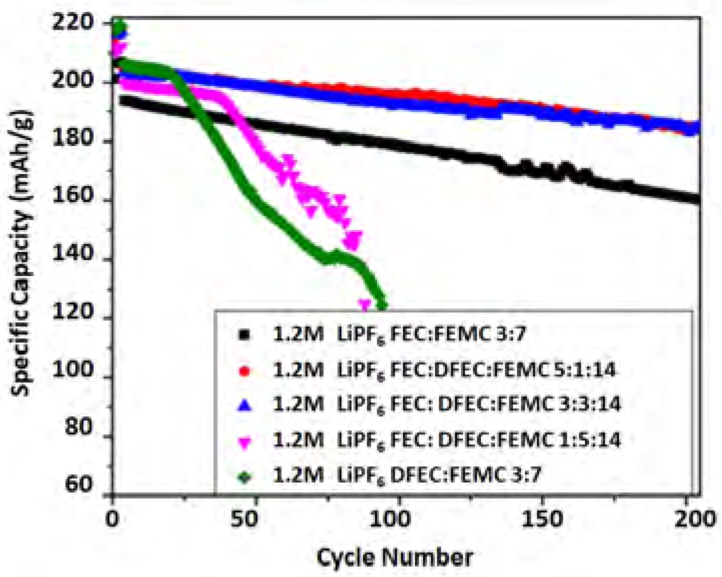


Figure 1: Cycling performance of Li||NMC811 cells using 1.2M LiPF6-FEC/DFEC/FEMC in different ratios.

(Source: ANL)

RATIONAL ELECTROLYTE SOLVENT MOLECULE TUNING FOR HIGH-PERFORMANCE LITHIUM METAL AND ANODE FREE BATTERIES (STANFORD UNIVERSITY AND SLAC NATIONAL ACCELERATOR LABORATORY)

Conventional electrolytes fall short when paired with lithium metal anodes. To enable practical Li metal and anode-free batteries, there are several requirements:

1. high Coulombic efficiency including during initial cycles, i.e. fast activation of Li anode;
2. anodic stability to avoid cathode corrosion;
3. practical conditions such as lean electrolyte and limited Li inventory;
4. high ionic conductivity for realistic cycling rates;
5. moderate Li salt concentration for low cost;
6. high boiling point and the absence of gassing to ensure processability and safety.

In 2022, researchers at Stanford University and SLAC National Accelerator Laboratory investigated a family of fluorinated 1,2-diethoxyethanes (fluorinated-DEEs) as electrolyte solvents. Selected positions on DEEs are functionalized with various numbers of fluorine (F) atoms through iterative tuning, to reach a balance between CE, oxidative stability, and ionic conduction. Paired with 1.2 M LiFSI salt, we found that a partially fluorinated, locally polar –CHF2 group results in higher ionic conduction than fully fluorinated –CF3 while still maintaining excellent electrode stability. Specifically, the best-performing F4DEE and F5DEE both contain –CHF2 group. In addition to high ionic conductivity and low and stable overpotential, they achieve roughly 99.9% Li CE with ±0.1% fluctuation (Figure 2a) as well as fast activation, i.e. the CEs of the Li||Cu half cells reach >99.3% from the second cycle (Figure 2b).

Aluminum corrosion is also suppressed due to the oxidative stability that originates from fluorination. These features enable roughly 270 cycles in thin-Li||high-loading-LiNi0.8Mn0.1Co0.1O2 (NMC811) full batteries (Figure 2c) and >140 cycles in fast-cycling anode-free Cu||$LiFePO_4$ (LFP) pouch cells (Figure 2d), both of which are state-of-the-art performances. The above solvents can be readily scaled up with low cost. Their high boiling point, high flash point, non-flammability and absence of gassing issue during battery cycling are desirable features.

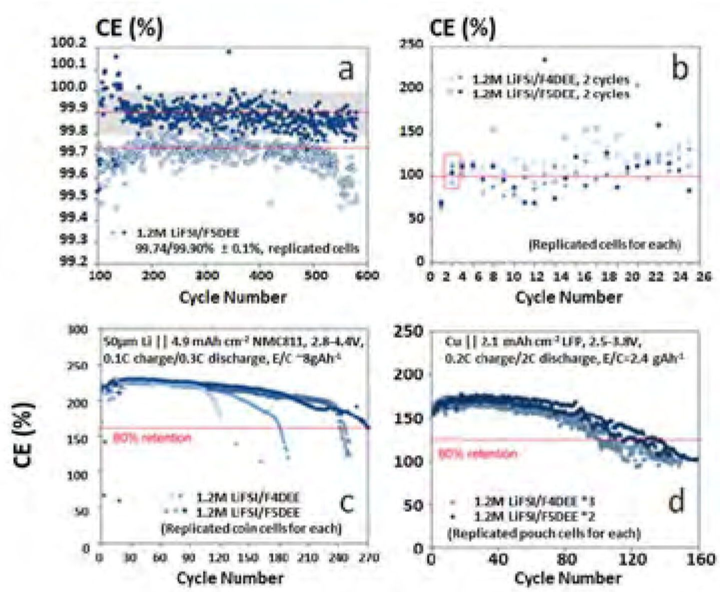


Figure 2: (a-d) Cycling performance of Li||Cu half cells, practical Li metal batteries and industrial anode-free pouch cells using NMC811 and LFP cathodes.

(Source: SLAC)

Lithium Sulfur Battery Technology

BACKGROUND

Lithium-sulfur battery technology has the potential to offer affordable, lighter-weight batteries that also have a safety advantage over present systems. In them, the metal-rich cathode of Li-ion cells is replaced with comparatively cheap and abundant elemental sulfur, a material that offers the theoretical potential for a five-fold improvement in capacity for the same weight. This results in lightweight and more cost-effective cells and reduced environmental and social concerns. However, there are some key challenges associated with this technology including the poor electronic conductivity of sulfur, the dissolution of discharge products (shuttle effect) and the poor reversibility of lithium.

DEVELOPING LOW-COST RECHARGEABLE LITHIUM-SULFUR BATTERIES (BATTERY500 CONSORTIUM)

The Battery500 Consortium has advanced the performance of a lithium-sulfur (Li-S) battery through innovation in battery electrolytes and improved understanding of a polymer-derived sulfur cathode. A 2Ah pouch cell with an energy density of 250Wh/kg (competitive with current lithium-ion EV cells) has been demonstrated.

Sulfurized PolyAcryloNitrile (SPAN) is a low-cost material containing no critical materials readily made by heating sulfur with PAN, an industrial product, at 300-500oC. Unlike elemental sulfur-based cathodes, SPAN appears to avoid the generation of soluble polysulfide species, which lead to capacity fade and is very sensitive to electrolyte amounts. To enable a long-life Li-SPAN battery, electrolytes need to be stable at both the Li anode and the SPAN cathode. The Consortium has developed a localized concentrated electrolyte consisting of 1.8 M lithium bis(fluorosulfonyl)imide (LiFSI) in diethyl ether (DEE) and Bis(2,2,2-trifluoroethyl) ether (BTFE). This electrolyte forms a protection layer on the SPAN surface that prevents loss of sulfur to the electrolyte. In addition, Li cycles stably due to the formation of a LiF-rich SEI. Both Li and SPAN show around 1000 stable cycles in coin cells using this new electrolyte.

To further improve the capacity and reversibility of SPAN, it is essential to understand its molecular structure and working mechanism. Using chemical analysis, electron microscopy, and surface analysis, it was established that SPAN undergoes an irreversible transformation during the 1st cycle that reduces its residual hydrogen content and produces a more extended conjugated molecular structure. As a result, its electronic conductivity increases by >100x and raises the working potential. This structural feature can serve as a blueprint for design of next generation materials. Electrolyte innovation and electrode engineering have allowed the fabrication of a first generation 2Ah Li-SPAN battery with an energy density of 250 Wh/kg, Figure 3. Cycling ended when the Li metal anode caused an internal short. Work is in progress to further increase the capacity of SPAN and formulate new electrolytes that will extend the cycle life of Li-SPAN batteries and to scale up SPAN cathode materials to enable more pouch cell manufacturing and testing.

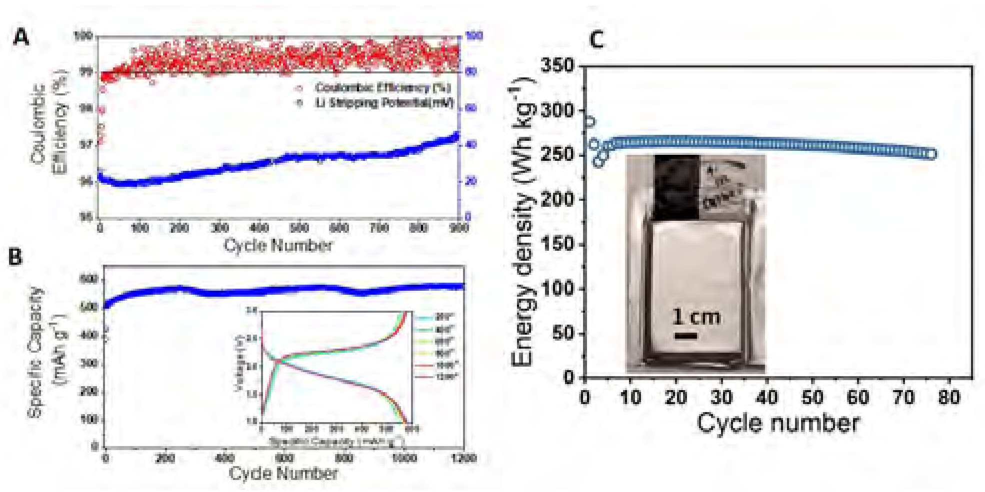


Figure 3: Progress of developing a low-cost Li-S battery by the Battery500 Consortium. The sulfur cathode is sulfurized polyacrylonitrile (SPAN). (a) and (b), Stable cycling of Li and SPAN in a localized concentrated electrolyte, respectively. (c) Demonstration of a 1st Generation Li-SPAN pouch cell of 2Ah with an energy density of 250Wh/kg.

(Source: Battery500)

Solid State Battery Technology

BACKGROUND

The liquid organic electrolyte in lithium-ion battery cells is highly reactive and flammable. There is growing interest in the use of solid lithium-ion conducting materials in place of the liquid electrolyte. Solid electrolyte materials are non-flammable, and they not only allow more robust cell operation but also the integration of metal-based anodes needed to achieve aggressive cost, energy density, and cycle life targets. Solid electrolyte materials face challenges, however, including low conductivity, poor voltage stability, and inadequate mechanical properties. Research attempts to overcome these challenges by research of new solid electrolytes that can address materials challenges and enable next-generation chemistries, complementary diagnostics, and modeling techniques to ensure materials development progress.

CYCLABLE ALL-SOLID-STATE CELL CHEMISTRIES WITH HIGH ENERGY DENSITIES (LBNL)

All-solid-state batteries (ASSBs) with Li metal anodes can deliver higher energy densities and better abuse tolerance than current Li-ion cells. The development of practical ASSBs, however, has met challenges such as Li dendrites, cathode instabilities due to oxidative degradation of the solid electrolyte (SE), and loss of mechanical integrity. Novel solutions are being proposed at LBNL with the following features: 1) conductive halide SEs with high oxidative stability to enable use of 4 V CAM and 2) single-crystal CAM particles to eliminate intergranular cracking associated with volume changes. Results obtained on ASSB cells with a single-crystal $LiNi_{0.8}Mn_{0.1}Co_{0.1}O_2$ (SC-NMC) CAM with 9.04 mg/cm^2 loading, a 300 um thick Li_3YCl_6 (LYC) SE, and a Li-In alloy anode are shown in Figure 4, along with data for an equivalent ASSB cells with a commercial polycrystalline NMC811 (PC-NMC). Much improved cycling performance was obtained in the SC-NMC cell. At C/2 rate, the discharge capacity decreased from ~105 to 80 mAh/g after 830 cycles in the PC-NMC cell and ~140 to 125 mAh/g after 1000 cycles in the SC-NMC cell, a capacity retention of ~76% and 89%, respectively.

Post-mortem analysis reveals superior mechanical stability of the SC-NMC cathode whereas large morphological changes were observed on the cycled PC-NMC counterparts, including cracking within the NMC particles and disconnections between the LYC and NMC. This design principle can be expanded to ASSB cells with other types of halide SEs and CAM materials.

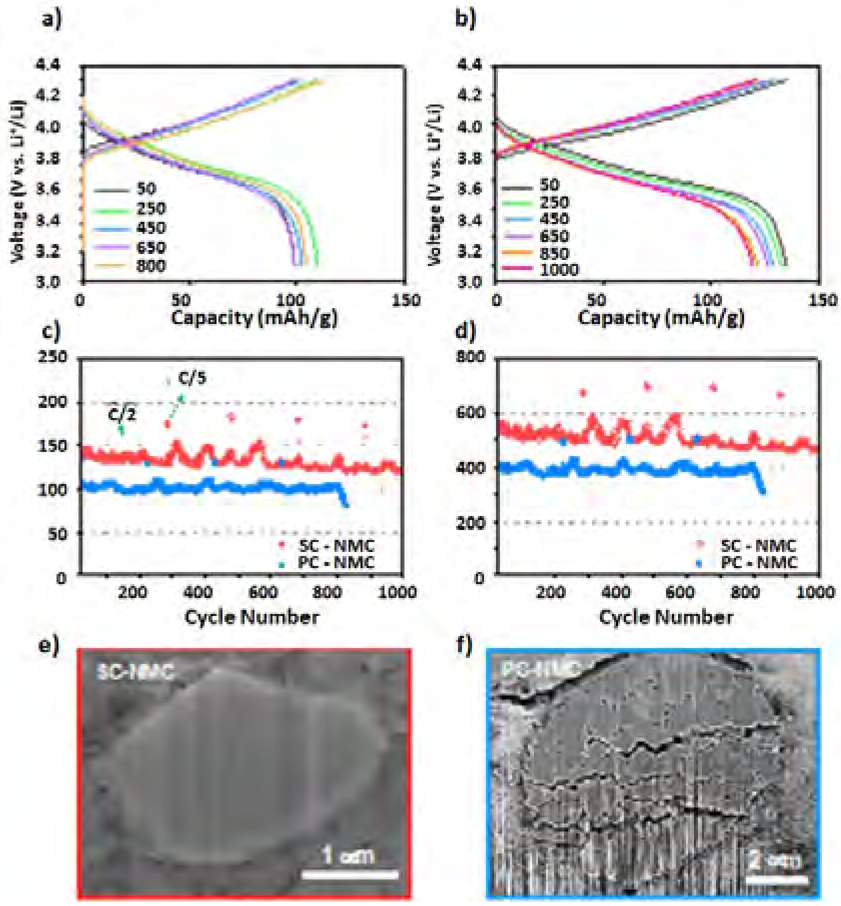


Figure 4: a-b) Voltage profiles of PC-NMC and SC-NMC ASSB cells, respectively. c-d) Discharge capacity and energy density retentions of the ASSB cells, respectively. e-f) Cross-sectional SEM images showing better mechanical stability of SC-NMC cathode composite upon cycling. All cells were cycled at room temperature at C/2 rate for 200 cycles followed by 3 cycles at C/5. This sequence was repeated throughout the testing. The performance fluctuation shown in c) and d) is due to room temperature variation in the laboratory, which ranged from 25±5oC during the test.

(Source: LBNL)

POLYMER CATHOLYTE FOR SOLID STATE BATTERIES ENHANCED WITH RESIDUAL SOLVENT (LBNL)

ASSBs promise high energy density via the use of a Li metal anode, and improved safety due to the absence of a flammable liquid electrolyte. Favorable cathode performance and durability are challenging to achieve, however, when restricting the choice of electrolyte materials to only solids. LBNL has shown that retained residual solvent improves the performance of a cathode containing solid polymer binder. The very small amount of solvent retained in the polymer/Li-salt composite plasticizes the polymer, increasing Li-ion conductivity. The cathode was combined with a solid sintered ceramic separator and Li metal anode (Figure 5), demonstrating a pathway to a viable ASSB.

Drying the cathode to different extents greatly impacts conductivity of the composite and therefore total cathode performance (Figure 6). By optimizing the amount of residual solvent and polymer/Li-salt ratio, promising performance and capacity retention was achieved (Figure 6). The positive effect of residual solvent was observed over a very wide temperature range from -10 to 60°C. Multiple solvents produced a similar effect, providing flexibility to select the solvent based on cost, safety, reactivity, and manufacturing considerations. The cycling data were obtained using a $LiNi_{1/3}Mn_{1/3}Co_{1/3}O_2$ cathode (2mg/cm^2 loading), Li metal anode, and a 300-micron thick $Li_{6.25}Al_{0.25}La_3 Zr_2O_{12}$ electrolyte. It was found that, without the residual solvent, the cell impedance was too high to cycle the cell.

Figure 5: Cross-section image of the separator/cathode structure. The separator is an oxide ceramic, and the cathode is a solid composite of NMC active material, carbon, polymer catholyte, and trace residual solvent.

(Source: LBNL)

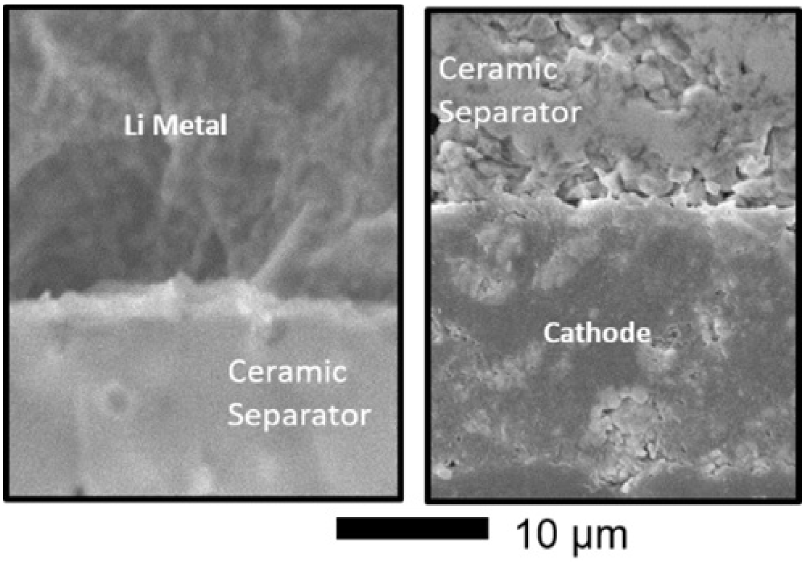
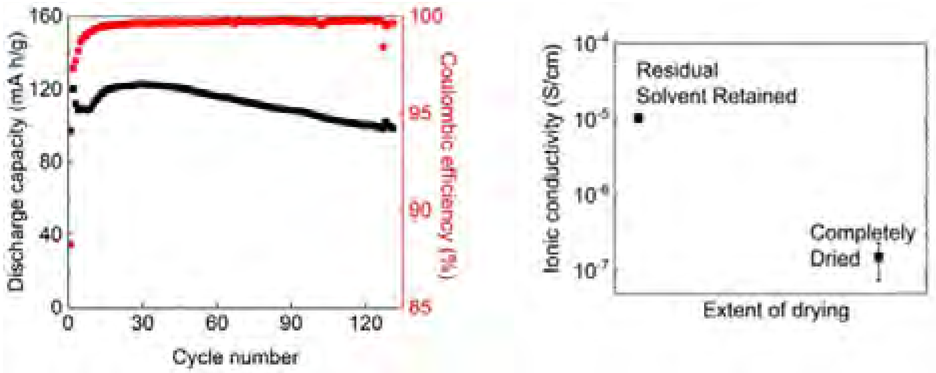


Figure 6: Capacity retention of a cell with residual solvent cycled at 25°C and 20 hour full charge/discharge cycle. Right most figure shows the conductivity of the polymer/ Li-salt composite with and without residual solvent.

(Source: LBNL)



Advances in Lithium Battery Recycling

BACKGROUND

There are strong reasons to recycle Li-ion batteries. Materials recovered from recycling can be used to make new batteries, reducing costs. Recycling would reduce the quantity of material going into landfills, avoiding contamination of soil and groundwater. More recycling would also mean less use of virgin material, and less environmental harm associated with it, as well as a slower depletion of these materials. There are also political costs and downsides due to use of rare-earth materials that recycling could help address.

LITHIUM BATTERY RECYCLING PRIZE (PHASE III)

In FY22, NREL Prize Administrators successfully concluded Phase III of the DOE Lithium-Ion Battery Recycling Prize. Six finalist teams participated in Phase III, which focused on pilot validation of proposed concept solutions. On March 8–11, 2022, the NREL organized and hosted virtual "site visits" for the six Phase III participating teams. These visits allowed teams to demonstrate their proposed solution on location, while reviewing aspects of their pilot validation approach. Following the final Phase III submissions to the prize (April 8, 2022), teams were required to attend Phase III virtual Participants Day to demonstrate how their proposal meets the goals of the prize.

Prize Administrators combined team feedback with key information metrics/results to develop winner recommendations. The winner announcement took place on June 21, 2022. As part of the Lithium-Ion Battery Recycling Prize, Phase III participating teams reported investing $4,300,371 in the development of proposed recycling solutions. In addition, Phase III participating teams spent $667,000 in voucher funds at five different facilities. As a result of Phase III pilot validation, these teams successfully delivered over 87,000 of battery cells and modules to recyclers.

Advances in Cobalt-free Materials

BACKGROUND

Currently, lithium-ion batteries contain a substantial amount of cobalt, a critical material that is both expensive (in 2017, average annual cobalt prices more than doubled) and dependent on foreign sources for production [1]. The Democratic Republic of Congo supplies nearly 60% of the world's cobalt with 60% going to China. China is the world's leading producer of refined cobalt and a leading supplier of cobalt imports to the United States[2]; this dependency could become a concern for U.S. end-users. The growth in demand for lithium-ion batteries for EVs will establish EVs as the largest end-user of cobalt and lithium; and could potentially create a cobalt and lithium supply risk [3,4,5]. Because of the above-listed concerns, DOE has been funding several R&D projects on low-cobalt/no-cobalt cathodes, including the two listed below.

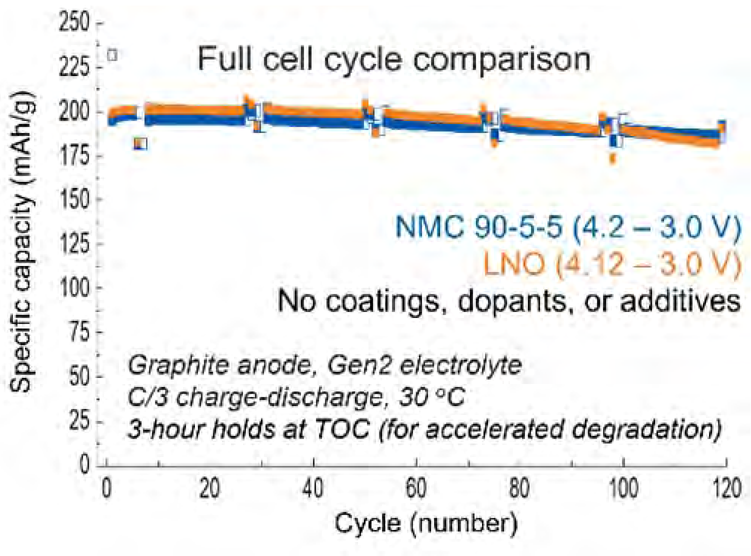
$LINIO_2$ ENABLED BY OPTIMIZED SYNTHESIS CONDITIONS (ANL)

The $LiNiO_2$ (LNO) cathode is of interest because of its high energy and the absence of (expensive) cobalt. However, commercial success has been elusive due to its cycling instabilities at high states of charge. However, due to the sensitivity of LNO to synthesis conditions such as precursor control, temperature, and atmosphere, virtually all LNO cathodes studied to date have limitations. Work at ANL has shown that near ideal, 'defect-free' LNO can be synthesized through better control of synthesis. ANL's 'defect-free' LNO cycles at high capacities (>220 mAh/g) over many cycles without dopants, coatings, or electrolyte additives. Such high performance, including very low initial irreversible capacity (~96%), has never been reported for LNO.

Key to achieving such results was precise control of synthesis parameters including novel precursor preparation, calcination conditions that facilitate minimum local defects (Li^+/Ni^{2+} mixing, O_2 vacancies, stacking faults), optimized primary and secondary particle morphologies, and a higher resistance to secondary particle cracking. Surprisingly, synthesis of 'defect-free' LNO could be enabled within a wide range of O_2 partial pressures, even as low as 0.2 atm. Full-cell tests with graphite anodes and Gen 2 electrolyte (1.2 M $LiPF_6$ in EC:EMC (3:7 by weight)) showed performance on par with $LiNi_{0.9}Mn_{0.05}Co_{0.05}O_2$, when cycled over similar states of charge, Figure 7. Three hour holds at the top of every charge were used to push stability limits.

Figure 7: Full cell performance comparison of optimized LNO vs. LiNi0.9Mn0.05C0.05O2.

(Source: ANL)



NEXT STEPS

The Task Manager is working with representatives from the member countries to identify topics and locations for future meetings.

References

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38 Marine Applications (e-ships)

Task 38 Task Manager

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STATUS
Ongoing

COUNTRIES
Norway
Chile
Denmark
The Netherlands
Canada

The main objective of Task 38 is to survey and encourage research, development, and deployment of marine vessels with onboard battery storage systems.

Thus, the Task focuses on gathering and sharing key knowledge on existing and planned projects for demonstration or deployment of battery-electric vessels, identification of achievable performance for key technologies, and the feasibility of electrification in different application segments.

The technical focus of Task 38 is on fully battery electric ships and related issues, such as battery technology and shore-to-ship charging systems. However, the Task will also cover technology for hybrid battery electric propulsion systems, including retrofit of battery storage into existing vessels for reducing emissions. Through a series of webinars and online meetings members share learnings on emerging technologies, standardization efforts, key stakeholders, best practices, environmental impact, and industrial perspective, including corresponding policies and measures aimed at successful commercialization of technology for electrification of marine transport. Development of regional and national initiatives for reducing emissions from marine transport can be facilitated with access to a wide international network of interested industry stakeholders, researchers and public entities involved.

Initially approved by the HEV TCP in 2017, activities were preliminarily started in 2018/2019. However, the Task was later placed on hold due to a change of Task Manager and the outbreak of the COVID-19 pandemic. National Norwegian funding for supporting the role of Task Manager was confirmed in 2021 and the Task was formally restarted in November 2021, with plans for three years of operation.

UPDATES FROM 2022

The main activity for Task 38 during 2022 was the organization of three webinars and corresponding discussions. These webinars were part of a series of four webinars on topics related to technology for the development and application of hybrid and battery electric propulsion systems for ships, which have been planned since 2021. The first webinar was organized on the 15th of December 2022, and has been described in the 2022 HEV TCP Annual Report, while the content of the three webinars organized during 2022 is summarized in the following sections.

The second webinar hosted by the Task was organized on the 29th of March 2022, with the title "Charging Technology for electric vessels." The webinar featured the following technical presentations, and corresponding sessions with questions and discussions:

1. *"Vessel Charging – Challenges and Solutions,"* by Jim Andriotis, Cavotec, NC, USA

2. *"Experiences and outlook on high power vessel charging"* by Rainer Altmeppen, Stemman-Technik GmbH/Wabtec, Germany

3. *"Introduction to standardization activities in marine charging"* by John Prousalidis, National Technical University of Athens (NTUA), Greece

4. *"Shore connections and battery charging for small vessels – experiences and outlook"* by Maria Bos, Plug AS, Norway

5. *"Wärtsilä Wireless Charging – practical experience and future possibilities,"* by Frode Jenset, Wärtsilä Norway, Norway

The first presentation by Cavotec addressed different technologies for high-power plug-based charging, including experiences with customized connectors and the characteristics of emerging solutions based on the Megawatt Charging Standard (MCS) for DC plugs with power capability up to 3MW. The presentation by Stemman-Technik discussed experiences with high power pantograph-based charging technology, including solutions for DC charging up to 5MW at 1000VDC and for AC charging up to 11MW at 11kV.

The third presentation provided an overview of established international standards and ongoing standardization activities related to electrical shipboard installations and ship-to-shore connections within the International Electrotechnical Commission (IEC) and Institute of Electrical and Electronics Engineers (IEEE). Professor Prousalidis also introduced the activities within the IEEE Power and Energy Society (PES)'s Marine System Coordinating Committee (MSCC) which are relevant to the work of Task 38.

The presentation by the Norwegian company Plug AS explored their experiences in developing charging infrastructure for small electric vessels based on standardized plugs from the automotive industry. In this way, the presented solutions were based on the use of standard Type 2 AC connectors or the CCS standard for DC connectors.

The last presentation introduced the experiences of Wärtsilä, Norway from the demonstration of a high power contactless inductive charging system, which has been developed for enabling power transfer of up to 2.5MW over distances up to 50cm. The presentation included discussion of the advantages and disadvantages of wireless inductive charging systems and the practical experiences from testing of the technology for a ferry route over a period of 12 months.

The webinar attracted about 50 participants with many questions to the presenters, leading to interesting technical discussions.

The third webinar hosted by the Task was organized on the 7th of November 2022, with the title "Battery technology for maritime applications." The webinar featured the following technical presentations, with corresponding questions and discussions:

1. *"High power battery system for ships"* by Jonas Sjolte, Siemens, Norway

2. *"High energy battery systems for ships"* by Lars Ole Valøen, Corvus, Norway

3. *"Overview of European strategic research efforts on battery technology"* by Alessandro Romanello, Battery Europe, and Wouter IJzermans, Batteries European Partnerships Association (BEPA), Belgium

The two first presentations of the webinar discussed the current state-of-the art in high power and high energy battery systems for ships from two leading manufacturers. The presentations also included discussion on their design considerations related to safety and on their experiences with supplying battery systems to different vessel segments. The third presentation offered an overview of the main organizations involved in the European strategic efforts on development of battery technology and their roles in defining or conducting research activities. This also included an introduction of how the main instruments for European Union research funding on battery technology are organized and how topics related to the whole value chain from raw materials to end-of-life are being considered.

The webinar attracted about 20 external participants, and each presentation was followed by questions from the audience with corresponding discussions.

The fourth webinar hosted by the Task was organized on the 21st of November 2022, with the title "Applications of hybrid and battery-electric propulsion in new vessel segments." The webinar featured the following technical presentations, with corresponding questions and discussions:

1. *"Shoreside Battery Charging – experiences and perspective"* by Edward Sciberras, Damen Research, Development & Innovation, The Netherlands

2. *"From Drawing to Reality – Development of a Scalable Hybrid Propulsion Plant in Chile,"* by Joel Pérez Osses, Universidad Austral de Chile, Chile

3. *"Experiences with design of battery-electric propulsion for small vessels,"* by Marius Dyrseth, Evoy AS, Norway

The first presentation included an introduction to the experience and perspective of Damen Shipyards Group on hybridization and battery-based propulsion for different vessel segments. The presentation also included a brief discussion of their perspective on the further developments and the need for standardization of charging technology for ship applications. The second presentation introduced the experiences with the development and demonstration of hybrid propulsion systems in Chile. A general perspective on the experience gained from the first local demonstration projects and on potential for electrification of the marine sector in Chile was also presented. Finally, the third presentation introduced the experiences of Evoy related to the development of battery electric propulsion systems for small and light vessels, with special attention to high-performance leisure vessels.

The webinar attracted 16 participants who contributed to the discussions, covering the full range of vessel types, from large commercial ships to small vessels for private recreational use.

In addition to the webinars organized during the year, Task 38's main activity has been discussion with potential contributors, and initial planning of further activities.

NEXT STEPS

Task 38 is still discussing participation from additional countries, with several countries having confirmed their interest in participating in its activities. Participating countries and organizations are expected to join efforts in terms of organization of the future meetings and workshops for collecting, exchanging, and disseminating information and experience on aspects within the scope of the Task.

Due to delays in confirmation of participation, no physical meeting was organized during 2022. Thus, the next steps will be to confirm additional participation, and to conduct further online meetings and discussions. Depending on the availability and budgets of Task 38 members—including the new members to be confirmed during 2023—it might be more suitable to organize large parts of the activity during the coming year as online meetings. Online activities will also be considered if one or two additional webinars are organized during the second half of 2023, in case there is no dedicated physical meeting and workshop before the autumn meeting of the IEA HEV TCP ExCo.

In general, the activities in Task 38 will still be mainly focused on the technology, projects, policies and potential deployment in Scandinavia and Europe, where a high number of battery electric vessels are already in operation. However, with the active involvement of Chile, a second phase of discussing the potential for adopting and expanding similar applications in the Americas has also been gradually started. A third phase of activities will also include a brief survey of applications and potential participation in Asia and the rest of the world.

Another activity during 2023 will be to start initial planning of a final task report to be delivered in 2024 or early 2025. The activities of Task 38 will also include coordination with other tasks, including Task 47 on "Electrification of ground freight related to port electrification."

40

CRM4EV: Critical Raw Materials for Electric Vehicles

Task 40 Task Manager

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STATUS
Closed

COUNTRIES
IEA HEV Members
Austria
China
France
Germany
The Netherlands
Norway
Republic of Korea
Spain
Sweden
USA
UK

External
Govt. of
Western Australia
AVERE
Copper Alliance
Botree (China)
Valuad (Belgium).

In addition, 6 industrial participants of the battery materials supply chain joined the task from2018-2021

Task 40, "Critical Raw Materials for Electric Vehicles," aims at providing accurate, credible, and up-to-date information on materials which are considered as (potentially) critical for the uptake of electric vehicles sales.

Task 40 has focused on defining and maintaining a list of Critical Raw Materials, rooted in clear definition of "criticality" of the Critical Raw Materials depending on geography, penetration rate in the EV application scenarios, the use of CRMs in EVs, and short-term versus long-term supply issues.

Raw Materials under consideration included in the scope of Task 40 CRM4EV are those materials which are economically and strategically important for the mass deployment of EVs and have a high-risk associated with their supply. The overall objective of Task 40 is to generate and continuously update the relevant information by and for Task 40 CRM4EV participants related to critical raw materials for EVs. This includes continuous data collection and (scenario) analyses including validation through various discussions within the workshops, as well as developing global views and regional or country perspectives.

Consideration intends to evaluate (future) availability of alternative solutions or materials, as well as the impact of permitting processes in expanding existing and opening new mines. Seeing as materials from different processes can have different characteristics, quality and purity requirements and issues must also be evaluated. Task 40 uses this to evaluate environmental and social lifecycle impacts, to fill gaps in understanding of the significance of recycling today and what obligations and/or legislation guide future outlooks for Critical Raw Materials.

UPDATES FROM 2022

Materials like Lithium, Nickel, Cobalt, Graphite, Rare Earth Elements, and others are already frequently in the news related to their (presumed) scarcity, environmental or social issues. Conflicting information makes it difficult for policymakers to get fact-based and reliable information. This is especially the case for both ongoing and potential future discussions related to the future mass deployment of EVs. In fact, internal combustion engine technologies also require critical materials, which is often overlooked or already accepted in these debates. Fuel Cells currently use Platinum Group Metals (PGMs), as do catalysts for diesel cars. The guiding focus is on the impacts of mass BEV deployment on currently critical raw materials, as well as the battery technology developments with respect to materials used with a trend to move away from potentially critical materials.

In 2022, more than 10 million EVs have been sold, of which almost 8 million BEVs. This ten-fold growth compared to 2017 has completely changed the view on and role of BEVs as part of the transition to zero emission (tailpipe) transport. The EU has the intention to allow only the sale of zero emission cars as of 2035. The outlook of a rapid transition has only increased the urgency to consider the sustainable supply of materials required for EVs.

Summary conclusions and recommendations for policymakers

It is recommended that policymakers take into account the potential impact of faster (mass) deployment of BEV and EV batteries in forecasts and policy developments. This will also require taking into account faster technology change and improvements towards higher performance, lower impact technologies and the reduction or elimination of potentially critical minerals.

Technology development policies and stimulation should go to the development of new technologies aimed at reducing or eliminating critical mineral content, environmental and social impacts. Avoid being locked in critical mineral dependent technologies. For batteries this is valid for all applications in transport and stationary energy storage.

Reducing geographical/geopolitical dependency is more important than ever, especially for resource poor countries or regions like the EU. This should include mining, but also intermediate steps like refining for minerals. Recycling as a means to reduce impacts and to reduce the need for virgin minerals will become increasingly important. Development and deployment of high-quality recycling processes recovering intermediates and a wide range of minerals is key.

For the mass deployment of EVs, several topics concerning raw materials need to be clarified. Raw Materials included in the scope of Task 40 CRM4EV are those materials which are economically and strategically important for the mass deployment of EVs and have a high risk associated with their supply. It is important to note that these materials can be classified as ‘critical’ for various reasons (Figure 1).

Battery and key mineral demands by 2030

The CRM4EV scenario studies and results have been presented in the HEV TCP Annual Reports 2022 and 2021. For the external (GBA, IEA, EV30@30) scenarios analyzed, the EV sales forecasts translate in a 2,500 - 3,500 GWh Li-ion battery demand for transport with mineral requirements of 1.5 million tons of nickel, 260-290 kton cobalt and 380 kton lithium (metal).

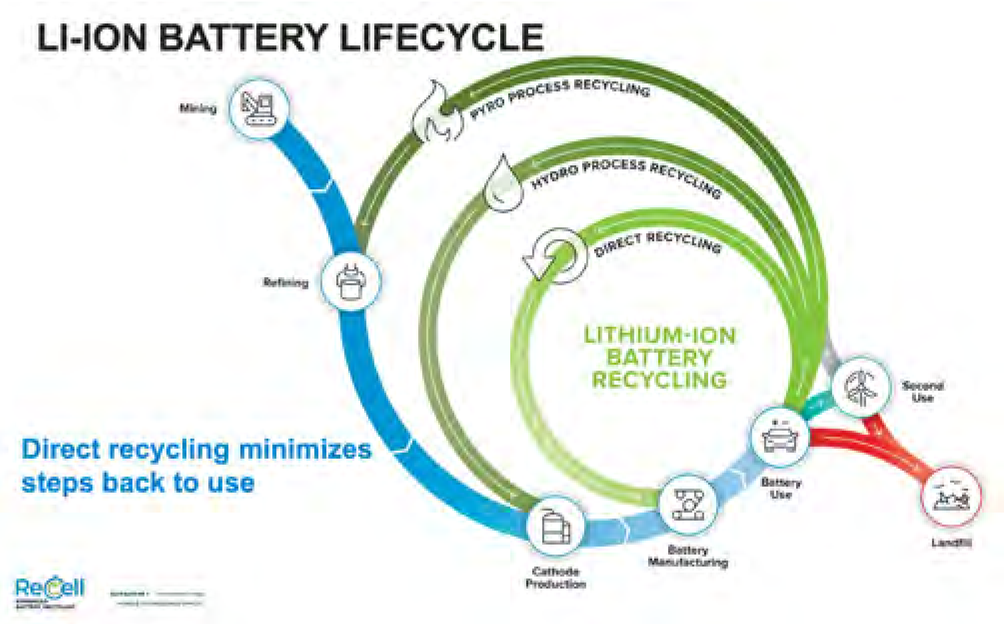

Figure 1: Public global scenarios (2021/2022) for battery and key mineral demands 2030 compared to CRM4EV scenarios and the COP21 (100% zero emission transport by 2050). The mineral requirements are based CRM4EV modelling or taken from the different scenarios (underlined data).

Nickel demand will outstrip supply according to our analysis in most external scenarios. Based on expert input, we estimate a maximum of 1.2 million tons of nickel will be available for batteries by 2030 from "conventional" nickel sources. Any additional nickel volumes will have to come from surface mining of NPI (nickel pig iron) in Indonesia, as is happening at this moment, or deep-sea mining in the long term. Both may have large negative impacts on ecosystems.

TECHNOLOGIES TO REDUCE OR REPLACE POTENTIALLY CRITICAL MATERIALS FOR LI-ION BATTERIES

We expect LFP and other low nickel (high manganese) chemistries to play a much more important role than generally expected—it is already the dominant technology in China. According to MIT, LFP had a global market share of 10% in 2018 and 40% in 2022, with the market share of LFP in China measuring 61% in 2022. LFP batteries have a lower cost, longer lifetime, safer, and a lower environmental footprint. This will likely provide an attractive alternative considering LFP's improvement to storage density. The rapidly increasing fast charging networks as well as the faster charging will reduce the need for large battery capacities. In our scenario where 50% of the batteries for transport are based on zero nickel and cobalt, and a significant part of the remainder on high manganese chemistry, the expected demand of nickel can be met. Manganese is not considered in CRM4EV as a critical mineral. Manganese is the 12th most abundant element in Earth's crust, reserves are 630 million tons, and 1.7 billion tons of resources are identified. Global production of manganese was 20 million tons in 2022 (USGS).

Solid state batteries are likely to become relevant faster and more significantly than projected currently. In our view, reaching a 20 to 40% market share by 2030 is possible. Advantages are lower weight, higher storage density, less materials, safer and a (much) higher fast charging capability.

The potential of sodium (Na) to replace lithium partially, substantially, and/or mainly will become clear in this decade, with commercial application expected to start in 2023/2024. Although lithium is geologically widely available, the current mining capacity is limited and will require a large effort to keep pace. Even a partial replacement of lithium with sodium will have a large impact. The “holy grail” for EV batteries would be to use none of the potentially critical materials like lithium, nickel, cobalt, but also graphite or manganese.

We can expect battery optimization and alternative technologies to reduce nickel and cobalt demand very significantly. Lithium will remain to be the anode material of choice for the coming years, but alternatives will continue to be developed and improved. A long-term scenario without lithium (dominance) should be considered.

RECYCLING OF LI-ION BATTERIES

Li-ion batteries: recycling can be done and processes to do so are already operational with many more in development including automated processes to dismantle the batteries. Recovery of components which then can be re-used as such is also done (for example to recover modules, to repair modules). Metals like nickel and cobalt can be recovered (yield above 90%) in all processes. To recover other materials needs more elaborate processes but it can be done. The significance of recycling as secondary raw material will increase in the coming 10 to 15 years.

In 2021 in China, 7% of nickel and cobalt, 4% of lithium and 5% of manganese used in battery production came from spent power batteries or battery production scraps (source Botree). This is related to the long-life time of the batteries (vehicle lifetime or more) and the possible second-use life of EV batteries. The main financial benefits of recycling used to come from the recovery of nickel and cobalt. However, with the high price of lithium (2022) the recycling of lithium is currently in China the most profitable part. Collection and recycling will not always be a guaranteed profit-making operation by itself and everywhere. Legislation is required and already implemented partially to assure at least partial recycling.

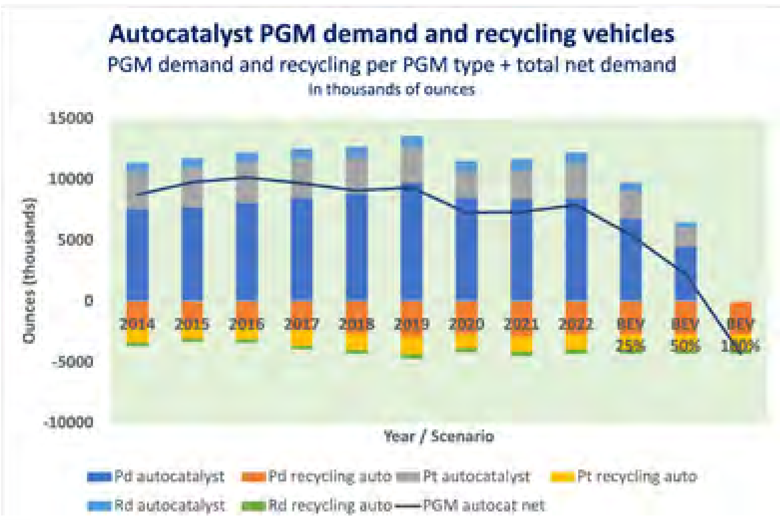

Figure 2: Different recycling processes for EV batteries. Pyrometallurgy: metal recovery as alloy (Ni, Co, Cu), requires hydrometallurgical refining for metal recovery. Li, Mn, Al into slag (recovery is challenging), energy intensive process. Hydrometallurgy: pre-treatment / sorting of different battery chemistries for constant process input, long process time, wastewater treatment. Direct recycling/ sorting of different chemistries, very sensitive to changes in input material.

Direct recycling: Direct recycling is defined as the recovery, regeneration, and reuse of battery components directly without breaking down the chemical structure, to keep the cathode crystal structure intact. It has also been called direct cathode recycling and cathode-to-cathode recycling. By recovering cathode material, several energy-intensive and costly processing steps can be avoided. Direct recycling could be used now for manufacturing scrap at low volumes. Advantages include low temperature and low energy consumption, and avoidance of most impacts from virgin material production.

Production scrap (from battery (materials) production) is another important source of material for recycling. Scrap rates for lithium-ion battery production are estimated to be about 5% for the best producers, 10% for typical producers, and as high as 30% or more during start-up phases. Whatever the actual rates are, this is a lot of material compared to that coming back at end of life because it is based on the current production rate, which is much higher than the rate when the EOL material was produced, because of rapid growth. ReCell scientists have already demonstrated that recovered cathode from manufacturing scrap can be used in new cells directly, without any steps to upgrade it.

Scrap is an important feedstock for North American recyclers like Li-Cycle and American Manganese. Redwood Materials gets scrap from Panasonic, which “alone provides about one gigawatt of material annually and a dozen other partners contribute a similar amount, for a total equivalent of about 20,000 tons of material per year.” In China, Hunan Brunp mainly produces ternary precursors for power batteries, using battery scraps from CATL as its main feedstock.

In terms of the outlook for improvements of battery recycling processes, **the EV battery recycling technology** is still evolving, nickel, cobalt, lithium, especially lithium, their recovery rate still has room for improvement. Yet, no mature technologies are available to generate high value use of graphite and electrolyte. The core is to improve the separation efficiency and accuracy of dismantling process, optimize separation and purification processes, and develop new types of separation agents and systems.

For the section on recycling, text contributions have been provided by Argonne NL (“Direct Recycling R&D at the ReCell Center - MDPI”) and Botree (China).

Lifecycle impacts of EV batteries

Looking at EV (LCA) impacts, we must look at the full lifecycle. In Task 40, the focus has been on the impacts of the battery materials and manufacturing, the impacts of BEVs in use and the impacts of recycling of the batteries.

Within this analysis, GHG and energy demand have been studied in detail. Existing LCA studies and expertise of Task participants has been used. An important attention point for future work is the harmonization of methodologies in existing CRM-LCA studies to better compare results. As EV batteries and EVs evolve and improve rapidly it is important to take these future developments into account through LCA scenario studies.

GHG EMISSIONS FROM BATTERY MATERIALS AND MANUFACTURING

For Li-ion batteries, most of the GHG emissions come from the materials used. In Figure 3, the GHG emissions for battery material production and the battery manufacturing are detailed for the "low emission" Norway and the "high emission" China situation. Battery manufacturing accounts for about 20% of the GHG emissions. For mined materials, global values are used. Nickel, for example in the NMC811 battery pack has an emission of about 5.4 kg CO2 per kWh. A shift in nickel sourcing to Indonesian NPI (Nickel Pig Iron) would increase this nickel related emission 3 to 10-fold. Cathode paste and aluminum (for casing) represent the highest impact materials for batteries. LFP has the lowest GHG emission per kWh.

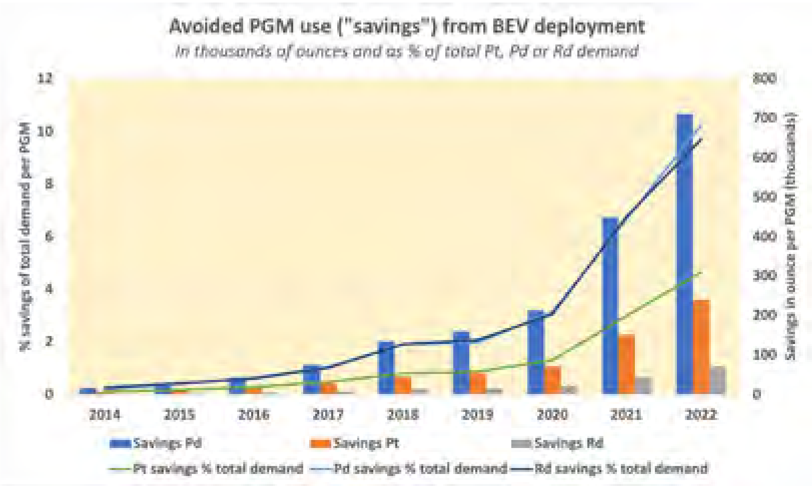

Figure 3: GHG emissions for Li-ion battery manufacturing comparing the 2020 Norway electricity grid (21 g CO2/ kWh) and China electricity grid (756 g CO2/kWh) impacts for intermediate production, battery manufacturing and recycling (credits).

Continuous improvements of EVs and Li-ion batteries

Li-ion battery and EV technologies develop very rapidly and in general with a trend which reduces the lifecycle impacts. Less materials used, replacing scarce materials with more abundant materials, simpler manufacturing processes and larger scale manufacturing, more efficient electronics and drive motors are examples of these developments. Also, the increased use of renewable energy in manufacturing processes and in the use of EV and better recycling contributes to the reduction of impacts. The impacts of these developments reinforce each other in many cases. Some examples of (partly already achieved) developments are given below.

Battery energy densities are increasing rapidly, for example for the Tesla Model Y from China using LFP chemistry 125Wh (watt hour) per kg batteries from CATL are being used (as of 2021). For 2023, an increase to 160Wh per kg is announced. CATL announced a LMFP variant increasing a further 15 to 20% on this. As of 2023, production of the Qilin NMC batteries, with a density of 255Wh per kg has started. Best in class energy densities at pack level were 100Wh per kg in 2015 and 200Wh per kg in 2020.

Battery lifetimes x10: EV batteries are in general guaranteed to maintain as a minimum 70% of charge for 8 years or 100,000 km of service. The actual performance is better. However, "1 million mile" batteries are developed (even 2 or 4 million miles), which means that a significant increase well beyond the vehicle lifetime will happen.

Energy use -50%: The Mercedes-Benz VISION EQXX is how we imagine the future of electric cars. Just one-and-a-half years ago, we started this project leading to the most efficient Mercedes-Benz ever built—with an outstanding energy consumption of less than 10 kWh per 100 kilometers. It has a range of more than 1,000 kilometers on a single charge using a battery that would fit even into a compact vehicle (Chairman of the Board, Daimler, 2022). This is about half of what comparable BEVs in 2022 realize.

Next to these performance improvements, gains are made in terms of more efficient manufacturing processes for batteries and vehicles, as well as the use of renewable energy in manufacturing processes and for the use of EVs.

Rare earth elements for EV (drive motors)

Electromotors for propulsion are currently almost exclusively based on permanent magnets (PM) motors (a publication of 2021 mentioned 93%) containing rare earths. The most notable non-PM motor being used is the induction motor in the earlier Tesla model S and X. PM-based motors offer a slightly higher efficiency. As the supply dependence and uncertainty of rare earths is high, much research goes into the rare earth free motors. CRM4EV scenarios indicate clearly that a continuation of the current REE-based drive motors for EVs is not sustainable. Tesla announced in 2023 its ambition to eliminate all rare earths from its next generation PM motors. For this next generation drive units, Tesla states: "Lower Cost & Higher Efficiency Drive Units Using Zero Rare Earths" (Tesla investor day 2023).

