IEA INTERNATIONAL ENERGY AGENCY
HYBRID & ELECTRIC VEHICLE
TECHNOLOGY COLLABORATION PROGRAMME

HEV TCP

Hybrid and Electric Vehicles

The Electric Drive Hauls

2019

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International Energy Agency

Technology Collaboration Programme on
Hybrid and Electric Vehicles (HEV TCP)

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May 2019

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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.

The TCP on Hybrid and Electric Vehicles (HEV TCP) is organised under the auspices of the International Energy Agency (IEA) but is functionally and legally autonomous. Views, findings and publications of the HEV TCP do not necessarily represent the views or policies of the IEA Secretariat or its individual member countries.

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Cover Photo: Scania's El Camino truck developed for trials on three e-highway demonstration sites on public roads in Germany. The truck is equipped with pantograph power collectors, developed by Siemens and constructed to use e-highway infrastructure with electric power supplied from overhead lines.

(Image Courtesy: Scania)

The Electric Drive Hauls

Cover Designer: Anita Theel

International Energy Agency

Technology Collaboration Programme on
Hybrid and Electric Vehicles (HEV TCP)

Annual Report Prepared by the Executive Committee
and Task 1 over the Year 2018

Hybrid and Electric Vehicles

The Electric Drive Hauls

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1 Chairperson's Message

As the new 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 pleasure to introduce the 2019 Annual Report.

It's an interesting time for anyone associated with or interested in electric vehicles, both from an industry and consumer perspective. Around the world, sales of EVs are growing at an accelerated rate. For the first time, global electric vehicle (EV) annual sales exceeded the 2 million mark in 2018, bringing the global population of EVs to just over 5 million. Some of the contributing factors include an increasing selection of vehicle models and types, the introduction of more affordable EV models, a significant increase in the availability of charging infrastructure, and financial incentives for both EVs and chargers.

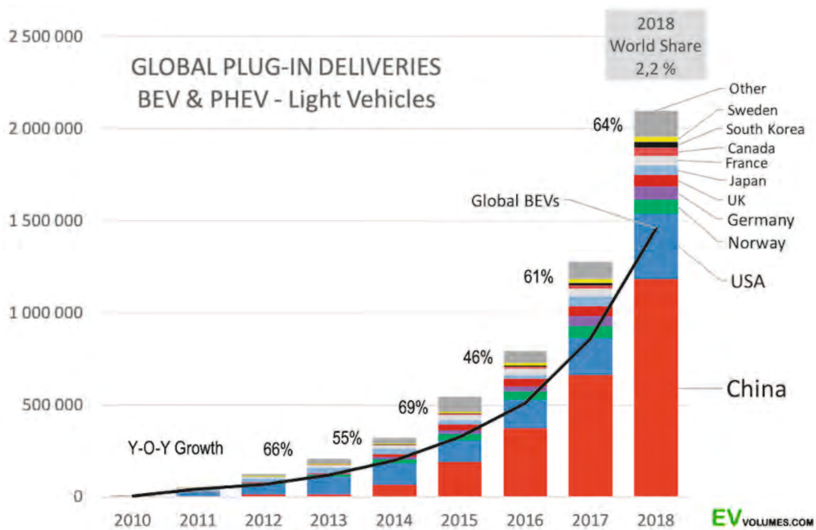

Figure 1: Schematic presentation of top-10 markets for plug-in vehicles which underlines the significance of China in the development of the sector (Source: EV volumes[1])

[1] http://www.ev-volumes.com/country/total-world-plug-in-vehicle-volumes/

Although EV sales continue to increase at a rate of approximately 60 % year-over-year, as shown in the figure above, there remain a number of technological challenges that require continued attention. Some of the key challenges include the cost of the EVs, which some say will reach price parity with conventional vehicles sometime in the mid-2020s, electric vehicle range, which will require breakthroughs in batteries to achieve desired energy density, and improved charging speeds without adversely affecting the batteries.

With current global EV forecasts and aspirational EV sales targets[2] , a great deal of attention is also being placed on the availability of critical raw materials for EVs and the readiness of the electricity grid to power these vehicles.

The HEV TCP, with a membership of 18 countries and 1 sponsor, collaborates on shared projects (Tasks) to better understand these and other challenges, and provide guidance to policy makers. The TCP currently manages a total of 18 Tasks. The following are the most recently initiated Tasks, some of which touch on the key challenges or areas of interest identified above:

- Task 39: Interoperability of e-Mobility Services
- Task 40: Critical Raw Materials for EVs
- Task 41: Electric Freight Vehicles
- Task 42: EV Cities Casebook (start in 2019)
- Task 43: Vehicle/Grid Integration (start in 2019)

Also in 2018, the TCP closed Task 31, for which the final report "Fuels and energy carriers for transport: Impact of different drivetrain options, fuels and vehicle use on GHG emissions of cars" is available for download on the HEV-TCP website at http://www.ieahev.org/.

The current five-year term of the HEV TCP will end in February 2020. In the summer of 2019, the TCP will submit a request for extension to the International Energy Agency for another five-year term. This will consist of an End-of-Term Report and a new Strategic Plan for the period 2020-2025.

The next Executive Committee (ExCo) Meeting will be held in Lyon, France, in May 2019, in conjunction with the EVS32, the 32nd International Electric Vehicle Symposium. At this meeting, we will formally welcome Norway as the newest member of the TCP, as of January 2019. Norway, is a recognized global leader in the adoption of EVs, and is a great addition to the TCP.

[2] IEA's Electric Vehicles Initiative (30 % EV sales by 2030); ZEV Alliance (100 % EV sales in 2050); individual countries (100 % EV sales by 2040)

Acknowledgements

As the new Chairperson for the HEV TCP, elected in October 2018, I would like to express my sincere gratitude to Professor Urs Muntwyler (Switzerland) for his dedication in serving as the Chairperson of the HEV TCP for the last 20 years.

I also wish to recognize the continued excellent support provided by Dr. James Miller (Argonne National Laboratory) as the HEV TCP Secretary, and the generous contribution from the US Department of Energy for financing the position of the Secretary. Two Deputy Chairs, David Howell (USA) and Ock Taeck Lim (South Korea) also support the HEV TCP ExCo. In addition to the ExCo, the management of the TCP includes the work of two sub-committees, the Strategic Planning Group and the Technical Committee, which count on the participation of various ExCo members. My appreciation goes out to the Operating Agents running the Tasks for their excellent leadership and hard work, as well as to the Task participants for their continued involvement.

As Chairperson, finally yet importantly, I wish to thank the member country delegates for their 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

2 The IEA and its Technology Collaboration Programme on Hybrid and Electric Vehicles

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

2.1 The International Energy Agency

2.1.1 Introduction

The IEA acts as energy policy advisor for the governments of its 29 member countries (see Table 1) and beyond to promote reliable, affordable, and clean energy for the world's consumers. IEA countries today account for just under half of the world's energy consumption. The IEA was founded during the oil crisis of 1973-74 with a mandate to coordinate measures in times of oil supply emergencies. This is still a core mission of the agency. In June 2011, the 28 IEA member countries participating at that time agreed to release 60 million barrels of oil in the following month in response to the ongoing disruption of oil supplies from Libya. This was the third time in its history that the IEA has been called upon to ensure an adequate supply of oil to the global market.

Table 1: IEA Member Countries

IEA Member Countries – 2018			
Australia	Finland	Luxembourg	Spain
Austria	France	Mexico	Sweden
Belgium	Germany	The Netherlands	Switzerland
Canada	Greece	New Zealand	Turkey
Czech Republic	Hungary	Norway	United Kingdom
Denmark	Ireland	Poland	United States
Estonia*	Italy	Portugal	
European Union**	Japan	Republic of Korea	

* Estonia joined IEA in 2014 as the 29th member
**The European Commission also participates in the work of the IEA

Since the 1980s, the IEA is engaged in establishing relationships with countries and international organisations beyond its membership. Particular interest of IEA lies in major energy consuming, producing and transit countries (including the accession candidates Chile and Mexico; the Association countries China, Indonesia and Thailand; and partner countries as Brazil, India, Russia, and South Africa). In this manner, the IEA puts lots of effort towards gathering all stakeholders – from policy makers to business leaders – with a truly international view of the world's energy system.

With the evolution of energy markets, the IEA mandate has also broadened. It now focuses on topics that are well beyond oil crisis management. The core agency objectives include improving energy efficiency, protecting the climate, enabling collaboration on energy technologies, and sharing its accumulated energy policy experience with the rest of the world. In 2013 alone, IEA held over three dozen workshops on wide-ranging topics, including energy storage technology, integration of carbon pricing with energy policies, and implications of climate change on the energy sector as well as opportunities for building resilience to its impacts.

The IEA plays an active role in discussions with producer countries and with the Organization of the Petroleum Exporting Countries (OPEC), particularly within the International Energy Forum (IEF). The IEA also supports energy-related work of the Group of 20 (G20), Group of Seven (G7), and Group of Eight (G8), as well as the Clean Energy Ministerial (CEM). Additionally, the IEA supports and contributes comprehensively to the energy agenda of the Asia Pacific Economic Cooperation (APEC) forum, and regularly advises in expert discussions at the Conference of Parties (COP) of the United Nations Framework Convention on Climate Change (UNFCCC).

Statistically, the IEA is a founding partner of the Joint Organisations Data Initiative (JODI), working alongside APEC, the Statistical Office of the European Communities (EUROSTAT), the Gas Exporting Countries Forum (GECF), the Latin American Energy Organization (OLADE), the United Nations Statistics Division (UNSD), OPEC and IEF. The IEA also works closely with the International Renewable Energy Agency (IRENA) to maintain a joint database of renewable energy policies and measures.

Regionally, the IEA also collaborates with multigovernmental organisations such as the Association of Southeast Asian Nations (ASEAN) and the African Union to promote energy co-operation among member states.

The shared goals of the IEA form the basis of balanced energy-policy making are:

- **Energy security:** Promote diversity, efficiency, and flexibility within the energy sectors of the IEA member countries. Remain prepared to respond collectively to energy emergencies. Expand international co-operation with all global players in the energy markets.
- **Environmental protection:** Enhance awareness of options for addressing the climate change challenge. Promote greenhouse gas emission abatement, through enhanced energy efficiency and the use of cleaner fossil fuels. Develop more environmentally acceptable energy options.
- **Economic growth:** Ensure the stable supply of energy to IEA member countries and promote free markets in order to foster economic growth.

2.1.2 Structure of the IEA

The IEA meets its evolving mandate through the activities of its offices and focused international collaboration. Fostering energy technology innovation is a central part of the IEA's work. Development and deployment of safer, cleaner, and more efficient technologies is imperative for energy security, environmental protection, and economic growth. IEA experience has shown that international collaboration on these activities avoids duplication of effort, cuts costs, and speeds progress.

The IEA Committee on Energy Research and Technology (CERT) coordinates and promotes the development, demonstration, and deployment of technologies to meet challenges in the energy sector. The CERT has established four expert bodies: (1) the Working Party on Fossil Fuels, (2) the Working Party on Renewable Energy Technologies, (3) the Working Party on Energy End-Use Technologies, and (4) the Fusion Power Coordinating Committee. In addition, expert groups have been established to advise industry and stakeholders on electric power technologies; research and development (R&D), in the context of priority setting and evaluation; and oil and gas (Figure 1).

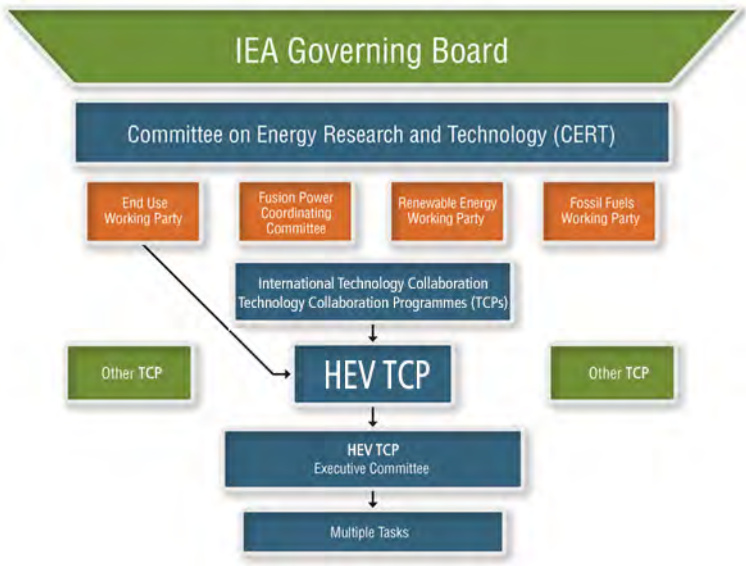

Figure 1: The IEA energy technology network[3]

2.1.3 IEA Technology Collaboration Programmes

The IEA also 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 work on it together. There are currently 40 TCPs covering fossil fuels, renewable energy, efficient energy use (in buildings, energy, and transport), fusion power, electric power technologies, and technology assessment methodologies. One of these TCPs is the Technology Collaboration Programme for co-operation on Hybrid and Electric Vehicle Technologies and Programmes (HEV TCP). HEV TCP reports to the Working Party on Energy End-Use Technologies (EUWP). An overview of the the activities and recent accomplishments of TCPs is available on the IEA web site[4].

IEA TCPs are at the core of the IEA's international energy technology network. This network embraces numerous other activities that enable policy makers and experts from IEA-member and non-member countries to share views and

[3] From 2015, the IEA is rebranding the IAs as Technology Collaboration Programmes - TCPs. Accordingly, IA-HEV was recently renamed to HEV TCP

[4] http://www.iea.org/publications/freepublications/publication/technology-collaboration-programmes.html

experience 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 lower cost. Such international co-operation helps to eliminate technological risks and duplication of effort while facilitating processes, like harmonization of standards. Special provisions are applied to protect intellectual property rights.

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

Participants in TCPs fall into two categories: Contracting Parties and Sponsors. This issue is defined in Article 3 of the framework:

- **Contracting Parties** may be governments of OECD member countries and OECD non-member countries (or entities nominated by them). They can also be international organisations in which governments of OECD member and/or OECD non-member countries participate, such as the European communities. 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 OECD 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.

Participation by Contracting Parties from OECD non-member countries or international organisations or by sponsors must be approved by the IEA CERT.

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. The benefits of international co-operation on energy technologies in TCPs are shown in Table 2.

Table 2: Benefits of International Energy Technology co-operation through IEA TCPs

Benefits of International Energy Technology Co-operation through IEA Technology Collaboration Programmes
• Shared costs and pooled technical resources
• Avoided duplication of effort and repetition of errors
• Harmonized technical standards
• An effective network of researchers
• Stronger national R&D capabilities
• Accelerated technology development and deployment
• Better dissemination of information
• Easier technical consensus
• Boosted trade and exports

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 carrying out their share of the work.
3. Combinations of cost and task sharing (such as in the case of the HEV TCP).

Effective dissemination of results and findings is an essential part of the mandate of each TCP. Wide-ranging products and results are communicated by various means to those who can use them in their daily work. The IEA Secretariat circulates the online OPEN Energy Technology Bulletin, which reports on activities of the TCPs. HEV TCP activities are regularly highlighted in the OPEN Bulletin. The IEA also issues the "Energy Technology Perspectives," or ETP, which is an annual publication that presents updates on roadmaps for the technologies addressed by TCPs. The ETP has been published since 2006 and, most recently, in May 2014. These reports can be downloaded for a fee at www.iea.org/etp.

In March 2008, the vice chairman for transport of the EUWP started a new initiative by organising a Transport Contact Group (TCG) workshop for the transport-related TCPs, with the objective of strengthening their collaboration. HEV TCP actively participates in the Transport Contact Group.

2.2 Technology Collaboration Programme on Hybrid and Electric Vehicles

Very few IEA countries do not have issues with urban air quality, and a few others are self-sufficient in oil, but all IEA countries have problems 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. A sound basis therefore exists for an IEA TCP dedicated to developing and deploying these vehicles.

The IEA Technology Collaboration Programme for co-operation on Hybrid and Electric Vehicle Technologies and Programmes (HEV TCP) was created in 1993 to collaborate on pre competitive research and to produce and disseminate information. HEV TCP is now in its fifth five-year term of operation that runs from March 2015 until March 2020. The 17 active Contracting Parties (member countries) as of May 2014 are Austria, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, The Netherlands, Republic of Korea, Spain, Sweden, Switzerland, Turkey, United Kingdom, and United States.

Compared to the automotive industry and certain research institutes, HEV TCP is relatively small, in the context of an 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 an Operating Agent (OA). (Before 2011, these task forces were called Annexes.) The work plan of a new Task is prepared by an interim Operating Agent (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 2015 and in early 2016 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 second, third and fourth terms of its operation (Phase 2, Phase 3 and Phase 4).

These are organized by task number. The strategy for the current term of operation, Phase 5 (2015-2020), and its details are reported in subsection 2.2.4.

2.2.1 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 considered suitable only for some market niches (such as neighborhood electric vehicles, small trucks for local deliveries, and two- or three-wheel vehicles). 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 in Phase 2 and their main achievements are described below:

- **Structured information exchange and collection of statistics (Task 1):** The format of today’s Task 1 was established, with a website divided into both public and members-only portions. The ExCo also decided that all participating countries in the HEV TCP should automatically be participants in Task 1 and established the financial arrangements to support this.
- **Hybrid vehicles (Task 7):** This task force published reports on questions pertaining to hybrid vehicles. Issues included their current costs and estimated future cost reductions; the environmental performance, fuel efficiency, and other advantages and disadvantages of the various types of hybrid vehicles; how hybrid vehicles could be most effectively introduced to the market; and questions on testing, licensing, and taxation. One of the most notable findings resulting from this task is that the decision of a customer to purchase a hybrid is based more on reduced fuel costs and projecting an environmentally responsible image rather than on the cost of the vehicle.
- **Deployment strategies for hybrid, electric, and alternative fuel vehicles (Task 8):** This Task considered 95 government programmes in 18 countries that were aimed at introducing (deploying) clean vehicles and fuels. The scope of work included both vehicles and fuels, and for this reason the task force was a joint effort between two IEA TCPs: HEV TCP and the Technology Collaboration Programme on Advanced Motor Fuels (TCP-AMF). The objectives of the task force were to analyze how governments can accelerate the deployment of advanced automotive technologies in the marketplace and to make recommendations that will enhance the

effectiveness of policies, regulations, and programmes. The final report made practical recommendations for future deployments, including how to apply lessons learned in previous deployments and among various countries, to avoid repeating mistakes.

- **Clean city vehicles (Task 9):** This Task arose because cities in many developing countries were growing very rapidly and experiencing the same or worse air quality and traffic problems as cities in IEA countries. At the same time, innovative solutions and technologies were being worked out in some of these developing countries, and there was much that IEA countries could learn from them. Planning was initiated for a task force, which became Task 9, to study the application of clean vehicle and fuel technologies in developing countries. In 2002, a joint workshop with IEA headquarters in Paris included representatives from Bangladesh, China, Colombia, Costa Rica, India, Indonesia, Kenya, Mexico, Nepal, Peru, and Thailand. As a direct result of the workshop, representatives from Bangladesh subsequently traveled to Bogotá to learn about the bus rapid transit system there, to construct a similar system in Dhaka.
- **Electrochemical systems (Task 10):** During Phase 2, this Task concentrated on the sharing of test methods for supercapacitors and batteries. Test procedures play a key role in moving new technologies from the laboratory to the market, and developing them involves a large amount of technical work that can easily cost more than a million dollars. Consequently, the sharing of test procedures can result in large savings. The Task also played a valuable role in coordinating the work of the fuel cell TCP, the hybrid vehicle Task, and itself in the field of electrochemical technologies.

2.2.2 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 objective general information on hybrid, electric, and fuel cell vehicles, with the same value-added aspects as described for Phase 2 in the previous section. 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. Topics addressed during the third phase are shown in Table 3.

Task 1 and Task 10 were the only Tasks remaining from Phase 2 during Phase 3, with the others having concluded operation during Phase 3 or before. Phase 3 also witnessed the introduction of new Tasks on electric cycles (Task 11), heavy-duty hybrid vehicles (Task 12), fuel cell vehicles (Task 13), lessons learned from market deployment of hybrid and electric vehicles (Task 14), and plug-in hybrid electric vehicles (Task 15). Many of the Tasks active in Phase 3 continued into Phase 4, while Tasks 11 through 13 had closed by the end of 2011.

HEV TCP's other achievements during Phase 3 include 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, in particular between the seven IAs containing transportation as an item in their work programme through the Transport Contact Group.

Table 3: Topics Addressed in the Third Phase of HEV TCP (2004-2009)

Topics Addressed in the Third Phase of HEV TCP (2004–2009)
• Information Exchange (Task 1) (The work includes country reports, census data, technical data, behavioral 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)

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

Interest in HEVs, PHEVs, and EVs as a means to reduce energy consumption and emissions from road transport is increasing significantly worldwide. At the same time, many questions remain still to be answered regarding such issues as 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.

For Phase 4 the ExCo has formulated the following strategic objectives:

1. To produce 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. This is done by such means as general studies, assessments, demonstrations, comparative evaluation of

various options of application, market studies, technology evaluations, and identification of industrial opportunities.

2. To disseminate the information produced to the IEA community, national governments, industries, and – as long as the information is not confidential – to other organizations that have an interest.
3. To collaborate on pre-competitive research projects and related topics and to investigate the need for further research in promising areas.
4. To collaborate with other transportation-related IEA TCPs (in Tasks or joint Tasks), and to collaborate with specific groups or committees with an interest in transportation, vehicles, and fuels.
5. To be a platform for reliable information on hybrid and electric vehicles.

Besides defined strategies for Phase 4, the HEV TCP ExCo has also identified topics to be addressed during that phase. In all, it has approved eight new projects (Tasks) since 2010, including two new ones in November 2013. These projects include the following:

- 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".

During Phase 4 many of the Tasks completed: Task 11 "Electric Vehicles", Task 12 "Heavy-duty Hybrid vehicles", Task 13 "Fuel Cell Vehicles", Task 14 "Market Deployment of Electric Vehicles", Task 15 "Plug-in Hybrid Electric Vehicles", and Task 16 "Alternatives for Buses". Nevertheless, many of the Task members are still involved in ongoing Tasks, for instance, members of the completed Task 14 are currently active in Task 18.

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

In November 2014, the IEA Committee on Energy Research and Technology (CERT) approved the fifth phase of operation for HEV TCP, which is scheduled to run from 1 March 2015 until 29 February 2020.

In the strategic plan for Phase 5, the participants in HEV TCP have formulated their expectations for the time frame 2015-2020. The first hybrid car – the Toyota Prius – has been introduced to the market at the end of the previous century. Today, hybrid electric vehicles have established a foothold in the market, and pure electric vehicles are becoming increasingly available. The market share of these vehicle technologies is still small and expected to increase in the coming five years. A number of developments in society play a role in how fast the market uptake will be. Decarbonisation of the global electricity mix is expected to continue by increasing the share of renewable energy, such as wind and solar power, resulting from climate policies in many countries. To bridge the time gap between renewable electricity production and electricity demand, smart grids with large numbers of battery electric vehicles plugged in may offer the electricity storage capacity that is required for large shares of renewable electricity. At the same time this will contribute to lowering the CO_2 emissions from road transport. Data history and long-term practical experience will become increasingly available and will play a key role for further hybrid and electric vehicle adoption. Incentives are expected to remain necessary for electric vehicle deployment during 2015–2020, and also policies aiming to build up a charging infrastructure will play a role. Regarding vehicle technology, battery R&D will continue to increase energy density and battery life, and at the same time reduce battery costs. Nevertheless, range anxiety may remain a concern for pure battery electric vehicles. Combining the electric drive with an internal combustion engine in plug-in hybrid electric vehicles (PHEVs) and in extended range electric vehicles (EREVs) may eliminate range anxiety. The price of hybrid and electric vehicles (H&EVs) is coming down, so the difference in purchase price to conventional vehicles is diminishing, which is advantageous for H&EV deployment. However, the oil price halved in the second half of 2014 and remained more or less on that level through the whole of 2015, which counteracts hybrid and electric vehicle deployment. Consumers become increasingly aware of the impact of CO_2 on the environment and have started to appreciate the advantages of the electric drive. Still, vehicle costs will remain an important factor in vehicle purchase decisions. High vehicle prices and lacking charging infrastructure are expected to remain the major hurdles for increased electric vehicle deployment in the coming five years.

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 in 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 to supply this target audience with objective information to support decision making, to function as a facilitator for international collaboration in pre-competitive research and demonstration projects, to foster international exchange of information and experiences, and sometimes to function as a promoter for Research, Development, Demonstration and Deployment (RDD&D) projects and programmes.

Against this background and to fulfil its mission, the HEV TCP Executive Committee has formulated the following strategic objectives for Phase 5 (2015-2020):

1. To produce and disseminate 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. This is done by means of general studies, assessments, demonstrations, comparative evaluations of various options of application, market studies, technology evaluations, highlighting industrial opportunities, and so forth.
2. To be a platform for reliable information on hybrid and electric vehicles.
3. To collaborate on pre-competitive research projects and related topics and to investigate the need for further research in promising areas.
4. To collaborate with other transportation related IEA Technology Collaboration Programmes, and to collaborate with specific groups or committees with an interest in transportation, vehicles and fuels.

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 fifth phase. Tasks that were active at the end of Phase 4 and that will continue in Phase 5 are shown in Table 4.

Table 4: HEV TCP Tasks that were active in December 2014 and that are scheduled to continue into Phase 5

HEV TCP Tasks that were active in December 2014 and that are scheduled to continue 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

In addition to the active Tasks, new topics will emerge in the coming five years.

The HEV TCP participants have listed possible topics for Phase 5 (2015-2020) and grouped these in three categories: technology evolution/progress (see Table 5), technology deployment/market facilitation (see Table 6), and environmental protection (see Table 7). Additional topics will certainly emerge, and depending on priorities and resources that can be made available, the HEV TCP ExCo will decide which topics will actually be addressed in Phase 5.

In 2018, the ExCo approved the start of three new Tasks:

- Task 41 “Electric Freight Vehicles”, and
- Task 42 “Scaling Up EV Markets and EV City Casebook” (start in 2019)
- Task 43 “Vehicle/Grid Integration (start in 2019)

Besides, in 2018 the Task 39 “Interoperability of E-mobility Services” and Task 40 “Critical Raw Material for Electric Vehicles (CRM4EV)” started to operate. Task 31 “Fuels and Energy Carriers for Transport” completed its work in 2018.

To pool resources and to increase the impact of its work, HEV TCP will aim to increase collaboration with other IEA Technology Collaboration Programmes such as TCP-AMF (Advanced Motor Fuels), TCP-AFC (Advanced Fuel Cells), TCP-PVPS (Photo-Voltaic Power Systems) and the co-operative programme on smart grids (TCP-ISGAN). HEV TCP will also aim to reinforce collaboration with organisations outside the IEA such as ACEA (European Automobile Manufacturers Association), AVERE (European Association for Battery, Hybrid and Fuel Cell Electric Vehicles), ICCT (International Council on Clean Transportation), and IRENA (International Renewable Energy Agency).

Table 5: Technology evolution/progress

Technology Evolution / Progress
• Effects of extreme conditions (temperature, highway grades, highway speed capability) on design of EVs • Optimal PHEV electric power for different kinds of use (urban, regional, or highway driving)

The HEV TCP is an international platform with a global view. It is a network for the exchange of knowledge and experience that provides access to experts in other countries. The collaboration of people from governmental bodies, research institutes and the private sector makes HEV TCP unique. Participants in the Agreement get the different views on the subject in all domains related to hybrid and electric vehicle deployment. Having the complete picture contributes to effective progress in HEV TCP member countries. Other countries are invited to join the Agreement and share the benefits of HEV TCP membership.

Table 6: Technology deployment/market facilitation

Technology Deployment / Market Facilitation
• Light electric vehicle parking and charging infrastructure (Task 23)
• Plug-in Electric Vehicles (Task 25)
• Wireless power transfer for electric vehicles (Task 26)
• Home grids and V2X technologies (Task 28)
• Electric and automated vehicles (Task 29)
• Total costs of ownership
• 2nd use of batteries
• Market development, strategies, incentives
• Behavior, awareness and education of customers
• Training and education of sales and vehicle maintenance staff
• Standards
• Interoperability
• Changes in society - own or use cars?
• Changes in society - attitudes of young people
• Changes in society - public transport and EVs
• Financing - next phase of vehicle deployment, without subsidies?
• Financing - changes in tax revenues for governments
• Assessment of infrastructure needs
• Smart regulations

Table 7: Environmental protection

Environmental Protection
• Renewable energies
• Smart grids
• Life Cycle Analysis
• Battery recycling
• City planning and EVs

2.3 IEA Engagement in other Activities Related with Electric Vehicles: the Electric Vehicle Initiative

The Electric Vehicle Initiative (EVI, http://www.cleanenergyministerial.org/initiative-clean-energy-ministerial/electric-vehicles-initiative and https://www.iea.org/topics/transport/evi/) 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 early 2019, governments currently active in the EVI include Canada, Chile, the People's Republic of China ("China"), Finland, France, Germany, India, Japan, Mexico, Netherlands, New Zealand, Norway, Portugal, Sweden, United Kingdom, and 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 campaign is currently supported by 11 EVI member countries (Canada, China, Finland, France, India, Japan, Mexico, the Netherlands, Norway, Sweden, and the United Kingdom), several partners from the research/NGO community and the seven major private sector companies (ChargePoint, Enel X, E.On, Fortum, Iberdrola, the Renault-Nissan-Mitsubishi Alliance, and Vattenfall).

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 Global EV Pilot City Programme, a global co-operative programme that aims to facilitate the exchange of experiences and the replication of best practices for the promotion of EVs in cities (https://www.iea.org/topics/transport/evi/pcp/). As of early 2019, the programme represents 36 cities.

To date, the EVI has developed analytical outputs that include the Global EV Outlook series with annual editions since 2015, the Nordic EV Outlook 2018 and two editions of the EV City Casebook, with a focus on initiatives taking place at a local level. 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.

For the development of EVI activities, the IEA secretariat co-operates 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.

3 Information Exchange (Task 1)

Members: Any HEV TCP member may participate

3.1 Introduction

Information exchange is at the core of HEV TCP's work (formerly IA-HEV), enabling members to share key policy insights and best deployment practices, as well as to identify common research interests in the rapidly growing international hybrid and electric vehicle field. Task 1 began in the first phase of HEV TCP in 1993 and continues as the main forum and portal for announcing news and results to the broader International Energy Agency (IEA) community.

The HEV TCP strategic plan for phase 5 (2015-2020) mentions that "a communication strategy will be established, to ensure that the different kinds of information that are generated by the Agreement reach their specific target public, and to increase the visibility of the Agreement and the results of its work. All possible communication tools will be considered to this end." Table 1 lists all phase 5 objectives, which include communication.

Table 1: Listing the Task 1 "new phase" objectives

HEV TCP Phase 5 Objectives (2015–2020)
• Produce objective information for policy and decision makers • Disseminate information produced by HEV TCP to the IEA community, national governments, industries, and other organizations • Collaborate on pre-competitive research • Collaborate with other IEA Technology Collaboration Programmes and groups outside the IEA • Provide a platform for reliable information

3.2 Objectives

Task 1 serves as a platform for information exchange among member countries. The objectives are to collect, analyze, and disseminate information on hybrid, electric, and fuel cell vehicles and related activities. This information comes from both member countries and nonmember countries.

Information exchange focuses on these topics:

- Research and technology development;
- Commercialization, marketing, sales, and procurement;
- Regulation, standards, and policies;
- Awareness raising measures, and
- Activities of HEV TCP Tasks.

3.3 Working Method

Experts from member countries serve as delegates at Task 1 meetings held every six months in conjunction with the HEV TCP Executive Committee meetings. Country delegates also write country-specific information for HEV TCP publications, such as the country chapters in this annual report. Many country delegates also serve dual roles as the official Operating Agent for a specific Task. In this role, they may also represent HEV TCP to a public audience by presenting Task results at international conferences, such as the EVS (Electric Vehicle Symposium) meetings.

The Task 1 Operating Agent (OA) is responsible for coordinating and leading the semi-annual experts' meetings, compiling the minutes of these meetings, maintaining the HEV TCP website (Figure 1), and editing and supervising the production of the newsletter and the Executive Committee (ExCo) annual report. The OA also acts as liaison to the other Task OAs, the ExCo Chair (together with the Secretary-General), and the IEA Desk Officer. Since the end of 2014, the responsibility for Task 1 has been transferred to Gereon Meyer of VDI/VDE Innovation + Technik GmbH (Germany) as the OA.

A significant component of the information exchange for the Task occurs at the experts' meetings, where participants brief the attendees on relevant reports, facts, and statistics pertaining to hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), and electric vehicles (EVs) in their home countries. These presentations generally cover current developments on the market situations for EVs and HEVs (national sales and fleet penetration, by vehicle type); the progress of international, national, or local programs and incentives in the field; and new initiatives in vehicle and component development arising from both the private sector and public-private partnerships.

Any member country of the HEV TCP can automatically participate in Task 1. There is no cost for Task membership. Each country designates an agency or non-governmental organization as its Task 1 expert delegate. Frequently, guest experts are invited to participate in Task 1 meetings to present their activities and to exchange experiences with HEV TCP participants. This is a valuable source for keeping up to date with worldwide developments.

3.4 Results

Notable events in 2018 included the following:

- Task 1 Information Exchange meetings were held in Dublin, Ireland, in April 2018, and in Burgdorf, Switzerland, in October 2018.
- The HEV TCP Annual Report on 2017 entitled Hybrid and Electric Vehicles – The Electric Drive Automates was published in 2018. Postcards with the cover page and the download link for the report were provided to all participants of the EVS-31 Conference in Kobe (Japan), in October 2018.

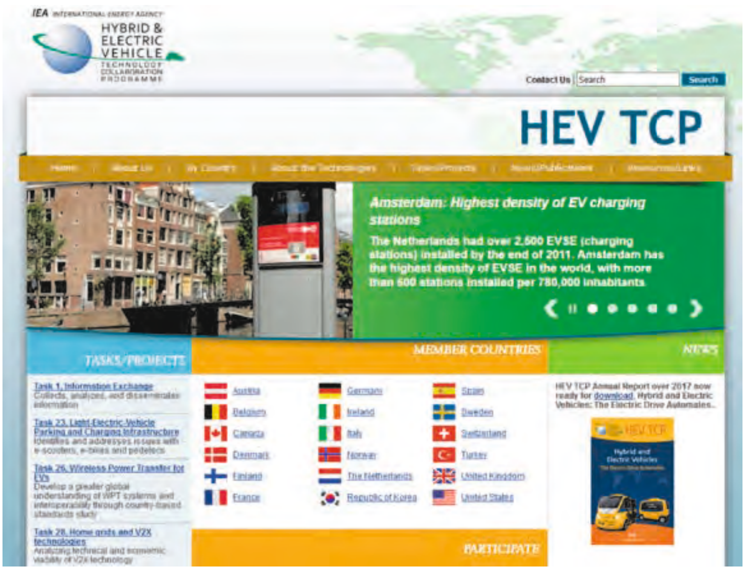

Figure 1: Home page of the HEV TCP website (www.ieahev.org), which includes comprehensive information on hybrid and electric vehicles in all member countries, updates on activities of the Tasks, and links to national organizations working to promote vehicle electrification

3.5 Next Steps

Access to proprietary data and other “late-breaking” information will continue to be limited to participating members as an incentive to non-member countries to join. Items from both member and non-member nations may be posted.

The Task 1 expert meeting schedule will coordinate with the future ExCo meeting schedule. The basic plan of the meeting is for country experts to report on the latest developments in hybrid and electric vehicles in their respective countries by using a thirty-minute time slot that includes both a presentation and follow-up discussion. Because of the growth in the number of members, the focus at each meeting is on fostering in-depth discussion of critical new developments in a subset of countries. Generally, each member country participates at least once per year.

The Task 1 OA welcomes suggestions for meetings, website, and newsletter topics from members.

3.6 Contact Details of the Operating Agent

For further information, please contact the Task 1 OA:

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4 Light-Electric-Vehicle Parking & Charging Infrastructure (Task 23)

Members: Belgium, Germany, Spain, Turkey

4.1 Introduction

The rapid growth in recent years in the usage of light electric vehicles (LEVs) including electric scooters (“e-scooters”), electric bikes (“e-bikes”), and especially the hybrid pedal/electric bike called the pedelec, as well as sharing bikes (electric and non-electric) requires addressing issues related to parking and charging infrastructure.

Figure 1: The Bicycle Sharing Fleet, which has reached probably close to 25 Million units globally in 2019, is turning electric. The market leaders from China like Meituan and OFO as well as US and European companies rush into this area. Electric rental cargobikes, small and big electric scooters as well cabin scooters like the new Seat MINIMO designed as sharing vehicles offering many mobility choices closing the gap between walking and public transport or car usage. By 2019, the global fleet of LEVs in sharing services will probably reach 5+ Million units worldwide and growing fast. (Source: Hannes Neupert – bike and pedelec sharing offered in front of Berlin Main station)

This includes the development of harmonized charging standards which are embedded in a public parking space management solution. Task 23 seeks to ensure that these issues are addressed at a governmental level, so that the outcome is as applicable as possible to both local and global policies. Task 23 will also encourage the development and establishment of both bicycle, e-scooter, pedelec sharing schemes and private usage (parking and charging) of such vehicles.

Figure 2: The Seat concept micro car with manual swappable batteries which MINIMO designed to be used in dockless sharing systems (Source: Seat)

4.2 Objectives

Representing the Interests of Local Governments in Standardization

Following the IEC TC69-WG10 61851-3-1/7 Series, the standardization group on Light Electric Vehicle standardization (system architecture, infrastructure, communication and standard batteries), the IEC SC23h is defining the connectors used for the future parking and charging infrastructure.

Since May 2016, Task 23 is active in the ISO 4210-10 which is defining the Pedelec internationally within a harmonized standardization body for the first time. Here the key activity is to ensure that there are no indifferences within the technical infrastructure defined by the IEC and that the standard would be an acceptable basis for international GTRs (Governmental Technical Regulations) defining that pedelecs may still be considered equal to a bicycle.

In 2016, the EN 50604-1 was published as the first Battery Safety standard by the European standardization body CENELEC and is setting the lead globally followed by the ISO 18243, also referencing to the IEC SC23h defined interface connector and the IEC TC69-WG10 defined communication protocol. This means that when the EN 50604-1 will be published within the Machinery directive and/or the Battery Directive of the European Union it will not only define the technical state of the art, it will become mandatory by law, enabling easy infrastructure interconnection down the road.

A key objective of Task 23 is to discuss the specific requirements from the governmental side (especially at the local level) LEV charging and parking infrastructure, and deliver these requirements to the IEC TC69-WG10 committee. This is to be done by the operating agent EnergyBus.org, which is also leading the German mirror group of the IEC TC69-WG10 61851-3-1/7 Series committee.

Figure 3: Many fatalities caused by LEV battery fires have led to a rigorous policy in China banning charging of lithium batteries inside buildings if strict requirements are not met. New regulations created a huge demand in public charging solutions for all kinds of LEVs in China The local governments do invest heavily into education programs which target the 300 million plus users of LEVs in China to become aware of the potential fire hazards of charging LEVs (Source: China Police)

4.2.1 Target a Blueprint for Public Tenders for LEV Infrastructure

After the complete publication of the IEC TS 61851-3-1/7 (unfortunately due to activities led by Japanese Experts delayed again to potentially late 2019) as TS (Technical Specification) of the IEC, the next step will be to create a blueprint for public tenders, which references to standard sets for the acquisition of public infrastructure, for parking, space management of LEVs and sharing bicycles two-wheelers, and for charging infrastructure. Such tenders would also include a section on the requirements and specifications of bicycles, pedelecs and electric scooters for public use. The need especially for the management of non-moving traffic just became totally obvious in China due to the extreme popular sharing bikes which literally flooded the city sidewalks and streets in a way that they became a serious hurdle creating traffic blocks and urging local governments to regulate this effectively. Here the Charge and Lock Cable system is perfectly suited to free dense urban areas from uncontrolled flooding with sharing as well as private vehicles. Japan has the longest history in parking management of bicycles and other mobility devices since the extreme dense space usage in Japan has forced governments to deploy strict regulations early.

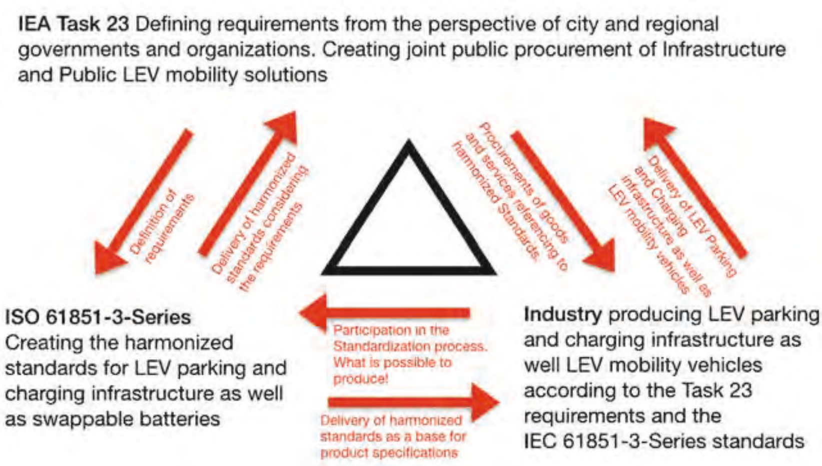

Figure 4: Environment and correlations of Task 23 activities and the interaction between Task 23, the standardization/governmental regulation and industry supply

Figure 5: The IEC standardized socket which will be used around the world by all kinds of privately owned as well as by shared LEVs and bicycles to park them in accordance to public interests regulated by non-moving traffic management regulations (Source: EnergyBus)

4.2.2 Creating Events for Information Exchange on LEV Infrastructure

Task 23 has been organizing events such as expert workshops and conferences, on the subject of LEV infrastructure as well as suitable vehicles, involving governments, city planners, public transportation experts, operating companies, consumer organizations, standardization bodies as well as the vehicle and infrastructure industries. Activities have been organized until now at: Taipei (TW), Tianjin (CN), Cologne (DE), Kirchberg (AT), Antwerp (BE), Malbrok (PL), Istambul (TK), Oslo (NO), Essen (DE), Tanna (DE), Grenoble (FR), Nante (FR), Frankfurt (DE), Prague (CZ), Taipei (TW) Shanghai (CN), Chengdu (CN), Rostock (DE), Osaka (JP) Beijing, Shenzen, Tianjin (CN) Zürich (CH) just to name some of them.

4.2.3 Best Practice Sharing Study Trips

Gathering experts at locations where local governments have established successful LEV infrastructure systems and sharing findings and summarizing the positive and negative experiences – distilling the findings into easy-to-follow recommendations was in Task 23 scope of work. In March 2015, an international group traveled around China for eight days. In June 2015, an international group traveled in Europe (DE, SE, & DK). In 2016, an international group of journalists and opinion leaders traveled to see key Chinese industry and city environments. In Spring 2017, a Chinese government and industry delegation traveled to Europe for the ISO 4210-10 meeting (PT) and traveled to France, Netherlands, Germany, and Austria for best practice sharing visits. In 2018, an internationalization of the participation in the ISO 4210-10 work was promoted by bringing members of the following countries on board: CH, NO, CZ, BE, which participated in meetings in Japan, the US, and France.

4.2.4 Publications with Recommendations on LEV Infrastructure

Creating publications summarizing key findings and listing recommendations on how to establish the most suitable LEV infrastructure. Several lectures have been held about Task 23 activities between 2017 and today.

4.2.5 Promoting the Needs to Potential Suppliers

Task 23 was making joint presentations at relevant trade shows and conferences, and explaining the use of suitable methods, the requirements for local governments, potential manufacturers and providers of LEV infrastructure and rental vehicles. Within 2017 and 2018, such presentations have been on B2B and B2C Tradeshows in DE, UK, PL, CZ, TW and CN.

Figure 6: EU Commissioner of Transport Mrs. Violeta Bulc visits the IEA Task 23 presentation at Frankfurt International Automobile Exhibition on 17 September 2015 (Source: IAA)

4.3 Working Method

Members of Task 23 can participate in events such as best practice sharing study trips, exhibitions and conferences. They may also host their own local events about Task 23, and invite international experts to share their insights. They may create tenders and joint tenders with other cities or regions for LEV infrastructure. They may create supplier lists, and share experiences with suppliers and their products, with other local governments and operators interested in acquiring similar components.