The rare earths used are Neodymium (Nd) and Praseodymium (Pr) for the magnetic performance and Dysprosium in small quantities for the temperature stability. Per PEV, 2.5kg PM is required on average for the e-drive motor is assumed (quantity depending on motor power); currently containing 27% Nd/Pr and 3% Dy for a total of 0.75kg.

For EVs, it can be stated that the PM-based motor is the preferred option in 2022, but that if needed alternatives exist. A lack of rare earths (for PMs) will not hinder substantially the transition to electric drive. In addition, future drive units without rare earths may be lower in cost and higher in efficiency. Tesla announced as much for its future generation drive motor at the Tesla Investor Day 2023.

Complete Transition to BEV will reduce 60% of the net Platinum Group Metals demand

The platinum group metals (PGM), Palladium (Pd) and Platinum (Pt), and Rhodium (Rh), are used in conventional combustion engine cars, hybrid cars, PHEVs and in the fuel cells of FCEVs.

Typical uses of PGM per car (sources Fraunhofer, Nornickel) are 2 to 6 grams in combustion engine cars. For commercial vehicles (diesel) they use catalytic convertors require 6-30 grams PGM per vehicle. The global use of PGMs in new vehicles (4 wheels or more) with a combustion engine was on average 3.8 grams per vehicle in 2018 globally. With declining diesel car sales, there is also a shift towards higher palladium content autocatalysis which is more effective for gasoline cars.

Of the net global demand (gross demand-recycling) of palladium and rhodium, 80% is used for autocatalysis. For platinum, this is 30% and for the PGM 60% (Figure 4). More than 80% of the recycled PGMs come from autocatalysts and recycling represents about one third of the total supply.

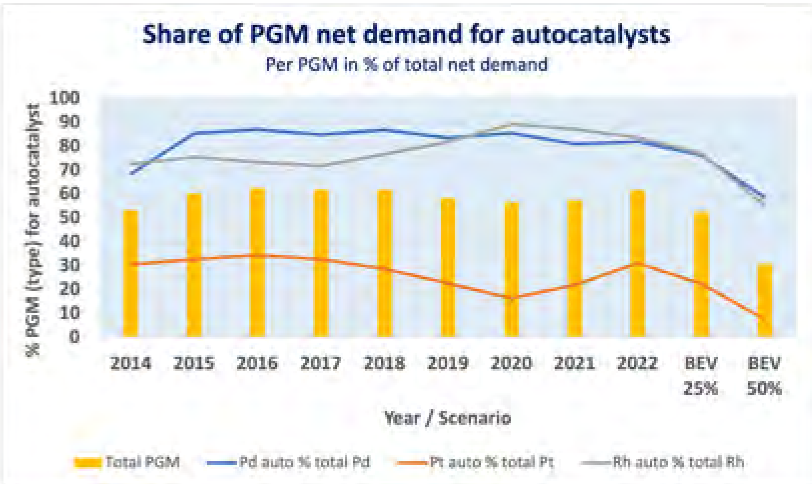

Figure 4: Percentage of the PGMs used for autocatalysis as % of the total net demand for each PGM.

IMPACT OF BEV DEPLOYMENT ON THE NET PGM DEMAND

In Figure 5, the calculated savings from actual BEV deployment is provided in ounces, as well as percentage for the different PGM. It presumes that one BEV avoids one ICE car, with an average PGM content of 3.8 grams per car. With 80% of palladium and rhodium used for autocatalysts, the impact is already significant.

In Figure 6, 3 scenarios are presented with 25%, 50% and 100% BEV market share for new vehicles (4 wheels or more). If this transition happens within 15 to 20 years, the recycling of autocatalysts will still be at or near today's levels assuming a catalyst lifetime of about 15 years. In the extreme case of a rapid 100% transition, the vehicle sector could become a net PGM supply. For palladium and rhodium, no mining would be required for several years and then level off at about 10% of the 2022 volume of 7 million ounce, assuming no changes in other uses. As palladium is mainly used for (gasoline) cars, a rapid decline scenario is realistic. In the same 100% scenario (around 2035-2040), platinum net demand could be reduced by 60-70%, to rebound back to around 70% of the 2022 net demand of 5 million ounces.

Figure 5: Impact of global BEV sales on the demand for PGMs for autocatalysis. Scenario in which one new BEV avoids one average car containing 3.8 gram of PGM

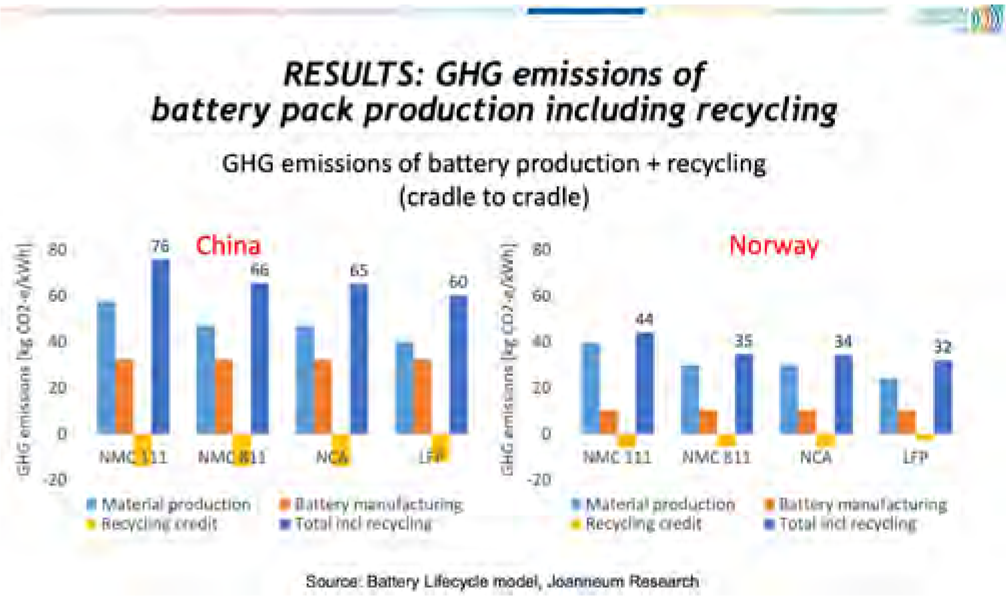

Figure 6: PGM demand for new vehicles and the recovery of PGM through recycling of end-of-life autocatalysis. Years 2014 – 2022 + BEV deployment scenarios 25% / 50% / 100%.

Summary of 2030 scenarios CRM4EV baseline 2021 EV sales IEA SDS 2021 - GBA 2020		Units	30% growth CRM4EV	40% growth CRM4EV	50% growth CRM4EV	GBA base	GBA target	EV30@30 midpoint	IEA STEPS	IEA SDS	BNEF	Road transport 100% electric "COP 21"
Batteries GWh												
	For transport	GWh	4277	7770	8905	2332	3389	2651	1490	2980	1322	10230
	Total for EV, ESS & CE	GWh	4567	8060	9195	2622	3679	2941	1687	3305	1612	10520
	Li-ion for transport	%	*94*	*96*	*97*	*89*	*92*	*90*	*88*	*90*	*82*	*97*
Mineral demand (CRM4EV modelling & scenario data)												
Nickel	High nickel	kton	2168	3910	4400	1003	1398	1365	767	1463	706	4924
	Ni demand external scenarios	kton				1061	1584		657	1584		
	50% LFP / High Ni / High Mn	kton	754	1300	1401							1487
	90% LFP / 10% High Ni	kton	232	355	409							484
Cobalt	High nickel	kton	352	639	719	191	274	220	129	251	111	805
	Co demand external scenarios	kton				214	290		109	263		
	50% LFP / High Ni / High Mn	kton	210	383	411							427
	90% LFP / 10% High Ni	kton	53	90	102							116
Lithium	All CRM4EV Li-ion scenarios	kton	516	911	1039	243	330	332	177	346	182	1189
	Li demand external scenarios	kton				164	378		164	378		

43 Vehicle-Grid Integration

Task 43 Task Manager

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STATUS
Ongoing

COUNTRIES
Spain
Switzerland
Republic of Korea
The Netherlands
Germany
France
Denmark
Italy
Canada
Belgium

Task 43 looks to investigate the means for facing the technical, economic, regulatory and social challenges of vehicle-grid integration.

The whole VGI value chain is considered in this process including power system operators, power electronics industry stakeholders, the most relevant original equipment manufacturers (OEMs), EV fleet and infrastructure operators and the end-user.

Task 43 focuses on the challenges identified in the following categories: charging technology and standards, infrastructure planning, electricity markets, technology development and user engagement—both in terms of exploring, identifying and giving answers to the gaps preventing the electric vehicles to be fully integrated in the electrical grid and improving the joint work between electric sector and mobility sector, which is a key point for the real energy transition. The scope and basic approach of Task 43 includes the analysis of all VGI aspects by means of expert workshop meetings with stakeholders involved in each of the identified gaps, cooperation between different sectors to find global solutions to overcome gaps and barriers, and interaction with other tasks within the TCP (batteries, EV consumers and interoperability) and in others TCPs (PV-EV, flexibility for buildings).

The goal of Task 43 in the coming years is to use the expected results both for policymakers and industrial partners to promote VGI worldwide. Furthermore, the gained knowledge and results of such investigations can be integrated into the market research and business modelling carried out by the different actors in the worldwide EV market.

UPDATES FROM 2022

With the objective of producing knowledge exchange workshops, a free and accessible database of VGI/V2G projects, tangible and targeted support for governments and standards agencies (position papers), publications and participation in related events, and support of collaboration and projects between different stakeholders, such as DSO, TSO, OEM, regulators, Task 43 has continued to explore across vehicle grid integration topics such as:

- Distribution grid impacts of massive EV penetration
- Integration of renewable generation: PV and EV
- Peak demand reduction by means of EVs
- Vehicle-to-Grid
- Regulation issues
- Consumer economics
- EVSE controls and networks
- EVSE cybersecurity issues

From October 13-14, 2022, members met for a workshop in Barcelona. The topic was Energy markets and charging technology for V2X. V2X refers to vehicle-to-everything (V2X) - the concept that vehicles can provide bi-directional power flow, enabling them to charge and discharge the vehicle battery to meet a variety of needs including local needs, providing backup power, and improving electric grid operation. This workshop brought together a host of knowledgeable partners from industry, research organizations, and academia to discuss the current state-of-the-art and identify the challenges and opportunities of introducing bi-directional charging to vehicle-to-everything.

The workshop was separated into three panels including:

1. V2X charging technologies and preparedness
2. Previous roadmap, European projects and new priorities
3. Energy and Service Markets for V2X technologies

During this event, participants learned about ongoing V2G and V2X projects in Switzerland, Denmark, Spain and the Netherlands. Topic areas also included MW charging, user facility overview, as well as work in business models and data management as well as and market and fleet management.

Additionally, a brainstorming activity was run to develop a list of challenges to enabling more rapid and a greater implementation of V2X charging technologies. This included identification of the types of challenges (technical, social, economic, regulatory), a description of each challenge, the groups that can address this challenge, the timeframe over which it should be addressed, and any regional constraints. The ideas in the following table were identified as challenges for V2X technologies.

Table 1: Summarized output from brainstorming process

	The forecast of V2G DC charger cost	The decision between installing a DC or AC V2X charger	Interdependencies of the AC charger and the EV design requirements for V2X	Wear and cost impact on the EV from V2G	Ownership and access to data
Type of Challenge	Technical	Economic	Economic	Technical	Regulatory
Description	What is the price evolution of the EVSE?	What are the tradeoffs between different charging strategies related to V2X?	Which capabilities are provided by the EVSE, and which are provided by the EV?	How much will the EV equipment be used and what is the resulting impact?	Who can access the data related to providing V2G?
Group(s) that can address	EVSE manufacturers, researchers, regulators	OEMs, researchers, regulators	EVSE manufacturers, OEMs, regulators	Researchers	EVSE manufacturers, OEMs, regulators
Timeframe	Short-term	Medium-term	Medium-term	Short-term	Short-term
Regional constraints	-	-	-	-	Possible

NEXT STEPS

Two workshops are planned for this year—one in May and one in September. The workshop in May will focus on a Reevaluation of barriers to VGI. It will be used to explore the progress to meet barriers and remaining issues for VGI in a more general sense and provide a transversal look at the status of VGI projects. In order to leverage ongoing events, the workshop in September will be paired with Avere's E-Mobility conference (www.avere.org/avere-e-mobility-conference-aec/).

45 Electrified Roadways (E-Roads)

Task 45 Task Manager

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STATUS
Ongoing

COUNTRIES
USA
Norway
The Netherlands
Switzerland
Germany
Sweden
Israel
Austria
Canada

Task 45 is primarily an information gathering and research documentation effort, focused on the complimentary technologies, standards, and the various challenges and applications of Electrified Roadways (E-Roads) also called electrified roadway systems (ERS).

E-Roads are defined as a combination of road infrastructure and technologies which allow for a vehicle to receive power (electricity) from an off-board source while the vehicle is in motion. This task has a broad scope of technologies and system deployments and includes E-Roads applications for light duty vehicles (LDVs), as well as commercial and transit vehicles.

Working with international companies, academic institutions, laboratories, and agencies, the task looks to develop a greater global understanding and awareness of E-Roads, related deployment activities, and technologies developed to advance electric mobility. The task gathers information regarding national policy and the benefits/challenges related to E-Roads to gauge the global interest and commitment levels and move the focus of research towards efforts to solve the greatest challenges.

The task provides information critical for decision makers who are considering E-Roads deployments and educate stakeholders of the progress of the various technologies. Having had its official kick-off meeting in June of 2021, there are currently 8 countries who are formally participating in the task.

UPDATES FROM 2022

Task 45 has continued to conduct bi-annual meetings, which include viewing locations of E-Roads, research or deployment activities, to gain first-hand knowledge of how these technologies are progressing and to inform the HEV TCP of advancements in E-Roads. Based on information gathered from participating countries, specific topics have been identified as critical areas for further research. The member countries have continued to report on related technology or analysis findings regarding the effectiveness of deployments or advancements in relevant technologies or safety & standards development.

Canada has recently increased their activities in dynamic charging systems research and has begun the paperwork to join Task 45, which is expected to be completed in early 2023. Along with existing member countries, Switzerland, Norway, Netherlands, Germany, Sweden, Austria, Israel and the United States, Canada will investigate and support development in E-Roads technology as each member country build their case (both economic and sustainability) for E-Roads deployment.

Task 45 organized workshop #3 in June 2022, the first in-person workshop event. The meeting was hosted by Siemens at their former world headquarters in Berlin, Germany. The event included a technology tour and ride-along experience at Siemen's test facility in Gross Dölln, Germany.

Considering that there are other E-Roads activities in Europe, the task was fortunate to have four presentations from guest speakers during the workshop, in addition to the many presentations and discussions from member countries. The Berlin location and timing also allowed for a number of task members to join a separate Electrified Roadways Systems (ERS) project review and workshop immediately prior to the Task 45 event. This additional event brought new perspectives into the operating environment which will be required for deployment of E-Roads at scale. For example, in the United States, there is no current organization to combine power distribution and the many roadway safety regulations.

The workshop presentation topics were centered around various evaluations of an E-Roads system and the inputs required to properly deploy E-Roads which are larger than a pilot system. A consideration here is the grid capacity for dynamic charging and the time allotments for building additional power generation if required. This task continues to have monthly meetings as a form of data, reporting and event information exchange.

Figure 1 shows the type of SCANIA hybrid truck, which connects to the Siemens' eHighway system. A prototype was available for attendees to ride in and experience grid-connected charging in motion.

Figure 1: The type of SCANIA hybrid truck which connects to the Siemens' eHighway system.

NEXT STEPS

The planning for the fourth workshop was completed in 2022. This workshop will be held in the United States in conjunction with the bi-annual Conference for Electric Vehicles and Roads (CERV) in Utah in February (For more information: https://cervconference.org/).

The fourth workshop will be a hybrid event, with many of the European members likely attending virtually. The technology tour and review of E-Roads projects at the Aspire center on the Utah State campus will be for in-person attendees only. The task also plans to have the fifth workshop in 2023 but will look to extend the task into 2024 for the date of the final workshop and project report. The location and timing for the fifth workshop has yet to be determined. Updates to the E-Roads deployment lists and standards activities will be the focus of some activity for Task 45 in 2023, and related topics will be covered during the fifth workshop.

The four Technologies of Interest (TOI)s which Task 45 will continue to focus on are:

- Dynamic Wireless Power Transfer (DWPT)
- Non-road Conductive (Overhead), which is separated into two sub-categories
- Non-road Conductive (Side)
- In-road Conductive

The inventory of pilot deployments of E-roads continues to expand and the interoperability for the technology between vehicle classes and throughout international deployments are key focus topics of the project.

46 LCA of Electric Trucks, Buses, 2-Wheelers and other Vehicles

Task 46 Task Manager

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STATUS
Ongoing

COUNTRIES
Austria
Canada
Germany
Norway
Republic of Korea
Switzerland
Spain
UK
USA

ACKNOWLEDGEMENT
The work of the Austrian participation and task management (2022–2024) is financed by the Austrian Climate and Energy Fund and the FFG.

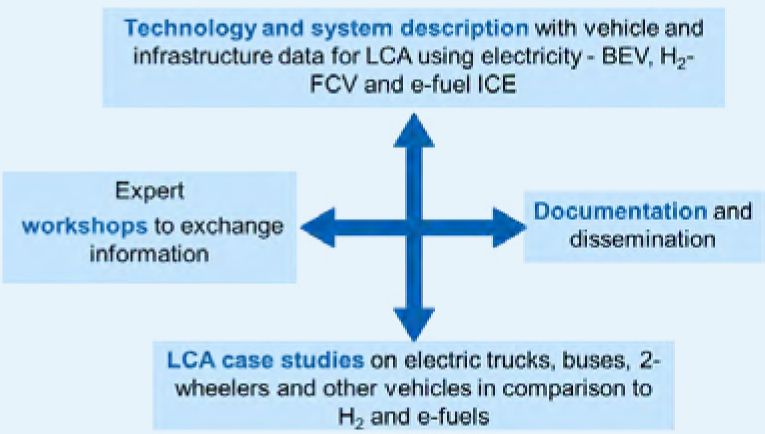
The IEA HEV TCP Task 46 (2022–2024) "LCA of electric Trucks, Buses, 2-Wheelers and other Vehicles" started in January 2022.

Executed in close cooperation with Task 64 "E-fuels and End-use Perspective" of the TCP on Alternative Motor Fuels (AMF), through Task 46, methodologies are developed to help countries implement EVs by identifying possibilities to maximize the environmental benefits. Various case studies are analyzed and networking, combined with information exchange, is supported within the Task's frames.

In recent Tasks 19 and 30, there was a strong focus on LCA of passenger vehicles and its comparison to gasoline and diesel vehicles. However, due to the strong development and market introduction of other battery electric vehicles (BEV), Task 46 task will focus on LCA of other BEVs than passenger cars and will also compare the environmental effects it to other fuels made from electricity like hydrogen and e-fuels. These are hydrogen fuel cell vehicles (H2-FCV) and internal combustion engines using e-fuels (e-fuel ICE).

By assessing climate neutrality and circularity from a LCA perspective and methodology, Task 46 looks to continue to identify the R&D demand for LCA comparison between renewable hydrogen, e-fuel systems, and conventional fuels.

Figure 1: Main objectives of Task 46



UPDATES FROM 2022

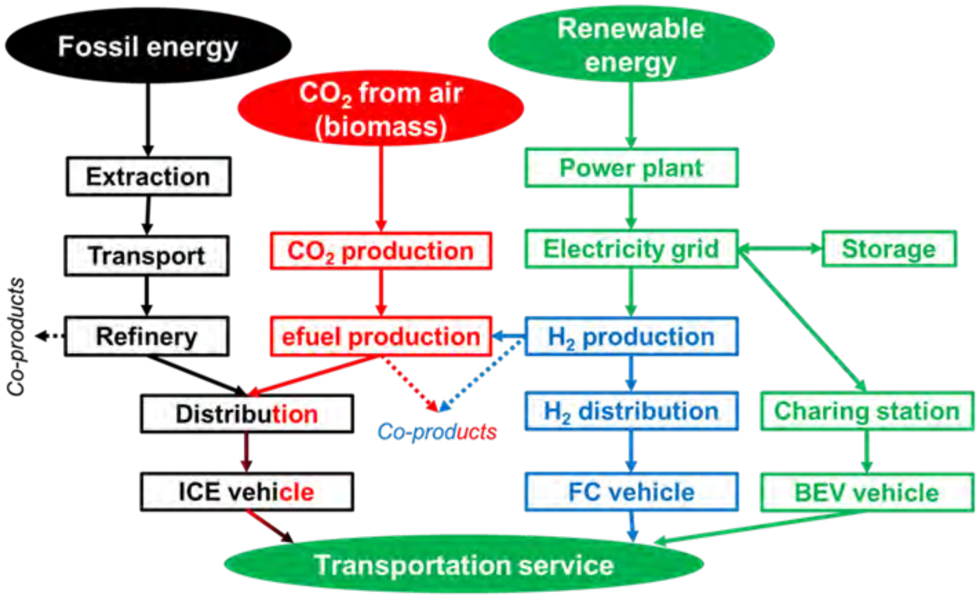
The Task proceeds by organizing a series of expert workshops covering the objectives described above, with a focus on:

- LCA of e-Trucks
- LCA of e-Buses
- LCA of e-2-Wheelers and other e-Vehicles

The results from the first year include:

- Expert workshop "Environmental Effects of Trucks – Towards Climate Neutrality and Circularity," held in October 2022
- Initial definition on climate neutrality
- Initial ideas on a circularity index and its application
- Starting of a case study on LCA of e-trucks and
- Dissemination activities.

Figure 2: LCA comparison to renewable hydrogen, e-fuel systems and conventional fuels



Expert workshop

The aim of the expert workshop "Environmental Effects of Trucks – Towards Climate Neutrality and Circularity" in October 2022 was to analyze, assess and discuss the environmental effects of trucks with different propulsion systems based on LCA.

The results on the key issues in LCA of trucks are:

- **Key parameters determining LCA:**
  - Lifetime of battery and truck
  - Battery capacity and range
  - Battery production
  - Energy demand for different driving cycles with different loads
  - Size of truck and specification
  - Type of electricity: additional renewable electricity needed
  - Functional units used: per t-km, per km and per total lifetime

- Recycling/reuse of batteries
- Charging strategies

- **Generalized current LCA results:**
  - Electric trucks have lower impacts if renewable electricity is used than H2-fuel cell, ICE with e-fuels and ICE (with diesel and CNG) trucks due to the high overall energy efficiency
  - Catenary battery electric vehicles (BEV-ERS) might have the lowest impacts
  - Relative advantages in the LCA of the BEV decrease with increasing vehicle (and battery) size
  - Urban delivery with e-trucks creates significant environmental benefits
  - Currently the main focus is on GHG emissions and primary energy demand

- **Further needs:**
  - Improved datasets on key raw materials: virgin/primary and recycled/ secondary
  - Understanding how further improvements to upstream processes/raw materials production might contribute
  - Improvements to the assessment of novel low-carbon fuels/production pathways, especially e-fuels
  - Methodological considerations for contributions by LCA to assessing climate neutrality and circularity

In the workshop there was a focus on a number of issues in group work, including LCA and climate neutrality; LCA and circularity; and LCA and e-fuels.

INITIAL DEFINITION OF CLIMATE NEUTRALITY

An initial definition of climate neutrality is the point at which human activities cause no changes to global temperature. Achieving such a state would require balancing of residual emissions with emissions (carbon dioxide) removal, as well as accounting for regional or local biogeophysical effects of human activities that, for example, affect surface albedo or local climate (IPPC).

Products and services are considered “climate neutral,” if in the total lifecycle no GHG emissions (CO_2, CH_4, N_2O, SF_6, FCKW, etc.) occur. “CO_2 neutral” only covers CO_2 emissions.

The definition of “Net Zero” is when the remaining and/or unavoidable GHG emissions are compensated permanently, e.g. CO_2-fixation and CO_2-storage by CCS (Carbon Capture & Storage) and/or CCU (Carbon Capture & Utilization). Within this, the timing of GHG emissions is essential and must be considered as such.

The aspects of climate neutrality can be addressed through a dynamic life cycle assessment (dyLCA), where the relevant GHG emissions are cumulated over time. Austria has already developed scenarios for a climate neutral transportation sector by applying dynamic life cycle assessment to the total existing vehicle fleet and its future possible development.

INITIAL IDEAS ON A CIRCULARITY INDEX

The following initial aspects were identified to be relevant for circularity and LCA of vehicles:

- Lifetime and durability
- Exchange and/or reparability of parts
- Reuse of parts
- Recycling of materials to
  - Same quality as primary material (Qin = Qout at point of substitution)
  - Lower quality as primary material (Qout/Qin < 1)
  - Composting of biological degradable materials
  - Energy recovery of heating value of materials to power, heat or fuels (e.g. quality of energy: exergyout/exergyin)
- Losses and disposal/landfill

Circularity is based on LCI: reuse + recycling + composting + energy recovery ≤1. LCA and dynamic LCA can address and assess circularity by using the already existing data from the life cycle inventory (LCI).

The Circularity Index should be an additional indicator for LCA not covered yet by well known existing impact categories. A useful example of this is the Material Circularity Indicator, based on the work of the Ellen MacArthur Foundation in 2015.

In Figure 3, the possible concept of a circularity index based on LCI of vehicles is shown, an indicator of 1 means a 100% circularity and 0 means linear non-circularity. Of course reuse and recycling contribute to a high degree of circularity, whereas disposal and energy recovery do not.

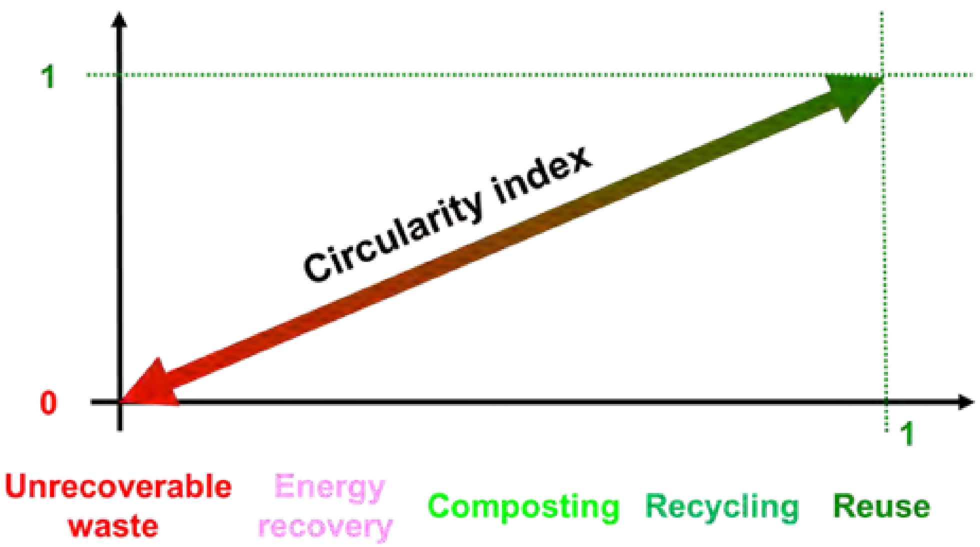


Figure 3: Concept of a circularity index based on LCI of vehicles

Based on this concept, Figure 4 shows the scheme of LCI of a vehicle to assess circularity over time covering virgin material, recycled material, reused material, energy recovery and composting over the lifetime. The circularity index is calculated mainly based on the used and recovered amount of recycled material and reused components.

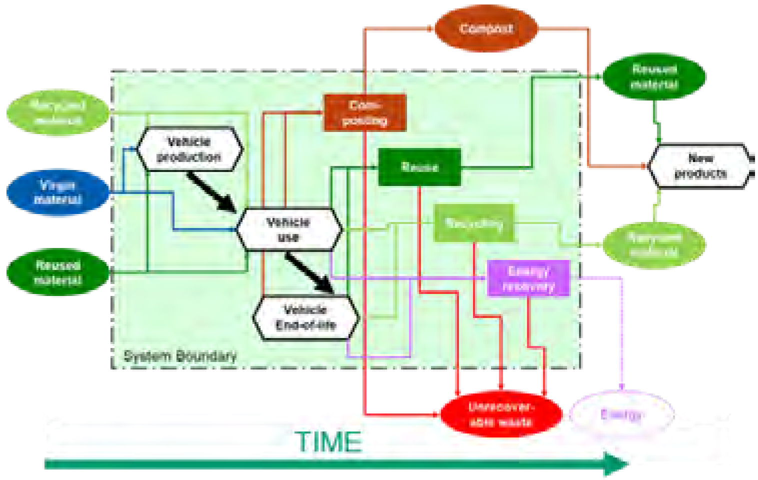


Figure 4: Scheme of LCI of a vehicle to assess circularity over time covering virgin material, recycled material, reused material, energy recovery and composting

In Figure 5, an initial example of applying the circularity index to ICE vehicles and BEV with the components of recycling and reuse of batteries shown. The circularity index is calculated using existing LCI data of ICE and BEV and applying the formula of the material circularity indicator from the Ellen MacArthur Foundation. The indicator is applied to the complete materials in the vehicles and also for the different main materials of the BEV.

This initial assessment already shows that the circularity index might be an additional indicator beside the other impact categories to assess circularity. As expected, steel and aluminum have a higher material circularity index than cobalt, lithium or graphite. The circularity index of an ICE might currently be higher than of a BEV, due to the current recycling possibilities of the battery. It becomes evident that using the second life of a battery in a stationary application increases the circularity due to reuse of a vehicle component.

Based on this initial approach, Task 46 will further develop a possible indicator for circularity, in terms of both its possible practical application but also its limitations.

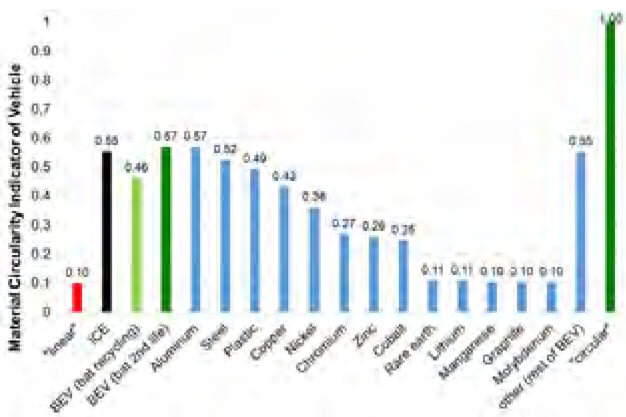


Figure 5: Initial example of applying the circularity index to ICE vehicles and BEV with recycling and reuse of batteries and its components

Case study on LCA of e-trucks

The Task will perform a LCA case study on trucks. The specialties and further LCA developments of this case study are identified and will be developed further.

In terms of electricity mix, initial focus will be on the renewable electricity mix (i.e. PV, wind, and hydro), and how the installation of additional renewable electricity generation may occur in the "production phase" of trucks, reflecting different lifetimes. Alongside consideration of infrastructure for charging and catenary lines, there will be additional consideration of the changing dynamics for the national electricity mix between 2022–2030 during the lifetime of a truck (5–6 years).

Assessment will consist of initial reflection on "climate neutrality" (GWP=0!), initial ideas of testing on "circularity," GWP of direct H2 emissions, and identification of the significant differences between electricity, hydrogen, and e-fuels. Presented results in ranges will include discussion of definition/setting of estimated ranges, focusing on the significant differences and testing of communication for estimated ranges.

The resulting case study will aim to identify significant differences of environmental effects of trucks with different propulsion system/fuel for the current (2023) and future state (2030 and beyond) of technology. The methodology of dynamic life cycle assessment will use generic global production data for materials, in order to provide specification of technology and systems with:

- Trucks: N1 (< 3.5t), N2 (3.5t > 12t) and N3 (< 16t), for example delivery trucks and heavy long-haul trucks among others

- Charging strategies, user profiles covered by typical driving cycles (weighting of urban rural and highway driving)

With sensitivity on country-specific electricity mixes in 2022, the fuels that will be considered span:

- Diesel
- e-diesel from renewable electricity mix and CO2 from
    - air
    - concrete/steel production (if foreground data available)
    - waste (if foreground data available)
- H2 with FC from renewable electricity mix: GH2 @ 700 bar and LH2
- Electricity for BEV and Catenary truck:
- Renewable electricity mix: 50% wind, 25% hydro and 25% PV
- CNG and e-CNG (if foreground data available)
- e-MeOH with FC

The functional units that will be utilized are per truck-km and per t-km. The countries which will be explored include HEV TCP member countries Austria, Canada, Switzerland, Germany, Spain, Norway, Republic of Korea, Turkey, the United Kingdom, and the United States. Members of the Advanced Motor Fuels (AMF) TCP: Japan, Brazil, and the Cote d'Ivoire, as well as EU 27 countries will be explored. Either average or specified countries within Africa and South America will also be considered.

The leading impacts looking to be addressed include:

- GWP (and perspectives towards climate neutrality)
- Primary energy demand
- Key raw materials for trucks: LCI, abiotic depletion potential, scarcity
- local emissions: NOx and PM (focus on stack emissions of ICEs if foreground data available)
- Circularity (testing of ideas)

These impacts are to be based on WtW of Heavy Duty Vehicle Evaluation from IEA TCP-HEV Task41 & AMF Annex 57, as well as LCI data from Argonne for vehicle production and EoL, e.g. material mix of components.

With an expected finalizing date of the end of 2023, the Task's documentation outputs include a slide show and summary document.

Figure 6: Model of charging e-trucks

Dissemination activities

The following presentations have been made by the task manager, and are available upon request:

- Climate Neutrality of Growing Electric Vehicles Fleets (2010 - 2050) in a Dynamic LCA Considering Additional Renewable Electricity: Example Austria; EVS35 Symposium June 11-15, 2022, Oslo, Norway.

- Diesel, Wasserstoff, Strom oder doch E-Fuels? – Umweltbewertung von PKWs im Lebenszyklus, 15. Münchner Gespräche, 21. Juli 2022

- Climate Neutral Mobility in Austria—Methods, Facts and Myths; 5. Europäisches Forum Alpbach 2022, Kreislauffähige und klimaneutrale Mobilität - Herausforderungen und Lösungen am Beispiel Fahrzeug, 26 August, 2022, Alpbach, Austria.

- How Ecological Electric Vehicles Really Are?—Lessons Learnt in IEA HEV Task 30 & 46, Ninth E-mobility Symposium, October 18–20, 2022, Belgrade, Serbia.

- LCA Approaches and Circular Economy to Enhance Sustainability of Mobility Solutions, including Tendering Process, Strategic Session 4.1 – TRA2022, November 14 -17, 2022, Lisbon, Portugal.
- Towards Climate Neutrality and Circularity–The Case of e-Trucks in Austria 2040+, A3PS ecomobility conference, Vienna, November 24–25, 2022, Vienna, Austria.
- The Possible Role of Electricity and Biofuels in A Climate Neutral Transportation Sector in Austria, Central European Biomass Conference, January 18–20, 2023, Graz, Austria.
- Climate Neutrality and Circularity – Current Knowledge and Future Perspectives on Battery Electric Vehicles, IEWT2023, February 15-17, 2023, Vienna, Austria.
- Climate Neutrality – Method of Dynamic LCA and its Application to the Austrian Transport Sector, CCCA-Klimatag, April 11–13, 2023, Leoben, Austria.

NEXT STEPS

The task will perform, present and discuss the LCA Case Study on e-trucks.

The task will organize the next expert workshop "Environmental Impacts of Buses – Aspects of Climate Neutrality and Circularity" in autumn 2023. The aim of this workshop is to analyze, assess and discuss the environmental effects of buses with different propulsion systems based on LCA. The workshop will be split into presentations and group work on:

- Identification of Key Issues on LCA of buses
- Assessment of Climate Neutrality in LCA
- Assessment of Circularity aspects in LCA

Figure 7: e-bus charging in Oslo/Norway

48 Battery Swapping

Task 48 Task Manager

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STATUS
Ongoing

COUNTRIES
China
Germany
Italy
Sweden

In 2021, the HEV TCP Executive Committee officially confirmed the establishment of the "Battery Swapping" task group, with China as the initiator and Botree Cycling taking charge of its implementation—becoming the 48th HEV TCP task: Battery Swapping.

With the main objective of investigating the influences of battery swapping employment on battery chemistry, grid infrastructure, environment, and business model, Task 48 focuses on the research and communication on the technology, application, standard and business model of battery swapping, analyzing battery assets whole life cycle management, and battery swapping technology evolution, while also shining light on the above-mentioned arguments. Through collaboration with existing task groups, establishing a project work group, and organizing international meetings, the Task covers battery swapping in the segments of two/three-wheelers, passenger cars, commercial vehicles, and ships.

Full promotion of battery swapping in the future still needs to leverage on the continuous exploration and breakthrough of battery technology, power grid facilities, and battery swapping business models. Therefore, the main purpose of task 48 is to study the impact of battery materials, grid infrastructure, environment, and business models on battery swapping technology—enhancing the global exchange of information on battery swapping technology, helping develop an ecosystem and traceability mechanism for battery swapping, and providing recommendations for policymakers and stakeholders.

UPDATES FROM 2022

Task 48 has continued to promote cooperative demonstration projects among member countries to exhibit the development of battery swapping technology and commercial operation models.

The task manager has committed to organizing two conferences (one in summer and one in winter) per year with each conference lasting for 1-3 days. The conference can be held in different member countries each time, to facilitate technical demonstrations and plant visits.

On March 22,2022, Task 48 held the kick-off meeting for Task 48. The theme of the meeting was the application of battery swapping technology in different scenarios. Participants include Botree Cycling, IEA HEV TCP Task 40, the Institute for Ecological Economy Research (IOW), Piaggio Group and The Swedish National Road and Transport research Institute (VTI). Mirattery from China also participated as an intended participant.

Figure 1: Task 48 diagram

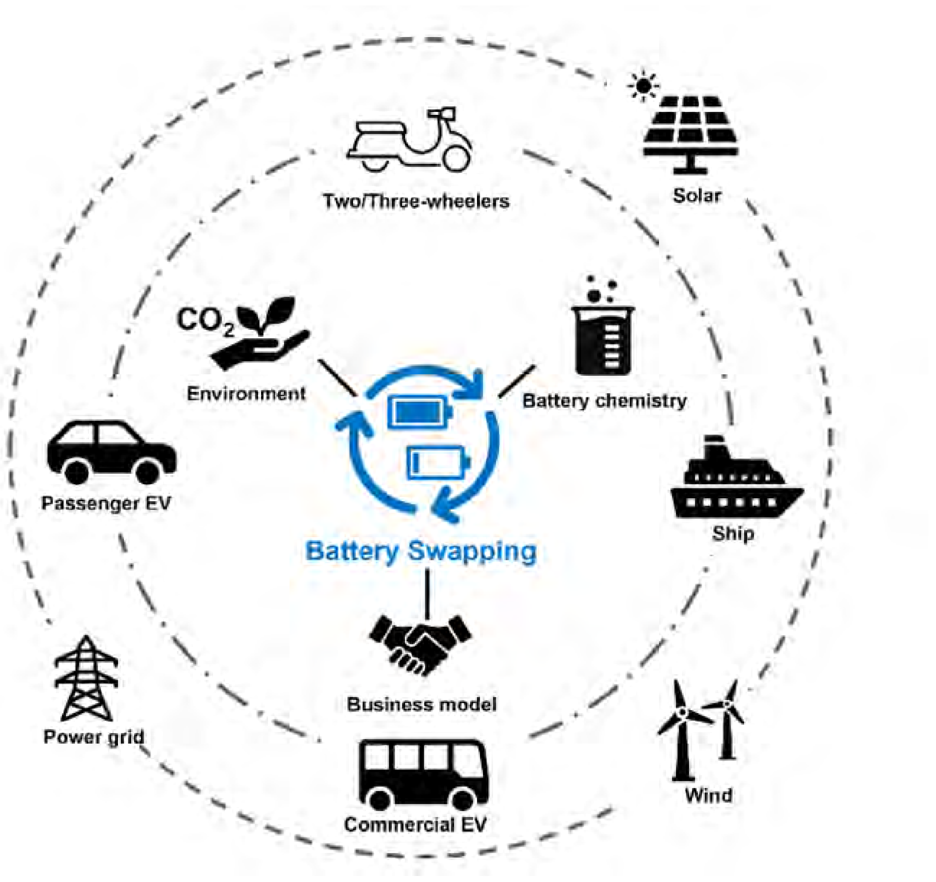

Figure 2: Task 48 member institutions

On April 29, 2022, Dr. Xiao Lin, as the Task Manager of Task 48, attended the final meeting of the Task 40 CRM4EV. CRM4EV was established to assess the impact of largescale use of electric vehicles on key raw materials and to evaluate the current and future availability of these materials, to explore how to plan for the most likely scenarios to balance supply and demand, to overcome environmental and social challenges, and to achieve positive improvements, with end-of-life power battery recycling being one of the key directions of the working group's work.

On June 1, 2022, Task 48 members attended a seminar on "Technology, Application and Business Model of electric Replacement Heavy Truck," which was jointly held by China EV100 and Swiss-China Transportation Electrification Academic Cooperation Platform Project. More than 200 participants were invited to the conference, including representatives from relevant government departments, industry experts, and representatives from domestic enterprises such as Guodian, GCL, Aodin, Star, Sany, Foton and Public Railway Green Chain. The meeting focused on the current development status, practical experience, and cooperation opportunities between China and Sweden in the field of swappable heavy trucks. Mr. Zhang Yongwei, the Vice Chairman and Secretary General of China EV100, and Mr. Jan Pettersson, Director General of Transport Electrification Bureau, Ministry of Transport of Sweden, delivered speeches on behalf of China and Sweden respectively.

On September 21, 2022, the routine workshop of IEA HEV TCP Task 48 Battery Swapping was organized in the form of an online meeting. This webinar focused on the latest information exchange in battery swapping technology and related industries. The members of the seminar included: Suzhou Botree Cycling Technology Co., Ltd, German Institute of Ecological Economics, Italian Piaggio Group, and Swedish Road Traffic Research Institute. In addition, industry experts from the China Electric Heavy Truck Battery Swapping Industry Promotion Alliance and the China Automotive Technology and Research Center Co. Ltd. also participated in the seminar.

On March 30, 2023, Task 48 organized a workshop event on “Battery swapping in electric two and three wheelers.” In addition to existing members, some new and well-known institutions in the industry also made a speech at the workshop, including Immotor (CN), Biliti Electric (USA), Zhizu (CN), Phylion (CN),Vammo (Brazil) and Swap (Indonesia). The workshop has attracted more than 40 audience members from China, UK, Norway, Korea, Italy, and Germany.

Figure 3: Workshop speakers

NEXT STEPS

In addition to electric two and three wheelers, battery swapping is now also widely used in cars and heavy-duty segment vehicles including trucks, buses, and construction vehicles.

Battery swapping is likely to be a critical enabler for electrification, not just in cars, but micromobility, rideshare fleets, autonomous vehicles and heavy-duty commercial fleets. It may also be one of the most economical ways to build the large stationary energy storage necessary to support the world's growing supplies of renewable energy.

Task 48 will also discuss domestic and international progress, standards of battery swapping in Commercial vehicles, Passenger EV, Maritime and aircraft applications. Three successive workshops on battery swapping are prepared by each quarter for the rest of 2023:

1. June 2023: Battery Swapping in Commercial vehicles

2. September 2023: Battery Swapping in Passenger EV

3. December 2023: Battery Swapping in Maritime and aircraft applications

49 EV Fire Safety

Task 49 Task Manager

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STATUS
Ongoing

COUNTRIES
Austria
Belgium
Italy
Norway
South Korea
The Netherlands
UK

In October 2022, a new task was approved on the topic of "EV Fire Safety." Having started in January 2023, the new task will run for 3 years.

Task 49 "EV Fire Safety" was initiated by Belgium, with the following countries having joined in the meantime: Austria, Italy, Norway, South Korea, The Netherlands, UK.

OBJECTIVES

Task 49 on "EV Fire Safety" has been initiated due to the fact that, although we see a growing interest in electric mobility from policy makers, companies and end users, there is still some lack of trust in the safety aspects of electric vehicles. Task 49 aims to collect and share objective information across different EV fire safety-related aspects, in an effort to increase overall trust in electric vehicles.

Task 49 will collect statistics on EV fire incidents, considering that risk assessments based on limited statistics could lead to too negative of a perception of EV fire safety risks, hampering the rollout of EVs and charging infrastructure in various settings, such as underground parking locations. Task 49 will stimulate knowledge exchange on EV fire safety aspects by sharing experiences between country experts to increase insights in EV fire safety risks and to share best practices in preventing or mitigating EV fire incidents (from a technological and regulatory perspective).

Task 49's target groups range from building and parking owners, OEMs (vehicles and charging infrastructure), fire rescue workers, transport and tow companies, insurance companies, policy makers, regulations, up to the EV drivers and general public.

WORKING METHOD

Task 49 will organize 5 online workshops on "EV Fire Safety" related topics to share and discuss collected information and best practice. Before defining the specific workshop topics, Task 49 will set up a database of expert and stakeholders from the participating countries to start with mapping the existing initiatives, working groups, and available information on "EV Fire Safety" aspects in each participating country.

The exact workshop topics will be decided upon in consultation with all participating countries and will focus on topics of the highest interest and/or on which there is the biggest benefit of sharing experiences between countries. Potential workshop topics are: "EV fire incident statistics," impact of electric vehicles on "Parking fire safety regulations," on "Insurances," "Fire rescue workers procedures," "Removal and after-treatment of damaged electric vehicles," among others.

A general overview of Task 49's work program is as follows:

- **Task 1:** Collection of information, including through desktop research, interviews, and conferences.
- **Task 2:** Development of a stakeholders database, helping define the roles of task working group and stakeholders' participation.
- **Task 3:** Collaboration with related IEA HEV TCP tasks, exploring possible links with ongoing tasks from their specific expertise, for example on the vehicle side (LEV, trucks, buses, marine, etc.), on batteries, or on charging infrastructure (extreme fast charging, battery swapping, etc.).
- **Task 4:** Organization of 5 online workshops on selected topics, consulting with all participating countries to prioritize ideas.
- **Task 5:** Dissemination of HEV TCP annual reports, newsletters, and conference participation
- **Task 6:** Task Management

50 Light Electric Vehicles

Task 50 Task Manager

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STATUS
Ongoing

COUNTRIES
Germany
France
Republic of Korea

This new task, beginning in 2023, aims to support the diffusion of Light Electric Vehicles (LEVs), in order to exploit their potential for more sustainable mobility, which in order to be successfully realized, requires a higher acceptance of LEVs. Improvements in technologies, use frameworks, and/or the availability to buy or rent LEVs could increase user acceptance.

Task 50 intends to contribute to this by collecting and sharing information, exchanging framing conditions, best practices and ideas, considering LEVs in the context of urbanization, ageing societies and energy transition.

Vehicles considered in the task are three- and four-wheel LEVs which are either classified as L-category vehicles, Kei cars or Microcars. Light EVs (M1) approximating the properties of class L7e might also be considered.

Despite a great potential for reshaping urban space and reducing greenhouse gas emissions by replacing a significant portion of car trips [1], LEVs are still a niche topic. A preceding Task 32 addressed this issue, by working on greater awareness and bringing together expert knowledge. This was also accomplished through the publication of a book on LEVs [2], which has been downloaded over 43,000 times. Light vehicles have been receiving more attention for some time now, but we are still a long way from realizing their substantial potential in terms of saving energy and greenhouse gas emissions, as well as reducing material and land use.

Meanwhile, the pressure to make our mobility more sustainable is high and changes are urgent. Multiple crisis such as the climate change and energy crisis require us to economize energy in order to reduce greenhouse gas emissions, save costs and manage with the energy that is available. This could change the general conditions for LEVs. Against this background, the work from Task 32 will be extended with this new task, including new topics in the context of global developments.

OBJECTIVES

Task 50 aims to support the diffusion of Light Electric Vehicles (LEVs) by collecting knowledge, fostering expert exchange and increasing visibility of LEVs. The following topics shall be addressed:

- Characterization of market conditions for LEVs in the international context: societal trends, industry, policies, different stakeholder perspectives
- Options for adaption of vehicles and surroundings towards better suitability e.g. vehicle safety through technologies, regulation and infrastructure
- Potential energy efficiency gains due to LEV compared to cars (M1, fleet level) on the road, as well as upstream and downstream (manufacturing etc.).

Figure 1: Urban mobility scenario with LEVs

(Image courtesy of DLR)

NEXT STEPS

At a kick-off meeting, the objectives and planned work will be agreed in detail with the task members. Interested institutions amongst HEV member countries are cordially invited to join and contribute to this new task. The first step will be the preparation of a workshop focusing on social and behavioral aspects against the background of international perspectives, which is planned for early 2024.

Task 50 envisaged workshops include topics such as the social/behavioral characteristics and international perspectives, vehicle concepts, technologies and costs, standards and regulations (homologation, usage), and life cycle analysis (LCA).

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[2] Ewert, A., Schmid, S., Brost, M., Davies, H., Vinckx, L., eds. (2021) 'Small Electric Vehicles An International View on Light Three- and Four-Wheelers'. Springer International Publishing. doi: 10.1007/978-3-030-65843-4 ISBN 978-3-030-65842-7.https://doi.org/10.1007/978-3-030-65843-4.

SECTION C

HEV TCP WORLDWIDE

Overview of Hybrid & Electric Vehicles in 2022

HEV TCP Member countries report new Hybrid and Electric Vehicle registrations and total numbers of these vehicle types registered (e.g. stock). The table below shows the total registrations of these vehicle types over the last three years. The country chapters provide more detailed numbers for 2022.

	HEVs				EVs & PHEVs			
Country	**2019**	**2020**	**2021**	**2022**	**2019**	**2020**	**2021**	**2022**
Austria	44,010	59,582	107,111	147,968	37,060	68,286	106,402	178,345
Belgium	n.a	n.a	n.a	n.a.	62,081	110,532	181,685	275,679
Canada	278,583	318,827	107,878	496,802	155,609	209,075	93,236	420,360
China	1,080,000	1,490,000	1,730,000	3,110,000	3,810,000	4,910,000	7,830,000	13,090,000
Denmark	21,401	29,726	36,510	43,150	25,361	61,607	144,489	217,625
Finland	n.a	n.a.	105,651	n.a.	29,365	55,868	99,911	154,937
France	n.a	534,000	n.a	1,284,455	227,381	292,658	785,245	1,049,188
Germany	437,208	724,228	1,103,095	1,482,895	238,792	588,944	1,184,416	2,005,259
Ireland	47,586	n.a	85,072	110,112	14,859	17,990	44,976	72,574
Italy	244,484	n.a	964,918	1,502,771	44,825	99,519	235,676	368,425
Netherlands	210,642	261,400	342,270	451,724	203,419	292,240	390,438	650,918
Norway	110,665	n.a	115,924	151,357	376,610	486,037	647,691	829,939
Rep. of Korea	506,047	674,461	908,240	1,170,507	89,918	134,962	231,443	389,855
Spain	343,000	139,609	684,873	928,587	52,832	98,483	153,195	316,436
Sweden	66,609	122,290	152,738	152,900	147,855	186,195	299,675	452,037
Switzerland	92,061	126,175	185,061	245,462	49,642	83,329	139,540	224,688
UK	518,339	667,519	n.a	1,200,900	247,199	409,184	710,259	1,002,200
USA	5,374,023	5,800,523	6,435,669	7,200,520	1,443,637	1,741,530	2,322,291	3,277,936
TOTALS	**9,374,658**	**10,948,340**	**13,065,010**	**19,680,110**	**7,256,445**	**9,846,439**	**15,600,568**	**24,976,401**

Table Source: HEVTCP Annual Reports and the European Alternative Fuels Observatory (alternative-fuels-observatory.ec.europa.eu)

Austria

Number of EVs & PHEVs registered

178,345

Number of EV chargepoints

15,941

MAJOR DEVELOPMENTS IN 2022

NEW REGISTRATIONS

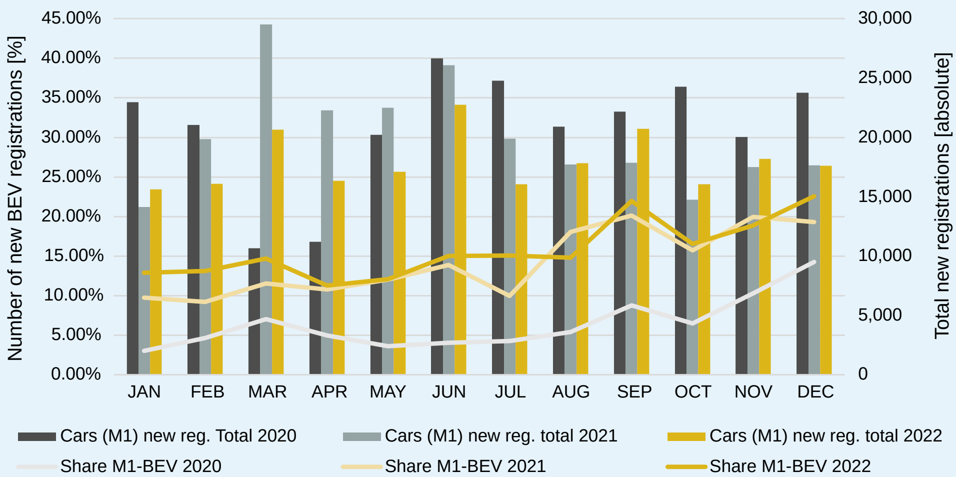
In 2022, 215,050 new passenger cars were registered, a decline of 10.3% compared to 2021 (2021: 239,803). New passenger car registrations are 34.7% below the level of the pre-crisis year, 2019, and reached their lowest level in 43 years. The decline is linked to a continuation of the significant decrease in petrol and diesel-fueled passenger car registrations. The number of petrol-powered passenger cars fell to 78,567 (2021: 91,478), corresponding to a share of 36.5% (2022: 38.1%), and the number of diesel-powered passenger cars fell to 48,155 (2021: 58,263): a share of 22.4% (2021: 35.9%).

Despite the overall trend, at 88,368 (2021: 90,062) cars, the share of all alternatively-powered passenger cars increased to 41.1% (2021: 37.6%), thus confirming the continued trend towards alternative drivetrains.

Among the alternative drivetrains, a shift towards battery electric vehicles (BEV) was observed, as new registrations for petrol-hybrid passenger cars (40,704; share: 18.9%) declined by 5.5%. New registrations for diesel-hybrid passenger cars declined by 0.9% (13,422; share: 6.2 %). Only new registrations of BEV passenger cars increased in absolute numbers in 2022: a 2.4% increase, with 34,165 new registrations and a share of 15.9%. Yet, the number of newly registered BEVs (40,081) still does not compensate for the increase in the total fleet numbers (54,444 vehicles).

Figure 1: Development of BEV new vehicle registration in Austria (2020-2022)

Source: Statistik Austria, Image courtesy of AustriaTech [1].



New policies, legislation, incentives, funding, research, and taxation

Austria offers a broad set of supporting instruments for e-mobility uptake, such as purchase subsidies, registration tax benefits ownership tax benefits, company tax benefits, VAT benefits, infrastructure incentives and free parking.

IMMEDIATE ACTION PROGRAMME (IAP) RENEWABLE ENERGY IN THE MOBILITY – KEY MEASURES

In support of the mobility transition, the Immediate Action Programme defines 41 measures, which contribute to the ten impact levels: strategy, legal/regulatory, financial, research/innovation, vehicles, infrastructure, digitalization of new services, user comfort, communication, and cooperation.

IAP MEASURE 2: "RIGHT TO PLUG"- LEGAL SIMPLIFICATIONS FOR THE INSTALLATION OF CHARGING INFRASTRUCTURE

On 1st January 2022, the "Right to Plug," a package of legal simplifications in the decision-making process for communal installations and in the required consent for individual installations, came into force. This package will help increase the number of charging points, especially in urban areas where public space is scarce. This legal change is a prerequisite for e-mobility uptake as in the past the installation of charging stations in apartment buildings was permitted, but often failed in practice due to difficulties in obtaining the consent of the other co-owners.

IAP MEASURE 33 – NATIONAL COMPETENCE CENTER FOR ELECTROMOBILITY (OLÉ)

A fast and efficient e-mobility rollout is key for achieving Austria's ambitious political decarbonization goals. OLÉ's role is the monitoring of national e-mobility developments and the provision of information to public authorities and the wider public about the status quo. For this purpose, data is processed, analyzed, concisely presented, and explained in neutral and fact-based publications.

Cooperative projects in municipalities, cities, regions and federal states are aimed at the establishment and expansion of charging infrastructure. Their successful implementation requires an intensive dialogue with partners and an alignment of goals, measures and timelines at regional and national level. OLÉ orchestrates this dialogue and, in collaboration with the Austrian Research Promotion Agency (FFG), designs a funding instrument aimed at the rapid expansion of public fast-charging infrastructure in undersupplied areas.

HEVS, PHEVS, AND EVS ON THE ROAD

FLEET DISTRIBUTION AND NUMBER OF VEHICLES IN AUSTRIA

In 2023, the total fleet of motor vehicles registered in Austria passed 7 million for the third time in history. With 7.27 million registered motor vehicles, there was an increase of 0.75% or 54,444 vehicles compared to 2021. Passenger vehicles represent 5.15 million vehicles (Table 1) the largest share of vehicles (70.9%). Fleet numbers indicate a continuous trend toward advanced alternative propulsion systems, especially towards BEVs and HEVs (Figure 2).

For instance, there were 110,225 BEVs and 147,968 HEVs in Austria in 2022, which shows a continuing positive trend from previous years, and which follows an exponential trajectory. The number of vehicles powered by compressed natural gas (CNG) and liquefied petroleum gas (LPG), including bivalent ones, shows a stable, but very moderate fleet level of 5,512 vehicles (2021: 5,787). There is a continuing slow decrease of bivalent vehicles to 2,947 (2021: 3,132), while the CNG vehicles fleet stays stable with 2,564 (2021: 2,654). With 62 (2020: 55) vehicles, the fuel cell electric vehicle (FCEV) fleet is still negligible.

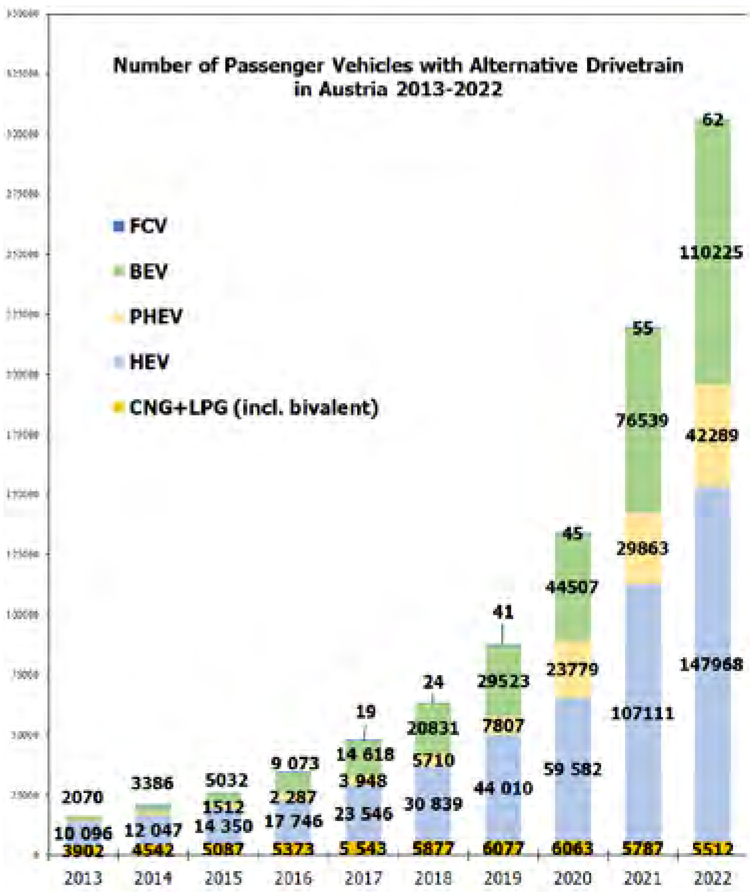


Figure 2: Trends for vehicles with alternative drivetrains in Austria, 2013–2022

Source: Statistik Austria

SHARE OF VEHICLE OWNERSHIP

In 2022, an average 66% of new passenger cars were registered to legal entities, companies and regional authorities, 34% to private vehicle owners. In relation to BEV registrations, the picture differs, as 78.8% of all new BEV car registrations can be assigned to legal entities, companies and local authorities, and only 22.2% to private vehicle owners.

Fleet Totals (as of December 31st 2022)

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Electric bike	n. a.	0	0	0	6,500,000
Electric moped (<50 kmph)	11,656	0	0	0	275,523
Auto-rickshaw	738	0	0	0	1,817
Motorcycle	4,669	4		0	617,188
Motorcycle with sidecar	n. a.	n. a.	n. a.	n. a.	n. a.
Motorized tricycle	28	2		0	3,832
Passenger vehicles	110,225	147,968	42,289	62	5,150,890
Buses and Minibuses	202	256		8	10,373
Light Commercial vehicles	7,582	591		0	498,325
Medium and Heavy Weight Trucks	99	4		1	54,924

Total Sales (1st Jan 2022 to 31st Dec 2022)

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Electric bike	203,515	0	0	0	496,434
Electric moped (<50 kmph)	2,229	0	0	0	10,722
Auto-rickshaw	301	0	0	0	316
Motorcycle	1560	0	0	0	32,929
Motorcycle with sidecar	n. a.	n. a.	n. a.	n. a.	n. a.
Motorized tricycle	2	0	0	0	323
Passenger vehicles	34,165	54,126	13,268	14	215,050
Buses and Minibuses	26	71		0	934
Light Commercial vehicles	2,067	284		0	22,069
Medium and Heavy Weight Trucks	57	0	0	1	3,131

*Total of vehicles of this type, including ICEVs

AVERAGE CO2 EMISSION OF PASSENGER CARS

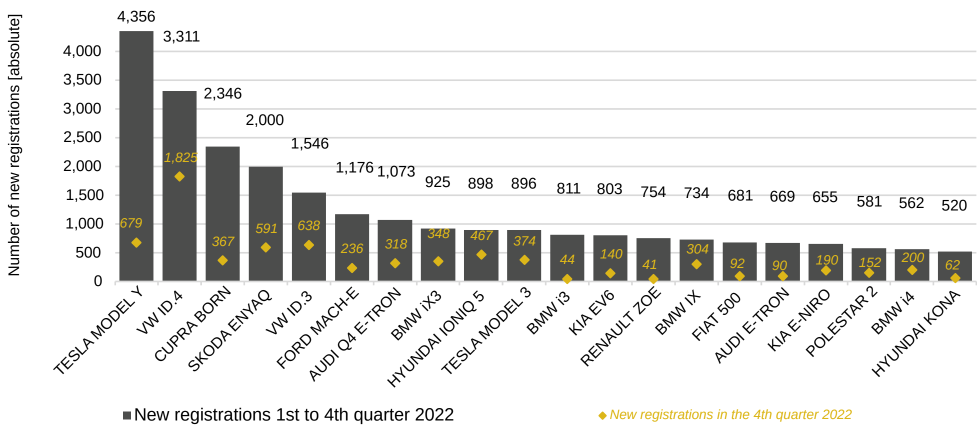
In 2022, the CO2 emissions of newly registered passenger cars measured on average 134g/km (2021: 135g/km), based on the Worldwide Harmonised Light Vehicles Test Procedure (WLTP) and excluding electric and hydrogen vehicles. The number drops to 112g/km (2021: 116g/km) if electric and hydrogen vehicles are included. The average emissions number for petrol-powered M1 vehicles is 138g/km (2021: 139g/km) and diesel-powered passenger vehicles show an average of 149g/km (2021: 150g/km).

BEV M1 BRAND DISTRIBUTION

In the period from January to December 2022, the most popular model was the Tesla Model Y with 4,356 units, followed by the VW ID.4 with 3,311 units. In relation to the overall brand market share, Tesla leads with 16%, followed by VW (16%), and BMW (9%).

Figure 3: BEV M1 registrations by model (2022)

Source: Statistik Austria; Image courtesy of AustriaTech



CHARGING INFRASTRUCTURE OR EVSE

The number of publicly accessible charging points is rising continuously. As of 2022, 13,315 normal power recharging points (with up to 22kW) and 2,626 high power recharging point (above 22kW according to the European Directive 2014/94/EU nomenclature) were operational.

PUBLICLY ACCESSIBLE CHARGING FACILITIES DIRECTORY [2]

The degree of diffusion and the availability of publicly accessible charging infrastructure is a decisive factor for the establishment of e-mobility. In order to create a reliable reference for publicly accessible charging infrastructure, an official directory of all publicly accessible charging facilities for electric vehicles in Austria has been created and made available online. This directory contains information on the technical equipment, the charging possibilities, and the charging capacity.

The charging point directory is designed to inform on the availability of publicly accessible charging infrastructure, to promote competition between charging infrastructure operators, strengthen the confidence of potential buyers of electric vehicles and counteract range anxiety. EVSEs with no public accessibility are not covered. Therefore, the numbers below do not include networks with restricted customer access such as TESLA charging facilities or limited charging possibilities, which are available to use for free as an offered service at locations including shopping malls and hotels.

*As of December 31st, 2022

Type of Public EVSE		Number of Outlets*	Number of Locations*
AC Level 1 Chargers	AC charging ≤ 3.7 kW	1,364	1,113
AC Level 2 Chargers	AC charging > 3.7 kW, ≤ 22 kW	11,951	7,847
AC Fast Chargers	AC charging 43 kW	196	241
DC Fast Chargers	DC charging ≤ 50 kW	1,307	868
Tesla Superchargers	DC charging > 120kW- 250kW	Not publicly accessible	Not publicly accessible
Ultrafast-High power chargers	DC charging > 50 kW and ≤ 350 kW	1,123	54,999
Inductive Chargers	EM charging	No data available	No data available

EV DEMONSTRATION PROJECTS

ENERGY MODEL REGION [3]

As part of the “Energy Model Region” initiative, Austrian-made energy technologies are developed and demonstrated in large-scale, real-world applications with international visibility. In the coming years, the Austrian Climate and Energy Fund (KLIEN) intends to invest up to €120 million ($127 million USD) in three Energy Model Regions. One such region—WIVA P&G—demonstrates the transition of the Austrian economy and energy production to an energy system based strongly on hydrogen. Particular emphasis is placed on the development of hydrogen transport applications. The WIVA P&G Energy Model Region forms part of the Mission Innovation Hydrogen Valley family [4]. A project database is available online.

KLIMAAKTIV MOBIL PROGRAM

Austria’s national action program for mobility management, known as klimaaktiv mobil, supports the development and implementation of mobility projects and transport initiatives that aim to reduce CO2 emissions. Since 2004, 21,000 climate-friendly mobility projects have been funded. The klimaaktiv mobil website offers a map with details of each project. Total financial support until 2021 amounted to €167.5 million ($177.5 million USD).

IAP MEASURE 27: R&I MOBILITY STRATEGY 2030

The R&I Mobility Strategy 2030 provides financial support for R&I projects and R&I activities for sustainable passenger and freight transport. The R&I Mobility Strategy 2030 focuses on four mission areas: Cities, Regions, Digitalization, and Technology. The annual budget ranges from €15 million to €20 million ($15.9 million to $21.2 million USD). A project database is available online.

AUSTRIAN NATIONAL BATTERY INITIATIVE AND M-ERA.NET ACTIVITIES

The development and production of battery cells, modules, packs and electric vehicles is of utmost importance for Austria, considering its strong automotive supply industry. Hence, the Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology (BMK) [5] has set up the Austrian National Battery Initiative [6] in close cooperation with industry and research. The initiative covers the whole value chain, from raw materials to the production of battery cells up to the module and battery pack and its integration within the vehicle. It includes recycling and sustainability in energy and battery production, as well as efficient industry 4.0 processes. As of the end of 2022, four battery initiative calls have been published.

In addition, Austria contributed to M-ERA.NET calls on batteries and lightweighting and set-up a dedicated Eureka Call on lightweighting. With the participation in the M-ERA.NET and the Eureka network Austria strives to overcome national research barriers and to intensify transnational cooperation with over 40 partners.

IMPORTANT PROJECT OF COMMON EUROPEAN INTEREST (IPCEI)

In 2021, Austria started to implement the IPCEI European Battery Innovation (EuBatIn) project, alongside more than 40 participants from twelve EU member states. In total, the project has triggered investments of up to €28 billion ($29.7 billion USD) dedicated to battery research and first industrial deployment. The IPCEI integrates the entire battery value chain from extraction of raw materials, design and manufacturing of battery cells and packs, and the recycling and disposal—with a strong focus on sustainability. Six Austrian partners contribute their expertise to establish a sustainable battery cell production in Europe.

IAP MEASURE 25: ZERO EMISSION MOBILITY

The Zero Emission Mobility (ZEM) [7] program funds flagship projects for implementing the Austrian Federal Government's e-mobility initiatives. The program focuses on zero emission mobility demonstration projects and their corresponding charging/refuelling infrastructure. With an obligatory implementation perspective, calls for projects are technology-neutral, encompassing the three pillars: vehicles, infrastructure, and user. Under the flagship program, 36 projects with 320 project partners have been initiated, representing an overall funding of €68 million ($72 million USD). Total investment in the program is €217 million ($230 million USD).

OUTLOOK

Austria's ambitious goal to become carbon neutral by 2040 calls for concerted activities across all sectors. Especially in the mobility sector, novel approaches are required. Therefore, Austria has launched the Mobility Master Plan, which lays out the path to climate neutrality in 2040 through identifying ways to avoid traffic, by shifting traffic to public transport and active mobility, while also increasing energy efficiency through replacing fossil fuels with renewable energy sources. New solutions from research, technology, and innovation need to be brought swiftly to market to achieve the mobility-related climate targets.

The Austrian Automotive Transformation Platform (AATP) [8] has been established to help facilitate the transition towards a carbon neutral mobility system. Its core is formed by a group of experts covering the whole mobility community, including representatives from the vehicle and supplier industry, the charging infrastructure industry, the service sector, as well as clusters, stakeholders, research and administration. The AATP will develop a catalogue of recommendations for action to support the transition of the mobility industry. The AATP forms part of the Immediate Action Programme Renewable Energy in the Mobility (Measure 41).

The Alternative Fuels Infrastructure Regulation (AFIR) is being discussed at the moment, which will set out the future framework for the deployment of charging and refuelling infrastructure across the European Union. The document will include mandatory targets for member states, instead of today's indicative targets.

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Belgium

Number of EVs & PHEVs registered

275,679

Number of EV chargepoints

24,000

ELECTRIC MOBILITY IN BELGIUM

In response to the Alternative Fuels Infrastructure Directive (AFID) (Directive 2014/94/EU) of the European Parliament and of the Council of 22 October 2014 on the deployment of alternative fuels infrastructure, Belgium has developed a policy framework regarding alternative transport fuels/infrastructure. The Federal Public Service of Economy and the Federal Public Service of Mobility & Transport (federal government of Belgium) coordinated the national development of the Belgian policy framework. However, the regions of Belgium (i.e., Flemish region, Walloon region & Brussels-Capital region) are responsible for most aspects of Directive 2014/94.

On 14 July 2021, the European Commission presented a package of proposals to make the EU's climate, energy, land use, transport and taxation policies fit for reducing net greenhouse gas emissions by at least 55% by 2030, compared to 1990 levels, known as the Fit for 55 package. The package included the proposal to revise the 2014 Directive on alternative fuels infrastructure. The Commission proposed to repeal the directive and replace it with a regulation (AFIR), suggesting that the change of instrument is needed to ensure "swift and coherent development" of the infrastructure network across the EU.

The objective of the proposed alternative fuel infrastructure regulation (AFIR) is threefold:

- to ensure that there is a sufficient infrastructure network for recharging or refuelling road vehicles or ships with alternative fuels
- to provide alternative solutions so that vessels at berth and stationary aircraft do not need to keep their engines running
- to achieve full interoperability throughout the EU and to make sure that the infrastructure is easy to use

For publicly available electric charging infrastructure for light duty road vehicles (cars and vans), the draft regulation sets out mandatory national fleet based targets (e.g. for every battery electric light duty vehicle, a total power output of at least 1kW should be provided through publicly accessible recharging stations (a recharging station is defined as single physical installation at a specific location, consisting of one or more recharging points); for every plug-in hybrid light-duty vehicle, a total power output of at least 0.66kW should be provided through publicly accessible recharging stations). It also sets out distance-based targets for light duty and heavy-duty road vehicles on the TEN-T core and comprehensive network (e.g. publicly accessible recharging pools (one or more recharging stations) dedicated to light-duty vehicles should be deployed in each direction of travel with a maximum distance of 60 km in between them). It also requires EU Member States to ensure a number of recharging stations are in place for heavy-duty vehicles in urban nodes. The draft regulation also includes provisions for ensuring user-friendliness of recharging infrastructure (e.g. payment options, price transparency and consumer information, non-discriminatory practices, smart recharging).

In the European Parliament, the file has been referred to the Transport and Tourism Committee (TRAN). Parliament's TRAN committee adopted its report on 3 October 2022. The report proposes a number of targets that are more ambitious than the Commission’s proposal. For electric charging along the EU's road network, it includes, for instance, higher power output requirements per charging station, and some infrastructure targets to be achieved earlier. For fleet-based targets, the report envisages faster rollout of infrastructure where EV uptake has been low to date. The report was adopted as Parliament's negotiating position on 19 October 2022.

In March 2023, a provisional political agreement between the Council and the European Parliament was reached. The provisional agreement retains the fundamental aspects of the Commission’s proposal, with some amendments on (e.g. total power of electric recharging pools, maximum distance between recharging pools in areas with very low traffic, payment and price-display options, etc.)

FLEMISH POLICY FRAMEWORK

The Flemish policy framework regarding alternative fuels infrastructure for transport in response to Directive 2014/94/EU began with the Flemish CPT-Action Plan 2020, which was followed by the CPT-Vision 2030. Extra concept notes related to “Approach roll-out charging infrastructure 2021-2025” and “Sustainable city logistics” have been added as integral part of the CPT-Vision 2030.

A Transition Manager for Clean Power Transport has been appointed and is the first point of contact for stakeholders with an active role in the transition towards zero emission vehicles in Flanders. Eliminating bottlenecks and facilitating a smart move towards Intelligent and Sustainable Transport is the main goal.

The ambitions in the CPT-Vision 2030, as included in the Flemish Energy and Climate Plan 2021-2030, have been scaled up, with 30,000 extra charging points by 2025 (locations will be mainly demand-driven). For passenger cars, the ambition is to reach 50% zero-emission passenger cars in new sales by 2030 and to study the date for a complete phasing out of the sale or registration of new internal combustion engine (ICE) passenger cars. At this moment, this date has been set for 2029. In the longer term, the ambition is to transition to a full zero-emission fleet for 2-wheelers, passenger cars, vans and city buses. Only for heavy-duty trucks multiple options will be studied.

The ambition in the CPT-Action Plan 2020 was to reach 100,000 (PH)EVs in Flanders in 2020 and this target was almost reached (around 91,000). At the end of 2020, there were around 5,000 public charging points spread over Flanders. Since 2017, the rollout of quick chargers started on the highways (partly via BENEFIC CEF funding).

The whole charging infrastructure rollout was complemented by projects promoting home and workplace charging. The balance between the number of charging points versus the number of EVs on the road needs to be monitored constantly.

More than 60 CPT-projects have been completed, studying electrification of taxis, buses, company car fleets, car sharing, LEVs and the integration of charging infrastructure into the grid (smart charging). These projects studied the benefits and barriers for the rollout of certain technologies which also gave input for future policymaking. A lot of focus went to passenger cars in the first CPT-projects. However, as preparation for the CPT-Vision 2030, specific studies for Light Electric Vehicles (LEVs) and electric buses have been carried out. A roadmap on reduction of emissions of freight transport has also been developed.

The ambitions in the CPT-Vision 2030 are to develop policies that support and accelerate the transition to zero emission transport. This requires a multi-disciplinary approach including aspects like the rollout of new technologies but also aspects like economic benefits, social inclusion and end user satisfaction. The ecological benefits of carbon emissions reduction contribute to the ambitions in the “Flemish Energy and Climate Plan 2021-2030.” The improvement of air quality is an equally important aspect and contributes to the “Air policy Plan 2030.” With focus set on densely populated city areas, the ambition is to, by 2025, have a zero-emission public transport system in inner cities and reduce the impact of freight transport. The use of low-emission-zones (or even zero emission zones) will continue to stimulate zero emission mobility in inner cities.

The new tax law on the greening of mobility in Belgium sets the ambition for all new company cars to be zero-emission cars by 2026. In general, the reform consists of three major elements. First of all, the tax treatment of company cars will evolve, and as of 2026, costs related to company cars will only be eligible for tax deductions in case of a zero emission company car. Next to that, the solidarity contribution will also undergo changes in order to stimulate the usage of zero emission cars. Generally, tax incentives will guide the deployment of electrical charging infrastructure in Belgium.

TCO-tool for alternative fuel vehicles has been updated in 2022, now containing many more models, including Light Commercial Vehicles (N1). The link for the tool is: https://mow.vlaanderen.be/tco/.

Table 1: Targets in new sales per type of vehicle

Source: CPT-Vision 2030

Passenger cars	2025	2030
Zero-emission	20%	50%
PHEV	10%	20%
CNG	10%	10%

Mopeds	2025	2030
Zero-emission	100%	100%

Motorcycles	2025	2030
Zero-emission	20%	50%

Vans	2025	2030
Zero-emission	11%	30%
PHEV	7%	14%
CNG	10%	20%

Trucks	2025	2030
Zero-emission	0%	5%
LNG/CNG	5%	15%

Buses (Public Transport)	2025	2030
Zero-emission	50%	100%
PHEV	20%	0%

Buses (Other)	2025	2030
Zero-emission	5%	10%
PHEV	10%	20%
CNG	10%	20%

Tax incentives for electrical charging infrastructure

The Belgian government's decision to entirely electrify the Belgian company car fleet will lead to an extensive increase in the need for infrastructure to charge electric cars. As a result, the new tax law also sets out two tax incentives to encourage companies and individuals to install charging stations.

INCREASED COST DEDUCTION FOR THE INSTALLATION OF PUBLICLY ACCESSIBLE CHARGING STATIONS

In order to encourage companies to invest in charging infrastructure for electric cars, the Belgian government announced an increased cost deduction for newly installed publicly accessible charging stations.

The increased cost deduction will be applicable for eligible investments made from 01/09/2021 until 31/08/2024. As the Belgian government wants to encourage short-term investments, the deduction rate will decrease over time.

The following rates apply:

- Eligible investments made between 01/09/2021 and 31/12/2022: 200%
- Eligible investments made between 01/01/2023 and 31/08/2024: 150%
- As of 01/09/2024: 100%

In order to benefit from the increased cost deduction, the charging station should be publicly accessible, which implies that the charging infrastructure should at least be accessible to third parties (during either the normal opening hours or during the normal closing hours of the company) and public, in the sense that users can verify both the location and availability of the charging station. Furthermore, companies have the obligation to report the available charging stations to FPS Finance so that the available charging stations can be mapped.

Another condition to benefit from the increased cost deduction lies in the fact that the installed charging station should be an intelligent charging station. This means that the charging time and charging capacity should be linked with an energy management system (however only necessary/applicable as from income year 2023). Investments in non-intelligent charging stations are thus not eligible for the increased cost deduction.

TAX REDUCTION FOR THE INSTALLATION OF A HOME CHARGING STATION

In principle, electric cars can be charged through a charging cable via a standard electrical outlet. However, studies have shown that this charging method entails serious risks for fire safety and overloading of the electricity grid. In order to reduce these risks, the Belgian government wants to encourage individuals to invest in a home charging station. A home charging station does not only reduce the risks, but the charging speed is also up to 10 times higher compared to charging via a standard electrical outlet.

As a result, the new law sets out a tax reduction for investments made by individuals in a home charging station. In this way, the Belgian government aims to encourage people to charge their electric car at home by reducing the total cost of the installation of a home charging station.

The tax reduction shall be granted for expenses paid by a taxpayer for the purchase and placement of a charging station at the address where he or she has established his/her place of residence on January 1st of the tax year in which the tax reduction is claimed. As a result, it is not necessary that taxpayers are already residing in the property where the home charging station is being installed at the moment of the installation or the payment of the home charging station. Furthermore, the tax reduction can not only be claimed by the owner of an immovable property but also by tenants who invest in a home charging station can enjoy the tax reduction.

Similar to the increased cost deduction for the installation of publicly accessible charging stations described above, the tax reduction is only applicable for investments in intelligent charging stations. However, the new law imposes an additional condition to benefit from the tax reduction: the home charging station may only use renewable energy. Furthermore, taxpayers who want to claim the tax reduction have the obligation to have the home charging station installed by a professional. Home charging stations installed by the taxpayer themselves are not eligible for the tax reduction.

The following expenses are eligible for the tax reduction:

- The purchase price and installation cost of the home charging station;
- Expenses to increase the electricity installation from one to three phases
- Expenses for the mandatory inspection of the installation.

The tax reduction can be claimed on a maximum amount of €1,500 per home charging installation and per taxpayer. The tax reduction is limited to expenses made between 01/09/2021 and 31/08/2024. A taxpayer can only benefit one time from the tax reduction. If a taxpayer made expenses during two different calendar years, he can only claim the tax reduction for the costs incurred in one of these two years.

The applicable tax reduction rate will decrease in time:

- Eligible expenses made between 01/09/2021 and 31/12/2022: 45%
- Eligible expenses made between 01/01/2023 and 31/12/2023: 30%
- Eligible expenses made between 01/01/2024 and 31/08/2024: 15%.

HEVS, PHEVS, AND EVS ON THE ROAD

Statistics on the number of PHEVs and BEVs on the road in Belgium can be found on the European Alternative Fuels Observatory.

In terms of the Belgium's total fleet, within the category of passenger cars (M1), there were 92,683 BEVs and 182,996 PHEVs on the roads as of the end of 2022. Of a fleet total of about 6.8 million passenger cars in Belgium, this represented a share of 1.56% (BEVs) and 3.08% (PHEVs).

New registrations: within the category of passenger cars (M1), there were 37,815 BEVs and 60,541 PHEVs as new registrations in 2022. This represented a market share in new registrations in 2002 of 14.24% (BEVs) and 18.47% (PHEVs).

Also, the new registrations in electric Light Commercial Vehicles (N1) increased a lot in 2022 (more than double compared to 2021).

Figure 1: Alternative Fuel Fleet (M1)

Source: EAFO

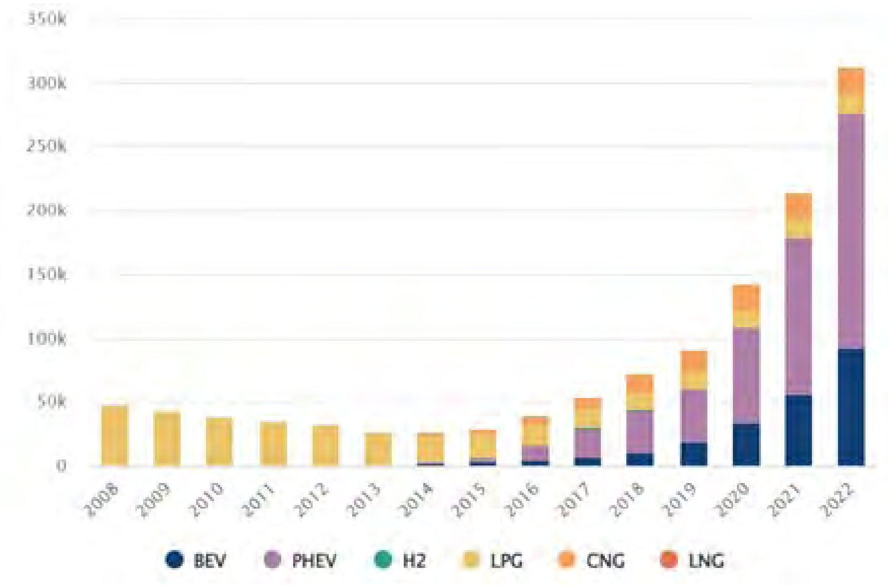


Figure 2: Alternative Fuel Fleet percentage of total fleet (M1)

Source: EAFO

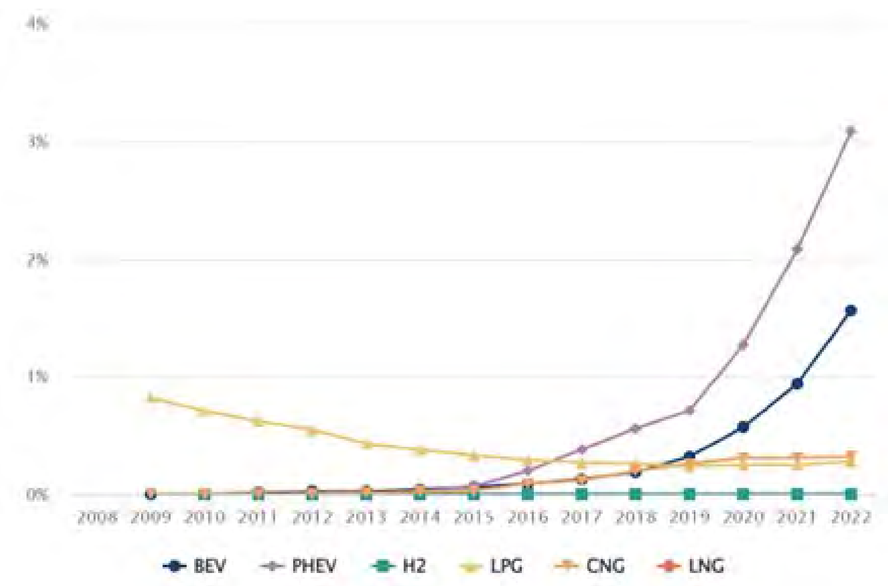


Figure 3: Alternative Fuel New registrations (M1)

Source: EAFO

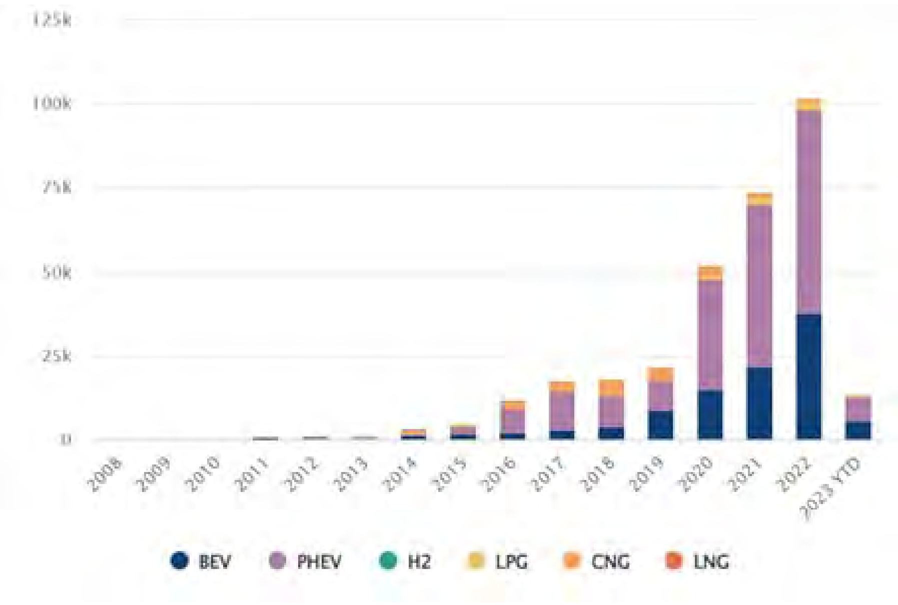
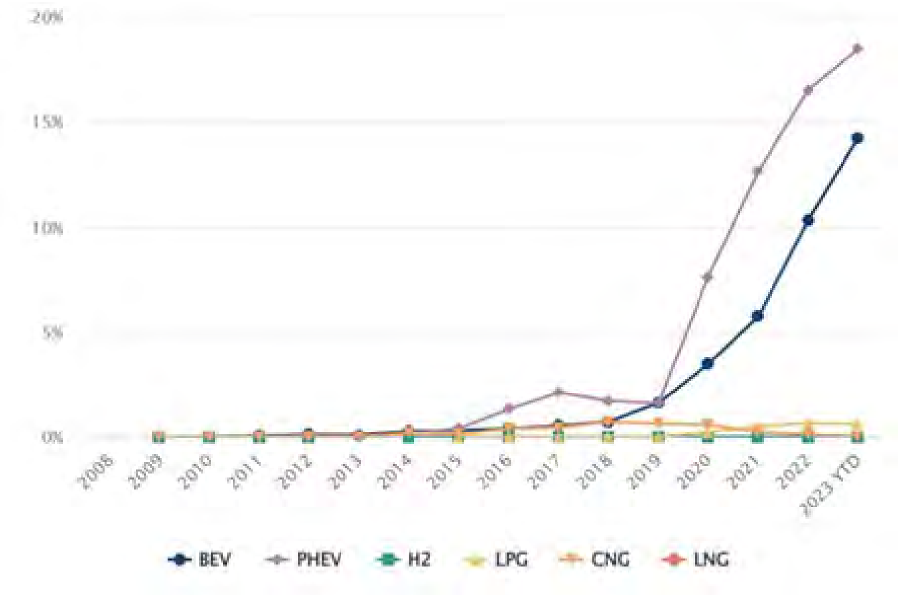


Figure 4: Alternative Fuel Market share of total registrations (M1)

Source: EAFO



CHARGING INFRASTRUCTURE OR EVSE

Introduction

Within the National Policy Framework "Alternative Fuels Infrastructure" extra policy measures have been taken to stimulate the market for charging infrastructure in Flanders, Walloon Region and Brussels Capital Region.

BENELUX Cooperation

In terms of the need for regional cooperation, Belgium, Netherlands, Luxembourg and its regions emphasize close cooperation with neighboring countries. Recalling the Benelux recommendation M (2015)10 on cooperation in the deployment of infrastructure for alternative fuels, which was signed in October 2015 by the three Benelux countries. This cooperation aims to strengthen the exchange of knowledge and best practice on the deployment of infrastructure for alternative fuels in the territories ensuring a minimum coverage by the end of 2020, 2025 and 2030.

Considering the proposed EU regulation on the deployment of alternative fuel infrastructure, particular attention will be paid to the deployment of charging points and hydrogen stations on the TEN-T core and comprehensive network for light-duty and heavy-duty vehicles, as well as urban infrastructure, to guarantee cross-border continuity and connectivity. Interoperability and information exchange between systems and citizens should also be considered.

The Benelux cooperation has been coordinated by a working group with the support of the Benelux Secretariat, which is an intergovernmental organization facilitating cross-border cooperation between Belgium, the Netherlands and Luxembourg. Located in Brussels, The Benelux General Secretariat has been appointed by the Benelux countries to ensure the operational implementation and maintenance of the Benelux IDRO website. A Benelux Decision was adopted establishing a common Benelux service for the registration of identifications as part of the Benelux ID Registration Organization (IDRO). This Benelux IDRO is a joint Benelux service managed by the Benelux General Secretariat on behalf of the relevant authorities of Flanders, Wallonia, Brussels-Capital Region, the Netherlands and Luxembourg.

Europe E-mobility ID Registration Repository (IDRR)

The Europe E-mobility ID Registration Repository (IDRR) is hosted by the Benelux IDRO on behalf of all European ID Registration Organizations (IDRO). The IDRR and its website have been introduced by the Consortium of the Programme Support Action IDACS in 2021.

IDACS is an abbreviation for 'ID issuing and data collection for alternative fuels' and aimed to support Member States in setting up data collecting for alternative fuels and make the data available through the National Access Points and to develop an effective, EU-wide coordination mechanism to assign unique identification codes to CPOs and MSPs.

IDRO - The IDROs need to maintain the ID registration for Charge Point Operators (CPOs) and Mobility Service Providers (MSPs) with a unique ID for each organisation. These IDs issued by the IDROs are used to identify charge contracts and charge stations (possibly also charge pools). The use of the unique IDs supports the cross-border use of charge stations by EV drivers, as it enables domestic and foreign ad hoc payments.

IDRR - The national IDROs collaborate at European level via the ID Registration Repository (IDRR). The IDRR provides relevant information on IDs, access to national ID registers and ID requests. It offers support to national IDROs with their activities and Member States who do not yet have their IDRO. Furthermore, the IDRR also ensures long-term sustainable ID management.

Statistics on Charging Infrastructure in Belgium

Statistics on publicly accessible charging infrastructure in Belgium is available on the European Commission's European Alternative Fuels Observatory.

Statistics on Charging Infrastructure in Brussels

Brussels wants to accelerate the transition to low-emissions transport. The aim for the Brussels Capital Region is to reduce CO2 emissions by 40% by 2030 and to reach net zero emissions by 2050. With road traffic alone being responsible for 27% of the city's CO2 emissions, the government is actively supporting the transition to less polluting forms of transport. The region has already taken several major steps, including introducing the region's Good Move mobility plan and the LEZ (low-emissions zone).

Electrify.brussels is the region's plan to roll out a network of publicly accessible EV charging points. Considering that Brussels, as of the end of 2022, has 2,589 public charging points, the plan sets the following targets:

- By 2024, at least 1 public charging point within 150m of every home in Brussels
- By 2025, that number will increase to 9,500
- By 2035, that number will increase to 22,000
- Reserving certain charging points for taxis and shared cars.

The basic principle for the number of EV chargers in public areas is that they must be realistic and not overestimating the needs. The charging infrastructure network must be introduced without public financing. In the interests of social justice, the cost of building the network should be paid for by the users.

An overview of all MSPs and CPOs active in Brussels can be found on: https://electrify.brussels/en/about/charging-suppliers.

There are currently two public CPOs operating in Brussels: TotalEnergies (the installer for Brussels' network of charging points from 2018 to 2021) and EnergyDrive (the charging point installer for Brussels for 2022), who install charging points, supply the energy, perform repairs and maintenance and provide support to users.

At the request of the Brussels Region, Sibelga is officially in charge of organizing the concessions and the installation of charging stations for electric vehicles in Brussels. The roadside stations will be placed both on plinths and also on public lighting poles.

EnergyDrive has been selected by Sibelga as the preferred partner for the rollout of public charging infrastructure in the Brussels Capital Region. This rollout is part of the ChargyClick programme for the installation of more than 11,000 public charging stations in Brussels by 2035. EnergyDrive will not only install these charging stations but will also operate them for 10 years.

The goal of the first Concessions (published in 2021 and 2022 respectively) was for every Brussels resident to have access to a charging station within a radius of 250 and 150 meters from their home, giving priority to the neighborhoods where residents do not have the possibility of installing their own charging station.

The new target is now driven by data, in that the locations of charging stations are chosen based on available charging data (locations of current charging stations on public roads, usage rate of charging stations, electric vehicle penetration rate according to municipalities, etc.). This plan is drawn up in collaboration with the 20 Brussels Road authorities (the 19 municipalities and Mobility Brussels), who must give their agreement on the number of charging stations to be installed and the installation zones. Sibelga handles most of the applications for the road permits.

The object of the future Concession(s) is the supply and installation and operation of 500 to 600 charging points per year, as well as 100 to 200 charging points per year on public lighting poles (single charging points).

The locations of the charging points will be decided by the Region (Brussels Mobility and Brussels Environment) and Sibelga based on a pre-defined set of criteria that aim to make the charging network accessible to as many people as possible. It won't be possible to request a public charger in a particular place, but local residents can still let us know where charging points are most needed via the "Tell us where a charger is needed" form.

To contribute to the acceleration of the deployment of off-street charging infrastructure, companies and individuals can get free individual support from a facilitator (Facilitateur.bornes@environnement.brussels) to guide them through the installation of charging stations for electric vehicles. The support of the charging infrastructure facilitator is a free service offered by Brussels Environment.

Statistics on Charging Infrastructure in Flanders

An overview of all publicly accessible charging points in Flanders is available on https://www.vlaanderen.be/.

Depending on the source, as of the end of 2022, there around 24,000 publicly accessible charging points in Belgium. Around 1,000 of them are DC chargers, but the main share are AC chargers up to 22kW. The highest number of publicly accessible charging points can be found in the cities of Antwerp, Gent and Brussels.

In Flanders, the ambition for 2020 was to have 7,400 publicly accessible charging points. A new ambition has been announced to install 30,000 extra charging points by

2025. The Flemish Government has foreseen a budget of €30 million and approved a concept note for the rollout of charging infrastructure for the period 2021-2025.

At the end of 2022, 12,376 semi-public charging points (more than 10 hours per day accessible) and 7,623 public charging points (24/7 accessible) public charging points are available in Flanders. Out of this total of 19,999 publicly accessible charging points, there are 947 ultrafast chargers and 405 fast chargers.

Part of the initial ambition is a product of the obligation of the Distribution Grid Operator (Fluvius) to install 5,000 publicly accessible charging points through public procurement by 2020. In order to differentiate between private and (semi) public charging infrastructure, a definition of publicly accessible charging points (24/7 accessibility) was integrated in the Energy Decree of the Flemish Government. The charging points were distributed over the more than 300 municipalities in Flanders. This tender was won by Allego and public charging points have been installed in the period 2016-2020. Concession periods were typically 12 years, so for the ones installed in 2016, this period is running until end of 2027. Local governments are responsible for the installation of the parking spot and parking policies (e.g. enforcement).

In 2022, a new tender "Oproep voor een Concessie van openbare dienst met als voorwerp het leveren, installeren, onderhouden en exploiteren van publiek toegankelijke normale Laadinfrastructuur voor Elektrische Voertuigen in Vlaamse Steden en gemeenten" was launched by MOW (Department of Mobility and Public Works) for the installation of normal charging points in Flanders, with fast/ultrafast charging points not in scope of the tender. A few cities (Antwerp, Genk, Gent and Oostende) opted out of this concession and decided to set up their own procedures for the installation of charging points in the public domain in their own city. This tender was awarded to two CPOs, Engie and Total Energy, each responsible for a certain region in Flanders.

The strategy for the rollout of public charging infrastructure is based on 3 principles:

- Demand driven: "charging point follows electric car," meaning a private person or a company with a charging need and no opportunity to install a charging point on its own location, can ask for a public charging point not more than 250 meters away. Requests can be submitted via a dedicated portal (*) after which an evaluation process will start.

- Data driven: "charging point follows charging point"

- Strategy driven: cities can make their own suggestions of strategic interesting locations to the CPO. In six months, 140 cities proposed a first series across about 1,500 strategic locations.

In September 2022, a new portal has been launched by Department of Mobility (MOW) so that EV drivers can order a public charging station in their area if certain conditions are fulfilled ("charging point follows electric car"). Some cities decided to coordinate the rollout of public charging infrastructure themselves and have set up their own portal, which can all be found on the Flemish Government website. In the first 6 months, more than 1,200 requests were submitted.

The number of fast and ultrafast chargers has been rising as a result of European projects like Fast-E, Ultra-E, Mega-E, and BENEFIC, among others. BENEFIC (BrussEls NEtherlands Flanders Implementation of Clean power for transport) is an innovative cross-border project for the development of charging and refuelling infrastructure for alternative fuels for transport initiated by the Flemish Government in partnership with the Brussels Capital Region and the Netherlands. BENEFIC is funded by the Connecting Europe Facility (CEF) programme of the European Union (www.benefic.eu). Through three open calls for proposals in period 2018-2021, the partners selected 57 infrastructure projects for (ultra)(fast)chargers for electric vehicles, electric taxis and electric buses, CNG and LNG infrastructure, hydrogen refuelling infrastructure and onshore electricity supply facilities for inland navigation. The projects must be realized before September 2022.

CPT project call 2021 focused on (semi-) public charging infrastructure on private domain like parking near shops, schools, and company premises. Conditions were that charging points need to be publicly accessible at least 10 hours per 24 hours. All EV drivers should get access at market conditions and also "ad-hoc charging" is a must. Charging points should also make use of only green electricity. In total, 210 projects have been approved for a total subsidy of €8.2 million, resulting in about 5,800 normal charging points, 130 fast chargers and 320 ultrafast chargers. The project is expected to run between 11/2021 and 11/2023.

CPT project call 2022 focused again on public charging infrastructure on private domain and the number of projects was even higher than in 2021 call. We see a clear trend towards ultrafast chargers of more than 150kW in the recently approved projects.

CPT project call 2023 will focus on subsidies for charging infrastructure for heavy-duty vehicles like trucks, vans and buses.

Alternative Fuels Infrastructure Facility (AFIF) calls (5 calls in period 2022 and 2023) offer an opportunity to get funding for installing extra infrastructure for alternative vehicles. For electric vehicles, the focus lies on ultrafast charging stations on highways and for heavy-duty vehicles. Co-financing for charging points above 150kW (20 k€) and above 350kW (30 k€). Co-financing is also possible for grid connections with capacity above 600kVA (20 k€) and related energy storage solutions. Project promoters are obliged to work together with a financial institution. AFIF has the ambition to combine grants with financing from public or private financial institutions.

Energy Performance of Buildings Directive (EPBD): The EPBD sets out rules for energy efficient building renovations and new building projects, but the revision of the EPBD will also stimulate the availability of charging points in buildings. The revision of the EPBD—presented by the Commission in December 2021—establishes the obligation to install at least one charger in new non-residential buildings with over five parking spaces, and to install at least one per every ten spaces in existing non-residential buildings by 2027. It also includes obligations on pre-cabling of buildings to facilitate the installation of chargers at a later stage as well as a 'right to plug' which would guarantee citizens a straightforward installation of chargers in their buildings. The Council of the EU adopted its position on the revised EPBD in a meeting of Energy and Transport Ministers in October 2022. For the most part, the Council agreed with the Commission's proposal but called for a reduction in some of the requirements (e.g., on pre-cabling) and for more buildings to be exempt from the obligations.

In contrast, the Parliament's ITRE Committee is proposing to go even further with the targets. The Committee adopted its report in February 2023, with political groups striking a deal in which they call to include one charger for every five spaces in new non-residential buildings, and at least one charger in most new residential buildings with over three spaces. Whatever the final targets, the revised EPBD will play a crucial role in increasing the number of charging points in the private domain.

EV DEMONSTRATION PROJECTS

Green Deal Sustainable Urban Logistics

Urban logistics can have a major impact on the liveability of a city, across aspects such as congestion, land use, noise nuisance, traffic safety, climate and air quality. Flanders has the ambition to supply the city centers in an emission-free manner by 2025. The Green Deal Sustainable Urban Logistics wants to contribute to this ambition.