4.3.1 Task 23 Members and Potential Members

It started with Antwerp (Belgium) and Barcelona (Spain), followed by Istanbul (Turkey), and talks about active involvement in Task 23 have subsequently been conducted with various local governments and stakeholders from around the world. To name just a few: Malta, the DIFU Institute representing most German cities, and the Green City AG Munich, Karlskrona and Växjö (Sweden), Hangzhou, Chengdu, Deyang (China), Taichung City (Taiwan), Kyoto and Osaka City (Japan), Copenhagen (Denmark), Warsaw (Poland), Graz & Bregenz (Austria), Indonesia, Delhi (India), Munich, Frankfurt, Cologne, Münster, Rostock, Hannover, Berlin, Merseburg, Tegernsee (Germany), Grenoble (France) – and these are just the most significant talks. To date, the active phase including the preparation of the blueprints for tenders to acquire LEV infrastructure has not yet started. It is expected to happen during 2019.

4.4 Results

A central event for Task 23 in 2015 was the joint booth within the framework of the G7 Traffic minister meeting held in conjunction to the Frankfurt Auto show IAA on 17 September 2015. There EU Commissioner for Transport Mrs. Violeta Bulc visited the IEA HEV TCP Task 23 special exhibition presented at IAA with a wide display. Mrs. Bulc was introduced to the results of the EU Mandate 468 of 2010.

The publication of the EN 50604-1 in 2016 was a major milestone and the finalization of the Connector Standard by the IEC SC23h group in 2017 too. By 2018, the long-postponed finalization of the IEC Technical Specifications on the Standard Series IEC TS 61851-3-1/2/3/4/5/6 and 7 defining all communication necessary as well as safety relevant procedures was finalized. Standards secure safe and interoperable technical ecosystems.

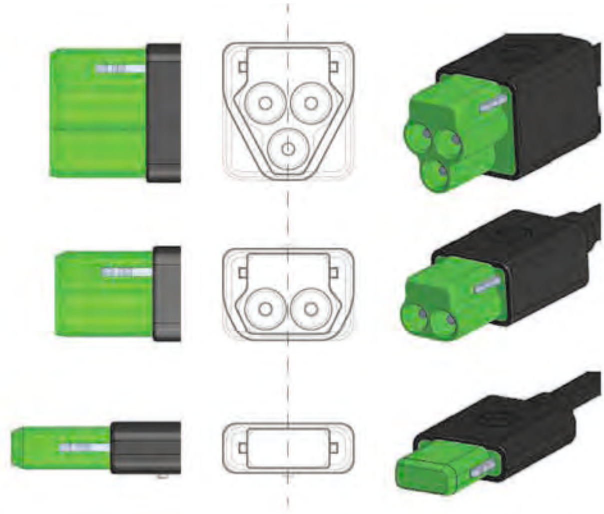

Figure 7: The three versions of the IEC connectors for public charging of LEVs all fitting into the same sockets to be installed in public and semi-public locations. The 3-pin connector version is meant for larger motor scooters or LEVs – this connector can handle up to 7.2 kw charge current at voltages up to 120 V DC. The 2-pin connector will be probably the most popular with power limited to 3,6 kw charge current and a maximum voltage of 60 V DC. The 0-pin connector could be used for non electric cycles which do use bicycle parking facilities (Source: Atelier Papenfuss)

4.4.1 The Charge & Lock Solution for Many Urban Issues

The Copenhagen Gobike pedelec share system is station-based, but can also offer free-floating service, and it should not have had to pay back the investment in establishing the infrastructure alone. Between the years 2011 and 2013, the first functional version of the EnergyLock was trialed in the Tegernsee region, Germany. The idea was proven to work. But a clear finding was that the locking system, based around a heavy duty locking mechanism and steel-reinforced cable, was considered as too heavy by users. This necessitated a complete reconsideration of the anti-theft concept. As a result, the mechanical safety layer was downgraded to a mild level, whereby the locking action is just good enough not to be unlocked easily by manual force, but it will pop open before it is damaged when pulled strongly. The anti-theft function is moved to the digital realm, in that all electronic components on the pedelec will deactivate themselves in the event of unauthorized disconnection. This would make removing a vehicle fully implementing this safety strategy very unattractive for a thief. On 18 March 2015, the next generation of the charge & lock cable was presented to the public for the first time as a working model at the Taipei Cycle Show 2015. It was received enthusiastically. It is based on discussions held within the IEC/ISO joint project team on LEV infrastructure in

November 2014 in Taiwan and Japan, as well as in Germany in December 2014. It has changed on the electrical side, too: instead of six conductor contacts it now has just two or three. CanOpen communication, as well as transfer of the 12V auxiliary voltage, is transferred to an induction-based system which is not sensitive to corrosion. The female socket would always be of a universal shape. But the male plug attached to the vehicle would be available in three different versions, catering appropriately to the specific needs of all three types of two-wheelers. This would allow a single infrastructure to cater for all types of two-wheelers: the system can be used both to manage the use of public space for two-wheeler parking, and to provide free two-wheeler electrical charging.

4.5 Next Steps

Task 23 would like to do further acquisition of members, cities, and regional governments to create as large a public tender base as possible for the procurement, with high purchasing and negotiating power, of LEV infrastructure and LEV rental fleet solutions. Beside the focus on standardization 2019, Task 23 will be mainly focused on pilot applications in China at the City of Deyang in the Sichuan province.

A political activity, started in July 2018, is the petition trying to initiate a change of the UN vehicle definition which was defined 50 years ago in Vienna. The target is to redefine the cycle to safely include the electric assisted cycle as well as new kinds of micro mobility. The proposed definition is based on the IEA HEV TCP Task 11 results presented in 2012.

Link to the petition is accessible via: https://www.openpetition.de/petition/online/pedelecs-e-bikes-sollen-dem-fahrrad-gleichgestellt-werden.

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5 Plug-in Electric Vehicles (Task 25)

Members: France, Germany, Republic of Korea, United States

5.1 Introduction

The cost competitiveness of different drivetrains depends on relative costs of vehicles, fuel, and other cost components. The tasks considers costs from the perspective of a consumer with sufficient foresight to consider relevant costs over the ownership period of the vehicle, or relevant cost of ownership (RCO), as suggested by Mock [1] and used by Redelbach et al. [2] and Rousseau et al. [3]. We examine how the RCO of PEVs compares to competing powertrains under various combinations of fuel consumption, annual driving distance, battery costs, and other factors that can vary significantly between different drivers in different countries. We examine ranges of these factors relevant to drivers in the United States and Germany using estimated future costs of vehicles and fuels.

To the extent that consumers choose vehicles on the basis of ownership costs, how fuel consumption is measured and reported are important. European and U. S. regulators have made or proposed updated fuel economy certification procedures to provide fuel economy estimates that are more representative of real world driving [4, 5]. Fuel economy values reported by U. S. drivers vary over a wide range [6]. Of potentially greater significance to the consumer considering a PEV purchase are vehicle prices and energy costs over the vehicle ownership period. PEV prices are driven by component costs, in particular the cost of the battery pack, but energy costs depend on fuel price and annual driving distance. For plug-in hybrid electric vehicles (PHEVs) and extended range electric vehicles (EREVs), fuel costs also depend on the utility factor (UF) - the fraction of distance driven in charge-depleting (CD) mode - which can differ widely between drivers owing to different charging frequencies and driving distances.

5.2 Objectives

The topics of the task include vehicle energy consumption, component costs, vehicle costs, total cost of ownership (TCO), and market penetration.

Objectives associated with vehicle energy consumption are:

- Compare full-function HEVs, PHEVs, and ER-EVs to advance conventional powertrains (clean diesel, turbocharged direct injection petrol, CNG, other).
- Include a wide range of powertrain configurations (i.e. BEV with and without multi-gear transmissions, BEVx…).
- Evaluate the technology potential on both standard and real world driving cycles.

Objectives associated with Component Cost, Vehicle Cost and TCO are:

- Conduct a systematic cost methodology comparison (i.e. battery, multiple TCO models).
- Examine whether a standard peak battery pack and electrical machine power level for both HEVs and PHEVs can be cost effective in spreading component costs across both HEV and PHEV platforms.
- Study powertrain depreciation attributes and impact on vehicle lifetime use costs. In particular, determine whether batteries must be replaced during vehicle lifetime, or vehicle use patterns must be adapted to less capable packs or both.

Objectives associated with Market Penetration are:

- Conduct a systematic market penetration methodology comparison using the same set of inputs.
- Using consistent methodologies, evaluate potential causes of increase in market(s) size, such as rising oil prices, lower battery pack costs, economical infrastructure adaption, changes of consumer perception.
- Evaluate policy alternatives to increase market(s) size.
- Taxes at initial purchase, annual fees, fuel/electricity tax.
- Subsidy structures and quantities.

5.3 Working Method

Vehicle Attributes

To evaluate the fuel efficiency benefits of advanced vehicles, each vehicle was simulated using Autonomie [7]. Each vehicle component powertrain is sized to meet similar vehicle technical specifications such as performance and grade-ability [8]. The energy efficiency was then estimated for the different vehicles over the Worldwide harmonized Light vehicles Test Cycle (WLTC) and the U. S. combined cycle. Conventional and plug-in midsize vehicles were simulated through six different timeframes (2020–2050) for gasoline and diesel fuels. The attributes of future vehicles were taken from Moawad et al. [8]. We focused on four different powertrains (conventional; split PHEV [PHEV20]; EREV [PHEV40]; and Battery Electric Vehicles [BEV100, BEV200 and BEV300]). The split PHEV was modelled with one electric motor and a power-split design, and the EREV was modelled with two electric motors and a powertrain similar to the Voltec design [21].

We assumed technology advancement based on the U. S. Department of Energy (DOE) Vehicle Technology Office research and development goals. Further details on the simulations can be found in Moawad et al. [8].

The above vehicles were simulated in Autonomie under the Worldwide harmonized Light vehicles Test Procedure (WLTP), U. S. Urban Dynamometer Driving Schedule (UDDS), and U. S. Highway Fuel Economy test (HWFET) drive cycles, using the same road load coefficients for all cycles. Adjustments were applied to the UDDS and HWEFT drive cycle fuel consumption values in accordance with the U. S. current fuel economy label procedures [4].

To estimate the UF (the fraction of distance driven in CD mode), the daily driving distance was assumed to follow a gamma distribution, which was found to fit detailed driving records from Seattle by Lin et al. [17]. A mean of 61.8 km/day and a mode of 20.6 km/day was assumed for U. S. drivers, based on an analysis of the U. S. 2009 National Household Travel Survey by Krumm [9]. This distribution gave a dependence of UF on the PHEV CD range that approximated the CD range dependence used in the standard practice recommended by SAE International for PHEVs that are charged once per day [10]. This distribution may not be accurate for other populations [11], but it captures the qualitative shape of realistic driving distributions and provides a convenient way to approximate how PHEV UF depends on daily average driving distance [12]. The mean distance was varied to account for different annual driving distances, and the mode was assumed to vary in proportion to the mean. A constant value of 300 driving days per year was assumed. PHEV drivers were assumed to charge once per day.

We estimated the ownership costs under different assumptions to represent U. S. and German consumers. Combinations of the following parameters were evaluated that make PEVs cost-competitive with competing (conventionally powered) vehicles:

- The fuel and electricity consumption as estimated by WLTP and U. S. adjusted drive cycles;
- The future vehicle prices, estimated for year 2025;
- A range of potential future battery cost estimates;

- The fuel prices (reflecting ranges of possible prices in the U. S. and Germany);
- The annual driving distance (ranges representative of U. S. and German drivers).

Cost Calculations

The vehicle costs are calculated from the characteristics of the components (power, energy, weight, etc.) [8]. Both the vehicle and fuel cost, based on the energy efficiency values, are then used to calculate ownership cost. Maintenance costs for year 2025 were assumed to be 0.05 USD_{2015}/km for all powertrain types. This value was in the middle of the range suggested by Rousseau et al. [3].

The assumptions shown in Table 1 are used to represent the near-term (year 2025) average prices of energy in Europe (Germany) and the United States and were assumed to be constant in future years. Constant electricity prices were assumed, neglecting alternative rate structures such as time-of-use, tiered rates, or special rates for PEVs.

Energy prices and average annual distance driven in the United States were based on the U.S. Energy Information Agency's Annual Energy Outlook (AEO) for 2017 reference case. Energy prices for Germany were estimated for the year 2025 based on the projected price of crude oil (Brent Spot price of 85.03 USD_{2015}/barrel). High and low energy prices were based on AEO 2017 High Oil Price and Low Oil Price cases. Annual distance driven in new light duty vehicles (LDVs) by U. S. drivers were taken from AEO 2016 reference case. The mileage for German drivers is taken from the latest national transport survey [20].

Table 1: Energy cost assumptions for 2025

Zone	Distance travelled (km/year)	Annual discount rate (%)	Vehicle life (years)	Gasoline price (USD_{2015}/liter)	Diesel price (USD_{2015}/liter)	Electricity price (USD_{2015}/kWh)
Germany	14,000	5	12	1.522	1.482	0.397
United States	22,530	5	12	0.677	0.727	0.116

Cost models were used to estimate manufacturing costs for major vehicle components and subassemblies, which were then summed to give the total manufacturing cost of each vehicle in year 2025 [8]. These manufacturing cost estimates were assumed to be the same for both American and European automakers (Table 2). Cost model parameters were assigned values based on input from U. S. DOE vehicle technology managers and industry experts who provided a range of values from highly optimistic (high case) to pessimistic (low case).

Table 2: Estimated future manufacturing cost

Year	Optimism of cost estimate	Glider cost (USD2015)	Battery pack cost (USD2015/kWh)			
			PHEV 20	PHEV 30	BEV100	BEV200 and BEV300
2025	Low	10,509	500	450	325	325
	Medium	11,319	400	375	250	250
	High	11,631	315	290	170	170

The RCO was calculated from vehicle prices and other costs [3]:

$$\mathbf{C_{RCO}} = \mathbf{C_{Invest}} + \sum_{t}^{N}\left(\frac{(\mathbf{C_{Energy,t}}+\mathbf{C_{Main,t}}+\mathbf{C_{Fees,t}})}{(1+r)^{t}}\right) - \frac{\mathbf{V_{Res}}}{(1+r)^{N}}$$

$$\mathbf{V_{res}} = \mathbf{C_{Invest}}(\mathbf{1 - 15 \times 10^{-7} \times N \times VKT - 0.476})$$

Where N = ownership period (years)

r = discount rate (%)

VKT = annual vehicle kilometers travelled.

Investment costs include the vehicle manufacturing direct costs, manufacturer mark-up (accounted for by a retail price equivalent [RPE] factor), sales tax or value-added tax, both applied to the retail price, incentive (or bonus/malus premium/charge), and initial registration/licensing fees or taxes. For the BEV in the United States, the cost of home electric vehicle service equipment (EVSE) is also included in the investment cost. Given the capacity of BEVs, charging times using only a Level 1 charger do not meet the requirements of most consumers: a recent survey of California drivers found that only 12 % of Nissan Leaf owners did not have Level 2 EVSE at home [13]. Because of the higher voltage level (240 V) in Europe, EVSE costs are not considered for Germany.

Residual values after a service time of 10 years were calculated using regression equations developed by Pröpfe et al. [18] for each powertrain type. These equations were developed from European vehicle sales data and may not accurately model resale values in the United States. Resale values are uncertain, particularly for PEVs, since the used PEV market is very immature. Residual values were estimated as a fraction of the total investment cost rather than purchase price, since the investment cost was assumed to approximate more closely the transaction cost as it includes incentives and fees, and since evidence suggests that incentives decrease residual values [19]. A residual value of zero was assumed after a service time of twelve years or a total distance travelled higher than 338,000 kilometers.

$$C_{Invest} = (C_{Manuf})(F_{RPE})(1 + Tax_{Sales}) - (C_{Incentives} + C_{Fee,init} + C_{Batt\,repl} + C_{Home\,EVSE})$$

where C_{Invest} = Total investment (upfront) cost

C_{Manuf} = Manufacturing cost

F_{RPE} = Retail price equivalent or mark-up factor = 1.5 [14]

$C_{Incentives}$ = Feebate (bonus/penalties) or incentive, see Table 3. Incentives are shown as positive if they decrease the cost and negative if they increase the cost.

$C_{Fee,\,init}$ = Fees payable upon vehicle purchase see Table 3

Tax_{Sales} =State sales tax

$C_{Batt\,repl}$ =Battery replacement (PHEV and BEV); we assumed no battery replacement in this paper.

$C_{Home\,EVSE}$ = Average cost of installing Level 2 EVSE [15]

The incentives have a high impact on the RCO and are geographically dependent. In the United States, we considered only the federal subsidies (tax credits) for plug-ins, which depend on the battery total rated capacity in kWh as follows: 2,500 U. S. dollars (USD) for each PEV with at least 5 kWh total battery capacity, plus 417 USD for each kWh in excess of 5 kWh, up to a maximum of 7,500 USD. We treat these values as 2015 USD. In reality, the subsidy decreases for each automaker after the automaker sells more than 200,000 PEVs, which was neglected in this study. In Germany, the subsidies are 3,000 EUR for each PHEV and 4,000 EUR for each BEV [16]. Using a conversion factor of one EUR to 1.0598 USD results in 3,179 USD for each PHEV and 4,239 USD for each BEV. These values are also treated as 2015 USD.

We evaluated sensitivities to assumptions by examining ranges of fuel prices, battery costs, and annual distance travelled. From these results, we examined which factors are most important in the United States and Germany for cost of ownership of PHEVs and BEVs, and under what combination of conditions PHEVs and BEVs are cost-competitive with other drivetrains.

Table 3: Values for initial fees, incentives, and EVSE for year 2025 in USD_{2015}

Area	Incentives, Costs, and Fees	Conventional Spark Ignition	Conventional Compression Ignition	PHEV	BEV
Germany	Incentives	0	0	3,179	4,239
	Initial fee	22	22	22	22
	Motor tax (USD_{2015}, period average)	29	121	0	0
	EVSE cost	0	0	0	0
	Maintenance (USD_{2015}/km)	0.06	0.06	0.06	0.05
U.S. federal	Incentives	0	0	> 2,500	> 2,500
	Initial fee	186	186	186	186
	EVSE cost	0	0	0	1,204
	Maintenance (USD_{2015}/km)	0.05	0.05	0.05	0.05

5.4 Results

To be concise, this report primarily focuses on ownership costs of a 2025 midsize car for average advanced technology and medium optimism cost estimates (cf. Table 2). In addition, we assumed a period of 10 years of ownership and that the customer is not going to change the battery pack during this period. The energy prices applied are displayed in Table 1. The incentives applied, EVSE installation cost, and other ownership fees are displayed in Table 1 according to the geographic area. Glider costs were assumed to be the same for the United States and Europe but vary by year (cf. Table 2). We also assumed that after the battery guaranty period (eight years or 160,000 km travelled), the total energy capacity of the battery pack decreases by 4 % each year.

Energy Consumption

Fuel and electricity (energy) consumption by different powertrains (conventional, PHEV, and BEV) are compared in Figure 1. One can notice that the U. S. cycle, even though it is less aggressive than the WLTC, leads to higher vehicle energy consumption, especially for electrified vehicles, because of its real-world adjustment factor. The right-hand axis of Figure 1 shows the relative difference in energy consumption in the U. S. combined cycle vs. the WLTC by each vehicle type.

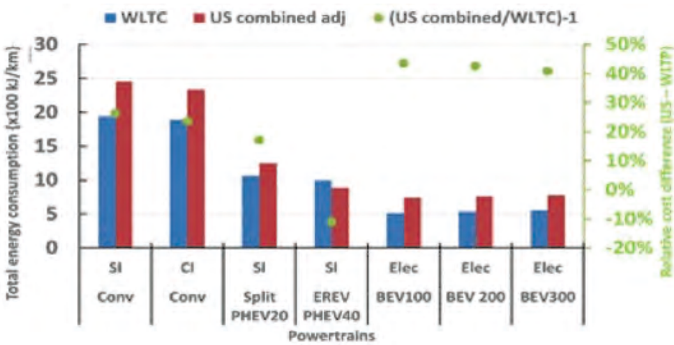

Figure 1: Energy consumption comparison by powertrain and driving cycle

Energy Costs

Figure 2 shows the cost metric in Europe (using the WLTC as reference) and in the United States (with the U. S. combined adjusted cycle as reference). Mainly because of higher European energy prices (cf. Table 1), the cost of the energy per kilometer travelled is higher in Europe than in the United States.

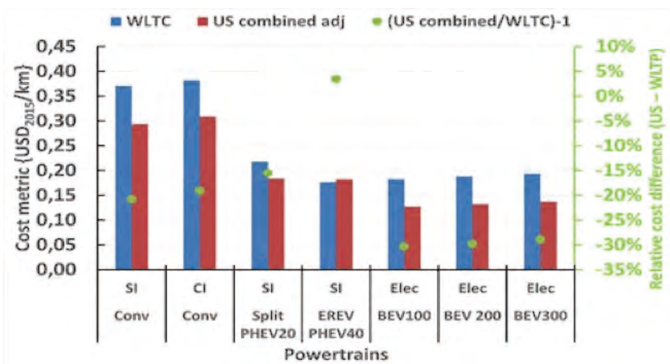

Figure 2: Cost metric comparison by powertrain and driving cycle

To properly compare the overall cost of ownership between the United States and Germany, we need to include the manufacturing cost, the maintenance cost over the years, taxes, and fees. These are shown in Figure 3 for Germany and Figure 4 for the United States. Negative costs (incentives) are shown below the axis and the total resulting RCO is shown as a filled, red circle.

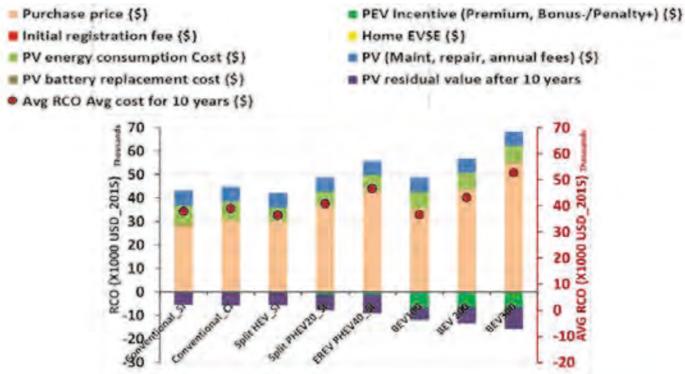

Figure 3: RCO comparison between powertrains for 10 years of ownership in Germany using the WLTC as reference

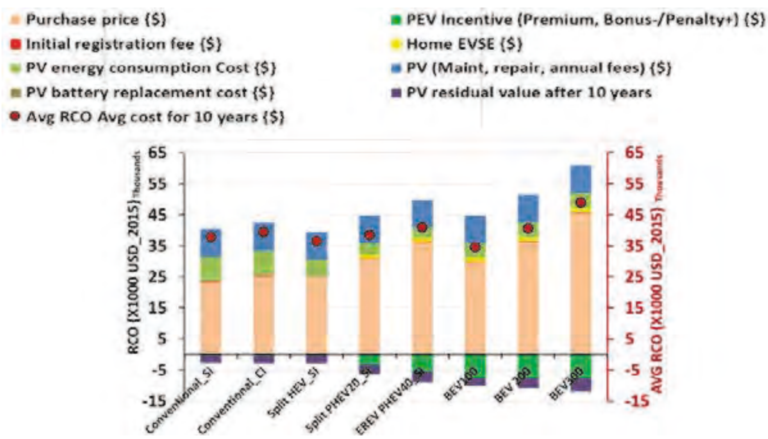

Figure 4: RCO comparison between powertrains for 10 years of ownership in the United States using the U.S. combined adjusted driving cycle as reference

For an ownership period of 10 years, only the BEV100 in both Germany and the United States seems to be cost competitive with conventionally powered cars when using the current market price as reference (cf. Figures. 3 and 4). However, as shown in Figure 5, even though the U. S. driving cycle leads to higher energy consumption for electrified vehicles compared to the WLTC, fuel savings by PEVs are higher in Germany than in the United States, because of the high price of fuel.

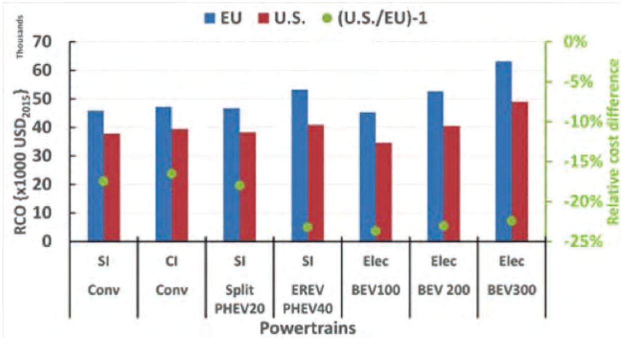

Figure 5: RCO comparison between the United States and Germany for 10 years of ownership

5.4.1 Impacts of Other Factors

We evaluated the effect of different factors on the competitiveness of PEVs on the U. S. and German markets.

Manufacturing Cost

The battery manufacturing cost has a direct impact on the selling price of the vehicle and hence on the customer purchase decision. The heat maps below (Tables 4 and 5) display the RCO by powertrain for a range of manufacturing battery costs. The color of each cell in the table indicates whether the RCO is higher (red) or lower (green) in comparison to the others. Values in Tables 4 and 5 are based on the annual distance, discount rate, and fuel prices shown in Table 1. Tables 4 and 5 show that the PEVs become more competitive as the battery cost decreases. For instance, the BEV300 becomes even more economical in the United States than conventional vehicles at 100 USD_{2015}/kWh or less, for an ownership period of 10 years.

Table 4: RCO by battery cost and powertrain for 10 years of ownership in the United States using the U.S. combined adjusted driving cycle as reference

		Conventional	Conventional	Split PHEV20	EREV PHEV40	BEV100	BEV 200	BEV300
Variable 1		SI	CI	SI	SI	Elec	Elec	Elec
Battery costs (USD_2015/kWh)	400	37,841	39,467	38,279	41,523	39,643	49,002	62,414
	300	37,841	39,467	36,876	38,949	36,270	43,355	53,472
	200	37,841	39,467	35,474	36,376	32,896	37,708	44,530
	100	37,841	39,467	34,873	34,378	29,523	32,061	35,588
	50	37,841	39,467	34,873	34,378	27,836	29,238	31,117

Table 5: RCO by battery cost and powertrain for 10 years of ownership in Germany using the WLTC as reference

		Conventional	Conventional	Split PHEV20	EREV PHEV40	BEV100	BEV 200	BEV300
Variable 1		SI	CI	SI	SI	Elec	Elec	Elec
Battery costs (USD_2015/kWh)	400	35,734	37,582	37,064	43,543	41,207	51,541	66,357
	300	35,734	37,582	35,531	40,728	37,518	45,366	56,578
	200	35,734	37,582	33,997	37,914	33,829	39,191	46,799
	100	35,734	37,582	33,340	35,729	30,140	33,015	37,021
	50	35,734	37,582	33,340	35,729	28,295	29,928	32,131

Annual Distance Travelled

As expected, the annual distance travelled by the customer will have a direct impact on the cost competiveness between different powertrains (cf. Figure 6); higher annual distance travel plays in favor of the PEVs. For instance, in the United States, at around 24,000 km/year for 10 years of ownership, the PHEV20 and BEV100 become more economical than the conventional spark ignition (SI) vehicle (Table 6). In Germany, largely owing to the higher fuel and electricity prices, the PHEV20 becomes competitive at higher distances travelled than in the United States (cf. Tables 6 and 7).

Table 6: RCO by annual distance travelled and powertrain for 10 years of ownership in the United States using the U.S. combined adjusted driving cycle as reference

		Conventional	Conventional	Split PHEV20	EREV PHEV40	BEV100	BEV 200	BEV300
Variable 1		SI	CI	SI	SI	Elec	Elec	Elec
Annual VKT (Km)	40,233	53,695	55,285	52,059	54,129	47,547	54,522	64,172
	32,186	47,112	48,779	46,503	48,956	42,379	48,968	58,331
	24,140	39,385	41,019	39,648	42,226	35,882	41,937	50,556
	16,093	31,660	33,260	32,842	35,502	29,386	34,908	42,781
	8,047	23,936	25,502	26,243	28,822	22,891	27,879	35,007

Table 7: RCO by annual distance travelled and powertrain for 10 years of ownership in Germany using the WLTC as reference

		Conventional	Conventional	Split PHEV20	EREV PHEV40	BEV100	BEV 200	BEV300
Variable 1		SI	CI	SI	SI	Elec	Elec	Elec
Annual VKT (Km)	40,233	65,514	65,916	62,098	69,968	58,991	69,494	81,625
	32,186	57,323	58,260	55,559	63,002	54,235	62,480	74,159
	24,140	47,769	49,109	47,375	54,082	46,021	53,541	64,216
	16,093	38,217	39,960	39,192	45,161	37,808	44,602	54,274
	8,047	28,667	30,813	31,009	36,223	29,597	35,665	44,333

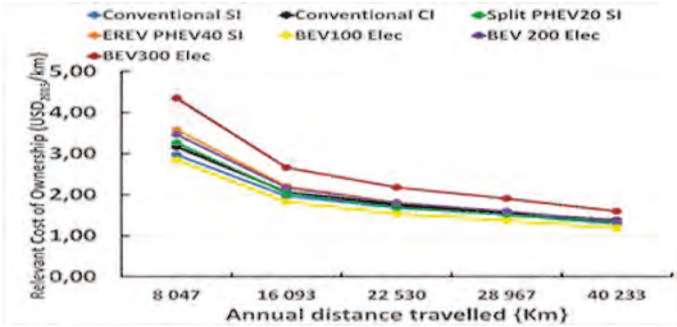

Figure 6: RCO by annual distance travelled and powertrain for 10 years of ownership in the United States using the U.S. combined adjusted driving cycle as reference

Energy Price

The impact of fuel price is far more important in Europe. Table 8 shows the impact of a potential fuel price evolution in Germany. At a gasoline price of 2.38 USD_{2015}/liter (9.01 USD_{2015}/gallon), the PHEV20 and the BEV100 will become more economical than conventional cars. The electricity price also plays a role in the overall cost for the owner of a PEV, as shown in Table 9. At electricity prices as low as 0.08 USD_{2015}/kWh, the PHEV20 and the BEV200 become cost competitive over an ownership period of 10 years. However, the RCO of the PHEV40 or the BEV300 are higher than for conventional cars even at an electricity rate as low as 0.08 USD_{2015}/kWh. If carbon emissions are priced, and the cost is reflected in higher fuel prices, this will tend to favor lower-carbon emitting PEVs, especially BEVs.

Table 8: RCO by fuel price and powertrain for 10 years of ownership in Germany using the WLTC as reference

		Conventional	Conventional	Split PHEV20	EREV PHEV40	BEV100	BEV 200	BEV300		
Variable 1		SI	CI	SI	SI	Elec	Elec	Elec		Variable 2
Gasoline price (USD_2015/Liter)	2.38	40,793	42,383	38,938	44,243	35,673	42,278	51,689	2.38	Diesel price (USD_2015/Liter)
	1.98	38,450	40,258	38,070	43,592	35,673	42,278	51,689	1.98	
	1.32	34,544	36,716	36,624	42,509	35,673	42,278	51,689	1.32	
	0.92	32,201	34,591	35,756	41,859	35,673	42,278	51,689	0.92	
	0.26	28,296	31,049	34,309	40,775	35,673	42,278	51,689	0.26	

Table 9: RCO by fuel price and powertrain for 10 years of ownership in Germany using the WLTC as reference

		Conventional	Conventional	Split PHEV20	EREV PHEV40	BEV100	BEV 200	BEV300
Variable 1		SI	CI	SI	SI	Elec	Elec	Elec
Electricity price {$/kWh}	0.4	35,734	37,582	37,083	42,868	35,725	42,332	51,745
	0.32	35,734	37,582	36,572	42,086	34,341	40,899	50,253
	0.24	35,734	37,582	36,060	41,303	32,957	39,465	48,761
	0.16	35,734	37,582	35,548	40,520	31,573	38,031	47,269
	0.08	35,734	37,582	35,037	39,737	30,190	36,598	45,777

For the combination of factors considered here (Table 1), the U. S. gasoline price must reach 1.32 USD_{2015}/liter (5.0 USD_{2015}/ gallon) for most PEVs to become cost competitive (cf. Table 10).

Table 10: RCO by fuel price and powertrain for 10 years of ownership in the United States using the U.S. combined adjusted driving cycle as reference

		Conventional	Conventional	Split PHEV20	EREV PHEV40	BEV100	BEV 200	BEV300
Variable 1		SI	CI	SI	SI	Elec	Elec	Elec
Gasoline price {USD_2015/Liter}	2.38	58,279	39,467	44,623	44,764	34,583	40,532	49,001
	1.98	53,517	39,467	43,145	43,859	34,583	40,532	49,001
	1.32	45,581	39,467	40,681	42,351	34,583	40,532	49,001
	0.92	40,819	39,467	39,203	41,445	34,583	40,532	49,001
	0.26	32,882	39,467	36,739	39,937	34,583	40,532	49,001

Incentives Influence

Incentives have a significant impact on the relevant cost of ownership. Therefore, we applied hypothetical variations on the initial value to enhance their impact on the RCO. Four different cases were applied in this study:

- Suppression of the incentive (0 % of the current incentive's values applied);
- Reduction of 50 % of the current value of the incentives;
- No change in the incentive (100 % of the current values applied);
- A hypothetical case of an increase of 50 % of the incentive (150 % of the current incentive's values applied).

Tables 11 and 12 below display the new RCO according the incentive variation and the geographical area. They show how much the incentive influences the RCO of electrified vehicles. Indeed, if the incentive is suppressed in the U. S., the RCO for the BEV100 will decrease by almost 10 % and by 7 % for the Split PHEV20. If PEV incentives are decreased or eliminated, this can be expected to reduce PEV market share.

Table 11: RCO by incentives variation and powertrain for 10 years of ownership in the United States using the U.S. combined adjusted driving cycle as reference

		Conventional	Conventional	Split PHEV20	EREV PHEV40	BEV100	BEV 200	BEV300
Variable 1		SI	CI	SI	SI	Elec	Elec	Elec
Incentive (% of current value)	0%	37,841	39,467	40,986	45,539	41,226	47,175	55,644
	50%	37,841	39,467	39,632	43,209	37,905	43,853	52,323
	100%	37,841	39,467	38,279	40,879	34,583	40,532	49,001
	150%	37,841	39,467	36,925	38,549	31,261	37,210	45,679

Table 12: RCO by incentives variation and powertrain for 10 years of ownership in Germany using the WLTC as reference

		Conventional	Conventional	Split PHEV20	EREV PHEV40	BEV100	BEV 200	BEV300
Variable 1		SI	CI	SI	SI	Elec	Elec	Elec
Incentive (% of current value)	0%	35,734	37,582	39,630	45,405	39,095	45,700	55,111
	50%	35,734	37,582	38,347	44,122	37,384	43,989	53,400
	100%	35,734	37,582	37,064	42,839	35,673	42,278	51,689
	150%	35,734	37,582	35,781	41,556	33,962	40,567	49,978

Combination of Factors

We examined ranges of factors to determine what combinations enable BEVs to be cost-competitive with conventional SI vehicles. The ratio of the RCO of a BEV200 to that of a conventional SI vehicle under different assumptions is shown in Figures 7 and 8. Those figures display the contours of a constant RCOBEV200/RCOConvSI ratio for ranges of battery costs and annual distance travelled for three different electricity prices. All other parameters remain constant (as given in Tables 1, 2, and 3).

In Germany, mainly due to the high fuel cost for conventional vehicles, at high annual distance travelled, the BEV200 can be competitive with conventional vehicles (Figure 7). Furthermore, the electricity price will also have an impact on both the cost ratio between BEV200 and conventional SI, and on the way the annual VKT and battery cost will affect this ratio. Indeed, (cf. contours outlined in red in Figures 7 and 8) the slope of the RCOBEV200/RCOConvSI lines increases as electricity price decreases and the difference in the energy cost per kilometer increases. As shown in Figure 8, at high electricity prices (0.35 USD_{2015}/kWh in the United States) while others parameters remain constant, the slope of contours become negative, since the energy cost per kilometer for the BEV is higher than that of the conventional vehicle, and the RCO ratio increases with annual distance travelled.

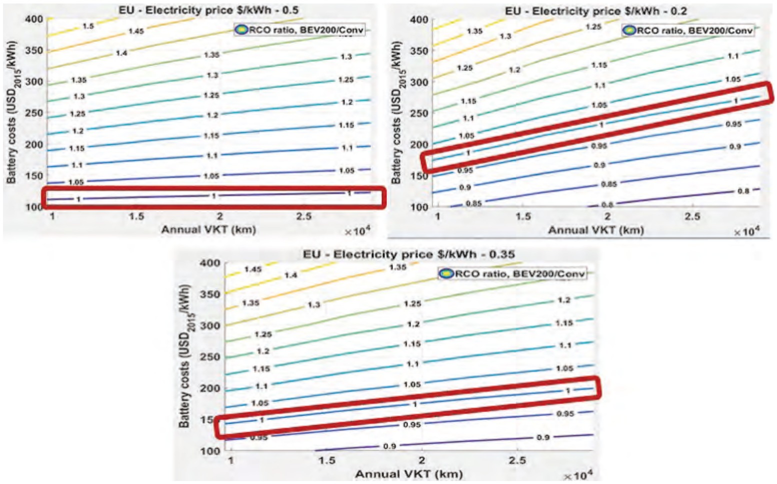

Figure 7: RCO ratio between BEV200 and conventional SI by annual distance travelled, battery cost, and electricity price, for 10 years of ownership in Germany using WLTC as reference

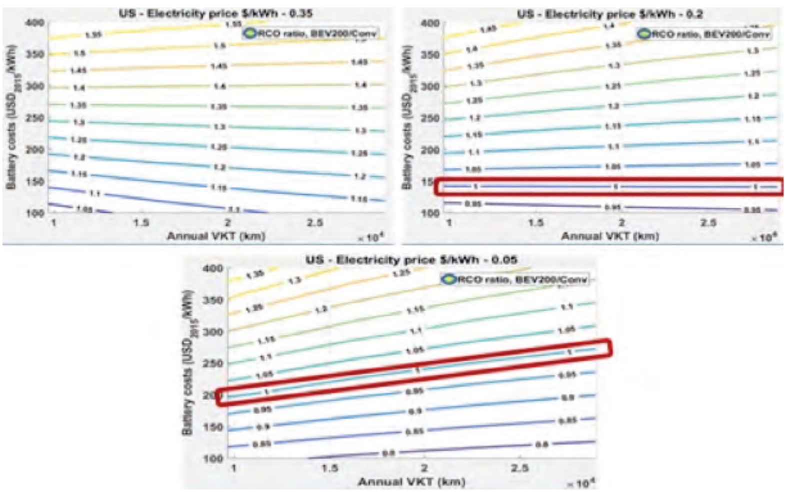

Figure 8: RCO ratio between BEV200 and conventional SI by annual distance travelled, battery cost, and electricity price, for 10 years of ownership in the United States using the U. S. combined adjusted driving cycle as reference

5.5 Conclusions

PEVs can be cost-competitive with other powertrains under favorable conditions. These include various combinations of high fuel prices, low battery costs, and high annual driving distances. Energy savings from PEVs, especially BEVs, are somewhat sensitive to the fuel and electricity consumption estimates. The differences in fuel costs between the WLTP and adjusted U. S. cycles indicate the importance of energy consumption values. These differences become more important under high fuel prices. When energy costs per kilometer for PEVs and conventional vehicles differ widely (high gasoline price and low electricity price), annual distance travelled becomes an important factor and PEVs can be cost competitive at high annual VKT. When energy cost per kilometer is similar, purchase price differences are more important, and PEV cost competitiveness is more sensitive to assumptions about battery costs. Since future fuel prices are uncertain, and driving distances differ between drivers, it is difficult to predict how competitive PEVs will be, but it is important to consider the interactions of multiple factors. However, there are factors that we did not consider that influence BEV adoption, such as the difference between the acceleration performance of PEVs and conventional vehicles, the limited range of the BEV100 and BEV200, and also availability of public charging stations. The Task 25 concluded in 2018.

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6 Wireless Power Transfer for Electric Vehicles (Task 26)

Members: Denmark, France, Germany, The Netherlands, Republic of Korea, Spain, Sweden, Switzerland, United Kingdom, United States

6.1 Introduction

Wireless charging of electric vehicles (EVs) has the potential to untether EVs from their charger cables and possibly reduce the size of EV batteries or extend their range for the same size battery if the vehicles can be charged while in motion in future. Research groups in industry, academia, and in national laboratories around the world are working to improve wireless power transfer (WPT) technologies so that EVs can charge by parking over a coupling device (referred to as static charging), by charging at natural stopping points but not parking (referred to as opportunity charging), or even while the vehicle is in motion (called dynamic charging).

However, the standards for WPT appear to vary in different member countries, or currently there exist no standards, which limits the interoperability among systems and slows the maturation of this technology. This Task is developing a greater global understanding of WPT systems and interoperability through a focused study of WPT technologies being developed in the participating countries. Topics covered by this Task include a study of country-based standards (JARI, SAE, ISO/IEC), technical approaches, grid interactions, interoperability, and safety codes for WPT.

6.2 Objectives

The Task coordinates a study of various country-based standards, technical approaches, grid interactions, and regulatory policy for WPT for EVs, and addresses interoperability, power levels, alignment, and safety. In addition, there are many fields of interest in WPT that this Task may address. Areas considered will be broad as the Task gets underway and narrow in focus as meetings progress. As there is an ongoing effort in many of these areas, the objectives are:

- Categorize deployment approaches and requirements for WPT technologies such that participants develop an understanding of what challenges are faced in different countries or markets and what it takes to put this technology into the field in these markets.

- Compare the characteristics of WPT systems being developed in the participating countries, and discuss how to address interoperability concerns.
- Catalog, discuss, and compare standards for WPT in different countries (JARI, SAE, ISO/IEC, etc.).
- Discuss and summarize safety issues regarding misalignment, leakage fields, and debris tolerance and response.

6.3 Working Method

The Task conducts bi-annual workshops and supports conference calls, which include visiting locations of WPT research or deployment activities to gain first-hand knowledge of how this technology is progressing and to inform the committee of new work. Based on information gathered from participating countries, specific areas may be identified as critical interest for off-line research.

The process for how this task operates is as follows:

- Develop an understanding of the challenges faced in various countries or markets by categorizing deployment approaches and requirements for WPT technologies.
- Compare current WPT technology development and address interoperability concerns for both static and dynamic systems.
- Summarize safety issues arising from misalignment, leakage fields, and debris tolerance and response.
- Establish a repository for the data collected and links to other activities available to task members.

6.4 Results

Task 26 sponsored three workshops in 2018. The first workshop was held on 19-20 March 2018 and focused on wireless charging and V2X grid and market integration. The workshop was co-organized with the HEV TCP Task 28, Home Grids and V2X Technologies. Newcastle University (United Kingdom) hosted this event. This location was selected for co-locating the workshop with the UK Energy Storage Conference, 20-22 March 2018, Newcastle University.

The second workshop focused on dynamic wireless charging and was held on 25-26 June 2018 in Torino, Italy the week after the final event of the European Union’s Feasibility analysis and development of on-road charging solutions for future electric vehicles (FABRIC) project. Politecnico Di Torino hosted this event. Workshop activities included technical presentations and a demonstration of FABRIC's on-road WPT installation in Susa, Italy.

The third workshop focused on wireless charging in general to get updates on various aspects of the technology and was held on 6 November 2018 in Detroit, Michigan, United States. The Hyundai American Technical Center, Inc. (HATCI) hosted this event. Workshop activities included technical presentations and a technical visit of the American Center for Mobility's (ACM) Willow Run, Michigan test site where HATCI demonstrated a wirelessly charged Kia Soul EV.

Summary of Wireless charging and V2X Grid and Market Integration Workshop, March 2018 (Workshop 7)

With the support of task members from Task 26 and Task 28, 18 speakers were identified to present on grid impacts and issues and also bi-directional wireless charging with grid support. The workshop consisted of presentations from Denmark, the European Commission, Greece, the Netherlands, Spain, the United Kingdom, and the United States. Speakers were selected by Task 26 and Task 28, and included government agencies, a university, industry, and a national laboratory. This workshop featured high-level world-speakers and academics from the fields of engineering, management, economics, and political science, among others, who exchanged their views and debated about wireless charging and V2X grid and market challenges and related topics. Table 1 summarizes the workshop presentations.

Workshop 7 Demonstration

The workshop included a technical visit to Newcastle University's Smart Grid Lab with a demonstration of their Energy Storage Test bed. The lab also includes a real-time network simulator with secondary life battery systems, battery emulators, smart appliances, and smart grid controllers which allow detailed models of the grid components, including wired and wireless chargers networks, to interact with physical laboratory environment and components.

Table 1: Presentations of the Wireless Charging and V2X Grid and Market Integration Workshop

Title	Presenter	Country
Introducing Newcastle University	Sara Walker, Newcastle University	United Kingdom

Title	Presenter	Country
Electric Vehicle Innovation Research at Newcastle University	Myriam Neaimeh, Newcastle University	United Kingdom
IEA Hybrid Electric Vehicle-Technology Commercialization Programme (HEV TCP) Task 26	Burak Ozpineci, Oak Ridge National Laboratory	United States
Task 28 “Home Grids and V2X Technologies”	Cristina Corchero, IREC/Catalonia Institute for Energy Research	Spain
V2G Status and Future Roll-out: the UK case	Marco Landi, InnovativeUK	United Kingdom
Efficient System Integration of Electric Vehicles	Thomas Maidonis, National Grid	United Kingdom
Electric Vehicles Impacts & Opportunities	Thazi Edwards, UK Power Networks	United Kingdom
Learnings from Denmark	Peter Bach Andersen, DTU Energy	Denmark
AC V2G in The Netherlands	Bram van Eijsden, AC V2G in The Netherlands	The Netherlands
Commercial Smart Charging with the JuiceNet aggregation platform	Vincent Schachter, JuiceNet by eMotorWerks	United States
Identifying the dimensions for a viable V2X model	Wang Yue, Northumbria University	United Kingdom
Multi-Output Wireless Charger for Electric Vehicles	Vu Binh, Newcastle University	United Kingdom
Learnings from including degradation in the techno-economics of systems that employ lithium ion batteries for storage	Kotub Uddin, OVO Energy	United Kingdom
Design and implementation of an 85 kHz Bidirectional Wireless Charger	Alicia Trivino, University of Malaga	Spain
Bi-directional Wireless Power Flow for Medium Duty Vehicle Grid Connectivity	Burak Ozpineci, Oak Ridge National Laboratory	United States
Cost Reduction Methods in high density rapid charging V2G hubs	Christopher Jackson, Powerstar	United Kingdom

Title	Presenter	Country
Impact of Static and Dynamic Fast Inductive Charging on the Distribution Network and its Mitigation through Effective Management	Ioannis Karakitsios, National Technical University of Athens	Greece
Dynamic wireless power transfer for EV charging: Grid impact and demand management strategies	Christina Anagnostopoulou, ISENSE ICCS	European Commission

Workshop presentations are available on the member's site for HEV TCP members. Additionally, a summary report of this workshop was developed, shared with the attendees of the workshop, and posted on the Task webpage. This summary report will provide input into the final task deliverable.

Summary of Dynamic Wireless Charging Workshop, Torino, Italy, June 2018 (Workshop 8)

With the support of the task members, eight speakers were identified to present on dynamic wireless charging. The workshop consisted of presentations from the European Commission, France, Italy, Greece, and the United States. Speakers were selected by Task 26 and the FABRIC team, and included government agencies, a university, and a national laboratory. Presentations provided good insight into the technical challenges associated with dynamic wireless charging systems focusing on the vehicle and charging systems. Table 2 summarizes workshop presentations.

Workshop presentations are available on the member's site for HEV TCP members. Additionally, a summary report of this workshop was developed, shared with the attendees of the workshop, and posted on the Task webpage. This summary report will provide input into the final task deliverable.

Workshop 8 Demonstration

Workshop attendees participated in a demonstration at Politecnico Di Torino and FABRIC's on-road WPT installation in Susa, Italy. A photo of the WPT installation is shown below in Figure 1. For the demonstration, vehicles were not available but a mobile platform was used to demonstrate the operation of dynamic wireless charging.

The setup in Susa was designed for a 100 m energized roadway with rectangular wireless charging coils of 0.5 m width and 1.5 m length. The vehicle side coil had a width of 0.5 m to match the width of the ground side coils. No shields or ferrites were used on the ground side to make the set up simpler. The coils were embedded in the road through micro trenches carved in the pavement. The grid-side front-end converter was set up to receive 400 V AC from an isolation transformer and convert it to 650 V DC, which fed the 22 kW rated high frequency inverters powering each coil (shown on the side of the road in Figure 1).

The research results showed that high voltage stress on the resonant capacitors and the impact of capacitance variation on the resonant operation required high quality, high accuracy, high cost capacitors. To solve the cost issue, the researcher at Polito invented a new capacitor called RES power cap.

Table 2: Presentations of the Dynamic Wireless Charging Workshop

Title	Presenter	Country
FABRIC Final Event The story of the Italian test site	Paolo Gugliemi, Politecnico Di Torino	Italy
Charging Process Control of Dynamic Wireless Power Transfer System	Mojtaba Khalilian, Politecnico Di Torino	Italy
Technology Development: Updates, Challenges and Opportunities	Burak Ozpineci, Oak Ridge National Laboratory	United States
Experimental performances assessment of a dynamic wireless power transfer system for future EV in real driving conditions	Stephane LaPorte, Institut VEDECOM	France
Feasibility analysis of dynamic wireless charging for electric vehicles: The achievements of FABRIC project	Christina Anagnostopoulou, ISENSE ICCS	European Commission
Collaborative, Pre-normative Research on electromobility: EMC, Interoperability, Efficiency	Harald Scholz, European Commission, Joint Research Centre	European Commission
Maximizing the transferred energy with a high system efficiency in dynamic inductive charging of EVs	Ioannis Karakitsios, National Technical University of Athens	Greece
Optimal Sizing of a Dynamic Wireless Power Transfer System for Highway Applications	Burak Ozpineci, Oak Ridge National Laboratory	United States

Another important result of the dynamic wireless charging implementation was that the coils embedded in the pavement did not function as inductors. The resonant frequency changed when the coils were embedded in the road. After six months of research, they came up with a material solution (patent pending) that eliminated the pavement interference on the coil. The resulting dynamic wireless charging system could transfer 6.5 kW maximum power with 81 % efficiency with a maximum speed of 50 km/h. The system also tolerated 30 cm of misalignment.

Summary of Wireless Charging

Another important result of the dynamic wireless charging implementation was that the coils embedded in the pavement did not function as inductors. The resonant frequency changed when the coils were embedded in the road. After six months of research, they came up with a material solution (patent pending) that eliminated the pavement interference on the coil. The resulting dynamic wireless charging system could transfer 6.5 kW maximum power with 81 % efficiency with a maximum speed of 50 km/h. The system also tolerated 30 cm of misalignment.

Figure 1: Politecnico Di Torino and FABRIC's on-road WPT installation, Susa, Italy (Source: private)

Workshop, Detroit, Michigan, United States, November 2018 (Workshop 9)

With the support of the task members, 10 speakers were identified to present on wireless charging. The workshop was attended by 35 individuals. Presentations covered several areas of importance, such as dynamic wireless charging, power levels, system-level studies, cyber security, standards, and system, coil, and air gap considerations (Table 3). Stakeholders from a broad range of perspectives presented, including those from national laboratories, the private sector, a vehicle original equipment manufacturer, a government agency, and a state university.

Workshop presentations are available on the member's site for HEV TCP members. Additionally, a summary report of this workshop was developed, shared with the attendees of the workshop, and posted on the Task webpage. This summary report will provide input into the final task deliverable.

Table 3: Presentations of the Wireless Charging Workshop

Title	Presenter	Country
IEA Hybrid Electric Vehicle-Technology Commercialization Programme (HEV TCP) Task 26: Wireless Charging for EVs	Burak Ozpineci, Oak Ridge National Laboratory	United States
Bidirectional Wireless Power Flow for Medium-Duty Vehicle-to-Grid Connectivity	Omer Onar, Oak Ridge National Laboratory	United States
Risk Analysis of Communication Protocols for Smart Modules in Vehicles	Mustafa Saed, HATCI	United States
Cutting the Charging Power Cord An Industrial Perspective	Laurence Dunn, Hyster-Yale Group	United States
Innovative Chargers and Converters	Omer Onar, Oak Ridge National Laboratory	United States
Material Classification for Electromagnetic Shielding and Infrastructure Impacts	Jason Pries, Oak Ridge National Laboratory	United States
NREL's Managed WPT Experiences and Lessons Learned	Ahmed Mohamed, National Renewable Energy Laboratory	United States
An Optimized Single-stage 120 kW Wireless EV Charging System	Gui-Jia Su, Oak Ridge National Laboratory	United States
Practical Challenges in Designing a Dynamic Wireless Charging System	Regan Zane, Utah State University	United States
Prospective views on Versaille-Satory site infrastructure developed for integrating and testing DWPT solutions	Stephane LaPorte, Institut VEDECOM	France

Workshop 9 Demonstration

The workshop concluded with a tour of the American Center for Mobility's (ACM) test environment in Willow Run, Michigan. While at the ACM, workshop attendees observed a WPT demonstration of a Kia Soul. The vehicle charged at

10 kW and featured WiFi communications for a control loop. A picture of the EV is shown in Figure 2.

Attendees toured the ACM wireless charging facility that includes a high-performance computing data center that has been operational for one year. This is a global testing site, and Intertek is the operating partner. The facility consists of two quads. The southern area is a new construction and features bi-directional charging, and the northern area is a testing loop that was formerly Michigan Department of Transportation property. To create different exiting and merging scenarios, the test quads utilize two different lighting patterns and road lanes with multiple exits. Other features include units for vehicle communications, global positioning systems within 2 μ accuracy, and 4 G WiFi. System capabilities include controlled signals, car-to-car technologies for developing technologies, and lane-keep and blind assist.

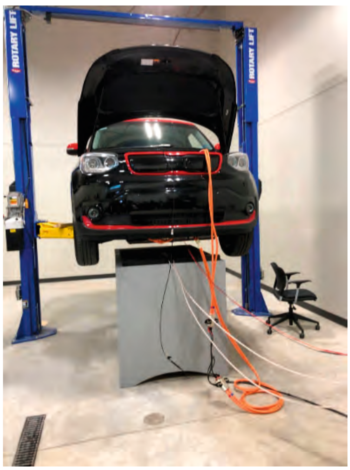

Figure 2: Wirelessly charged Kia Soul EV demonstrated during Workshop 9, Detroit, Michigan. (Source: private)

6.5 Next Steps

Task 26 concludes in 2019. This task plans to hold its final workshop in June 2019, which will include a review of the final task report. Table 4 provides the topic and location for the remaining workshop. The final report of Task 26 will be submitted at the Fall 2019 ExCo Meeting.

Table 4: Schedule for remaining workshop

Workshop Topics	Anticipated Dates	Host/Location
Task 26 Workshop and Final Report Review	17-21 June 2019	Wireless Power Week (WPW) 2019, London, UK

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7 Home Grids and V2X Technologies (Task 28)

Members: Belgium, Canada, Denmark, France, Germany, Ireland, The Netherlands, Republic of Korea, Spain, Switzerland, United Kingdom, United States

7.1 Introduction

The HEV TCP Executive Committee (ExCo) unanimously approved this Task at the Executive Committee meeting in May 2014 held in Copenhagen. It was expected to continue until December 2016, but it was extended until the end of 2018.

This Task explores the technologies and accompanying issues associated with the use of electric storage from plug-in electric vehicles (PEVs) for uses other than powering the vehicles. Customers may use their PEV electric storage capabilities for other applications such as vehicle-to-grid (V2G), vehicle-to-home (V2H), vehicle-to-load (V2L) or vehicle-to-vehicle (V2V). The main characteristics of these applications include the following:

- V2G: Electric utility may be willing to purchase energy from customer during periods of peak demand, and/or use the EV battery capacity for providing ancillary services.
- V2H: Use of the PEV as a home generator during periods of electrical service outage and for increasing self-generated renewable energy usage.
- V2L: Use of the PEV storage to provide power to a remote site or load that does not otherwise have electrical service. Examples include construction sites or camp sites.
- V2V: Use of the PEV storage to transfer electrical energy to other PEVs in case of emergency.

These electric vehicle applications are known as Vehicle to Everything (V2X), a term that represents the strategic technology for ensuring sustainable, secure, and cost-effective deployment of electric mobility. Note that although the possibilities are multiple, most of the research and the demonstration projects are focused on V2G and V2H applications which have shown further grid benefits and higher revenue potential. In particular V2H technology holds a high potential for energy cost reduction by means of enabling energy arbitrage and increasing on-site renewable energy generation capacity while improving security and quality of supply.

7.2 Objectives

Task 28 aims to address the technical and economic knowledge gaps including regulatory issues preventing V2X technology to fully deploy.

The initial Task objectives were the following:

1. Analyze the technical and economic viability of V2X technology, specifically, give responses to a number of identified questions.

- When will V2X be available as a consumer application?
- Which are the potential synergies with self-generated electricity in households?
- Which is the value provided by V2X in terms of security of supply?
- Which impact is to be expected on tax revenues?
- Which are the roles of the different industry players?
- Which is the impact of the different regulatory frameworks in different countries?

2. Develop a set of best practices by connecting and synchronizing the existing V2X research and demonstration projects.

3. Develop a policy-making toolbox and a technology roadmap definition in order to serve decision makers seeking to introduce V2X technology in their respective countries.

4. Establish a worldwide technical information exchange platform enabling information sharing among scientific institutions and industrial representatives working in V2X issues.

5. Promotion of new V2X technology demonstration projects.

The gained knowledge and results of such analysis can be used by policy-makers and industrial partners in the promotion of V2X technology as well as by different players on the EV market within their market research and business modeling.

7.3 Working Method

The overarching objective of Task 28 is to investigate the means to overcome the technical, economic, and policy challenges of the V2X technology. The whole V2X value chain will be considered in this process including power system operators, power electronics industry stakeholders, and the most relevant original equipment manufacturers (OEMs).

Utilizing the existing HEV TCP framework, Task 28 provides the opportunity to bring together the key actors in the EV industry including research and industry players and energy policymakers in order to discuss the requirements for the development and the use of V2X technology. Two annual meetings are programmed on different strategic topics. By leveraging the technical skills and different experiences of the participants, it will be possible to improve the currently available market analyses of V2X technology.

In addition to expert workshops, a close relation and coordination major V2X technology players is planned in order to connect existing V2X research and demonstration projects. The promotion of new V2X technology demonstration projects will be done by collaborating with international organizations and call for proposals.

7.4 Results

- Workshop VIII: V2X market potential and business models. This session took place on the 20 March 2018 in Newcastle (UK), with support from Newcastle University. The session was scheduled to coincide with the UK Energy Storage Conference and covered the topics of technology development, market potential and business models. It was a joint Workshop with Task 26.
- Workshop IX: V2X Technology. This final session of Task 28 was focused on scientific research and lessons learnt from the industry and was held in Barcelona (Spain) on the 6 and 7 June 2018. The session included presentation and panel sessions, covering topics including battery derogation, new standards and optimization for markets and building integration. There were significant contributions made from Canada, the EU and Korea.

7.4.1 V2X Roadmap

One of the physics outputs from Task 28 is a "V2X Roadmap" to assist policy makers and industrial partners in the promotion of V2X technology. The roadmap provides an overview of the different V2X applications and routes to generate value. A description of the current state of the technology and pilot projects is also provided. Finally, key barriers slowing the development of V2X technology are identified, along with goals and actions required to support and accelerate development.

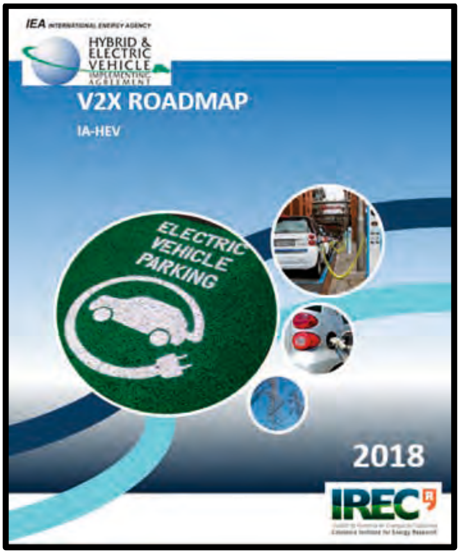

Figure 1: V2X Roadmap (Source: IREC)

7.4.2 Markets and Regulation

Demonstration projects in Europe have highlighted a number of challenges when it comes to connecting to grids and participating in energy markets. Since most DSOs are not used to qualifying EVs or EVSE as generators, V2G projects have regularly experienced slow and costly network connections.

Further, TSO frequency regulation markets are challenging for aggregators to enter, since there is significant variation between countries, pre-qualification processes are complex and market design is often ill-suited for V2G aggregation. Denmark is home to the first commercial V2G scheme, where TSO frequency response is provided by an aggregator in return for annual revenue of around 1,400 EUR per EV. A study from Canada also showed the potential for V2X to generate energy cost savings of around 20 % through peak shaving and frequency regulation. However, in many countries flexibility markets have been very competitive in recent years and the risk of market saturation could threaten the business case for V2G.

In Spain, regulations have proven to be prohibitively expensive for V2X and the priority in this region is to change regulation to permit the entry of aggregators into electricity markets. Other countries in Europe have reported other bottlenecks to development, such as taxes for energy storage and interoperability.

7.4.3 Technology Development

A number of projects are underway in Europe and Korea to test and develop bidirectional AC charging system, comprising onboard DC/AC converters. This type of V2X charger is less developed than the DC equivalent and more work is required to upgrade hardware and software for these systems. There is also a need for grid code modification to connect AC V2X chargers and the development of performance indicators to maintain service quality.

Several standards have been updated to include provision for V2X, although more work is required to harmonize these with existing charging protocols and grid codes. Current standards for V2X include: IEC/IOS, CHAdeMO, OCPP, OSCP, and OpenADR. There are three requirements of standards in order to unlock grid connection and energy market participation: (1) controllability, (2) observability and (3) performance measurement.

Research programs in Europe and Korea are currently testing new V2X standards for reliability and controllability. This includes the implementation of the ISO 15118 protocol in new bidirectional DC and AC chargers in Korea. France is also carrying out tests on new protocols, including speed tests which have shown reaction times of AC charges to be within a few seconds, sufficient for grid services such as voltage control.

7.4.4 EV Grid Integration in the UK

UK Power Networks for the UK have reported on the challenge and innovation opportunities of EV growth to DSOs. This includes improving forecasting of load growth from EVs and improved network visibility to inform development of smart alternatives to network reinforcements, such as smart charging and V2G schemes. They note that e-taxis and e-buses will also be a significant contributor to load growth. It was brought up that the lower reliability of V2G (i.e. vehicles are not always connected) may prohibit provision of certain services to the DSO, but five projects are currently underway to test potential. The UK TSO has also carried out pre-qualification tests of V2G for participation in balancing markets.

7.4.5 Customer Engagement and Business Models

Demonstration projects to date have focused on the development of technology, whilst customer engagement and business models remain largely unexplored. The next generation of V2X demonstration projects will need to test what motivates EV users to adopt V2X technology and develop novel business models to share benefits between stakeholders. Amsterdam and Newcastle Universities have recently carried out research on possible incentive schemes, including gamification, air miles, free power and bundled services. Other factors, such as environmental responsibility and energy autonomy may also influence the V2X value proposition to end users.

In the UK a 30 million BRP fund has been made available for eight V2X demonstration projects to develop and test customer centered business models. These projects will focus on a range of user groups, including commercial fleets, public transport providers and domestic users. Several of these projects will also offer services to the DSO, thus developing new value streams for V2X based on local grid support.

7.4.6 Battery Aging Impacts

Canada is carrying out several investigations into battery aging from V2X. One explored how the battery aging impacts of V2X may change with the 2nd generation EVs, which will have larger battery capacities than their predecessors. V2X impacts were simulated to be significantly reduced in 2nd generation EVs, down to near negligible levels. This was due to large batteries extending the battery End of Life (EoL), such that additional aging caused by V2X did not result in a short lifespan for the EV or trigger the need for battery replacement.

Another study looked at battery aging impacts under non ideal isothermal conditions. Pervious battery aging models have assumed that the temperature of the battery has been in an ideal state, which is not the case under real driving conditions. The simulation and lab results indicated that battery life could be reduced by 1 to 2 years compared with ideal conditions, depending on the battery cooling system used. These impacts are much more significant than V2X impacts.

The final study explored the business case for V2X in Canada, taking into account the cost of battery aging. Results indicated for most applications of V2X in most provinces of Canada the benefits for providing V2X services are not sufficient to offset battery aging impacts. The two applications that seem to be net positive were V2H back-up generation, since this elevated the capital cost of a generator, and TSO spinning reserve, which experiences few calls and low volumes of energy throughput.

7.5 Next Steps

Task 28 finished at the end of 2018 with the completion of a V2X Roadmap capturing the key lessons from the Task activities and setting out priorities moving forward. The Roadmap and key outcomes from Task 28 will be presented in 2019 at relevant conferences and events.

In 2019, members will be seeking approval from the HEV TCP Executive Committee to continue from Task 28 with a new Task, titled “Vehicle-Grid Integration”, which will focus specifically on the issues associated with connecting EVs to the power system. This topic is likely to become a salient matter with the mass uptake of electric mobility from 2020, along with increased levels of distributed generation and smart grid technologies. This Task aims to cover different charging technologies, including smart charging, fast charging and V2G.

7.6 Contact Details of the Operating Agent

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8 Electrified, Connected and Automated Vehicles (Task 29)

Members: Austria, Germany, United States

8.1 Introduction

The convergence of technologies for connectivity and automation with the electrification of road vehicles may offer a multitude of synergies in both performance of the technical systems and added values for users and businesses. Interdependencies between the development and innovation processes in automation and electrification are likely, due to similarities in the electronic architecture both technologies rely on. Furthermore, functional complementarities as well as commonalities in the systematic character of the operating environment enlarge synergetic effects. Thus, the combination of these technologies may define novel products, designs and services contributing to higher customers' acceptance of electrified vehicles.

On the other hand, concerns exist over potential rebound effects: High-degree automation of vehicles may lead to a more intense use of them and thus increase the energy needs even though the technology is more efficient. Along these lines, concepts of sharing economy not just provide new market opportunities for the merging automotive and IT sectors, but also offer ways to compensate negative effects of a higher mobility demand. In order to discuss opportunities and challenges of electrification in combination with connectivity and automation of road vehicles, and particularly to exchange information about the implementation of related innovation funding programmes, Task 29 was launched by the HEV TCP.

8.2 Objectives

Task 29 focuses on the following objectives:

- Analyze the potential technological synergies of electrification, connectivity and automation of road vehicles and derive research, development and standardisation needs.
- Study the business models by combining electrification and connectivity/automation of road vehicles with concepts of sharing economy and identify action fields for companies and/or governments.

- Asses the impact of user/driver behavior on the combination of electrification, connectivity and automation and conclude on needs for measures in awareness and legislation.

The participants of Task 29 particularly aim to understand the impact that the topic has on innovation policy, i.e. roadmaps, funding programmes and regulations.

8.3 Working Method

Task 29 is organising a series of expert workshops scheduled in conjunction with dedicated conferences. The workshops gather a variety of stakeholders coming from academia, industry, and public authorities. The purpose is to identify trends and scenarios, to analyze challenges and opportunities, and to deliver conclusions for future actions. Moreover, the exchange of information about the impact on research funding policies and on regulatory actions shall be fostered. The actual activities are aligned to the interests of the Task participants, including the member state representatives, as well as the industries and R&D centers involved in the Task. The results of the Task 29 meetings will be presented in form of a report and a roadmap. It shall be made available as a book.

8.4 Recent Advancements

On 6 December 2018, Task 29 organized an expert workshop on "Synergies of Automated Driving and Electric Mobility" in Berlin, Germany. The workshop covered programmes, strategies and projects of research and innovation linking automation and electrification, and provided an opportunity to discuss best practices and lessons learned.

As Task 29 is particularly aiming to understand the synergetic potential of combining the topics in research and innovation funding programmes, the workshop was opened with presentations on Austrian and German innovation policies.

For Austria, Walter Mauritsch of AustriaTech on behalf of the Ministry for Transport, Innovation and Technology (BMVIT) presented measures for the promotion of alternative propulsion systems and fuels as well as the new Austrian Programm on Automated Mobility 2019-2022. According to his presentation, an automated electric fleet would be expected in the future, since the EV is more reliable as it has a lot less moving pieces compared to an internal combustion engine vehicle while an autonomous car needs more electrical brainpower to manage the vision, guidance and mapping technology. Also, an overall optimisation of the whole mobility system would become possible this way.

For Germany, Cornelius Schuberth of VDI/VDE-IT spoke on behalf of the Federal Ministry of Education and Research (BMBF) on the funding activities on enabling technologies for the automobile in the context of the Framework Programme Microelectronics 2016-2020. He also introduced the Government Programme on Electric Mobility and the Government Strategy on Automated and Connected Driving. Moreover, he explained that the synergies of the two thematic fields had been covered in recent calls for proposals such as Auto-Dis and Elektronom.

Complementing government policies, industrial innovation activitites were presented by Kerstin Mayr (Bosch) on behalf of the eNOVA Strategy Board Automobile Future and Gereon Meyer (VDI/VDE-IT) for the Lighthouse Mobility.E of the European Joint Undertaking ECSEL on electronic components and systems.

To illustrate the funding activities, five projects were presented: Alp.Lab, Digibus Austria, and Via-Autonom from Austria, as well as KLEE, and UniCarAgil from Germany. UniCarAgil, e.g., is clearly showing the potential synergies of electrification and automation at both levels, the electric and electronic architecture and the application: It shall combine modular structures for agile, automated vehicles with disruptive concepts in hardware and software architecture and a modular platform with dynamic electric modules. At the end of the project, four prototypes with different characteristics shall be presented, ranging from a delivery van to an on-demand shuttle.

Finally, Sven Beiker from Silicon Valley Mobility, USA, addressed the question whether an autonomous car will automatically be an electric car by considering two persepctives:

(i) Benefits of electrification for autonomous functionality:

- Electric drive systems are easy to control electronically
- Abundant electrical power supports steer / brake by wire and processing
- Abundant electrical energy supports software updates while parked
- Electric vehicles have a lower total cost of ownership (TCO), which matters in autonomous / shared pods

(ii) Benefits of automation for electric vehicles:

- Autonomous drive can proceed to charging without human interaction

At the same time, Sven Beiker admitted that from his perspectives the strongest link would be that both trends happen in the same time frame, i.e. in a transition over the next 20 years. Synergies resulting from the coindicence might be manifold and cover not just technology, but also corporate strategies, use cases and regulation.

In the next step, Task 29 is planning to assess the synergetic impacts that have been achieved and still can be expected from combining the electrification and automation of vehicles in the innovation strategies and funding programmes at the level of the European Union, e.g. in to the context of the Lighthouse Mobility.E.

8.5 Financing and Sponsorship

Becoming a member of Task 29 is free of charge. Please contact the Operating Agent for more information.

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9 Assessment of Environmental Effects of Electric Vehicles (Task 30)

Members: Austria, Canada, Germany, Spain, Republic of Korea, Turkey, United States

9.1 Introduction

Electric vehicles have the potential to substitute for conventional vehicles to contribute to the sustainable development of the transportation sector worldwide, for example, in the reduction of greenhouse gas (GHG) and particle emissions. There is international consensus that the improvement of the sustainability of electric vehicles can only be analyzed on the basis of life cycle assessment (LCA), which includes the production, operation, and the end-of-life treatment of the vehicles and the fuel cycle (Figure 1). All environmental impacts must include the whole value chain and – if relevant – interactions from recycling in the dismantling phase to the production phase, if recycled material is used to produce new vehicles.

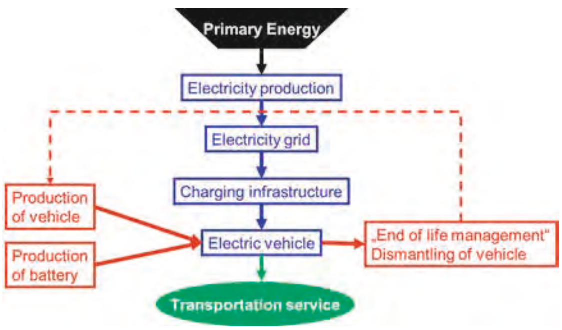

Figure 1: System boundaries for life cycle assessment of EV

9.2 Objectives

The aim of Task 30 (2016 – 2020) is to analyze and assess environmental effects of electric vehicles (EVs) on water, land, resources, and air – based on life cycle assessments in a cooperation of the participating countries in the International Energy Agency (IEA).

Task 30 is using the results of the completed Task 19 "Life Cycle Assessment of Electric Vehicles" (2011 – 2015, www.ieahev.org/tasks/task-19-life-cycle-assessment-of-evs/, led by JOANNEUM RESEARCH) as a foundation to subsequently examine the environmental effects – benefits and impacts – of vehicles with an electric drivetrain (EVs), based on life cycle assessment (LCA). With an eye on the three phases of LCA, such as production, operation and dismantling of EVs, various environmental effects of EVs on water, land, resources, and air, among others, will be analyzed and assessed. Thereby a strong accent is put on the comparison of environmental effects between pure battery EVs (BEV) and Plug-in hybrids (PHEVs) on one hand and conventional ICE vehicles using gasoline and diesel on the other side.

In recent years the focus in environmental assessments of electric vehicles was on global warming and primary energy consumption. But now it is recognized that other impacts gain additional relevance and must be addressed by life cycle based comparisons like water, land use, resource consumption, local PM and NO_x emissions. Therefore, Task 30 will focus on the following topics covering methodologies, data, and case studies:

- Effects of EVs on water (emissions to water, waste water, "Water Footprint" of EVs)
- Effects of EVs on air (local emissions and effects of NOx, PM and CxHy, human health effect and non-energy related emissions from tires and brakes)
- Effects of EVs on land use, resources, waste (land use, occupation and degradation, demand of renewable and fossil resources, recycling)
- Overall environmental effects and their assessment (comparing and assessing different impact categories, single score methodologies, stakeholder involvement).

9.3 Working Method

Within the Task, methodologies for helping countries implement EVs by identifying possibilities to maximize the environmental benefits will be developed. Besides, various case studies will be analyzed and networking combined with information exchange will be supported within the Task's frames (Figure 2). The Task will proceed by holding a series of expert workshops addressing the following objectives:

- Methodologies on assessment of environmental effects
- Analyses of necessary and available data
- Overview of international studies/literature
- Analyses of current knowledge and future challenges
- Overview of key actors and stakeholders and their involvement

- Communication strategies to stakeholders
- Summarizing further R&D demand

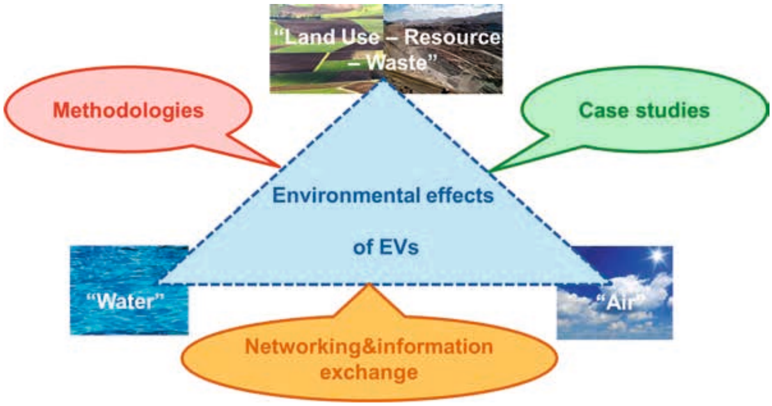

Figure 2: Working method in Task 30

9.4 Results

9.4.1 Expected Final Results

Members in this Task will compile a list of environmental benefits and impacts of EVs with the goal to increase their overall acceptance by providing facts and figures on the environmental effects of EVs. Thus, numerous advantages of EVs compared to conventional vehicles will be shown. These results should help the industry and government to support further development and employment of EVs in all transport modes. The results will document and summarize the state of current knowledge and future challenges (incl. methodologies and case studies) on

- Effects of electric vehicles on water
- Effects of electric vehicles on air
- Effects of electric vehicles on land use – resources – waste
- Overall environmental effects and their assessment of EVs
- R&D demand

In addition to these technical and scientific results a glossary on "Frequently asked questions" (FAQ), a framework for communication strategies to stakeholders and dissemination activities (e.g. proceedings, reports, papers, notes, presentations) will be available.

9.4.2 Results on Water Issues

In January 2017, Task 30 held an expert workshop on the environmental effects of electric vehicles (EVs) on water, energy consumption, and air emissions based on life cycle assessment in Graz/Austria. The aim of the workshop "Environmental Effects of Electric Vehicles (EV) – Water Issues and Benefits of EV-Fleets on Energy Consumption and Air Emissions " was to present and discuss the current status and the future perspectives of the environmental performance of electric vehicles in comparison to conventional vehicles with an internal combustion engine (ICE) in a life cycle perspective.

In an interactive group work the following key issues were discussed, summarized and documented:

- Main drivers
- Water inventory
- Most relevant water issues for LCA of EV and ICE (Figure 3)
- "Water footprint"
- Water issues in electricity production
- Water issues in value chain of EVs and ICE
- Research questions on water issues & EVs

The possible next activities of the HEV TCP Task 30 might be on the following activities:

- A report giving a summary of the current state of knowledge on water issues in the LCA of EVs covering
    - methodological aspects
    - data issues
    - case studies comparing EVs and ICEs
    - further R&D demand
- Collection and compilation of water consumption (WCF) of global electricity production to analyse and assess water consumption of current global EV fleet. This might than be included in the FACT SHEETS for the HEV TCP countries and worldwide.
- Screen methodologies, data and case studies to expand analyses and assessment to include
    - stress index (or other kind of index) by region/scenario
    - impact assessment (e.g. water quality, thermal pollution, etc.)

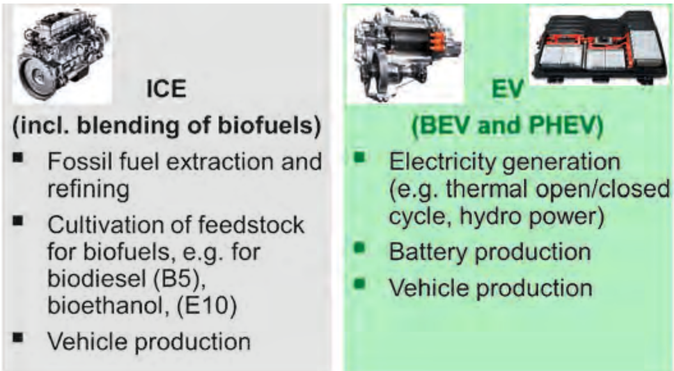

Figure 3: Main water issues in LCA of ICE and EV

9.4.3 Results on Effects on Air

In September 2018, Task 30 held an expert workshop on emissions to air in the LCA of electric vehicles in Stuttgart, Germany. The aim of the expert workshop of Task 30 was to analyse and assess environmental effects of electric vehicles (EVs) on emissions to air based on life cycle assessment in a cooperation of the participating countries in the International Energy Agency (IEA).

The aim of the workshop is to present and discuss the current status and the future perspectives of emission to air in the LCA of Electric Vehicles in comparison to conventional vehicles with an internal combustion engine (ICE).
In a group of relevant stakeholders from government, industry, research, and NGOs the relevant issues of effects on air emissions were identified and discussed referring to the ongoing large scale market introduction of EVs.
The summarized results of the workshop are the following:

- The main air emissions analysed in the inventory (LCI) and assessed (Impact Assessment) are CO_2, NO_x, SO_2, CO, PM and CH_4 and N_2O.
- The main sources of these air emissions in LCA of EVs and ICEs are
  - ICE-vehicle
  - PHEV-vehicle
  - Thermal power plants providing the electricity for the EVs and
  - Oil refineries to convert raw oil to gasoline and diesel
- These mains sources of air emissions must be documented in the foreground data in the LCA (beside the energy consumption of the vehicles) explicitly to allow better communication and comparison of the LCA results.

- The main impacts directly related to these air emissions are
  - Global warming potential in CO_2-equivalent (CO_2, CH_4, N_2O)
  - Acidification in SO_2-equivalent (NO_x, SO_2)
  - Ozone formation in C_2H_4-equivalent, CH_4, NO_x, CO, (NMVOC)
- The Canadian Case Study also assessed Human health (DALY) and Ecosystem Quality (PDF m² year).
- The air emission of ICE and PHEV vehicles should be derived from real world driving conditions including user behaviour and climate conditions reflecting the cooling and heating demand in different regions/countries.
- Most LCA studies presented comparing EVs and ICE vehicles mainly analyse and assess greenhouse gas emission and primary energy demand, only few studies also assess other impact categories, e.g. air emissions.
- The emission associated with the production and end of life of the automotive batteries are very relevant issues, whereas currently the “generally accepted” GHG emission are 175 (150 - 200) kg CO_2-eq/kWh (ivl 2017, ICCT 2018) and referring to about 35 g CO_2-eq/km (ICCT 2018) (Figure 4).
- Other air emission from battery production where not presented.
- As the development of automotive batteries is very quick and innovate as well as the mass production of automotive battery production is starting these days, no average new data on battery production based on material demand and energy demand for cell and system assembling were presented.
- The end of life (EoL) of automotive batteries might become relevant for the impacts of battery production. Two different EoL strategies are discussed, the materials recycling and the second use in a stationary application. Generally it is not expected that the direct use of the old automotive batteries (< 80 % SOC) for stationary application e.g. storage for PV plant) will gain commercial interest. A commercial business case could be to disassemble the cells and use the “best” cells to make a new stationary battery to give adequate warrantee.
- For the LCA of batteries the EoL might have significant influence in the case of second use, as a significant part of the impacts of battery production might be allocated to the automotive and the stationary use, e.g. allocated according to the total electricity throughput in these two applications. The case of material recycling might not affect the total impact of automotive batteries significantly as the increasing amount of battery production volume requires big amounts of primary materials while the recycling material is still limited to the small number of used automotive batteries available for recycling.

- The general results of the LCAs comparing ICE and EVs show the following:
  - If the BEVs use a high share of renewable electricity the impacts on air emissions are significantly lower than from ICE.
  - Beside using renewable electricity the impacts of PHEV strongly depend on the share of electric driven kilometres. In purse electric mode the PHEV has similar impacts as the BEV. In combustion mode the impacts of a PHEV are more or less equal to an ICE or an HEV.
  - If the electricity used for the EVs has a high share of fossil based electricity the impacts of the EVs are similar to the impacts of an ICE.
- Modelling can also be done using dynamic LCA data on electricity production in order to determine CO_2-eq e.g. per half hour interval due to electricity production. This can help to set policies considering not only the supply and demand of electricity, but also for charging the vehicles when renewables are supplying electricity to the grid.
- Currently the LCA based comparison of EVs and ICE is done for single vehicles, whereas now first application of LCA to whole fleets of vehicles become relevant, e.g. when modelling future scenarios to fulfil PARIS targets (single vehicle vs. vehicle fleets).
- In applying LCA to vehicle fleets the questions of really substituting ICEs by EVs become ever more relevant. It is observed that the global, national and regional vehicle stocks of ICE are still growing while also the stock of EVs is growing, even much faster than those of ICEs. Additionally it is observed that EVs become also the second and third vehicle in households. So for LCA used in scenario analyses or for whole fleets of vehicles these developments mean that maybe in reality not each new EV substitutes an ICE. These effects are called “(direct) rebound effects”.
- For applying LCA to EV fleets compared to IE fleets a methodological approach must be developed to integrate possible rebound effects in the LCA methodology, e.g. that 1 km driven by an ICE is not 100 % substituted by an EV.
- The methodological combination of LCA with scenario analyses will become interesting in future in which a burden shifting from transport sector in the electricity or industry sector becomes relevant and must be shown explicitly. There is also the possibility of using consequential LCA analysis to model this effect.

In the workshop the key issues on “Emissions to Air in the LCA of Electric Vehicles” were identified and discussed.

These six key issues were grouped as follows:

- Manufacturing of vehicle and battery
- Vehicle operation
- Electricity for EVs
- End of life (EoL) of batteries
- Battery characteristics
- Data availability and quality

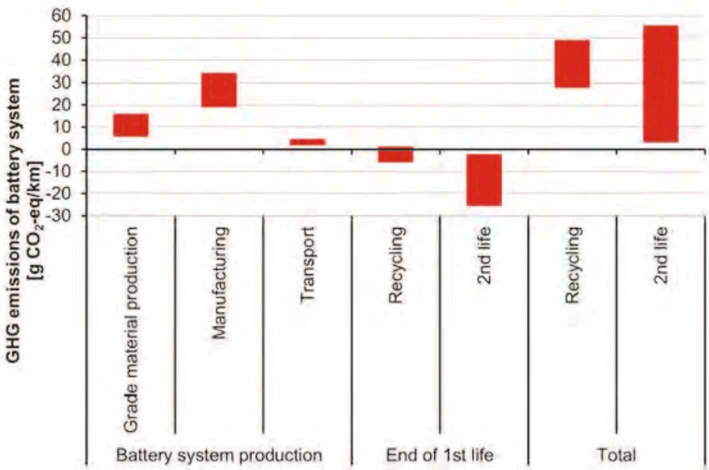

Figure 4: Ranges of GHG Emissions from Battery System per km

The details collected and discussed on these 6 key issues were:

- Manufacturing of vehicle and battery
    - Air emissions of (future) battery production
    - New inventory data on battery production
    - Energy demand of battery production
    - Vehicle manufacturing
    - Impacts of mining the materials
- Vehicle operation
    - Use and document real world energy consumption and emission data for ICE, BEV and PHEV
    - Non GHG gases
        - Function of exhaust gas treatment
        - “non linearity”
        - Dependent on conditions

  - Influence of user
    - Driving profiles
    - Charging behaviours
    - Thermal comfort
    - Rebound effects
  - Influence of climate (cold weather can decrease battery efficiency, hot weather can cause faster battery degradation)

- Electricity for EVs
  - Reliable air emission data of electricity generation today and in future
  - Air emissions of renewable electricity generation mainly based on material used
  - Electricity generation mix and future developments
  - Influence of flexile charging (mix versus marginal)
  - Regional dynamic grid mix
  - Handling of import and export of electricity in region/country
  - Include storage for renewable electricity (esp. PV and wind)

- End of life (EoL) of batteries
  - Recycling vs second life
  - Assessing second use and recycling
  - Estimation on influences of EoL for vehicles and batteries on LCA comparison

- Battery characteristics
  - Energy density of battery
  - Battery life time

- Data availability and quality
  - ICE and PHEV: NO_x, PM, C_xH_y
  - Thermal power plants: NO_x, PM, C_xH_y, SO_2; share of heat use in CHP plants
  - Pre-chain air emissions, e.g. steel, lithium, aluminum, copper
  - Indicators for data quality
  - Data availability: how to close data gaps

In the workshop the following future developments in the LCA of EVs were identified and discussed:

- Air emission of ICE, PHEV, power plants and refineries must be foreground data

- Are there any other relevant air emissions beside NO_x, SO_x, CO, PM?
- Find and define reasonable ranges for air emission in LCI and LCA
- Consider regional and seasonal differences of vehicle operation and electricity
- Where is or might be a problem of air emission with EVs? Possible solutions
- Parameters to decide on electricity generation for EVs
- Criteria to decide on marginal vs current/future electricity grid mix
- System boundaries with or without second battery life as energy storage
- Consideration of building new infrastructure (macro level vs functional unit level) (charging infrastructure)
- Criteria to include or exclude impacts from road infrastructure
- Impact assessment of GHG emission with CO_2-eq or contribution to the future increase/decrease of global temperature
- Systematic description of results showing the shares of emissions of sectors and countries: Burden shifting between countries and between sectors
- Possible rebound effects and influences on LCA results – new functional unit
- Time effects in LCA: changing of electricity mix during lifetime of EV
- Develop LCA methodology to be applied for vehicle fleets and identify differences to "single vehicles"

9.4.3 Estimated Environmental Effects of Worldwide EV-Fleet

Since 2014, the Task estimates the LCA based environmental effects of the worldwide electric vehicle fleet in 35 countries. In the LCA of these vehicles using the different national framework conditions, the environmental effects are estimated by assessing the possible ranges of greenhouse gas emissions (CO_2, CH_4, N_2O), acidification (NO_x, SO_2), ozone formation (NO_x, CO, NMVOC, CH_4), particle matter (PM) emissions and primary energy consumption (total, fossil, nuclear, renewable) in comparison to conventional ICE vehicles. The system boundaries chosen are shown in Figure 2. As the key parameters influencing the environmental effects of vehicles with electric drivetrains are the electricity demand per distance travelled and the mix of technology for electricity generation.