In the Green Deal, about fifty parties are active, mainly companies and local authorities. Cities can also play an important role by giving the example of making its own city fleet "greener." The actions can be divided into four different pillars:

- The first pillar has to do with avoiding vehicle kilometers, through cooperation or through setting up urban distribution centers on the outskirts of cities.
- The second pillar is the shift to more environmentally friendly modes of transport.
- The third pillar wants to change the vehicles that are still needed.
- The fourth pillar has to connect actors.

Lessons learned until today include the need for a coherent and legal framework to support zero-emission urban logistics. The specific challenges with electric vehicles include weight, the need for different driving licenses, lower payloads, and the need for charging infrastructure in public domain and at depots which are mostly rented.

Heavy-duty battery electric vehicles

Road freight transport is moving towards a zero-emission future. Due to the spectacular development of battery technology, battery-electric trucks can make a cost-efficient and substantial contribution to the road. Battery technology is becoming increasingly powerful, so that heavy-duty battery electric trucks with a driving range of several hundred kilometers are already a reality. Moreover, the increasingly strict regulations and pressure for sustainability are forcing the logistics sector to change.

Colruyt Group, a family business that has grown over three generations into a retail group with almost 33,000 employees with a large focus on sustainability, has commissioned the first Scania BEV in Belgium. This will be used in logistics for Solucious, Colruyt Group's food service company. The Belgian retailer announced that it wants to fully focus on zero-emission vehicles, both for its own transport to and from the stores, and to the distribution centers via suppliers. By 2035, the family business wants all goods transport to be zero emission. The commissioning of the battery-electric Scania is an important first step in this process. Colruyt Group has now opted for the 250 BEV with a total range of up to 250 kilometers. The electric motor with a continuous power of 230kW is powered by a battery pack with a total installed capacity of 300kWh. With 130kW DC charge, the nine batteries can be fully charged in less than 1.5 hours.

Figure 5: Belgium's first full electric refrigerated truck

Source: SCANIA

Bakker Belgium, which is part of Greenyard, started in 2023 using a Volvo FH Electric to deliver 18,000,000 kilograms of fruit and vegetables annually to Delhaize's distribution centre in Zellik.

In Logibat, VIL investigated the operational and economic conditions to make battery electric transport feasible and what the requirements are to rollout a nationwide charging network both at shippers and depots and at (semi)public stopping points. The project was executed in cooperation with 30 partners and ran from May 2021 until November 2022.

For the new business models emerging in this ecosystem, the role of logistics companies as providers of charging infrastructure has been explored. In addition, the potential for Catenary Solution in Road Systems within Flanders has also been studied.

So-called Catenary Electric Road Systems (ERS), trucks equipped with a pantograph like a train or tram, not only make it possible to drive emissions-free under overhead wires. At the same time, truck batteries can be charged while driving. In this way, they offer a possible addition to fixed charging points for trucks at depots and along highways. ERS can be part of the solution for the rollout of a nationwide charging network for trucks. The University of Antwerp developed a calculation model specifically for Flanders, with a model that takes into account, among other things, the arrangement of the road network, the distribution of logistics hubs and business parks, the traffic volumes on the Flemish highways, the performance of the various vehicle technologies and their economic characteristics, the construction costs for a system of overhead wires, energy prices, among other factors. First results showed that only a relatively modest investment in ERS is needed for comprehensive coverage in Flanders. The investment for extensive coverage in Flanders is less than €2 billion, representing 0.8% of GDP in Flanders. Thanks to ERS, batteries in trucks can be smaller, resulting in lower investment costs and better TCO. The calculations show that with a broad rollout of a network of overhead lines, even with the smallest battery capacity of 100kWh, almost all industrial sites in Flanders remain accessible.

Figure 6: First eHighway in Germany

Source: Siemens Mobility

The network will also benefit greatly from use by international freight traffic. There has been an in 'eHighways' projects in countries like Germany, UK, Canada and Sweden. The Netherlands also did a study on the opportunities of ERS and the Ministry of Infrastructure and Water Management concluded that an Electric Road Systems (ERS) system, certainly on busy transport corridors including port areas, but perhaps also elsewhere within a relatively short period of time, can be the desired intermediate step for rapid sustainability of heavy road transport, considering that the technology has proven itself, its construction is relatively simple and circular, there do not seem to be any serious safety issues and, from the transporters' point of view, the Ministry mainly sees advantages.

The payback period for a transport company is estimated at 1.5 years, depending on the electricity price and the length of the ERS network that a transporter can use. The technology readiness level scores between 7 and 9 on a scale of 9. The infrastructure costs for the construction of overhead lines and intermediate stations are around €2 million per kilometer. The maintenance costs would be 1% of the construction value and the total system has a depreciation period of approximately 40 years. The infrastructure is circular and can be broken down into parts if necessary.

Besides pilots on ERS or eHighways in some European countries, we also start to see more and more initiatives to support the rollout of charging infrastructure for heavy-duty vehicles (e-trucks and e-buses). In July 2022, Milence was established as a joint venture between the Volvo Group, Traton Group and Daimler Truck, and plans to install and operate at least 1,700 high-performance green energy charge points on, and close to, highways as well as at logistics hubs across Europe. The parties are committing to invest €500 million in total, which is assumed to be by far the largest charging infrastructure investment in the European heavy-duty truck industry to date.

The JV, based in Amsterdam, intends to take a catalyzing role as a charge point operator in the value chain by installing and managing charging stations for heavy-duty trucks and coaches. As a clear signal to all stakeholders, the charging network initiated by the three parties will be open and accessible to all heavy commercial vehicles in Europe, regardless of brand. The first locations will be equipped with 300 or 350kW CCS chargers, among the highest power outputs available today, and megawatt charging will be implemented as soon as possible.

Global Agreement On Zero-Emission Trucks And Buses

First introduced at COP26, the Global Memorandum of Understanding on Zero-Emission Medium- and Heavy-Duty Vehicles (Global MOU) puts countries on a path to 100% new zero emission medium- and heavy-duty vehicle (MHDV) sales by 2040 at the latest, with an interim goal of at least 30% new sales by 2030. Sixteen leading nations (Austria, Canada, Chile, Denmark, Finland, Luxembourg, The Netherlands, New Zealand, Norway, Portugal, Scotland, Switzerland, Turkey, United Kingdom, Uruguay, and Wales) have become the first wave of countries to sign the Global Memorandum of Understanding (MOU). At November 2022's COP27 in Egypt, the United States of America, Ukraine, Ireland, Aruba, Belgium, Croatia, Curaçao, Dominican Republic, Liechtenstein, and Lithuania announced they would join the world's most ambitious agreement to address climate emissions from transport.

The Global MOU is co-led by the Netherlands and CALSTART/Drive to Zero. Drive to Zero is a campaign of the Clean Energy Ministerial, a high-level global forum to promote policies and programs that advance clean energy technology, and a program of CALSTART, a clean transportation industry non-profit consortium with 270+ members.

The ambition of the Global MOU is grounded in real-world data on model availability and technology readiness. Historically seen as a challenging segment to electrify, there are currently more than 800 models of zero-emission MHDVs on the market globally. The Zero-Emission Technology Inventory (ZETI) is an interactive online resource to establish a current and shared knowledge base for worldwide commercially available offerings of zero-emission medium- and heavy-duty vehicles (ZE-MHDVs), including battery-electric and fuel-cell electric vehicles (https://globaldrivetozero.org/tools/zeti/). The ZETI team also launched a companion tool that allows a user to explore, filter, and produce customizable figures from the data. The ZETI Data Explorer is also publicly available and serves to provide another level of detail to all stakeholders interested in the progression of the ZE-MHDV market. The Zero-Emission Technology Inventory and ZETI Data Explorer are constantly being updated with the most recent vehicle information as new models come to market.

The limited time horizon and the level of ambition needed to decarbonize the European transport sector by 2050 require ambitious policies on all levels. Belgium joined the Global MOU at COP27 and is committed to put all its efforts into sustainable, emission free mobility because of the clear benefits for the climate and air quality. At the same time, Belgium is motivated to put the existing production of trucks on a future-oriented track, for example through sustainable battery production and job creation in Belgium.

The Multi-Country Action Plan provides the policy framework for national governments to adopt by showcasing current policies adopted to date and providing guidance on next steps to establishing their own strong plans and building on existing progress. The Action Plan highlights the importance of nurturing the development of all aspects of a country’s policy ecosystem and lays out recommendations for each dimension for governments to adapt into their own planning and rulemaking processes. Achieving harmony between national governments driving innovation is critical to scaling supply, reducing costs, encouraging interoperable infrastructure, and ultimately achieving the proliferation of ZE-MHDVs, clean air and a brighter future for all.

Circusol

CIRCUSOL (“Circular Business Models for the Solar Power Industry”) is an Innovation Action project coordinated by VITO and funded by the Horizon 2020 program of the European Commission. CIRCUSOL wants to unleash the full potential of circular business models, in particular Product-Service Systems (PSS), simultaneously delivering real environmental, economic and user benefits.

Solar photovoltaic (PV) and EVs have been two key engines powering the energy transition. As the amount of PV and EVs on the market rises, resource efficiency is becoming an increasingly critical factor for the long-term success of these sectors. As these markets grow, so will their demand for raw materials, as well as their "waste" output such as decommissioned PV panels and batteries.

The demonstrator site Cloverleaf (Heusden-Zolder, Belgium) consists of a truck stop and an electric vehicle (EV) charging site that is primarily powered by PV (provided by Futech) and second-life batteries (provided by SNAM). The objective of the demonstrator site was to demonstrate both the economic and technical feasibility of a storage-as-a-service model using second-life batteries for a commercial end user.

Canada

Number of EVs & PHEVs registered

420,360

Number of EV chargepoints

18,999

MAJOR DEVELOPMENTS IN 2022

National Developments

BUDGET 2022

In the spring of 2022, the Government of Canada released its annual budget, which committed $1.25 billion USD over five years to extend the Incentives for Zero Emission Vehicles (iZEV) Program, as well as provide further funding to expand the Program to include medium and heavy-duty vehicles (MHDVs) [1]. The Budget further committed $368 million USD in large-scale urban and commercial zero-emission vehicle (ZEV) charging and refueling infrastructure, with an additional $295 million USD for infrastructure in suburban and remote communities. This will contribute to the Government of Canada's commitment to adding 50,000 new ZEV chargers and hydrogen fueling stations across the country.

CANADA'S 2030 EMISSIONS REDUCTION PLAN

The Government of Canada released the 2030 Emissions Reduction Plan in June 2022, which introduced vehicle sales mandates for ZEVs [2]. These regulations will require that at least 20 percent of new light-duty vehicles (LDVs) sold are ZEVs by 2026, 60 percent by 2030, and 100 percent by 2035. These mandates will put Canada on target to end the use of internal combustion engine in LDVs by 2050.

The Emissions Reduction Plan also outlines sales mandates for MHDVs. The Government of Canada is mandating that 35 percent of MHDV sales be ZEVs by 2030, with 100 percent of sales for a subset of vehicle types (to be determined based on feasibility) by 2040.

The Government of Canada also commits to supporting school boards in transitioning their bus fleets to zero-emission technologies through funding, planning and deployment, as well as the purchasing of 5,000 ZEV school buses and the necessary supporting infrastructure.

CANADA’S ACTION PLAN FOR CLEAN ON-ROAD TRANSPORTATION

In December 2022, Transport Canada released Canada’s Action Plan for Clean On-Road Transportation [3]. The Plan outlines steps that the Government of Canada is taking to help the country meet its targets set out in the 2030 Emissions Reduction Plan. These steps include incentives for purchasing and producing ZEVs, regulations to ensure the safety of ZEVs and their supporting infrastructure, awareness to increase the uptake of ZEVs, and investments to bolster the battery supply chain.

Incentives

Under the 2022 Federal Budget released in April 2022, the Government of Canada announced the extension and expansion of the iZEV Program [4]. Now eligible for the $3,680 USD incentive are any battery-electric, plug-in hybrid electric, or hydrogen fuel cell cars that have a base model Manufacturer’s Suggested Retail Price (MSRP) that is less than $40,500 USD, and larger zero-emission vehicles (such as sports utility vehicles, minivans, and pick-up trucks) that have a MSRP under $44,200 USD. This incentive is applied directly at the point of sale and can be applied in addition to any available provincial or territorial incentive.

The Government of Canada further announced the expansion of these incentives to MHDVs with $404 million USD in funding that will provide purchase incentives worth approximately 50% of the price difference (up to $147,000 USD) between an electric vehicle and a conventional internal combustion engine vehicle. Provinces and territories, municipal and local governments, organizations, and businesses are currently able to apply for the subsidy for any eligible vehicle.

The Government of Canada is also providing incentives on the production side by committing to a temporary 50% reduction for general corporate and small business income tax rates for businesses that manufacture zero-emission technologies domestically [5]. This includes zero-emission vehicles, batteries, and charging stations.

Regulations

While purchase incentives are helping to address the upfront costs of medium and heavy-duty zero-emission vehicles (MHZEVs), more work is required to adapt Canada’s regulations so that these vehicles can quickly and safely be used.

To that end, in 2022 the Government of Canada announced the five year, $55.6 million USD Zero Emission Trucking Program [6]. This program has five main objectives: support provinces and territories with funding to develop, modernize, and align codes, standards and regulations for zero emission trucking; support heavy-duty zero emission vehicle deployments to evaluate the technology in Canadian conditions, share best practices, and accelerate readiness; address data and knowledge gaps to remove barriers to the introduction of zero emission trucks in the Canadian marketplace; invest in facility upgrades to the Motor Vehicle Test Centre to increase MHZEV testing capabilities; and undertake MHZEV safety research to validate MHZEV crashworthiness performance and inform the development of new safety requirements as needed.

Awareness
In 2022, Natural Resources Canada launched the Zero Emission Vehicle Awareness Initiative (ZEVAI) to help increase consumer confidence in ZEV technology. This program funds outreach, education, and capacity-building activities that have the ultimate goal of increasing ZEV uptake among Canadians [7].

Funded through this initiative was the EV and Hydrogen Vehicle Expo hosted by the City of Edmonton in September 2022 [8]. This Expo was created as a way to introduce people who are unfamiliar with electric mobility to a variety of makes of EVs, e-bicycles, and e-scooters. The expo also offered test drives and educational sessions led by industry experts.

Batteries
With an increasing number of electric vehicles on the road comes an increase in demand for the minerals, metals, and materials needed for battery production. In 2022, the Government of Canada launched the Canadian Critical Mineral Strategy, which was backed by a $2.9 billion USD investment via Innovation, Science, and Economic Development Canada's Strategic Innovation Fund [9]. In this strategy, the Government detailed the prioritization of six critical minerals (lithium, graphite, nickel, cobalt, copper, and rare-earth elements), which will help to meet the increasing demand in both domestic and global battery supply chains.

Provincial/Territorial Developments

BRITISH COLUMBIA

Improving Affordability of EVs
LDV sales in British Columbia (B.C.) continued to grow in 2022. Since 2016, the number of EVs on the road has increased by over 1,900%, and in 2022, EVs made up 18.1% of new light-duty passenger vehicles sold in the province.

To help further incentivize ZEV sales, in August 2022, the Government of British Columbia announced that they would be improving the accessibility of its rebates under the Go Electric BC program to ensure that money is going to those who need it most. Under the changes, the maximum rebate for battery-electric, fuel-cell, and long-range plug-in hybrid electric vehicles will be increasing from $2,200 USD to $2,900 USD, with the maximum rebate for lower range plug in EVs increasing from $1,100 to $1,460 USD.

Further, the government announced that eligibility for the rebates will be based on individual or household incomes; Individuals making $58,760 USD or less per year ($91,800 USD household income) will be eligible for the full rebate, with a sliding scale for individuals making between $58,760 and $72,280 CAD ($91,800 USD and $121,200 USD household income). Individuals making over $72,280 CAD ($121,200 USD household income) will not be eligible for provincial rebates.

Clean B.C. Roadmap
In 2022, the Government of British Columbia released its Clean B.C. Roadmap to 2030 [10]. This document highlights key action items for the transportation sector, including accelerating the switch to ZEVs, expanding BC's public charging network, and improving vehicle efficiency.

The Roadmap further commits to introducing new sales targets for MHDVs that will be in alignment with the state of California (100% of new MHDV sales must be zero-emission by 2045). The Roadmap also puts forward a target of 10,000 public EV charging stations by 2030 that will complete B.C.'s electric highway and ensure broad geographic coverage of charging stations.

Lastly, the Roadmap makes a commitment to develop a Clean Transportation Action Plan. This plan will evaluate concrete actions that can contribute to the reduction of greenhouse gas emissions by 27-32% (from 2007 levels) by 2030 and enable B.C. to meet legislated and Roadmap targets.

NEWFOUNDLAND AND LABRADOR

From 2021 to 2022, battery electric vehicles registered in the province increased from 317 to 715 and from 1,408 to 2,149 for plug-in hybrids.

To help encourage further EV uptake, the province's 2022 Budget emphasized making EVs and their necessary charging infrastructure more accessible to the general population [11]. The budget accounted for EV purchase incentives, with $1,840 USD available to those who purchase or lease all-electric vehicles, and $1,100 USD available to those who purchase or lease plug-in hybrid electric vehicles.

Additionally, throughout 2022 the provincial utilities expanded the province's fast charging network by deploying 19 additional Direct Current Fast Chargers (DCFCs) in strategic locations.

ONTARIO

In March 2022, the Government of Ontario announced a $66.5 million USD investment to help make EV charging more widely available [12]. The funding will focus on deploying chargers in community hubs such as hockey arenas and municipal parks, and will prioritize small and rural communities. In addition, the funding will support installing charging stations at government sites, such as highway rest stops and Ontario parks. The Government of Ontario will also support the development of business cases for the electric and low emission conversion of the Ontario Public Service fleet and the GO Transit network.

NEW BRUNSWICK

In 2022, New Brunswick Power continued to deliver the provincial government's EV incentive program, which provides up to $3,600 USD for new EVs, up to $1,800 USD for used EVs, and $550 USD towards the installation of an at-home charger [13]. In 2022, New Brunswick Power provided 562 EV rebates.

To further encourage the adoption of EVs, New Brunswick Power held a test drive tour in the Summer of 2022. During this tour, New Brunswick Power travelled across the province and educated the public on EVs. The tour provided just under 600 test drives, and over 75% of those who attended said they were now more likely to purchase an EV.

Figure 1: Residents attend New Brunswick Power's test drive tour.

Image courtesy of Natural Resources and Energy Development New Brunswick.

QUÉBEC

2022 marked the first annual review of the 2030 Plan for a Green Economy [14]. As a result of this review, the 2022 to 2027 Implementation Plan was developed which called for an increase to certain targets, including the number of zero-emission LDVs on the road from 1.5 million to 1.6 million by 2030. To support this transition, the target for the installation of charging stations was also raised to 2,780 by 2030. The Plan further calls for $2.5 billion USD in investments to promote the electrification of the transportation sector in Québec.

In 2022, the Government of Québec also announced the Government Vehicle Acquisition Policy [15] which calls for the electrification of 100% of LDVs and 25% of pickup trucks in the government fleet by 2030. To date, the government fleet has just over 1,900 EVs on the road.

ALBERTA

Through the Alberta Zero Emissions Hydrogen Transit Fund, the province is developing and demonstrating a hydrogen fueling station for highway capable, heavy-duty commercial fleet vehicles that will operate in a completely integrated system in real world conditions [16]. Making use of the demonstration infrastructure, the Alberta Zero Emissions Hydrogen Transit Fund will use these fueling stations, as part of a pilot of hydrogen fuel cell buses in the City of Edmonton and Strathcona County.

Further, throughout 2022, Alberta's Municipal Climate Change and Action Centre launched various programs that aimed to support municipalities and businesses in installing new, publicly available EV charging stations.

Industry Developments

In collaboration with provincial governments, the Government of Canada is supporting the industrial transformation of the transportation sector and building a green economy. As the industry pivots to low and zero-emission vehicle production, Canada is solidifying its position in the electric vehicle and battery supply chain via key investments and in advanced manufacturing.

In March 2022, with the support of the Ontario, federal, and municipal governments, LG Energy Solutions and Stellantis announced they would be building Ontario's first large-scale EV battery manufacturing plant. This project will involve $4.1 billion USD to build a facility in Windsor, Ontario that is planned to be fully operational by 2025 [17].

Further, in July 2022, Umicore announced a $1.1 billion USD investment to develop an industrial scale cathode and precursor materials manufacturing plant [18], while Ventra Group announced they would be investing $13.5 million USD—with additional funding from the Ontario government—to create the Flex-Ion Battery Innovation Centre. This facility will be used to conduct basic product and manufacturing technology research, as well as development for its advanced lithium-ion batteries pilot line [19].

Also in 2022, General Motors, Stellantis, and Honda Canada each announced that with assistance from the Ontario and federal governments, they would be upgrading existing plants to become capable of HEV production [20].

HEVS, PHEVS, AND EVS ON THE ROAD

The rise in EV registrations for passenger vehicles in Canada during 2022 can be attributed to several factors: heightened consumer knowledge, expanded charging infrastructure, advancements in vehicle technology, wider options of plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs) from manufacturers, as well as governmental incentives at the provincial and federal levels.

At the end of 2022, Canada had 418,420 LDV ZEVs on the road, a 40% increase from the previous year, while the registrations of battery EVs grew 54% from 2021. The total number of EV buses and minibuses also increased by over 60%. Registrations of medium and heavy-duty ZEVs and hybrid electric vehicles also increased throughout 2022, going from nil to 924 and 100 respectively. To note, previously published data in the 2021 chapter for vehicle fleet totals was overstated due to provincial governments not enforcing license plate renewals during the COVID-19 pandemic. Because of the special circumstances, vehicles in operation were not actively removed in 2021.

Fleet Totals (as of December 31st 2022)

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Electric bike	N.A.	N.A.	N.A.	N.A.	N.A.
Electric moped (<50 kmph)	N.A.	N.A.	N.A.	N.A.	N.A.
Auto-rickshaw	N.A.	N.A.	N.A.	N.A.	N.A.
Motorcycle	628	0	0	0	1,166,831
Motorcycle with sidecar	N.A.	N.A.	N.A.	N.A.	N.A.
Motorized tricycle	N.A.	N.A.	N.A.	N.A.	N.A.
Passenger vehicles	283,495	493,920	134,622	303	24,935,139
Buses and Minibuses	691	2782	0	0	71,122
Light Commercial vehicles	N.A.	N.A.	N.A.	N.A.	N.A.
Medium and Heavy Weight Trucks	924	100	0	0	2,456,920

Source: S&P Global Mobility, Vehicle In Operation database, Canada, 2022.

Total Sales (1st Jan 2022 to 31st Dec 2022)

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Electric bike	N.A.	N.A.	N.A.	N.A.	N.A.
Electric moped (<50 kmph)	N.A.	N.A.	N.A.	N.A.	N.A.
Auto-rickshaw	N.A.	N.A.	N.A.	N.A.	N.A.
Motorcycle	198	N.A.	N.A.	N.A.	102,970
Motorcycle with sidecar	N.A.	N.A.	N.A.	N.A.	N.A.
Motorized tricycle	N.A.	N.A.	N.A.	N.A.	N.A.
Passenger vehicles	91,311	85,359	23,775	19	1,213,714
Buses and Minibuses	194	137	0	0	1629
Light Commercial vehicles	7,029	11,749	3,144	18	200,761
Medium and Heavy Weight Trucks	897	0	0	0	137,961

Source: S&P Global Mobility, New Vehicle Registrations, Canada, 2022.

*Total of vehicles of this type, including ICEVs

CHARGING INFRASTRUCTURE OR EVSE

The Government of Canada has prioritized the demonstration and deployment of ZEV infrastructure to ensure Canadians can charge their ZEVs across the country. By the end of 2022, Canada had 18,999 EV chargers across the country, an increase from 2021 of nearly 5,000 chargers. Significantly, 2,069 of the public chargers are either DC fast chargers or ultrafast-high power chargers and 1,614 are Tesla superchargers.

It is important to note that respective jurisdictions do not require registration of EVSEs as they are installed. As a result, tracking of operational charging stations is performed through the issuance of service contracts to collect the charger information, or through voluntary reporting by charging network owners and managers, as well as end users. Level 1 chargers are not reported on since this infrastructure typically relates to charging via a residential wall outlet.

*As of December 31st, 2022

Type of Public EVSE	Power	Number of Outlets*	Number of Locations*
Level 1 Chargers		N/A	N/A
AC Level 2 Chargers	>3.7 kW and ≤ 22 kW	15,304	7,076
	>22 kW and ≤ 43 kW	10	5
	Total	**15,314**	**7,081**
AC Fast Chargers	43 kW+	2	1
DC Fast Chargers/ Ultrafast-High Power Chargers	≤ 50 kW	1,365	936
	> 50 kW and ≤ 350 kW	704	490
	Total	**2,069**	**1214**
Tesla Superchargers	> 120kW and ≤ 250kW	1,614	171
	Total	**1,614**	**171**
Inductive Chargers	EM charging	0	0

ZERO EMISSION VEHICLE INFRASTRUCTURE PROGRAM

To help meet the ZEV sales targets set by the Government of Canada, Natural Resources Canada launched the Zero Emission Vehicle Infrastructure Program (ZEVIP) in May 2022 – a $500 million USD fund that runs through 2027 [21]. The objective of ZEVIP is to increase access to charging and refueling stations in Canada, which is currently one of the key barriers preventing ZEV uptake in the country. The program targets various infrastructure streams including public places, workplaces, on-street, multi-unit residential buildings, and commercial and public fleets. The program provides funding for the deployment of hydrogen refueling stations, as well as fast chargers ranging from Level 2, 3.3kW to 200kW and above fast chargers.

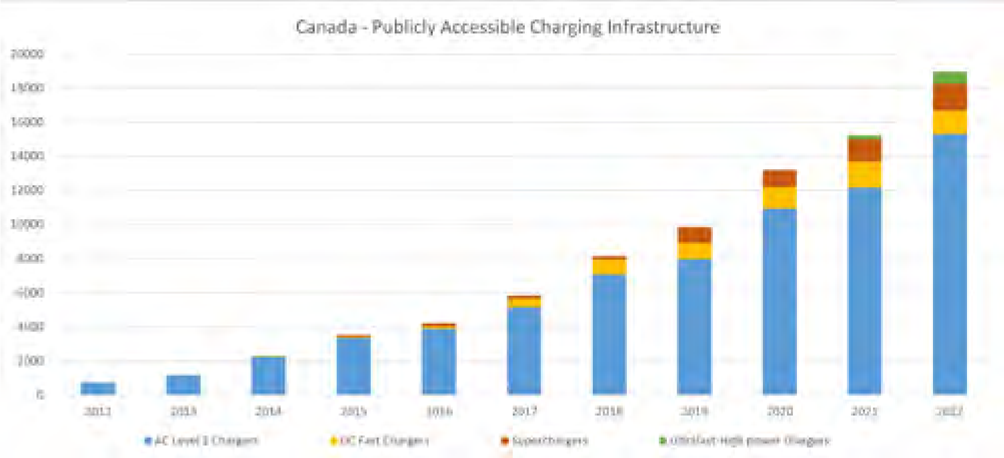


Figure 2: This graph shows the year over year increase in publicly accessible charging infrastructure in Canada.

Graph courtesy of Natural Resources Canada.

EV DEMONSTRATION PROJECTS

Demonstration of a Central Access Option for EV Drivers for Charging Network Account Management

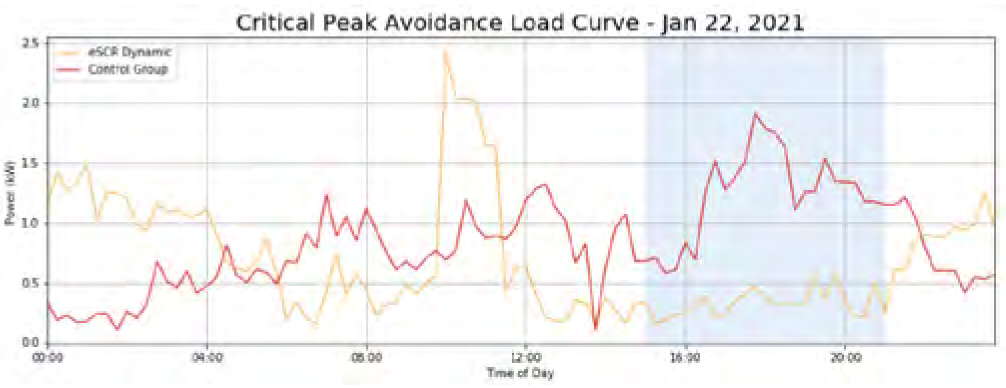
Interoperability continues to be a challenge with charging infrastructure in Canada; there are nearly 20,000 publicly available networked charging stations in the country that are operated by nearly 20 networks. This means that EV drivers must create multiple network accounts to access charging stations. However, Mogile Technologies has addressed these problems by developing a network independent interoperability hub solution that allows EV drivers to access and pay for any EV station using a single account from their app of choice [22]. This project has enabled the seamless use of EV charging infrastructure, including activation and payment anywhere in Canada. Today, approximately 10,000 stations from 8 different partner charging networks can be accessed via a single driver account and app.

Charging Infrastructure with Dynamic and Distributed Price Signal for Load Shaping

As EV use increases in Canada, so too does the demand on electrical grids. To mitigate demand surges, Geotab developed and tested a system that can help shift electrical loads at the grid level, which reduces the need for expensive electrical infrastructure upgrades in some circumstances [23]. This project tested the effect of whole house pricing, active load management, distributed price signals, and dynamic price signals on encouraging EV owners to charge their vehicles at off-peak hours. Geotab was able to demonstrate that each of the price signals were successful in shaping EV loads and can serve as useful tools for local distribution companies.

Figure 3: This graph shows the load control curves of a control group compared to one exposed to a dynamic price signal.

Image courtesy of Geotab Inc.



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China

Number of EVs & PHEVs registered

13,090,000

Number of EV chargepoints

1,797,000

MAJOR DEVELOPMENTS IN 2022

Driven by a series of effective policies, the Chinese automobile market recovered and achieved positive growth in 2022, despite the impact of many adverse factors, such as the fluctuating COVID-19 pandemic, structural shortage of chips, high prices of raw materials for power batteries, and local geopolitical conflicts. Notably, new energy vehicles (NEVs) still maintained explosive growth, with production and sales increasing by 96.9% and 93.4%, respectively, compared with 2021. The market share increased to 25.6%, 12.1 percentage points higher than in 2021, achieving the target of 20% penetration three years ahead of schedule. New energy vehicles are rapidly replacing traditional fuel vehicles, which forms an alternative relationship between them.

Macro Industry Planning

To implement the “Development Plan for New Energy Automobile Industry (2021-2035),” on March 29, 2022, the Ministry of Industry and Information Technology, the Ministry of Public Security, the Ministry of Transport, the Ministry of Emergency Management and the State Administration for Market Regulation jointly issued the “Guiding Opinions on Further Strengthening the Construction of the Safety System for New Energy Automobile Enterprises.” This document put forward the requirements for establishing and perfecting a product quality and safety responsibility system; rationally distributing an after-sales service network and power battery recycling service network; and establishing and perfecting the data safety management system of the whole process. In April 2022, the “Notice on the Trial Implementation of the Sandbox Supervision System for Automobile Safety” and the “Notice on the filing of the Online Upgrade of Automobile Software” were issued successively, further improving the safety supervision and management system for new energy vehicles.

Compliance of Credit Policies

On July 7, 2022, the Ministry of Industry and Information Technology issued the "Decision on Revising the 'Parallel Management Measures for Corporate Average Fuel Consumption and New Energy Vehicles Credits for Passenger Vehicles' (Draft for Comments)" which tightened the requirements for the assessment of new energy credits again. The NEV credit percentage targets for automakers have been increased from 16% in 2022 to 18% in 2023. In addition, the Ministry of Industry and Information Technology has set up a credits pool to collect, store, and release positive credits for new energy vehicles to ensure the smooth operation of the credits trading market.

Fiscal and Tax Policies

To further support the development of the high-quality new energy vehicles industry, the Ministry of Finance, the Ministry of Industry and Information Technology, the Ministry of Science and Technology, and the National Development and Reform Commission jointly issued the "Notice on the Fiscal Subsidy Policy for the Promotion and Application of New Energy Vehicles in 2022," which was implemented on January 1, 2022, further clarifying the subsidy measures for new energy vehicles in 2022. Overall, subsidies for the purchase of new energy vehicles (non-public sector) in 2022 declined by 30% compared with 2021. In order to accelerate the electrification of public transport and other sectors, such as urban buses, road passenger transport, taxis (including online car-hailing), sanitation, urban logistics and distribution, postal express delivery, civil aviation airports, as well as government and party organs' official business, the subsidy standard has been reduced by 20% compared with 2021. To sum up, the notice clarified subsidy standards for different types and sectors of automobile products, providing a basis for the precise implementation of subsidy policies. And it confirmed that the policy of subsidy for the purchase of new energy vehicles will be terminated on December 31, 2022, and vehicles registered after December 31, 2022, will not be subsidized.

The method for calculating the subsidy standard for battery electric vehicles is as follows:

$$\text{Min}\left(\text{E-range subsidy standard, vehicle electricity capacity} \times \text{Upper limit of subsidy per unit electricity}\right) \times \text{Adjustment coefficient of battery system energy density} \times \text{Adjustment coefficient of vehicle energy consumption} = \text{Subsidy amount for each battery electric passenger vehicle}$$

The method to calculate the subsidy standard for plug-in hybrid electric passenger vehicles (including E-REV) is as follows:

$$\text{Subsidy base per vehicle} \times \text{Adjustment coefficient} = \text{Subsidy amount for each plug-in hybrid electric passenger vehicle (including E-REV)}$$

Item	Scope of technical indicators	Subsidy-Standard/Coefficient			
		Non-Public Sector		Public Sector	
		2021	2022	2021	2022
The upper limit of subsidy per unit electricity (USD/kWh)	/	62.00 USD	43.40 USD	76.73 USD	61.38 USD
Subsidy standard for e-range per vehicle	<300 km	/	/	/	/
	300–400 km	2015.04 USD	1410.52USD	2511.04 USD	2015.04 USD
	≥400 km	2790.05 USD	1953.03 USD	3487.56 USD	2790.05 USD
	125 (inclusive) –140 Wh/kg	80%	80%	80%	80%
	140 (inclusive) –160 Wh/kg	90%	90%	90%	90%
	≥160 Wh/kg	100%	100%	100%	100%
Adjustment coefficient of vehicle energy consumption	Better than the limit value by 0–10%, in terms of power consumption per 100 kilometers	80%	80%	80%	80%
	Better than the limit value by 10 (inclusive)–25%, in terms of power consumption per 100 kilometers	100%	100%	100%	100%
	Better than the limit value by 25 (inclusive), in terms of power consumption per 100 kilometers	110%	110%	110%	110%

Table 1: Changes in subsidy standards for battery electric passenger vehicles in 2021 and 2022
(1 USD equals 6.4515 CNY)

Item	Technical requirements		Subsidy-Standard/Coefficient			
			Non-Public Sector		Public Sector	
			2021	2022	2021	2022
Subsidy base per vehicle	2021 - 2022: E-range R ≥ 50 km (NEDC) E-range R ≥ 43 km (WLTC)		1,054.02 USD	744.01 USD	1,395.02 USD	1,116.02 USD
Adjustment coefficient	E-range is less than 80km (the ratio of fuel consumption to the limit value of conventional fuel consumption under state B in assessment)	Ratio less than 55%	100%	100%	100%	100%
		Ratio between 55% (inclusive) and 60%	50%	50%	50%	50%
	E-range is greater than 80 km (the limit value of energy consumption per 100kms under state A in assessment)	The electricity consumption per 100 kilometers under state A meets the requirements for the limit value of energy consumption of battery electric passenger vehicles	100%	100%	100%	100%

Table 2: Changes in subsidy standards for plug-in hybrid electric passenger vehicles (including E-REV) in 2021 and 2022 (1 USD equals 6.4515 CNY)

HEVS, PHEVS, AND EVS ON THE ROAD

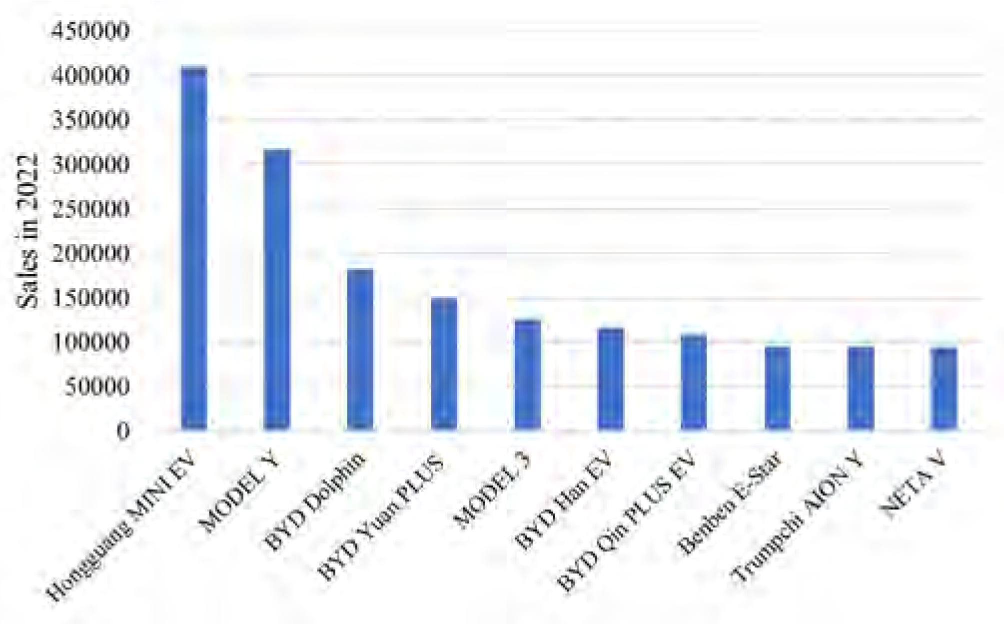
The stock of NEVs in China has increased by more than one million for five consecutive years, and the production and sales of NEVs in China has ranked first in the world for eight consecutive years. Table 3 shows the stock of electric vehicles on the roads in China from 2017 to 2022. The stock of electric vehicles reached 16.21 million in 2022. The stock of battery electric vehicles (BEVs), hybrid electric vehicles (HEVs), and plug-in electric vehicles (PHEVs) reached 10.45 million, 3.11 million, and 2.64 million, respectively, accounting for 64.47%, 19.19%, and 16.29% of the stock of electric vehicles. Fuel cell vehicles (FCVs) are mainly for demonstration operation and are in the initial stage with a stock of only about eleven thousand vehicles.

Table 4 shows the annual sales of electric vehicles in China from 2017 to 2022. The annual sale of electric vehicles increased by 84.4% in 2022 as compared with the annual sales in 2021. The sales of BEVs and PHEVs increased by 81.6% and 151.6%, respectively, as compared with their sales in 2021. In addition, the annual sales of HEVs increased by 26.7%, reaching up to 863,000.

Product diversification has become the main driving force for the development of the NEV market, and an accurate product definition is the key to triggering demand. HongGuang Mini EV has effectively met consumers' demands for low-speed electric vehicles, becoming the most popular model in China with a very high-cost performance ratio. The sales reached 409,000 in 2022, driving sustained high growth of the mini-car market. Leading auto manufacturers such as Tesla and BYD have achieved excellent performances with diversified product portfolios. Among them, the annual sales of Tesla Model Y and Model 3 reached 441,000, due to their top technological attributes. Many of BYD's products, such as Dolphin and Song, which are innovative in styling and advanced in technology, have performed well in the battery and plug-in hybrid electric passenger vehicle markets. The BYD brand achieved annual sales of 1,600,000 in 2022. New domestic auto manufacturers represented by NIO, XPENG, and LEAD INGIDEAL have won the favor of users with innovative products and leading service concepts, achieving 375,000 sales in 2022.

Figure 1: 2022 Annual sales of battery electric passenger vehicles for market leaders

Source, CATARC)



Fleet Totals at the end of 2017 - 2022* (units in millions)

<table>
<tr><th>Vehicle Type</th><th>2017</th><th>2018</th><th>2019</th><th>2020</th><th>2021</th><th>2022</th></tr>
<tr><td>HEVs**</td><td>0.46</td><td>0.71</td><td>1.08</td><td>1.49</td><td>1.73</td><td>3.11</td></tr>
<tr><td>BEVs</td><td rowspan="2">1.53</td><td>2.11</td><td>3.10</td><td>4.00</td><td>6.40</td><td>10.45</td></tr>
<tr><td>PHEVs</td><td>0.50</td><td>0.71</td><td>0.91</td><td>1.43</td><td>2.64</td></tr>
<tr><td>FCVs</td><td>0.001</td><td>0.002</td><td>0.004</td><td>0.006</td><td>0.006</td><td>0.011</td></tr>
</table>

Table 3. Annual fleet totals for the period 2017–2022.
Source, Ministry of Public Security of the People's Republic of China (in millions).

Total Sales During Years between 2017 and 2022* (units in thousands)

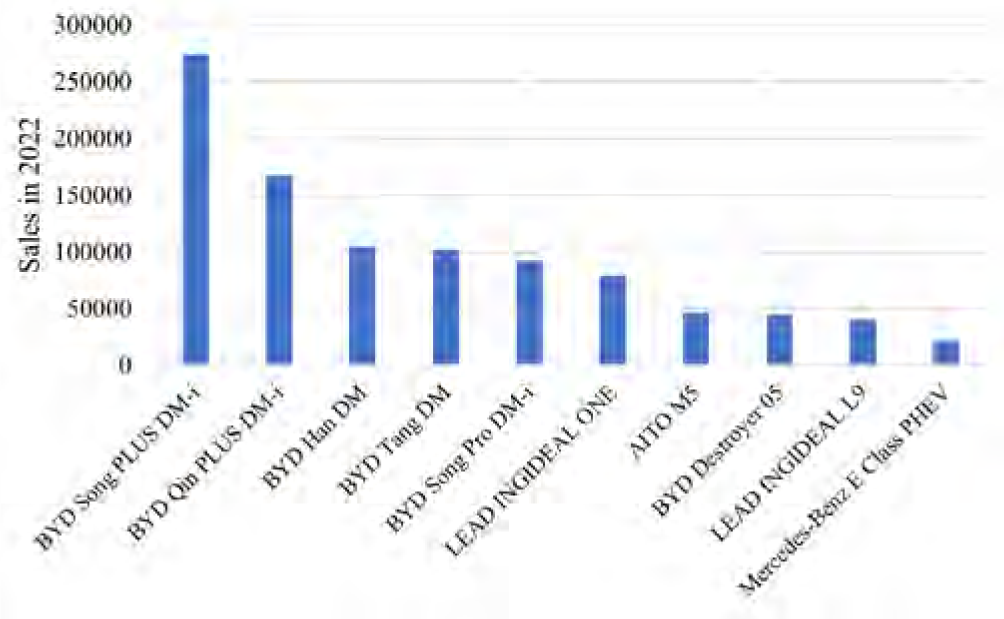
Vehicle Type	2017	2018	2019	2020	2021	2022
HEVs**	183	260	382	523	681	863
BEVs	652	984	972	1115	2916	5365
PHEVs	124	271	232	251	603	1518
FCVs	1.3	1.5	2.7	1.2	1.6	3.0

Table 4: Annual total sales from 2017 to 2022.
Source, CAAM (in thousands).

*UNECE categories M1,M2,M3,N1,N2,N3.
**HEV and FCV data are from CATARC.

Figure 2: 2022 Annual sales of plug-in hybrid electric passenger vehicles (including E-REV) for market leaders

Source, CATARC



CHARGING INFRASTRUCTURE OR EVSE

According to data from the China Electric Vehicle Charging Infrastructure Promotion Alliance, by the end of 2022, there were 5.21 million charging pillars in China, which was an increase of 99.1% as compared with 2021. The ratio of NEVs to charging pillars is about 2.3:1. By the end of 2022, there were 1.797 million public charging pillars and 3.413 million private charging pillars, representing an increase of 56.7% and 132.1%, respectively, as compared with 2021. The battery swapping mode of EVs has also begun to take shape, and the number of battery swapping stations has reached 1,973 nationwide, representing an increase of 52.0% as compared with the number of stations in 2021.

Table 5: Public charging infrastructure on 31 December 2022

Source, China Electric Vehicle Charging Infrastructure Promotion Alliance

Type of Public EVSE	Quantity
AC Charging pillars	1,036,000
DC Charging pillars	761,000
Total charging pillars	**1,797,000**
Battery Swapping Station	1973

With respect to charging infrastructure operators, a large-scale operator-dominated market has formed comprising small and micro operators. As of 2022, there were 34 large-scale operators (charging pillars ≥1000) in China, of which 16 operators (charging pillars ≥10,000) accounted for 95.2% of the total public charging market.

Figure 3: Distribution of the public charging pillars in China by December 31, 2022

Source, China Electric Vehicle Charging Infrastructure Promotion Alliance

OUTLOOK

With the improvement of charging supporting facilities, the iterative progress of product technology, and the diversified supply of products, consumers' recognition and acceptance of NEVs have been further improved. The penetration rate of NEVs, especially in the middle-end product markets, will increase rapidly. Second and third-tier cities, and even rural areas, have huge development potential and will be the main source of NEVs sales. BEVs are expected to remain the main driver of NEVs increment in 2023. PHEVs that can better meet the demand across multi-scenario usage will accelerate the replacement of traditional fuel vehicles. The share of PHEVs and E-REVs in new energy vehicles (especially mainstream household models and high-end large SUVs) will further increase.

Denmark

Number of EVs & PHEVs registered

236,151

Number of EV chargepoints

9,492

MAJOR DEVELOPMENTS IN 2022

Vehicle trends

In 2022, the number of battery electric passenger cars skyrocketed, passing a total amount of 100,000, with a growth rate of 69% [4]. The expansion of the EV charging infrastructure took a significant leap as the total amount of Ultrafast-High power chargers (≥ 150kW) more than tripled from 243 in 2021 to 784 in 2022.

BEVs accounted for 20% of new passenger car registrations. The BEV share of new car sales reflected BEVs as the preferred alternative to internal combustion engine cars. BEVs overtook HEVs and PHEVs in both new registrations and total stock. PHEV registrations were equivalent to about 18% of registrations, in 2022 [4].

Electric buses accounted for 60% of new registrations in 2022, taking a majority share of new registrations. In comparison, the share of electric buses, in 2021, corresponded to 35% of the registrations.

Electric mopeds are also becoming popular with a 47% EV share of new registrations. As of 2022, electric mopeds correspond to nearly 12% of the total stock [4].

Regulation

Taxes on new cars in Denmark are high, but EVs and PHEVs are subject to tax exemptions, as an incentive to push their uptake in the market. The taxes and tax exemptions scales correspond with the costs of a car, meaning higher-end cars and their carbon intensity are subject to higher tax shares.

Moving towards 2030, the tax policies will gradually relieve incentives favoring EVs and PHEVs, as they become more mainstream. PHEVs have been criticized for their real-world electricity share being lower than advertised. The tax exemption rate for PHEVs decreased in 2022, meaning that the price of a medium class PHEV of around €47,000 increased by approximately €2,000, compared to 2021. For BEVs, only cars with costs higher than €63,000 were affected by adjustments to the conditions compared to 2021—and to a relatively more limited extent.

In 2022, the Danish parliament modified the taxation of electric and plug-in hybrid company cars. The new rules will be active from 2023 up until 2026. BEVs became cheaper while PHEVs had their tax exemptions slightly relieved. The agreement includes exempting the tax on the electricity provided by employers for charging electric vehicles at the workplace. Furthermore, funds will be allocated to co-finance charging stations in housing associations, establish a center of knowledge for charging infrastructure, and support the trial of road pricing for private cars [6].

HEVS, PHEVS, AND EVS ON THE ROAD

The share of BEVs in the total stock of passenger cars reached 4% in 2022. Similarly, HEVs and PHEVs accounted for 1.5% and 3.8% respectively. Subsequently, BEVs and PHEVs accounts for just below 8% of the passenger car fleet. The data from 2022 indicates that BEVs are now the preferred alternative to the internal combustion engine. The share of EVs is projected to increase exponentially towards 2030 and onwards. This development is expected to accelerate following the Fit-for-55 EU regulation requirement for cars sold by 2035 and onwards to be zero emission vehicles.

The top 10 selling brands of EVs in 2022 were:

Source: Bilstatistik.dk (DBI IT A/S) https://www.bilstatistik.dk/ [4]

Brand	Count	Share
Volkswagen	5.222	16,94%
Tesla	3.003	9,74%
Skoda	2.432	7,89%
Mercedes-Benz	2.400	7,79%
Audi	2.382	7,73%
BMW	2.075	6,73%
Kia	1.545	5,01%
Polestar	1.480	4,80%
Hyundai	1.374	4,46%
Volvo	1.317	4,27%

In 2022, some segments were already influenced or even dominated by the EV alternatives in new registrations. As of 2022, electric buses and mopeds have shares in new registrations of 60% and 47% respectively.

Fleet Totals (as of December 31st 2022)

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Electric bike	n.a.	0	0	n.a.	n.a.
Electric moped (<50 kmph)	11,689	0	0	0	100,569
Auto-rickshaw	n.a.	n.a.	n.a.	n.a.	n.a.
Motorcycle	382	0	0	0	169,551
Motorcycle with sidecar	n.a.	n.a.	n.a.	n.a.	n.a.
Motorized tricycle	n.a.	n.a.	n.a.	n.a.	n.a.
Passenger vehicles	112,679	43,152	104,954	147	2,794,000
Buses and Minibuses	704	0	0	0	8,624
Light Commercial vehicles	4,449	2,519	1,152	0	364,652
Medium and Heavy Weight Trucks	142	0	0	0	43,500

Total Sales (1st Jan 2022 to 31st Dec 2022)

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Electric bike	n.a.	n.a.	n.a.	n.a.	n.a.
Electric moped (<50 kmph)	3,645	0	0	0	7,622
Auto-rickshaw	n.a.	n.a.	n.a.	n.a.	n.a.
Motorcycle	57	0	0	0	3,277
Motorcycle with sidecar	n.a.	n.a.	n.a.	n.a.	n.a.
Motorized tricycle	n.a.	n.a.	n.a.	n.a.	n.a.
Passenger vehicles	30,824	9,204	26,440	6	148,281
Buses and Minibuses	402	0	0	0	667
Light Commercial vehicles	1,932	540	366	0	27,172
Medium and Heavy Weight Trucks	89	0	0	0	4,884

*Total of vehicles of this type, including ICEVs

CHARGING INFRASTRUCTURE OR EVSE

Public charging infrastructure is expanding vastly, none the least in the segment of DC ultra-fast chargers, with a growth rate higher than 300%–significantly improving the ratio between EVs and ultra-fast chargers. In 2021, the ratio between total EVs and ultra-fast chargers on the road was 274:1. By the end of 2022, this number was 144:1.

The public charging network is built, operated and maintained by multiple charging operators—the most dominant being Clever, Eon, Spirii. OK, Sperto and Tesla [1]. There are, however, a wide range of charging operators collaborating across platforms and apps in addition to these operators. Some operators focus efforts on ultra-fast charging in cities and along highways while others install slow-chargers across the country.

Private charging is incentivized through an electric vehicle tax exemption. EV owners can be eligible of a refund when charging from home. The charge refund is approximately 0.12 EUR/kWh. The EV owner must comply with the framework conditions, meaning that a designated company must deal with the reporting and repayment (usually acquired through a monthly subscription of approximately €10) and the owner must own a suited charger allowing the required features of communication with the respective company. The incentive is set to expire in 2030.