The analysis is done for each of the 35 countries separately and the main country specific results are summarized in a "Country Factsheets on Estimated Environmental Impacts of Current EV-Fleet" documenting

- "BASIC DATA" on electricity and electric vehicle fleet
    - share of national electricity production

- estimated environmental effects of electricity at charging point
- development national electricity market (incl. import&export)
- electric vehicle fleet: number of BEV and PHEV

• "Estimation of LCA based ENVIRONMENTAL EFFECTS" by substituting conventional ICE

- absolute annual change
- relative annual change (Figure 5)

The updated assessment for 2014 to 2018 is available in summer 2019.

Generally it can be observed that the share of fossil produced electricity has a substantial influence on the emissions. In countries with a relatively high share of renewable or/and nuclear electricity, the estimated emission reduction is significant (e.g., NO, FR, AT) whereas in countries with a relatively high share of fossil electricity, an increase of emissions occur (e.g., PL, CN).

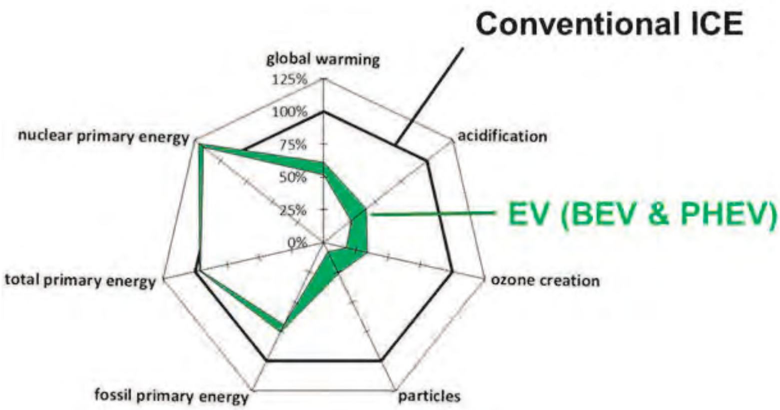

Figure 5: Estimated change of environmental effects of EV fleet compared to substituted ICE fleet in Austria

The main conclusions of the environmental assessment of EV fleets based on Life Cycle Assessment compared to conventional vehicles are:

• The results show that the environmental effects depend on the national framework condition, e.g., national electricity generation. In most of the countries, a significant reduction of these LCA based emissions of up to 90 % is reached.

• The broad estimated ranges are mainly due to variation in:

- Emissions of national electricity production
- Electricity consumption of EV fleets at charging point
- Fuel consumption of substituted conventional ICEs
- Data availability, uncertainty and consistency

- Additional renewable electricity with adequate charging maximizes environmental benefits
- Adequate loading strategies to optimize the use of renewable electricity are essential for further significant reductions

9.5 Next Steps

The next workshops are scheduled as follows

- "Effects of EVs on Land Use – Resources – Waste" & incl. special topic: "LCA of Autonomous Vehicles", 13/14 June 2019, collocated with the Annual Merit Review in Washington DC (USA) organized by ARGONNE
- "Overall Environmental Assessment of EVs", April – May 2020, Barcelona (Spain) organized by IREC

The dissemination activities are:

- Paper & presentation: *LCA Based Estimation of Environmental Effects of the Global Electric Vehicles Fleet - Facts&Figures from the IEA Technology Collaboration Program on Hybrid&Electric Vehicles*, Transport Research Arena TRA 2018 in Vienna, Austria, 16-19 April 2018
- Paper & presentation: *Water Issues and Electric Vehicles - Key Aspects and Examples in Life Cycle Assessment*, EVS31 – Electric Vehicle Symposium, Kobe, Japan, 3 September to 3 October 2018
- Poster: *Environmental Effects of Electric Vehicles Globally - An Assessment in HEV TCP Task 30*, A3PS Conference 2018 "Future Propulsion Systems: Different Regions - Different Strategies - Different Solutions, 12-13 November 2018, Vienna, Austria
- Presentation: *Evaluation of the Environmental Benefits of The Global EV-Fleet in 40 Countries – A LCA Based Estimation in HEV TCP*, EVS32 – Electric Vehicle Symposium Lyon, France, 19-22 May 2019
- Presentation: *Time and Rebound Effects in the LCA of Electric Vehicles - Methodological Approach and Examples*, IEWT 2019, Vienna University of Technology, 13-15 February 2019

Acknowledgement
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10 Small Electric Vehicles (Task 32)

Members: Belgium, Germany, Republic of Korea, Switzerland, United Kingdom

10.1 Introduction

Pressure on reconsidering transport options is increasing. Growing global population, a global motorization rate that rose by 27 % between 2005 and 2015 , progressing urbani-zation, problems related to climate change and limited resources result in the need to use available space, material, and energy most efficiently. Global emission targets quantify the need to reduce emissions and require innovative mobility solutions. Small electric vehicles (SEV) could effectively support reaching the targets. The variety of SEV models has increased in recent years, including few models from established OEMs (e. g. Renault Twizy, Toyota i-Road) as well as many models offered by small companies (e. g. Tazzari EV Zero City, Clean Motion Zbee). However, SEVs still constitute a very low share of the existing vehicle fleet and vehicle registrations.

Small electric vehicles considered in this Task include three- and four wheeled vehicles that are propelled by a locally emission free technology and are classified in one of the L-categories L2, L5, L6, and L7 according to UNECE Regulation . The task additionally comprises locally emission free vehicles that do not exceed 3.50 m, a maximum drive power of 55 kW and an unladen weight up to 1,200 kg. Examples for this type of vehicle would be the Smart fortwo ED or Mitsubishi i-MiEV.

10.2 Objectives

The objective of this Task is to promote a broader commercialization, acceptance and a further development of SEVs by collecting and sharing pre-competitive information, exchange about framing conditions, best practices and ideas, how to develop the market conditions and mobility concepts further. In this sense, the objectives in short are two-fold:

1. Increased safety, comfort and usability at lower costs for SEVs due to techno-logical progress.

2. Better market perspectives for SEVs due to a change in surrounding conditions such as regulations, transport policies and mobility concepts.

The key aspects are SEV concepts, status of technologies and needs for research as well as the conditions to put them on the market. Apart from the vehicles themselves, the focus is on the potential future role of SEVs in advanced mobility concepts, including e. g. their role in concepts of sharing, increased automation and new public transport.

10.3 Working Method

The main approach of Task 32 is to collect and exchange information in workshops aimed at professionals from research, enterprises and policy makers, depending on the individual topics. The topics and the individual orientation of the workshops will be decided by the Task partners. The concept of presentations from individual stakeholders together with more interactive parts has proven to be attractive. Individual meetings / workshops might be handled confidential if asked for by participants.

While the Task partnership could constitute from academic institutions, NGOs or policy makers, contributions from industry and the participation in workshops is explicitly welcomed.

In addition to the workshops, information can be gained by surveys and special sessions at conferences to gather interested stakeholders and exchange knowledge.

The results of the Task are shared with the public as agreed with the workshop partici-pants. The presentations and discussions within the workshops are shared by the partici-pants. Verbatim quotes from company representatives can be excluded by gentleman's agreement. Publications are in the interest of the participating researchers. The papers and presentations will exclude confidential and/or non-official statements. A final report summarizing the overall results of the Task will be prepared by the operating agents with the contributions from the partners.

Workshops

Two workshops are organised with a focus on "vehicle concepts and technologies of SEVs", one in Europe and one in Asia or North America. One or two workshop(s) are organised with a focus on "market conditions for SEVs". One workshop will be organ-ised with a focus on "mobility concepts and SEVs".

Public Outreach

A flyer is prepared which presents the Task. Results will be published by writing papers, providing presentations, offering webinars or attending conferences, according to indi-vidual expectations of the Task partners. A final report will provide a compilation of material elaborated during the three years project duration: presentations and conclusions of the workshops, conference contributions and scientific publications.

The Task is based on a work sharing principle and in kind contribution is expected.

10.4 Results

The **first workshop** "Differences in worldwide regulations for SEV: problems and options for improvements" (Focus L7) was held in Rüsselsheim (Germany) on 1 December 2016 at the Opel Training Center. Experts from OEM and research institutions from Germany, Switzerland, Belgium, United Kingdom, and South Korea joined the workshop. Topics presented and discussed at the workshop were:

- RAK e: A concept SEV from Opel
- EU regulations relevant for small 4-wheeled road vehicles
- Kyburz - company and concept presentation
- Twike - company and concept presentation
- Safety aspects of SEV
- Homologation of L7 in South Korea

Participants discussed and exchanged knowledge in a workshop session on the topics of main difficulties in homologation and options for improvement.

The **second workshop** "Market Conditions and Mobility Concepts" took place in Brussels, Belgium, on 18 September 2017 at the German Aerospace Center (DLR) Brussels Office. The main topic of the workshop was the exchangeof information on common interests and future activities of SEV lobby organisations and key stakeholders.

The **third workshop** "Accelerating SEV uptake, is present diversification in regulatory requirements in different markets a positive attribute or is harmonisation required?" was held in Rotterdam, the Netherlands, on 20 November 2017. The workshop focussed on vehicle manufacturers from six European countries and one from the United States. Amongst the main conclusion especially on ultra-lightweight vehicles were:

- The regulation was the primary focus as well as the in-use phase

- Consensus that there is limited consolidation in this area and this is detrimental
- Attendees look for support to understand how the regulatory landscape will develop
- Requirement for comprehensive assessment of regulatory landscape.

From March to October 2018 a **survey consisting of interviews and an online questionnaire** were conducted, acquiring qualitative and quantitative data about the following main topics:

- Knowledge about SEVs
- Target Groups and Usage Concepts
- Obstacles and Chances.

The survey collects assessments of international experts from municipalities, research institutes, consultants, associations and manufacturers. We held 32 interviews and received answers from a total of 90 participants from Asia, USA and Europe in the online questionnaire.

Taking into account the barriers to market acceptance, the lack of a dedicated transport infrastructure is the most critical aspect. An appeal can only be made by measures such as separate lanes or access to restricted traffic zones in order to create an advantage over cars. Furthermore, the lack of knowledge about SEV within the urban population is a major factor to overcome and goes along with the small variety of models to choose from compared to cars. Another important aspect is safety, as the requirements for type approval are low and no crash tests are required.

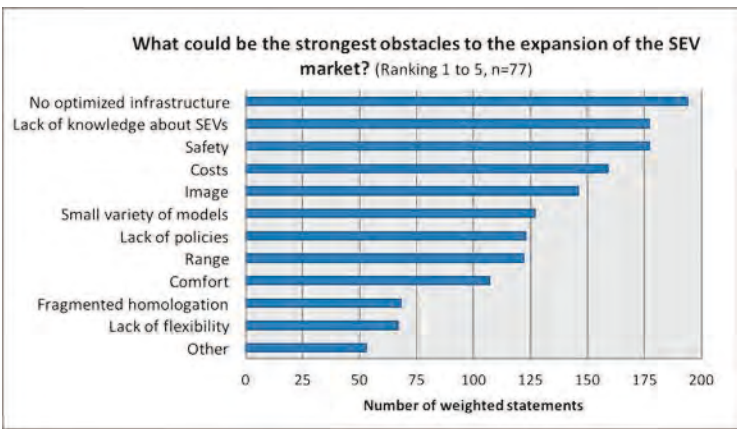

Figure 1: Obstacles to a market uptake of SEV

Overall there are a number of hurdles that stand in the way of a wider market acceptance. However, they indicate that there are measures to foster SEVs in municipalities especially with the help of public bodies. Therefore, charging and transport infrastructure including parking management are seen as the most effective ways to achieve good results. In addition to incentives, however, restrictions on the use of larger vehicles must also be created (see Figure 2). Ultimately, only a combination of various measures leads to a promising outcome.

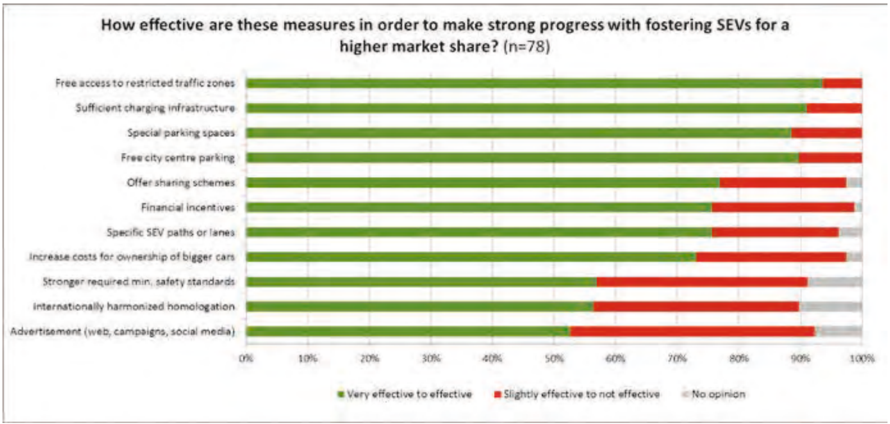

Figure 2: Measures to foster SEV

10.5 Next Steps

- Development of a database with L-category regulation
- Next workshop about "Policies for mobility concepts with SEVs: viewpoints of cities and municipalities, mobility planner and regulators" is planned to take place at the 'micromobility expo' in Hannover, Germany beginning of May 2019.

The dissemination activities were:

- Presentation: Prospects for Small Electric Vehicles (SEVs) in the Transition of Urban Mobility Concepts, AEC 2018 - Avere E-Mobility Conference, Brussels, Belgium, 17-18 October 2018.
- Presentation: TCP Hybrid and Electric Vehicles - Small Electric Vehicles: Regulations and Opportunities for Improving Market Uptake, Low Carbon Vehicle 2018, Millbrook, United Kingdom, 12-13 September 2018.
- Presentation and Conference Paper: "Small Electric Vehicles" – A new Taskforce by IEA Hybrid & Electric Vehicle TCP, 1st World Light Electric Vehicle Summit, September, 2016.

10.6 Contact Details of the Operating Agent

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11 Battery Electric Buses (Task 33)

Members: Austria, Canada, Finland, Germany, Republic of Korea, Spain

11.1 Introduction

Battery electric bus systems have gained increasing attention in recent years. Several cities and urban bus operators aim to electrify bus fleets partially /completely in the near future. Recent developments show that new charging strategies and advanced energy storage technologies enable full-day operation of electric buses, e.g. using the opportunity of fast charging concepts. Significant cost reductions are expected due to technology standardization and economies of scale. More than 20 bus producing companies in Europe already offer various types of electric buses. Main bus companies intend to start electric buses in serial production soon, because battery electric bus systems have the potential to substitute diesel buses in cities soon.

Numerous innovative projects were initiated in recent years, especially in central European countries, from pilot projects towards commercial use (e.g. Geneva, Amsterdam, Helsinki). They are testing and demonstrating various types of electric buses, charging methods and strategies as well as energy storage systems. Based on the daily collection of experiences in operating battery electric buses an evaluation and analysis of key aspects of worldwide electric bus projects (e.g. charging strategies, electric energy storage systems) is ongoing. Urban public transport is the promising sector for the implementation of electric buses due to its structured system layout, professional line management and synergies to existing electric infrastructure.

Figure 1: Electric bus at charging station in Graz (Source: Graz Holding Linien)

11.2 Objectives

The objective of Task 33 (2016 – 2019) is to analyze and assess the current state of technology & demonstration experiences of battery electric buses towards a broad market roll out. This on the one hand covers the bus technology e.g. battery or capacitor system, and on the other hand the charging infrastructure, e.g. fast charging stations at the bus stop and its optimal integration in an urban infrastructure, e.g. synergies with trams, metro or trolley bus systems. The task work is done based on an analysis of ongoing demonstration projects of battery electric buses worldwide. Based on this, the future perspectives and challenges for battery electric buses are analysed and described. This includes the identification of major challenges e.g. technology, costs, public acceptance and the necessary R&D demand. Finally the key aspects for a successful broad introduction of battery electric buses and the necessary framework conditions are concluded.

The work is done in close cooperation of the relevant stakeholders from the three focus groups:

1. Providers of public transportation services
2. System and technology providers
3. Research institutions.

The results are continuously documented and disseminated via presentations, workshops, conference contributions and publications.

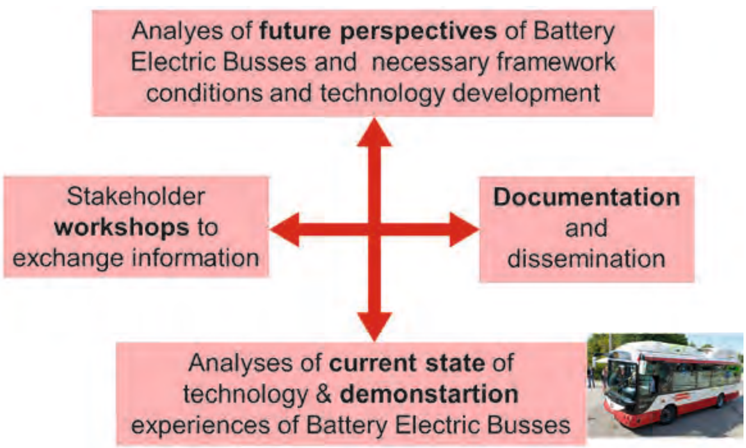


Figure 2: Objectives of Task 33 – scheme

The major activities are:

- Identify &analyze state of technology and systems of battery electric buses
- Collect and document „International Success Stories“ in a common format
- Give overview of systems &technology providers with characteristic data
- Stakeholder involvement in 2 - 3 workshops in combination with site visit
- Analyze combination of trolley and battery bus systems
- Integration and use of existing infrastructure of trams, trolleys, and metro
- Identify success factors, e.g. size of bus, distances between bus stops
- Define loading strategies
- Analyze sustainability issues – economic, environmental &social aspects
- Identify R&D demand
- Conclude and summarize future perspectives
- Presentations and contribution at conferences.

11.3 Working Method

The most important activity of the working method is the organization of workshops in different member countries to involve the stakeholders in the value chain of battery electric buses, e.g. providers of public transportation services, system and technology providers, research institutions. The organization of workshops with participation from industry, research organizations, technology policy experts, and governmental institutions provides an international basis for the exchange of information on the relevant activities. The focus of the expert workshops is to analyze, discuss and document the

1. State of technology for battery electric buses
2. Future perspectives of battery electric buses

The workshops are combined with a site visit to an ongoing demonstration of battery electric buses in daily life application.

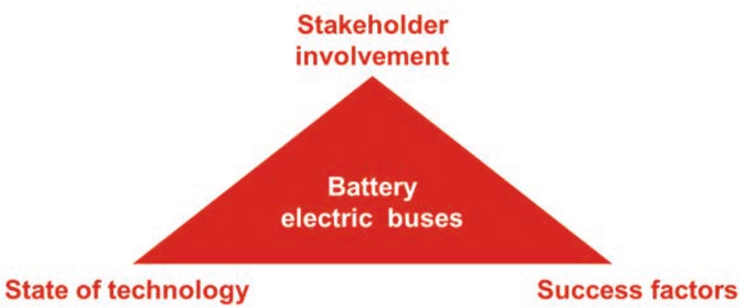


Figure 3: Working method

11.4 Results

In December 2018, Task 33 held the expert workshop "Battery Electric Buses – State of Technologies and Practical Experiences" in Helsinki/Finland. The workshop was organised in cooperation with

- IEA AMF Annex 53: Sustainable Bus Systems (https://iea-amf.org/content/projects/map_projects/53-1), and
- proEME – Promoting Electric Mobility Europe (www.pro-eme.eu).

The aim of the expert workshop of Task 33 was to analyse, discuss and assess the current state of technology of battery electric bus systems.

The main topics of the workshop were:

1. Charging technologies and strategies
2. Bus technologies
3. Environmental and economic assessment
4. Experiences worldwide.

to gain conclusion in group work on

2. State of technology of battery electric buses
3. State of technology of charging technologies and concepts
4. Identification of key aspects for battery electric bus systems.

The main results of the workshop are covering the following issues:

- European projects
- Current experiences
- Lessons learnt from demonstration
- Main charging strategies
- Manufacturers of battery electric buses
- Interoperability
- Heating and cooling
- Key performance indicators
- Additional indicators
- Hydrogen fuel cell bus
- Environmental effects
- Economic effects
- Main challenges for battery electric buses
- Strategy to have Zero-Emission public transport
- Rolling out phase
- Pilot Cities for rolling out battery electric buses
- Case City "Eindhoven".

In Europe the following **European projects** are most relevant in demonstrating and preparing the broad market rollout for battery electric buses in cities:

- ZeEUS – Zero Emission Urban Bus Systems (finished: http://zeeus.eu/)
- ELIPTIC – Electrification of Public Transport in Cities (finished: http://www.eliptic-project.eu/)
- ASSURED – boosting the electrification of urban commercial vehicles and their integration with high power fast charging infrastructure, evaluating several infrastructures in different cities across Europe (ongoing: https://assured-project.eu).

Currently there are three **main charging strategies** under demonstration and testing, whereas combinations are realised:

- Overnight (slow) charging in the depot, which requires buses with a high battery capacity (> 300 kWh)
- Opportunity fast charging at final stops
- Opportunity fast charging at intermediate stops, which needs the lowest battery capacity (< 100 kWh) but a highly developed charging infrastructure with adequate grid connection.

Figure 4: Geneva's high capacity eBus L23 (Source: tpg 2018)

Current experiences and assessments show no clear advantages or favour for one of these three charging strategies, as it totally depends on the local conditions of the line served and available infrastructure (e.g. bus depot, public space available for charging, battery costs and their future development, grid connection). In general it can be observed that there are more demonstration projects with opportunity charging at final or intermediate stops. In some cities battery electric buses using a range extender with hydrogen and fuel cells are under consideration also and tested to enlarge the driving range and limit the battery capacity.

The main **lessons learnt from demonstration projects** are:

- Gradual vehicle introduction depending on knowledge of public transport operator (PTO) and technology chosen to ensure service operation
- Paradigm shift: from vehicle procurement to system procurement
- Early stakeholder involvement in the planning, joint feasibility study
- IT supporting fleet monitoring to optimise operation
- Identification of main elements needed for "local" LCC (Life cycle cost) model
- Integrating e-bus services into the overall city transport decarbonisation/defossilisation strategy.

Some of the most relevant manufacturers of battery electric buses are: VDL, Van Hool, Solaris, BYD, Linkker, IRIZAR, SAFRA, VOLVO, Wrightbus, and DAIMLER.

The interoperability of future battery buses (of different brands) and charging infrastructure (of different suppliers) is essential for the future success and for taking the right investment decision. In 2019, an ISO Standard is expected which will guarantee the interoperability. The standard for inductive and wireless charging of electric buses should be agreed upon in late 2019.

Using the energy of the battery for heating and cooling might reduce the driving range significantly, therefore also diesel heaters are used as an interim solution for the transition period when electrifying bus fleets. New technologies are under development and tested, e.g. heat pumps.

The key performance indicators for battery electric bus systems are:

- Operating costs and energy consumption
    - Energy costs for driving (EUR / km): including electricity (from grid) and heater fuel
    - Operational driving distance (% / km): operational (on route) distance driven compared to the planned bus circulation
    - Total electricity consumption (kWh / km): totally charged external energy (from charger) / kilometres driven (both on route and total kilometers)
- Charging system performance
    - Time required positioning the bus at the charger (s): time to manoeuvre the bus to the charger (from arrival at the charger proximity to the point when the driver initiates the charging)

- Total charging time (s): charging duration per sequence step from the charging start command to bus being ready to leave
- Charging node utilization (%): time when the charging position is occupied / time available (time occupied includes the active and dead times)

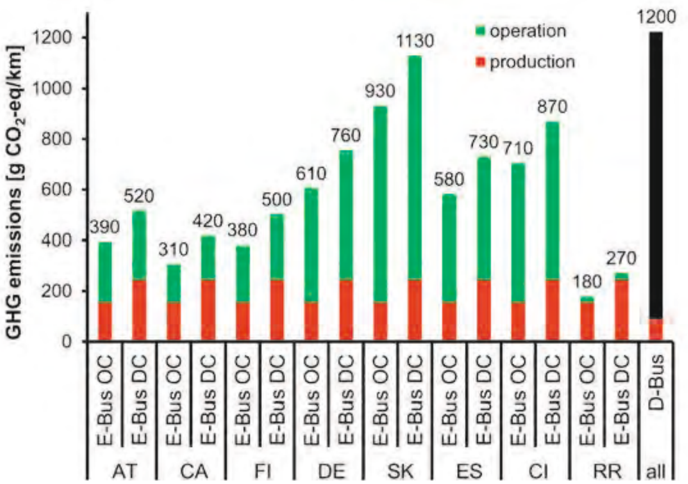
- System performance
  - Departure on schedule (%): percentage of departures on schedule
  - Availability of the vehicles (%): percentage of the time that the vehicles have been available for service
  - Availability of the infrastructure (%): percentage of time when charging service is available / calendar time.

As **additional indicators** the following are relevant:

- Powertrain electricity consumption (kWh / km): inverter consumed electricity / kilometres driven (on route)
- Heating electricity consumption (kWh / km): electricity consumed by the HVAC system (both on route and total)
- Auxiliaries electricity consumption (kWh / km): electricity consumed by other electric auxiliaries, such as power steering, air compressor and DC/DC (on route)
- Fuel consumption (l / h): fuel heater fuel consumption vs. temperature
- Charging efficiency (%): electricity from the grid / electricity into the battery
- Dead time in charging (%): dead time in charging / total charging time
- Battery efficiency (%): electricity out of the battery / electricity into the battery
- Total system energy efficiency (%): electricity out of the battery / Electricity from the grid
- Minimum SoC in operation: lowest battery state of charge in operation
- Average delta SoC in operation: estimate from operational data
- Battery health, SOH (%): Percentage of the remaining battery capacity vs battery nominal capacity.

A **hydrogen fuel cell** bus, where hydrogen is used in a fuel cell to provide the electricity is also a local zero emission bus. The main advantage of hydrogen fuel cell buses are the fast charging (about the same time as a conventional diesel bus), the similar driving range as a diesel bus and the use of the waste heat from the fuel cell for heating in winter time. The main disadvantages are currently the higher cost for the bus and the hydrogen infrastructure as well as the lower energy efficiency. In general it is expected that battery electric buses are relevant for intercity bus lines in urban areas with a limited driving range where fuel cell buses have the potential for long distance bus lines. The most relevant ongoing European hydrogen fuel cell demonstration project is JIVE – Joint Initiative for Hydrogen Vehicles across Europe (ongoing: https://www.fuelcellbuses.eu/projects/jive).

The **environmental effects** of battery electric buses can only be assessed on the basis of Life Cycle Assessment (LCA) taking the entire life cycle into account – production of the bus (incl. battery) and the infrastructure, operation of the bus including the supply of the electricity and the end of life management of the facilities, e.g. recycling, reuse. The environmental effects deriving from LCA must be compared to a diesel bus (and hydrogen fuel cell bus if of interest). The environmental benefits of battery electric buses can be maximised if additional renewable electricity is used and future battery production will be on high production capacity realising economy of scale efficiency potentials and using renewable energy. The current battery production mainly in Asia is associated with relevant GHG and fossil energy demand in the LCA of current bus systems. By using a high share of renewable electricity for battery buses the total GHG emission and fossil energy demand are significantly lower than diesel buses. And battery electric buses have no local emission (e.g. PM. NO_x) and contribute to the improvement of air quality in cities.



OC....opportunity charging; DC....depot charging overnight;
RR....Renewable Republic fictive country with 100% renewable electricity

Figure 5: Life cycle based GHG emission of battery electric buses in 8 countries with current national electricity mix compared to diesel buses

The **economic effects** must be calculated on the basis of total costs of ownership (TCO), whereas the investment costs for the buses, the charging infrastructure and the grid connection as well as the operating costs must be considered. The TCO of battery electric buses must be compared to current diesel buses. Currently the costs in €/km of diesel buses are generally about 20 % lower than of battery electric buses. Additionally it must be considered, if more battery electric buses are needed to provide the same service as with diesel buses. For opportunity charging possibly more time for the driver is needed, which might increase costs for the driver.

The **main challenges for battery electric buses** derived from various demonstration activities are:

- High upfront cost
- New challenging operations
- New ways to procure
    - Vehicles & charging equipment
    - Operation services
- Standardisation / Interoperability
- Reinforcing cooperation between electricity sector and bus operation.

After the successful demonstration of battery electric buses the **rollout phase** for battery electric buses is going to come, where some cities e.g. Amsterdam, Eindhoven, Hamburg, and Barcelona are taking the lead in Europe and Santiago de Chile in South America and Shenzhen in China.

Amsterdam and Eindhoven in The Netherlands are currently identified as the most advanced **Pilot Cities** in rolling out battery electric buses systems. In most of the cities, which plan a massive roll out of electric buses and charging infrastructure, there is a **strategy to have Zero-Emission public transport** in coming years which give a strong motivation for Public Transport Operators (PTO) to invest in battery electric systems.

The main characteristics of the battery bus system in the **Case City "Eindhoven"** are:

- 43 electric buses
    - 18m VDL Citea SLFA-E181
    - NMC batteries with 180 kWh
- Opportunity charging
    - 300 kW
    - Opportunity charging at bus depot: ~40 minute charge time

- Overnight charging
  - 30 kW
  - 4 to 5 hours
- Operational conditions
  - Line numbers: 400, 401, 402, 403, 404, 405, 406 and 407
  - Topology: City centre and suburban
  - Topography: Flat
  - Length: 4.4 – 12.3 km
  - Average commercial speed: 18.5 – 27.5 km / h
  - Total daily hours of operation: 20 h
  - Total km driven per day per vehicle: avg. 200 km, max. 300 km
  - Average number of passengers per day: 11,500 passengers per line
  - Factors for success
  - PTO got to keep ticket revenue
  - One company responsible for the whole bus system: vehicles and charging system
  - Very high system availability (over 99 %)
  - Good public reception: ”10 % increase in average ridership”
- Results and lessons learned
  - Battery temperature is an important parameter in fast-charging and air-cooled batteries
  - Driver training is important, especially with e-bus operations
  - Extend limited range
  - E-buses are so quiet that tram bell needed to warn pedestrians
  - Choosing best charging strategies require open mind-set
  - New heating strategies are being developed to improve fast-charging sessions
- Future plans
  - Development phase 2: adding 65 E-Buses during period 2019 - 2021
  - Development phase 3: adding 65 E-Buses during period 2022 - 2024
  - Charging facility expansion to further locations

11.5 Next Steps

The expert workshop „ Future Perspectives of Battery Electric Buses“ will take place in autumn 2019 and details will be made available via the HEV TCP webpage.

The workshop will focus on the following aspects:

- Key notes covering views from PTOs, bus manufacture s and charging infrastructure
- Future perspectives on Battery Bus Systems in urban environment
- Overall system of buses & charging technologies
- Lessons learnt from demonstration projects
- Market aspects: charging system and bus providers
- Economic aspects / TCO
- Environmental aspects
- Comparison to hydrogen fuel cell buses
- R&D demand
- Upscaling to large fleets e.g. electric grid connection
- Summarizing key issues incl. R&D demand
- Business models and procurement procedure

The dissemination activities are:

- Poster & paper: *Successful Demonstration of Battery Electric Buses Worldwide – A Game Changer in Urban Public Transport*, Transport Research Arena TRA 2018 in Vienna, Austria, 16-19 April 2018
- Participation in UITP-Training on *Electric Buses*, 2-4 July 2018, Cologne, Germany
- Poster: *Challenges of Battery Electric Buses - Assessment of Demonstration Activities in HEV TCP Task 33*, A3PS Conference 2018 "Future Propulsion Systems: Different Regions - Different Strategies - Different Solutions, November, 12-13 2018, Vienna, Austria
- Participation in ZEB 2018 - *Zero Emission Bus Conference*, 27-28 November 2018, Cologne,Germany
- Task 33 Working document: *E-Bus using Opportunity and Depot Charging in 8 Countries – GHG Emissions and Energy Saving Compared to Diesel Bus*

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11.6 Contact Details of the Operating Agent

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12 Batteries (Task 34)

Members: Canada, Germany, Sweden

12.1 Introduction

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 world-wide to develop higher energy density, abuse-tolerant and affordable batteries – i. e., batteries that would cost less, weigh less, last longer, avoid range anxiety, and lead to widespread electrification of the transportation sector.

12.2 Objectives

Task 34's goal is to encourage the sharing and dissemination of current information about battery topics of interest to the vehicle community.

12.3 Working Method

There are a large number of public meetings on batteries held every year. Most of these meetings follow the same general format: a series of speakers address the audience using set presentations. There may be time for short questions at the end of a presentation or a set of presentations. There is little or no time for an in-depth discussion of a topic by all those present. Because these meetings are public, speakers tend to avoid proprietary information. Presentations rarely include negative data or mention potential problems. For the battery community to stay abreast of the most accurate information on battery systems, there must be an opportunity for experts in the field to candidly discuss various battery topics, problems encountered, and potential solution approaches. These discussions must be honest and candid. These discussions must allow participants to express differences of opinion. To speak candidly, individuals must be comfortable that their comments will not be misquoted.

The primary focus of this Task is on collecting and reporting information on EV battery performance and cost state-of-the-art, and on R&D being conducted worldwide through country to country information exchange and public meetings.

12.4 Results

12.4.1 International Discussion on Lithium-Ion Battery Recycling

Over the past few years, the volume of EVs sold in the USA has steadily increased and all current projections indicate that this trend will accelerate. One of the consequences that accompanies this trend is the increased use of elements such as cobalt, nickel and lithium. Cobalt which is the majority element within the cathode for portable electronics, and a major component of EV batteries, is a limited-supply metal with an inherent price volatility. In vehicle applications, there are major efforts to reduce the amount of cobalt employed; current indications are that cobalt (~ 5-10 % by weight of the cathode) will be required for the near future. In addition, many of the other components of EV batteries are materials which require significant energy input to produce, refined metals, graphite and fluorine-based materials. With the continuing increase in the development and deployment of lithium-ion batteries the need for some form of recycling must be considered. Along with the need to preserve cobalt, there are environmental issues with the disposal of batteries in increasing numbers.

On 30-31 May 2018, the U.S. Department of Energy (DOE) and the national Renewable Energy Laboratory (NREL) sponsored an international discussion group of industrial experts at Golden, Colorado to consider options for battery recycling and to identify needs in a first step toward the development of a recycling roadmap. The workshop included battery and recycling representatives from the USA, China, South Korea, the United Kingdom, Australia, and the European Union. There were 41 participants present, including 15 industrial, ten national laboratories (US and International), six independent research organizations, five universities and five DOE attendees. The two days of the meeting were divided into short expert presentations followed by panel discussions.

The overall aim of the meeting was to gain information and insight on:

- Critical materials issues related to EV batteries
- The potential role of battery recycling to alleviate critical materials issues
- Policy landscape and regulations impacting battery recycling
- Current lithium-ion battery recycling methods and challenges
- Current R&D activities and identification of R&D gaps.

The workshop was broken into the following general sections: international perspectives, the policy landscape, stakeholder perspectives, and technical talks from researchers.

International Perspectives

At the beginning of the meeting, talks from the USA, UK, China, South Korea, Australia, and Europe provided a foundation as to the current and near future plans for lithium-ion recycling within each global region.

- David Howell (DOE) presented an overview of the *critical materials needs for EVs* and how DOE is approaching materials challenges such as cobalt and lithium as well as a historical account of the funded projects in the area of battery recycling.
- Paul Anderson (University of Birmingham) gave an overview of *the Faraday Challenge* which comprises a 246 million GBP commitment over the next four years to fully exploit the industrial opportunity of vehicle electrification through world-leading batteries which are developed, designed and manufactured in the UK. One of the four fast-start projects belongs in battery recycling and is considered a major thrust for the UK battery development strategy.
- *The China perspective*, presented by Qiang Dai (ANL), detailed the Chinese Government commitment, mandating that new EV manufactures will be responsible for the collection, sorting, transportation and storage of used EV batteries. This impetus has led to the formation of several battery recycling companies. Currently, most of the technology employed by the China-based recycling entities is using hydrometallurgical technology.
- *The Korean overview* was given by Dr. Yu-Tack Kim (Korea Battery Association) who informed that battery recycling is covered by *Extended Producer Responsibility* (EPR). The EPR mandates that producers and importers of products that fall under it must recycle a certain amount of wastes from products or packaging materials. He also described the current recycling options underway which include second life and hydrometallurgical battery recycling.
- Dr. Gavin Collis (CSIRO) described *the Australian position* on battery recycling, currently in its infancy, but recently gaining more attention with the development of a white paper report "*LIB Recycling in Australia*". Australia is projecting 135,000 tonnes/annum of lithium-ion waste by 2035. It does not have a significant battery manufacturing base yet, but is a major mineral supplier and recycled materials could be easily returned to this market. He then described an issue that became a major theme of the

workshop which was collection issues. Current collection rates for lithium-ion batteries are 1.8 % recovered with the remainder ending up in landfills.

- The final talk in this session was by Dr. Marek Bielewski (European Commission) who detailed the EU landscape for recycling and the impact of legislation related to battery recycling, specifically *2006/66/EC on batteries and accumulators and waste batteries and accumulators* which prohibits landfilling or incineration of automotive and industrial batteries. Again, collection rates across the EU became a major discussion point for the workshop. The panel discussion focused on possible ways for incentivizing collection of used batteries, specifically those from consumer electronics that may be lying idle.

The Policy Landscape

The policy landscape talks were presented by The Responsible Battery Coalition, NREL, the Fiat Chrysler Automobiles (FCA), Umicore, and the National Alliance for Advanced Transportation Batteries (NAATBatt). This provided a good overview of relevant standards and policy options for lithium-ion batteries. One of the major points of discussion was related to the transportation of used batteries and whether the packs/cells would be considered hazardous waste under the US legal framework. Most of the panel discussion was related to ways to characterize the battery, if/when it becomes waste and what would be needed to ensure its safe transport and the storage of used EV packs.

Stakeholder Perspectives

This section of the meeting involved Renata Arsenault (Ford) , Brittany Westlake (EPRI), Peter Karlson (GM), and Richard LeCain (A123) who covered the challenges and opportunities for recycling. Topics in this section ranged from second use options, design for recyclability and the use of “recycled” materials. Questions as to who would consider using reconditioned cathode/anode materials dominated much of this discussion.

Breakout Session Summary

- *Regulations:* For regulations to be enforceable, they must be based on sound supporting information, such as industry standards, guidelines, or best practices. The group identified several key challenges that must be addressed before regulations for battery recycling can be formulated. *Battery history* determines how it can be safely handled and where it should go. *Dismantlers* need to be involved. Since there is no common BMS, other assessment tools are needed to characterize the battery. Batteries must be inspected, classified (hazardous?), and labeled at EOL. They must be evaluated for suitability for 2nd life and recycling. It needs to be decided how the "second life" is to be regulated. Legal aspects, such as liability, must be addressed. Any regulations that are passed should be consistent from place to place; global harmonization is needed, including the use of common terminology. The responsibility for harmonization needs to be appropriately assigned. Incentives have to be designed to promote the return of batteries. Renault's Battery Lease Program was cited as a good example.

- *R&D Gaps:* Research benefits industry by addressing high-risk questions and trouble-shooting potential problems that would apply across chemistries. Some examples of these include the effects of trace impurities and how to manage small quantities of potentially hazardous components such as fluorides. Because battery chemistry continues to evolve, not only with changing electrode element mixes, but with varied doping and morphology, sensors and sorting methods are important. Sensors are also needed to prevent cross-contamination among battery types in the recycle stream. Economics and market competition will be influenced by the results of R&D. Recycled materials will only find market acceptance if quality is proven to be sufficient at a lower cost than virgin material.
- *Collection and Transportation:* This area provoked much discussion, since it is a perceived bottleneck for recycling.
    - *Collection:* Most consumer batteries are not recovered. There are collectors and sorters for consumer electronic batteries (organizations like Call2Recycle), but they could be more successful, perhaps with education, workplace collection, and school collection. Automotive battery collection is likely to fare better. Auto batteries still under warranty go back to dealers, and cars out of warranty get sold at auction and taken to scrapyard, which removes salable or hazardous parts. The Automotive Recycling Association currently educates dismantlers on how to remove batteries for recycling. Companies like Blue Whale will evolve to buy used batteries.
    - *Transportation:* The cost associated with moving batteries would be dependent on applicable regulations; one needs to verify the common belief that transport costs are half of the recycling cost. Transportation of whole cars (with batteries included) is exempted from regulation; removal of the batteries could subject them to the potentially extra costs of regulation. Industry could benefit from DOE working to understand how to avoid transporting batteries as Class 9. It would be useful to convene regulatory agencies to understand current and projected regulations and requirements. R&D is needed to develop robust

packaging (possibly including insert-filling options) that is certified to ensure safe transportation. U.S. rail carriers are currently restricting transport of batteries because of safety concerns. Current DOT regulations allow for batteries to be placed on a pallet and trucked. Fees charged for this for EV batteries are unknown. Standards are being developed for air transport; 30 % of new batteries into U.S. arrive by air, according to a harmonized tariff schedule (HTS). An alternative to shipping whole batteries is to shred or deactivate them first. But such pretreatment would have the disadvantage that batteries could not be reused.

12.4.2 Reducing Dependence of Lithium-Ion Batteries on Critical Materials Supply Chain

Currently, lithium-ion batteries contain a substantial amount of cobalt, a critical material that is both expensive (average annual cobalt prices more than doubled in 2017) and dependent on foreign sources for production.[5] 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 (see Figure 1).[6,7,8]

To achieve this strategic goal and address potential critical materials issues, the U.S. DOE will support three key areas of R&D (see Figure 2):

- Next generation low-cobalt battery R&D
- Lithium battery recycling R&D center
- Battery recycling prize

Next Generation Low-cobalt Battery R&D

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 ; this dependency is also a concern for U.S. end-users. Because of these factors potentially limiting the

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[5]U.S. Geological Survey, Mineral Commodity Summaries, Cobalt, January 2018, https://minerals.usgs.gov/minerals/pubs/commodity/cobalt/mcs-2018-cobal.pdf

[6]Hype Meets Reality as Electric Car Dreams Run Into Metal Crunch, Bloomberg, January 2018, https://www.bloomberg.com/graphics/2018-cobalt-batteries/?cmpId=flipboard

[7] Lithium-Ion Batteries: Examining Material Demand and Recycling Issues, L. Gaines and P. Nelson, TMS 2010 Annual Meeting and Exhibition, Seattle, WA (February 2010)

[8] National Renewable Energy Laboratory analysis, utilizing data published by Bloomberg New Energy Finance, 2018, https://www.bloomberg.com/news/articles/2018-06-10/cobalt-battery-boom-wavers-as-china-demand-lull-brings-out-bears

supply chain and increasing demand of cobalt and rapid price increase in lithium-ion batteries, cobalt is considered the highest material supply risk for EVs in the short- and medium-term.

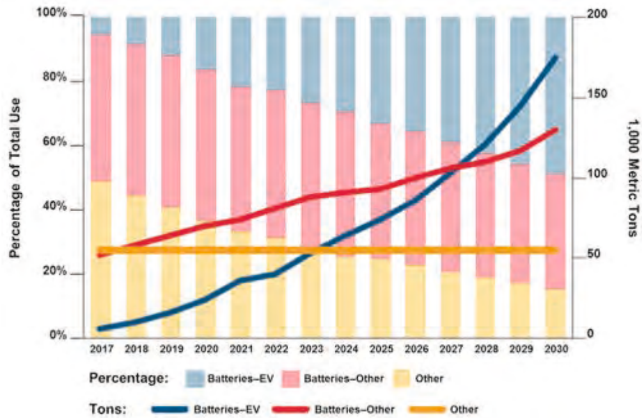

Figure 1: Forecasted Global Cobalt Demand by End-Use (Source: U.S. Geological Survey, Mineral Commodity Summaries, Cobalt, January 2018)

Figure 2: Critical materials strategies for batteries (Source: ANL)

Recognizing the issues of Cobalt price volatility and supply reliability, reducing the amount of cobalt in lithium-ion batteries for EVs by substituting it with other materials has been a major focus within DOE/VTO's R&D portfolio. Accordingly, DOE awarded seven new projects to develop/optimize low cobalt cathode materials in 2018 (Table 1).