Danish building codes require preparation and installation of charging infrastructure at new or renovated buildings. For example, a new residential building with more than 10 parking spaces must prepare all parking spaces for charging stations. Similarly, a new non-residential building with more than 10 parking spaces must install at least one charging station and provide at least every fifth parking space. A non-residential building undergoing significant renovation with more than 10 parking spaces must install at least one charging station and provide at least every fifth renovated parking space. In addition, any existing non-residential building with more than 20 parking spaces, must install at least one charging station before January 1, 2025 [2].

*As of December 32st 2022

Type of Public EVSE	Number of Outlets*	Number of Locations*
AC Level 1 ≤ 3.7 kW	n.a.	n.a.
AC Level 2 >3.7 kW, ≤ 22 kW	8256	2050
AC Fast Charger 43 kW	n.a.	n.a.
DC Fast Charger ≤ 50 kW	452	250
Tesla Supercharger DC > 120kW- 250kW	n.a.	17
Ultrafast High Power DC > 50 kW and ≤ 350 kW	784	173
Inductive Chargers EM Charging	n.a.	n.a.

EV DEMONSTRATION PROJECTS

Showcasing all types of EVs

Since 2020, 'eCarExpo' has become an annual event to showcase a wide variety of EVs. As EVs are becoming increasingly popular, the event grows larger every year. With a focus on showcasing and promoting electric cars, e-bikes, e-scooters, charging infrastructure, and sustainable mobility solutions, the vehicles on display may include the latest models, prototypes, and concept cars. The expo brings together car manufacturers, charging station providers, government agencies, and other stakeholders to present the latest developments in the electric vehicle industry, including new car models, charging technologies, and green transportation initiatives. Visitors to eCarExpo have the opportunity to test drive electric cars, learn about the benefits of electric mobility, and engage with experts and industry leaders.

eCarExpo also invites speakers from the industry to share their knowledge and insights on the latest trends and developments in the electric vehicle industry. Keynote speakers and panel discussions provide an opportunity for guests to learn from experts and industry leaders.

OUTLOOK

Denmark is currently working towards a 70% economy-wide reduction of GHG emissions by 2030, compared to 1990-levels. The transport sector is one of the largest sectors in terms of greenhouse gasses, with private road cars being responsible for the majority of the emissions. Therefore, the whole sector is required to reduce the emissions levels significantly in the lead up to 2030.

Looking forward towards 2030 and 2035, EVs are considered the dominant alternative to ICE drivetrains. The development of hydrogen-related fuels and drivetrains may well play a role, especially within freight and heavy-duty transport. But the continued development is yet to determine which technologies will dominate as alternatives to ICE drivetrains within and across the various segments of road transport.

Overall, BEV passenger cars are projected to continue their uptake in the Danish car fleet. The tax exemptions for private charging is expected to continue to secure comparatively cheap fuel for EVs up until 2030 [3].

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Finland

Number of EVs & PHEVs registered

154,937

Number of EV chargepoints

9,264

MAJOR DEVELOPMENTS IN 2022

EV sales

In Finland, the proliferation of electric vehicles (EVs) has continued, with more than 14,500 new EVs having been registered. This amount accounted for 18 percent of all new passenger cars, reflecting an increase of 43 percent from 2021—even though the number of new cars registered in Finland in 2022 fell by 17 percent compared to the year 2021.

While sales of EVs rose, those for cars powered by petrol and diesel declined. So did the sale of plug-in hybrids, whose market share dipped to about 20 percent, barely outpacing fully-electric cars. By the end of 2022, plug-in cars (including hybrids and fully-electric) made up nearly half of all cars sold in Finland.

In December 2022, there were about 45,000 EVs and 104,000 plug-in hybrids on the road, soaring from fewer than 10,000 and 46,000 respectively in 2020. About 66% of total new buses are electric with no hybrid buses, constituting half of the total electric bus fleet in Finland. The sale of electric light commercial vehicles doubled during 2022. In 2022, 15 new electric trucks were sold, whereas only two were sold in 2021.

Active Policies

The car tax (paid when the vehicle is first registered) percentage is based on the CO2 emissions of the car, with higher emissions taxed harder. For electric and hydrogen cars, the tax is 0%, while the maximum percentage is 50% for cars with emissions of 360+ gCO2/km (WLTP). The vehicle tax (paid annually) has two parts: the basic part being based on the CO2 emissions of the car (€53.29-654.44/year) and the power source part based on the used power source (gasoline, diesel, electricity, etc.) multiplied by the weight of the car [1].

The taxable value of electric company cars used by a company's employee is reduced by €170 per month for both free use (company pays for everything) and operating use (employee pays for electricity). For free use cars, an additional €120 per month (or €0.08 per kilometre) reduction is also in place. The charging of a company car at either work or public charging point is also tax exempted for both electric and hybrid cars. These incentives are in place for the years 2021-2025. From now on, a home charging point for employees is considered an optional extra for electric and hybrid company cars when calculating their taxable value [2].

There are also three purchase incentives for EVs in place:

- A purchase incentive was put in place for the year 2022, targeted at private persons buying or leasing an electric van. The subsidy is granted for a purchase or at least 3-year lease of a battery electric van. The amount of the subsidy is €2,000-6,000, depending on the size of the van [3].

- A purchase incentive is in place for 2022-2023, targeted at private persons buying or leasing an electric truck. The subsidy is granted for a purchase or at least 3-year lease of a battery electric truck. The amount of the subsidy is €6,000- 50,000, depending on the size of the truck [4].

- There are two subsidies in place for building EV charging infrastructure, with one aimed for housing companies and the other for workplaces:

- The subsidy for housing companies for building EV charging infrastructure covers 35% of the costs incurred from building electrical system surveys, wiring installations and charging equipment. The minimum requirement is to build readiness for five charging points [5].

- The subsidy for workplaces building EV charging infrastructure in 2022 and 2023 amounts to €750/charger, with €1.5 million reserved for both years [6].

HEVS, PHEVS, AND EVS ON THE ROAD

The biggest brand in new electric passenger vehicles in 2022 was Volkswagen with 1,947 new EVs, followed by Tesla (1,689 new EVs) and Volvo (1,309 new EVs). In plug-in hybrid electric vehicles, the top three brands were Volvo (3,714 new PHEVs), BMW (3,020 new PHEVs) and Mercedes-Benz (2,182 new PHEVs) [7].

Fleet Totals (as of December 31st 2022) [7] [8]

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Electric bike	n.a.	n.a.	n.a.	n.a.	n.a.
Electric moped (<50 kmph)	3,522	n.a.	n.a.	n.a.	99,157
Auto-rickshaw	n.a.	n.a.	n.a.	n.a.	n.a.
Motorcycle	89	n.a.	n.a.	n.a.	141,332
Motorcycle with sidecar	n.a.	n.a.	n.a.	n.a.	n.a.
Motorized tricycle	7	n.a.	n.a.	n.a.	623
Passenger vehicles	44,889	n.a.	104,039	2	2,740,393
Buses and Minibuses	550	n.a.	2	n.a.	11,115
Light Commercial vehicles	1,556	n.a.	258	n.a.	343,715
Medium and Heavy Weight Trucks	25	n.a.	n.a.	n.a.	92,633

Total Sales (1st Jan 2022 to 31st Dec 2022) [7] [8]

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Electric bike	n.a.	n.a.	n.a.	n.a.	n.a.
Electric moped (<50 kmph)	1,133	n.a.	n.a.	n.a.	4,254
Auto-rickshaw	n.a.	n.a.	n.a.	n.a.	n.a.
Motorcycle	33	n.a.	n.a.	n.a.	3,800
Motorcycle with sidecar	n.a.	n.a.	n.a.	n.a.	n.a
Motorized tricycle	n.a.	n.a.	n.a.	n.a.	n.a
Passenger vehicles	14,531	25,709	16,171	n.a.	81,699
Buses and Minibuses	279	n.a.	n.a.	n.a.	417
Light Commercial vehicles	684	338	27	n.a.	11,193
Medium and Heavy Weight Trucks	15	n.a.	n.a.	n.a.	3,341

*Total of vehicles of this type, including ICEVs

CHARGING INFRASTRUCTURE OR EVSE

*As of December 32st 2022
**DC charging < 100kW
**DC charging > 100kW [9].

Type of Public EVSE	Number of Outlets*	Number of Locations*
AC Level 1 ≤ 3.7 kW	n.a.	n.a.
AC Level 2 >3.7 kW, ≤ 22 kW	7,683	1,925
AC Fast Charger 43 kW	n.a.	n.a.
DC Fast Charger ≤ 50 kW	520**	356**
Tesla Supercharger DC > 120kW- 250kW	52	9
Ultrafast High Power DC > 50 kW and ≤ 350 kW	1,009***	305***
Inductive Chargers EM Charging	0	0

EV DEMONSTRATION PROJECTS

The electric refuse truck pilot started operations in 2022. All-electric garbage trucks will start collecting waste in the inner city of Helsinki in 2022. The goal of the yearlong experiment is to reduce the noise of waste collection, as well as exhaust gas and particle emissions. At the same time, valuable experience will be gained in using a fully electric garbage truck in northern conditions [10].

OUTLOOK

The Finnish government has decided on a roadmap to fossil-free transport, which includes the intermediate goal of halving CO2 emissions from transport by 2030 (compared to 2005 levels) with the ultimate goal of fossil-free transport by 2045. This roadmap includes the intermediate targets of reaching 700,000 passenger EVs and 45,000 light commercial EVs (of which at least 50% are fully electric), as well as 4,600 electric trucks and buses by 2030. A target has also been set for 2 million fully electric passenger vehicles by 2045 [11].

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France

Number of EVs & PHEVs registered

1,049,188

Number of EV chargepoints

83,317

MAJOR DEVELOPMENTS IN 2022

Deployment of charging stations for light and heavy-duty electric vehicles: A Call for Projects

As part of the investment plan "France 2030", a call for projects was launched in 2022 with the aim of accelerating the deployment of high-power charging stations. This call for projects is targeted to private companies as well as public actors, namely territorial communities. Public access to charging stations is required without any restrictions or discrimination, and interoperability must be guaranteed using specialized platforms like Gireve.

Each charging station in mainland France must have at least 4 charging points, half of which must deliver a simultaneous unit power of at least 150kW. For stations located in the French overseas territories and stations dedicated to heavy vehicles, no specific minimum requirement has been set neither for the number of charging points nor for their power.

Candidates must deliver detailed engineering studies to justify the location and installed capacity of each future station. Impact studies on the electrical network of this deployment are also expected.

This call for projects will run until 2025 under the coordination of The French Agency for Ecological Transition (ADEME). The first selection wave, which closed in July 2022, resulted in seven projects for a total of 178 charging stations and 1,153 high-power charging points. All the stations will be constructed and open for service within 3 years.

Successful candidates agree to contribute regularly to an open governmental platform of public data, providing the different static and dynamic information related to the characteristics of the stations and the charging points.

French Mineral Resources Observatory: a battery working group

Initiated following the Varin report on the supply of strategic metals, the French Observatory of Mineral Resources for Industrial Sectors (OFREMI) has been established. In association with public authorities and main industrial sectors, it will provide its partners with a strategic, economic and technical watch on global supply chains and the current and future needs of the industrial sector in order to produce the risk analyses necessary for any investment decision.

A working group on the battery for mobility topic has been set up with the participation of the French geological survey (BRGM), French Alternative Energies and Atomic Energy Commission (CEA), French Institute of Petroleum (IFPEN), and ADEME. One of the first challenges is to evaluate the "short-term" needs (by 2030) in active materials for French and European battery production plants, according to different EV and HEV development scenarios for light and heavy vehicles.

The battery working group aims to establish multiple "possible futures" by comparing different mobility scenario options, battery chemistry evolution, battery evolution sensitivity to material costs, and integration of other parameters such as: stationary storage, power-to-grid, and development of mobility alternatives (e.g. hydrogen). The first deliverables of this work are expected in June 2023.

EV and charging infrastructure: ADEME technical note

A few days before the October 2022 Paris Motor Show, ADEME published a technical note to present the state of knowledge on electric vehicles and their uses. The technical note lists a number of ADEME's recommendations including:

- Battery capacity is the most important criterion for environmentally friendly mobility. Over its entire lifespan, an electric car driven in France has a carbon impact 2 to 3 times lower than that of a similar internal combustion model, if its battery has a reasonable capacity that is below 60kWh,

- Securing supplies and recycling batteries are among the biggest challenges of the coming decades, requiring cooperation on a European scale,

- Make electric vehicles affordable to as many people as possible. Over its lifetime, the complete cost (after deducting subsidies) of an electric vehicle recharged at home, with a battery of about 60kWh, is lower than that of a comparable internal combustion vehicle today. Heavy electric vehicles with powerful batteries will cost more overall than a combustion vehicle. Hence the importance of the emergence of a range of smaller, more fuel-efficient, more affordable vehicles suitable for everyday use, as well as intermediate vehicles, for which it is urgent to create an industrial sector in Europe. This is a major challenge if EVs are to be adopted on a massive scale by the majority of people,

- Choose the right time to recharge the vehicle and, more broadly, promote recharging control techniques in order to favor the use of renewable and low carbon electricity,

- To meet the needs of high autonomy, the technology of plug-in hybrids can be relevant in a transitory period, under the condition that all the journeys below the electric autonomy of the vehicle are effectively carried out in "pure electric" mode, which requires a systematic daily recharging practice.

Launch of the Ecological Planning Secretariat: mobility and electric vehicles

The Prime Minister announced the implementation of a government action plan for the ecological transition, coordinated by the new General Secretariat for Ecological Planning (SGPE). This action plan aims to enable France to achieve its objectives in terms of reducing greenhouse gas emissions, adapting to climate change, preserving resources, restoring biodiversity and preventing health problems (health-environment).

The mission of the SGPE is to ensure the coherence and monitoring of environmental policies, to initiate and structure the mobilization of ministries and stakeholders, to coordinate all negotiations and finally to measure the performance of the actions undertaken.

One of the main topics of the SGPE is transport and mobility, which aims, among other objectives, to improve the environmental quality of the vehicles made in France. Notably, SGPE has been tasked with producing 2 million electric vehicles annually by 2030. The Government will accelerate the reconversion of vehicle production sites and the deployment of low-emission areas (ZFE) to help facilitate these objectives.

EV and HEV acquisition subsidies have evolved

The decree modifying the changes in vehicle purchasing aid for 2023 was published on December 31, 2022 in the Official Journal. The decree reduces the maximum amount of the ecological bonus for the purchase or lease of an electric passenger car by 1,000 euros (from €6,000 to €5,000). Vehicles costing more than €47,000 and/or weighing more than 2.4 tons are no longer eligible for any ecological bonus, while plug-in hybrids are, as expected, no longer included within the scope.

On the other hand, the maximum amount of the conversion bonus (granted when scrapping a diesel vehicle prior to 2011 or a gasoline vehicle registered before 2006) has been increased by €1,000 (from €5,000 to €6,000) for the purchase or lease of a "low-polluting" car. The price (below €47,000) and weight (below 2.4 tons) constraints are the same as for the ecological bonus.

The ADVENIR program

The Advenir program, led by Avere-France, offers 12 subsidies for collective buildings, companies, local authorities, and public entities. By the end of 2022, it has passed the milestone of 110,000 recharging points financed.

By the end of 2025, the program's goal is to reach more than 125,000 additional financed charging points and 50,000 people trained in electric mobility as part of the Advenir Formations program, which aims to increase public awareness, as well as that of real estate and automotive professionals, elected officials and local stakeholders. As of the end of 2022, 25,000 people have been trained.

HEVS, PHEVS, AND EVS ON THE ROAD

As of December 2022, new electric and plug-in hybrid vehicles had a 22.2% market share, with 42,461 registrations.

Over the whole year, 346,875 electric and plug-in hybrid vehicles (passenger cars and commercial vehicles) were introduced, including 219,755 BEV models. The total number of electric and plug-in hybrid vehicles on the road was 1,102,975.

TOP 5 MOST REGISTERED NEW LIGHT EVS IN 2022:

- Peugeot e-208: 20 408
- Dacia Spring: 18379
- Tesla Model 3: 17005
- Renault Mégane E-Tech: 15681
- Fiat 500e: 15186

TOP 5 MOST REGISTERED NEW LIGHT PHEVS IN 2022:

- Peugeot 3008: 10775
- Peugeot 308: 6718
- Citroën C5 Aircross : 6652
- Mercedes GLC: 5555
- Hyundai Tucson: 4786

Fleet Totals (as of December 31st 2022)

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Electric bike	n. a.	n. a.	n. a.	n. a.	n. a.
Electric moped (<50 kmph)	n. a.	n. a.	n. a.	n. a.	n. a.
Auto-rickshaw	n. a.	n. a.	n. a.	n. a.	n. a.
Motorcycle	n. a.	n. a.	n. a.	n. a.	n. a.
Motorcycle with sidecar	n. a.	n. a.	n. a.	n. a.	n. a.
Motorized tricycle	n. a.	n. a.	n. a.	n. a.	n. a.
Passenger vehicles	622,424	1,284,455	426,446	579	40,267,625
Buses and Minibuses	n. a.	n. a.	n. a.	n. a.	n. a.
Light Commercial vehicles	n. a.	n. a.	n. a.	n. a.	n. a.
Medium and Heavy Weight Trucks	318	n.a.	n.a.	6	660 483

Total Sales (1st Jan 2022 to 31st Dec 2022)

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Electric bike	n. a.	n. a.	n. a.	n. a.	738,454
Electric moped (<50 kmph)	n. a.	n. a.	n. a.	n. a.	n. a.
Auto-rickshaw	n. a.	n. a.	n. a.	n. a.	n. a.
Motorcycle	32,330	n.a.	n.a.	n.a.	182,576
Motorcycle with sidecar	n. a.	n. a.	n. a.	n. a.	n. a.
Motorized tricycle	n. a.	n. a.	n. a.	n. a.	n. a.
Passenger vehicles	219,755	332,663	127,110	193	1,529,035
Buses and Minibuses	549	n. a.	n. a.	n. a.	5432
Light Commercial vehicles	n. a.	n. a.	n. a.	n. a.	348,072
Medium and Heavy Weight Trucks	139	n. a.	n. a.	n. a.	44,016

*Total of vehicles of this type, including ICEVs

CHARGING INFRASTRUCTURE OR EVSE

83,317 publicly-accessible charging points were operating in France as of December 31, 2022, an increase of 53% in one year. This means that more than 25,000 charging points have been installed in one year, representing more than what was installed between 2016 and 2020.

With the addition of private recharging points, France had approximately 1,200,000 recharging points at the end of last year.

*As of December 31st, 2022

Type of Public EVSE	Number of Outlets*	Number of Locations*
AC Level 1 ≤ 3.7 kW	29,259	n.a.
AC Level 2 >3.7 kW, ≤ 22 kW	44,320	n.a.
AC Fast Charger 43 kW	1,518	n.a.
DC Fast Charger ≤ 50 kW	1,856	n.a.
DC Fast Charger ≥50 kW, < 150kW	3,153	
Tesla Supercharger DC > 120kW - 250kW	2,286	n.a.
Ultrafast High Power DC > 50 kW and ≤ 350 kW	925	n.a.
Inductive Chargers EM Charging	n.a.	n.a.

Germany

Number of EVs & PHEVs registered

2,005,259

Number of EV chargepoints

71,591

MAJOR DEVELOPMENTS IN 2022

The year 2022 marked a turning point for the spread of electric vehicles (EVs) in Germany. Almost half a million battery electric vehicles (BEVs) were newly registered. As a result, there are now over one million battery electric vehicles in the German fleet. Together with plug-in hybrids (PHEVs), BEVs accounted for almost a third of newly registered passenger car EVs in 2022 [1].

Considering this growth, there is a need to provide charging infrastructure to facilitate market uptake of electric vehicles. As of January 2023, in Germany, there are 80,541 charging points, of which 67,288 are fast and 13,253 are rapid charging points, at a total of 42,293 publicly accessible charging facilities. This is equivalent to an increase of nearly 35% compared to the number of charging facilities in 2020.

Germany continued to work closely with other EU member states to develop battery and fuel cell production. According to the plans of automotive manufacturers and suppliers in Germany, a total of around 400GWh of battery capacity per year is to be built up by 2030 [2]. The Important Project of Common European Interest (IPCEI) "Hy2Tec" on hydrogen technologies and systems was approved in July 2022. It includes a total of €5.4 billion in public funding and has mobilized €8.8 billion in private funding. Among the selected projects is the construction of a large fuel cell production plant by Cellcentric, which shows that the funding program also focuses on hydrogen applications in the transport sector [3].

In 2022, total CO2 emissions in Germany decreased slightly by 1.9% compared to 2021. The transport sector was responsible for 148 million tonnes CO2 equivalent emissions, an increase of 0.7% compared to the previous year [4].

New policies, legislation, incentives, funding, research, and taxation

The Ministry of Transport presented an immediate action program in July 2022 to meet the climate targets in the transport sector [5]. The program includes further incentives for the ramp-up of electromobility, in order to meet the target of 15 Mio BEVs in Germany's car fleet by 2030, by accelerating the expansion of the charging infrastructure through the "Masterplan Ladeinfrastruktur II" (master plan charging infrastructure II).

Funding of €6.3 billion is projected for the expansion to one million public charging points in Germany by 2030 [6]. Charging should be made possible everywhere, without the need for detours and longer waiting times. To reach this, the masterplan details various targets, for example [7]:

- By the end of 2025, about a quarter of all employee parking spaces should be equipped with charging infrastructure.
- At least 50% of all fuel stations should be equipped with fast-charging infrastructure by the end of 2024 (at least 75% by the end of 2026)
- All federal authorities should, if possible, provide 25% of their own parking spaces with charging facilities.

The plan also defines for the first time a strategy to rollout public charging infrastructure for heavy commercial vehicles, which is structured in two phases. In the first phase, standardization processes (especially for Megawatt Charging Systems) are initiated, and plans will be developed for the nationwide development of the infrastructure. In the second phase, starting in 2024, the focus is on a coordinated development of the charging infrastructure [7].

ELECTRIC VEHICLE PURCHASE BONUS SCHEME FOR NEW VEHICLES

In 2016, the Federal Government introduced the "Umweltbonus" (environmental bonus), a purchase bonus for electric vehicles aimed at promoting their market uptake. Half of the environmental bonus is paid by the car manufacturers and half by the government [8]. In February 2020, the government increased the bonuses and extended the program until December 2025.

As part of an economic stimulus package introduced in June 2020 in response to the COVID-19 crisis, the German government temporarily introduced an additional purchase bonus ("Innovationsprämie") [9], doubling the federal share of the environmental bonus (while the manufacturers' share remains unchanged). The increased bonus rates are in place from 3 June 2020 to 31 December 2022.

In 2022, the purchase bonus applied different rates to the acquisition of new full electric cars and vans (BEVs and fuel cell electric vehicles) and PHEVs. In November 2022, the German government announced modifications to the purchase bonus scheme. From 2023, the scheme will only subsidize fully electric vehicles. Plug-in hybrids will therefore no longer be considered [10]. Furthermore, the amount of the subsidy will decrease from 2023 onwards. Table 1 summarizes the rates available for plug-in hybrid and full electric vehicles according to the current scheme in place, valid until December 2024.

Table 1: Purchase bonuses (environmental and innovation bonuses) for plug-in hybrids, battery electric and fuel cell vehicles [11]

*As long as the subsidy budget lasts

Type of vehicle	Year of registration	Net list price EUR	Purchase bonuses EUR
BEV + FCEV	2022	< 40,000	9,000
BEV + FCEV	2022	40,000 – 65,000	7,500
PHEV	2022	< 40,000	6,750
PHEV	2022	40,000 – 65,000	5,625
BEV + FCEV	2023	< 40,000	6,750
BEV + FCEV	2023	40,000 – 65,000	4,500
PHEV	From 2023	All price ranges	No more subsidy
BEV + FCEV	From 2024*	< 45,000	4,500

Bonuses are also provided for leasing contracts of new electric vehicles, as well as the purchase of used vehicles up to an age of 12 months, in case these had not benefitted from the bonus scheme previously.

Overall, electric vehicle purchase bonuses have been running for more than six years. In 2022, the number of applications increased significantly. The cumulative number of applications for BEVs and for PHEVs grew by almost 80% in 2022. As of the February 1st, 2023, in total 1,875,543 applications have been submitted. The applications distribute among the vehicle categories as follows [12]:

- BEVs: 1,070,437 (57%)
- PHEVs: 804,672 (43%)
- FCEVs: 434

The most popular models benefitting from the purchase bonus schemes are the Volkswagen e-up!, ID.3 and Golf GTE; the Tesla Model 3 and Model Y; the smart EQ fortwo; the Hyundai Kona Elektro and the IONIQ 5; and the MINI Cooper SE (until February 2023) [12].

For the commercial vehicle sector, the German government has initiated the funding program "Klimaschonende Nutzfahrzeuge und Infrastruktur (KsNI)" for the promotion of light and heavy commercial vehicles with alternative, climate-friendly powertrains and associated refueling and charging infrastructure, which subsidizes 80% of the additional investment costs for vehicle and infrastructure. In addition, feasibility studies are subsidized by 50% [13]. Recently, the funding program was extended to the end of 2026 and is applicable to commercial vehicles and converted diesel vehicles with battery and fuel cell as well as plug-in hybrids and hybrid overhead line powertrains. In total, around €1.6 billion is available to subsidize the purchase of electric commercial vehicles [14].

CREDITS FOR ELECTRICITY USED IN BATTERY ELECTRIC VEHICLES

The "greenhouse gas quota" in Germany is based on EU's Renewable Energy Directive and obliges suppliers of petrol and diesel to gradually decrease CO2 emissions from the production and use of fuels and to increase the renewable energy share of the road sector [15]. Since 2017, fuel suppliers can demonstrate decreases in CO2 emissions through the purchase of CO2 credits from the use of electricity in battery electric vehicles [16]. Therefore, market intermediaries emerged, offering the possibility to private electric vehicle owners to buy their credits, either based on a fixed price (such as €250-350 per year) or according to the market rates of the certificates, less transaction fees [17].

Automotive industry

The German automotive industry has adjusted to the stricter EU climate policy and accompanying CO2 fleet targets. For example, Mercedes-Benz intends to sell 100% battery electric cars by the end of this decade wherever the markets allow, and Volkswagen plans for at least 80% of its vehicles sold in Europe to be purely electric by 2030 [18]. Worldwide, German OEMs produced around 921,000 passenger cars with an all-electric powertrain in 2022. This is an increase of 52% from the produced vehicles in 2021.

Figure 1: The BMW iX xDrive50 [19]

The BMW Group offers 25 electrified models in all segments including two-wheeled vehicles and plans to have brought more than two million fully electric vehicles into the market by 2025 [20]. At the end of 2021, they launched their technology flagship BMW iX, which is an all-electric four-door luxury sports activity vehicle (SAV) covering ranges of more than 600km. Despite the model's large frontal area, the WLTP energy consumption of 19.5 kWh/100km is quite low compared to different market competitors [21]. According to BMW, this is due to sophisticated aerodynamics resulting in a drag coefficient of 0.25, a highly efficient electric drivetrain and an adaptive brake recuperation which couples the intensity of brake energy recovery with navigation data and driving assistance systems. The customer can choose among different battery sizes and drive variants, with a maximum usable lithium-ion battery size of up to 105.2kWh and maximum system power output of 385kW.

Figure 2: The Opel Rocks-e was launched in March 2022 [22]

Affordable EV models for the entry-level segment are coming on the market. Volkswagen's ID.2 all-compact car for under €25,000 is scheduled for 2025 [23]. Alternatives to the trend towards larger and heavier BEV are offered by so-called light electric vehicles (LEVs). In 2022, Opel has introduced the Opel Rocks-e in Germany, which is a L6e-class vehicle based on the successful Citroen Ami. This LEV, with a maximum speed of 45 km/h weighs less than 500 kg, can already be driven in Germany with driving license class AM from the age of 15 and has an entry price of €7,990 [24].

Progress is announced also by the German commercial vehicle industry. Daimler Truck Group, the world's largest commercial vehicle manufacturer, has announced that by 2030 they will sell more electric than diesel-driven commercial vehicles in Europe. Starting with its first heavy duty series vehicle, the Mercedes-Benz eActros is an articulated truck for distribution haulage. It is configurated with three battery packs, each offering an installed capacity of 112kWh. A continuous power of 330kW is generated via two electric motors. With a range up to 220 kilometers, the eActros can be charged at up to 160kW. At a DC fast charging station with 400A, just over an hour is needed to charge from 20 to 80 percent. In April 2022, the Mercedes-Benz eActros as a semi-trailer tractor has been added to the portfolio [25].

Figure 3: The Mercedes-Benz eActros was launched in June 2021 and is purposed for heavy distribution transport [26]

HEVS, PHEVS, AND EVS ON THE ROAD

In 2022, new car registrations in Germany totaled 2,651,357. The BEV sales had a market share of 17.7%. The PHEV sales had a market share of 13.7%, with 94% of them are powered by gasoline engines. The sales of HEVs increased by 8% to 465,228 vehicles including approximately 370,000 mild-hybrids (based on DLR internal analysis of KBA and ADAC data). New registrations of conventional gasoline vehicles fell by 11.2%, dropping to 863,445 vehicles which corresponds with a market share of 32.6%. Diesel vehicles fell by 9.9% compared with 2021, dropping to 472.274 vehicles with a market share of 17.8% [27].

More than one third of vehicles were registered by private owners, leaving around 1.7 million vehicles commercially registered. More than 29% of the overall registered vehicles are SUVs (up 16.6% year-on-year), relegating the long-term segment winner, compact cars, to second place, with only a share of 15.9%, followed by small vehicles, with 12.4%, and off-road vehicles with 11.3%. The large van segment recorded the highest growth in newly registered vehicles up to 26.9%, while smaller vehicles such as minis, small and compact vehicles suffered declines of between 8-12% [40].

The share of new BEVs in each vehicle segment was highest for minis with a share of 52% followed by luxury class vehicles with a share of 39%. One quarter of all 778,127 registered SUVs were battery electric, which is higher than the BEV share of the total newly registered vehicles [28].

The proportion of passenger cars with alternative drive systems rose from 4.7% to 6,9% (+47%) in the course of the year 2022. The share of cars with electric drive systems (including BEVs, PHEVs and FCEVs) increased from 2.44% to 3.85% (+58%).

Fleet Totals (as of December 31st 2022) [28]

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Electric bike	n.a.	n.a.	n.a.	n.a.	n.a.
Electric moped (<50 kmph)	n.a.	n.a.	n.a.	n.a.	n.a.
Auto-rickshaw	n.a.	n.a.	n.a.	n.a.	n.a.
Motorcycle	60,644	1,055	0	0	4,913,099
Motorcycle with sidecar	n.a.	n.a.	n.a.	n.a.	n.a.
Motorized tricycle	n.a.	n.a.	n.a.	n.a.	n.a.
Passenger vehicles	1,013,009	1,473,183*	864,698	1,989	48,763,036
Buses and Minibuses	1,884	4,595	22	69	82,932
Light Commercial vehicles Medium and Heavy Weight Trucks	60,803	2,247	493	37	3,617,755
Others	3,394	1,815	312	44	2,732,297
TOTAL	**683,958**	**1,110,065**	**566,553**	**1,309**	**60,133,124**

Ref.[28], ** including Mild-Hybrids

Total Sales (1st Jan 2022 to 31st Dec 2022) [28]

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Electric bike	n.a.	n.a.	n.a.	n.a.	n.a.
Electric moped (<50 kmph)	n.a.	n.a.	n.a.	n.a.	n.a.
Auto-rickshaw	n.a.	n.a.	n.a.	n.a.	n.a.
Motorcycle	33,684	17	3	n.a.	223,889
Motorcycle with sidecar	n.a.	n.a.	n.a.	n.a.	n.a.
Motorized tricycle	n.a.	n.a.	n.a.	n.a.	n.a.
Passenger vehicles	470,559	465,228**	362,093	835	2,651,357
Buses and Minibuses	631	1,049	15	6	4,883
Light Commercial vehicles Medium and Heavy Weight Trucks	18,747	967	83	30	339,343
Others	1,501	688	134	17	21,006
TOTAL	**524,849**	**467,949**	**362,328**	**888**	**3,240,478**

*Total of vehicles of this type, including ICEVs, ** including Mild-Hybrids

CHARGING INFRASTRUCTURE OR EVSE

Since April 2017, the German Bundesnetzagentur has published an interactive overview map of charging points for electric vehicles. This map is updated monthly and contains the locations and technical characteristics of the loading points, which are registered as mandatory. Recently Bundesnetzagentur updated the website and now they share the summary of the publicly available charging stations in Germany.

The map (http://www.bundesnetzagentur.de/ladesaeulenkarte) shows the charging stations of all operators who have successfully completed the notification procedure of the Bundesnetzagentur and agreed to publication on the Internet. As of January 2023, there are 80,541 charging points in Germany, of which 67,288 are normal and 13,253 are fast charging points, at a total of 42,293 publicly accessible charging facilities. Given that at the beginning of 2022, there were around 31,241 charging facilities, the total number of charging facilities has increased by nearly 35% in 2022 [29]. Approximately 90% (71,591) of the charging points are explicitly documented in the inventory provided by Bundesnetzagentur [30]. A breakdown of publicly accessible charging points and their corresponding stations by plug types is shown in Table 3.

Table 3: Number of publicly available charging points and locations in Germany based on [30].

*As of December 31st, 2022

Type of Public EVSE	Number of Outlets*	Number of Locations*
AC Level 1 ≤ 3.7 kW	641	506
AC Level 2 >3.7 kW, ≤ 22 kW	59,713	31,889
AC Fast Charger 43 kW	1,402	1,318
DC Fast Charger ≤ 50 kW	2,636	2,201
Tesla Supercharger DC > 120kW- 250kW	431	431
Ultrafast High Power DC > 50 kW and ≤ 350 kW	6,768	3,903
Inductive Chargers EM Charging	n.a.	n.a.

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Ireland

Number of EVs & PHEVs registered

72,574

Number of EV chargepoints

1,991

MAJOR DEVELOPMENTS IN 2022

In 2022, 22% of all new vehicles registered were BEVs, representing an increase of 7% from 2021. Supply was still an issue in 2022, with some customers waiting 6 months or more for a new EV. The PHEV grant was fully removed from new passenger vehicles from the start of 2022. Several new initiatives were rolled out in 2022 which are detailed below.

Launch of Zero Emission Vehicles Ireland (ZEVI)

In July of 2022, the Minister for Transport launched a new office within the Department of Transport called Zero Emission Vehicles Ireland (ZEVI). This office is charged with supporting consumers, the public sector and businesses to continue to make the switch to zero emission vehicles. The funding for all EV and charging infrastructure programmes will come from this office [1].

EV Dealership Awards

EV dealers have a vital role to play in encouraging car buyers to consider EVs as an alternative to an ICE vehicle. Following the EV mystery shopping that was completed in 2021, the EV Dealership Awards were created. The aim of these awards is to reward dealerships who promote and educate customers on EVs and encourage customers purchasing a new vehicle to go electric.

The award scheme is open to all EV dealerships registered with SEAI for the EV grant scheme. 116 dealerships applied for the awards in 2022. They were assessed on their training, sales and website, with 70% of the marks going towards a mystery shopping experience. The top dealer from each county in the Republic of Ireland received a certificate and wall plaque, as well as assistance to promote their win in local media. The national winner was announced at the annual SEAI Energy Show. They received a certificate and plaque, as well as an advertorial in an auto trader magazine. The awards are to be run again in 2023 [2].

Figure 1: EV Dealership Awards Winners 2022 [2]

Apartment Charger Grant

Overnight charging at home is the easiest and cheapest way to charge an EV. Those who live in apartments or multi-unit dwellings have an additional challenge in terms of determining how to charge an EV.

In order to address this issue, an Apartment Charger Grant scheme, administered by SEAI, was launched in 2022. This grant provides 60-90% of the installation costs to the apartment Management Company, Housing Body, Local Authority or Build to Rent developments. This includes cabling, controllers, chargers, civil works and labor. There is also an option once the infrastructure is in place for an individual homeowner to avail of the SEAI Home Charger Grant to get €600 towards the cost of the charge point [3].

Home charger updates

Changes were made to the existing home charger grant administered by SEAI. It is no longer a requirement to prove ownership of an EV to avail of this grant. Any homeowner can apply for a home charger grant, with one grant available per MPRN (electricity meter number). Anyone with a holiday home or who may travel to visit family members can now install a charger at that home.

Large Panel Van Grant

In July of 2021, a price cap of €60,000 was put on the EV grant programme. Any vehicle with a full list price over this cap would not be eligible for a grant. This change removed all large panel N1 vans from the grant scheme. Van drivers generally do a lot more annual milage than passenger cars, which if done in an ICE van, is adding to emissions.

The costs of these vans are typically from €60,000 upwards. A grant of €7,600 was introduced in 2022. It is available for the purchase of a large panel N1 category van with a technically permissible maximum mass of exactly 3500kg and a full price of €90,000 or less.

Total Cost of Ownership (TCO) Tool

SEAI has provided a TCO tool to compare the total cost of buying and running an M1 passenger EV versus an ICE vehicle for the span of 10 years. In 2022, this tool was expanded to include the cost of an N1 van. This is to show the saving that can be made for a business if they change their transport needs to an EV.

A website widget has been created for M1 passenger car vehicles. Piloted on the Carzone.ie website, anyone looking at a vehicle could get a comparison of the running cost of that vehicles against an EV, without having to leave the website

Dublin City Council (DCC) – Community Mobility Hub

In September 2022, DCC launched a pilot mobility hub to include 1 AC and 1 DC charger, as well as an EV car share space and 8 ebikes [4].

HEVS, PHEVS, AND EVS ON THE ROAD

Supply continued to be an issue for all vehicles in 2022, as supply chains began to recover following the COVID-19 pandemic. Brexit has caused the reduction of imported used vehicles from the UK due to additional charges.

Fleet Totals (as of December 31st 2022)

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Electric bike	n.a.	n.a.	n.a.	n.a.	n.a.
Electric moped (<50 kmph)	n.a.	n.a.	n.a.	n.a.	n.a.
Auto-rickshaw	n.a.	n.a.	n.a.	n.a.	n.a.
Motorcycle	179	n.a.	22	n.a.	47,235
Motorcycle with sidecar	n.a.	n.a.	n.a.	n.a.	n.a.
Motorized tricycle	n.a.	n.a.	n.a.	n.a.	n.a.
Passenger vehicles**	36,555	109,547	33,191	n.a.	2,273,977
Buses and Minibuses	13	180	100	n.a.	11,688
Light Commercial vehicles***	2,135	385	379	n.a.	389,184
Medium and Heavy Weight Trucks	n.a.	n.a.	n.a.	n.a.	n.a.

Source: National Vehicle & Driver File, Department of Transport, Jan 2023

Total Sales (1st Jan 2022 to 31st Dec 2022)

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Electric bike	n.a.	n.a.	n.a.	n.a.	n.a.
Electric moped (<50 kmph)	n.a.	n.a.	n.a.	n.a.	n.a.
Auto-rickshaw	n.a.	n.a.	n.a.	n.a.	n.a.
Motorcycle	n.a.	n.a.	n.a.	n.a.	n.a.
Motorcycle with sidecar	n.a.	n.a.	n.a.	n.a.	n.a.
Motorized tricycle	n.a.	n.a.	n.a.	n.a.	n.a.
Passenger vehicles**	15,678	21,252	7,678	n.a.	105,398
Buses and Minibuses	n.a	n.a.	n.a.	n.a.	n.a
Light Commercial vehicles***	310	71	6	n.a.	23,510
Medium and Heavy Weight Trucks	25	34	n.a	n.a.	2,492

Source: www.beepbeep.ie

*Total of vehicles of this type, including ICEVs

** Passenger Vehicles include Taxis and Hackney category vehicles

*** Only Goods Vehicle category was available in time which includes Light/Medium/Heavy vehicles all together

CHARGING INFRASTRUCTURE OR EVSE

*As of December 31st, 2022

Notes: Charge points operators include ESB Ecars, Tesla, Ionity and EasyGo. Charger locations selected include on-street locations, public car parks, shopping centers, refueling stations, civic buildings and hotels, but exclude private or commercial location car parks.

Type of Public EVSE	Number of Outlets*	Number of Locations*
AC Level 1 ≤ 3.7 kW	n.a.	n.a.
AC Level 2 >3.7 kW, ≤ 22 kW	1,159	675
AC Fast Charger 43 kW	57	57
DC Fast Charger ≤ 50 kW	312	116
Tesla Supercharger DC > 120kW- 250kW	38	7
Ultrafast High Power DC > 50 kW and ≤ 350 kW	125	27
Inductive Chargers EM Charging	0	0

EV DEMONSTRATION PROJECTS

EV COMMERCIAL FLEET TRIALS

The uptake of EVs for commercial use vans is relatively low in comparison to private passenger vehicles. In order to demonstrate how an EV could work for a business with transport needs an EV Commercial Fleet Trial was created to be run over 14 months using 50 vehicles (30 M1 passenger cars and 20 N1 light commercial vehicles). The aim of this trial is to collect real-world data and experience in using an EV for all types of businesses and industries. The businesses taking part include SMEs, larger industry and public sector bodies and there is a geographical spread across Ireland to include urban and rural coverage.

200 business were offered the use of an EV free of charge. Each business gets a vehicle for 3 months. In addition, a charge point was offered, also free of charge, with support up to €1,000 or 80% of the cost of installation. As part of this trial, data has been collected, including distance travelled, charging cycles, and type of charge (i.e. own charger or public network, etc.) The first vehicles were placed at the end of 2022. Data will be collected after each 3-month block [5].

ELECTRIC COMMUNITY CAR – SKERRIES, COUNTY DUBLIN

This scheme has been running since 2019 and is being expanded to more parts of County Dublin. Volunteers are given an EV to drive to transport those with limited mobility and who struggle to use public transport. Over 20 volunteers have signed up to this, providing a vital link to those who need it and helping combat social isolation [6].

OUTLOOK

The overall outlook on transport within Ireland is Avoid, Shift, Improve. This is to encourage people to examine how and why they travel. For example, does someone need to travel for the purpose of what they want to do? If they do, then decide how you get there—can you walk, cycle or use public transport? If someone does need to travel and they have to use a car, they should ensure it is an efficient car such as an EV. The following schemes are planned for the coming years to drive this change.

There are plans for a DART plus, which would expand the Dublin rail system to new lines in the greater Dublin area. There are also similar plans for the Dublin tram service, LUAS. A metro to connect Dublin city with Dublin Airport is also planned.

Mobility hubs are to be piloted in communities to include ebikes, e-car clubs, charging infrastructure, and links with public transport.

The grant for M1 passenger vehicles will be reduced from €5,000 to €3,500 from the 1st July 2023. The reason for this is to direct more funding towards expanding the charging network and support other categories of transport. A grant for L category electric motorbikes will be introduced. Progress is being made on legislation in relation to e-scooters and ebikes to allow them on public roads, as well add some restrictions in relation to speeds.

The Electric Vehicles Charging Infrastructure Strategy 2022-2025 [7] sets out the plans for the next 3 years. This includes a Shared Island Sports Club scheme to support the installation of chargers at local sports clubs, neighbourhood and community charging schemes, a co-charger trial, e-mobility hubs and destination charging support.

Grant support will continue for taxis to move to EVs as well as support to transition HGVs to other fuel types. The current toll incentive scheme will remain in place offering reduced toll costs to EVs.

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Italy

Number of EVs & PHEVs registered

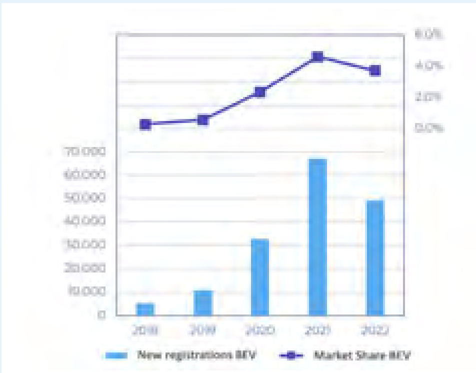
368,425

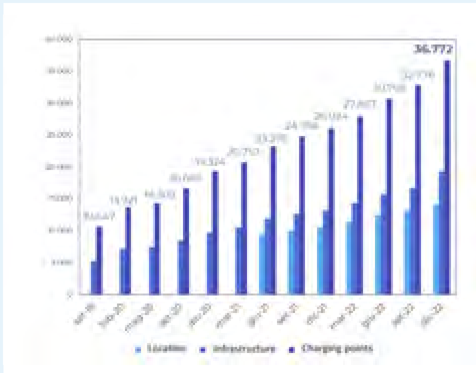
Number of EV chargepoints

36,772

Figure 1 (Left): Number of new registrations and market share of BEVs in Italy during the last 5 years. 'Image courtesy of Motus-E' [1].

Figure 2 (Right): Historical trend of charging points, infrastructures, and location in public places. 'Image courtesy of Motus-E' [1].





MAJOR DEVELOPMENTS IN 2022

New policies, legislation, incentives, funding, and taxation

During 2022 several incentives and legislations have been introduced to increase the uptake of alternative fuels vehicles and charging infrastructure in Italy.

Ownership tax benefits: electric vehicles are exempt from the annual ownership tax for a period of 5 years from the date of their first registration. After this period, they can benefit from a 75% reduction of the tax rate applied to equivalent petrol vehicles in many Italian regions. Hybrid/electric cars can benefit from free access to the limited traffic zone (LTZ) and free parking in many urban centers [2].

Company tax benefits: Starting from 2020, cars emitting up to 60g/kmCO2 are taxed at a lower rate of 25% of the ownership tax based on conventional parameters related to an average journey and cost per kilometer.

In addition, the new legislation introduces different rates based on car emissions:

- 30% of the ownership tax for cars emitting from 61 to 160 g/km CO2.
- 50% of the ownership tax for cars emitting from 161 to 190 g/km CO2.
- 60% of the ownership tax for cars emitting from 191 g/km CO2 upwards.

Table 1: Ownership taxation (2022) [2]

Electric vehicles	Exempt up to 5 years, 75% reduction after 5 years	
Electric / hybrid vehicles	Free access to limited traffic zones (LTZ)	
Internal combustion engine vehicles	**CO2 Emissions (g/km)**	**Tax Rates**
	0 - 60	25%
	61 - 160	30%
	161 - 190	50%
	> 191	60%

Regarding the incentives to purchase low emission vehicles, the ECOBONUS incentive has been renewed through the Ministerial Decree (DCPM 17/2022) [3]. This has allocated new funds for the reconversion of the automotive industry in the measure of €700 million for 2022 and €1 billion from 2023 to 2030. Most of these funds will be targeted towards financing "green" vehicles and therefore electric vehicles.

For the purchase of charging infrastructures of standard power not accessible to the public, the Budget Law 2022 has extended the ECOBONUS incentives until 2025 [3].

National Incentives Currently Active have been organized as follows:

INCENTIVE TO PURCHASE A PASSENGER VEHICLE (INCLUDE ELECTRIC VEHICLES AND IT IS VALID UNTIL 12/07/2025, ECOBONUS).

The Ministerial Decree (DPCM) published on 04/08/2022 [4][5], issues an incentive of €3,000 when purchasing a passenger vehicle (category M1) with a value up to €35,000 (VAT excluded) and CO2 emissions lower than 20g/km. This contribution is aimed at promoting purchasing for those who usually rent vehicles. An additional contribution of €2,000 is issued when scrapping a vehicle of class lower than EURO 5. The amount allocated for this incentive is €190 million.

Table 2: Direct incentives for purchasing new passenger cars in 2022 (include electric vehicles) [2], [3], [6]

	Issued funds (million EUR)			Incentives		
CO_2 Emissions (g/km)	**2022**	**2023**	**2024**	**Bonus with scrapping (EUR)**	**Bonus without scrapping (EUR)**	**Maximum vehicle price (EUR)**
00 - 20	220	230	245	5,000	3,000	35,000
21 - 60	225	235	245	4,000	2,000	45,000
61 - 135	170	150	120	2,000	-	35,000

INCENTIVE TO PURCHASE A PASSENGER VEHICLE (INCLUDE ELECTRIC VEHICLES AND IT IS VALID UNTIL 12/07/2025, ECOBONUS).

The Ministerial Decree (DPCM) published on 04/08/2022 [4][5], issues an incentive of €3,000 when purchasing a passenger vehicle (category M1) with a value up to €35,000 (VAT excluded) and CO2 emissions lower than 20g/km. This contribution is aimed at promoting purchasing for those who usually rent vehicles. An additional contribution of €2,000 is issued when scrapping a vehicle of class lower than EURO 5. The amount allocated for this incentive is €190 million.

Table 3: Direct incentives for purchasing motorcycles and moped in 2022 [3]

	Issued funds (million EUR)			Incentives	
Vehicle Category	2022	2023	2024	Bonus with scrapping (EUR)	Bonus without scrapping (EUR)
Electric/hybrid	15	15	15	40% (up to EUR 4,000)	30% (up to EUR 3,000)
Internal combustion	10	5	5	40% (up to EUR 2,500)	-

INCENTIVE TO PURCHASE A RECHARGING POINT FOR DOMESTIC USE (ECOBONUS).

The Ministerial Decree (DPCM) published on 04/08/2022 [2][4][5], issues an incentive up to 80% of the purchase price of a domestic recharging point (including the installation). The incentive has a price cap of €1,500, but it can rise to €8,000 for installations within common areas of residential buildings. The total funding amount allocated for this incentive is €40 million.

The Budget Law, which sets the incentive for businesses and professionals purchasing and installation of charging infrastructure, has been extended until 2024. The financial resources (€90 million in total) are allocated as follows:

a) 80% is directed to companies for fees less than €375,000.
b) 10% is directed to companies for fees larger than €375,000.
c) 10% is directed to professionals.

This incentive is also issued based on the charging power:

a) AC charging infrastructure with a power between 7.4kW and 22kW can benefit from an incentive of €2,500 per device for a Wallbox with only one charging point, whereas an incentive of €8,000 is issued for charging columns equipped with two charging points [3].

b) DC charging infrastructures with a power up to 50kW can benefit from an incentive of €1,000. Charging infrastructures (per column) with power between 50kW and 100kW can benefit from an incentive up to €50,000, whereas for infrastructures (per column) with power larger than 100kW the incentive rise to €75,000 [3].

INCENTIVE TO SMES AND TO TAXI-NCC LICENSE HOLDERS.

A new Decree introduced incentives to transportation firms for the purchase of electric buses (category M2) for long distance trips and for tourism tours [8]. This incentive could also include the scrapping of obsolete vehicles. The incentive can rise to €70,000 when purchasing new buses with a capacity larger than 22 passengers, otherwise it caps at €50,000 for minibuses (category M3) with a capacity of 9 and 22 passengers. The total amount allocated for this incentive is €25 million.

An incentive up to 75% of the total invested amount is offered to bus companies for the production of electric and connected vehicles [9]. To benefit from this incentive, the investment should range between €1 and €20 million, and should only interest buses and minibuses of category M2 and M3. The amount allocated for this incentive is €80 million.