Also, DOE is funding two current "deep dive" projects being conducted by national laboratory-based research teams:

- **Reducing cobalt in cathode to less than 5 % weight**: University, industry, and national lab research in next generation cathodes focused on reducing cobalt content much below the current state of-the-art cathodes while continuing to improve cathode material performance in EV batteries. This project focuses on developing high energy capacity materials at high voltages using nickel-manganese based materials with cobalt substitution (see Figure 3).

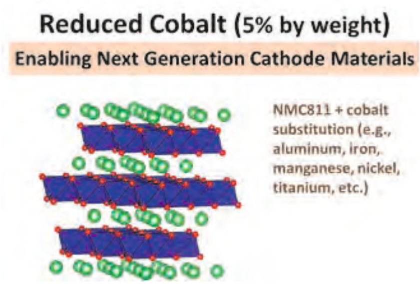

Figure 3: Critical materials strategies for batteries

- **Disordered rock-salt structured materials using cobalt-free oxides**: A multi-laboratory research consortium led by Lawrence Berkeley National Laboratory is exploring cathodes based on completely novel material compositions with no cobalt fabricated in experimental processing techniques and using first principle modeling (see Figure 4).

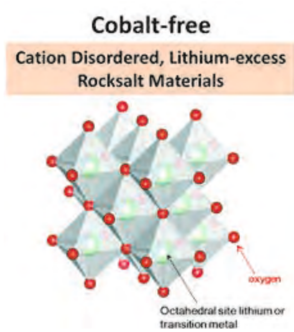

Figure 4: Critical materials strategies for batteries

Table 1: Low Cobalt / No Cobalt Project Awards

Awardee	Description
Cabot Corporation	Aerosol manufacturing technology for production of low-cobalt lithium-ion battery cathodes
NexTech Materials, Ltd. dba Nexceris, LLC	Cobalt-free lithium manganese nickel titanium oxygenate spinel cathodes for next generation lithium-ion batteries
Oak Ridge National Laboratory	Cobalt-free aluminum iron nickelate cathode materials for next generation lithium-ion batteries
Pennsylvania State University	High-performance coated low-cobalt cathode materials for Lithium –ion Batteries
University of CA, San Diego	Cobalt free cathode materials and novel architectures
University of CA, Irvine	Enhancing oxygen stability in low-cobalt cathode materials
University of Texas at Austin	High-Ni cathode materials for high-energy, long-life, low-cost Lithium –ion Batteries

Lithium Battery Recycling R&D Center

More than 15 cathode chemistries are used in lithium-ion batteries that make them practical for more applications and therefore increases demand for materials. As new chemistries become commercially available, the need arises to develop flexible and reliable processes to maximize economic value to the recycler. Advanced recycling approaches can significantly meet the demand for materials.

VTO is investing in early-stage research to develop recycling technologies for extraction and reuse of the main components and materials in lithium-ion batteries that would be economical and have lower energy and environmental impacts. This includes the selection and establishment of a Lithium Battery Recycling R&D Center focused on cost-effective recycling processes to recover critical lithium battery materials. The Center will be led by Argonne National Laboratory along with the National Renewable Energy Laboratory and Oak Ridge National Laboratory and three universities. The team will focus on developing innovative and efficient recycling technologies for current and future battery chemistries and consist of four research areas.

Battery recycling and sustainability projects investigate the material and energy flows pertaining to battery material production, battery manufacturing and assembly, and battery recycling, to characterize the life-cycle energy and environmental burdens of lithium-ion batteries (LIBs). By interacting with battery manufacturers and recyclers, researchers obtain primary data on the energy and water use for commercialized LIB production and recycling, and identify environmental impact drivers, production bottlenecks, and other barriers, for LIB production and recycling. Challenges to be faced for Li-ion battery recycling are shown in Table 2, along with suggested R&D areas for how they can be addressed. Detailed understanding of recycling processes will be necessary to maximize material recovery.

Table 2: Challenges for Li-Ion Battery Recycling

Challenge	R&D Needed to Address
Long-term performance of some recycled materials is not proven	Long-term testing
There is no standard chemistry or design	Convergence of chemistries and designs, Flexible processes, Design for recycling Automation
There are no regulations, so restrictive ones could be imposed	Fashioning regulations that will protect health and safety without hindering recycling
Many of the constituents have low market value	Process development to recover multiple high-value materials
Low value of mixed streams, prevention of fires and explosions	Effective labeling and sorting

DOE launched the ReCell Battery Recycling R&D Center, a 4 million USD/year effort by a multiple lab consortium with ANL, NREL, and ORNL which will focus on novel approaches to recycling to maximize economic yield of batteries at their end of life. This is expected to increase the rate of recycling for lithium-ion batteries and decrease dependence on foreign sources for critical materials. The focus areas of the ReCell Center include direct recovery of cathode material, separation methods, battery design for recycling, recovery of other materials, and advanced characterization of recycled material.

During 30-31 May 2018, an international discussion group of industrial experts was convened at the National Renewable Energy Laboratory (NREL) in Denver, Colorado to consider options for battery recycling and to identify needs in a first step toward the development of a recycling roadmap. The workshop included battery and recycling representatives from the USA, China, South Korea, the United Kingdom, Australia, and the European Union. There were 41 participants present, including 15 industrial, ten national laboratories (US and International), six independent research organizations, five universities and five DOE attendees. The two-day meeting was broken into short expert presentations followed by panel discussions. The overall aim of the meeting was to gain information and insight on critical materials issues related to EV batteries, the potential role of battery recycling to alleviate critical materials issues, policy landscape and regulations impacting battery recycling, current lithium-ion battery recycling methods and challenges, and current R&D activities and identification of R&D gaps. At the beginning of the meeting talks from the USA, UK, China, South Korea, Australia, and Europe provided a foundation as to the current and near future plans for lithium-ion recycling within each global region. The policy landscape talks provided a good overview of the relevant standards and policy options for lithium-ion batteries. The Stakeholder perspectives section of the meeting involved Ford, EPRI, GM and A123 who covered the challenges and opportunities for recycling – including the topics of second use options, design for recyclability and using "recycled" materials. The breakout session covered regulations, R&D gaps, and collection/transportation issues.

Lithium Battery Recycling Prize

Currently, lithium-ion batteries are only collected and recycled at a rate of less than 5 %.[9] Recycled material could potentially provide one-third of US cathode material needs for lithium-ion batteries by 2030.[10] The current infrastructure for collecting, storing, transporting and recycling of lithium-ion batteries is limited, particularly for larger batteries used in EVs and industrial applications. This is unlike lead-acid batteries' infrastructure which has resulted in 99 % collection and recycling of lead acid batteries. To address the lack of a well distributed, efficient, and profitable infrastructure to enable recycling of lithium-ion batteries, DOE VTO has established a Battery Recycling Prize (amounting to 5.5 million USD) to incentivize American entrepreneurs to find innovative solutions to solve current challenges associated with collecting, storing, and transporting spent or discarded lithium-ion batteries for eventual recycling. The goal of the Battery Recycling Prize is to develop innovative business and technology strategies with the potential to capture 90 % of all lithium-based battery technologies (consumer electronics, stationary, and transportation applications) in the United States; and that make collecting, sorting, storing, and transporting lithium-based batteries safe, efficient, and profitable.

The prize will facilitate entrepreneurs to leverage the resources of incubators, universities, and the national labs to transform innovative early-stage concepts into prototypes primed for industry adoption. Successful concepts must consider cost-effective methods or technologies such as separation and sorting of various collected battery types and sizes; rendering lithium-based batteries safe or inert

[9] https://www.call2recycle.org/

[10] M. Mann, A. Mayyas, D. Steward, Impact of Li-Ion Recycling on the Supply Chain, NREL, presented at the International Li-Ion Battery Recycling Work

during storage; or reducing the hazardous classification of lithium-based batteries in order to reduce shipping costs.
The three consecutive innovation phases of the Battery Recycling Prize (see Figure 5) will accelerate entrepreneurs' efforts to create disruptive solutions to collect, store, and transport 90 % of spent or discarded lithium-ion batteries. In each phase, the winners are determined by a panel of expert judges evaluating concepts based on feasibility, cost to implement, and potential impact.

Figure 5: The three phases of the Lithium-ion Battery Recycling Prize

12.5 Next Steps

The OA, in conjunction with other colleagues in the field, is planning the next discussion meeting. The schedule for this meeting is not yet decided. The OA is working with representatives from the member countries to identify topics and locations for future meetings.

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13

Fuel Cell Electric Vehicles (Task 35)

Members: Austria, Republic of Korea

13.1 Introduction

The transport system has significant impacts on the environment, spending between 20 % and 25 % of world energy consumption and produce carbon dioxide emissions. The majority of the emissions comes from direct burning of fossil fuels. Greenhouse gas emissions from transport are increasing faster than any other energy using sector. Road transport is also a major contributor to local air pollution and climate change. Fuel cell vehicles (FCVs) have the potential to significantly reduce our dependence on fossil oil and lower harmful emissions that contribute to climate change. FCVs run on hydrogen gas rather than gasoline and emit no harmful tailpipe emissions. Several challenges must be overcome for them to be competitive with conventional vehicles, but their potential benefits are substantial. FCVs run on hydrogen can be represented as one of the sustainable mobility modes. The interest in hydrogen as an alternative fuel stems from its ability to power fuel cells in zero-emission electric vehicles, its potential for domestic production, and the fuel cell's potential for high efficiency and the easier to overcome distance anxiety unlike electric vehicles. In fact, a fuel cell coupled with an electric motor is two to three times more efficient than an internal combustion engine running on gasoline. However, nowadays, FCVs still have limitations because only a few hydrogen stations are available. Thus, the major manufacturers such as Hyundai and Toyota, for example, are currently offering their production fuel cell electric vehicles for sale or lease to customers living in markets where hydrogen fuel is available. Therefore, it will be very useful to look in detail into FCVs as a sustainable mobility representative and its energy infrastructure such as its technology concepts, prospects, research needs, market condition, and hydrogen stations (international differences and best practices).

13.1.1 Global FCEV Cumulative Sales and Hydrogen Policy

Currently, there are 10,820 hydrogen fuel cell vehicles sold worldwide [1] according to the market research company 'Information Trends'. Korea plans to supply 15,000 hydrogen vehicles by 2022. It is trying to strengthen environment-friendly vehicles to solve environmental problems such as climate change or fine particular matter and to secure global initiative.

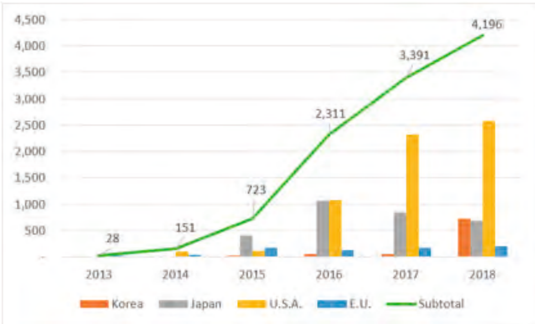

Figure 1: Worldwide sales subtotal of FCEV (Source: Monthly global EV shipment database)

Japan is attempting to establish a large-scale hydrogen supply system in order to realize a hydrogen society by 2022. The United States plans to provide approximately 175 million dollar to build a hydrogen infrastructure by 2023. In Europe, Fuel Cells and Hydrogen Joint Undertaking is mainly focused on the supply of hydrogen cars and refueling stations. This may represent that now the world is on competition along the hydrogen [2].

Table 1: Worldwide sales subtotal of FCEV

Region	2013	2014	2015	2016	2017	2018	Total
Korea	5	7	31	60	61	727	891
Japan	-	7	411	1,055	843	689	3,005
U.S.A	1	100	110	1,082	2,313	2,584	6,190
E.U.	22	37	171	134	174	196	734
Total	28	151	723	2,311	3,391	4,196	10,820

13.1.2 Technical Analysis of FCV and Hydrogen Refueling Station

There are two current FCV technologies, including the technology being studied. The first is the way to get electricity using hydrogen fuel cells (Hyundai-Nexo, Toyota-Mirai, Honda-Clarity). There is also a method that uses the same method as conventional internal combustion engines using hydrogen as fuel, but the latter is still under study. In addition, it has a disadvantage in that it is inefficient compared to a hydrogen fuel cell and a fuel system must be newly developed. The core device of the FCEV vehicle is a fuel cell. The fuel cell consists of two electrodes and an electrolyte membrane that transfers hydrogen ions to the two electrodes. One electrode is supplied with hydrogen. And oxygen is supplied to the other electrode. In the hydrogen side electrode, hydrogen molecules are separated into hydrogen ions and electrons, and hydrogen ions move into the electrolyte and are transferred to the oxygen side electrode. On the oxygen side electrode, hydrogen ions and oxygen combine to form water. The process of converting this chemical energy into electric energy generates a voltage of about 0.7 V. This is connected in series to generate the desired voltage. This voltage drives the electric motor [3].

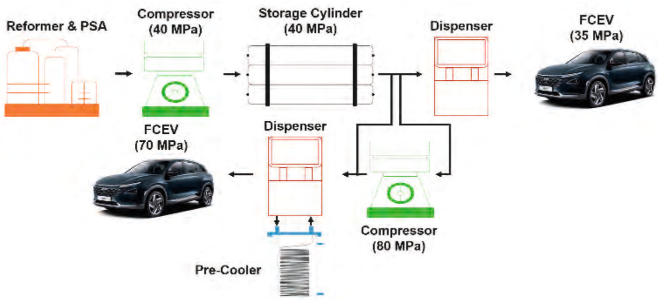

Figure 2: Schematic diagram of on-site method hydrogen station (Source: see Reference [3])

The hydrogen storage tank stores hydrogen at 400 atm. When the pressure of the supplied hydrogen is low, the compressor is used to increase the pressure. Generally 5 to 6 kg of hydrogen is stored and takes 5 to 6 minutes to charge. When high-pressure hydrogen is injected at high speed, heat is generated, therefore the cooling device is required. There are three types of hydrogen refueling stations: off-site hydrogen is supplied from the outside through tube trailers or hydrogen piping, on-site production of hydrogen from itself through natural gas or LPG reforming, and there is also an electrolytic on-site charging station [4].

In the case of hydrogen passenger vehicles, standardization has been done, but commercial use has not yet been standardized. Six companies, including Hyundai Motor, Air Liquide, Nell, Nicolas, Shell, and Toyota, have signed a memorandum of understanding and a consortium to develop high-capacity, high-pressure charging components for commercial hydrogen-powered electric vehicles. Standardization of car and charger parts that can withstand refueling rapidly of high-pressure gas to a hydrogen tank is necessary. In the case of passenger cars, standardization has been done, but commercial use has not yet been standardized [5].

13.1.3 FCVs Technologies, Prospects and Research Needs

The advantages of FCV are no emissions and they can provide fresh air to earth. A hydrogen electric bus that is operating in Korea, can provide fresh air to 85 adults per year. The actual driving test of the hydrogen electric bus shows it can purify 4.863 kg/km of air [6] These effects show that there is a need for a wide range of studies on hydrogen vehicle technology. But the limit is clear. No matter how good the air purification capacity is, if the hydrogen infrastructure is not built up, it is useless. In order to expand the hydrogen car market in the future, the supply of hydrogen vehicles and infrastructure should develop together.

Figure 3: Hydrogen electricity bus of Hyundai Motor (Source: Hyundai)

13.2 Objectives

The objectives of Task 35 are to analyze the technology for FCVs and hydrogen stations and to disseminate the policy of FCVs and hydrogen stations. Furthermore, to share the information of the related technology among the stakeholders through workshops and conferences and to document and disseminate to several related topics such as:

- FCVs concepts: technologies, prospects and research needs.
- Hydrogen stations for FCVs concepts: technologies, prospects and research needs.
- Market condition for FCVs and hydrogen stations: international differences and best practices.

13.3 Working Method

The workshops aim to attract professionals from research, enterprises and policy makers, depending on the individual topics. An international survey distributed to a wider audience complements the workshops. Major insights and results together with other findings from desktop research will be published at conferences and in scientific journals.

Utilizing the existing HEV TCP framework, Task 35 will answer the main key questions related to FCVs research and development, which are e.g.:

- What are technologies to improve FCVs, their efficiency, range, comfort and how to lower their costs?
- Which barriers exist for bringing more FCVs to the market?
- What safety concepts for FCVs exist, how efficient are they and where are options for improvement?
- Safety for hydrogen stations

13.4 Contact Details of the Operating Agent

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1. INI Industrial research, "Monthly global EV shipment DB", (Figure 3, Table 1)

2. Jin-nam Park "Status of Hydrogen Station Technology and Policy" , The Korean Society of Industrial and Engineering Chemistry , 21 , Vol.3 , 10-19 , June 2018

3. Hyundai Mobis "Science principles in environmentally friendly hydrogen cars", HMG journal of Hyundai Motor group , 21 August 2018

4. Jin-nam Park "Status of Hydrogen Station Technology and Policy" , The Korean Society of Industrial and Engineering Chemistry , 21 , Vol.3 , 10-19 , June 2018,

5. Hyundai Motor "Develops commercial hydrogen fuel filling parts with five global companies" , HMG journal of Hyundai Motor group , 04 March 2019

6. Hyundai Motor "The vehicle removes fine dust." , HMG journal of Hyundai Motor group , 28 March 2018

14 EV Consumer Adoption and Use (Task 36)

Members: Canada, Germany, Sweden, United Kingdom

14.1 Introduction

Transportation accounts for nearly 14 % of global greenhouse gas (GHG) emissions, around 40 % of which come from light-duty vehicles (LDVs), i.e., passenger cars and trucks. Consumer adoption of fuel-efficient vehicles is a crucial step in improving energy utilization and reducing emissions from the LDV sector. To promote adoption, multiple supply- and demand-side policies such as fuel economy standards, zero emission vehicle mandate, renewable fuel standard, low carbon fuel standard, ethanol subsidies, financial and non-financial incentives, have been employed. For these policies to achieve their intended goals, understanding the demand for fuel-efficient and electric vehicles (EVs) from the consumer's perspective is paramount.

14.2 Objectives

The task aims to provide a platform to connect stakeholders with researchers working on consumer adoption and use of EVs. The goal is to distill a set of policy-relevant messages from the latest consumer research findings and related discussions in the form of an edited book. The book would offer a comprehensive and accessible picture of the state of the art in the field of consumer research on adoption and use of hybrid and electric vehicles. In particular, the book provides

(i) an introduction to the field that allows non-experts to navigate the rapidly growing body of evidence
(ii) a detailed overview of the latest evidence by technology and market and a set of policy-relevant messages that can be derived from it, and
(iii) a clear sense of the directions in which the field is evolving, the latest methods and data, and the new insights that these are capable of generating in future.

14.3 Working Method

The book compilation involves engaging researchers from key geographic areas: North America, Europe, China, and the Middle East to gather evidence and insights from the latest consumer research.

14.4 Results

Some highlights of the book include:

- Book combines latest empirical evidence with detailed discussion of key methods, e.g.:
  - Effect on EV adoption of evolution of policy support measures in Norway, the Netherlands, Germany, and China
  - Qualitative and quantitative methods for the study of attitudes and preferences of early and mainstream adopters, applied to case studies in the UK and Canada
- Important themes emerging across the different book chapters include:
  - Strong feedback among policy, technology and consumers behavior, the development of which cannot be studied in isolation
  - Majority of EV owners in North America and Europe are multi-car households and their needs can often be satisfied by battery electric vehicles
  - Mainstream adopters and single-car households however seem to prefer plug-in hybrid electric vehicle, which are currently disfavored by policy but may be required to reach high levels of EV penetration
  - EV policy support in many countries today is insufficient to achieve the ambitious penetration levels aimed at by governments
  - Consumer analysis and modelling studies can help assess this gap and design policies that can help meet the targets most effectively.

14.5 Next Steps

The book is expected to be complete by 1Q 2019 and available in publication form by 2Q 2019.

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15 Extreme Fast Charging (Task 37)

Members: United States

15.1 Introduction

Battery electric vehicles (BEVs) have continued to increase their market share worldwide, with advantages in efficiency, low operating costs, and emissions. However despite decreases in cost within the BEV powertrain and significant improvements in drivability and performance, the BEV market still accounts for a small share of new vehicle sales annually. An identified gap to wider adoption of BEVs is the ability to refuel quickly or to fast charge. Currently the majority of BEV recharging is done at home, but data shows that having access to public direct current (DC) fast chargers can have a big impact on BEV utility from a consumer perspective. Studies have shown that in areas where drivers have access to 50 kW or 120 kW fast charge stations, annual electric vehicle (EV) miles traveled increased by over 25 %, even in cases where fast charging was used for 1 % to 5 % of total charging events[11][12]. Having access to these fast charge stations can help alleviate the "range anxiety" commonly cited as a reason for consumer hesitation to buy a BEV.

Based on these trends, even higher power charging stations could drive further BEV adoption. To address the fast charge barrier, charging at power levels up to and even exceeding 400 kW, often referred to as extreme fast charging (XFC), have been proposed. This Task focuses on XFC technology, gaps, installations, and operations.

15.2 Objectives

Task 37 is focusing on the following objectives: investigating station siting – what factors are considered (i.e. space requirements, city center, community/corridor, etc.); quantifying the costs of installation – including physical site location and

[11] Lutsey, N., S. Searle, S. Chambliss, and A. Bandivadekar, 2015, "Assessment of Leading Electric Vehicle Promotion activities in United States Cities," International Council for Clean Transportation, July 2015

[12] McCarthy, Michael, 2017, "California ZEV Policy Update," SAE 2017 Government/Industry Meeting, Society of Automotive Engineers, 25 January 2017, Walter E. Washington Convention Center, Washington, DC, conference presentation

infrastructure costs as well as costs associated with the charging equipment; documenting grid connection details for current and planned installations, including any co-located renewable generation or energy storage; understanding the implications of XFC on battery design, performance, and cost; documenting pay structures and/or consumer interfaces for payment; and studying consumer education methods and topics.

15.3 Working Method

Task 37 continues to finalize member countries, and is currently reporting out XFC related activities and reports from the United States. The Task plans to organize a series of workshops scheduled in conjunction with dedicated conferences and IA-HEV Executive Committee (ExCo) meetings. The workshops will gather a variety of stakeholders coming from academia, industry and public authorities. Workshops may also include site visits to XFC installations, providers, or manufacturers. The purpose is to identify trends and scenarios, to analyze challenges and opportunities, and to deliver conclusions for future actions.

15.4 Results

Charging infrastructure for vehicle charging at 400 kW and beyond from a multi-port refueling plaza similar to today's gasoline stations will reasonably require at least 1 MW of power conversion capability. A load of this magnitude is expected to require a primary voltage service from the electrical distribution infrastructure. While this could be served by onsite low-frequency transformers this been identified as an opportunity to investigate medium voltage connected power electronics. The following table provides a summary of US Department of Energy industry-led efforts which are developing designs for light-duty vehicle charging stations to deliver at least 1 MW of combined load or connect directly to medium voltage grid feeds.

Table 1: Extreme Fast Charging R&D Projects

Project	Lead	Description
High-Efficiency, MV-Input, Solid-State-Transformer-Based 400 kW / 1000 V / 400 A Extreme Fast Charger for Electric Vehicles	Delta Electronics	• 5, 15 kV class - Solid State Transformer • 1 kV DC/DC charger
Intelligent, Grid-Friendly, Modular Extreme Fast Charging System with Solid-State DC Protection	North Carolina State University	• Solid State Circuit breakers • 15 kV class - Solid State Transformer, 1 kV DC/DC • NC State XFC charger design
DC Conversion Equipment Connected to the Medium-Voltage Grid for XFC Utilizing Modular and Interoperable Architecture	Electric Power Research Institute	• Provides DC-as-a-Service with DC metering • Eaton designed charger with 15 kV class - Solid State Transformer
Enabling Extreme Fast Charging with Energy Storage	Missouri University of Science and Technology	• Energy Storage integration and bidirectional conversion 15 kV class - Solid State Transformer • 12.47 kV three-phase 60 Hz input • Isolated DC-DC converter to provide 1150 V DC

15.5 Next Steps

Thus far, Task 37 has identified the following key challenges for the Task to investigate critical barriers to the widespread deployment of extreme fast charging:

- Medium-voltage power conversion equipment- Design of charging equipment that directly connects to the MV distribution may improve operating cost through more efficient power conversion and reduce capital costs by reducing the footprint of the installed equipment on the site.
- Integrated charging sites- Charging sites that incorporate onsite generation and storage technologies may benefit from reduced electricity costs by shifting load. Development of these sites in conjunction with existing large load facilities may prove beneficial if controllable load, generation, and storage resources can be leveraged across the site.
- Grid interaction and interconnection- Connection of highly dynamic large (>1 MW) non-linear load will require utility assessment and may require costly infrastructure improvements to ensure stable operation of the distribution system. A foundational understating of the grid integration of extreme fast chargers is needed to develop a harmonized interaction of the charging hardware and support rapid growth of extreme fast charging sites.

The task is working to gain participation from other countries to further investigate and refine these objectives. Future meetings and workshops will be scheduled with input from members.

15.6 Contact Details of the Operating Agent

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16 e-Ships (Task 38)

Members: Denmark, United States

16.1 Introduction

The IEA HEV TCP Executive Committee (ExCo) unanimously approved Task 38 in 2017. Task 38 will run until February 2020. Until now Parties from Canada, Netherlands, Norway, Japan, Sweden, South Korea, Germany, European Commission, Chile and Switzerland have shown interest to become members. New members are encouraged to participate. Task 38 focuses on overviewing and encouraging the development and deployment of e-Ships. The working method to achieve this will be by building and sharing key knowledge on projects, technology performance, segments and demand. Including in three regional workshops at the moment tentatively planned for being held in Europe/Scandinavia, the Americas and Asia.

Fully electric ships are a new and emerging technology tail winded by the substantial reductions in battery and renewable electricity production costs. Electric maritime propulsion also supports direct use of renewable energy, significant improvements in energy efficiency and zero emission transport.

With the Paris Agreement, nations have agreed to keep the global mean temperature rise to be well below 2°C by 2100. Shipping industry is one of the large carbon emitters. As the demand for shipping is continuously growing, there is a great need for low and zero emission shipping. The focus of the Task is on battery electric ships and related issues such as battery and charging technology. But it will also include related and relevant topics including hybrid battery electric systems, electric retrofit readiness for new ships and the synergy between electric and autonomous ships.

As a new Task, acquisition of additional member countries and parties are important and ongoing. The Task scope, deliverables, and products will be refined and consolidated with all the members. The first phase of Task 38 will be to give an overview of e-Ships projects, technology, policies and potential deployment with the focus on Scandinavia and Europe, where many new electric projects are being built. The second phase is planned to include the Americas and the third phase to overview Asia and the rest of the world. There will be a cross cutting focus on e-ships on islands. A country and stakeholder workshop will be held in each of the regions.

Participating parties and countries are expected to provide information and relevant contact persons on e-ships related to their own country or region. Attendees at the meetings are kindly asked to cover their own costs linked to participation (i.e., salaries, travel expenditures, accommodation, etc.).

16.2 Objectives

Task 38 currently emphasizes on present state of technology and demonstrates e-Ships projects with the following objectives:

- Provide a leading network and platform on e-Ships for policymakers, researchers and industry bridging 'blue' maritime, 'green' energy, e-mobility including energy system, charging and automation perspectives
- Document international e-Ships success cases in a common format
- Overview, characterize and showcase technology, economics, policies, energy and environmental aspects, applications and market potentials
- Look for segmentation, convergence and scaling of supply and demand
- Analyze and document the current drivers and future perspectives for e-Ships
- Develop methods for data collection and key figures for modelling, for EU Directive on Infrastructure, for IEA, EVI etc.
- Concentrate knowledge and data into policy relevant information to advance adoption and market acceptance of e-Ships

16.3 Working Method

Within the Task, a number of workshops and meetings are to be planned in different member countries/regions and draw interest of other countries and stakeholders to join the Task. The workshops will involve stakeholders from various research institutes, maritime organizations, battery technology companies, shipbuilders and owners etc.

All the members will collect data about technology, projects, policies, economics, environmental aspects, etc. from their countries and all around the world. The information and data on the state of present e-Ships technology and future prospects will be discussed and documented. Every member country/party will also write a detailed country report, on relevant projects and the current market organization, including market players and supporting policy measures and framework.

Task 38 will offer a global network and platform for building and sharing knowledge and data about e-Ships, including on technology, policies and measures, standardization, environmental and industrial perspectives. Members will get the opportunity to learn about key stakeholders, best practices, latest developments and implementation measures aimed at successful commercialization of e-Ships technology. New projects, accelerated deployment and pooling of demand for more segmented serial production could be facilitated by network between interested industry and demanders from countries, islands, cities, industry etc.

16.4 Results

The Task will deliver a yearly updated overview and status on e-Ships in terms of technology, performance, projects, economy, environment, deployment, industry, markets and perspectives, including data. A number of pioneering projects on e-Ships have been started in the recent years. Assessments of ferries, cargo ships, etc. around the world have indicated promising potentials for e-Ships to be more profitable and efficient in comparison to the traditional ships. As a Danish example, a report from 2016 by Siemens analyzed the 42 domestic routes along the Danish coast serviced by 52 ferries. The conclusion was that 30-35 of these ferries would be more profitable as electric ferries[13].

In 2016 it was estimated that there were 50 routes in Norway alone where battery-powered ferries could operate profitably[14]. Furthermore, battery technology, including in the automobile industry has been advancing very rapidly, leading to a greener future with electric vehicles. Also maritime battery systems are expected to become considerably more efficient and less expensive in the future. Some of the innovative examples of projects on e-Ships are described briefly below.

The Danish Ærø e-Ferry project

"Ellen" is a highly energy efficient medium sized and a long 22 nautic mile range e-ferry for passengers, cars, trucks and cargo in island communities, coastal zones and inland waterways. It is supported by the European H2020 initiative, demonstrating design, building and operation of a fully electric powered 'green' ferry. Electricity from wind power of the Danish island Ærø will allow "Ellen" to run without any emissions. The e-ferry is expected be in operation in 2018/2019.

[13] https://www.siemens.com/press/pool/de/feature/2015/corporate/2015-05-e-ferry/study-electrification-e.pdf

[14] https://www.siemens.com/innovation/en/home/pictures-of-the-future/mobility-and-motors/electromobility-electric-ferries.html

Figure 1: Left hand side, the image by the e-Ferry project. On the right, photo made by the former OA

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The World’s Largest Battery-driven Ferries HH-ferries/Scandlines

Tycho Brahe and Aurora cross 4 km between Helsingborg in Sweden and Helsingör in Denmark carrying 7.3 million passengers and 1.8 million vehicles annually. The combined 8,320 kWh battery is equivalent to 10,700 car batteries. With a 15 minutes schedule, charging must be fast and automated with shore-side charging in both ports using robots, 3D laser scanning and wireless communication between ship and shore to optimize connection time and maximize charging period. Tycho Brahe is expected to be in full electric operation in summer 2018. The project is co-financed by the European Union Connecting Europe Facility.

Figure 2: The largest battery driven ferries (Source: HH-ferries/Scandlines)

Fast Electric Commuter E-Ferry

BB Green by Green City Ferries is the world’s first fully electric and air lifted commuter ferry. The concept reduces friction by 40 %, reduces waves and increases speed up to 30 knots. It is targeted sheltered waterways and relatively short routes (5 – 14 NM).

Figure 3: The BB Green e-ferry (Source: http://www.volvopenta.com/marinecommercial/en-en/news/2017/june/bb-green-electric-commuter-ferry-awarded-electric-and-hybrid-pro.html)

BB Green is used as a zero emissions commuter ferry for up to 99 passengers on the inland waterways around Stockholm, the capital of Sweden. The project is supported by the European Union Seventh Framework Programme.

Electric Ferries in Norway and Finland

“Ampere”, operated by the Norwegian ship owner Norled is the world's first fully electrical car- and passenger ferry. It started operation in May 2015, and has traveled a distance of more than 1.5 times around the equator. It travels six kilometers in 20 minutes across the fjord 34 times a day. Shifting from diesel propulsion to battery has reduced fuel costs by up to 60 %. “Ampere” was the result of a competition in 2010 by the Ministry of Transport and Communications and the Public Roads Administration, where successful development of an electrical ferry would receive a 10 year concession. After “Ampere” Siemens has delivered several electric ferries.

In June 2017, “Elektra” began regular operation between Nauvo and Parainen in the Turku archipelago in Finland. With nearly 98 meters long and 16 meters wide, Elektra can transport up to 90 cars per trip when traveling the route every 15 minutes. The batteries are charged in five minutes. The two lithium-ion batteries each have a capacity of 530 kWh.

Figure 4: The “Ampere” e-ferry in Norway (Source: Siemens via www.siemens.com/press)

Figure 5: The “Elektra” e-ship in Finland (Source: Siemens via www.siemens.com/press)

Electric Container Barge to Connect Rotterdam and Vossenberg-West

Two battery-electric container ships to be owned by Port-Liner and hired by logistics company GVT from Tilburg are expected to connect Rotterdam (Netherlands) and Vossenberg-West business park (Belgium) from late 2018. Sized 110 m times 11.4 m it can carry up to 270 containers in inland waterways. The battery packs are expected to operate up to 34 hours and stored in a container it can either be swapped or charged at a terminal. Port-Liner is reported to build a total of 15 electric-powered cargo ships of different sizes, to join ship fleets in the

Netherlands and Belgium. The first six electric container ships are estimated to remove 23,000 trucks from the roads annually in the Netherlands. The project is supported by the European Union.

Figure 6: Electric container ship (Source: https://electrek.co/2018/01/12/large-tesla-ships-all-electric-barges/)

World's First Fully Electric and Autonomous Container Ship in Norway

Yara Birkeland is the world's first fully electric and autonomous container ship with zero emissions. The ship is propelled by electric motors driving two azimuth pods and two tunnel thrusters with a battery capacity of 7.0 – 9.0 MWh. The ship will have a cargo capacity of 120 TEU (Twenty-foot Equivalent Units), operating between Herøya and Brevik (~7 nautical miles) and between Herøya and Larvik (~30 nm) at a service speed of 6 knots.

Figure 7: The operating route of Yara Birkeland (Source: https://www.km.kongsberg.com/ks/web/nokbg0240.nsf/AllWeb/4B8113B707A50A4FC125811D00407045?OpenDocument

Figure 8: The first fully electric and autonomous container ship in the World (Source: https://www.km.kongsberg.com/ks/web/nokbg0240.nsf/AllWeb/4B8113B707A50A4FC125811D00407045?OpenDocument)

In the first phase a detachable maneuvering and navigation bridge will be implemented. When the ship is ready for autonomous operation this module will be lifted off. Delivery into full operation is expected in 2019 and fully autonomous operation in 2020.

16.5 Next Steps

The Task is looking for more members to join efforts, and to make workshops and exchange of knowledge and data possible, so stakeholders and experts can showcase projects and knowledge about recent developments in technology, policy and concepts related to e-Ships. Hereby, the development, the deployment and the environmental impact of maritime electric propulsion is supported.

The next major step will be to organize and have the first of three Task workshops. This will be in the fall of 2018 and it will have a European and Scandinavian focus on e-Ships.

16.6 Contact Details of the Operating Agent

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17 Interoperability of E-Mobility Services (Task 39)

Members: Belgium, The Netherlands, Spain, Switzerland, United States

17.1 Introduction

The IEA HEV TCP Executive Committee (ExCo) unanimously approved Task 39 at the 48th ExCo meeting held in April 2018 in Dublin (Ireland). Task 39 will run for two years from 1 April 2018 until 30 March 2020. Belgium initiated Task 39 and The Netherlands officially joined from the start. During the first year the following countries joined or are considering to join: Switzerland, United States, Spain, Canada, Germany, UK, Sweden, and France.

Task 39 will focus on user friendly charging infrastructure and more specifically at the interoperability aspects for charging passenger cars in the public and semi-public domain. Also smart charging is within the scope of Task 39.

The market of electric vehicles is growing worldwide at an increasing speed. More and more electric vehicle models are being introduced on the market. End users and governments get more and more interested in the potential benefits of electric mobility since it offers a great potential to solve many of our environmental, societal and economic challenges. Therefore, policy makers are implementing supportive measures to facilitate the further uptake of electric mobility in their region. Main barriers to be addressed are the higher purchase cost, limited driving range and limited charging infrastructure.

Governments and industry are making huge investments in charging infrastructure in the public and semi-public domain to facilitate the further uptake of electric mobility and to try to convince the end users to take this step. Charging will be needed, in more or less quantities, at all locations: residential, workplace and also the semi-public and public domain.

However, it is not only about the quantity of available charging points in a region. Much more important is the quality of the charging service offered to the end user. This charging service needs to be easy to use, reliable and cost transparent. Information about the location and availability of charging points, about the way to get access to these charging points, about the tariffs, etc. are crucial for the end user to be confident enough to take the step to electric mobility.

Interoperability between the different e-mobility services offered today is therefore crucial for the comfort and ease-of-use for the end users. Look at the roaming in the telecom sector. But interoperability is equally important for the governments and companies making investments in charging infrastructure and services. Information exchange between the back offices of the different stakeholders like charge point operators and mobility service providers is an important aspect, so providing open and interoperable solutions can have a positive impact on the business case and on the flexibility to offer higher quality and/or combined e-mobility services to the end user.

17.2 Objectives

Today, EV drivers are still not given easy access to all necessary information about the charging possibilities in their region. Many initiatives are being started to improve this situation, but EV drivers today still have to put a lot of time and effort in collecting this crucial information about the charging infrastructure (location, availability, accessibility, pricing, etc.) for their specific charging needs. Only EV addicts will make this effort while most other people interested in electric mobility will wait until this situation improves.

Task 39 will bring together experts from member countries to share information and best practices to improve the interoperability and accessibility of charging services.
Aspects to be studied related to charging in the (semi-) public domain are:

- How to find the charging station: static database, real-time navigation, apps, etc.?
- How to know the real-time status of the charging station: free, in use, defect, etc.?
- How to reserve the charging station (= optional)?
- Which authentication is needed at the charging station: none, via RFID card, via app, ad-hoc use possible, etc.?
- Pricing and payment information: which tariff scheme is applicable for you at this specific charging station?

An overview of the ongoing initiatives to stimulate interoperability of e-mobility services will be set-up.

Every member country will also write a detailed country report, explaining the current local market organization (market players & supporting policy measures), which will be very valuable information for the EV drivers in that specific country.

Ultimately, Task 39 will set-up recommendations for governments and industry how to improve the interoperability of charging services. The main focus in Task 39 will be on “standard” charging services, but also the aspect of “smart” charging and its interoperability aspects will be taken into account.

17.3 Working Method

Task 39 will be executed in a pragmatic way and will make use of mainly telco’s and two workshops to collect, discuss and write down the existing knowledge available from the experts of the member countries. This information will be complemented by additional desktop research and contacts with different initiatives to collect the most recent information.

All collected information will be stored in the IEA HEV TCP SharePoint site and will be accessible to the member countries.

Putting the available information on paper in a clear and concise way and share it with the EV community (end users, governments and industry) is the ultimate ambition of Task 39. The country reports and recommendations will be shared via the Annual Report and the website of IEA HEV TCP.

The working method and number of workshops can be adapted when new member countries join and/or opportunities arise.

17.4 Results

The first months of Task 39 focused on contacting the interested member countries to exchange further information and to fine-tune the workplan. A higher number of member countries leads to more and higher quality information exchange and ultimately to better recommendations to stimulate interoperability of e-mobility services, not only within one country but also across borders.

In 2018, Task 39 also started with the collection of relevant information via desktop research and contacts with experts in the field. Many projects dealing with interoperability and roaming have been detected.

The focus in 2018 was mainly on Europe, because a lot of the ongoing projects have been set-up with European funding (FP7, H2020 or Interreg). All these funded projects study the interoperability aspects, but sometimes from a different perspective. Examples of European funded projects:

- **H2020 – NeMo** (http://nemo-emobility.eu/): NeMo’s vision is to create a Hyper-Network of new and existing tools, models and services which will provide seamless interoperability of electric mobility services, creating an open, distributed and widely accepted ecosystem for electric mobility. The lack of interoperability gave rise to the recent concept of electric mobility roaming platforms, often called e-roaming or eRoaming. The problem of interoperability between platforms still remains. In order to tackle this, the pan-European eRoaming initiative was announced in 2015 and its objective, namely the interconnection of existing eRoaming platforms, will be specifically pursued within the NeMo Hyper-Network for electro mobility.

- **Interreg - evRoaming4EU** (https://www.evroaming4.eu): The main objective of the project is to facilitate roaming services for charging electric vehicles and provide transparent information to consumers about charging locations and prices of charging in Europe, by making use of the open independent Open Charge Point Interface (OCPI) protocol. The ultimate goal is to allow any EV driver to charge at any charging station in the EU.
- **PF7 – Cotevos** (http://cotevos.eu): Concepts, capacities and Methods for Testing EV Systems and their Interoperability within the Smart Grids.

Besides funded projects, we also see market players joining forces in initiatives like eMI3 *"eMobility ICT Interoperability Innovation Group"* (www.emi3group.com). Under the umbrella of ERTICO, the eMI³ Group is an open interest group of global market players to enable global EV services interoperability by harmonizing existing and preparing standardization of future ICT data standards & protocols including security and authentication. Examples of members of eMI3 are roaming platforms like Hubject (www.hubject.com) and Gireve (www.gireve.com) and Task 39 partner ElaadNL is member of eMI3, too.

The EC-DG MOVE also launched a Programme Support Action on data collection related to Alternative Fuels infrastructure and unique identification codes of e-mobility actors. This call was addressed at EU member states. The objective is the collection of data related to the alternative fuels infrastructure and coordination and establishment of a repository concerning unique Identification Codes (IDs) of e-mobility actors, which are an essential part for a future harmonized development of electro mobility services in Europe. The primary focus is on electric charging points and hydrogen.

The EU "Clean Power for Transport" directive (2014/94/EU) also requested all European countries to set-up a national action plan to stimulate the roll-out of public charging infrastructure. User friendliness and interoperability is an important aspect as mentioned in the report of SGEMS "Sub-Group to foster an Electro-Mobility Market of Services". The CPT-directive triggered further national initiatives to stimulate interoperability.

One of the first countries taking interoperability seriously on a national and cross-border level is the Netherlands. For many years they have been working already to reach an open and interoperable charging infrastructure market. Task 39 is very pleased that The Netherlands joined with three experts so that their experience can be shared with the other member countries:

- **ElaadNL** (www.elaad.nl): ElaadNL is the knowledge and innovation centre in the field of (smart) charging infrastructure in the Netherlands. ElaadNL actively contributes to the development of open standards like OCPP, OSCP, and OCPI. Open standards or open protocols ensure that EV charging systems speak the same language. By providing rules and guidelines for data communication, open standards unleash new market opportunities. ElaadNL also actively contributes to roaming through its platform www.e-clearing.net, a platform with the purpose to exchange roaming authorisation, charge transaction and charge point information data.
- **eViolin.nl** (www.eViolin.nl): eViolin is an association of charging station operators and service providers, pursuing national roaming with an international connection, using open standards. eViolin is not responsible for price information on using charging infrastructure. Providing transparent and accurate pricing information is the responsibility of the individual operators and service providers.
- **NKL** (www.nklnederland.com): The Netherlands Knowledge Platform for Public Charging Infrastructure EV is the platform where government, knowledge institutions and companies come together to achieve affordable public charging of electric vehicles. NKL stimulates development in the public charging sector, facilitates innovative projects, supports various initiatives and ensures the exchange of knowledge. NKL's current programs are sector optimization, protocols and standards and smart charging.

Interoperability is of course not only a national or European issue, it is also important that some aspects are being discussed on an international level. Therefore, the European Commission's Joint Research Centre (JRC) and U.S. Department of Energy's Argonne National Laboratory already work together via their EV-Smart Grid Interoperability Centers. They provide a venue for global industry-government cooperation that is focused on the joint development of EV standards and test procedures. The objective is to study interoperability issues between the electric vehicles and the charging infrastructure, covering hardware and information exchange protocols. Also interoperability of the EV fleet and the smart grid is investigated. Pre-normative research is conducted to identify gaps in standards or technology and to support to the formulation of regulations addressing interoperability issues.

17.5 Next Steps

Task 39 is still open for extra member countries. A higher number of countries leads to more and higher quality information exchange and ultimately to better recommendations to stimulate interoperability of e-mobility services, not only within one country but also across borders.

The next step is to organize two workshops to stimulate the further exchange of information/best practices between the stakeholders from the different member countries. The collected information via desktop research and direct contacts will be stored in the IEA HEV TCP Task 39 SharePoint site which is accessible for all member countries.

The Task 39 member countries will also write the country chapters on their local charging infrastructure market and these chapters will disseminated via the next IEA HEV TCP Annual Report and website.

In the first months of 2020, the final report with recommendations to improve the interoperability of e-mobility services will be finalized.

17.6 Contact Details of the Operating Agent

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18 Critical Raw Material for Electric Vehicles CRM4EV (Task 40)

Members: Austria, France, Germany, Republic of Korea, Spain, Sweden, United Kingdom, United States

18.1 Introduction

Task 40 aims at providing accurate, credible and up to date information on materials which are considered as (potentially) critical for a quick ramp up of electric vehicles sales.

Issues which will be covered are for example:

- Which materials are critical raw materials for EVs?
- Are there currently already supply chain issues?
- What are other uses of the CRMs and how will these develop?
- Towards a future of mass deployment, are there potential supply chain issues? If so, are these temporarily or structural and under what circumstances would these issues occur?
- Are there alternative materials or solutions available, and if so, are there any drawbacks on using these?
- What are the impacts of evolving battery technologies?
- What is the nature of potential supply chain issues: material availability, environmental impacts, social impacts, geographical dependencies (concentration)?

Raw Materials under consideration to be included in the scope of Task 40 CRM4EV are those materials which are economically and strategically important for the mass deployment of Electric Vehicles, but have a high-risk associated with their supply.

It is important to note that these materials can be classified as 'critical' for various reasons:

- They have a high-supply risk due to limited mining (refining/smelting) capacity and/or a high level of concentration in particular countries.

- There is a lack of (viable) substitutes, due to the very unique and reliable properties of these materials for existing, as well as future applications for EVs.
- There can be significant environmental impacts through the supply chain of these materials and intermediate products.
- There can be significant issues concerning responsible sourcing of the materials and/or its intermediate products.

Materials like Lithium, Cobalt, Graphite, Rare Earth Elements and others are already frequently in the news related to their (presumed) scarcity, environmental or social issues. But also, less discussed materials like Nickel and Copper will probably be in the scope of Task 40 as may be some materials which may play an important role for EVs in the future like Niobium.

Conflicting information is making it difficult for policymakers and administrations to get fact based and reliable information. This is especially the case for discussions related to future mass deployment of EVs which may start to be relevant in the next decade. Combustion engine technologies also require critical materials, often with overlooked or already accepted impacts. Fuel Cells currently use PGMs (Platinum Group Metals as do catalysts for diesel cars). The Task will review impacts of mass BEV deployment on the currently critical raw materials as well as from a material availability point of view.

18.2 Objectives

The Task 40 overall objective is to generate and continuously update the relevant information needed by Task member countries and other stakeholders (such as AVERE, Cobalt Institute, Copper Institute, Nickel Institute, Anglo American, Umicore) related to critical raw materials for EVs. This includes:

- Publications in the form of easy accessible for all, “factsheets/infographics” which inform stakeholders on the current status for the relevant materials or issues, but also provide scenario based information related to mass EV deployment.
- Continuous data collection and analyses including validation through multiple opinions and discussion within the workshops.
- Development of global views as well as regional or country perspectives, based on the stakeholder needs (information, analysis, scenarios).

To achieve this, the Task will build a global representative network on the topic "Critical Materials for EVs" with stakeholders from administrations, industry, policy makers, researchers and other relevant stakeholders representing the different value chains of the identified "in-scope" critical materials. External experts will be involved as well.

The network will meet twice per year through workshops and a structure with several sub-groups for different critical materials, topics may be defined. The actual need for information and analyses from governments (and the EU) and those of other stakeholders is used as the basis to define the detailed tasks to be conducted. IEA HEV TCP participating countries will be in the lead for this!

18.3 Working Method

- Define and maintain a list of critical raw materials to include in the scope of the Task CRM4EV.
- Define « criticality » of the critical raw materials in scope:
    - Depending on geography
    - Depending on penetration rate in the EV application (scenarios)
    - Depending on the use of the CM in EVs, cars and in other applications
    - Short term versus long term supply issues
- Evaluate (future) availability of alternative solutions or materials (e.g. rare earth element free electro-motors, solid state batteries).
- Define the different sources (mines: where, what) and exploitable reserves of the different critical raw materials (are they exploited as primary or secondary product?). Evaluate the impact of permitting processes in expanding existing or opening new mines.
- Evaluate quality (and purity) requirements and issues (materials from different mines / processes can have different characteristics).
- Evaluate environmental (life cycle) and social impacts.
- Evaluate importance of recycling today, gap analyses in recovery and recycling technologies. Cost position of recycling, legislation?
- Evaluate LCA impacts, variations by region, source, refining processes and other parameters.
- Review existing (and developing) recycling processes and the collection of materials for recycling, obligations (legislation), costs.
- Define and analyse scenarios for future requirements and needs for CRMs for EVs.

18.3.1 Reporting and Deliverables

Priority has been put on the development of “fact sheets” for the raw materials and topics (like recycling of Lithium-ion batteries, environmental impacts of Li-ion batteries). The fact sheets are easy to understand, up to date infographic-style documents aimed at informing especially non-expert stakeholders like politicians, journalists, people working in national administrations, NGOs etc. The factsheets will describe the current situation, but also highlight some scenarios for a possible mass deployment of EVs and the impact thereof on the raw material needs and impacts.

Other possible deliverables which are considered are listed below:

- List of EV critical raw materials and « needs to know « for these CRMs
- List of transport (vehicles) CRMs impacted by EVs (replacement)
- Short summary « fact sheets » on CRMs and CRM4EV topics (like recycling, LCA)
- Insights in the current mining, refining, main applications of the CRMs
- Insight in planned and potential mining and refining capacities
- Insight in current and projected (scenarios) needs of the CRMs
- Insight in need of the CRMs per unit, current and future
- Insight in alternatives of the CRMs (and impacts if alternative is used)
- Insight in recycling processes and legislation (including collection potential)
- Workshops and dissemination at relevant conferences
- Yearly reports
- CRM4EV Casebook

18.4 Results

The Task 40 has held its first (2-day) workshop in November 2018 in Brussels. It was attended by around 40 people - Task participants, invited speakers and observers. As a result of this workshop the action plan for the coming period was defined and the priority was set at the development of the “infographics” which will be developed. In collaboration with external experts and stakeholders, the data collection has started.

The IEA HEV TCP Task 40 CRM4EV has been presented at the following conferences and events:

- Argus Conference “Batteries in Automotive”, Wiesbaden, 18 September 2018.
- EIT Raw Materials Expert Forum – Sustainable Materials for Future Mobility: E-drives, Magnets, Batteries, 23 October 2018, Darmstadt, Germany (The European Institute of Innovation and Technology (EIT) is an independent EU entity).

- DEMETER Final Symposium, 6 February 2018 – Leuven, Belgium (DEMETER is an EU H2020 project on the recycling of Rare Earths from permanent magnets).
- Paydirt's Battery Minerals Conference, 12 March 2018, Perth, Australia.
- CRM Alliance event, "Transitioning to a low carbon and energy efficient economy: Battery Raw Materials vs CRMs behind the scene", Brussels, Belgium, 20 March 2018.
- Mineral and Investment week, 2nd Annual Lithium & Battery Metals Conference, 21 March 2018 Perth, Australia

18.5 Next Steps

Workshop 2 will be in May 2019, in Lyon, France. The target is to publish the first "fact sheet" in May as well.

A website dedicated to Task 40 CRM4EV (www.crm4ev.org) will go live in March 2019 and will serve for external and internal communication.

EV mass deployment scenarios will be developed in the first half of 2019 and a coordinated action to review the environmental (LCA) impacts and recycling of Lithium-ion batteries will be started early 2019.

Infographics "one pagers" and more elaborate ones will be designed for the CRMs in scope as well as to relatated topics.

Task 40 CRM4EV will continue to be presented at relevant conferences and events.

18.6 Contact Details of the Operating Agent

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19 Electric Freight Vehicles (Task 41)

Members: Austria, Germany, Switzerland, Turkey, United Kingdom

19.1 Introduction

Road freight transport is one of the fastest growing modes of transport and has an increasing share in the total GHG emissions of transport. Global trends such as growing population, urbanisation and booming e-commerce have almost doubled the worldwide road freight activity and energy use in the last two decades.[15] Furthermore, higher gradients are observed for freight emissions compared to passenger travel emissions for most of the IEA countries[16]. Fleet target are recently set by the European Union for average CO_2 emissions for light and heavy freight vehicles aimed at reducing the increase in freight emissions[17]. Various technical and non-technical options exist for reducing the GHG emissions of road freight transport, such as improving the efficiency of freight logistics or fuel consumption performance of vehicles. Current emphasis is on incremental technology developments to reduce fuel consumption of conventional vehicles. However, there are potentials for (near) zero tailpipe emission vehicles that could result in the large-scale GHG reduction that is needed. In addition to global impacts, air pollutants are emitted locally through combustion of fossil fuels. This is a major problem in densely populated cities since road freight transport is responsible for the last mile delivery in these areas. Alternative delivery concepts can have an important contribution to sustainable urban logistics.

19.1.1 Prospects of Electric Freight Vehicles

The International Motor Show in 2018 characterized an increasing electrification strategy for commercial vehicles. Different manufactures showcased their first battery-electric vehicle concepts. Especially in the light segment, vans from Volkswagen, Daimler, MAN, IVECO, Nissan, and Renault are already in series

[15] International Energy Agency, Energy Technology Perspective 2012, Pathways to a Clean Energy System, OECD/IEA, Paris 2012

[16] Eom, J.; Schipper, L.; Thompson, L.: We keep on truckin': Trends in freight energy use and carbon emissions in 11 IEA countries, Energy Policy 45 (2012) 327-341, 2012

[17] https://ec.europa.eu/clima/policies/transport/vehicles_en

production. Prototypical BEVs have also been developed for the medium and heavy-duty segments and are currently being tested in various pilot projects with customers. For example, Daimler is testing its electrified Actros model with different logistic companies like DACHSER and Hermes[18]. Since 2018, MAN Truck & Bus has also been testing the eTGM model in cooperation with its Austrian partner, the Council for sustainable logistics (CNL)[19]. The SOP of these medium and heavy freight vehicles is set for 2021[20].

Figure 1: Renault Master Z.E. at the IAA Nfz fair 2018 (Source: private)

However, electric heavy articulated tractors and semitrailer trucks are currently manufactured and sold primarily by small suppliers such as the Swiss E-Force One AG and the German Framo GmbH. These are so-called electric vehicle converters, which replace the combustion engine of trucks from MAN, Daimler and Co. with their electric drivetrain. In the future the heavy freight vehicle market may also be shaped by American start-ups such as Tesla, Thor, and Nikola Motors. Their vehicle concepts promise higher ranges for sustainable and reliable long-distance transport.

[18] https://www.daimler.com/produkte/lkw/mercedes-benz/eactros.html

[19] https://www.truck.man.eu/de/de/man-etruck.html

[20] https://media.daimler.com/marsMediaSite/de/instance/ko/Praxistest-des-eActros-startet-in-Mannheim-Mercedes-Benz-Trucks-uebergibt-Elektro-Lkw-an-TBS.xhtml?oid=41514787

Figure 2: Volkswagen Caminhões e Ônibus e-Delivery electric truck (left) and Mercedes-Benz eActros (right) at the IAA Nfz fair 2018 (Source: private)

Nonetheless, current BEV concepts do not show long-distance suitability compared to conventional vehicles. Higher electrical ranges are in conflict here with additional battery weight. A solution for this can be offered by electric trolley trucks which are powered with overhead wires on the road. On various test tracks in Germany, Sweden and the USA (California), these are currently being tested in traffic. Trolley trucks with a plug-in hybrid powertrain are also being tested today.

Figure 3: Scania plug-in hybrid trolley truck at the IAA Nfz fair 2018 (left) and electric converted DAF Truck tested in the eRoadArlanda (Sweden) project (right)

19.1.2 Prospects of Fuel Cell Electric Freight Vehicles

Potential for sustainable long-distance transport is also seen in fuel cell electric vehicles. Asian manufacturers such as Toyota and Hyundai have developed first concepts which are currently being tested in practice. However, the potential and challenges of the fuel cell, especially for long haul transport, depends on how the hydrogen refuelling infrastructure network will develop around the world.

19.2 Objectives

Task 41 aims to support the early market introduction of electric freight vehicles (EFVs) by considering the following guiding questions:

1. What is the state of vehicle technology and production costs, what are the next step potentials and how big is the cost gap to conventional and other alternative technologies?
2. Which policies can support and secure the market perspectives of EFVs?
3. If EFVs are introduced successfully in the market, which transport tasks can they substitute best, and up to which extend can EFVs substitute internal combustion engines considering the total freight vehicles fleet?

The first area addresses the technical and economic viability of EFVs – the supply side. Task 41 aims to monitor the technological progress over time and to show the potentials for the future. Cost reductions of the past and their future potentials, taking into account traction battery production for the car and rail sector and other effects on EFVs. A comparison in terms of energy efficiency to ICE-diesel and alternative systems and fuels, including synthetic fuels completes the picture. Aspects of energy consumption will be discussed based on modelling results and real world data collected.

The second area of interest deals with the boundary conditions under which EFVs reach the market as backstop technology. The role of monetary incentives in market development and in particular the long-term policy framework including non-monetary incentives will be discussed. The application of new business models can be just as much a topic as the question of how high up-front investments can be managed.

The third area looks at demand-side issues and is linked both to end customers and to policies. Based on best practice pilot projects, the question of further business opportunities arises. In view of the different suitability of EFV technologies for the replacement of conventional diesel engines, the analysis of the potential contribution of EFVs to CO_2 reduction targets as a share of the overall transport sector is analysed. In this context, we strive for an exchange on methods and data, problems and possibilities as well as on modelling activities.

The scope of Task 41 includes vehicles of the size classes N1, N2 and N3 and all kinds of electrified or electric powertrains like hybrid, plugin-hybrid, battery electric, fuel cell electric, and electric road powertrains.

19.3 Working Method

The main approach of Task 41 is to collect and exchange information in workshops and through contacts to other international networks and projects. According to the objectives, the workshops are aimed at professionals from manufacturers, TIER1 suppliers, researchers, project managers, city planners, policy makers and other stakeholders. The topics and the individual orientation of the workshops are determined by the Task partners. There are both public and non-public workshops planned. Individual contributions/sessions can be treated confidentially at the request of the participants.

Task 41 is a fee-based Task. Parties may join using an HEV TCP voucher from the Secretariat. If no voucher is available, the fee to join the Task is 7,500 EUR (2,500 EUR per year). A concept for sponsors is available.

19.4 Results

Since Task 41 has just started, there are no results available yet.

19.5 Next Steps

A kick-off meeting is planned in the year 2019 as well as a first workshop in the second half of the year.

19.6 Contact Details of the Operating Agent

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20 Scaling-up EV Markets and EV City Casebook (Task 42)

Members: Canada, Denmark, Germany, Ireland, The Netherlands, Republic of Korea, Saudi Arabia, Sweden, United Kingdom, United States

20.1 Introduction

The IEA forecasts that the number of EVs on the road around the world will grow from 3 million in 2018 to 125 million by 2030. This is supported by the declared ambitions of governments to phase out fossil fueled vehicles, including: Norway (2025), Ireland (2030), The Netherlands (2030), France (2040), and the UK (2040).

This Task explores the incentives, investments and infrastructure needed to support this growth and how policymakers should respond to this changing market.

It will collect learning and best practices from existing and planned large scale deployments of EVs around the world. The task will also explore the role of governments in supporting this growth, including requirements to ramp-up supportive policies and how best to phase-out incentives and financial support.

20.2 Objectives

The objective of Task 42 is to highlight key global developments, provide insights on the role of policymakers in accelerating the uptake of EVs and offer guidance on how best to phase out public support.

It will seek to answer three key questions:

1. What are the incentives, investments and infrastructure that will drive growth in markets for EVs?
2. How can the public and private sector work together to accelerate widespread uptake of electric vehicles?
3. How will public policy need to change over time?

20.3 Working Method

The Task will build on the approach and learning from previous successful Tasks (Task 18: EV Ecosystems and Task 22: EV Business Models).

The scope will include different vehicle applications (private cars, taxis, car sharing, delivery vehicles, buses) as well as different models of infrastructure deployment and different funding/financing mechanisms.

Data will be collected through a mix of workshops, interviews, online surveys, and desk research to be programmed throughout the project.

20.4 Results

Task 42 will produce two key deliverables:

- An EV City Casebook that summarises key global developments in concise, accessible, and visually appealing format.
- Policy guidance briefing providing high-level recommendations to policymakers on the role of governments and how policy will need to change over time.

20.5 Next Steps

An international call for projects and data will be launched in the first half of 2019 to source case studies for the EV City Casebook.

This will be followed by a programme of interviews with shortlisted projects, with work to develop an EV City Casebook starting in the second half of 2019.

20.6 Contact Details of the Operating Agent

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21 Overview of Hybrid and Electric Vehicles in 2018

Member countries of the HEV TCP regularly report the sales of HEVs, EVs and PHEVs,

Table 1 shows the fleet totals for passenger vehicles[21] of HEVs, EVs, and PHEVs over the last three years. The numbers for 2016 and 2017 have been taken from the previous HEV TCP Annual Reports or other indicated sources. The country chapters provide more detailed numbers for 2018 sales and fleet totals for EVs, PHEVs, and HEVs.

[21] UNECE category M1 – please refer to vehicle defintions given at the end of the Annual Report

Table 1: Actual or estimated (estimates in italic) electric vehicle (EV + PHEV) and hybrid electric vehicle (HEV) populations for passenger vehicles only in HEV TCP member countries, as of December 31 of each year

	HEVs			EVs and PHEVs		
Country	**2016**	**2017**	**2018**	**2016**	**2017**	**2018**
Austria	17,746	23,546	30,839	11,360	18,566	26,541
Belgium	n.a.	52,559	62,617	17,268	30,498	43,681
Canada	186,057	211,019	228,070	29,270	47,788	90,100
Denmark	n.a.	16,500	24,970	8,373	10,161	14,965
Finland	18,732	n.a.	40,374	3,285	n.a.	15,499
France	283,670	n.a.	408,590	82,229	121,470	165,720
Germany	167,552	192,291	274,414	61,465	98,280	150,172
Ireland	13,637	20,295	32,271	2,053	3,580	7,362
Italy	*117,898*	181,296	177,583[a]	8,822	13,233	7,469[b]
Netherlands	141,559	158,245	180,562	112,008	119,332	142,686
Norway	n.a.	n.a.	93,048	114,050[c]	176,310[c]	290,893
Rep. of Korea	58,596	n.a.	404,759	11,210	25,910	55,417
Spain	94,771	164,696	238,257	8,562	16,283	28,805
Sweden	55,770	70,237	90,273	29,320	43,216	66,058
Switzerland	53,159	n.a.	72,346	14,103	14,539	33,091
Turkey	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
UK	215,053	320,180	n.a.	89,339	135,406	198,048[d]
United States	4,267,157	4,430,000	4,986,911[e]	560,885	750,000	1,117,764[e]
Totals HEV TCP	**5,691,357**	**5,840,864**	**7,345,884**	**1,163,602**	**1,624,572**	**2,454,271**

n.a. = not available
[a] Sums up statistics for HEVs and PHEVs
[b] BEV only
[c] Source: Global EV Outlook 2018
[d] Source: eafo via https://www.eafo.eu/
[e] Statistics include numbers for passenger vehicles and light trucks

22 Austria

22.1 Major Developments in 2018

In 2018 the number of newly registered Battery Electric Vehicles (BEVs) increased by 24.4 % to 6,757. The share of BEVs related to all new registered passenger cars rose from 1.54 % to 1.98 %. Striking is that registrations were predominantly undertaken by legal entities, companies and regional authorities (80.1 % of new BEV registrations), while the share of private registrations declined from 21.4 % in 2017 to 19.9 % in 2018. The overall Electric Vehicle (EV) share rose from 2.02 % to 2.54 % (see Figure below: Development of BEV/ PHEV registration in Austria).

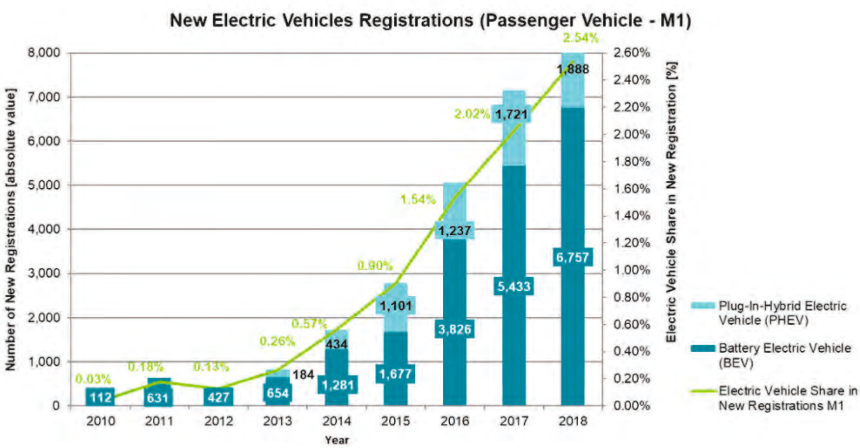

Figure 1: Development of BEV / PHEV vehicle registration in Austria (Source. BMVIT)

The Austrian government adopted the Austrian Climate and Energy strategy. Core of the strategy is a flagship initiative on e-mobility, which is designed to pave the way towards low and zero-emission vehicles on Austrians roads. In support of the flagship initiative Austria offers a package of measures for a quicker e-mobility uptake. The package covers private and commercial vehicles purchase subsidies as well as funding for charging infrastructure installations.

An Austrian National Battery Initiative has been set up complimentary to the European Battery Alliance and in close cooperation with Austrian industry and research organisations. Its objective is to further strengthening and enhancing the competences of Austrian's automotive industry in sustainable production, battery packaging and integration by public R&D funding.

22.1.1 New Policies, Legislation, and Incentives

Austrian Climate and Energy Strategy #mission2030

In May 2018 the Austrian government adopted the Austrian Climate and Energy Strategy *#mission2030*[22] with climate and energy targets for implementing the Paris Agreement. Austria aims to achieve an essentially CO_2-neutral transport sector by 2050. In road transport the objective is the switch to mainly zero-emission vehicles based on renewable energy and nearly zero-emission vehicles. Investment in the strategically planned and demand-driven development of infrastructure is included as an essential prerequisite for promoting e-mobility and alternative propulsion methods.

E-Mobility Funding Measures

In October 2018, the Austrian Ministry for Transport, Innovation and Technology (BMVIT)[23] announced measures to promote electric vehicles with the main focus on local measures such as free parking for EVs and granted free access to bus lanes. In addition, on 01 January 2019 a package of funding measures to support e-mobility, the *Förderpaket für Elektromobilität*[24], entered into force. The package will run for two years and will make 92 million EUR available for the purchase of EVs and charging infrastructure. The package provides funding for electric vehicles, such as e-bikes, e-scooters, e-cars, e-buses and light and heavy-duty e-vehicles as well as funding for the expansion of charging infrastructure and for investments in e-mobility management, e-fleets and e-logistics.

The e-mobility funding package is the successor of the previous 2-years funding program, in which a number of 14,300 funding applications for electric passenger cars and electric 2-Wheelers had been submitted. The share between private and company applications was balanced. Concerning electric passenger vehicles 88 %

[22] Austrian Climate and Energy Strategy: https://mission2030.info/wp-content/uploads/2018/10/Klima-Energiestrategie_en.pdf

[23] Austrian ministry for Transport, Innovation and Technology (BMVIT): https://www.bmvit.gv.at/en/index.html

[24] e-mobility funding: https://www.umweltfoerderung.at/aktuelles-detail/newseintrag/zeige/aktionspaket-zur-foerderung-der-e-mobilitaet-1.html

of the applications fell upon battery electric vehicles while 12 % concerned HEVs and vehicles with range extenders.

Austrian National Battery Initiative

The development and production of battery cells, modules and packs and electric vehicles is of utmost importance for Austria due to its strong automotive supply industry. Hence, the BMVIT set up the *Austrian National Battery Initiative*[25] complimentary to the European Battery Alliance 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 in the vehicle taking recycling and sustainability in energy and battery production as well as efficient industry 4.0 processes into account. The initiative focuses on two main action lines, firstly, to establish a Pre-Production Center for Producing Battery Cells, -Modules und -Packs and secondly, to support the set-up of a Cluster for Battery-Systems, -Integration and -Management.

22.2 HEVs, PHEVs and EVs on the Road

Provisional Total Fleet Number for 2018

According to provisional figures, for the reference day 31 December 2018 the total fleet of motor vehicles registered in Austria amounted to about 6.90 million, by 1.8 % more than in 2017. Passenger cars, the most important type of vehicle (share: 72.2 %), showed an increase by 1.6 % to 4.98 million vehicles. The number of commercial vehicles and trucks recorded 476,329 vehicles (N1, N2 and N3) in total (+4.3 %).

Newly Registered Vehicles

In 2018, registrations of new passenger cars decreased by 3.5 % to 341,068. Nevertheless, after 2017 (353,320) and 2011 (356,145), this is the third highest result ever recorded. Passenger car registrations (341,068) were by 12,252 lower than 2017 (353,320), but still significantly above the twenty-year average of 315,573. Petrol-driven passenger cars (share: 54.0 %) reported an increase of 12.5 %, those with diesel drive (share: 41.1 %) faced a decline of 20.1 %.

[25] Austrian National Battery Initiative: https://www.ffg.at/downloadcenter_mobilitaetderzukunft_call2018as12

24.4 % Increase of Newly Registered Private Electric Vehicles

The number of newly registered BEVs increased by 24.4 % to 6,757, the share related to all new registered passenger cars rose from 1.54 % to 1.98 %. Their registrations were predominantly undertaken by legal persons, companies and regional authorities (80.1 % of new electric passenger car registrations), the share of private registrations declined from 21.4 % in 2017 to currently 19.9 %.

Average CO_2 Emission of Passenger Cars Rises to 126 g / km

In 2018, CO_2 emissions for newly registered passenger cars documented an average of 126 g/km (2000: 169 g/km). For petrol-powered passenger cars, the value rose from 122 g/km to 125 g/km (2000: 176 g/km). Diesel cars recorded an increase in CO_2 emissions from 125 g/km in 2017 to 129 g/km in 2018 (2000: 162 g/km).

UNECE N Categories Vehicles Show the Highest Registration Number Ever Recorded

In 2018, registrations of new commercial vehicles and trucks increase, reaching a new all-time high of 47,947 (+8.7 %). This value exceeds the previous peak of 2017 (44,127) by 3,820 registrations. Commercial vehicles (UNECE category N1; +8.6 %) and UNECE category N3 vehicles (+11.0 %) increased, while UNECE category N2 vehicles (-4.3 %) showed a decrease.

Figure 2 illustrates the number of newly registered passenger BEVs for selected OEM models. This year Volkswagen is the most popular brand in front of Renault Zoe, the top seller of previous years.

Table 1: Distribution and sales of EVs, PHEVs and HEVs in 2018 (Data source: Statistik Austria, https://www.statistik.at)

Fleet Totals on 31 December 2018					
Vehicle Type	**EVs**	**HEVs**	**PHEVs**	**FCVs**	**Total[hi]**
Bicycles	370,866[1]	0	0	0	6,000,000[1]
Mopeds[a]	6,274	2		0	275,372
Motorbikes[b]	1,312	11		0	539,505
Quadricycles[c]	1,028	0		0	32,478
Passenger vehicles[d]	20,831	30,839	5,710	24	4,978,852
Commercial vehicles[f]	2,141	0		0	422,745
Trucks[g]	11	10		0	53,582
Buses[e]	154	5		0	10,037
Totals without bicycles	**31,751**	**36,577**		**24**	**6,312,571**

Total Sales on 31 December 2018					
Vehicle Type	**EVs**	**HEVs**	**PHEVs**	**FCVs**	**Total[h]**
Bicycles	120,574[1]	0	0	0	414,000[1]
Mopeds[a]	1,850	0	0	0	12,172
Motorbikes[b]	316	0	0	0	26,220
Quadricycles[c]	85	0	0	0	2,025
Passenger vehicles[d]	6,757	7,513	1,888	7	341,068
Commercial vehicles[f]	446	0	0	0	43,641
Trucks[g]	17	0	0	0	923
Buses[e]	10	0	0	0	3,788
Totals without bicycles	**9,481**	**7,513**	**1,888**	**7**	**429,837**

n.a. = not available

[1] Data source: https://www.vcoe.at, bicycle fleet sales for 2017; fleet totals estimated on 5 years sales total 2013-2017

[a] UNECE categories L1-L2

[b] UNECE categories L3-L5

[c] UNECE categories L6-L7

[d] UNECE categories M1

[e] UNECE categories M2-M3

[f] UNECE categories N1

[g] UNECE categories N2-N3

[h] Including both conventional and alternative technologies

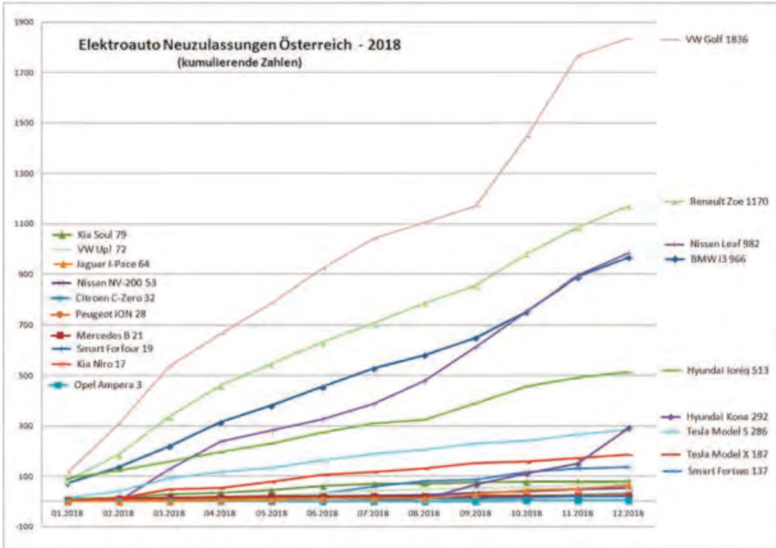

Figure 2: Newly registered electric passenger vehicles in Austria in 2018[26] (Source: BMVIT)

Table 2: Available vehicles and prices (Data source: ÖAMTC: https://www.oeamtc.at, November 2018)

Market-Price Comparison of Selected EVs and PHEVs in Austria	
AvailablePassenger Vehicles	**Untaxed, Unsubsidized Sales Price (in EUR)**
Audi A3 e-tron	41,270
BMW i3	38,850
BMW i3 Rex	n.a.
Citroen Berlingo	34,680
Citroen C-Zero	21,990
Ford Focus Electric	n.a.
Hyundai Ioniq Elektro	35,490
KIA Soul EV AC	33,290
Mercedes Benz B-Klasse Electric Drive	n.a.
Mercedes Benz S 500 Plug-In Hybrid	86,750
Mitsubishi i-MIEV	29,990
Mitsubishi Outlander PHEV	44,640
Nissan e-NV200 2.Zero Edition	44,200
Nissan Leaf Visia 40kWh	35,600

[26] Data Source: https://myampera.wordpress.com/statistik/; based on Statistik Austria Data

Peugeot iOn	21,990
Peugeot Partner	34,680
Porsche Panamera 4 E-Hybrid	111,754
Renault Kangoo Z.E.1	33,180
Renault Twizy 45 Life2	11,680
Renault Zoe R903	32,490
Smart Fortwo Electric Drive4	19,133
Tesla Model S 75D	89,180
Tesla Model X 75D	97,180
Toyota Prius Plug-In Lounge	38,890
VW e-Golf	39,390
VW e-up!	27,590

22.3 Charging Infrastructure or EVSE

In Austria 4,975 charging points are publicly accessible out of which 4,142 charging points are AC Level 2 Chargers with a loading capacity of up to 22 kW. Further 686 fast charging points with a loading capacity above 43 kW are available. This number encompasses the following types of chargers: AC Level 2, CCS and CHAdeMO. Figure 3 visualizes fast charging points (> 43 kW loading capacity) in yellow, the other charging points are indicated in red. Trans-European Transport Network (TEN-T) corridors[27] are highlighted in light blue. Besides the publicly accessible charging points, there are 16 Tesla charging stations providing in 147 charging points (according to the Tesla homepage, January 2019). Due to the lack of an official Austrian register for charging points each provider registers and updates its EVSE data voluntarily.

The majority of the Austrian fast charging infrastructure is multi-standard. Each fast charging station offers in average two or three charging points. A number of public and private initiatives for enhancing further the EVSE network are being carried out. One inititiative example started at the beginning of 2018 in Vienna with the objective to install 1000 additional charging points until 2020.

Hydrogen Fueling Stations in Austria

Austria has seven hydrogen fueling stations (HFS), out of which five are public accessible, for one access is limited to companies, commercial enterprises and municipalities and one is dedicated to hydrogen research. Except for the latter all

[27] European TEN-T corridors: https://ec.europa.eu/transport/themes/infrastructure_en

HFSs support a pressure of 70 MPa. In 2018 24 fuel cell electric vehicles (FCEVs) are registered in Austria.

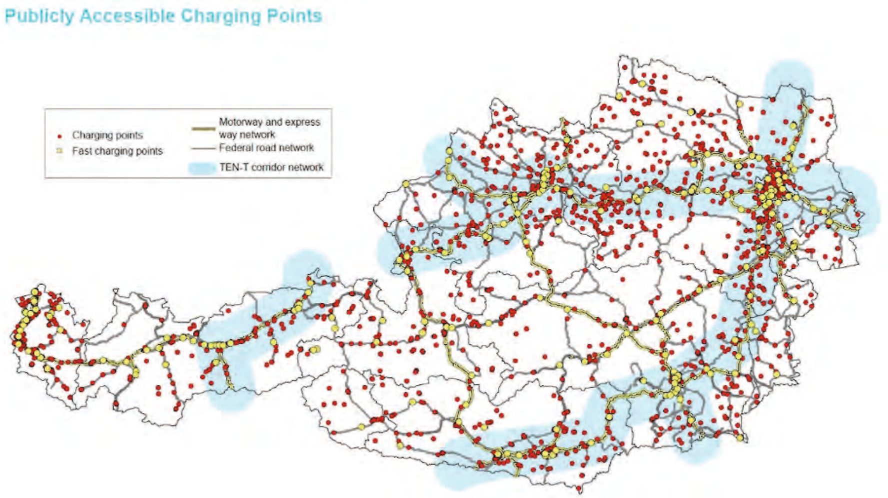

Figure 3: Publicly accessible charging points in Austria (Data source: BMVIT)

Table 3: Information on charging infrastructure in 2018 in Austria (Data source: http://e-tankstellen-finder.com)

Charging Infrastructure on 31 December 2018	
Chargers	**Quantity**
AC Level 1 Chargers	n.a.
AC Level 2 Chargers	4,304
CHAdeMO	255
CCS	269
Tesla	147
Inductive Charging	n.a.
Totals	**4,975**

22.4 EV Demonstration Projects

Programme Klimaaktiv Mobil

klimaaktiv mobil[28] , the national action program for mobility management provides free advice to businesses, fleet operators and property developers, as well as cities, municipalities, regions and tourism operators to develop and implement mobility

[28] klimaaktiv mobil: https://www.bmnt.gv.at/english/environment/Air-Noise-Traffic/klimaaktivmobil.html

projects and transport initiatives that aim to reduce CO_2 emissions. The program funds alternative vehicles, electric mobility, the promotion of cycling and mobility management. Since 2006 11,600 climate-friendly mobility projects received financial support. The *klimaaktiv mobil* website offers a map with the details of each project. The implementation of these projects enabled annual savings of half a million tons of CO_2. The financial support amounted to 106 million Euros until the end of 2017. In 2017 13.9 million EUR funding has been made available.

Zero Emission Mobility Programme

The *Zero Emission Mobility*[29] program forms the research core for implementing the e-mobility initiative of the Austrian Federal Government. The focus of the program is on zero emission mobility projects in road transport with integrated demonstration and a clear implementation perspective. The calls are technology neutral encompassing the three pillars, vehicle – infrastructure – user, from the predecessor program, the Austrian Electric Mobility Flagship Projects.

Up to today under the flagship program 9 calls have been published, which lead to 21 projects with 244 project partners and an overall funding of 53 million EUR.

Mobility of the Future Programme

The research program *Mobilität der Zukunft*[30] , (Mobility of the Future) is an Austrian national transportation R&D-funding program for the period 2012–2020. The Austrian Federal Ministry for Transport Innovation and Technology (BMVIT) is fully in charge of the program content and the four complimentary thematic fields: Personal Mobility, Mobility of Goods, Vehicle Technology and Transport Infrastructure. The annual budget of Mobility of the Future is between 13 and 19 million EUR.

Austrian Association for Advanced Propulsion Systems (A3PS)

In 2006 the Austrian Federal Ministry for Transport Innovation and Technology (BMVIT) founded the "Austrian Association for Advanced Propulsion Systems (A3PS)[31]" in order to support an active technology policy of the ministry and to strengthen Austrian research and development activities. A3PS is a strategic public-private partnership, serving as a reliable partner for the ministry as well as for the partner companies and scientific institutions. A3PS addresses advanced

[29] Zero Emission Mobility projects: https://www.klimafonds.gv.at/wp-content/uploads/sites/6/Klien_Emobilitaet18_englisch.pdf

[30] Mobility of the Future: https://www.bmvit.gv.at/en/innovation/mobility/future_mobility.html

[31] A3PS: https://www.a3ps.at/

powertrain and vehicle technologies such as advanced Internal Combustion Engine (ICE) technologies, hybrid, battery electric and fuel cell vehicles as well as advanced fuel technologies including bio fuels and active safety measures such as Advanced Driver Assistance Systems (ADAS).

22.5 Outlook

The existing political framework is focussing on positive incentives such as purchase subsidies for EVs or free access to buslines. The new registration numbers in the coming years will indicate whether Austria has to adapt its set of incentives based on the experience gained in countries.

In the light of around 90 % of EV owners charging at home the continuous development of public accessible charging is not sufficient. The installation of public accessible charging infrastructure has to be complemented by further reducing the barriers to install private charging infrastructure in existing residential buildings. Especially in urban areas the adaption of existing legal requirements to the installation requirements of charging infrastructure in apartment blocks is required e.g. for wall boxes.

In 2018, the European Union has published Directive (EU) 2018/844[32] aimed at tackling charging infrastructure barriers e.g. Member States have to ensure that new or renovated non-residential buildings with more than 10 car parking spaces have a minimum of one electric-vehicle charging point. EU Member States are required to transpose the directive by 10 March 2020.

[32] Directive (EU) 2018/844: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.L_.2018.156.01.0075.01.ENG

23 Belgium

23.1 Major Developments in 2018

23.1.1 Electric Mobility in Belgium

Introduction

The vehicle industry in Belgium is in a transition to a clean and smart mobility industry. The vehicle industry has always been an important industrial sector in Belgium, but especially the car assembly was under severe pressure during the past years. For future job creation, our industry has to make the right choices and has to be very efficient and innovative. Within the automotive sector, it is not only about making and selling vehicles anymore. It is about offering a clean, comfortable and cost-efficient mobility service to the end customer.

Electric vehicles can play an important role, especially when we combine this with the growth of renewable energy sources in our energy supply. The transport and energy sector will get more and more interlinked and this creates new economic opportunities for companies in this new e-mobility value chain (vehicles, charging infrastructure, ICT, mobility and energy services).

A dedicated study on these economic opportunities has been concluded at the end of 2016 within the framework of IEA HEV TCP Task 24 “Economic Impact Assessment of E-Mobility”. It was a cooperation between the following countries : Austria, Belgium, Denmark, France, Germany, the Netherlands, Switzerland, and USA. All results can be found online on http://www.ieahev.org/tasks/economic-impact-assessment-of-e-mobility-task-24/.

In March 2018, Agoria also started a one-year-study called “LIFEBAT”, with the goal to map out the opportunities and challenges for the companies in the Flemish Region in the complete value chain of the Lithium-ion battery. This study aims at concrete recommendations regarding actions and initiatives that are needed from the industry, from the government and from knowledge centers in order to strengthen the position of the Flemish Region in the complete Lithium-ion battery value chain.

Passenger Cars

Today, Belgium still hosts two car assembly plants: Audi in Brussels and Volvo Cars in Ghent. Both OEMs are active in the field of electric mobility.

The site of **Audi Brussels** in Belgium is a key plant for electric mobility in the Volkswagen Group. Audi Brussels has been producing the Audi A1 family in the European capital of Brussels since 2010. In September 2018, Audi Brussels began mass production of the Audi e-tron, the first full-electrical model from the brand with the four rings. The sporty SUV combines the space and comfort of a typical luxury class automobile with a range suitable for everyday use, catapulting the driver into a new era with the electrical all-wheel drive. With a charging capacity of up to 150 kW at quick-charging stations, it is ready for the next long-distance stage in about 30 minutes. Audi presented the unveiled electric car for the first time at its world premiere in San Francisco on 17 September 2018.

Figure 1: The Audi e-tron on the finish-line at Audi' s plant in Brussels (Source: Audi Brussels)

Since summer 2016, the Audi Brussels plant has extensively rebuilt its body shop, paint shop and assembly line step by step, and has set up its own battery production. Driverless transport systems bring the batteries for the electric cars to the assembly line just in sequence. The employees in Brussels have received more than 200,000 hours of training for the first all-electric Audi and are thus perfectly prepared for the start of production.

Audi attaches great importance to resource-conserving production. As the first of its kind, the e-tron will be produced completely CO_2-neutrally at the converted Brussels plant, where also the model's batteries are assembled. Audi has been investing considerably in rebuilding the factory. The site is now covering all production processes and all other emissions generated at the plant by either renewable energies (approximately 95 %) or environmental projects (approximately 5 %). Audi Brussels thus operates the world's first certified CO_2-neutral high-volume production plant in the premium segment.

Figure 2: Robots are positioning and fixing the top cover of the lithium-ion battery in the brand new battery assembly-line (Source: Audi Brussels)

Volvo Car Gent has been producing cars in Ghent since 1965. For the ninth year in a row, Volvo Car Gent is reporting volumes in excess of 200,000 cars. 2018 was a challenging year for Volvo Car Gent. The production of the XC40, European car of the year, reached cruising speed with over 89,000 vehicles made. The new V60 was introduced in September 2018 and over 5,000 were produced in the last four months of the year. In 2019, Volvo Car Gent is to focus on expanding capacity for the XC40. The goal is to double the production capacity for this compact SUV by 2020, a process that will take place in three waves and is intended to respond to the high worldwide demand for this model.

Leadership in electrification: every Volvo launched in 2019 will have an electric motor, placing electric mobility at the core of the future business of Volvo Cars. The aim is that 50 % of sales by 2025 is made up by fully electric cars.

Volvo Car Gent is preparing for its role in the electrification strategy of Volvo Cars. As regards to technical and logistical aspects, all preparations are being made to be able to produce hybrid and electric vehicles. Besides the end assembly of the vehicles, the building of a battery assembly plant has started and first assembly of battery packs is expected in 2020.

Figure 3: Volts by Volvo Cars (Source: Volvo Cars)

Volvo Cars is stimulating it's end customers to drive on green electricity via the "Volts by Volvo Cars" offer in Belgium.

Volvo's sustainability goal of achieving climate-neutral production by 2025 also remains a priority for Volvo Car Gent. All the electricity used in the plant is already green energy and further steps are being taken in this direction. In addition to previous initiatives such as installing wind turbines and solar panels, the vehicle spraying process is to be made more environmentally friendly and studies have begun to look at ways of using the waste water from the plant.