Table 4: Direct incentives for purchasing electric commercial vehicles in 202 [3]

	Issued funds (million EUR)				
Vehicle Category	**2022**	**2023**	**2024**	**Bonus with scrapping (EUR)**	**Weight**
N1 electric	10	15	20	4,000	< 1.5 ton
				6,000	1.5 ton< W < 3.5 ton
N2 electric				12,000	3.5 ton< W < 7 ton
					7 ton< W < 12 ton

INCENTIVE TO PURCHASE COMMERCIAL VEHICLES (VALID UNTIL 12/07/2025, ECOBONUS).

An incentive has been issued to SMEs for the purchase of commercial electric vehicles of categories N1 (light trucks) and N2 (medium size trucks) when scrapping a vehicle of class lower then Euro 4 [5]. The incentives are issued as follows: €4,000 for category N1 up to 1.5 tons; €6,000 for category N1 bigger than 1.5 tons and up to 3.5 tons; €12,000 for category N2 bigger than 3.5 tons and up to 7 tons; €14,000 for category N2 bigger than 7 tons and up to 12 tons. The amount allocated for this incentive is €15 million. Generally, the amount of the incentive usually depends on the type of fuel or power source (electric vehicles obtain the highest incentive). Only the region Lombardy has adopted an incentive scheme based on the combination of NOx and CO2 values (based on manufacturers' declared values).

HEVS, PHEVS, AND EVS ON THE ROAD

The number of passenger cars registered in the year 2022 was about 1.3 million, with a slight drop compared to 2022, in which about 1.4 million vehicles were registered. This is in part due to the economic situation, which has seen an increase in inflation by more than 10% during the year 2022.

Although the year 2022 was characterized by a large growth of charging infrastructure, this was not followed by a relevant increase of new registrations of electric vehicles. On December 2022, there were about 170,000 BEV passenger cars with about 50,000 BEV new registrations (49,058) compared to 67,000 new registration of the previous year 2021. Therefore, there was a decrease of 27% and a share falling from 4.6% to 3.7% on the total market compared to 2021. PHEVs, with 65,580 units registered, showed a decreased of about 7%, compared to 70,472 units in 2021. The market of HEVs remained stable, with about 449,993 new vehicles registered in 2022 compared to 422,190 on 2021.

CHARGING INFRASTRUCTURE OR EVSE

In 2022, an increasing trend of public charging infrastructure has been observed. This is the result of persistent work by several energy players in the charging sector. On 31 December 2022, the number of charging points in Italy reached 36,772 across 19,334 charging stations or columns, in 14,048 publicly accessible locations. Compared to 2021, charging points saw an increase of 10,748 units (41%). If we compare this trend with the one registered in 2021, in which charging points increased by 35%, there is an observable growth. A close look at the distribution between charging points installed on public and private grounds, the 72% of the charging points is located on public grounds (i.e., roads), while the remaining 28% is located on private grounds for public use (i.e. supermarkets or shopping malls).

Regarding charging power, 88% of the installed charging points operate with alternate current (AC), while 12% operate with direct current (DC). It is important to note that Italy is seeing an increase of infrastructure operating with high power. Indeed, besides having doubled the number of DC chargers in 2022 (in 2021, DC charging points were 6% of the total, compared to 12% in 2022), the number of ultrafast charging points (charging points with a power larger than 150 kW) has tripled.

Fleet Totals (as of December 31st 2022)

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Electric bike	1,400,000	n.a.	n.a.	n.a.	50,000,000
Electric moped (<50 kmph)	n.a.	n.a.	n.a.	n.a.	1,200,000
Auto-rickshaw	n.a.	n.a.	n.a.	n.a.	n.a.
Motorcycle	n.a.	n.a.	22	n.a.	7,100,000
Motorcycle with sidecar	n.a.	n.a.	n.a.	n.a.	n.a.
Motorized tricycle	n.a.	n.a.	n.a.	n.a.	n.a.
Passenger vehicles	170,428	1,486,483	183,055	56	39,822,723
Buses and Minibuses	792	n.a.	n.a.	13	100,199
Light Commercial vehicles	12,977	16,284	1,087	n.a.	4,290,042
Medium and Heavy Weight Trucks	64	4	n.a.	n.a.	783,000

Sources: ANCMA, Motus-E, ENEA, EAFO, ACI

Total Sales (1st Jan 2022 to 31st Dec 2022)

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Electric bike	295,000	n.a.	n.a.	n.a.	1,680,000
Electric moped (<50 kmph)	5,904	n.a.	n.a.	n.a.	21,245
Auto-rickshaw	n.a.	n.a.	n.a.	n.a.	n.a.
Motorcycle	10,436	n.a.	n.a.	n.a.	259,980
Motorcycle with sidecar	n.a.	n.a.	n.a.	n.a.	n.a.
Motorized tricycle	n.a.	n.a.	n.a.	n.a.	n.a.
Passenger vehicles	49,169	454,989	64,632	11	1,316,919
Buses and Minibuses	123	n.a.	n.a.	n.a.	3,255
Light Commercial vehicles	4,138	n.a.	614	n.a.	161,096
Medium and Heavy Weight Trucks	17	n.a.	n.a	n.a.	25,341

Sources: ANCMA, ANFIA, UNRAE

*Total of vehicles of this type, including ICEVs

*As of December 31st, 2022

Source: Motus-E, Tesla

Type of Public EVSE	Number of Outlets*	Number of Locations*
AC Level 1 ≤ 3.7 kW	4,183	16,700
AC Level 2 >3.7 kW, ≤ 22 kW	26,942	
AC Fast Charger 43 kW	921	
DC Fast Charger ≤ 50 kW	1,201	
Tesla Supercharger DC > 120kW- 250kW	384	
Ultrafast High Power DC > 50 kW and ≤ 350 kW	4,347	
Inductive Chargers EM Charging	n.a.	n.a.

Charging infrastructure on the motorways is still not widely covering the Italian territory. To date, there are only 496 public recharging points on the motorways. However, more than half of these points (64%) have a power equal or larger than 150kW. In addition, the presence of charging points along motorways is experiencing fast growth compared to 2021, when there were only 118 charging points (as of December 2021). Therefore, during 2022, the charging infrastructure on the Italian motorways is 4 times that of 2021 (+378 charging points). During the last year, efforts have been made along the most important motorways and within proximity to highway toll booths.

Principal investments in charging infrastructure have been made only by the Autostrade Group, which owns the largest number of charging points along motorways. It should be noted that more than half of Italian City Councils (58%) do not have public charging points installed within their territory. On the other hand, almost 99% of the Italian territory has at least one charging point within a radius of 20km, with 86% of the territory also within a radius of only 10km.

A survey has been carried out in Italy in 2022 to analyze the use of the electric car and charging infrastructure, with the goal of highlighting possible gaps [3]. The survey has gathered about 1,000 answers among electric car owners, as well as users interested in purchasing one. About 70% of people interested in buying an electric passenger car are concerned about its high price. Another concern, even if less relevant, is “range anxiety,” or the fear that the driver’s fear battery will run out of power before reaching the destination or a charging point.

From the survey, it can be observed that the main driver of buying an electric passenger car is related to its environmental impact and to the low maintenance costs throughout the car’s lifetime. Another important driver is the potential to install a domestic charging point. Overall, the purchase of an electric vehicle is largely reliant on public incentives, which were used by almost 76% of the people who bought an electric car.

Regarding the charging habits, during the year 2022, about 70% of electric car owners also own a domestic electric charging point, whereas fewer users, about 9%, use charging points located at their workplaces. Overall, about 46% of electric car owners charge their car at a domestic charging point, whereas about 21% of electric car owners mainly use public charging points. More precisely, 79% of survey respondents use charging points located on urban roads, with a 20% increase compared to 2021. Other respondents use charging infrastructure near points of interests (74%), in public parking (68%) and, along extra-urban roads (35%), showing an increase of +11%, +18% and +16% respectively compared to 2021. Finally, the survey highlighted that 9 out of 10 electric car owners have declared they do not want to repurchase an internal combustion engine vehicle in the future.

In Italy, the growth between "normal charge" (≤ 22 kW) and "fast charge" (> 22 kW) charging types is uneven and unbalanced, with higher prevalence of fast charging. Already in 2021, an increase of +67% and +158% was observed compared to 2022. This trend has also been observed in 2022.

In July 2022, about 33,000 public charging points have been estimated in Italy. However, the infrastructure has shown an uneven distribution among different geographical regions. Indeed, a clear difference is observed between North and South Italy. About 60% of the charging infrastructure is located in Northern Italy, about 24% in Central Italy, and the remaining 16% in Southern Italy (including Islands of Sicily and Sardinia). More precisely, the regions Lombardy, Piedmont, Emilia Romagna, and Veneto host 48% of charging infrastructure, followed by Lazio and Toscana with almost 17% of the charging points.

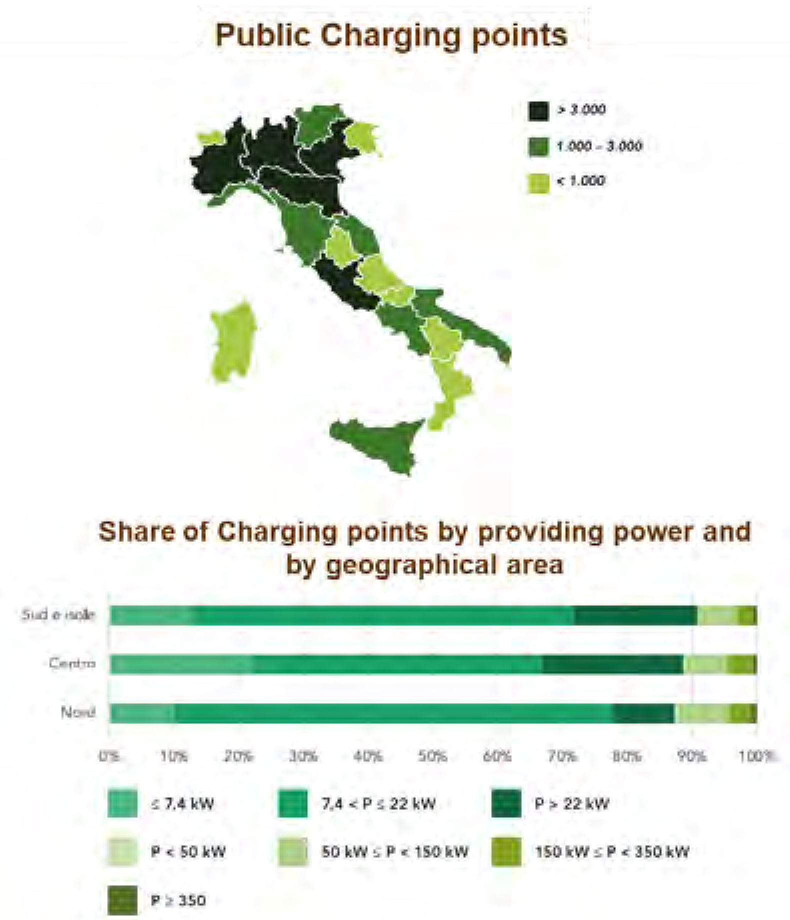


Figure 3: Regional distribution of charging points in Italy. 'Image courtesy of Politecnico di Milano, Smart Mobility Report 2022' [3].

The AC chargers are more present across all geographic areas, almost covering between 87% and 91% of the charging points. On the other hand, the majority of DC chargers provide power within the range 50–150 kW (63% in Northern Regions, 59% in the Central Region, and 65% in the Southern Regions and Islands). In July 2022, about 320 fast and ultra-fast public charging points have been estimated along motorways, still with an uneven distribution between regions.

Between 2020 and 2022, a gradual increase has been observed in the average range distance travelled by BEVs. In particular, the passenger vehicle in the C-segment (medium car), showed an increase of their travelling distance by about 24%. On the other hand, the average selling price of BEV in the A-segment (city cars) has shown a significant reduction by 14% compared to 2020. While the selling price for the B-segment or other segments has shown no reduction, the C-segment has seen an increase of 9% compared to 2020.

Finally, improvements have been observed in the charging efficiency of passenger vehicles in the A-segment (city cars) with an observed reduction charging time of 7% for the same kilometers travelled compared to 2020.

EV DEMONSTRATION PROJECTS

In September 2022, the Italian factory Rampini, which is active in the construction of buses, presented Hydron, the first minibus fully powered by hydrogen [10]. The vehicle has been created completely in Italy, in the province of Perugia, following 10 years of work and research. Hydron is a vehicle of 8-meter length which can carry 48 persons with an autonomy of about 450km. The Rampini Factory also presented two other zero emission vehicles. The first one is Sixtron, a six-meter-long electric bus able to move within small Italian historical centers. The second electric vehicle is named Eltron and is the evolution of the E80, the first electric bus built by Rampini. Eltron can carry up to 48 passengers and with a length of 8 meters. As of 2018, the Rampini company has stopped the production of endothermic vehicles. The company invests the 10% of its revenues in research and development and export in Greece, France, Germany, Austria, and Spain. In April 2022, Rampini and Sapio (who is active in the production of industrial gases) have signed an agreement to set up a hydrogen production chain entirely made in Italy.

Figure 4: Hydron, the hydrogen bus built by the factory Rampini (Italy)

Image courtesy of Vaielettrico

In October 2022, the first demonstrator of the new air taxi service took off from the Rome - Fiumicino International Airport [11]. The service is expected to be active in 2024, together with the first experimental Italian Vertiport. This will be infrastructure that allows a safe vertical landing of light aircraft for passenger transport along urban routes. The service will be operated by the Volocopter, a fully electric aircraft with vertical takeoff, with 18 engines and capable of transporting two people and 250kg of goods. With a range of around 100km, the Volocopter will transport passengers from Rome-Fiumicino Airport to the center of Rome in about 20 minutes.

Figure 5: The Volocopter, the first aero taxi service from Rome-Fiumicino International Airport active from 2024.

Image courtesy of Il Messaggero.

A yard truck equipped with a hydrogen engine has been developed as part of the Atena consortium initiative, as part of the wider European project “H-Ports” [12]. The initiative has received the support of the Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA), the Cantieri del Mediterraneo, the University of Naples Parthenope and the University of Salerno. Technically, the truck is a port tractor fueled with hydrogen and with hybrid propulsion made of fuel cells and lithium-ion batteries. The tractor will be able to accomplish routine work of loading and unloading from cargo ships. The use of hydrogen will allow good operability, short refueling times, low maintenance costs and, above all, zero emissions.

Figure 6: The hydrogen yard tractor developed by the Atena Consortium (Italy)

Image courtesy of Tgcom24

The accumulation system of the prototype of the tractor is characterized by a total capacity of 12kg of hydrogen that can guarantee up to six hours of operation, that is the average time of the typical work shift. The electric engine mounted on the tractor is very efficient and can be used for operations requiring high power; it can source motion energy both from the fuel cell and the battery. The battery can be recharged when breaking and decelerating. Currently, the tractor is being tested in the port of Valencia, Spain. According to the most recent estimations, if a fleet of 6 hydrogen tractors are regularly used in a medium size port terminal, it will avoid emissions of about 501 tons of CO2 a year and 5 tons of NOx a year.

OUTLOOK

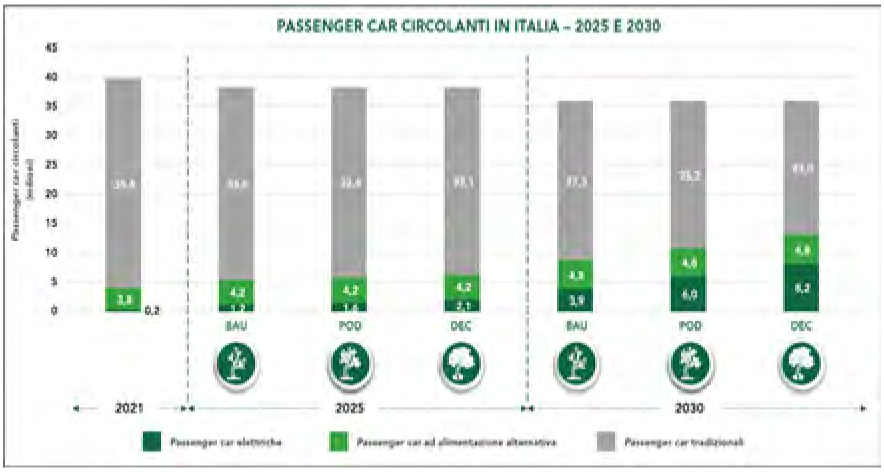
Alongside reporting a detailed analysis of technologies, regulations, and current car market, the "Smart Mobility Report," published by the Italian Polytechnic Institute in Milan in October 2022 [3], presents forecasts from three automotive market scenarios that can be summarized as follows:

- "Business-As-Usual" scenario: this scenario foresees an adoption of almost 3.9 million of electric vehicles by 2030.
- "Policy Driven" scenario: in this scenario, the number of electric vehicles is foreseen to reach 6 million by 2030.
- "Full Decarbonization" scenario: in this scenario, the number of electric vehicles is foreseen to reach about 8.2 million by 2030.

It should be noted that, the value foreseen by the "Policy Driven" scenario in 2030 is equal to that envisaged by the Integrated Energy and Climate National Plan [13]. These forecasts are shown in Figure 7 together with forecasts of sales.

Figure 7: Forecast on fleet and new registration of passenger cars.

Image courtesy of Politecnico di Milano, Smart Mobility Report 2022



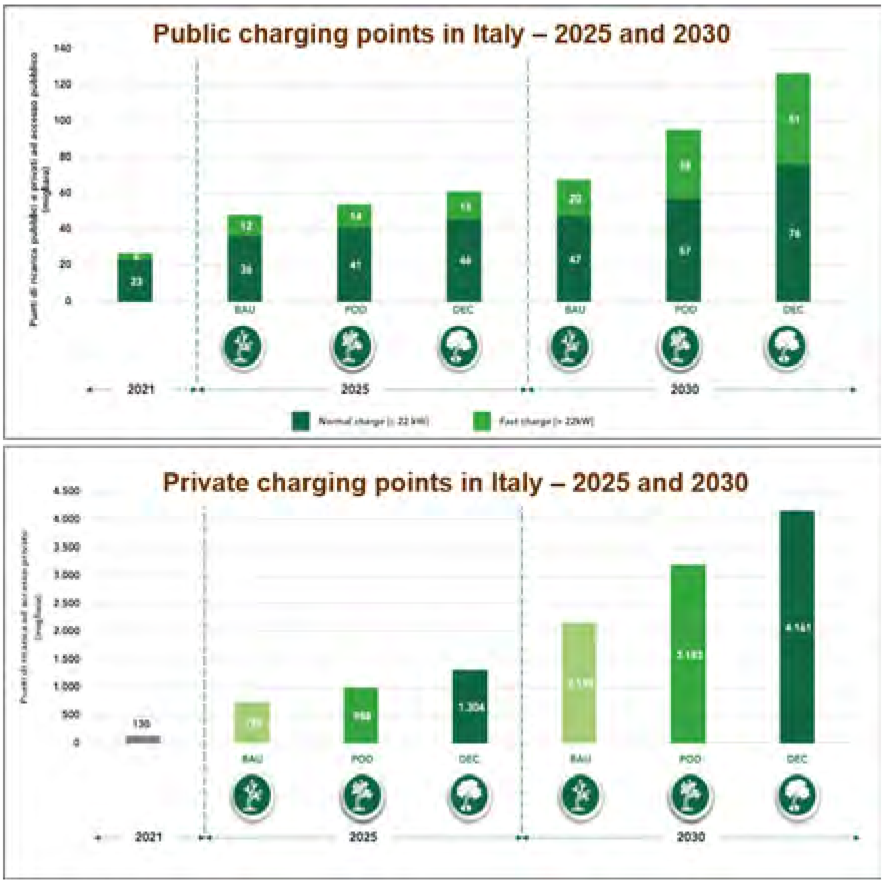
In regard to the publicly accessible charging points forecasted for 2030, the following projections are available:

- 67,000 charging points are foreseen in the "Business-As-Usual" scenario.
- 127,000 charging points in the “Decarbonization” scenario.
- 95,000 units in the “Policy Driven” scenario.

With regard to private charging points for electric vehicles, the "Business-As-Usual" scenario foresees 2.16 million units by 2030, 3.18 million units in the “Policy Driven” scenario and 4.16 million units in the “Decarbonization” scenario (Figure 8).

Figure 8: Forecast on charging points

Image courtesy of Politecnico di Milano, Smart Mobility Report 2022.



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The Netherlands

*119,197 public and semi-public charging points. 4,164 fast charging points. Private charging points are estimated to be around 350,000

Number of EVs & PHEVs registered

650,754

Number of EV chargepoints*

473,361

MAJOR DEVELOPMENTS IN 2022

2022 marked the recovery from the COVID-19 pandemic. A steady growth of electric passenger cars was monitored. The sales share of electric passenger cars accounted for 35% of the total passenger car sales. That is an increase of 5% compared to 2021. The ambition is that in 2025 50% of all new passenger cars sold will have an electric powertrain and a plug and at least 30% of these vehicles will be zero emission (BEV or FCEV). If the growth continues as it did over the last years this ambition can be realized.

In December 2021, the coalition agreement was presented by the new cabinet of the Netherlands. In the agreement, there is a strong emphasis on sustainability and the role of the government in combating climate change. Climate policy is seen as something that provides opportunities to build a sustainable and strong economy and create jobs. The Netherlands wants to take a leading role in Europe when it comes to the transition to a green economy.

After the Fit for 55 package was presented by the European Union in the summer of 2021, the Dutch government adapted its standards and made them even stricter. Under these stricter standards, the Netherlands is aiming for a 60% reduction in CO2 to make sure the goal of 55% is reached.

To reach these goals, the National Charging Infrastructure Agenda and the Formula E-Team continued to work on the rollout of both charging infrastructure and the transition to electric vehicles in 2022. The National Charging Infrastructure Agenda is a multiyear and multi-stakeholder agenda to ensure that charging infrastructure is not a barrier for the electrification of the mobility sector. The Formula E-Team is a public private partnership that advises the ministry of Infrastructure and Water management on policies to be executed and thereby helps reach climate targets and actualize the economic opportunities and benefits within the sector.

Policy Developments

The new cabinet was installed in January 2022. In the coalition agreement, a climate and transition fund was announced with a budget of €35 billion to expand the current energy infrastructure, realize green industry politics, and help make mobility systems and the built environment more sustainable.

The Netherlands also kept pushing forward on international initiatives, such as the Global Memorandum of Understanding (MOU) on Zero-Emission Medium- and Heavy-Duty Vehicles, which was initiated by the Netherlands in late 2021. In this MOU, countries sign an agreement that aims for all new heavy duty vehicles and buses in their respective countries to be zero emission by 2040. Transport organizations, companies and regional governments can endorse the Global MOU. In 2022, another 12 countries signed the Global MOU, bringing the number up to 27.

In November 2022, the Dutch Climate and Energy Exploration (KEV) was published. This yearly report monitors the progress made on the climate and energy policies. After the KEV was published, the government announced that a multi-departmental climate research program would be conducted. The goal of this research was to explore any extra measures that could be taken to achieve the goals that have been set. As far as mobility is concerned, the most drastic measure proposed is a potential ban on fossil fuel company cars from 2025. Decisions on which measures will actually be implemented will be made in the spring of 2023.

Financial and Fiscal Incentives

One of the drivers behind the steady increase of electric vehicles in the Netherlands is fiscal and financial incentivization. The focus is on stimulating zero-emission vehicles, which means certain taxes for plug-in hybrid vehicles will slowly be increased to the same level as conventional cars. Table 1 provides an overview of the incentives that were in place in 2022, including purchase subsidies.

In 2022, the height of the purchase subsidy available for electric passenger cars was increased drastically, from €28 million in 2021 to €91 million in 2022, increasing its availability for consumers. There were also two new purchase grant schemes presented in 2022. One for zero emission trucks and one for zero emission construction equipment. Both schemes were very successful and the available budget depleted quickly. All purchase grant schemes will therefore be continued over 2023. Other than road transport, a subsidy was also announced for shore power supply for seagoing vessels. With shore power, electricity can be supplied to ships from the electricity grid on the mainland. By using this shore power, the (diesel) auxiliary engines of the ship can be switched off after mooring at the quay.

Policy measure	Details
Registration Tax	Zero emission cars are exempt from paying registration tax. For conventional cars, the system is progressive, with a starting tariff and 5 levels of CO2 emissions with incremental amounts of registration tax. Plug-in hybrid cars get a discount compared to conventional cars, they do not have a starting tariff and have 3 levels of CO2 emissions with lower amounts of registration tax. Diesels have a surcharge.
Road tax (circulation tax)	Zero emission cars are exempt from paying road tax. Plug-in hybrid cars < 51 gr CO2/km pay half the tariff (up to 2024). For conventional cars this tax is € 400 to € 1,200 (depending on fuel, weight and address).
Surcharge on income tax for the private use of company cars	In the Netherlands, income tax has to be paid on the private use of a company car. This is implemented by imposing a surcharge of 12% or 22% of the catalogue value on the taxable income. For BEV cars with a purchase price less than €35,000, this percentage is 16%. For BEVs costing more than €35,000 and for other cars, including plug-in hybrid cars, it is 22%. For FCEV and solar cars (>1 Kilowatt-peak), the surcharge is 12% over the total purchase price, which means there are no limitations.
Tax deductible investments	The Netherlands has a system of facilitating investments in clean technology, by making these investments partially deductible from corporate and income taxes. Zero emission and plug-in hybrid cars that emit less than 31g CO2/km (no diesel engine) are on the list of deductible investments, as are the accompanying charging points.
Purchase grant electric passenger cars	Private persons can get a purchase subsidy of €3,350 for a new electric car and €2,000 for a used electric car. The subsidy is applicable to BEVs with an action radius of at least 120 km, with a catalogue value between €12,000 and €45,000. The subsidy is not applicable to converted cars. Subsidies are also available for lease cars.
Purchase grant emission free delivery van	Companies can get a 10% subsidy of the net catalogue value for new emission-free N1 and N2 vehicles, with a maximum weight of 4,250 kg. The maximum subsidy amount per van is €5,000. SMEs can get a 12% subsidy.
Purchase grant zero emission trucks	Companies can get a purchase subsidy for zero emission N2 and N3 vehicles. The size of this subsidy is between 12.5% and 37% of the purchase value, depending on the size of the company that requests it and also on the weight of the vehicle.
Purchase grant zero emission construction equipment	Companies can get a purchase subsidy for a zero emission construction machine. The subsidy has a maximum of €300,000 per construction machine, with a maximum of €1,000,000 per company. Subsidy to retrofit construction machines is also part of this scheme.
Subsidy for shore power supply	A temporary subsidy in 2022 and 2023 is available for companies who are looking to build a shore power supply that is mainly used for seagoing vessels. The subsidy has a maximum of 35% of the eligible costs with a maximum of €5,000,000 per project.

Table 1: Fiscal and financial incentives

Market Developments

Vehicle2Grid will be further developed over the upcoming period. In 2022, the city of Utrecht had a world premiere of V2G technology for deployment on a large scale. Hyundai contributes to the project in Utrecht, deploying 25 IONIQ 5 vehicles with V2G technology and using them as a bidirectional production car. The IONIQ 5 vehicles are deployed by We Drive Solar, a company offering different types of shared car memberships to residents of Utrecht. Utrecht has thereby made important steps in its ambition to become the first bidirectional city and region in the world.

Figure 1: We Drive Solar launch with IONIQ 5 vehicle

Image: We Drive Solar

The total cost of ownership was much more positive for an electric car in 2021 than in 2022. This is due to not only the energy prices rising drastically over the course of 2022, but also the average purchase price of an electric car. Together, this leads to a pricing barrier that could slow down the transition to electric vehicles.

Technology is developing very quickly still and the Technical University Eindhoven has presented a model that can predict the energy use of electric buses. More and more buses in the Netherlands are electric; in 2022 they increased to around 80% of new sales. As it is often hard to predict how much energy is left in the battery, more buses are put on schedule than actually necessary—with companies planning months in advance. The model presented by the TU Eindhoven can predict the energy use of a bus on a certain route that takes into account route information such as the maximum speed but also the weather and the incline of the road. By using this model, bus schedules can me made dynamically which leads to efficiency and flexibility.

HEVS, PHEVS, AND EVS ON THE ROAD

At the end of 2022, the number of electric vehicles on the road (over 515,000) accounted for 5.8% of the total passenger car fleet. 65% of these are BEVs, with BEV passenger cars having increased to 328,295. Like in 2021, the number of PHEVs showed a strong growth, with the total number going up by 35% to 186,947 cars. By the end of 2022, 596 FCEV cars were on the road, a 20% increase compared to 2021.

Over the year 2022, 35% of total new passenger car registrations were electric. Of this 35%, the majority (24%) was fully electric. The share of PHEVs in new registrations was 11%. Other vehicle types also steadily increased in numbers, as can be seen from Figure 2.

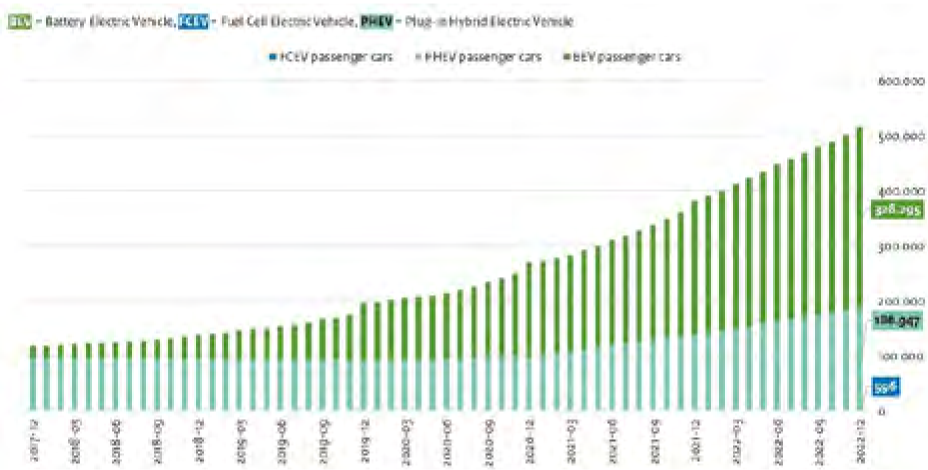

Figure 2: Electric passenger cars in Dutch Fleet 2017 – 2022

Source: Dutch Road Authority

Fleet Totals (as of December 31st 2022)

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Electric bike	30,835	n.a.	n.a.	n.a.	30,835
Electric moped (<50 kmph)	102,857	n.a.	n.a.	n.a.	1,299.265
Auto-rickshaw	n.a.	n.a.	n.a.	n.a.	n.a.
Motorcycle	1,372	n.a.	n.a.	n.a.	759,055
Motorcycle with sidecar	n.a.	n.a.	n.a.	n.a.	n.a.
Motorized tricycle	164	n.a.	n.a.	n.a	16,136
Passenger vehicles	337,782	450,370	192,588	645	9,403.680
Buses and Minibuses	1,466	116	11	55	9,513
Light Commercial vehicles	14,106	1,203	130	13	1,094.321
Medium and Heavy Weight Trucks	384	35	58	35	182,233

Total Sales (1st Jan 2022 to 31st Dec 2022)**

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Electric bike	4,633	n.a.	n.a.	n.a.	4,633
Electric moped (<50 kmph)	15,699	n.a.	n.a.	n.a.	31,442
Auto-rickshaw	n.a.	n.a.	n.a.	n.a.	n.a.
Motorcycle	421	n.a.	n.a.	n.a.	34,056
Motorcycle with sidecar	n.a.	n.a.	n.a.	n.a.	Onbekend
Motorized tricycle	63	n.a.	n.a.	n.a.	1,746
Passenger vehicles	91,058	105,317	53,884	116	556,719
Buses and Minibuses	99	9	n.a.	14	393
Light Commercial vehicles	4,678	602	52	n.a.	80,612
Medium and Heavy Weight Trucks	123	42	9	28	19,375

*Total of vehicles of this type, including ICEVs

** New and occaion import

CHARGING INFRASTRUCTURE OR EVSE

The Netherlands has a well-developed network of charging points, as illustrated in Figure 3, which shows the division of (semi) public charging points across the provinces. All charging is interoperable in the Netherlands, as has been the case since 2011.

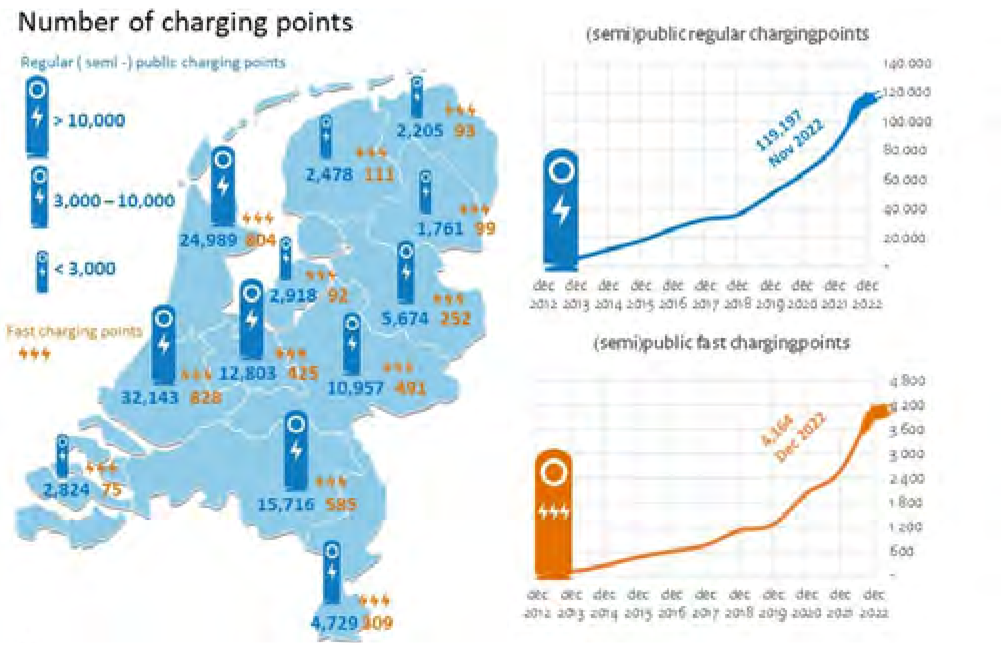

Figure 3: Number of charging points. Source: Eco-Movement, edited by RVO

In 2022, the rollout of charging infrastructure progresses quickly, which can be seen clearly when looked at the percentage increase over 1 year. Compared to the end of 2021, the number of (semi)public charging points increased by almost 40% in 2022, to 120,000 charging points. Fast charging can be done at 972 locations with 4,164 charging points, which is an increase of 60% compared to 2021. There are no official statistics on the number of home charging points, but the estimate is around 350,000. At the end of 2022, there were 10 publicly accessible hydrogen fueling stations in the Netherlands, most of them supplying 350 and 700 bar.

The Dutch government, knowledge institutions, and companies together call for the use of open standards and protocols in charging infrastructure, so as to stimulate innovation and global access—thus favoring EV uptake.

*As of December 31st, 2022

Type of Public EVSE	Number of Outlets*	Number of Locations*
AC Level 1 ≤ 3.7 kW	2,512	278
AC Level 2 >3.7 kW, ≤ 22 kW	114,823	41,384
AC Fast Charger 43 kW	1,035	677
DC Fast Charger ≤ 50 kW	802	85
Tesla Supercharger DC > 120kW- 250kW	1,301	49
Ultrafast High Power DC > 50 kW and ≤ 350 kW	1,136	698
Inductive Chargers EM Charging	n.a.	n.a.

EV DEMONSTRATION PROJECTS

In 2022 there was a strong focus on the upcoming transition to zero emission heavy duty vehicles, partly as a result of the announcement of more zero emission zones in cities over the coming years. As of the end of 2022, 30 cities have announced a zero emission zone from 2025 onwards. To gain knowledge and prepare for this transition, the Living Lab Heavy Duty charging plazas were started in 2022. In six locations, a testing ground was opened to enable quick upskilling on the best design and use of charging facilities for e-trucks in connecting urban areas with top logistic locations, such as ports and areas with a high concentration of distribution centers.

In a similar context, 2022 also marked the year in which an international test center was opened in the Netherlands to research the charging of electric vehicles—the ElaadNL Testlab was opened in June 2022 by His Majesty King Willem-Alexander. At this test center, cars, buses and trucks will be tested. Dutch and international vehicle manufacturers, charging station manufacturers, charging station operators, companies that provide energy services, network operators and educational institutions can use the test facilities in Arnhem. The power quality can be measured with specialized equipment and there is infrastructure to charge power in a short time and with high voltage. The testing lab can also examine the entire communication chain of the vehicle, charging station, back office and interaction with other elements such as solar panels.

Figure 4: His Majesty King Willem-Alexander at the opening of the ElaadNL Testlab

Image: Patrick van Gemert

OUTLOOK

Following an initial focus on electric passenger cars, 2022 showed a serious shift in focus towards a diverse range of commercial vehicles. Medium and heavy duty vehicles, inland ships and even construction machines are emerging technologies and will continue to be so in the years to come.

To further decarbonize mobility and transition to zero emission vehicles, grid capacity is a big concern, as it has the potential to become a bottleneck in the rollout of charging infrastructure. This has led to the National Network Congestion Action Program, which was published in December 2022. In this action program, measures are presented which are necessary to take in order to build grids faster and to match the available grid capacity as closely as possible with the demand for electricity transmission, both for production and consumption. The program focuses on three main goals: faster realization of grids, better use of the available capacity and public-private partnership for smart solutions.

Another action plan has been launched in the final months of 2022, which focuses in specifically on how to best use the available grid capacity. The action plan was launched under the smart charging working group of the National Charging Infrastructure Agenda and is called ‘Smart Charging for everyone 2022 – 2025’. The goal of the action plan is for 60% of all charging sessions to be ‘smart’ by 2025. If this is achieved, millions of electric vehicles can be used to temporarily store energy, helping make the energy system more flexible.

In conclusion, the upcoming period will focus on continuing the shift to zero emission in all modalities and understanding how to build an energy system that works hand in hand with the mobility system to create a clean, green and sustainable future.

Norway

Number of EVs & PHEVs registered

829,939

Number of EV chargepoints

23,395

MAJOR DEVELOPMENTS IN 2022

The biggest development in 2022 was that the number of battery electric passenger vehicles in the fleet passed 600,000, equivalent to 20% of the total fleet with another 7% being PHEVs. 27% of all passenger vehicles had thus a plug and could use grid electricity fully or partially. The BEV market share reached a new high of 78% with PHEVs constituting another 6%. It was the first year of significant sales of battery electric trucks, which came after the large OEM truck producers started series production.

The access to ultra-fast chargers increased significantly during 2022 after Tesla opened most of their Supercharger network to all BEV owners. The fast charger ecosystem is fragmented and inconvenient for users. Large operators do not allow roaming across networks and BEV owners may need to use 20-30 apps to find and use all chargers, and 14 different payment systems are in use [1]. Bank cards can only be used in a few locations. Several large policy revisions were suggested in the national budget documents for 2023 and agreed upon in the Parliament. The overall target was to preserve and regain lost tax revenue from vehicle sales and use, and to protect toll road projects from running into financial difficulties as the BEV share of the fleet continues to rise. The changes are:

- A new weight-based registration tax element on each kg above 500kg was introduced for ICEVs and BEVs, including small light commercial vehicles and minibuses. It hits BEVs harder than ICEVs.
- BEVs with a purchase price below 500,000 NOK will still have a zero Value Added Tax (VAT). VAT (25%) will apply on the part of the sum that is above 500,000 NOK for more expensive BEVs. This scheme will continue until 2025.
- BEVs can now be levied up to 70% of the road toll rate of ICEVs, up from the 50% that has been the rule since 2018.
- The re-registration tax incentive and the company car benefit tax reduction incentive were both removed.

HEVS, PHEVS, AND EVS ON THE ROAD

A major achievement in 2022 was that the number of BEVs passed 600,000 and the BEV share of the total fleet passed 20%. PHEVs accounted for another 200,000 vehicles and 7% of the vehicle fleet. All other vehicle segments have fleet shares below 5%. The battery electric bus fleet share is 5.0%, light commercial vehicles share is 4.3%, that of mopeds 3.0%, motorcycles 1.3% and trucks 0.7%.

The biggest development in 2022 was that the number of battery electric passenger vehicles sold within a year for the first time passed 150,000, and the market share passed 78% which was 15 percentage points higher than 2021.

An extreme number of BEVs were registered before 31 December 2022, to avoid the weight tax and VAT on the price exceeding 500,000 NOK introduced from 1 January 2023. 2022 was also the first year with substantial sales of battery electric trucks. The sales of battery electric buses reached new heights, but the absolute numbers will differ between years as city and regional bus sales are driven by public tenders. Oslo will become a city with close to 100% battery electric bus coverage by the end of 2023, as 320 new battery electric buses will be phased in [4]. In 2022, the fleet share passed 40%.

CHARGING INFRASTRUCTURE OR EVSE

The biggest change in 2022 was the opening of Tesla's Supercharger network to non-Tesla BEVs. 15 locations with 305 Supercharger plugs were opened in January and another 42 locations with 497 Supercharger plugs opened in May. Another 8 locations opened in the Summer.

High electricity prices have led to price increases throughout 2022 and more volatile pricing. Pricing is now varied across different parts of Norway, reflecting differences in electricity prices according to electricity transfer capacity bottlenecks. Extreme price increases for curbside municipal charging in Oslo had caused an uproar among BEV owners without access to home charging, as the prices were well above the energy cost of diesel ICEVs. The price increase has since then been reversed.

Fleet Totals (as of December 31st 2022)

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Electric bike	n.a.	n.a.	n.a.	n.a.	n.a.
Electric moped (<50 kmph)	4,309	n.a.	n.a.	n.a.	141,953
Auto-rickshaw	n.a.	n.a.	n.a.	n.a.	n.a.
Motorcycle	2,303	n.a.	n.a.	n.a.	184,673
Motorcycle with sidecar**	n.a.	n.a.	n.a.	n.a.	n.a.
Motorized tricycle**	n.a.	n.a.	n.a.	n.a.	n.a.
Passenger vehicles	600,464	150,679	199,966	220	2,931,378
Buses and Minibuses	704	105	54	n.a.	14,112
Light Commercial vehicles	21,676	573	6	1	507,425
Medium and Heavy Weight Trucks	456	n.a.	1	4	65,932

Total Sales (1st Jan 2022 to 31st Dec 2022)

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Electric bike	n.a.	n.a.	n.a.	n.a.	n.a.
Electric moped (<50 kmph)	1,301	n.a.	n.a.	n.a.	3,179
Auto-rickshaw	n.a.	n.a.	n.a.	n.a.	n.a.
Motorcycle	289	n.a.	n.a.	n.a.	11,171
Motorcycle with sidecar**	n.a.	n.a.	n.a.	n.a.	n.a.
Motorized tricycle**	n.a.	n.a.	n.a.	n.a.	n.a.
Passenger vehicles	152,707	12,304	16,334	57	194,997
Buses and Minibuses	309	n.a.	n.a.	n.a.	642
Light Commercial vehicles	6,995	n.a.	n.a.	n.a.	29,230
Medium and Heavy Weight Trucks	365	n.a.	n.a.	n.a.	4,893

*Total of vehicles of this type, including ICEVs

** Included in Motorcycle category

*As of December 31st, 2022

**Tesla Superchargers with CCS connector open to all BEVs are counted as Ultrafast-High power chargers.

***Includes 2551 3.6 kW Type 2 outlets and 357 combined Type 2/Schuko outlets, 4193 Schuko-outlets, 50 Type 1 outlets and 34 other.

****Includes 85 charge outlets using Tesla connectors and industrial plugs

Type of Public EVSE	Number of Outlets*	Number of Locations*
AC Level 1 ≤ 3.7 kW	7,185***	1,116
AC Level 2 >3.7 kW, ≤ 22 kW	10,373****	2,510
AC Fast Charger 43 kW	168	60
DC Fast Charger ≤ 50 kW	1,593	756
Tesla Supercharger** DC > 120kW- 250kW	484	42
Ultrafast High Power DC > 50 kW and ≤ 350 kW	3,590	820
Inductive Chargers EM Charging	2	1

EV DEMONSTRATION PROJECTS

Tesla's opening of Superchargers to other BEV owners started as a demonstration/pilot project in January 2022 but is now in a phase of regular operation. Established by transport industry stakeholders, "Green Land Transport program" (Grønt Landtransportprogram) [6] is a platform for establishing pilots and demonstrators within zero-emission heavy duty vehicle use. Zero-emission in this network encompasses battery electric, hydrogen and biogas. The first demonstrators have been within battery electric trucks and the associated charging infrastructure, biogas production and distribution, and testing of long-distance zero-emission buses.

OUTLOOK

The removal of some incentives, reduction of others, the new weight tax on all vehicles, and the large number of BEV registrations just before 1 January 2023, may affect 2023 BEV sales negatively. In 2023, Oslo will become a city where all city buses will be battery electric. The market share for battery electric trucks should increase due to the increased availability of series produced trucks from several of the large OEMs, and interest from the truck operators. A new ENOVA funding program provide support for depot chargers for trucks, which previously was only available for open access chargers outside depots. Large orders of battery electric buses for Oslo and elsewhere will be delivered during 2023 so their market share will also be high in 2023.

References

[1] Figenbaum E., Wangsness P. B., Amundsen A. H., Milch V. 2022. Empirical Analysis of the User Needs and the Business Models in the Norwegian Charging Infrastructure Ecosystem World Electr. Veh. J. 2022, 13 (10), 185. Special Issue EVS35-International Electric Vehicle Symposium and Exhibition (Oslo, Norway). DOI: https://doi.org/10.3390/wevj13100185

[2] ESA=EFTA Surveillance Authority (the EEA agreement equivalent of the EU Court)

[3] ENOVA, a Government agency, supports charging infrastructure.

[4] Ruter#. "All kollektivtrafikk utslippsfri i Oslo i 2023." Accessed at: https://www.mynewsdesk.com/no/ruter/pressreleases/all-kollektivtrafikk-utslippsfri-i-oslo-i-2023-3192752.

[5] Date from the Norwegian charging infrastructure database NOBIL.

[6] Grønt Landtransportprogram. Accessed at: https://www.nho.no/samarbeid/gront-landtransportprogram/.

Republic of Korea

Number of EVs & PHEVs registered

389,855

Number of EV chargepoints

62,789

MAJOR DEVELOPMENTS IN 2022

The Korean Ministry of Environment has been actively promoting subsidy policies over recent years and has laid the foundation for the popularization of electric vehicles (more than 70% of the annual number of electric vehicles sold are public and popular vehicles with a price of less than 417 thousand dollars), such as distributing 402,000 cumulative electric vehicles. In addition, subsidies were paid differentially according to performance, leading to the development and spread of electric vehicles (400km driving distance per charge) with excellent performance in a short period of time.

With the increase in the supply of electric vehicles, expectations for not only vehicle performance but also safety and usage conditions have increased, and various roles, other than supporting the purchase of electric vehicles, are required from subsidies. In particular, it is necessary to go beyond strengthening differentiated subsidies according to performance of electric vehicles, towards providing subsidies for innovation in related core technologies such as battery technology.

There is considerable public opinion that subsidies should serve as the foundation to a healthy EV ecosystem. In addition, opinions have been continuously raised that the convenience of use should be improved, such as charging electric vehicle batteries and expanding after-sale service infrastructure. The Korean Ministry of Environment has extensively reviewed these various social needs, and based on three principles:

- Safe and high-performance vehicle-centered support,
- The promotion of distribution at the time of purchase, support that considers safety and convenience after purchase, and
- Customized support for the vulnerable class and small business owners. The subsidy was reorganized by these principles.

The main contents of the subsidy reorganization plan by vehicle type are described in the following sections.

Figure 1: Example of electric passenger car, KIA EV6

(https://www.kia.com/kr/vehicles/ev6/gallery#localnav)

DIRECTION OF REORGANIZATION

In order to promote the dissemination of high-performance and mass-market vehicles, electric passenger cars are reorganized to lead to the achievement of distribution goals and the improvement of the convenience of using electric vehicles by strengthening differentiation according to vehicle performance and post-management capabilities and utilizing various support measures (incentives).

BASIC PRICE BASIS

Adjusting the subsidy payment ratio for each vehicle base price is a complex process. In the meantime, in order to promote the spread of mass-market electric vehicles at a reasonable price, the entire subsidy has been paid only for vehicles priced below about $41,700 USD. However, considering how the price of batteries has risen due to the recent surge in raw material prices, and the corresponding pressure to increase vehicle prices, the base price standard at which the subsidy is fully paid was raised from about $41,044 to about $42,537 (Conversion: $1=1,340KRW).

ADJUSTMENT OF UNIT PRICE

Rationalizing the subsidy unit price by considering life cycle cost analysis and fairness by vehicle class may also accelerate the supply of electric cars by significantly increasing the amount of support. Instead of reducing the unit price of mid and large-sized electric passenger car performance subsidies by about $760 USD (from about $4500 to $3800), the amount of subsidy for electric passenger cars has increased by about 31% (from 160,000 to 215,000 units) compared to the previous year. In addition, considering the price difference between vehicle classes, the upper limit on the performance subsidy for small and light electric vehicles was newly established at about $3,000 USD, and the subsidy for ultra-small electric vehicles was reduced from about $3,000 USD to about $2,700 USD. In addition, an additional 10% of the subsidy calculation amount was covered for low-income families and small business owners, with additional support expanded to 20% for ultra-compact electric vehicles.

STRENGTHEN PERFORMANCE EVALUATION

In order to promote performance improvement by strengthening subsidy differentiation according to performance such as mileage, the subsidy for electric passenger cars with a mileage of less than 150km per charge is reduced by about 20%, and the differential section of the mileage differential per charge is expanded from the original 400km to 450km subsidy calculation, so that high-performance vehicles receive more subsidies.

POST-MANAGEMENT COMPETENCY EVALUATION

The plan is to evaluate manufacturers' post-management capabilities across aspects such as the operation of direct maintenance centers and computerized management of maintenance records, in order to provide performance subsidies at a maximum of 20%. The post-management capability evaluation was newly introduced during this subsidy reorganization as complaints were continuously filed that the post-management infrastructure for electric vehicles was insufficient and that maintenance centers were inconvenient due to differing levels of expertise, service quality, and price.

The highest level of evaluation is given to maintenance centers operated directly by the manufacturer. In this, even if the backup management system in the form of consignment to the maintenance center is operated, if the manufacturer fulfills certain responsibilities, such as directly conducting professional training for maintenance personnel, it is regarded as equivalent to the operation of a direct maintenance center and thus these setups will also receive subsidy provision.

INCENTIVES

Various support measures (incentives) will be introduced to promote the supply of low-emission vehicles, the expansion of charging bases, and the development and adoption of innovative technologies by manufacturers. This year, in order to alleviate the burden on manufacturers due to the increase in the supply target for low-emission vehicles and to encourage the implementation of the target, the ‘supply target fulfillment subsidy’ was increased from approximately $530 to $1,060 USD. The companies eligible for the low-emission vehicle distribution target system are 10 companies, including five domestic manufacturers (Hyundai, Kia, SsangYong, Renault, and GM Korea), and five overseas manufacturers (Mercedes, BMW, Volkswagen, Toyota, and Honda). In addition, in order to induce manufacturers to expand their electric vehicle charger provision, a 'charging infrastructure subsidy' (approximately $150 USD) is provided for electric cars produced by manufacturers that have installed more than 100 rapid chargers (10 slow chargers are considered as one fast charger) within the last three years. In addition, the plan for this year is to support 'innovative technology subsidies' (approximately $150 USD) for vehicles that increase the utilization of electric vehicles through innovative applications of technologies with high added value, such as vehicles equipped with a V2L (Vehicle to Load) functions which convert an electric vehicle into a mobile energy storage system (ESS).