Besides car assembly, Belgium has a lot of other activities in the automotive sector. **Toyota Motor Europe** has its European headquarter, logistics centers, and technical R&D center in Belgium. Belgium has about 300 local automotive suppliers (for more details see below). There are assembly plants for trucks (**Volvo Europa Trucks**), heavy-duty vehicles (**MOL CY**) and for buses (**Van Hool** and **VDL Bus Roeselare**) in Belgium.

Electric Buses

Belgian bus companies Van Hool, Green Propulsion, and VDL Bus Roeselare are very active in this field.

Van Hool is an independent Belgian manufacturer of buses, coaches and industrial vehicles. The company, founded in 1947, is established in Koningshooikt. The vast majority of its production goes to Europe and the United States. Van Hool has over 4,400 employees worldwide, of whom the largest share work at the production sites in Koningshooikt (Belgium) and Skopje (Macedonia).

Van Hool is very active in electric and fuel cell buses. Van Hool presented its inductively charged electric buses driving in the city of Bruges already at Busworld

2015. With EquiCity, the so-called tram bus, Van Hool developed an innovative concept for sustainable public transport in which hybrid, battery electric or fuel cell powertrain can be integrated. In March 2018, Van Hool announced that will build 58 tram buses for Trondheim in Norway, where they are set to enter service as from August 2019. Also in the Brussels area 14 tram buses will be put in operation.

Figure 4: Van Hool builds first 100 % electric coach for the American market (Source: Van Hool)

Van Hool will introduce a fully electric-powered coach of the type CX45E type on the North American market in 2019. Van Hool selected Proterra, a leading American producer of battery technology for heavy-duty vehicles, to provide the E2 battery technology. The 100 % electric-powered vehicle will have an action radius of +300km and will be primarily used for travel between home and work for groups of employees and/or regular transports of passengers over shorter distances. The vehicle will be designed and developed at the Belgian parent company in Koningshooikt. The first prototypes will be built there as well. Just like the CX35, the CX45 is currently already being built in Skopje, Macedonia, and consequently the production of the CX45E will take place at this site.

Van Hool is also coordinator for important fuel cell electric bus European projects like "High VLO City" and "3Emotion", in which a total of 49 fuel cell buses are being introduced in San Remo, Aberdeen, Cologne, Rotterdam, London, Antwerp, and Rome. At the beginning of 2018, Van Hool announced that it has signed a significant contract with RVK Köln and WSW Wuppertal (Germany), to supply 40 hydrogen buses of the latest generation. This order consists of 30 fuel cell buses for Cologne and 10 for Wuppertal, making it the largest order for hydrogen-powered vehicles ever been placed in Europe. These high-tech vehicles will be built in the Van Hool factory in Koningshooikt. The first buses will be delivered in spring 2019.

VDL Bus Roeselare, part of VDL Bus & Coach bv, produces public transport buses and coaches in the city of Roeselare. VDL Bus Roeselare plays a significant role in the development and production of the full electric public transport bus portfolio within the VDL Group and has supplied its products to numerous European projects, e.g. 43 articulated buses in Eindhoven (NL) and 100 articulated buses in Amsterdam (NL).

Figure 5: VDL Citea SLFA Electric bus fleet in Amsterdam (Source: VDL Bus & Coach bv)

The VDL Citea is available in 9, 12 and 18m length-variants of which the latter two are produced in Roeselare. VDL Bus Roeselare has supplied its hybrid and electric buses to cities in Norway, Sweden, Finland, Denmark Germany, the Netherlands, Switzerland, Belgium, Luxembourg, and France.

Electric Motorcycles

Saroléa (www.sarolea.com) was the first Belgian producer of motorcycles, and one of the first producers of motorcycles in the world. This Belgian factory was established in 1850 by Joseph Saroléa. As of 2008, Saroléa has been focusing on the development and production of high-performance electric two-wheelers and electric drivetrains.

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The Saroléa SP7 electric race bikes and the Saroléa MANX7 road bikes are built around an innovative carbon fibre monocoque chassis and an ultra-efficient 180 kW axial flux motor, powered by a 22 kWh interchangeable battery pack. This combination of materials and techniques results in ultra-efficient motorcycles with an autonomy already surpassing 330 km.

Saroléa is also supplying high-performance / high-capacity battery packs as well as electric drive-trains for automotive, nautical and aerospace applications.

Figure 6: Saroléa SP7 electric race bike with DC quick-charge capabilities (Source: Saroléa)

Suppliers

Belgium hosts about 300 suppliers to the automotive industry. A lot of the innovations in the automotive are taking place on the suppliers side. In Belgium we have renowned suppliers like e.g. **Umicore, Siemens, ABB, Melexis, PEC, Leclanché, DAF, Borit, Punch Metals, Solvay, 3M, JSR Micro,** and **Punch Powertrain**. Most of these companies are active in electric mobility.

Umicore, the Belgian materials technology and recycling group, is uniquely positioned in clean mobility materials, having focused its products and services on technologies that address the key global challenges of clean air (automotive catalysts), electrified transport (rechargeable battery materials) and resource scarcity (recycling). Umicore’s innovation pipeline spans the next 20 years and beyond, aiming for higher energy density and longer driving range in electrified vehicles.

From 2016 to 2018, Umicore invested a total of 460 million EUR to further increase its production of rechargeable battery materials used in Lithium-ion batteries for electrified transport. These investments led to the construction of a new facility in Korea and a brownfield expansion in China, both completed ahead of schedule in 2018.

Figure 7: Umicore battery materials plant in Korea (Source: Umicore)

Given Umicore's roadmap for European rechargeable battery materials and the surging demand from its customers, a further investment of 660 million EUR was announced in February 2018 for a new facility in China and a first production facility in Europe. Located in Nysa, Poland, this European plant is expected to come on-stream in late 2020. Umicore also announced a new process competence center at its site in Olen, Belgium, expected to be commissioned in late 2019, to further strengthen its leadership in innovative energy-efficient production processes.

One of the key elements in rechargeable battery materials is cobalt. In 2015, Umicore invested 25 million EUR to upgrade and expand its cobalt-refining and recycling plant in Olen. Since December 2016, Umicore has obtained third-party validation for its sustainable procurement framework for cobalt. Leading the way in ethical sourcing as early as 2004, Umicore was the first company to introduce a sustainable procurement framework and the first to obtain external validation for its ethical and sustainable procurement approach.

Punch Powertrain continued its efforts to develop its hybrid electric powertrain which has a transmission based on the VT2/3 CVT and uses a PMAC motor. The Switched Reluctance Motor developed earlier was not market ready for PHEV applications. In parallel additional application projects are targeted with other customers. Punch Powertrain also elaborated an electric trike demonstrator and developed an electric powertrain for an electric race car which had its world premiere on EEVC (Geneva). The Punch Powertrain Solar Team was very successful in 2018 by winning the very severe solar car race “Carrera Solar Atacama” in Chile.

PEC (http://www.peccorp.com) delivers the building blocks for the development and manufacturing of large format cells and modules used in electric mobility. PEC released a new generation of battery cell testers, the ACT0550 and CT0550, specifically designed for materials research, life cycle testing and simulation of hybrid and battery electrical vehicles applications, supporting currents up to 4000 Amps. PEC continued the delivery of its automated cell finishing lines to cell makers all over the world. Recent customer research showed that battery cells produced on PEC’s automated cell finishing lines have a much better cycle life and show an improved consistency in cell capacity and impedance due to a more homogenous forming of the SEI layer in the battery cell.

More information about the Belgian vehicle industry can be found on the following websites:

- www.beautomotive.be is the homepage of the Belgian vehicle industry. The sector represents about 300 companies and 70,000 employees, or 10 % of the Belgian export. Beautomotive.be brings together information on relevant companies, events, job opportunities and news items from the sector, covering the topics innovation, technology, talent, investments and internationalization.
- www.avere-belgium.org is the Belgian section of the European AVERE network for manufacturers, suppliers, importers, and distributors of electrically propelled vehicles (battery, hybrid, fuel cell,...) and accessories. The purpose of the association is to promote the use of battery-electric, hybrid and fuel cell electric vehicles and supporting scientific and technological developments.

Research Institutes

The Belgian automotive industry is ready for a transition to a green and smart mobility industry. Many new research and demonstration projects related to electric mobility have been set up in 2018 together with research partners like e.g. Flanders’ MAKE, VUB-MOBI, and VITO/EnergyVille.

The list of projects is too long to summarize in this country report, so we recommend to take a look at the following websites :

- **VUB-MOBI**: mobi.vub.ac.be
- **Flanders' MAKE**: www.flandersmake.be
- **VITO/EnergyVille** : www.vito.be and www.energyville.be

VUB-MOBI: The Mobility, Logistics and Automotive Technology Research Centre (MOBI) is nested at the Vrije Universiteit Brussel (VUB) and is a leader in electric and hybrid vehicles with an impressive track record. It develops electric and hybrid vehicles technologies, and evaluates new concepts in mobility and logistics on their sustainability. Its multidisciplinary team of 100 specialists enables a holistic approach. The group possesses considerable expertise in the scientific and operational management of multi-partner research projects, and is currently involved in multiple European projects. It has a unique position to address the EU roadmapping activities. Some example project references are: FIVEVB - Five Volt Battery, ELIPTIC - Electrification of public transport in cities, and ASSURED - Fast and Smart Charging Solutions for Full Size Urban Heavy Duty Applications.

Flanders' MAKE: Flanders Make is the strategic research center for the manufacturing industry and works together in a structural way with research departments of the five Flemish universities. The aim is to realize a top-level research network in Flanders that delivers full support to the innovation projects of manufacturing companies to contribute to new products and processes that help to realize the vehicles, machines and factories of the future.

VITO / EnergyVille: EnergyVille is an association of the Flemish research institutes KULeuven, VITO, imec, and UHasselt in the field of sustainable energy and intelligent energy systems. EnergyVille provides expertise to industry and public authorities on energy-efficient buildings and intelligent energy networks for a sustainable urban environment. Electric vehicles will play an important role in energy networks based on more and more renewable energy sources. EnergyVille is performing research on batteries (stationary and in vehicles), battery management systems, grid integration, demand side management, energy management systems, business models, etc. Some example project references are: ZEB – Zero Emission Bus Platform, VKSL – Flemish Knowledge Platform Smart Charging, and EVERLASTING - Electric Vehicle Enhanced Range, Lifetime And Safety Through INGenious battery management.

23.1.2 National Policy Framework - "Alternative Fuels Infrastructure Directive (AFID)"

In response to the **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 introduction and roll out of alternative fuels in the Belgian transport sector could contribute significantly to the following objectives: the reduction of our oil dependence, the integration of more renewable energy in the transport sector, the strengthening of our economy & the creation of additional employment, the improvement of air and sound quality and the fight against climate change. However, a significant introduction of alternative fuel vehicles has progressed relatively slowly over the past few years in Belgium. This is mainly due to some persisting barriers that are difficult to overcome, such as for example: the higher purchase price of alternative fuel vehicles, the lack of recharging infrastructure, the limited driving range and the lack of objective and correct information (which causes prejudices among consumers).

Given the complex institutional context in Belgium (both regional and federal entities are directly involved) and the various involved policy areas such as economy, mobility, energy, environment, finances, etc., an **interdepartmental transversal government working group (Energy-Transport)** was created.

The Federal Public Service of Economy and the Federal Public Service of Mobility & Transport (federal government of Belgium) coordinated the national concertation and development of the Belgian policy framework. However, the regions of Belgium (i.e. Flemish region, Walloon region & Brussels-Capital region) are competent for most aspects of Directive 2014/94.

Also the cooperation with neighboring countries is taken into account e.g. via the **Benelux** recommendation M(2015)10 on cooperation regarding the deployment of infrastructure for alternative fuels which was signed by the three Benelux countries in October 2015. This cooperation aims to strengthen the exchange of knowledge and best practices on the deployment of infrastructure for alternative fuels in the territories ensuring a minimum coverage by the end of 2020, 2025, and 2030. In December 2017, the ministers of the Benelux-countries signed a political declaration on borderless e-mobility services, also referred to as **eRoaming**.

Table 1: Division of competences regarding alternative fuels in Belgium (Source: National Policy Framework Belgium)

	Federal	Regional	Local (municipalities)
Fiscal measures	- Tax reduction motorcycles, tri- or quadricycles; - Deductibility of clean company cars; - System of taxable benefits of all kinds (company cars); - Excise duties.	- Purchase premium for electric vehicles (private individuals); - Car registration tax; - Annual circulation tax; - Kilometer based road charge.	/
Mobility & Transport	- Highway code; - Registration of vehicles; - Technical standards of vehicles.	- Public road infrastructure (highways and regional roads); - Availability of alternative fuels on rest areas along highways - Public refueling and charging infrastructure; - Vehicle inspection; - Homologation vehicles; - CNG/LNG/Shore Power installations in ports and along inland waterways; - Public transport (bus/tram); - H2 installations.	- Public road infrastructure (local roads); - Parking facilities on municipal territory.
Energy	- Access to transmission network - Security of supply	- Regulation of gas and electricity retail markets; Access to distribution networks; - Distribution tariffs; - Renewable energy sources (except offshore wind energy); - Energy R&D (except nuclear).	/
Economy & other	- Standardisation/ normalisation - Price indication of energy products & inspection of price indications	- Integration of refueling and charging points in petrol stations; - Development of public network of refueling and charging infrastructure; - Spatial planning.	/

Table 2: Number of targeted alternative fuel vehicles in Belgium (2020) (Source: National Policy Framework Belgium)

Targeted AFVs (2020)	Total	Flemish Region	Walloon Region	Brussels Capital Region
Electric vehicles	**86,641**	74,100	9,903	2,638
CNG vehicles	**42,584**	41,000	1,344	240

Table 3: Number of targeted recharging points in Belgium (2020) (Source: National Policy Framework Belgium)

Targeted recharging points (2020)	Total	Flemish Region	Walloon Region	Brussels Capital Region
Normal & high power recharging points (Public)	**8,324**	7,436	688	200
Shore-side electricity supply in maritime and inland ports	**527**	524	-	3

Underlying regional and federal policy frameworks aim at providing an overview of the current and/or planned policies and measures in favor of the development of alternative fuel infrastructure and vehicles in Belgium. Moreover, specific targets have been determined regarding the roll-out of alternative fuels infrastructure in Belgium.

Flemish Policy Framework

The Flemish policy framework regarding alternative fuels infrastructure for transport in response to Directive 2014/94/EU is based on the **Flemish Action Plan on the deployment of alternative fuels infrastructure** as adopted by the Flemish Government on 18 December 2015. With this Action Plan, the Flemish Government wants to accelerate the transition towards the roll out of an alternative fuels vehicle market in Flanders and to support the European dimension regarding this topic, e.g. in rolling out cross-border infrastructure for alternative fuels. As observed in other countries, multiple actions will be set up simultaneously in order to achieve maximum effect. Market support for green vehicles must be accompanied by the development of charging and refuel infrastructure while at the same time informing the stakeholders concerned, including the early adopter-drivers of Clean Power vehicles. In conclusion, the implementation of the actions as defined in the Action Plan should operate as a driving force during the period 2015-2020, stimulating future Clean Power development.

The Action Plan focusses on four-wheelers and integrates 2020 objectives for electric vehicles and vehicles on natural gas as well as objectives for charging and refueling infrastructure. Long-term goals (horizon 2025 and 2030) are to be further explored and examined. The main actions stimulate market uptake for Clean Power vehicles and aim for a fast expansion of the infrastructure required. The actions should remove the main barriers as experienced by current users, more specifically the purchase price, the lack of charging infrastructure, and the limited user knowledge regarding Clean Power. A well-organized coordination structure with working groups for the implementation, including feedback and reporting mechanisms, ensures the transversal character and the involvement of all stakeholders concerned in the policy development. Key concerns are clear consumer information, visibility and user friendliness.

In order to reach the targets set forward in the Flemish Action Plan, the following policy measures are being implemented:

- Fiscal incentives for Clean Power vehicles (exemption from registration and annual circulation taxes).
- Financial incentives for zero-emission vehicles. A zero-emission premium of 5,000 EUR maximum for individuals when purchasing or leasing battery-electric or hydrogen vehicles has been introduced in 2016. The zero-emission premium has been revised to also allow electric car-sharing companies and non-profit organizations to make use of the zero-emission premium. Also, electric mopeds and motorbikes are now included.
- The 2 year prolongation of the financial support provided under the ecology subsidy to companies for the installation of electric charging infrastructure.
- The setup of a website dedicated to Clean Power (www.milieuvriendelijkevoertuigen.be) and an accompanying communication campaign.
- The development and provision of a tool to compare the total cost of ownership (TCO) of Clean Power vehicles to one another and other vehicles.
- The design of an electric mobility guide for local governments and a guide for charging and home charging.
- The obligation of the Distribution Grid Operators (DGOs) to install 5,000 extra publicly accessible charging points through public procurement in 2020 distributed over the more than 300 municipalities in Flanders. Local governments are responsible for the installation of the parking spot and parking policies (e.g. enforcement). The charging points should enable EV drivers to conveniently charge in Flanders.
- The introduction of a notification requirement for publicly accessible charging points. Gather data on locations of publicly accessible charging points/fueling stations in Flanders and inform citizens through our clean vehicles website.
- The deployment of the first publicly accessible hydrogen refueling stations.
- The setup of actions to encourage the use of shore power for vessels on inland waterways.
- The use of European financial instruments to stimulate infrastructure development in Flanders. Initiated by Flanders and in cooperation with the Netherlands and Brussels Capital region, the BENEFIC Action

(www.benefic.eu), which was selected for financial support under the CEF transport call 2016, has the ambition to implement more than 700 additional infrastructure points for clean vehicles on the TEN-T core network and in the urban nodes, combining normal/fast/ultra-fast charging points, natural gas and hydrogen fueling stations and shore power installations.

- In addition, a number of European projects, initiated by stakeholders, will stimulate the up-take of infrastructure for alternative fuels on the TEN-T core network in Flanders (e.g. FAST-E, ULTRA-E, UNIT-E, H2Benelux, LNG Blue Corridors, etc.).
- The mobilization of funds (1 million EUR each year) to support studies (e.g. light electric vehicles) and Clean Power projects. At the moment, 17 CPT projects are being implemented (e.g. zero-emission buses and taxis, projects on car-sharing and light electric vehicles, projects on grid integration).
- Communication campaign “From Euh? To Aha!” to remove the prejudices from end customers towards electric mobility.
- Group purchase electric vehicles and charging infrastructure will be open for registrations early 2019.

Meanwhile, Flanders is preparing a following-up policy programme for a further transition towards zero-emission transport horizon 2030. A first version of the CPT-Vision 2030 has been set-up in early 2018. The vision contains targets for the market shares of multiple vehicle types in 2025 and 2030 and is partly included in the policy plans on air quality and climate and energy. The ultimate goal is the transition to zero-emission mobility.

Walloon Policy Framework

The Walloon Region has recently boosted its intent to foster alternative fuels on its territory. While electric mobility has improved its ability to replace fossil fuels vehicles in recent years, we have reached a point where an increased support to alternative fuels becomes necessary. Recently, the Walloon Government has approved some decisions that will impact the development of alternative fuels in coming years (i.e. 2030 and 2050). The government has set up a ban on diesel vehicles in 2030 and a 50 % replacement rate on battery electric vehicles (100 % in 2050).

In order to reach these ambitious objectives, several formal decisions have been approved:

- 2 million EUR budget to support deployment of publically accessible charging infrastructures

- 50 million EUR investment plan for power to hydrogen innovative projects where transport will be specifically addressed (with an aim on logistics and public transportation)
- 40 million EUR for 2018 and 2019 for specific climate actions where transport is a major objective to be encountered
- Implementation of the first hydrogen refueling station within the H2BENELUX project
- 400 hybrid buses to be deployed within two to three years (already 20)
- Study of the potential of electric mobility as a support to the electricity grid
- Specific scope on transport and mobility within the National Plan on Energy and Climate
- Plan FAST that will boost intermodality in transport and aiming at the creation of 100 platforms with shared electric or CNG vehicles, refueling infrastructures, etc. A provisional budget has been approved in order to launch the first platform at last in 2019

Brussels Policy Framework

Especially the numerous diesel vehicles daily entering and circulating the roads contribute strongly to the emissions of particulate matter and nitrogen oxides, causing immense health problems, as well as damage to ecosystems and cultural heritage. Changing the way of transportation towards more sustainable modes of transport (walking, cycling, public transport) is the main driver in the regional mobility policy and is translated in the region's objective to reduce motorized traffic by 20 % by 2018, compared to 2001.

In order to reach the BCR's targets regarding air quality and climate change, additional actions are necessary. These actions have been defined by the 'Air-Climate-Energy Plan' (**ACE plan**), adopted on 2 June 2016 by the Brussels' regional government. Besides rationalizing the transport demand and encouraging a modal shift, the plan includes several measures to improve the environmental performance of vehicles. The introduction of a Low Emission Zone (excluding the most polluting diesel and petrol cars, vans and buses) in the complete BCR territory as of January 2018, is one of the most important measures which have been decided upon. The vehicle taxation (annual circulation tax and registration tax) will also be reformed, as part of the ACE plan, giving an advantage to environmentally friendly vehicles.

Alternatively fueled vehicles form an interesting solution for the nuisance caused by conventional diesel and petrol vehicles, although these vehicles will not resolve the problem of congested roads. Seen the urban context of the BCR and the fact that on average only five kilometers are travelled inside the region per trip, electric vehicles are considered as the most promising alternative vehicle technology. This is especially the case for captive fleets, such as taxis, car sharing, public fleets, etc.

To stimulate the transition towards electric transport, the BCR has already taken different measures, e.g. a quota on electric cars in public fleets, financial support for small and medium enterprises to purchase hybrid, electric, and fuel cell vehicles, electric taxis, etc. The public transport company of the BCR (STIB/MIVB) is currently testing electric buses as to prepare the transition for an electric bus fleet as from 2030.

In 2017, the deployment of a public charging infrastructure network will take a lead, with an objective to have 200 recharging points by 2020 for 2,000 electric cars and 600 light duty vehicles. A concession is being prepared for the installation of public charging infrastructure in the Region. The first normal charging points were installed in summer 2018, as to create a regional basic infrastructure, after which the next round of points will be installed based on users demand.

Currently, only one public CNG station is operational in the BCR, which will be expanded towards three public stations by 2020.

The port of Brussels (an inland port, part of the TEN-T core network) will also start the transition towards alternative fuels for vessels with the installation of three shore-side electricity supply points by 2020, as well as one LNG refueling point by 2030.

The urban context and limited presence of motorways on the BCR territory directs the objectives of the Brussels policy framework strongly towards electric recharging infrastructure. Infrastructure for hydrogen or LNG for heavy duty vehicles is currently not included in this policy framework due to safety considerations within our densely populated region.

The Brussels Capital Region (BCR) is also partner in the BENEFIC action (www.benefic.eu), together with the Flemish Region and the Netherlands with the purpose to provide financial support for the installation of two additional CNG stations, ten fast chargers, one ultrafast charger, and three shore-side electricity points for the Brussels' port.

Federal Policy Framework

The main elements with regard to Directive 2014/94 can be found in the policy frameworks of the three regions being mainly competent for aspects regarding alternative fuels infrastructure.

The federal part of the Belgian policy framework describes the main federal policy measures/competences which directly or indirectly regard alternative fuels /

vehicles / infrastructure. The federal part goes beyond the scope of Directive 2014/94.

The federal government of Belgium however played an important role in support actions like the coordination of the national policy framework. The Federal Public Service of Economy and the Federal Public Service of Mobility & Transport coordinated the national concertation and development of the Belgian policy framework. In the ENOVER-Transport working group, all regional and federal energy and mobility related policy makers work together. Input from industry and research was collected via stakeholder meetings and communication has been done via the “Belgian Platform Alternative Fuels”.

The federal government also plays a coordinating role in Belgium related to the cooperation with the other policy levels: Benelux, EU Sustainable Transport Forum, IEA TCP Hybrid & Electric Vehicles, etc.

Main federal policy measures/competences are related to federal fiscal measures, economy & employment, mobility & transport (networked and integrated transport), energy & environment (synergy electric mobility and renewable energy), federal government fleet, standardization (CEN – NBN) and security.

Some examples of federal policy measures:

- Federal fiscal measures for (alternative) company vehicles: advantageous deductibility rates for clean company cars in function of CO_2 emissions, lowering deductibility rates for polluting vehicles, incentives via system “benefit in kind” for company cars, advantageous excise duties for example for natural gas as a motor fuel, equalization of excise duties between petrol and gasoil, etc. Fiscal measures with regard to private vehicles are a regional competence in Belgium.
- Economy & employment: incentives were created by the federal government (tax shift - reduced employer contributions, tax benefit systems for shift work, tax credit for research and development,…) which facilitated the choice of Audi to produce its first EV models in Brussels. The plant in Brussels will also produce the batteries for the electric vehicles. Further efforts will be made in order to attract additional investments with regard to the production of electric vehicles/batteries in Belgium. In February 2018, the federal government organized a stakeholders meeting on Batteries.
- Mobility & Transport: new federal regulation and incentive measures were adopted in 2017 with regard to speed pedelecs. Moreover, in February 2018, a smart mobility call was launched by the federal government (budget: 4 million EUR). The call focused on projects regarding car sharing,

intermodality, services / apps which provide real time information on transport services, open data with regard to mobility, among others.

- Federal government fleet: new rules were adopted in 2017 with regard to the purchase of vehicles for the federal government. In general, the following objective was set: the federal government fleet consists of at least 25% of battery-electric , hybrid or CNG vehicles and at least 25 % of the fleet has an "ecoscore" of 75 (or higher).
- Standardization issues: various standards have been developed and published by the Belgian national organization for Standardization (NBN), also regarding Directive 2014/94.
- Mobility Allowance or "Cash for Car" scheme: the government has set-up this scheme with the goal to create a shift in mobility behaviour by providing a cash alternative for the current company car schemes.
- Mobility budget scheme: The mobility budget offers workers who have a company car the possibility of exchanging it for a less polluting model (maximum 95 grams of CO_2 per kilometre) and to dedicate the budget freed up to means of sustainable mobility (bicycle, public transport, shared cars, etc.) or even the payment of their rent (or interest on a mortgage loan) if they live within 5 km of their place of work.
- Governance of the Energy Union: in order to meet the EU's new energy and climate targets for 2030, Member States are required to establish a 10-year Integrated National Energy and Climate Plan (NECP) for the period of 2021 to 2030. Belgium submitted its first draft NECP to the European Commission at the end of 2018 and the NECP can be consulted on the following website: https://www.cnc-nkc.be/nl/NEKP. The final NECP will be notified to the European Commission by the end of 2019.

23.2 HEVs, PHEVs and EVs on the Road

In 2018, 13,437 electric passenger cars have been sold in Belgium: 9,704 PHEV's and 3,733 BEV's.

PHEV's top sellers in 2018: BMW 530E, Volvo XC60 Plug in Hybrid, Mercedes GLC350E, Porsche Panamera S E-Hybrid and Mini Countryman Cooper SE.

BEV's top sellers in 2018: Nissan Leaf, Tesla Model S, Volkswagen Golf, BMW i3, and Tesla Model X.

All statistics (fleet sales 2018 and fleet totals) on electric passenger cars but also on 2-wheelers, light electric vehicles, commercial vehicles, trucks and buses can be found below.

Table 1: Distribution and sales of EVs, PHEVs and HEVs in 2018 in Belgium (Data source: Federal Public Service of Mobility & Transport)

Fleet Totals on 31 December 2018					
Vehicle Type	**EVs**	**HEVs**	**PHEVs**	**FCVs**	**Total[h]**
Mopeds[a]	21,221	148	n.a.	0	176,633
Motorbikes[b]	21,896	153	n.a.	0	641,458
Quadricycles[c]	1,061	1	n.a.	0	23,844
Passenger vehicles[d]	10,853	62,617	32,828	26	5,848,155
Commercial vehicles[f]	1,019	56	8	0	769,925
Buses[e]	21	496	n.a.	4	16,167
Trucks[g]	17	11	n.a.	0	146,818
Totals without bicycles	**56,088**	**63,482**	**32,836**	**30**	**7,623,000**

Total Sales during 2018					
Vehicle Type	**EVs**	**HEVs**	**PHEVs**	**FCVs**	**Total[h]**
Mopeds[a]	10,686	0	n.a.	0	21,307
Motorbikes[b]	10,874	0	n.a.	0	44,939
Quadricycles[c]	156	0	n.a.	0	727
Passenger vehicles[d]	3,733	13,226	9,704	8	555,692
Commercial vehicles[f]	265	11	2	0	77,804
Buses[e]	14	221	n.a.	0	1,059
Trucks[g]	1	4	n.a.	0	11,259
Totals without bicycles	**25,729**	**13,462**	**9,706**	**8**	**712,787**

n.a. = not available
[a] UNECE categories L1-L2
[b] UNECE categories L1-L5
[c] UNECE categories L6-L7
[d] UNECE categories M1
[e] UNECE categories M2-M3
[f] UNECE categories N1
[g] UNECE categories N2-N3
[h] Including both conventional and alternative technologies

23.3 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. See chapter “National Policy Framework” for more details.

Getting an up-to-date overview on all charging points available in a country is not an easy task, because this information is spread out over the different market players. For previous annual reports, we collected this information via a survey sent to the different market players in Belgium. But this only gave a rough idea of how this charging infrastructure market is growing and which companies are active in this market.

Worldwide, drivers of electrics vehicle need much more detailed real-time information on the charging infrastructure : location, ways of access, availability, prices, etc. There is still a long way to go, because at the moment all the information is scattered over different databases/websites/apps and not always up-to-date and certainly not available in a standardized way. So big improvements are needed in user-friendly access to charging infrastructure information. Therefore **Task 39 on “Interoperability of e-mobility services”** has been started within the framework of the IEA HEV TCP. Task 39 will be coordinated by VITO (Belgium). In the annual report of 2019, a more comprehensive country chapter focused on the charging infrastructure market in Belgium will be included. New initiatives like the European Project “ID and Data Collection for sustainable fuels in Europe” (IDACS) will also be described in more detail.

Before 18 November 2019, all Member States need to submit a progress report related to Directive 2014/94/EU “Alternative Fuels Infrastructure Directive (AFID)” towards the European Commission. This progress report, which has to be updated every three years, will contain more updated numbers on existing charging infrastructure in Belgium.

Statistics on Charging Infrastructure in Flanders

For this annual report we will focus in more detail on the statistics on charging infrastructure in Flanders.

The ambition is to have 7,400 publicly accessible charging points in 2020 in Flanders. Currently, 3,047 normal charging points are registered in Flanders.

Part of the ambition will be realized via the obligation of the Distribution Grid Operators (DGOs) to install 5,000 publicly accessible charging points through public procurement in 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 are distributed over the more than 300 municipalities in Flanders. Local governments are responsible for the installation of the parking spot and parking policies (e.g. enforcement). The charging points should enable EV drivers to conveniently charge in Flanders. An overview of all publicly accessible charging points is available on the clean vehicles website (www.milieuvriendelijkevoertuigen.be/laden).

The number of fast and ultra-fast chargers is also rising as a result of European projects like Fast-E, Ultra-E, Mega-E, and BENEFIC among others. BENEFIC (www.benefic.eu) is an innovative cross-border project for the development of charging and refueling infrastructure for alternative fuels for transport initiated by the Flemish Government in partnership with the Brussels Capital Region and the Netherlands. Through open calls for proposals, the partners selected about 30 infrastructure projects for (ultra)(fast)chargers for electric vehicles, electric taxis and electric buses, CNG and LNG infrastructure, hydrogen refueling infrastructure and onshore electricity supply facilities for inland navigation. The projects have to be realized in the summer of 2020. Currently, 72 fast chargers are registered in Flanders spread over 38 locations.

Triggered by the end customer needs and by the European and national/regional governments, the market for charging infrastructure is trying to organize itself to aim for an open and interoperable charging network. In Flanders, this process started already in the Flemish Living Lab Electric Vehicles (2011-2014) within the interoperability working group. Afterwards, different initiatives like EVORA and OpenChargePoint.be continued this huge effort of bringing the different stakeholders together to set-up “code-of-conducts” in which the main and basic conditions for public accessible charging are described. This code will be used as a standard in Flanders, as it was also referred to in the Flemish EV policy. The code covers topics such as charging definitions, conditions for accessibility, payment standards, and interoperability.

As described in the chapter “National Policy Framework”, a lot of new policy measures have been taken to stimulate the alternative fuels infrastructure. To avoid duplication of information, we recommend to read that chapter. All measures aim for having more publicly accessible charging points and for giving the potential EV drivers more accurate information.

All information is centralized on the following website: https://www.milieuvriendelijkevoertuigen.be/laadpalen-in-kaart

23.4 EV Demonstration Projects

LIFEBAT

Agoria started a one-year-study called “LIFEBAT” in March 2018, with the goal to map out the opportunities and challenges for the companies in the Flemish Region in the complete value chain of the lithium-ion battery. This strategic study is coordinated by Agoria, together with the clusters Flux50 and SIM Flanders and is performed in collaboration with experts in the field of battery technology.

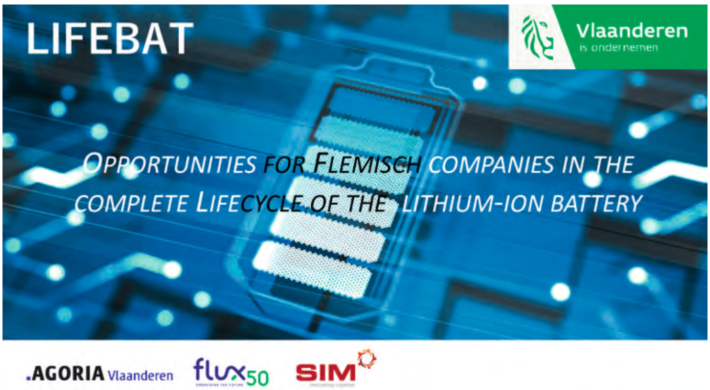

Figure 8: LIFEBAT consortium

This study seeks to answer the following questions:

- How will the global value chain of lithium-ion batteries evolve and what are the underlaying technological and economic trends?
- What are the demands and requirements of the energy storage sector and of the automotive sector?
- What know-how and products are the worldwide battery producers willing to acquire externally and how can we set-up the required supply-chain for that?
- Which related knowledge and products are available at our companies, universities and knowledge centers and how can this be engaged in a European and international context.

This study aims at concrete recommendations regarding actions and initiatives that are needed from the industry, from the government and from knowledge centers in order to strengthen the position of the Flemish Region in the complete value chain. Special attention is also given to SME’s.

Other results of the study include knowledge on the expected evolution in the value chain and cost of lithium-ion batteries, insights in the required performances to use batteries for stationary storage and for automotive applications, insights in the aspects of circular economy of batteries (second life), etc.

Further, this study will provide an overview on the materials related know-how and products available in the Flemish Region, that can be applied on or adapted to the complete value chain (e.g. recycling technology, coating processes, inspection systems, active components and additives, etc.).

Finally, this study will identify the opportunities for the technological companies in the different aspects of the complete value chain and for the complete life cycle of the battery.

The detected stakeholders will participate in dedicated workshops in 2019 on three selected themes to build further upon the results of the LIFEBAT project.

Punch Powertrain Solar Team Wins Carrera Solar Atacama 2018

The Carrera Solar Atacama is described as the most extreme solar car race worldwide. The 2,600 km long track runs right through the bone-dry Atacama desert, in the north of Chile, and through the Andes mountain range. Big differences in altitude (from sea level to peaks of 3,400 meters hight) and the high levels of solar radiation make this race an ultimate test for the participating solar cars.

Punch 2, the solar car built by students of KULeuven, was the first to cross the finish line in Arica, in the north of Chile in October 2018. The Punch 2, which left all the opposition behind in Chile, is already the seventh solar car designed and built by students of Leuven University.

Every year students form a new team that draw lessons from previous races to further improve the solar car technology. A solar car generates electricity via photovoltaic cells. This power does not only drive the electric motor, but it is also stored in the on-board batteries – so that the car does not come to a standstill in the absence of sunlight. A reliable battery management system (BMS) is indispensable here. The electrical system monitors and protects the battery so that it doesn’t break down under extreme conditions. In addition, the BMS indicates, accurately and in real time, how much energy is left in the batteries.

The BMS of the Punch 2 was developed by VITO/EnergyVille. This BMS is one of the few systems available that can balance the battery both dynamically and actively. Thanks to the balancing system, each cell can be individually recharged or discharged. This allows to make the most of the inherent capacity of the entire battery pack. The BMS ensures that all battery cells are kept in balance, while the entire battery pack is being – simultaneously – charged or discharged. Thanks to this BMS, it is therefore possible for all the individual battery cells to be fully charged and discharged under safe conditions to their limit.

Figure 9: Punch 2 Solar Car (Source: Geert Vanden Wijngaert - Agoria Solar Team)

In 2019, the team will continue under the name Agoria Solar Team. VITO/EnergyVille will continue to support the Solar Team with a view to the World Solar Challenge in Australia in October 2019.

E-Buses in Belgium

ZEB Platform

The Flemish Zero Emission Bus Platform (ZEB Platform) has been running from 2017 until mid-2018 (http://www.platformzeb.be/).

The Zero Emission Bus project aimed to accelerate the transition to zero emission bus transport in Flanders, by improving the cooperation and knowledge sharing between the different stakeholders. Many workshops have been conducted. The ZEB platform worked closely together with the ZeEUS project (www.zeeus.eu), to translate the huge amount of knowledge build up by ZeEUS on the European level to the local situation in Flanders.

At Busworld 2017, the first intermediate results have been presented and the final ZEB report with conclusions and policy recommendations (in Dutch) has been presented during an event in the Flemish Parliament mid-2018 and at the final event at Multiobus, one of the active partners of the ZEB Platform.

De Lijn

The Flemish public transport company – Vlaamse Vervoermaatschappij De Lijn – has been running daily services with hybrid buses and also electric and hydrogen vehicles for several years.

Figure 10: Flemish Zero Emission Bus Platform closing event (Source: FBAA)

In 2010 – 2011, 79 hybrid buses build by Van Hool, came into service. These buses use ultracapacitors as an energy storage system, the diesel engine produces the mechanical power for the generator to feed the traction motors and to drive other auxiliary equipment. This series of buses allowed De Lijn to gain the first experience in electric drive technology, including the necessary maintenance and safety competences. These buses are in service mainly in Ghent (articulated hybrid buses) and Leuven (12m electric buses), but also Antwerp, Bruges, and Hasselt have this kind of hybrids.

Next steps in the path towards cleaner public transportation were the orders of hybrid buses in 2013 and 2014, were 120 VDL 12m buses (type Citea SLF) and 18 Van Hool city buses (type A309 H) were ordered. In the evolution of the hybrids it became ‘all electric vehicles’, where all the auxiliary equipment is electrically driven and they are equipped with batteries. The big advantages are better energy management and the start-stop functionality which allows to stop the diesel engine at stops and to run on the battery over a few 100 meters. The energy management is focused on fuel saving, and results in an overall value of 25 % reduction calculated over all seasons and includes the fuel consumption of auxiliaries such as the water heater in winter. Several optimizations were needed and are successfully executed by Van Hool and VDL.

Since the technology is continuously improving in this field a next generation of hybrid buses is coming into operation. In 2017-2018 De Lijn ordered a total of 150 VDL 12m hybrid buses (type Citea SLE) and 36 Van Hool city buses (type A309 H). A first order of 14 double articulated so called tram-buses (BRT-buses) has been placed at Van Hool (ExquiCity) to run on the corridor around the Brussels Region towards the airport in Zaventem. The basics of these 12m buses are in fact electric buses equipped with a diesel engine. They are prepared to receive fast charging equipment and to be turned into real electric buses with a range extender when charging stations will be available. The Van Hool buses could also be extended to be rechargeable buses (PHEV). It is foreseen to have total fleet of about 400 hybrid buses in operation by the end of 2019. Actually, all hybrid buses together ran over 54 million kilometres since their introduction. The fuel saving over the last three years is estimated over 3 million liter of fuel.

Figure 11: Hybrid bus from order period 2017-2018 (Source: De Lijn)

Before this last investment in hybrid buses, De Lijn executed a new research on other alternative fuels for buses, which has led to the principle that the last diesel buses were to be ordered in 2018, and from 2019 on only hybrid buses as a transition or electric and hydrogen buses will be tendered.

A tendering procedure was started to order electric buses and charging stations for three cities (Ghent, Leuven and Antwerp) for start-up projects with full electric buses. In total 13 electric buses with 85 kWh batteries and the possibility for fast charging at 300 kW are ordered, together with fast chargers and depot chargers. The systems will be implemented by VDL, ABB and Engie Fabricom. Actually for the cities Leuven and Ghent the preparation of the construction of the charging infrastructure is on-going. Testing and operations are foreseen at the second half of 2019. Antwerp will follow in 2020.

2019 will be a year full of changes on the bus side. As a transition, extra hybrid buses with the possibility to use them as electric buses will be ordered to continue the replacement of buses with Euro III engines. As the implementation of a large number of electric buses need charging infrastructure, either on own or public domain, and the regrouping and reorganization of bus routes, a masterplan is to be set up this year. The goal is to build up an electric bus service in the main cities in Flanders and on the connecting bus routes. The scope of the overall project consists of around 900 electric buses. The existing interaction with the subcontractors of De Lijn is taken into account. In the period of 2019–2024 around 1,200 busses of De Lijn should be ordered to replace diesel buses in order to increase liveability in the city centres and to fulfil the requirements on the Low Emission Zones. A huge amount of work is to be done to create the necessary charging infrastructure on the modal nodes where buses can charge without doing extra (often empty) miles. In the study of the deployment of electric buses, technologies for automated driving systems will be observed to keep the possibilities open for future upgrades.

As De Lijn is still operating five hydrogen buses, an investment in the fuelling station is made, to connect this station in the depot instead of the current location in order to decrease the fuelling time and distance, and increase the useful range. This transfer is planned in 2019. The hydrogen buses operate in the North of Antwerp (quartier Luchtbal and towards Kapellen). Hydrogen is seen as the next step for clean buses on the horizon to be tendered in four to five years, in order to replace buses on regional lines.

STIB / MIVB

STIB / MIVB, the Public Transport company of the Brussels Capital Region, is currently testing electric buses (37 electric buses from different types) as to prepare the transition for an electric bus fleet as from 2030.

Figure 12: MIVB starts to use full electric buses in Brussels in 2018 (Source: MIVB)

TEC Group

TEC Group, the Public Transport company of the Walloon Region, has very ambitious plans in the electrification of its bus fleet.

Figure 13: Volvo 7900 Electric Hybrid charging in Namur (Source: TEC Group)

TEC is currently using 101 electric buses (Volvo 7900 Electric Hybrid buses) and 12 ABB charging stations in Charleroi and Namur.

Platform Electric Company Cars (PEB)

The ‘Platform Elektrische Bedrijfswagens’ (Platform Electric Company Cars or ‘PEB’) aims at accelerating the adoption of electric vehicles in Belgian company fleets. PEB offers a platform for fleet/mobility managers, market players (energy providers, car manufacturers, lease companies and other EV market providers) and policy makers to exchange knowledge and challenge each other to further enhance the implementation of EV’s on the road. PEB is an initiative from Fleet & Mobility (the Belgian organization of fleet owners), Traxio (the Belgian umbrella organization of mobility retailers), The New Drive (management consultants in e-mobility) and Bond Beter Leefmilieu (environmental NGO). The platform is supported and co-financed by the Flemish government through the Clean Power for Transport program and started on 1 January 2017.

With a clear multi-stakeholder path, PEB further established its EV learning community in 2018, whilst developing practical tools and disseminating relevant information. The platform grew from 30 to 47 fleet owners as members over the course of 2018. Together they are responsible for more than 30,000 company cars in Belgium. These members are a mix of government institutions, large companies, SMEs and NGOs, all having an interest and ambitious intentions in EV.

In 2018, PEB actively oriented companies on EV implementation by disseminating best practices and tools through different communication means. The platform launched the model e-car policy in March 2018 and made its interactive EV manual available to members in October 2018. The digital EV manual is build up around six topics with step-by-step explanation and accessory checklists. Both in March and October PEB also held its annual spring and autumn conferences for the broader community. Additionally, a conversation group was launched in September 2018, where market operators and fleet owners had the chance to speed-date to challenge each other around EV charging facilities for company fleets.