NEW POLICIES

In 2020, the government planned to subsidize 99,950 electric vehicles, including 65,000 passenger cars, 13,000 trucks, 650 buses, 21,000 motorcycles, and 300 plug-in hybrid electric vehicles (PHEVs). The plan was to provide 520 billion won ($393.42 million USD) for passenger cars, 210 billion won ($158.73 million USD) for trucks, 70 billion won ($52.91 million USD) for buses, 24 billion won ($18.14 million USD) for motorcycles, and 1.5 billion won ($1.13 million USD) for PHEVs, respectively.

The total amount is 820 billion won ($620.44 million USD). The amount of subsidies is the addition of 110 billion won ($83.64 million USD) to the main budget of 710 billion won ($537.81 million USD).

INCENTIVES

In 2020, the Ministry of Environment of Korea specified guidelines for handling subsidies to stipulate related tasks, such as subsidy support standards and procedures for supplying electric vehicles and establishing charging infrastructure. A total of 718,200 million won was invested in the project, primarily based on state funds. Of the total project costs, KRW 694,200 million was invested in the development of electric vehicles within local governments' capital assistance, and KRW 24,000 million was invested in the development of slow chargers for the private business, the Korea Environment Corporation.

The government provided 94,000 electric and hydrogen vehicle purchase subsidies in 2020, up 57% from 60,000 in 2019. However, the amount of support per unit decreased from up to 9 million won (4.2 million won for ultra-small vehicles) to 8.2 million won (4 million won for ultra-small vehicles). In addition, the subsidy system has improved the subsidy calculation system and expanded the differential range to induce the improvement of electric vehicle performance, centered around technical and environmental performance, and to improve the efficiency of subsidy distribution[1].

FUNDING

The Ministry of Environment has raised the fast charging fee from the current $0.134/kWh to $0.1967/kWh (USD) starting on July 6. From July 2021 to June 2022, the basic fee has been reduced by 25% and the electricity consumption fee by 10%, and from July 2022, the discount has been completely eliminated.

In reality, the Ministry of Environment, which operates approximately 90% of the public fast charging stations, and Korea Electric Power Corporation (KEPCO), have both raised the charging fee from $0.134 to $0.197/kWh, a 47% increase. Most of the private operators of slow charging stations have set their charging fees at around $0.15/kWh, with some increasing their fees by two to three times. According to the Ministry of Environment's explanation in 2016, if the usage fee for fast charging stations were to have returned to $0.24 when the discount was completely eliminated in 2022, the usage fee for fast-charging stations would have increased to about 44% for gasoline cars and 62% for diesel cars.

RESEARCH

Electric dedicated platform 'E-GMP'

Hyundai Motor Group has unveiled its electric vehicle-exclusive platform, "E-GMP." The introduction of E-GMP serves as a starting point for producing innovative electric vehicles that address the shortcomings of conventional vehicles in various aspects such as driving range, charging methods, interior space utilization, design, and safety.

E-GMP features a structure that is exclusively designed for electric vehicles, unlike previous electric vehicles that utilized internal combustion engine designs. Space previously occupied by engines, transmissions, fuel tanks, and other components is reduced to accommodate batteries, motors, body, and chassis structures specifically for electric vehicles.

Hyundai Motor Group claims that the technology enables a driving range of over 500km (based on domestic standards) on a single charge and allows for fast charging of up to 80% in 18 minutes with the world's first 800V charging system.

Figure 2: Electric dedicated platform ‘E-GMP’

E-GMP is equipped with new propulsion systems, including motors, reducers, inverters for power conversion, and batteries, developed specifically for the next generation of electric vehicles. The motor's maximum speed has been increased by 30-70% compared to conventional models, and efficiency has been improved through weight reduction.

Unlike conventional electric vehicles that only receive power from external sources, E-GMP is designed for a two-way charging system, allowing the vehicle to transfer any remaining power back to the power grid or even supply power to the grid directly. E-GMP has a flat floor, unlike the internal combustion engine platform, which allows for more flexible interior space utilization and potentially new interior and exterior designs. Hyundai Motor Group has designed E-GMP as a flexible platform that allows for the development of various types and grades of electric vehicles beyond sedan and SUV models, including high-performance and high-efficiency models, with the ability to expand the electric vehicle lineup in a short period [2].

TAXATION

Car tax is classified as "other passenger cars" under Article 127 (tax base and tax rate) of the Local Tax Law. For non-commercial electric cars, a total of 130,000 won, including a local education tax of 30%, is levied. As for tax benefits for electric cars, the individual consumption tax has a maximum reduction of 5% of the vehicle price—up to 3 million won—the education tax has a maximum reduction of 30% of the individual consumption tax—up to 900,000 won—and the acquisition tax is 7% of the vehicle price (4% for small cars) up to 1.4 million won [3]. Since 2020, there has been a change in the electric vehicle special pricing system that was applied to charging fees for electric vehicles up until 2019. The previous pricing system was applied until June 2020, and benefits will be gradually reduced until July 2022 [4].

HEVS, PHEVS, AND EVS ON THE ROAD

Figure 3: Example of electric bus, Woojin Industrial Systems, Apollo 900

(https://www.wjis.co.kr/kr/business/apollo.php)

DIRECTION OF REORGANIZATION

As the electric van is equipped with a high-capacity battery, it is reorganized to increase battery safety and technological level by introducing evaluation that is specific to battery characteristics.

BATTERY CHARACTERISTICS EVALUATION

Since electric vans have a large battery capacity compared to other vehicle types, and how a vehicle's battery has a great impact on vehicle load, fuel economy, and safety, subsidies are differentiated after evaluating battery characteristics. First, for safety, preferential treatment (approximately $2,300 USD support) is given to those who present a report from a domestic accredited test institute for the 'drive battery safety test' among the automobile safety standards under the 'Automobile Management Act,' to enhance reliability and objectivity of the safety test results. In addition, in order to promote the high quality of electric vans and development of electric vehicle battery technology, vehicles with high energy density batteries (grade 1 energy density of 500Wh/L or more to grade 4 energy density of less than 400Wh/L) will receive more subsidies.

ENHANCED PERFORMANCE EVALUATION

Considering the improvement in overall vehicle performance, the subsidy differential according to performance has been expanded. The mileage differential section per charge has been expanded to 440km (originally 400km) for large electric vans and 360km (originally 300km) for medium-sized electric vans. In addition, a "minimum fuel economy" criterion will be added as a factor in the distribution evaluation to determine whether or not vehicles will be eligible for subsidies in the future, to ensure fuel efficiency beyond a certain level.

AFTER-SALES MANAGEMENT COMPETENCY EVALUATION

Subsidies will be provided differently according to the after-sales service (A/S) capabilities of each manufacturer. Up to 20% of the performance subsidy (approximately $5.08 million USD (large size) or approximately $3.56 million USD (medium size)) is paid depending on whether the maintenance and parts management center is operated and the maintenance history is computerized. The same follow-up management capability evaluation criteria will be applied to electric cargos with similar follow-up management conditions.

Fleet Totals (as of December 31st 2022)

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
2 and 3 Wheelers	n.a.	-	-	n.a.	n.a.
Passenger vehicles	389,855	1,170,507	n.a.	n.a.	1,560,362
Buses and Minibuses	n.a.	-	-	-	n.a.
Light Commercial vehicles	n.a.	-	-	-	-
Medium and Heavy Weight Trucks	n.a.	-	-	n.a.	n.a.

Total Sales (1st Jan 2022 to 31st Dec 2022)

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
2 and 3 Wheelers	12,530	-	-	-	12,530
Passenger vehicles	16,622	15,637	9,637	5,855	47,751
Buses and Minibuses	700	-	-	-	700
Light Commercial vehicles	1,412	-	-	-	1,412
Medium and Heavy Weight Trucks	14,394	-	-	-	14,394

*Total of vehicles of this type, including ICEVs

Electric Cargo

DIRECTION OF REORGANIZATION

The electric cargo subsidy is reorganized to increase benefits for the vulnerable class and small business owners, promoting performance improvement by providing the full amount of electric cargo subsidy according to performance and with consideration of livelihood demand.

UNIT PRICE ADJUSTMENT

Considering the increasing trend of small electric cargo (from 14,093 units in 2020, 26,273 units in 2021, to 37,630 units in 2022), the subsidy unit price was reduced by approximately $1,500 from the previous year (approximately $1.06 to $0.91 million USD), but the number of subsidies increased from 40,000 to 50,000.

However, in the case of electric cargo, considering that most of them are livelihood demand, the additional level of support for vulnerable groups and small business owners was expanded to 30% of the subsidy calculation amount (initially 10%), so that they could receive subsidy benefits similar to the previous year.

ENHANCEMENT OF PERFORMANCE EVALUATION

The basic subsidy item, which was provided as a fixed amount regardless of performance, has been abolished, and the total amount is supported according to performance, while the differential section of mileage per charge has been expanded to 250km (originally 200km).

SYSTEM IMPROVEMENT

The period for limiting subsidy support when an individual purchases the same car model has been extended from 2 years to 5 years.

Figure 4: Example of electric cargo, Hyundai XCIENT

(https://trucknbus.hyundai.com/hydrogen/ko/hydrogen-vehicles/xcient-fuel-cell)

As of 2022, Hyundai Motors has delivered 47 units of its hydrogen-powered electric truck, the XCIENT Fuel Cell, to 23 Swiss companies, and is set to supply 27 units to seven logistics and manufacturing companies in Germany and three units to Israel. The XCIENT Fuel Cell is a large cargo truck with a total weight of 42 tons, equipped with a 180kW hydrogen fuel cell system composed of two fuel cells and a 350kW electric motor that can travel up to 400km on a single charge.

The XCIENT, with a total weight of 28 tons (load capacity of 10 tons), can travel about 570km on a full charge. It has superior power (maximum output of 476 horsepower, maximum torque of 2237Nm) compared to a diesel XCIENT of the same weight. In particular, the fuel cell system applied to the XCIENT hydrogen electric truck is lighter than the battery used in large electric trucks, making it suitable for long-distance heavy commercial vehicles as it can be fully charged in 15-20 minutes. The XCIENT Fuel Cell is the world's first mass-produced large hydrogen electric truck, and is currently being operated in Korea, Switzerland, Germany, and New Zealand.

In particular, the 47 units introduced in Switzerland have exceeded a cumulative driving distance of 6.7 million kilometers, the first time a mass-produced large hydrogen electric truck has exceeded this milestone. Hyundai Motors plans to expand its supply of hydrogen electric trucks throughout Europe, targeting many countries that aim to transition to a hydrogen society based on the success in Switzerland. In addition, Hyundai Motors plans to launch a full-scale attack on the hydrogen commercial vehicle market in Germany, based on the supply of the XCIENT Fuel Cell. They plan to strengthen promotional activities targeting various businesses centered on HHMG and build a service network. They also plan to expand the supply of the XCIENT Fuel Cell to other European countries including Austria, Denmark, France, and the Netherlands in the future. In addition, a total of 35 units of the XCIENT Fuel Cell supplied to California through the "NorCAL ZERO California Port Clean Truck Project" and the "2021 TAG (Targeted Airshed Grants)" program hosted by the US Environmental Protection Agency (EPA), are expected to begin commercial operation in the third quarter of next year.

CHARGING INFRASTRUCTURE OR EVSE

The Korean Ministry of Environment announced a plan to reorganize the electric vehicle slow charging facility subsidization project for electric vehicle charging companies, by collecting the contents discussed through a meeting of business operators.

APPLICATION METHOD

In order to reduce the excessive operating expenses of business operators due to competition in securing charging sites, the existing business operator's application for installation as an agent will be revised to a method in which applications are made for installation directly. After designating a charging installation area by accessing the integrated zero emission vehicle website, charging companies that are permitted to be installed in the area are arranged, and applicants can apply directly according to selection process guidance.

QUANTITY OF SUPPORT

According to the policy of increasing the total budget of the Ministry of Environment of Korea but reducing the subsidy per unit, up to 5% of the existing number of parking spaces is supported compared to 2% of support previously.

SUPPORTED MODEL AND UNIT PRICE

In order to respond to the charging demand of various electric vehicle users with supported models, chargers with a capacity of 30kW or more have been newly included. A subsidy of approximately $3,770 USD for the first unit, approximately $3,020 USD for the second unit, and $2,640 USD for the third or more unit will also be provided. The majority of installations are expected to be built around large mart parking lots and tourist facilities. Electric vehicle charger subsidies of 11kW or more, 7kW to less than 11kW, kiosk, power distribution type, etc. all decreased by about $150 USD, and subsidies for the outlets required for charging have decreased by about $40 USD, to $260 USD.

EXECUTING ORGANIZATION

All companies with an application score of 85 or higher are selected as deploying organizations, which marks a change from the previous method of selecting the top 25 companies with a score of 85 or higher. However, the weight interval in the qualitative evaluation is increased for each company in order to prevent monopolization.

CONVENIENCE

A complaint center will be newly established to oversee complaints regarding electric vehicle charging. Using the QR code attached to the charger, the center operated by the Korea Environment Corporation monitors and automatically delivers customer feedback to the operator. In addition, a system that can report civil complaints without the use of a QR code will be established.

*As of December 31st, 2022

Type of Public EVSE	Number of Locations*
AC Level 1 ≤ 3.7 kW	62,789
AC Level 2 >3.7 kW, ≤ 22 kW	n.a.
Fast Charger >22 kW, ≤43.5 kW	n.a.
Superchargers > 43.5 kW, ≤ 120 kW	n.a.
Inductive Chargers EM Charging	n.a.

EV DEMONSTRATION PROJECTS

Figure 5: Hyundai's E-pit (charging station network)

According to Hyundai, Genesis is preparing to introduce wireless charging technology to provide a new user experience in electric vehicle battery charging and is currently conducting a pilot project for wireless EV charging services. Three wireless charging stations for electric cars have been installed in the metropolitan areas of Gangnam, Suji, and Goyang.

Including wireless charging stations operated by affiliated companies such as Seocho Grand City, GS Tower, and Lotte World Tower, a total of 23 stations have been installed. Wireless charging can be accessed by the GV60 and GV70 electric models, which are equipped with wireless charging systems. For this pilot project, Genesis electric vehicles have been equipped with separate modules, allowing them to experience these services. Although component and technology companies such as Continental, Qualcomm Halo, and Electrion have developed wireless charging technology, Genesis is the first complete car brand to directly prepare for wireless charging services for electric cars.

Genesis' wireless charging system consists of three main components: the power control station (PCS), which serves as a charger in the existing charging method, the wireless charging pad (GA-R), which is connected to the PCS and installed on the floor, and the power receiving device (VA) installed under the front axle of the electric car. The PCS converts the power needed to charge the battery into a high-frequency current of 85kHz, which is supplied to the GA-R. The GA-R creates a magnetic field for wireless power transmission by utilizing the received high-frequency current to cause resonance and is then transferred to the electric car's power receiving device (VA) installed under the vehicle's bottom, which then goes through the converter before being charged into the battery. Genesis' wireless charging service offers a higher output of 11kW than the typical slow charger (7kW) and provides a level of convenience that is different from the dimensions offered by existing companies.

The process of operating the charger and connecting and disconnecting the charging connector to the vehicle is not required when the driver exits the vehicle. First, the driver can intuitively check the condition of the PCS and whether there is any foreign object obstructing charging on the GA-R by checking the LED indicators. If the white light is on, the pad is free of obstructions and ready to be charged immediately. When the vehicle is within 10 meters of the charging station and the transmission is in park, a pop-up screen appears on the infotainment screen. From there, the driver can select the charger and park the vehicle on the pad according to the parking guide displayed on the surround view monitor. When the green icon indicating that the vehicle can be charged is displayed on the surround view meter, the driver can turn off the vehicle's power to start wireless charging.

OUTLOOK

In the transportation sector, the South Korean government has set a target of supplying 4.5 million electric vehicles by 2030, accelerating the transition to clean vehicles through the expansion of hydrogen and electric vehicles, expansion of charging infrastructure, and promotion of the scrapping of internal combustion engine vehicles. The government also plans to enhance support to increase the global market share of clean vehicles and raise Korea's market share from 5% (currently the 6th in the world) to 12% by 2030, by providing bold support for production, technology, demand, and other aspects of the ecosystem.

To achieve this, the government will promote close support for land and related infrastructure, as well as easing regulations to ensure that more than about $72 billion USD of production investment plans can be implemented smoothly from this year until 2026.

In order to develop clean vehicles with the world's best competitiveness in terms of driving range, battery life, and price, the government aims to improve the average driving range of electric vehicles from the current 500km to 600km by 2025 and reduce charging time from 18 minutes to 8 minutes by 2025. For hydrogen commercial vehicles, the government plans to extend the durability from the current 300,000km to 800,000km by 2030, and also increase the fuel efficiency from the current 13km/kg to 17km/kg in 2030.

To alleviate the inconvenience of using electric vehicles and other clean vehicles, the government plans to expand electric vehicle charging facilities to 500,000 units by 2025 and hydrogen charging stations to 450 by 2025.

In addition, the government plans to promote the expansion of demand industries such as securing next-generation battery technology, developing domestic materials for stabilizing the supply chain, and recycling used batteries. Furthermore, the government plans to introduce a rating system for electric vehicle charging and a fuel efficiency system for medium and heavy-duty trucks.

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Spain

Number of EVs & PHEVs registered

316,436

Number of EV chargepoints

18,128

MAJOR DEVELOPMENTS IN 2022

Relevant Strategies, Policies and Standards at National Level

The promotion of electric mobility is a multisectoral and multidisciplinary challenge in Spain, involving local, regional and General State administrations. To accelerate EV development, on June 15, 2022, the Government created a governance group for the deployment of Electric Vehicle Charging Infrastructure (GTIRVE) in which Sectoral associations and administrations at different levels are represented. The main objective of the group is to identify barriers hindering the deployment of public access charging infrastructure and to propose measures to accelerate this deployment.

In the regulatory field, measures have been developed to reduce administrative barriers to the deployment of charging infrastructure, as well as measures to facilitate a significant deployment of infrastructure both in service stations and in non-residential car parks.

In terms of incentive programs, the Recovery, Transformation and Resilience Plan has provided a historic opportunity for electric mobility in Spain. On the one hand, the PERTE of the Electric and Connected Vehicle makes it possible to consolidate and accelerate the industrial commitment to electric mobility from the supply side. On the other hand, the MOVES programs make it possible to stimulate this market from the demand side.

New standards related to electric mobility in Spain, during 2022 include the following:

ROYAL DECREE 450/2022, OF JUNE 14, WHICH MODIFIES TECHNICAL BUILDING CODE (CTE), APPROVED BY ROYAL DECREE 314/2006, OF MARCH 17. This modification establishes a minimum requirement for electric vehicle charging infrastructure in new buildings and interventions within certain existing buildings.

These requirements differ depending on whether the buildings are used for private residential use or for other uses:

- For private residential-use buildings with more than 20 parking spaces, CTE requires the pre-installation for charging infrastructure for 100% of the parking spaces.

- For buildings with uses other than private residential that have more than 10 parking spaces, the standard requires pre-installation of charging infrastructure for 20% of the parking spaces, as well as the installation of a charging point at every 40 parking spaces.

- For buildings belonging to the General State Administration, the requirement for charging points rises to one charging point for every 20 parking spaces.

This Royal Decree marks the completion of the transposition of Directive (EU) 2018/844 of the European Parliament and of the Council, of May 30, 2018, which modifies Directive 2010/31.

This Royal Decree also modifies Royal Decree 1053/2014, passed on December 12, which approves the Complementary Technical Instruction ITC-BT 52 of the Low Voltage Electrotechnical Regulation. The modification of Royal Decree 1053/2014 is necessary given that it currently establishes the minimum allocations for electric vehicle charging infrastructure associated with both buildings and parking lots not attached to buildings in Spain.

The modifications to both CTE and of the aforementioned Royal Decree 1053/2014 are part of the legal reforms of the Recovery, Transformation and Resilience Plan (PRTR). The modification of both regulations is included in the C1.R1 reform called "Plan for the deployment of the electric vehicle recharging and impulse infrastructure."

ROYAL DECREE-LAW 29/2021, OF DECEMBER 21.

Completing the framework of requirements for electric vehicle charging infrastructure associated with car parks, urgent measures are adopted in the energy field for the promotion of electric mobility, self-consumption, and the deployment of renewable energies.

In this Royal Decree-Law, a requirement was established for existing car parks—both linked to a building and not—with more than 20 spaces, requiring them to have a charging station for every 40 spaces or corresponding fraction before January 1, 2023, or a charging station every 20 spaces or corresponding fraction in the case of buildings owned by the General State Administration.

ROYAL DECREE 1052/2022, OF DECEMBER 27, WHICH REGULATES LOW EMISSION ZONES.

Derived from article 14 of Law 7/2021, of May 20, on climate change and energy transition, it is expected that from 2023, all cities with more than 50,000 inhabitants will implement Low Emission Zones (hereinafter ZBE) with limited access to the most polluting vehicles. This will undoubtedly promote the increase of electric vehicles in cities, establishing the minimum requirements that ZBEs must meet.

NEW PROJECT ORDER REGULATING ACCESS TO STATE HIGHWAYS, SERVICE ROADS AND THE CONSTRUCTION OF SERVICE FACILITIES.

Public consultation on a new project Order has been launched to simplify the procedures in highways of the State incorporating mechanisms of responsible declaration and organizational measures.

Incentives Programs to promote EVs

MOVES III PROGRAM (INCENTIVE PROGRAM FOR ELECTRIC MOBILITY).

https://www.idae.es/ayudas-y-financiacion/para-movilidad-y-vehiculos/programa-moves-iii

In keeping continuity with previous editions of the MOVES Program, on April 14, 2021, the Council of Ministers published Royal Decree 266/2021, MOVES III. MOVES III establishes direct grant amounts to the different regions within the framework of the European Recovery and Resilience Facility, initially endowed with €400 million—with the potential to be increased up to €1.2 million at the request of regional administrations.

The program will be open to applications until December 31, 2023, and is aimed at incentivizing the purchase of electric vehicles and the deployment of charging infrastructure for these vehicles:

- Program of incentives for purchasing EVs: Electric (and fuel cell) cars, vans, quadricycles, and motorcycles are supported within the framework of this program. The eligible vehicles may be new or up to nine months old.

The aid amount depends on the type of vehicle purchased, whether there is additional scrappage of another old vehicle, and on the details of the beneficiary. This amount can be increased by 10% in the case of individuals with reduced mobility and those who need an adapted vehicle, for taxis and vehicles with driver (VTC), and for inhabitants of municipalities with less than 5,000 inhabitants.

- Program of incentives for infrastructure deployment: for both private and public use of whatever recharging power. Also, it is supported pre-installation and communication services required, in the case of communities of owners (parking facilities of living blocks). The levels of incentives are outlined in the following table:

Group	Charging infrastructure incentives (% eligible costs)	
	General Placement	Municipalities < 5,000 hab.
Individuals, self-employed people, housing blocks, public administration without economic activity	70%	80%
Companies and public entities with economic activity, with public service recharging and P≥50kW	35% (45% Medium Companies) (55% Small Companies)	40% (50% Medium Companies) (60% Small Companies)
Companies and public entities with private service recharging (any charging power) or public service recharging with P≤50kW	30%	40%

Depending on the type of beneficiary, the aid limit can reach up to €800,000 per request file, and up to €2.5 million for the same beneficiary throughout the validation period of the corresponding regional call (at the end of 2023).

At the end of 2022, the budget already amounted to a total of around €700 million, with aid requests for 59,713 electric vehicles and 53,024 charging points.

MOVES SINGULAR PROJECTS II (INCENTIVES PROGRAM FOR ELECTRO-MOBILITY AND INNOVATIVE PROJECTS IN THE TRANSPORT SECTORS).

Through Order TED/800/2021, of July 23, the regulatory basis of the incentive Program for Singular projects in electric mobility (MOVES Singulares II Program) was approved, within the framework of the Recovery, Transformation and Resilience Plan.

This program consists of the selection and granting, on a competitive basis, of projects related to experimental and innovative developments, carried out in the national territory and related to electric mobility, across the following topics: electric mobility and ICT applications; innovative electric vehicle recharging infrastructure, hydrogen recharging for vehicles; new battery developments and electrical storage for mobility and development of new processes or prototypes of electric vehicle or components.

The first call for grants, through Resolution of September 20, 2021, of the Director General of IDAE, was endowed with €100 million. 173 applications were received in the first call, far exceeding the budget available.

To remain consistent with the first call, a second call for aid, endowed with €264 million, was approved by Resolution of September 24, 2022, of IDEA. MOVES Singulares II program represents part of Component 1, Investment 2 of the Recovery, Transformation and Resilience Plan (PRTR).

The difference with the first call is that projects related to the installation of hydrogen generators were not eligible, since other Programs related to promoting the production and use of green hydrogen within the framework of Component 9 of the PRTR have already been published.

For this second call, a total of 279 applications have been submitted, with a total requested budget of €311.5 million.

MOVES FLEET PROGRAM (INCENTIVES PROGRAM FOR LIGHT VEHICLE FLEET ELECTRIFICATION PROJECTS)

The Ministry for Ecological Transition and Demographic Challenge has approved Order TED/1427/2021, of December 17, which regulates the basis of the Aid Program for light vehicle fleet electrification projects (MOVES FLOTAS Program), endowed with an initial amount of €50 million and aimed at the selection and concession, under a competitive bidding regime, of aid corresponding to projects for the electrification of light vehicle fleets in the national territory.

The MOVES Fleet Program, managed by IDAE, is part of the Recovery, Transformation and Resilience Plan (Component 1, Investment 2) and complements other Programs already published within the framework of the aforementioned component and investment, such as MOVES III and MOVES Singulares II.

Included in this program are projects for the electrification of light vehicle fleets by electric and fuel cell vehicles, which operate in more than one region. The projects require renewal of vehicle fleets, with a maximum of 500 and minimum of 25 vehicles per application. Beneficiaries can submit applications for a total maximum aid amount of €2.5 million.

The projects also may include the provision of recharging infrastructure for the new fleet at a company's facilities, as well as the acquisition or adaptation of energy management fleet systems, to, among other things, digitize route control, as well as training of company personnel to carry out a transition of the fleet towards electrification.

A total of €50 million in MOVES Fleet aid was approved by Resolution of November 30, 2022. For this second call, a total of 31 applications have been submitted, for a total requested budget of €17.5 million.

OTHER RELEVANT CURRENT PROGRAMS TO PROMOTE ELECTROMOBILITY (AT NATIONAL SCALE):

Transformation of heavy vehicles for road transportation: the Council of Ministers published, on November 16, Royal Decree 983/2021, to establish direct granting to the different regions within the framework of the European Recovery and Resilience Facility. Endowed with €400 million, the decree is intended for the transformation of passenger and freight transport fleets.

Second call for ZBE implementation and the digital and sustainable transformation of urban transport: The Ministry of Transport, Mobility and Urban Agenda has opened the second competitive call for aid to municipalities for the implementation of low emission zones and the sustainable and digital transformation of urban public transport, within the framework of the Recovery, Transformation and Resilience Plan.

The 2022 call has an initial endowment of €500 million from Next Generation EU funding and, continuing from the first call which was endowed with 1,000 million euros to decarbonize and digitize urban mobility. The call's objective is to complete the 1,500 million euros in aid included in Investment 1 of Component 1 of the Recovery Plan to improve air quality and reduce noise in cities, deploy fleets powered by zero-emission alternative fuels, and promote cycling and pedestrian itineraries for an alternative, active mobility.

EVS AND HEVS ON THE ROAD

In 2022, a total of 102,513 electric vehicles were registered in Spain, consisting of BEVs, PHEVs and REEVs (Table 1), representing an increase of 20.2%, compared to the 85,324 EVs registrations at the end of 2021. This increase was sustained by the continuation of incentives programs to support the purchase of EVs, in collaboration between different administrations.

In the specific case of electric passenger cars (BEVs, PHEV/EREVs), there were 81,739 vehicles registered, representing a market penetration of 9% (Table 1). Considering both electric and conventional hybrid vehicles (HEVs), they accounted for 326,612 vehicles, resulting in a market penetration of 35.7 %.

Considering all vehicle categories (except electric bicycles), the fleet of electric vehicles in Spain (BEVs, PHEVS and REEVs), at the end of 2022, resulted in a total number of 316,436 (Table 2), representing an increase of 42.8 % respect the previous year 2021, which saw 221,592 EVs on the road.

Finally, and focusing on conventional hybrid vehicles, there was marked penetration of hybrid passenger car registrations, with 244,873 registrations in 2022 (a 27% car market penetration), due in part to the impact of environmental car labelling, promoted by Spanish Traffic Authorities, and also because of measures/initiatives (e.g. ZBEs) implemented for clean mobility and air quality in urban areas.

Fleet Totals (as of December 31st 2022)

Vehicle Type	BEVs	HEVs	PHEVs	FCVs	TOTAL*
Bicycles (assisted pedaling)	910,000	0	0	0	30,000,000 approx.**
Mopeds	29,672	0	0	0	1,779,491
Motorcycles	38,316	0	0	0	4,017,332
Quadricycles	4,682	0	0	0	69,568
Passenger cars	95,655	920,400	133,333	22	25,260,575
Commercial vehicles	13,756	5,860	190	0	4,117,998
Buses	455	2,021	114	9	65,310
Trucks	236	306	27	0	968,005
Totals (without bicycles)	**182,772**	**928,587**	**133,664**	**31**	**36,278,279**

Total Sales (1st Jan 2022 to 31st Dec 2022)

Vehicle Type	BEVs	HEVs	PHEVs	FCVs	TOTAL*
Bicycles (assisted pedaling)	250,000	0	0	0	1,570,000**
Mopeds	5,582	0	0	0	16,582
Motorcycles	10,355	0	0	0	183,353
Quadricycles	933	0	0	0	2,427
Passenger cars	32,564	244,873	49,175	4	914,810
Commercial vehicles	3,515	2,179	94	0	114,307
Buses	141	343	1	7	2,853
Trucks	150	1	3	0	33,114
Totals (without bicycles)	**53,240**	**247,396**	**49,273**	**11**	**1,267,446**

*Total of vehicles of this type, including ICEVs

**Estimated data at the end of 2021 ((Source AMBE -Spanish Association of Bicycles)

CHARGING INFRASTRUCTURE OR EVSE

For 2022, an official total number of charging points for Spain was not available. However, the national government, through the State Secretariat for Energy, is working on a European project on the identification and placement of recharging points that will be available throughout 2023.

According to sector estimates (Spanish Association of Car and Trucks Manufacturers—ANFAC—based on "Electromaps" data), at the end of 2022, there were 18,128 charging points available for public use (10,327 of them, placed on roads and the other 7,801 in urban areas), covering all the possible power ranges.

Considering that charging at home and in fleet places could cover around 85% of need, the other 15-20% should be covered by public charging points, known as "opportunity charging."

Figure 1: ANFAC; Public use recharging infrastructure (at the end of 2022)

In terms of power infrastructure, public use charging points in Spain, at the end of 2022, can be classified in the following way:

Source: ANFAC, Recharging points at the end of 2022.

Charger Locations	Charger Power				
	P≤22	22<P≤50	50≤P≤150	150≤ P<250	P≥250
Urban Areas	8.768	395	976	125	53
On Road	5.619	418	1.234	317	203

Other sources, such as AEDIVE (Spanish Association for the Development and Promotion of Electric Mobility) estimate that at the end of 2022, there were available 21,000 charging points for public use.

Finally, as mentioned before, related to public recharging points in non-residential buildings, with more than 20 parking spaces, it must be pointed out that the Royal Decree Law 29/2021, is facilitating the installation of a minimum of public use recharging points, from 1st January 2023 (at least, one recharging point for each 40 parking lots).

The objective of PRTR in Spain is between 80,000—100,000 recharging points by the 2023.

EV DEMONSTRATION PROJECTS & GOOD PRACTICES

AMBRA Project

AMBRA is a project co-financed by the European Commission, through the 2017 CEF Mechanism (Connecting Europe Facility) Blending Call, which aims to install high-power charging points (greater than 40kW) for electric vehicles in Italy, Spain and Romania.

The project aims to deploy and operate a network of Normal, Fast and Ultra-Fast Charging Stations (up to 350 kW) for electric vehicles in Europe, providing linked coverage for long-distance travel and enabling cross-border trips towards Italy, Spain and Romania in order to support these Member States to speed up in terms of deploying electric vehicle infrastructure.

The project intends to deploy 3,169 electric vehicle charging stations on 6 TEN-T Core Networks Corridors. The use of the charging points is expected to be possible either with ad-hoc payments or using any Mobility Service Provider in case of contract-based charging.

Charging station of the Madrid Bus municipal company (EMT) in Carabanchel

The city of Madrid has presented its new electric charging station at the Operations Center of the municipal company in Carabanchel. This infrastructure is made up of 52 inverted pantograph charging points, and a powerful photovoltaic installation that will guarantee the supply of 10% of the charging stations' energy for the management of a constantly growing fleet of electric buses.

Currently, with 22 zero emission lines, Madrid has the most electric bus lines of any city in Spain. It has gone from 49 electric buses in 2019 to 180 in 2023, largely thanks to the fact that it has carried out a tender for the procurement of 150 electric vehicles in 2022. The zero-emission fleet, which will reach 330 units with the planned additions between now and the end of 2023, will represent 20.4% of its fleet in 2024 and 25% in 2025.

Total breakeven investment for the installation of the pantograph recharging point, plus the installation of the photovoltaic plant, amounts to more than €5.5 million, of which 90% is financed by European Next Generation funds. This contribution is part of the Recovery, Transformation and Resilience Plan, specifically its aid program for municipalities for the implementation of low emission zones and the digital and sustainable transformation of urban transport.

The project designed for the electrification of the Carabanchel Operations Center has been structured into four phases, of which the first two have already been completed between 2021 and 2022. These facilities currently have 52 charging points out of 100kW per inverted pantograph and with 95 cable charging points (100-120 kW). At the end of the four phases, which is expected to be in December 2024, there will be a total of 329 charging points: 234 inverted pantographs and 95 charging points by cable.

Sweden

Number of EVs & PHEVs registered

452,037

Number of EV chargepoints

19,567

MAJOR DEVELOPMENTS IN 2022

Electrification has progressed strongly in 2022, as shown in Sweden's annual vehicle statistics. At the same time, changes in the operating environment had a negative impact on the automotive market during the year. The world economy, the war in Ukraine, and changes in policy instruments in Sweden will continue to affect the market in 2023.

The 2022 automotive year has been characterized by several external factors. The aftermath of the pandemic and the ongoing conflict in Ukraine have resulted in component shortages and long delivery times, as well as price increases as well as uncertainty for both consumers and companies. Political reforms such as the changes in the bonus-malus system that took place in several stages and by different governments during the year have also had an effect.

The harsh boundary conditions from the beginning of the year have affected the market. In total, the number of newly registered passenger cars has decreased by just over four percent in 2022 compared to 2021. By the end of the year, however, there have been some improvements in the supply chains. At the same time, however, the industry remains unbalanced in supply chains with higher demand than supply.

A total of 288,000 new passenger cars were registered in 2022, compared to 301,006 in 2021. The share of newly registered rechargeable passenger cars increased from 45 percent in 2021 to 56 percent in 2022. At the same time, the mix of electrified vehicle types has changed, where the number of electric cars has increased by 65 percent, while the number of plug-in hybrids has decreased by almost 15 percent. This year's strong electrification contributed to the decrease in average carbon dioxide emissions from new passenger cars, which fell by 22.5 percent, from 89.2g/km in 2021 to 69.1g/km in 2022.

The clear electrification trend in 2022 cannot only be found in the passenger car segment. The share of newly registered light electric trucks has also increased from 7.5 percent in 2021 to 14.5 percent. As in the passenger car segment, the number of newly registered light trucks has decreased during the year by almost five percent compared to 2021. For newly registered heavy trucks, however, the picture is opposite, as the total number increased by just over three percent in 2022. For heavy trucks, electrification is still in the starting stages. The share of newly registered heavy electric trucks has increased slightly compared to 2021, from 0.9 percent to 2.7 percent. The vehicle type that has increased its sales volume the most during the year is buses, which increased by just over 70 percent, from 728 in 2021 to 1,240 in 2022. However, the share of newly registered electric buses is lower compared to 2021, about 21 percent in 2022 compared to about 25 percent in 2021.

Funding and Research

INDUSTRIKLIVET, THE INDUSTRIAL STEP PROGRAM

Industriklivet, The Industrial step program can provide support for projects involved in such things as strategically important initiatives such as the application of new technology, or other innovative solutions within industry that significantly contribute to reducing greenhouse gas emissions in society—for example in the areas of batteries and hydrogen. The program is handled by the Swedish Energy Agency.

FFI PARTNERSHIP PROGRAM, THE STRATEGIC VEHICLE RESEARCH AND INNOVATION PROGRAM

The FFI programme is one of Sweden's largest research programmes, with an annual total budget of approximately €100 million. The initiative has been around since 2009 and covers the environmental and safety dynamics of road and machine vehicles. A major update of the program was carried out in 2021-2022, when new goals and sub-areas were decided. Two of the new sub-programs are FFI Circularity and FFI Accelerate. The FFI Circularity sub-program has the goal of reducing emissions from manufacturing to scrapping the vehicle and includes, for example, reducing emissions from the entire material value chain.

Of course, one of the main issues here will be to reduce the environmental impact of batteries. The sub-program Accelerate refers to such larger, more market-oriented investments that will be necessary in achieving the climate goals. Within FFI, a number of the major demonstration projects have been financed.

THE SWEDISH ELECTROMOBILITY CENTRE (SEC)

SEC brings the academia and automotive industry together, with a range of different research disciplines. All are connected through their relevance to electric and hybrid vehicle technology. They promote deep and narrow technological studies, as well as cross-discipline and cross-institution research. The work is focused within the five theme areas: system studies and methods, electrical machines drive systems and charging, energy storage, electromobility in society, and interaction between vehicles and grid.

The Swedish Energy Agency, together with industry, public sector and academy, funds SEC that will accelerate the transition to a fossil-free society and will strengthen Swedish competitiveness. The total budget is €28 million for the period between 2022-2026.

SWEDISH ELECTRIC TRANSPORT LABORATORY (SEEL)

The Swedish Electric Transport Laboratory (SEEL) is a test center for research and development in the field of electromobility. It is owned and run by Chalmers [1] and RISE [2] as a joint venture. SEEL will establish three facilities in Gothenburg, Nykvarn and Borås. The aim is to consolidate efficient knowledge development and improve the conditions for collaboration in the field of electrified transport in Sweden and Europe. Players in the automotive, aerospace and maritime sectors, as well as other companies developing technology in relevant areas, will gain a common platform on which to meet and jointly benefit from the knowledge development and technology shift currently taking place.

At the same time, researchers at higher education colleges, universities and research institutes will gain access to advanced research infrastructure in the field of electric mobility, with the test bed expected to be operational by 2023. The test center is part of European investment in a value chain for batteries. The €57 million state aid from the Swedish Energy Agency for the electromobility lab SEEL is being provided within the parameters of an Important Project of Common European Interest (IPCEI) to support the creation of a European battery value chain. The ten-year project involves 17 participants from seven member states. It includes major European investments in the field of raw and advanced materials for batteries, battery cells & modules and entire battery systems, as well as in the use, recycling and refinement of recycled materials. The investment is being made within the parameters of the European Battery Alliance [3].

HEVS, PHEVS, AND EVS ON THE ROAD

288,000 new passenger cars were registered in 2022, which is a decrease of 4.3 percent compared to 2021. The share of rechargeable passenger cars of the total new registrations amounted to roughly 56 percent in 2022 compared to 45 percent the year before. The share of electric cars increased from 19.1 percent in 2021 to 33 percent in 2022.

The most influential policy to promote plug-in electric vehicle sales in Sweden is the EU's CO2 emission reduction targets for new vehicles and plug-in electric vehicles now comprise 6% of all passenger cars. In 2022, there were three major national demand-side policies to promote the sales of plug-in electric vehicles in Sweden.

Bonus malus scheme 2018-Nov 2022

Sweden's new government announces on November 7, 2022, that the so-called climate bonus for cars with low or no emissions will cease after November 8, 2022. Below is a description of how the policy instrument distributed its support before then.

The Swedish bonus-malus scheme was introduced in July 2018 and replaced a purchase rebate scheme. The bonus-malus scheme included elements of decreasing the purchase cost of a vehicle, as well as the vehicle tax. In 2022, battery electric vehicles (BEVs) and fuel cell vehicles (FCV) were eligible for the maximum bonus, which was about €6,000. For plug-in electric vehicles (PHEVs), the bonus decreased down to 60gCO2/km (based on the WLTP). The bonus-malus also includes light-duty vans, which were excluded in the previous purchase rebate scheme. The vehicle tax system was revised as the bonus-malus scheme was introduced. Previously, PEVs were tax-exempt in the first 5 years of ownership, but since July 2018, the tax exemption has been reduced to 3 years.

In 2021, the government changed the upper bonus threshold of the bonus-malus scheme from a maximum of 70 gCO_2/km to 60 gCO_2/km and increased the bonus for BEVs and FCVs to about €7,000.

Reduced value of fringe benefits

For a long time, it has been beneficial to receive a car as part of one's salary in Sweden. For electric vehicles, this benefit has been even larger. This has meant that about 75% of the Swedish electric vehicles have been subsidized in this way, but there are still some subscriptions for electric vehicles. This benefit has now been generally reduced, and in 2022, this has meant that there is a more even distribution between electric company cars and privately-owned electric cars.

EV bus/trucks/work machines rebate

In 2016, the Government introduced a purchase subsidy specifically targeting electric buses. Initially, only battery-electric and plug-in hybrid buses could be granted a rebate. However, in 2017, fuel cell buses using renewable hydrogen were also included in the scheme. In 2018, the EV bus scheme further expanded to also grant private transport companies the purchase rebate, and in 2019, the government decided to include electric trucks and heavy equipment. In December 2021, €144 million was allocated to the scheme for 2022 and €1 million was earmarked for trucks and heavy equipment. The Swedish government also decided to increase the premium for electric buses from 10% to 20% of the purchase price.

Fleet Totals (as of December 31st 2022)

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Electric bike	n.a.	n.a.	n.a.	n.a.	n.a.
Electric moped (<50 kmph)	n.a.	n.a.	n.a.	n.a.	102,000**
Auto-rickshaw	n.a.	n.a.	n.a.	n.a.	n.a.
Motorcycle	338**	n.a.	n.a.	n.a.	313,000
Motorcycle with sidecar	n.a.	n.a.	n.a.	n.a.	n.a.
Motorized tricycle	n.a.	n.a.	n.a.	n.a.	n.a.
Passenger vehicles	197,700	152,700	239,500	n.a.	4,980,500
Buses and Minibuses	900	100	n.a.	n.a.	14,200
Light Commercial vehicles	13,200	100	160**	n.a.	608,900
Medium and Heavy Weight Trucks	231		8		86,100

Total Sales (1st Jan 2022 to 31st Dec 2022)

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Electric bike	n.a.	n.a.	n.a.	n.a.	n.a.
Electric moped (<50 kmph)	n.a.	n.a.	n.a.	n.a.	n.a.
Auto-rickshaw	n.a.	n.a.	n.a.	n.a.	n.a.
Motorcycle	4,800	n.a.	n.a.	n.a.	12,700
Motorcycle with sidecar	n.a.	n.a.	n.a.	n.a.	n.a.
Motorized tricycle	n.a.	n.a.	n.a.	n.a.	n.a.
Passenger vehicles	96,200	28,400	66,800	3	299,200
Buses and Minibuses	206	n.a.	n.a.	n.a.	832**
Light Commercial vehicles	4952	135**	56**	n.a.	36,900
Medium and Heavy Weight Trucks	36	1	7	1	7,300

*Total of vehicles of this type, including ICEVs

** Numbers from 2021

CHARGING INFRASTRUCTURE OR EVSE

*As of December 31st, 2022

**Numbers from 2021

The Swedish electricity market is completely deregulated, which enables almost anyone to become a charging point operator (CPO). This has created a vast ecosystem of charging infrastructure, which benefits from both private and public efforts to deploy EVSE. Below is a description of the various supports available for the implementation of a charging station in Sweden

KLIMATKLIVET – THE CLIMATE LEAP

In September 2015, the Swedish government launched the investment support scheme Klimatklivet, "the Climate Leap." Klimatklivet is a general investment support scheme, not specifically aimed at charging infrastructure deployment, which grants up to 50% of a relevant investment cost. In 2022, 320 charging stations received support, with a special focus on fast charging stations and charging stations for heavy vehicles.

For 2023, the appropriation for Klimatklivet is SEK €310 million, of which €40 million is a special investment in charging infrastructure. Until 2026, there are additional funds available.

REGIONAL ELECTRIFICATION PILOTS

These is a new form of support from the Swedish government that can go to charging infrastructure and tank infrastructure for hydrogen. They are, together with the Climate Leap among other things, part of the government's effort to accelerate the electrification of freight transport. So far, the Swedish Energy Agency has granted support to 139 charging stations, 12 hydrogen filling stations, and a combined charging and hydrogen filling station for a total sum of €140 million. The requirement for receiving support is that any charging or filling station for which financial support is applied for must be completed by autumn 2023, and that the beneficiary shares its lessons learned and information about the use. The aid applies to up to 100 percent of the investment costs.

HOME CHARGING SUPPORT SCHEME - TAX REDUCTION FOR GREEN TECHNOLOGY

As of January 1st, 2021, there is an opportunity to get a tax reduction for parts of the cost when a company is hired for the installation of green technology. Only work and materials are entitled to a deduction. The deduction may not exceed 15 percent of the cost for installing solar cells and may not exceed 50 percent for the installation cost of systems for storage of self-produced electricity or installation of a charging point for electric vehicles. It is possible to receive a maximum of €5,000 in tax reduction for the installation of green technology per year. For 2021, €49 million has been paid for the installation of almost 50,000 charging points.

FAST CHARGING STATIONS ALONG MAJOR ROUTES

To complete a nationwide fast-charging network, the government allocated €25 million for 2020-2023. The Swedish Transport Administration estimates that 70-80 additional locations for fast charging are necessary to fulfil a nationwide network.

The first call opened in the autumn of 2020, where 21 identified locations along major public roads were subject to a reversed auction and 20 locations got tenders. In 2021, the second call comprised about 70 locations. For the 2023 call, in order to qualify for funding, the road section shall lack direct current charging of 150kW or more, and there shall be more than ten miles between existing fast charging stations. Previously, the starting point was 50kW, but 150kW is considered to suit the current development better.

*As of December 31st, 2022
**Numbers from 2021

Type of Public EVSE	Number of Outlets*	Number of Locations*
AC Level 1 ≤ 3.7 kW	4,575	n.a.
AC Level 2 >3.7 kW, ≤ 22 kW	11,557	n.a.
AC Fast Charger 43 kW	200	n.a.
DC Fast Charger ≤ 50 kW	1,166	n.a.
Tesla Supercharger DC > 120kW- 250kW	890	69
Ultrafast High Power DC > 50 kW and ≤ 350 kW	1,177	n.a.
Inductive Chargers EM Charging	2**	n.a.

EV DEMONSTRATION PROJECTS

MOBILE CHARGING SOLUTION FOR ELECTRICITY AND HYDROGEN TO ENABLE THE ELECTRIFICATION OF WORKING MACHINES

This project intends to demonstrate a mobile charging solution for both electricity and hydrogen, that will also be able to travel in challenging terrain. The charging station combines a hydrogen storage system for refuelling hydrogen-powered vehicles and a fuel cell that can convert the hydrogen into electricity for charging electric vehicles.

The innovation lies less in the development of the individual parts of the system and more on the systems level, as well as in making the charging solution usable off-grid and off-road. The project will end with a demonstration of the entire system where

Figure 1: A conceptual view of MHRS and its various parts

the mobile hydrogen storage facility will be able to supply both hydrogen-powered and electric working machines with energy.

The project is a collaboration between Volvo Technology and the company Euromekanik. Where Volvo is mainly responsible for the development and construction of the vehicle and fuel cell, Euromekanik is responsible for equipment linked to hydrogen refuelling. The Swedish Energy Agency’s assessment shows that the mobile charging solution has the potential to facilitate the transition of different working machines to both more energy-efficient as well as fossil-free operation. This is especially true of working machines used at workplaces with no or limited access to the power grid. The solution can also be utilized in other areas of application, for example as mobile backup energy in crises. The total budget is €8.6 million, of which €2.3 million is support from the Swedish Energy Agency. The project runs from October 2022 to March 2025.

PEPP - PUBLIC EV POWER PILOTS

It is not clear whether public bidirectional charging can be applied on a larger scale, as there are currently many unanswered questions regarding technical systems, how people perceive and use bidirectional charging in public environments, and what values the services create. Through unique user studies on real-life pilots across twelve vehicles, the project will evaluate bidirectional charging in a public environment from a systems perspective. In this way, relevant user studies can be carried out, technical systems and customer benefits can be validated in a real environment, business models and incentives can be inventoried and analyzed, and policies and regulations can be evaluated. Technical systems for the optimization of carpools, user interaction and energy optimization will be developed.

Large-scale Swedish system demonstrators of bidirectional public charging will be prepared by identifying and mobilizing partnerships for relevant applications and support services for the rollout of 100s of vehicles. Running from 2022–2024, the project is led by “Lindholmen Science Park” and together there are 13 different parties involved, representing everything from electricity producers, parking companies, vehicle manufacturers and manufacturers of charging equipment.

ELECTRIC ROAD SYSTEMS

In July 2021, the Swedish Transport Administration decided that Sweden's first permanent electric road will be built on the E20 between Hallsberg and Örebro. Procurement and choice of technology are now underway. The electric road is expected to be completed as early as 2025, covering a total route of about 21kms, with two lanes in each direction.

OUTLOOK

The development of the market share for plug-in electric passenger cars, city buses, and distribution trucks looks very positive in Sweden. One major driver for this development is the EU CO_2 reduction requirements for new vehicles. The Swedish policy framework has accomplished a high allocation compared to other EU markets. Future developments in Sweden depend on Swedish policy frameworks, as well as other EU countries, which could influence the allocations of vehicles to Sweden. Major efforts are now being made to enable public fast charging for heavy vehicles. Continuous charging, so-called electric roads systems, are being explored more widely on public roads.

How the 2023 automotive year will turn out, both in terms of total volume and share of electrification, will be greatly affected by both delivery capacity, the ongoing economic recession, and new political decisions. An observed trend reversal since the end of 2021 is that private leasing has in years past been a driving force in electric car registrations, but recently, a sharp decrease in demand for private leasing can be observed. Increased interest rates, as well as the discontinued climate bonuses, contribute to a significantly increased monthly cost, which above all negatively affects private leasing.

References

[1] Chalmers University of Technology. Accessed at: https://www.chalmers.se/en/.

[2] Rise Research Institutes of Sweden. Accessed at: https://www.ri.se/en.

[3] European Battery Alliance. Accessed at: https://www.eba250.com/.

Switzerland

Number of EVs & PHEVs registered

224,688

Number of EV chargepoints

12,328

MAJOR DEVELOPMENTS IN 2022

Between 2000 and 2022, the road vehicle stock (excluding mopeds) increased by 39% to 6.4 million vehicles. Passenger cars accounted for 74% of this stock.

A total of 232,556 passenger cars were put on Swiss roads in 2022, representing 5.1% fewer than in 2021 and more than a quarter less than in 2019. This situation was likely influenced by the ongoing conflict in Ukraine, which has exacerbated pandemic-related supply bottlenecks. However, the market share of electric cars has increased.

Electric vehicles on the Swiss market

Remarkably, the share of newly registered BEVs (17.8%) was for the first time significantly higher than the proportion of diesel cars, which now accounts for barely one in ten new registrations. Continued increase in BEV sales has exceeded targets and expectations. This is notable as Switzerland provides no direct national purchase incentives and only modest support at cantonal and local level, mainly through reduced or no vehicle registration tax.

It is also remarkable that the general trend is towards BEVs, with new PHEV registrations having fallen from 9.1% in 2021 to 8.3% one year later. At the end of 2022, just over 128,000 pure electric passenger cars were on the road in Switzerland, representing 2.7% of the total car fleet (PHEV: 1.5%).

Recent developments in the regulatory framework

RIGHT TO CHARGE AT HOME

Switzerland has a high proportion of tenants compared to homeowners. The availability of home charging options is therefore a widespread problem and is currently one of the main reasons people do not choose electric when buying a new car. However, discussions in parliament on this issue have not resulted in the development of a legal right to a home charging station.

TOTAL REVISION OF CO_2 ACT REJECTED AT THE BALLOT BOX

In a 2021 referendum, the Swiss people rejected a new CO_2 Act to set the framework for achieving net zero by 2050 and meeting the obligations of the Paris Agreement.

A new revision of the CO_2 Act is under discussion in parliament, again including subsidies for charging infrastructure. The aim of this incentive is in particular to reduce the initial investments required for the installation of the basic equipment needed for the later deployment of charging stations in multi-apartment buildings, but also in public car parks. This new law should come into force in 2025.

V2G POTENTIAL

A member of parliament asked the Federal Council to present a report showing how batteries from electric vehicles could be used as a storage and grid balancing solutions to improve the overall stability of the electricity supply. The report will present the state of knowledge and experience in this field in Switzerland and abroad, the potential of this type of solution, as well as possible technical, financial, legislative and implementation obstacles, and suggest ways to overcome them.

FAST CHARGING STATIONS AT REST AREAS IN FEDERAL HANDS

The Federal Council identified already in 2014 conditions to facilitate the development of a network of fast charging stations along national highways. On this basis, the Federal Roads Office launched in 2018 a tender for the construction and operation of fast-charging stations at 100 rest areas along national roads. In order to ensure that a network covering the whole of Switzerland can be set up quickly, the permits were not granted individually for each rest area, but in the form of five lots, each comprising 20 rest areas. To facilitate the rollout, the federal government is pre-financing the grid connection required for the fast-charging parks. By the end of 2022, 26 rest areas were equipped and 54 by the end of 2023. The goal is to have all 100 rest areas equipped by 2030.

FURTHER INCENTIVES

Also in 2022, the federal government waived the 4 percent automobile import tax for new electric vehicles. This tax benefit could be challenged in the coming years.

At regional and local levels, some cantons and municipalities propose tax incentive or even subsidies to alternative energy vehicles and charging infrastructure.
For vehicles, these subsidies are often modest, with support for hybrid electric vehicles being gradually phased out. Grants are increasingly focused on recharging infrastructure, especially the basic equipment needed for the later deployment of charging stations. The federal and cantonal governments are also working to remove barriers to the planning, installation and operation of charging stations.

Impact of road transport electrification on energy consumption

The Swiss Federal Office of Energy is closely monitoring the electrification of the road transport sector. Deviating from what was envisaged a few years ago, in most scenarios, a trend towards battery powered trucks rather than hydrogen is observed. The impact of this development on the Swiss energy system and on the infrastructure is currently being analyzed.

Electromobility Roadmap 2022 and its flagship measures

In late 2018, key representatives from the automotive, mobility, energy and real estate sectors, as well as members of the federal government, cantons, cities and municipalities signed the electromobility roadmap [1]. Together and on a voluntary basis, they have committed to work on concrete measures favorable to the development of electric mobility. The first step was to reach 15% of BEV and PHEV cars among new registrations by 2022.

This goal has been surpassed, with 26.1% EV among new registrations as of December 31st, 2022. Achieving the 2022 targets ahead of schedule prompted the roadmap community to define more ambitious goals for 2025: (i) 50% BEV+PHEV in new car registrations by 2025, (ii) 20,000 publicly accessible charging stations and (iii) easy and grid-friendly charging at home, at work and on the road. All organizations involved in the roadmap formally endorsed the new 2025 targets at a national summit held in May 2022, attended by the then Minister of Energy, Federal Councillor Simonetta Sommaruga.

In the meantime, more than 60 leading organizations have renewed or developed over 75 measures supporting the new roadmap goals. In agreement with the Electromobility Roadmap community, the Confederation has encouraged its members to work on the following four “master measures:”

- Charging in multi-unit residential buildings
- District Charging
- Charging at point of interest
- Circular economy of batteries

The idea is that the interest groups concerned by each of these 4 topics takes responsibility for developing shared solutions, within the framework of round tables and workshops involving their representatives at the highest level. This framework is facilitated and accompanied by the federal government. For example, the different sectors concerned by home charging (i.e. representatives of tenants, of building owners, of the energy and automobile sector, etc.) agreed on a common technical, legal and economic model to facilitate the development of home charging stations, without having to be regulated at the legal level. The results of this work are recorded in practical guides that are co-signed and disseminated by each of the contributing organizations.

Figure 1: Federal Councillor Simonetta Sommaruga and representatives of more than 60 Swiss leading organisations at the signing ceremony for the electromobility roadmap.

Source: roadmap-elektromobilitaet.ch

HEVS, PHEVS, AND EVS ON THE ROAD

With a total of 322,387 newly registered motor vehicles in Switzerland (including among others agricultural and industrial vehicles, but not counting mopeds), new registrations in 2022 fell 7.8% behind 2021 (-21.2% compared with the pre-Covid year 2019). The under category of passenger cars was proportionally less affected, with a drop of 5.1% over the last 12 months.

However, the share of all-electric cars in new registrations increased again over the previous year to 17.8%, with PHEV new registrations having fallen from 9.1% to 8.3%. By the end of 2022, BEVs represented 2.7% of the total vehicle fleet (PHEV: 1.5%).

In the bicycle sector, delivery delays due to the COVID-19 pandemic could finally be compensated for in 2022. These enabled deliveries of electric bicycles to reach a new record of 218,730 units (cumulative total for the 25km/h and 45km/h categories), an increase of 17%. Compared to the previous year, however, the overall bicycle market declined for the second time in a row by 2 percent, to 483,562 units. In the near future, one out of two bikes sold will be an electric bike.

Fleet Totals (as of December 31st 2022)

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Electric bike	n.a.	n.a.	n.a.	n.a.	n.a.
Electric moped (<50 kmph)	5 111	4	0	0	18,706
Auto-rickshaw	7 556	1	0	0	7,906
Motorcycle	5 080	52	0	0	698,298
Motorcycle with sidecar	0	0	0	0	3,028
Motorized tricycle	238	1	0	0	4,342
Passenger vehicles	128,204	244,152	71,354	207	4,804,058
Buses and Minibuses	301	809	0	0	14 269
Light Commercial vehicles	6,475	425	1	0	433,945
Medium and Heavy Weight Trucks	368	18	0	50	60,105

Total Sales (1st Jan 2022 to 31st Dec 2022)

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Electric bike	195,947	0	0	0	483,562
Electric moped (<50 kmph)	1,601	0	0	0	1,951
Auto-rickshaw	1,014	0	0	0	1,041
Motorcycle	1,644	0	0	0	44,421
Motorcycle with sidecar	0	0	0	0	53
Motorized tricycle	5	0	0	0	270
Passenger vehicles	40,266	55,822	18,711	72	232,556
Buses and Minibuses	127	103	0	0	609
Light Commercial vehicles	2,383	115	0	0	25,284
Medium and Heavy Weight Trucks	175	0	0	1	3,763

*Total of vehicles of this type, including ICEVs

CHARGING INFRASTRUCTURE OR EVSE

*As of December 31st, 2022

** There are 1,296 points with max 3.7kW (Type 1 cable). However, they are almost all connected to a charging station that is also capable of supplying 22kW with Type 2 cable (both cable Type 1 and 2 – are connected to the same charging station).

Type of Public EVSE	Number of Outlets*	Number of Locations*
AC Level 1 ≤ 3.7 kW	1296	110**
AC Level 2 >3.7 kW, ≤ 22 kW	8919	3793
AC Fast Charger 43 kW	159	26
DC Fast Charger ≤ 50 kW	926	358
Tesla Supercharger DC > 120kW- 250kW	313	28
Ultrafast High Power DC > 50 kW and ≤ 350 kW	715	282
Inductive Chargers EM Charging	n.a.	n.a.

EV DEMONSTRATION PROJECTS

Vehicle-grid integration

The efficient integration of electric mobility in the energy system remains a focus of research and pilot and demonstration projects. Whereas the feasibility of V2X has been demonstrated in earlier pilot projects, 2022 saw the start of two large-scale demonstration projects focusing on V2X business models.

V2X SUISSE

Mobility, the largest car-sharing company in Switzerland, added 50 Honda e to their fleet in 2022. In addition, 40 Mobility locations were equipped with bidirectional-charging. With this setup, V2X can be tested at an unprecedented large scale. The flexibility of the 50 bidirectional vehicles is pooled and made available for several grid services, such as secondary frequency regulation, local utilities, and self-consumption communities.

Figure 2: Bi-directional charging of a shared electric vehicle.

Source: www.mobility.ch/en/v2x.

SUNNYPARC

This project aims to explore synergies between local renewable production and electric mobility. The Y-Parc area in Yverdon combines about 1000kWp photovoltaic production, 250 charging stations in the municipal P+R car parks and some large industrial consumers in a local grid. Within this microgrid, several modes of control and pricing will be tested, actively involving the EV owners.

Electric vehicles

The Federal Office of Energy launched a tender on the “electrification of freight- and special-purpose vehicles.” In many of these applications, replacing an internal combustion engine with an electric drive would be highly effective, but the small markets and special applications have so far prevented a fast transition. The successful projects deal with agricultural, communal and delivery vehicles as well as construction machines.

In addition, numerous projects are underway to accelerate the electrification of bus lines. With relatively harsh and cold winters, temperature management is a considerable challenge in purely electric vehicles.

Megawatt charging

The rapidly increasing share of electric trucks poses new challenges for Switzerland’s charging infrastructure. Heavy trucks are equipped with batteries of up to 1000kWh capacity. Current operating concepts foresee fast charging to take place during the mandatory 45 minutes breaks the driver take. To recharge large batteries, a charging power exceeding one megawatt will be necessary. A Megawatt Charging System (MCS) based on CCS has been introduced by CharIN at the EVS 35 in Oslo. In a project supported by the Federal Office of Energy, Designwerk and industry partners are currently building a megawatt charging station based on a large buffer with second-life batteries to reduce its impact on the grid.

Figure 3: Megawatt charging of an electric truck. The container houses and array of second-life batteries.

Source: https://www.designwerk.com/megacharger/.

OUTLOOK

Vehicle-grid integration

Generally speaking, to decarbonize its transport system, Switzerland will continue to focus on modal shift and electrification. The key stakeholders, even those who consider the electrification of transport as a constraint, are now all convinced that the development of electric mobility will be rapid, inescapable, and that it must be actively supported. Many of them have contributed to the acceleration of the transition by setting ambitious targets in the national Electromobility Roadmap.

The “right to plug” will probably not come into force any time soon, as the idea is struggling to find a majority in parliament. One of the main challenges will therefore remain the development of charging infrastructure, especially at home and at the workplace.

While the vast majority of Swiss people are tenants, the most recent surveys, such as those by TCS [2], show that the penetration rate of BEVs is currently almost five times higher among homeowners compared to tenants. Equipping residential parking lots with charging stations therefore remains a major challenge, which the real estate industry now seems to be aware of. Barriers to the installation of charging stations are identified and initiatives are taken by the relevant stakeholders to reduce them, in particular with the framework of the electric mobility roadmap.

Another development that will deliver results in 2023 is the project "Understanding Charging Infrastructure 2050" commissioned by the Federal Office of Energy. This study tries to define the charging infrastructure needed up to the year 2050 and will make recommendations. The work is carried out in close collaboration with key representatives from different sectors of the industry. The objective is first to develop a common understanding of the assumptions and factors that will influence the charging infrastructure development. The input variables include socio-demographic and technical developments as well as new transport perspectives.

Five typical charging behaviours (home, workplace, neighbourhood, point of interest (POI) and fast charging) are described and quantified in 3 scenarios. The latter differ in the expectations for public (slow and fast) charging and home charging infrastructure. In the end, a relatively clear model of what the charging landscape in Switzerland could look like by 2035 and 2050, in terms of the number of charging points required as well as their characteristics, will be uncovered.

The fact that battery-powered trucks are particularly well-suited to the relatively short distances travelled in Switzerland further increases the adoption rate of these vehicles. The need for charging in freight transport (Mega Chargers) and the impact of this development on the energy system and infrastructure will be a central topic in the coming years.

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United Kingdom

Number of EVs & PHEVs registered

1,002,200

Number of EV chargepoints

38,700

MAJOR DEVELOPMENTS IN 2022

In November 2020, the UK was the first G7 country to announce ambitious phase-out dates for petrol and diesel cars and vans by 2030, and from 2035, all new cars and vans must be zero emissions at the tailpipe. Phasing out the sale of new petrol and diesel cars and vans by 2035 will reduce greenhouse gas emissions faster, with savings equivalent to almost five million fewer cars on the road each year by 2035.

2022 was an important year for the UK's drive to decarbonise road transport with a number of firsts achieved. In September 2022, the UK reached the milestone of over one million plug-in vehicles on its roads. The number is increasing, with over one in five cars sold in 2022 having a plug. December 2022 was also the best ever month for new battery electric car registrations, with more sales than in all of 2019 combined and making up 32.9% of the market share.

In March 2022, the Government published the Electric Vehicle Charging Infrastructure Strategy [1], which set out the vision and commitments to make EV charging cheaper and more convenient than refuelling at a petrol station.

To ensure that the transition to EVs takes place in every part of the country, in August 2022 the Government launched a £10 million GBP ($12.5 million USD) Local EV Infrastructure Fund pilot [2]. The pilot, serving as a springboard for the development of the full fund, will deliver over 1,000 on-street chargepoints and £8.6 million GBP ($10.8 million USD) in private investment.

In March 2022, Government also announced new regulations for public chargepoints to improve confidence in the charging network and to make the user experience truly seamless [3]. Drivers will benefit from easier payment methods as well as the ability to compare prices and access real-time information about chargepoints. Government will ensure that there is a 99% reliability rate at rapid chargepoints. Chargepoints will also need to have open data so that they are easy to find using digital apps and mapping services.

The UK Government also published the Transport Decarbonisation Plan: One Year On [4] to update on progress on the key commitments made to drive down transport emissions. This included reinforcing its commitments to bring forward our zero emission vehicle mandate, to set an end date for the sale of new, non-zero emission.

HEVS, PHEVS, AND EVS ON THE ROAD

The uptake of EVs in the UK continued to grow in 2022, with over one in five new cars sold coming with a plug.

ACEA analysis shows that more plug-in vans were sold in the UK in 2022 than any other country in Europe [5].

CHARGING INFRASTRUCTURE OR EVSE

The UK is a global front-runner in supporting provision of charging infrastructure. As the sale of plug-in vehicles continues to soar, the UK Government has published a landmark strategy setting out its plans to accelerate the rollout of a world-class charging network.

The EV Infrastructure Strategy laid out that Government expects at least 300,000 public chargepoints to be installed across the UK by 2030. This rollout will be supported by our Local EV Infrastructure [6] and Rapid Charging [7] Funds, as well as the On-Street Residential Chargepoint Scheme [8].

Government is supporting the installation of private chargepoints through our Domestic and Workplace chargepoint grant schemes. In April 2022, the Office for Zero Emission Vehicles reformed its Electric Vehicle Homecharge Scheme, which provided funding for domestic chargepoints to homeowners with off-street parking, to focus its support on accelerating the provision of chargepoints in flats and rental accommodation. The new EV Chargepoint Grants [9] are available to freeholders owning or leasing properties including social housing providers and private landlords. Additional support is available to help install chargepoints in residential car parks, particularly apartment blocks, with grants of up to £30,000 GBP ($37,500 USD) available.

The Workplace Chargepoint Scheme provides help to businesses to transition to EVs and install chargepoints for their fleets and staff. Small and medium enterprises can additionally apply for grants of up to £15,000 GBP ($18,700 USD) to kit out their staff or fleet parking with chargepoints. Workplace chargepoint grants are also available to small accommodation business and the charity sector for use by guests and staff. This will help accelerate EV uptake in rural areas and support he UK tourist industry.

World-leading legislation which requires new homes and non-residential buildings (as well as those undergoing major renovation) with associated parking in England [10] to have a chargepoint installed came into force on 15 June 2022.

Fleet Totals (as of December 31st 2022)

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Electric bike	n.a.	n.a.	n.a.	n.a.	n.a.
Electric moped (<50 kmph)	n.a.	n.a.	n.a.	n.a.	n.a.
Auto-rickshaw	n.a.	n.a.	n.a.	n.a.	n.a.
Motorcycle	12,900	0	0	0	1,457,700
Motorcycle with sidecar	n.a.	n.a.	n.a.	n.a.	n.a.
Motorized tricycle	300	0	0	0	20,000
Passenger vehicles	548,400	1,199,300	397,300	200	33,326,290
Buses and Minibuses	1,800	0	0	0	146,900
Light Commercial vehicles	38,700	1,600	2,700	0	4,574,300
Medium and Heavy Weight Trucks	100	0	0	0	512,100

Total Sales (1st Jan 2022 to 31st Dec 2022)

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Electric bike	n.a.	n.a.	n.a.	n.a.	n.a.
Electric moped (<50 kmph)	n.a.	n.a.	n.a.	n.a.	n.a.
Auto-rickshaw	n.a.	n.a.	n.a.	n.a.	n.a.
Motorcycle	5,200	0	0	0	94,400
Motorcycle with sidecar	n.a.	n.a.	n.a.	n.a.	n.a.
Motorized tricycle	100	0	0	0	800
Passenger vehicles	175,600	244,500	75,000	0	1,216,200
Buses and Minibuses	500	0	0	0	3,500
Light Commercial vehicles	11,700	0	400	0	214,700
Medium and Heavy Weight Trucks	500	0	0	0	31,200

*Total of vehicles of this type, including ICEVs

Note: Data is only available up to September 2022

*As of December 31st, 2022

Type of Public EVSE	Number of Points*
Slow 3-6kW	8,913
Fast 7-22kW	21,255
Rapid 25-100kW	4,592
Ultra Rapid 100kW+	2,295

EV DEMONSTRATION PROJECTS

Government's Office for Zero Emission Vehicles (OZEV) has funded over 100 projects, advancing technologies for ZEVs and accompanying infrastructure. This includes, for example, £10 million for wireless charging technologies.

The Net Zero Strategy [11] announced that Government is taking forward a £200 million GBP ($250.3 million USD) Zero Emission Road Freight Demonstrator programme. This will trial three zero emission technologies at scale on UK roads, with the first competitions expected to focus on battery electric and hydrogen fuel cell long haul zero emissions HGVs.

In March 2022, the Department for Business, Energy and Industrial Strategy launched an [£11.4 million GBP] $14.2 million USD Vehicle-to-Everything (V2X) Innovation Programme to address barriers to this technology, including hardware cost and a lack of business models for a variety of consumers. Phase 1 (£2 million GBP / $2.5 million USD) will support the development of V2X bi-directional charging prototype hardware, software or business models, in 12-month projects which began in September 2022. Phase 2 of the competition, supporting small-scale V2X demonstrations, launched in March 2023. [12]

OUTLOOK

2023 will be another vital year for the UK's drive to decarbonise our road transport.

Government will publish key initiatives, including the last consultation on our zero emission vehicle mandate [13], setting targets requiring a percentage of manufacturers' new car and van sales to be zero emission each year from 2024, as well as accompanying CO_2 emissions regulation. Regulations will be laid out in 2023 and come into effect in January 2024. In addition, we will set out our approach to defining Significant Zero Emission Capability for cars and vans sold between 2030 and 2035, after which all new cars and vans sold will need to be completely zero emission.

We have launched the Local EV Infrastructure Fund, providing capital and resource funding to support local authorities to work with industry and transform the availability of charging infrastructure for drivers without off-street parking.

We will lay out our consumer experience regulations to increase confidence in the charging network, reduce charging anxiety and making charging as convenient as refuelling at a petrol station.

We will continue to work with industry on the development of our Rapid Charging Fund to future-proof electrical capacity at strategic locations to help to deliver a comprehensive charging network, tackling consumer anxiety. We expect to initiate pilot activity in mid-2023.

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United States

Number of EVs & PHEVs registered

3,277,936

Number of EV chargepoints

136,413

MAJOR DEVELOPMENTS IN 2022

The United States (U.S.) population continues to rely on vehicles for personal transportation. Because of the improvement in the global COVID-19 pandemic situation, individuals drove more and there was improvement from 2021. The cumulative national vehicle miles traveled (VMT) for the year 2022 was 3,169.4 billion vehicle miles (data available till the end of December 2022), which represents an increase of 0.9% (+29.3 billion vehicle miles) compared to the prior year [1].

Sales of electric vehicles in the U.S. in 2022 continued the rapid rebound and increased nearly 46% from their 2021 value (927,572 in 2022 compared to 635,591 in 2021), the cumulative total reached 3.28 million plug-in electric vehicles (PEVs) using December 2010 as the base. During 2022, there were 82 PEV models sold, including both plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs); as well as 27 hybrid electric vehicle (HEV) models, for total sales of ~1,693,750 units [2].

Industry and Market

MARKET DEVELOPMENTS

- 6K and Albermarle signed a joint development agreement to produce novel lithium-ion battery materials [3].
- 24M Technologies finalized a strategic partnership deal with Volkswagen Group through which Volkswagen will manufacture EV batteries using the 24M platform for those EVs [4].
- GM is investing $6.5 billion USD in a new battery factory being built in partnership with LG Energy Solution to manufacture Chevy and GMC e-trucks, to which Michigan is providing $824 million USD worth of incentives [5].
- LG Energy Solution proposed $1.5 billion USD facility expansion of its manufacturing plant in Holland, Michigan [6,7].
- Ford will spend $20 billion USD to orient its business to EVs [8].

- Solid-state battery start-up Sparkz opened a pilot facility in Livermore, California [9].
- VW announced it will invest $7.1B to produce EVs in North America and offer 25 new EV models to customers by 2030 [10].
- Envision AESC, a Japanese EV battery technology company, will invest $2 billion USD to build a new gigafactory in Bowling Green, Kentucky [11].
- LG Energy Solution has selected Arizona for $1.4 billion USD battery plant [12].
- Stellantis and Samsung SDI plan to invest over $2.5 billion USD in joint venture for Li-ion battery plant in Kokomo, Indiana, with an initial capacity of 23GWh/year, increasing to 33GWh over time [13].
- Ford is investing $2 billion USD in EV production in Michigan as part of a $3.7 billion USD expansion of EV production across Michigan, Missouri, and Ohio [14].
- Panasonic Energy plans to build a $4 billion USD EV battery plant in Kansas [15].
- LG Chem said it plans to invest more than $11 billion USD in its US EV battery operations by 2025 [16].
- VW began production of its first US-assembled EV at a Tennessee plant [17].
- Gotion announced plans for a $2.36 billion USD battery component plant in Michigan [18].
- Electrovaya will build a Li-ion battery factory in New York [19].
- Honda and LG Energy Solution announced an Ohio EV battery plant [20].
- VW started building EVs in its US Plant in Chattanooga, Tennessee [21].
- BMW plans $1.7 billion USD investment in US EV production [22].
- Hyundai broke ground on a $5.54B EV and battery plant, in Georgia [23].
- ICL plans to build a $400 million (USD) LFP cathode manufacturing plant in St. Louis, Missouri [24].

BATTERY TECHNOLOGY

Solid-state Li-metal battery company Quantum Scape announced its battery cells have completed 400 consecutive 15-minute fast-charging (4C) cycles from 10% to 80% of the cell's capacity at above 80% of the initial energy [25].

Another market player, Farasis Energy said it has developed and validated a direct recycling process for Li-ion batteries [26].

CHARGING INFRASTRUCTURE

Electrify America said it raised $450 million USD in a deal that includes its first external investor as it aims to accelerate its rollout of fast charging stations in the U.S. and Canada [27]. The deal includes $100 million USD from Simmons and the rest from VW. Electrify America has also unveiled its first MW-level battery energy storage system (BESS) for EV charging stations [28].

Policy and Government

FEDERAL GOVERNMENT

- The US DOE, in coordination with DOL and the AFL-CIO, announced the launch of a national workforce development strategy for Li-battery manufacturing. As part of a $5M investment, DOE will support up to five pilot training programs in energy and automotive communities and advance workforce partnerships between industry and labor for the domestic Li-battery supply chain [29].

- President Biden signed a directive authorizing the Defense Production Act for usage for the critical materials that go into large-capacity batteries [30].

- DOE awarded $2.8 billion USD to 21 projects to expand domestic manufacturing of batteries for EVs and the electrical grid and for materials and components imported from other countries. Of that, $1.6 billion will go to 11 projects in the materials separation and processing segment of the supply chain [31].

The EPA announced $500 million USD in new funding for school districts and other eligible bus operators to begin replacing the nation’s fleet of school buses with American-made zero-emission buses [32].

STATE AND LOCAL GOVERNMENTS

In terms of state-level government EV updates, Michigan announced that it plans to have the nation's first in-road wireless charging system for EVs operational by 2023. The system will debut in a mile-long section of road outside Detroit [33].

On the West coast, the Los Angeles city council passed a motion to electrify its municipal fleet with over 10,000 EVs [34].

HEVS, PHEVS AND EVS ON THE ROAD

This section provides the number of hybrid and electric vehicles on the road in the U.S. at the end of 2022. It also includes price overview of the most popular-selling hybrid and electric vehicles. Figure 1 illustrates cumulative sales for HEVs, BEVs, and PHEVs between January and December 2022. It is observed that all three curves show a steady rise throughout the year. It is also noted that in 2022, the sale of BEVs picked up and came close to that of HEVs. As a result, the U.S. sale of PEVs (PHEVs and BEVs, taken together) exceeded one million, well over that of HEVs.

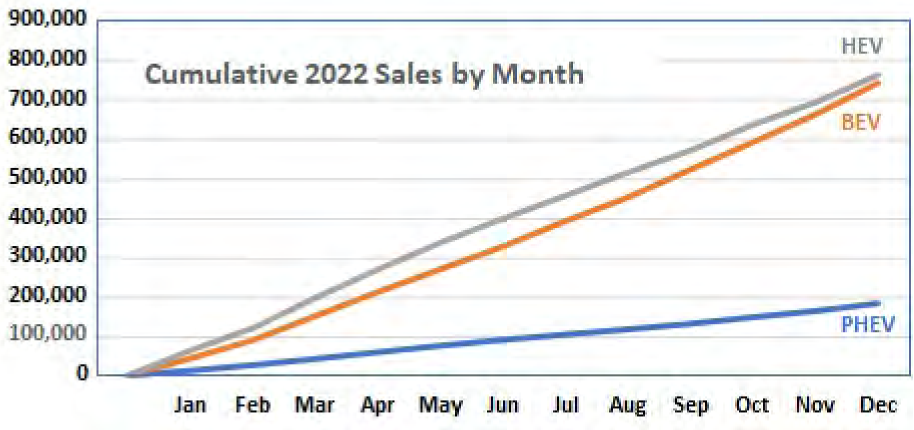


Figure 1: Cumulative sales of electrified vehicles in 2022, not including FCEVs.

Data source: Argonne National Laboratory

Figure 2 shows the 2022 sales for the U.S. EV market leaders. It is observed that 2022 HEV sales decreased 4% (to 755,186 in 2022 from 799,046 in 2021). There were 34 different models sold across the top six manufacturers (Toyota, Honda, Ford, Hyundai, Acura, and Fiat Chrysler Automobiles). The top-selling eight models include Toyota RAV4, Toyota Sienna, Honda CR-V Hybrid, Toyota Highlander, Toyota Camry, Honda Accord, Ford F Series, and Toyota Venza, which together accounted for 60% of the U.S. HEV market. The Toyota Prius lineup, once dominant in the market, further dwindled to 3% of the total market share (it was 4% in 2021), yet Toyota and Lexus together accounted for about 61% of the U.S. HEV market in 2022.

There were 35 different PHEV models sold across 10 manufacturers. The top five models include Jeep Wrangler PHEV, Chrysler Pacifica Plug-in, Jeep Grand Cherokee, Toyota RAV4 PHEV, and Prius PHEV; and together account for 54% of sales. There were 48 different BEV models sold across 15 manufacturers. Of those, the top seven models included Tesla Model Y, Tesla Model 3, Tesla Model S, Tesla Model X, Ford Mustang Mach E, Ford F Series, and Ford Transit Van, which together accounted for 70% of BEV sales.

Figure 3 shows the evolution of the U.S. HEV market (2006-2022) for prominent manufacturers. The corresponding information for the PHEV and BEV markets (2010-2022) appears in Figure 4 and Figure 5.

The total 2021 PEV sales reached around 927,527 units, ~53% above their total sales in 2021. Eighteen of the PEV models sold over 10,000 units in 2022, thirteen of which were BEVs.

The highest-selling 2022 PEV models included Tesla Model Y, Tesla Model 3, Jeep Wrangler PHEV, Ford Mustang Mach E, Tesla Model S, Chevy Bolt EUV, Tesla Model X, Hyundai IONIQ 5, Chrysler Pacifica Plug-in, Volkswagen ID.4, and Kia Motors EV6, selling 20,000 or more each—together accounting for 70% of the combined PEV market. The 2022 sales data demonstrates continued dominance of Tesla's share of BEV sales: ~63% of BEV sales in 2022 (about the same as in 2021).

Table 1 provides estimated total stock and sales numbers for the electrified fleet, followed by a list of the top-20 bestselling vehicles and their respective prices in Table 2 and Table 3, for BEVs and PHEVs, respectively. In both cases, the listed models together represent about 94% of the market.

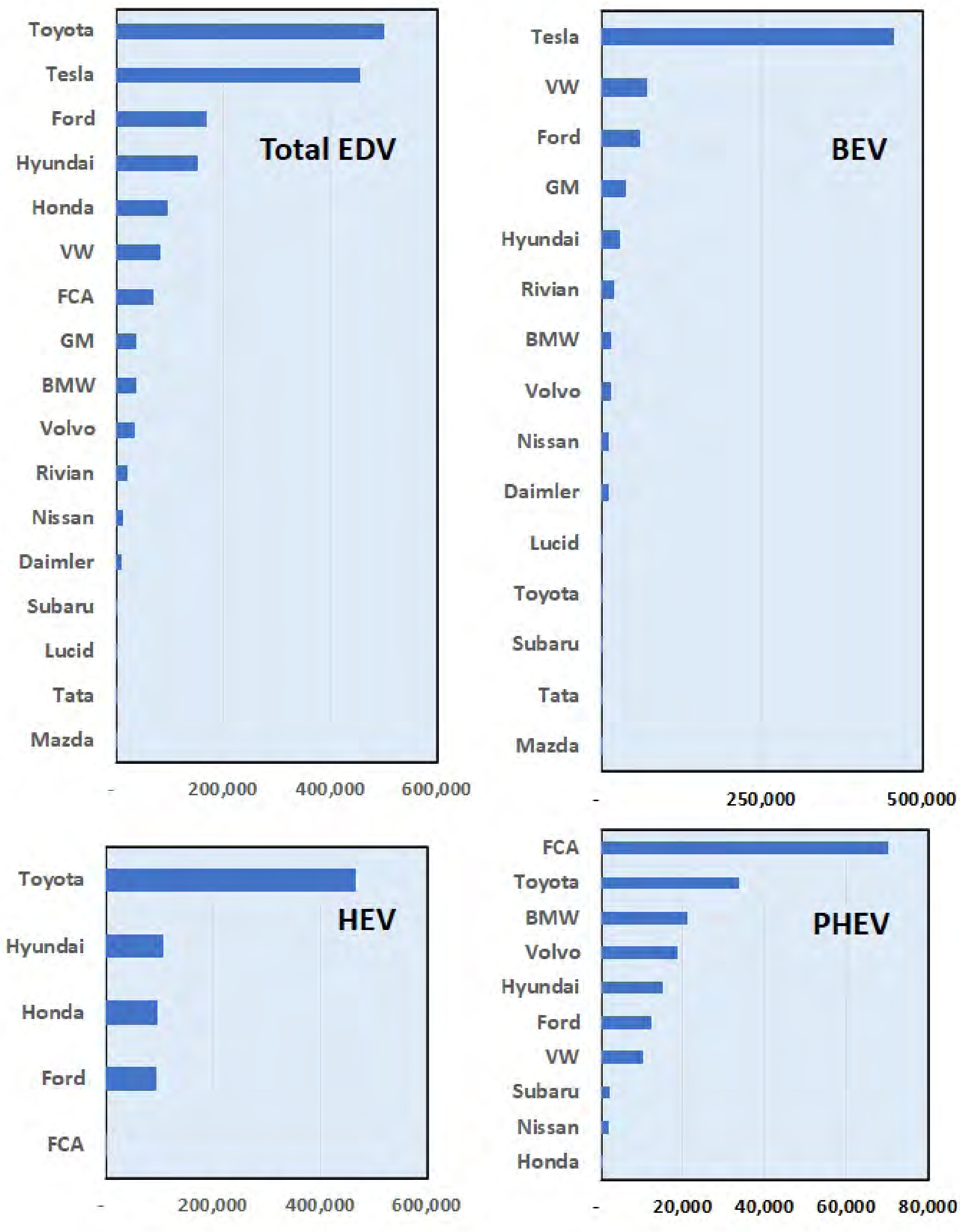


Figure 2: 2022 sales of electrified vehicles for market leaders.

Data source: Argonne National Laboratory

Figure 3: Evolution of the U.S. HEV market over time (2006-2022).

Data Source: Argonne National Laboratory

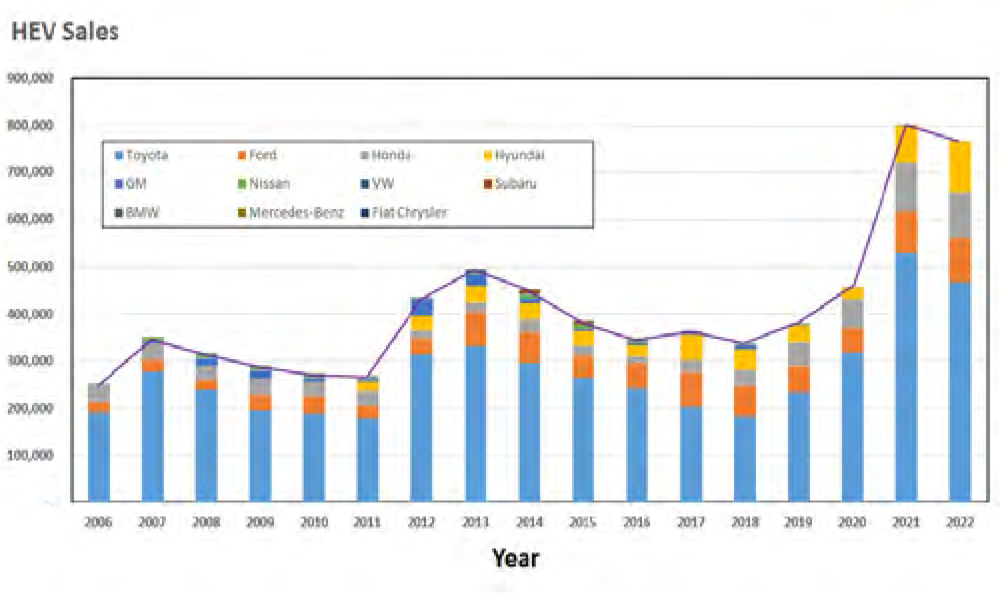
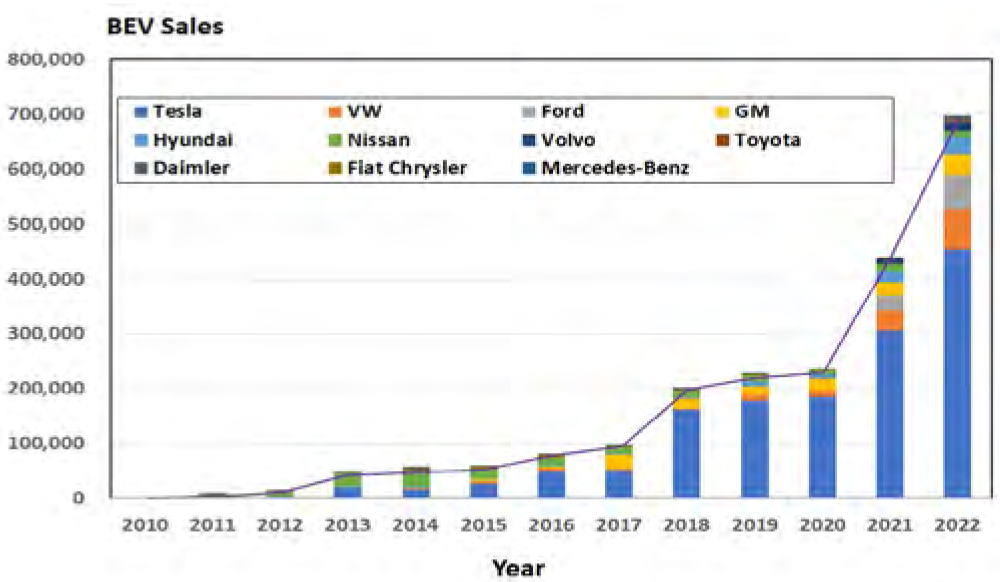


Figure 4: Evolution of the U.S. PHEV market over time (2010-2022).

Data Source: Argonne National Laboratory

Figure 5: Evolution of the U.S. BEV market over time (2010-2022).

Data Source: Argonne National Laboratory



Fleet Totals (as of December 31st 2022)

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Passenger Vehicles**	2,278,710 [35]	7,200,520 [35]	999,226 [35]	14,934 [35]	105,000,000 [36]
Light trucks***					148,000,000 [36]
Medium and Heavy Weight Trucks****	n.a.	n.a.	n.a.	n.a.	13,479,000 [36]

Total Sales (1st Jan 2022 to 31st Dec 2022)

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Electric Bicycles	550,000 [37]	n.a.	n.a.	n.a.	n.a.
Passenger Vehicles**	741,213 [35]	216,027 [35]	186,359 [35]	2,707 [35]	2,836,703 [35]
Light trucks***		550,159 [35]			10,899,520 [35]
Medium and Heavy Weight Trucks****	n.a.	n.a.	n.a.	n.a.	841,000 [36]
Totals (without bicycles)	**741,213**	**766,186**	**186,359**	**2,707**	**14,577,223**

Table 1: Distribution and sales of EVs, PHEVs and HEVs in 2022.

*Total of vehicles of this type, including ICEVs

**U.S Cars

***U.S. Class 1-2 Trucks (<10,000 lbs. GVWR)

****U.S. Class 3-8 Trucks

BEV	Untaxed, Unsubsidized Sales Price (USD)	BEV	Untaxed, Unsubsidized Sales Price (USD)
Audi e-Tron	$49,800	Mercedes-Benz EQS	$108,510
BMW i4	$52,995	Nissan LEAF	$28,040
Chevy Bolt	$26,500	Polestar 2	$55,900
Chevy Bolt EUV	$27,800	Porsche Taycan BEV	$90,900
Ford F SERIES	$59,974	Rivian R1T	$73,000
Ford Mustang MACH E	$45,995	Tesla Model 3	$41,990
Ford TRANSIT VAN	$49,575	Tesla Model S	$84,990
Hyundai IONIQ 5	$41,450	Tesla Model X	$94,990
Kia EV6	$48,700	Tesla Model Y	$49,990
Kia Niro EV	$39,550	Volkswagen ID.4	$38,995

Table 2: Market-Price Comparison of the Top-20 Best-selling BEVs in the U.S.

BEV	Untaxed, Unsubsidized Sales Price (USD)	BEV	Untaxed, Unsubsidized Sales Price (USD)
Audi Q5 Plug-in	$44,200	Kia Niro Plug In	$33,740
BMW 3-series Plug-In	$44,900	Kia Sorento	$49,990
BMW 530e (5-Series) Plug-in	$57,600	Lexus NX	$58,655
BMW X5	$65,700	Lincoln Corsair Plug-in	$51,810
Chrysler Pacifica Plug-in	$50,795	Prius PHEV	$27,450
Ford Escape PHEV	$40,500	Subaru Crosstrek Hybrid	$36,845
Hyundai Santa Fe	$42,110	Toyota RAV4 PHEV	$42,340
Hyundai Tucson	$37,300	Volvo V60 Plug-in	$70,550
Jeep Grand Cherokee	$62,095	Volvo XC60 Plug-In	$57,200
Jeep Wrangler PHEV	$54,735	Volvo-XC90 Plug-In	$56,000

Table 3: Market-Price Comparison of the Top-20 Best-selling PHEVs in the U.S.

CHARGING INFRASTRUCTURE

Table 4 provides an overview of the number of public charging stations in the U.S. by type–including Level 1 and 2 chargers, fast chargers, and Tesla superchargers. This information is continuously collected by the U.S. DOE's Alternative Fuels Data Center (AFDC) and published on its website [38]. It is seen that from 2021 to 2022, the overall EV charging infrastructure availability in the U.S. continued to grow. The total number of available stations grew from 48,498 to 54,098, or by 12%. This total increase reflects the respective 13% and 36% increases in the number of Level 2 and DC fast-charging stations, which more than offsets the 3% decrease in Level 1 charging stations. The average number of plugs at each station increased by 13% for Level 2 chargers and by 36% for DC fast chargers from 2021 to 2022.

Table 4: Information on charging infrastructure in 2022, excluding non-public charging stations. Numbers represent the total installed stations while those in parentheses indicate the total number of available plugs

Source: U.S. DOE AFDC, accessed Apr 18 2023

	Number of charging stations		
Chargers	2021	2022	Change
AC Level 1 Chargers	502 (1,169)	196 (799)	-61% (-31%)
AC Level 2 Chargers	42,104 (92,987)	46,675 (105,413)	+11% (+13%)
Fast Chargers	5,892 (22,278)	7,227 (30,201)	+23% (+36%)
Superchargers (incl. in Fast Chargers)	1,273 (12,878)	1,735 (18,691)	+36% (+45%)
Totals	**48,498 (116,434)**	**54,098 (136,413)**	**+12% (+17%)**

Table 5 shows the state-level distribution of charging stations and EVSE plugs respectively for the U.S., with California leading other states in the number of charging stations, at nearly five times that of the next largest state, New York.

Table 5: List of the top 10 U.S. States with maximum number of EVSE plugs, grouped by charging level.

Data source: U.S. DOE AFDC, accessed Apr 18, 2022.

Number of charging stations 2022

State	AC Level 1 Chargers	AC Level 2 Chargers	Fast Chargers	Superchargers (included in Fast Chargers)
California	38 (178)	12,744 (29,521)	1,773 (8,868)	347 (5,383)
New York	5 (7)	3,069 (8,085)	273 (1,219)	83 (787)
Florida	9 (24)	2,494 (5,539)	384 (1,799)	129 (1,278)
Texas	2 (3)	2,272 (4,843)	315 (1,675)	115 (1,291)
Massachusetts	3 (3)	2,327 (4,995)	151 (634)	44 (432)
Washington	8 (69)	1,515 (3,355)	236 (849)	42 (435)
Georgia	10 (200)	1,349 (3,037)	266 (866)	41 (477)
Colorado	5 (56)	1,513 (3,338)	274 (757)	34 (324)
Maryland	4 (13)	1,201 (3,042)	232 (743)	44 (371)
Pennsylvania	4 (15)	1,190 (2,528)	167 (773)	62 (534)

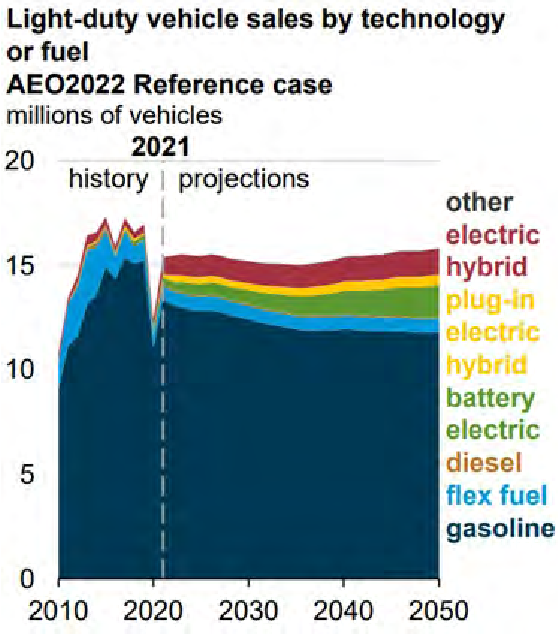
OUTLOOK

Electric Drive Vehicle Sales

The only DOE-published electric vehicle market projections appear in the Energy Information Administration's (EIA) Annual Energy Outlook (AEO) [39]. The 2022 AEO Reference Case represents its best assessment of U.S. and world energy markets through 2050, using key assumptions intended to provide a baseline for exploring long-term trends. EIA based the economic and demographic trends reflected in the Reference Case on the current views of leading economic forecasters and demographers—assuming improvements in known energy production, delivery, and consumption technologies, but no changes in current laws and regulations for the energy sector. Projections of light-duty vehicle sales are shown in Figure 6.

Figure 6: Light-duty vehicle sales by technology/fuel

Source: [2022 Annual Energy Outlook]



According to an earlier study by researchers at the Institute of Transportation Studies at the University of California, Davis (ITS-Davis), California's transition to zero emission vehicles (ZEVs) will begin to save the state money by as early as 2030. The study shows that the initial higher vehicle costs over the next decade in the ZEV scenario are eventually repaid through lower fuel costs, particularly for electric vehicles [40].

Global sales of light, medium, and heavy duty PEVs are estimated to continue growing according to forecasts from Bloomberg New Energy Finance which forecasts that EVs will become cheaper to make than gasoline vehicles and will globally sell 75 million units in 2025 [41]. Passenger EV sales are set to continue rising sharply in the years ahead as policy pressure continues to increase, more models hit the market, and consumer interest takes off.

Charging Infrastructure Requirements

The Edison Electric Institute (EEI) and the Institute for Electric Innovation (IEI) originally estimated that 9.6 million charging ports will be required in the U.S. by 2030 to support EV sales. In June 2022, they released an update [42] to that report. The updated report details new insights into the coming wave of EV sales and the charging infrastructure needed to support the projected electric vehicle (EV) growth. Its consensus forecast is based on four independent forecasts done by Boston Consulting Group, Deloitte, Guidehouse, and Wood Mackenzie, as well as analysis from NREL. It concludes that the number of EVs on U.S. roads is projected to reach 26.4 million in 2030 (up from its original 2018 projection of 18.7 million). It is expected that these EVs will make up nearly 10 percent of the 259 million light-duty vehicles (cars and light trucks) expected to be on U.S. roads in 2030.

Annual sales of EVs will be nearly 5.6 million in 2030, i.e., more than 32 percent of annual light-duty vehicle sales in 2030. Accordingly, nearly 12.9 million charge ports will be needed to support the projected 26.4 million EVs that will be on U.S. roads in 2030. Of this amount, approximately 140,000 Direct Current (DC) fast charging ports will be needed to support the level of EVs expected to be on U.S. roads in 2030.

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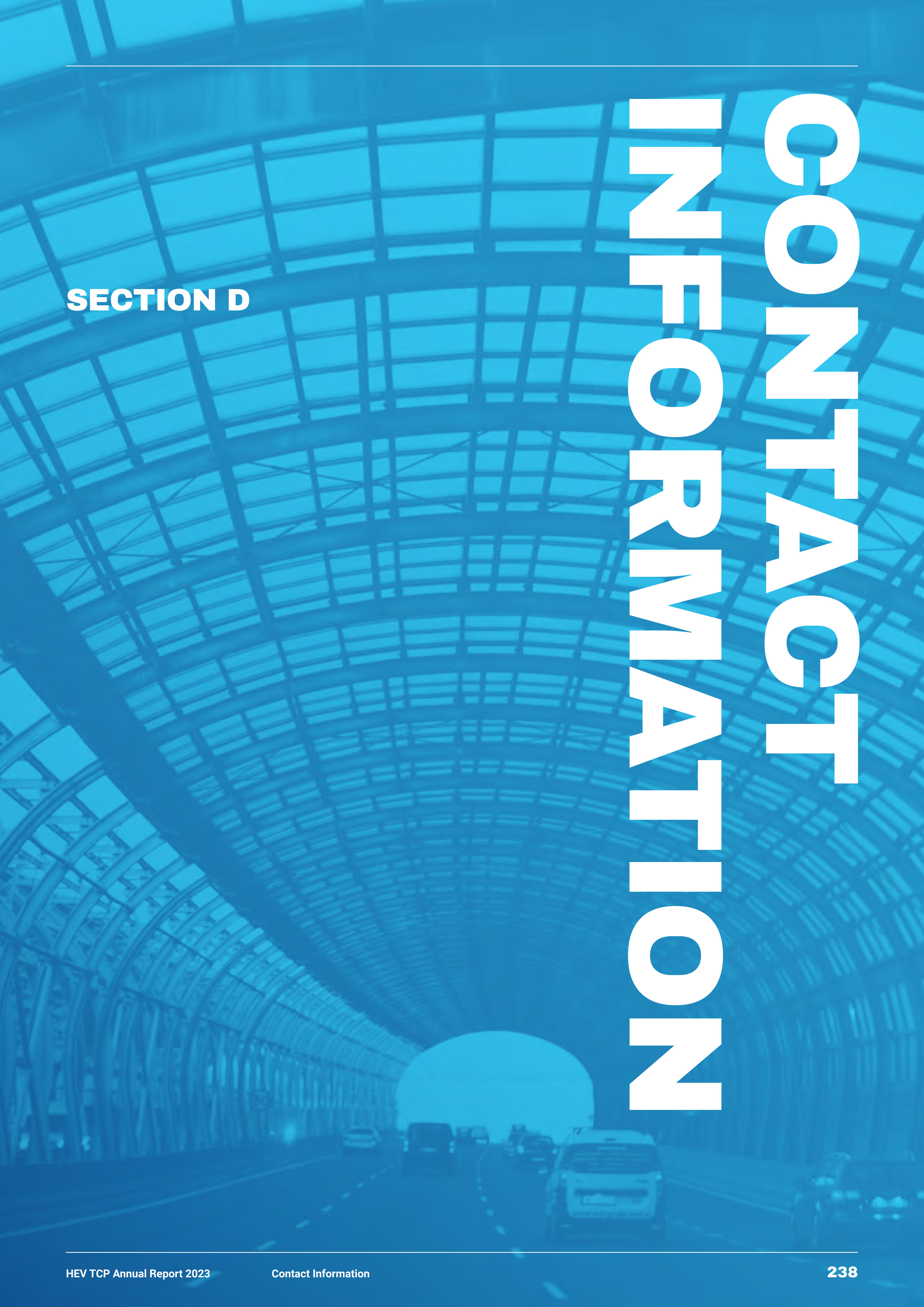

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