PEB has various kinds of partnerships with different stakeholders in which knowledge sharing, event support, enlarging PEB's reach, business (product/service) development and the enhancement of a dialogue between supply and demand are the focus. Since 2018, PEB has built five new strategic partnerships with ENGIE, Powerdale, Lampiris, EV-box, and Ecopuur.

In 2019, PEB aims to further develop its learning network, with the objective to increase the number of EVs in company fleets. Over the course of 2019, PEB will offer an Academy for fleet and mobility managers and organize EV test experiences. Also, a first group purchase will be organized to accelerate the introduction of battery electric vehicles to the Belgian market.

E-Deal

E-deal encourages local governments and companies towards electric car sharing. This project is an initiative of Autodelen.net and its partners, The Shift, Fluvius and Bond Beter Leefmilieu. E-deal is supported and co-financed by the Flemish government through the Clean Power for Transport program and runs over two years (2018-2019).

The overall objective is to partner up and mentor 15 municipalities and 15 companies to share one or more electric vehicles by 2020. E-deal will work towards this goal by disseminating targeted communication about EV car sharing opportunities for municipalities and companies, as well as supporting tangible implementation of electric car sharing at municipalities and companies. Therefore, the projects works together with all interested car sharing service providers.

Sharing an EV company/government fleet is advantageous: reduced km's and CO_2 emissions, retrieved (urban) space and increased social cohesion. Moreover, car sharing is cost saving. Furthermore, introducing electric car sharing is good for a company or government's reputation and stimulates the introduction of EV to the local community.

In 2018, the project organized six national information sessions for municipalities and three information sessions for companies. The project was also presented at several international conferences in Riga, Bradford and Manchester. Both local government institutions and companies will be guided and mentored towards electric sharing once on board of the project. A municipality or company can share their own EV fleet with personnel and their community, or can replace its own fleet by subscribing to an existing car sharing service provider in the neighborhood.

Since the beginning of 2018, the project implemented electric car sharing at four municipalities and seven companies. Moreover, thirteen municipalities and two companies are in the specification phase of initiating EV sharing. Another seven municipalities and nine companies have shown preliminary interest.

During the spring of 2018, E-deal carried out a survey among companies to gain knowledge about the opportunities and thresholds of electric car sharing. At the same time, a survey was carried out among car sharing providers to get insight in what they can offer to companies. This research disclosed gaps and questions concerning electric car sharing insurance, maintenance and taxation. E-deal will develop a business case around electric car sharing to try and close these gaps.

In 2019, E-deal will further implement electric car sharing at municipalities and companies, create targeted communication, disseminate good practices of those already implementing electric car sharing and launch an interactive electric car sharing manual including the business model.

Clean Power for Taxis

The “Clean Power for Taxis” project is led by BBL and taxi federation GTL with support from the Flemish government. The scope of the project is to have at least one out of ten taxi’s driving electrically in 2020. The “Clean Power for Taxis” further builds on the pilot projects in Antwerp and Louvain and will also roll-out in Bruges, Ghent and Mechelen. The project wants to support cities and taxi companies in the process to introduce electric taxis. In the second half of 2018, the municipalities Oostende, Hasselt and Knokke-Heist also joined the project.

At the end of 2018, about 30 electric taxis were in operation in Flanders. The five participating municipalities formulated their ambitions and policy measures related to zero-emission taxis. In 2019, the project will start a communication campaign to sensibilise cities and taxi companies, but also to make the customers rather use e-taxis.

Figure 14: Clean Power for Taxis (Source: Jasper Léonard)

23.5 Outlook

Autonomous Vehicle and Infrastructure Cooperative Architecture

In March 2018, Flanders' government adopted a policy note on connected and automated mobility to realize investment priorities for a smart and safe transport system in Flanders, including regulatory aspects.

Research for autonomous vehicles (functional safety, path planning, control and ADAS information functions) is carried out by Strategic Research Centers, amongst others the AVICA program (Autonomous Vehicle and Infrastructure Cooperative Architecture), enabling Flemish OEMs, tier1, infrastructure, component and service provides to provide proof of concept of their products on system level.

Field Operational Tests on connected and autonomous driving are implemented by knowledge partners imec in the European (CEF) project CONCORDA, complemented with the Flanders' publicly funded innovation project SmartHighway, and a recent public private innovation partnership MobiliData (for cloud service applications for smart traffic infrastructure), other C-ITS projects Citrus, Intercor.

Autonomous Driving @De Lijn

De Lijn, the Public Transport company of the Flemish Region, expects self-driving vehicles to transform mobility and offer the society important challenges and opportunities.

The challenges connected to the introduction of autonomous driving are mainly a result of the induced increase of transport demand which could raise congestion levels significantly. This increase in transport demand will mainly be the result of people being willing to travel more often and longer when the in-vehicle time is no longer perceived as time lost, because the driver is freed from steering or monitoring the vehicle. Furthermore in the future new groups of customers

(-18y/+80y/disabled) will be offered flexible means of efficient transport and new services will arise.

On the other hand, new mobility concepts also offer valuable new opportunities to the society. De Lijn believes autonomous mobility can and should create large societal benefits by leading to the rise of flexible efficient and very attractive forms of shared transport with smaller shuttle bus vehicles operating with short waiting times and transporting groups of customers along flexible trajectories. An important role for the government is to guarantee that this mobility revolution results in the development of such shared and thus sustainable transport. Pilot projects are necessary to gain learning effects in order to be able to steer this revolution in the right direction and maximize public benefits.

Therefore De Lijn works on several pilot projects with autonomous shuttles.

In a first project in Brussels Airport, the pilot stage was recently launched, in which the transport system provider 2getthere aims to demonstrate the safe functioning of a first electric autonomous shuttle vehicle in mixed traffic. According to the current timeline, the implementation of a large scale transport system for passengers can start in mid-2020 after a successful pilot stage. Mid-2021 the first passengers can then be transported. The figure below shows the 2getthere vehicle as selected for the Brussels Airport pilot project.

Figure 15: 2getthere vehicle as selected for the Brussels Airport pilot project (Source: De Lijn)

In collaboration with the cities Antwerp, Genk, Leuven and Mechelen, De Lijn is now finalizing feasibility studies which serve as a preparation for a second wave of pilot projects with autonomous shuttle vehicles. For these projects the next step will be to validate technical and financial feasibility by launching a public tender in 2019 in order to select a technology partner for these pilot projects.

Brussels Airport – Electric Buses

Brussels Airport is one of the largest airports in Europe, handling 25,7 million passengers and 732,000 tons of freight annually.

In 2019, Brussels Airport will introduce electric buses to carry passengers between their gate and the plane. With these new electric buses, Brussels Airport – which achieved carbon neutrality in 2018 – is stepping up its efforts to drive down its environmental footprint.

Over the years, a wide number of measures have been put in place, including in terms of the airport's vehicle fleet. In addition to our investment in CNG-powered service vehicles, Brussels Airport is gradually replacing buses used to carry passengers between the terminals and the aircraft with modern e-buses. Starting from 1 March 2019, the majority of the buses that take passengers to and from the aircraft at Brussels Airport will be powered by electricity. These buses will be built by the European branch of the Chinese company BYD. The charging infrastructure for this project is co-funded by the financing instrument of the European Union, Connecting Europe Facility (CEF), through BENEFIC. The electric bus project fits in with Brussels Airport's ambition to drive down its carbon dioxide emissions by 40 % by 2030 (compared to 2010).

Figure 16: Electric buses to be introduced on Brussels Airport in 2019 (Source: Brussels Airport Company)

24 Canada

24.1 Major Developments in 2018

Canada joined numerous nations at the Paris climate talks in 2015 in pledging to reduce carbon emissions 30 % below 2005 levels by 2030, with deeper reductions beyond that. To achieve this goal, the federal, territorial, and a majority of provincial governments agreed to the Pan-Canadian Framework (PCF) on Clean Growth and Climate Change. The key commitments in the PCF include carbon pricing in all jurisdictions by 2018, accelerated nationwide coal phase-out by 2030, a nationwide strategy for zero-emission vehicles by 2019, the accelerated deployment of charging infrastructure, the implementation of a federal clean fuel standard, and a reduction in methane emissions from the oil and gas sector of 40-45 % by 2025.

Thanks to Canada's wide range of energy resources such as hydropower, a growing renewable power and storage capacity, and various nuclear facilities, almost 80 % of Canada's electricity is from non-emitting sources. Canada is the world's second largest producer of hydroelectricity and uranium, the world's fourth largest producer of renewable energy, the sixth largest producer of nuclear power, and has the world's largest biomass reserves per capita. Electricity is only a small portion of Canada's overall energy use (22 %)[33], therefore significant emission reductions will have to come from industry, transportation and heating in order to meet emission reduction targets.

Transportation accounts for a quarter of GHG emissions in Canada[34], with almost half coming from cars and light trucks. Canada's communities and markets are regionally dispersed, with industries such as manufacturing, energy, mining and agriculture, depending on a strong transportation system. Given the potential to significantly reduce emissions through zero emission vehicle (ZEV) technology,

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[33]Natural Resources Canada, Energy supply and demand, 2017 https://www150.statcan.gc.ca/n1/daily-quotidien/181220/dq181220e-eng.htm

[34] Pan Canadian Framework (Page 13) http://publications.gc.ca/collections/collection_2018/eccc/En1-77-2018-eng.pdf

the Government of Canada, working with public and private stakeholders, is committed to efforts to put more ZEVs on the road.

In 2018, Canada's EV industry saw periods of growth, but was also faced with challenges. In the first half of 2018, Canada experienced record breaking EV sales. This growth can be attributed to several factors: (1) car buyers are increasingly comfortable and interested in the vehicle technology; and (2), new EV models are being crafted to fill market segments and to respond to consumer's preferences for the ideal vehicle. While these trends apply broadly, Canadian specific factors that account for this record breaking year include the release of the Tesla Model 3 into Canadian markets. The greatest challenge encountered, was in July 2018, when Ontario, Canada's most populated province, cancelled its electric and hydrogen vehicle and electric vehicle charging incentive programs.

24.1.1 National Developments

ZEV Targets

In January 2019, Canada's Minister of Transport announced new federal targets for ZEVs to reach 10 % of new light-duty vehicle sales by 2025, 30 % by 2030, and 100 % by 2040. These federal targets align with the provincial targets announced by British Columbia in 2018 as part of the CleanBC Plan. Additionally, Québec has committed to having one million ZEVs on the road by 2030.

Pan-Canadian Framework

In 2017, the Government of Canada along with provincial and territorial governments released the first annual synthesis report on the status of the PCF[35]. As part of this work, federal, provincial and territorial governments committed to modernize transportation systems through new emission standards for vehicles, a plan for establishing retrofit requirements for heavy-duty vehicles, and a strategy to put more zero-emission vehicles (ZEVs) on the road.

Year 2018 was the second year of PCF implementation, which saw a shift from design and planning towards results and delivery. Federal, provincial and territorial governments are continuing to collaborate and partner with Indigenous communities and other stakeholders to deliver on PCF objectives in 2019. Key actions involve implementation of carbon pollution pricing, investment in green infrastructure, support for clean technology and the release of climate action plans to support adaptation and climate resilience. In 2019, work to advance the

[35] Government of Canada. "Pan Canadian Framework on Clean Growth and Climate Change." https://www.canada.ca/en/services/environment/weather/climatechange/pan-canadian-framework.html

implementation of the federal carbon pollution pricing system continues in applicable jurisdictions, with the publication of the first phase of the Clean Fuel Standard, funding decisions for the Low Carbon Economy Fund Challenge, construction of renewable energy projects, hosting the Clean Energy Ministerial/Mission Innovation Ministerial and addressing scientific knowledge gaps.

Clean Fuel Standard

The Government of Canada is developing a Clean Fuel Standard[36] to reduce Canada's GHG emissions through the increased use of lower carbon fuels, energy sources and technologies. The Clean Fuel Standard will apply to all those who produce, import, and in some cases distribute fossil fuels in Canada. It establishes lifecycle carbon intensity requirements separately for liquid, gaseous, and solid fuels, and goes beyond transportation fuels to include those used in industry and buildings. The objective of the Clean Fuel Standard is to achieve 30 megatonnes of annual reductions in GHG emissions by 2030.

On 20 December 2018, Environment and Climate Change Canada released the Regulatory Design Paper for the Clean Fuel Standard[37], which focuses on liquid fuels stream regulations. In this paper, it explains that the Clean Fuel Standard will allow some end-use fuel switching to generate credits. Electricity used by light-duty and heavy-duty EVs will generate credits proportional to the avoided emissions when factoring lifecycle emissions of the fossil fuels being displaced and of the electricity being used to charge the EVs. Final regulations for the gaseous and solid fuel streams of the Clean Fuel Standard are set to be published in 2021. The Clean Fuel Standard would complement the pan-Canadian approach to pricing carbon pollution.

In 2018, provinces and territories engaged in discussions with the Government of Canada to examine a potential shift towards cleaner fuels, with a number of provinces continuing implementation or introducing renewable fuel content regulations. Actions by provinces and territories will complement the federal Clean Fuel Standard. Through the Climate Action Incentive, the Government of Canada will return 90 % of direct proceeds generated under the fuel charge to individuals and households in Ontario, New Brunswick, Manitoba, and Saskatchewan, with the remaining 10 % getting returned to small and medium enterprises (SMEs),

[36] Government of Canada. "Clean Fuel Standard." https://www.canada.ca/en/environment-climate-change/services/managing-pollution/energy-production/fuel-regulations/clean-fuel-standard.html

[37] Government of Canada. "Clean Fuel Standard regulatory design: summary" https://www.canada.ca/en/environment-climate-change/services/managing-pollution/energy-production/fuel-regulations/clean-fuel-standard/regulatory-design.html

businesses, municipalities, universities ,and Indigenous communities, amongst other community groups.

Investing in Electric Vehicle and Alternative Transportation Fuel Infrastructure

The government of Canada is investing 138 million USD over 6 years (2016-2022) to support the construction of green transportation infrastructure to advance a clean growth economy, create well-paying jobs and contribute to Canada's climate goals. The measure, which includes a demonstration and a deployment component, is now in its second phase and has resulted so far in over 260 charging stations, of which more than 100 are publicly accessible EV fast chargers, four natural gas refueling stations, and two hydrogen refueling stations in seven provinces.

The Electric Vehicle Infrastructure Demonstration Program[38] received 58 million USD over 6 years to support innovative and next-generation EV charging solutions in real-world applications such as in multi-unit residential buildings, at workplaces, and for public transit. The Electric Vehicle and Alternative Fuel Infrastructure Deployment Initiative[39] received 73 million USD to further deploy NG refueling stations along key freight corridors, establish H2 refueling stations in key metropolitan areas, and to bolster Canada's coast-to-coast EV fast charging network. Finally, 7 million USD has been allocated for codes and standards development that support electric and alternative fuel vehicles, and supporting charging and refueling infrastructure.

Encouraging Innovation with the Smart Cities Challenge

The Government of Canada's Smart Cities Challenge[40] encourages communities to improve the quality of life for urban residents through better urban planning, the implementation of clean, digitally connected technology including greener buildings, smart roads and energy systems, and advanced digital connections for homes and businesses. The challenge will award 60 million USD to the four communities who have best demonstrated these characteristics of urban planning design and implementation. All applications for the Challenge were submitted by April 2018 and the twenty finalists were announced in June 2018. The winners will be announced in spring 2019.

[38] Electric Vehicle Infrastructure Demonstrations https://www.nrcan.gc.ca/energy/funding/icg/18386

[39] Electric Vehicle and Alternative Fuel Infrastructure Deployment Initiative https://www.nrcan.gc.ca/energy/alternative-fuels/fuel-facts/ecoenergy/18352

[40] Smart Cities Challenge https://www.infrastructure.gc.ca/cities-villes/index-eng.html

Greening Fleets / Leading by Example

In December 2017, the Government of Canada released an aggressive strategy to reduce emissions from all Government operations, including facilities and fleets. This strategy includes commitments to adopt low-carbon mobility solutions, deploy supporting infrastructure in its facilities, and modernize its fleet. Starting in the 2019-2020 fiscal year, 75 % of new light-duty administrative fleet vehicle purchases will be ZEVs or hybrids, with the objective that the Government's administrative fleet comprises at least 80 % ZEVs by 2030. Priority is to be given to purchasing ZEVs. Also starting in the 2018-2019 fiscal year, all new executive vehicle purchases will be ZEVs or hybrids.

To assist all federal departments in succeeding in this commitment, the Government is coordinating across all departments to help collect and analyze the energy usage of vehicles in their fleets, and determine the lowest emitting option that continues to meet their operational needs. This includes identifying options for electrification, fuel switching, fleet right sizing, and fuel-efficient driver training. In June 2018, the Government released a Greening Government Fleets Best Practices[41] guide. This Guide, developed in collaboration between Federal, Provincial and Territorial governments, outlines a comprehensive strategy, which fleet managers at all levels of government can use to assess current fleet vehicle usage, and determine lower emitting options, including deployment of more EVs.

24.1.2 Provincial Policies and Incentives

ZEV sales advance at different rates across the provinces and territories, reflecting regional differences such as geography, climate, electricity generation, local EV policies, availability of EVs, and consumer preferences.

British Columbia

British Columbia has a multitude of policies and programs to accelerate the deployment of low-emission vehicles within the province. They are one of Canada's leaders in new ZEV purchases and charging infrastructure. BC is investing in job training in the ZEV sector, ZEV research, development and demonstration, support for fleets to adopt ZEVs, and public outreach. In 2018, BC released their Climate Action Plan entitled "*CleanBC*[42]" which commits to incremental increases in new ZEV sales, with targets of 10 % by 2025, 30 % by 2030, and 100 % by 2040. Under *CleanBC*, the government will continue to

[41] Greening Government Fleets Best Practices https://www.nrcan.gc.ca/energy/transportation/alternative-fuels/resources/21314

[42] Clean BC https://cleanbc.gov.bc.ca/

provide rebates for light-duty vehicles and expand incentives for clean buses and heavy-duty vehicles. Point-of-sale incentives of up to 5,000 CAD are available for the purchase or lease of new BEVs and PHEVs, and up to 6,000 CAD for hydrogen FCVs.

Home, workplace, and fleet charging station incentives were offered in 2018. To help more drivers make the shift to a ZEV, in 2018 the provincial government, along with other partners, made investments to more than double the size of British Columbia's DC Fast Charger (DCFC) network to 64 sites. As part of this expansion, British Columbians gained access to nine new public EV charging stations installed at highway rest areas throughout the province. Three additional sites are under construction and the B.C. Ministry of Transportation and Infrastructure is planning the installation of eight new rest area charging stations in 2019. A BC cross-ministry working group is collaborating to install EV charging station infrastructure to support the province's public sector fleet. Additionally, the B.C. Ministry of Citizen's Services is investing in EV charging stations for employee and visitor use, and will install ten EV charging stations in 2019.

As a member of the Pacific Coast Collaborative, BC made new commitments to transportation resilience in September 2018, committing to make 10 % of its fleet purchases ZEVs by 2020. Through this initiative, BC is part of larger regional initiatives such as the West Coast Electric Highway and West Coast Electric Fleets. To encourage the transition to EVs, EVs displaying an official decal are allowed in high occupancy vehicle (HOV) lanes in BC regardless of the number of passengers in the car. The EV in HOV lanes program is very popular and since 2016, the B.C. Ministry of Transportation and Infrastructure has issued a total of 10,384 decals. Half of these (5,143) were issued in 2018.

Figure 1: Hope Slide rest area, completed in fall 2018 - two fast chargers, one Level 2 (Source: Government of British Columbia)

Ontario

Ontario is one of Canada's leaders in EV adoption, with over 34,000 EVs on the road, and the deployment of EV charging infrastructure, with over 2,000 public access charging points, including 300 Level 3 chargers. Ontario's EV incentive and charging infrastructure programs were closed in 2018, following the cancellation of the cap and trade program that funded them. Under Ontario's new government, the province decided not to proceed with a ZEV mandate. The government, however, aims to work collaboratively with automakers, the not-for-profit sector, and academia to increase the uptake of electric and hydrogen vehicles.

In November 2018, Ontario's new government released a new climate plan, "Preserving and Protecting our Environment for Future Generations: A Made-in-Ontario Environment Plan[43]". This plan adopts Canada's Paris Agreement emissions reduction target of 30 % below 2005 levels by 2030. The plan points to policies that support ZEV uptake by collecting energy use data from EVs to understand how they can cut costs and reduce emissions, while integrating emerging smart grid technologies and distributed resources, including energy storage. EVs with Green Vehicle Ontario license plates can access provincial high occupancy vehicle (HOV) and high occupancy toll (HOT) lanes with a single occupant, at no cost. Ontario plans to remove rules and regulatory barriers that prevent private investors from deploying various types of charging infrastructure for light- and heavy-duty vehicles, without the support of government subsidies.

Québec

From 2015 to 2020, Québec committed 65.8 million USD to its Transportation Electrification Action Plan[44]. The Plan includes a number of initiatives, including, among others, establishing incentives for electric public transportation, investing in EV charging infrastructure, subsidizing freight delivery electrification, financing R&D for EV technology, and electrifying government fleets. ZEVs in Québec possess green license plates, granting them free access to certain reserved highway lanes, toll bridges, and ferry services. The Highway Safety Code of Québec now prohibits non-EVs from parking at public charging stations. The government's on-going support for the electrification of transportation is demonstrated through several promotional and educational projects that they have financed.

[43] A Made in Ontario Environment Plan https://www.ontario.ca/page/made-in-ontario-environment-plan

[44] Transportation Électrification Action Plan https://transportselectriques.gouv.qc.ca/wp-content/uploads/CIAO-050-LG2-MTQ-Rapport2016ENv2.1_.pdf

As of 31 December 2018, the number of EVs in Québec exceeded 39,000, an annual increase of 79 %[45]. Under Québec's Drive Electric Program[46], eligible new EVs qualify for up to 8,000 CAD in purchase rebates. The Program also offers incentives for the purchase and installation of Level 2 charging stations for residential and workplace chargers. In addition, the Drive Electric Program is undertaking a pilot project that offers rebates on the purchase of used EVs. Many initiatives are planned to be undertaken in the province, in order to ensure that the province's goals of 100,000 EVs and 2,500 public charging stations by 2020 will be reached.

In 2017, the Société de transport de Montréal started using electrical public transit buses as part of a pilot project. In 2018, a decision was taken to fully electrify the bus line. New super-station charging stations, stations with many fast charging points, (Fig. 23.2) are being built across Québec and some existing stations are being upgraded to include faster charging options. Meanwhile, Québec is also developing standards for EV road signs, for example, to help locate charging stations.

Figure 2: Super-station charging station (Source: Government of Québec)

New Brunswick

New Brunswick was the first province in Canada to be fully connected with an EV fast charging network. The province has the fastest growing EV market in Canada with a 124 % year-over-year increase. This increase in publically available charging infrastructure reduces range anxiety and increases consumer confidence

[45] Société de l'assurance automobile du Québec.

[46] Discover Electric Vehicles http://vehiculeselectriques.gouv.qc.ca/english/

in EVs. In 2018, 12 new standard Level 2 charging stations were made available to the public at Provincial Parks across the province.

As of 2018, residents of New Brunswick can receive a 1,000 CAD rebate towards the purchase of a new or used EV or PHEV, when they trade in their gas-powered car. New Brunswick launched an electric school bus pilot program, invested in EVs for government travel, and is developing an EV strategy. Additionally, New Brunswick participated on the Federal Provincial Territorial committee to identify programs to encourage the adoption of fuel saving/emission reduction devices in the trucking industry.

Figure 3: NB Power's charging site at Grey Rock Power Centre, Madawaska First Nation in Edmundston (Source: Government of New Brunswick)

Nova Scotia

Nova Scotia is undertaking work to support the adoption of ZEVs in the province. Nova Scotia Power Inc., the provincial utility, is a strong supporter of the EV movement, as demonstrated through the installation of Nova Scotia's first EV fast-charging network, connecting the province end-to-end. In 2018, Nova Scotia Power Inc. installed a network of 12 Level 3 fast chargers from Yarmouth to Sydney, making it a more viable option to drive an EV in Nova Scotia. The province also installed an additional 12 Level 2 chargers at the same locations. These chargers provide a charging solution for PHEVs that are unable to charge using Level 3 chargers. This network fits into the larger initiative of a coast-to-coast EV charging network in Canada and encourages the adoption of EVs in the province. There are no hydrogen or natural gas refuelling stations in Nova Scotia.

In October 2018, the Government of Nova Scotia passed its cap-and-trade legislation and published associated regulations. Nova Scotia's planned cap-and-trade system is on track to meet the federal benchmark stringency requirements. Through the province's Connect2 grant program, the province is supporting its partners to improve active transportation, alternative forms of transportation, and transportation efficiency. These actions, along with the cap-and-trade program, help Nova Scotia move toward their goals of reducing GHG emissions while growing Nova Scotia's economy.

Prince Edward Island (PEI)

PEI is making progress towards policies that encourage and support the wide-spread adoption of ZEVs. Starting in 2019, vehicle registration fees will be cut in half for hybrid vehicles and free for PHEVs and EVs. Additionally in 2019, the Government of PEI will install six high speed chargers across the province. PEI has already added its first EV to the Government's fleet, completed an EV education program across the province, and developed a proposal for the installation of a high-speed EV charging network across the province.

Northwest Territories

The Northwest Territories (NWT) face unique challenges in the widespread adoption of EVs, including lack of charging infrastructure and the effects of extreme cold weather on vehicle range. Tests of a hybrid gasoline-electric vehicle (Figure 4) found that the technology works in the climate and results in GHG reductions.

The Government of the Northwest Territories (GNWT) will offer a pilot grant program for the purchase of low or zero emission vehicles in communities that are serviced by hydroelectricity. The program will provide a subsidy for eligible vehicles and for the installation of charging stations. The grant is limited to communities powered by hydroelectricity, since EV use in diesel powered communities will result in more GHG emissions compared to gasoline vehicles. Many northern or remote communities are off-grid and rely on diesel for power generation. Beyond extreme cold climates and harsh conditions, this adds another challenge to the introduction of EVs in these regions.

As part of its 2030 Energy Strategy, released in 2018, the GNWT committed to introducing rebate programs for low or zero-emission vehicles and participated in the development of a draft national ZEV Strategy. As part of their short term goals (2018-2021), the GNWT will support community-based transportation initiatives through a new Government GHG Fund that encourages the reduction of emissions through active transportation, public transportation, and community fleet efficiency. In the long term (2021-2030), the GNWT has the goal of assessing the feasibility of completing ZEV Transportation Corridors in the NWT.

Figure 4: NWT Volt (Source: Government of the Northwest Territories)

24.2 HEVs, PHEVs and EVs on the Road

Increased consumer awareness, greater availability of charging infrastructure, improvements in vehicle technology, more PHEV and BEV choices offered by vehicle manufacturers, purchase incentives offered by provinces, and infrastructure support from all levels of government, have all contributed to record breaking ZEV sales in Canada in 2018.

As illustrated in Table 1, at the end of 2018, Canada had approximately 90,100 EVs on the road. The distribution between BEVs and PHEVs continues to be almost equal with 51 % BEVs and 49 % PHEVs. In 2018, sales of BEVs and PHEVs almost doubled compared to 2017, and Canada has seen more EVs sold across the country in 2018 than the previous five years combined. Also notable is the fact that sales of EVs (44,150) now significantly surpasses sales of HEVs (27,770), which has increased only slightly compared to 2017 (23,860 HEVs). The Canadian EV market reached a milestone in 2018, with the EV market share surpassing 2 % of the light-duty passenger vehicle market, increasing to 2.2 % from 0.9 % the previous year.

A more detailed analysis of EV sales shows that as of November 2018, the top four EV models, representing 50 % of sales to date in 2018, were the Tesla Model 3 (15 %), Nissan Leaf (13 %), Mitsubishi Outlander PHEV (12 %), and Chevrolet Volt (10 %).[47]

[47] http://ev-sales.blogspot.com/2018/12/canada-november-2018.html

Table 1: Distribution and sales of EVs, PHEVs and HEVs in 2018 in Canada (Data source: Des Rosiers Automotive Consultants Inc. “Automotive Reports: Market Snapshot December 2018, Global EV Outlook 2018, and IHS Markit)

Fleet Totals on 31 December 2018				
Vehicle Type	**EVs**	**HEVs**	**PHEVs**	**Total[b]**
Passenger vehicles[a]	46,280	228,070	43,820	23,302,620

Total Sales during 2018				
Vehicle Type	**EVs**	**HEVs**	**PHEVs**	**Total[b]**
Passenger vehicles[a]	22,660	27,770	21,490	1,985,000

[a] UNECE categories M1

[b] Including both conventional and alternative technologies - Total fleet estimated from 2017 vehicle stock (Statistics Canada), 2018 sales data, and a 6 % scrappage rate stad data at the end of 2018

Table 2: Available vehicles and prices in Canada (Data source: Plug’n Drive via https://www.plugndrive.ca/ electric-vehicles-available-in-canada/)

Market-Price Comparison of Selected EVs and PHEVs in Canada	
Available Passenger Vehicles	**Untaxed, Unsubsidized Sales Price (in USD)**
Audi A3 e-tron	32,297
BMW i3	38,553
BMW i8	114,735
BMW 330e	40,893
BMW 530e xDrive	52,798
BMW 740e xDrive	84,835
BMW X5 xDrive/40e	56,033
Cadillac CT6 PHEV	64,295
Chevrolet Bolt	32,293
Chevrolet Volt	29,228
Chrysler Pacifica Hybrid	38,461
Ford Focus Electric	34,998
Ford Fusion energy	25,110
Honda Clarity Plug-in	29,829
Hyundai IONIQ Electric	26,651
Hyundai IONIQ Plug-in	23,922
Hyundai Sonata Plug-in	32,894
Karma-Revero	112,217

Kia Soul EV	26,835
KIA Optima Plug-in	32,143
Mercedes-Benz GLC350e	44,782
Mercedes GLE-550e 4Matic	44,782
Mini Cooper Countrymen S E	32,513
Mitsubishi Outlander	32,145
Nissan Leaf	26,912
Porsche Cayenne S E Hybrid	67,510
Porsche Panamera S E Hybrid	84,687
Smart Fortwo Electric Drive	21,718
Tesla Model S 100D	72,257
Tesla Model 3	34,091
Tesla Model X 100D	82,387
Toyota Prius Prime	24,663
Volvo XC60	51,939
Volvo XC90	54,815
Volvo S90	55,972
VW e-Golf	27,179

The end of the EV purchase incentives in Ontario, announced in early July 2018, had a major impact on EV sales in the province. As shown in Figure 5, a significant decrease in EV sales was observed beyond the September 10 cut-off for deliveries to customers. The Tesla Model 3, previously identified as the top seller in Canada in 2018, was ramping up sales as this was happening.

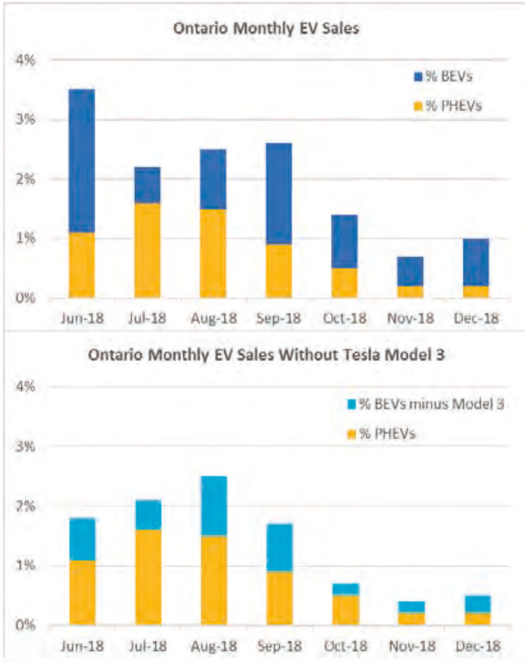

Figure 5: Ontario monthly EV sales over period when EV incentives cancelled (Source: CanadaEVSales.com)

24.3 Charging Infrastructure or EVSE

Due to initiatives by the federal, provincial, and municipal governments, as well as utilities and private firms, public charging infrastructure is continuing to grow in Canada. As shown in Table 3, there were approximately 8,148 EVSEs in Canada in 2018, of which 7,100 were Level 2 (240V AC) and 1,048 were DCFC or Superchargers. This represents a 38 % increase in public charging infrastructure in 2018.

Most of the newly installed charging infrastructure was in British Columbia, Ontario, and Québec, however, other provinces, such as Nova Scotia and New Brunswick also saw notable increases.

It is important to note that there are no requirements by respective jurisdictions to register 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 (120V AC) EVSEs are not reported on since this infrastructure typically relates to charging via a residential wall outlet.

Table 3: Information on charging infrastructure in 2018 in Canada (Data source: Government of Canada. “Natural Resources Canada: Electric Charging and Alternative Fueling Stations Locator”)

Charging and Refuelling Infrastructure on 31 December 2018		
Chargers	**Quantity of Outlets**	**Quantity of Locations**
AC Level 2 Chargers	7,100	3,595
Fast Chargers	840	520
Superchargers	208	27
Hydrogen	3	3
Totals	**8,151**	**4,145**

Coast to Coast Charging Infrastructure

In addition to the Canada’s investments in both Budget 2016 and 2017 to support a coast-to-coast EV fast charging network, Petro-Canada, a Suncor business operating a network of petrol stations across Canada announced that it will be building a cross-country network of EV fast chargers. More than 50 EV fast charging stations will be installed along the Trans-Canada highway at strategic points from Nova Scotia to British Columbia. Construction is set to begin in spring 2019 with sites opening in the next year. These stations will offer DC fast chargers with both CHAdeMO and CCS/SAE connectors, will provide up to a 200 kilowatt charge and will be capable of 350 kilowatt charging with future upgrades.

24.4 EV Demonstration Projects

24.4.1 Bi-directional Capable EV Charging Stations in Combination with Solar Photovoltaic (PV) and Battery Storage

NRCan has contributed 2 million USD to Sky Solar’s electric vehicle demonstration project to advance bi-directional charging station infrastructure in combination with solar photovoltaic and battery storage. The project will provide an assessment of the barriers to EV bi-directional charging stations and their potential to address issues such as load balancing and power security for commercial, institutional and remote locations. Economic models related to bi-directional charging will also be investigated to inform EV owners and charging site owners of the financial potential for the bi-directional charging technology.

Figure 6: EV demonstration project (Source: Sky Solar)

24.4.2 Charge the North

Natural Resources Canada contributed 2.6 million USD to CrossChasm Technologies Inc. to track the charging behaviors of EV owners. The project aims to collect and analyze real-world vehicle charging data, such as battery state and charge events in order to improve the operation and the deployment of EV charging infrastructure. To date, vehicle-side data is being collected on 1,000 EVs representing 25 makes and models, spanning PHEVs and BEVs. Early results are revealing changes in charging behaviour as longer range models are deployed and buyer personas transition from the early adopter to the early majority segment. While the majority of charging still occurs at home, a growing amount of charging occurs away-from-home with the specific fraction dependent on the range of the BEV. The large sample size and measurement across different rate structures will enable an assessment of load impacts on the distribution infrastructure and analysis of the impact of rate structure on charging behaviour. Detailed results are expected later in 2019.

24.4.3 Next Generation EV Charging Infrastructure

British Columbia Institute of Technology (BCIT) received approximately 0.8 million USD to demonstrate EV charging solutions for the urban environment. The project demonstrates both curbside and commercial outdoor parking lot charging using existing streetlight infrastructure in order to reduce the cost of installation. The project also demonstrates an open source Electric Vehicle Energy Management System (EVEMS) to provide charging solutions for MURBs and other environments where the built electrical infrastructure was never designed for the additional load of EV charging. The EVEMS uses an open, non-proprietary communication protocol to improve interoperability between charging technologies from different vendors. This work is helping to inform the development of a new standard for EVEMS. Next steps include refinement of the EVEMS, and integration of the technology into existing manufacturers' product lines.

Figure 7: Streetlight mounted EV charger (Source: BCIT)

24.4.4 Borden "Mine of the Future" Energy Innovations

The Borden Mine in Ontario will replace all diesel mobile equipment with battery electric vehicles, making it Canada's first all battery electric underground mine. This project will demonstrate the technical and economic feasibility of not only a full fleet BEVs, but also a fully automated Ventilation On Demand system and an underground mine without a surface air compressor plant. This project brings significant environmental benefits through the elimination of diesel, which results in a substantial reduction in heating and ventilation energy use. The project is funded through the Clean Growth Program (CGP), which helps advance emerging clean technologies in the energy, forest and mining sectors.

Figure 8: Sandvik DD422iE is part of the all-electric fleet at Borden Lake (Source: Sandvik)

25 Denmark

25.1 Major Developments in 2018

In 2018, electric (EVs) and charging hybrid vehicles (PHEV) accounted for 1.9 % of total passenger car sales. This is a significant increase from previous years, and the highest share since the second half of 2015, which was just before taxes were imposed on electric cars.

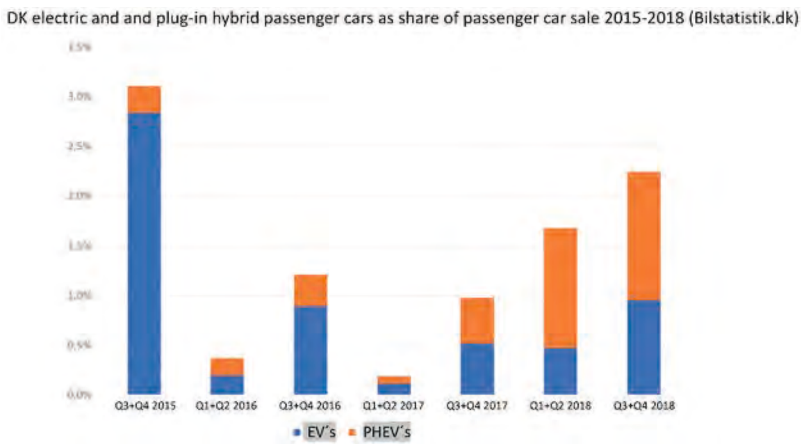

Figure 1: BEVs and PHEVs as the share of passenger car sales in Denmark (Source: Bilstatistik.dk)

This development reflects that taxation of EV´s was introduced from 2016. And furthermore, also that EV taxation in 2017 was reduced to revitalize the EV market by extending the 20 % registration tax break until the end of 2018 or until 5,000 additional sales. These changes created “stop and go” effects where consumers expected taxation and prices to rise the following year. 2018 seems to be the first year where sales seem to grow on top of sales from last year. PHEV´s sales seem to increase more rapidly. Taxation issues are explained further later in the text.

The best-selling electric cars in 2018 were Nissan Leaf and Renault Zoe. For plug-in hybrid cars, Kia Niro PHEV and VW Golf GTE were the 2018 top sellers. Q1 2019 continues the positive trend with 513 EVs and 855 PHEVs sold.

Top 10 EV´s sold in Denmark in 2017 and 2018 (Bilstatistik.dk)

		2018	2017
1	Nissan Leaf	637	20
2	Renault Zoe	431	386
3	Hyundai Ioniq	151	28
4	Bmw I3	87	26
5	Nissan E-Nv200	78	55
6	Renault Kangoo	61	4
7	Tesla Model X	48	53
8	Tesla Model S	47	46
9	Volkswagen Golf	34	36
10	Volkswagen Up!	19	46

Top 15 PHEV´s sold in Denmark in 2017 and 2018 (Bilstatistik.dk)

		2018	2017
1	Kia Niro PHEV	1113	152
2	VW Golf GTE	535	153
3	Hyundai Ioniq PHEV	363	0
4	Kia Optima PHEV	335	53
5	Toyota Prius PHEV	207	0
6	Volvo XC60 Twin Engine	169	39
7	VW Passat GTE	111	58
8	Mercedes-Benz Glc 350e	96	72
9	Volvo V90 Twin Engine	38	14
10	Volvo XC90 Twin Engine	37	23
11	BMW 225XE Iperformance	32	13
12	Mitsubishi Outlander PHEV	24	0
13	BMW 530E PHEV	22	10
14	BMW 330E E	13	9
15	BMW I3 REX	11	15

Figure 2: Top 10 BEVs and top 15 PHEVs sold in Denmark in 2017 and in 2018 (Source: Bilstatistik.dk)

In October 2018, the Danish Government presented a **new climate and air proposal** "*Together for a greener future*", in order to take the next steps towards the ambitious goal of a climate-neutral Denmark by 2050.

The proposal includes 38 concrete initiatives for cleaner transport and taxis in cities and countryside, shipping and green transition in housing, industry and agriculture.

EV and PHEV share of brand sale in DK in 2018 (Bilstatistik.dk)

1	TESLA	100,0%
2	KIA	18,3%
3	NISSAN	6,5%
4	HYUNDAI	6,4%
5	VOLVO	4,7%
6	RENAULT	3,0%
7	BMW	2,3%
8	MITSUBISHI	2,3%
9	VOLKSWAGEN	1,9%
10	TOYOTA	1,1%

Figure 3: The most popular EV and PHEV brands in Denmark in 2018 (Source: Bilstatistik.dk)

Key transport initiatives in the climate and air proposal include:

- Stop sale of new petrol and diesel cars in 2030, and plug-in hybrids in 2035
- From 2020, all new buses must be climate-friendly powered by e.g. electricity, hydrogen, biogas, or biofuels
- From 2030, city buses and taxis may not be powered by fossil fuels, but by non-emission like electricity or hydrogen
- Clean air in big cities through stricter environmental zones

Furthermore, the government has called for 1 million EVs and PHEVs in 2030, and a commission has be established to look at long term taxation and revenue.

The present government have announced a new climate plan to implement the above proposals after the 2019 general elections.

In June 2018, the Danish government also signed a **new energy agreement** with the unanimous support of all parties in the Danish parliament to keep Denmark's position in the world's elite in renewable energy and energy efficiency.

The energy agreement allocates an additional 67 million EUR towards support for green transport solutions over the period 2020-2024.

The energy agreement also reduces electricity taxes and starts exploration of possible dynamic electricity taxes. Dynamic taxes mean that the tax levels will vary, e.g. according to the time of day. This could be used to increase demand during periods with low electricity prices and high RE output. Lower and dynamic taxes will promote electrification of society, including the transport sector and ensure better utilization of the increasing volumes of renewable energy.

New modes of electric transport are gaining momentum in Denmark. Large electric ferries and electric harbour buses are introduced, more electric buses are entering public transport, several free flow electric car-sharing services are operational including DriveNow, GreenMobility and LetsGo.

In 2017, wind power generation in Denmark corresponded to 43.4 % of the electricity consumption, this is more than a doubling since 2008, also making electric transport more sustainable.

25.1.1 Danish Framework for Electrification of Transport Sector

Denmark is supporting the Paris Agreement including a very ambitious national target of being fully independent of fossil fuels by 2050, and a 2030 milestone of 50 % of energy consumption supplied by renewable energy.

Globally, as well as in Denmark, transport is recognized as a challenging sector for greenhouse gas emission reductions. Transport demand, energy consumption and greenhouse gas emissions are all increasing. And transition to low carbon and renewable solutions is depending on a range of new technologies to mature, scale industrially and be price competitive before becoming a mass market mover.

For more than a decade, the transformation of the Danish transport sector has been seen in relation to the very ambitious transformation of the Danish energy sector. Denmark holds several years of world records of fluctuating wind power in the electricity mix. In 2017, the wind power generation in Denmark corresponded to 43.4 % of the electricity consumption.

The June 2018, the Danish new energy agreement with unanimous support of all parties in the Danish parliament secures Denmark's position as the global leader in offshore wind. Three new very large offshore wind farms are decided on and will ensure 55 % of the energy needs as renewable energy by 2030. The three new offshore wind farms that will supply at least 2,400 MW of green electricity to the energy system – more than the total combined electricity consumption of all Danish households.

In 2017, 2016 and 2015 World Energy Council ranked Denmark as number one among 125 countries energy systems on three core dimensions: energy security, energy equity, and environmental sustainability. The combination of a price winning, strong and flexible energy system with record-breaking shares of fluctuating renewable energy positions Denmark as an interesting test laboratory for exploring the interplay between the energy system, renewable energy and e-mobility in terms of smart grid, smart energy and storage. Well-developed public transport focus on new and electric mobility, new business models and e-mobility as a service, e-carsharing, e-buses and autonomy will also be at the front in the coming years. Upcoming is electric maritime propulsion, with several ongoing e-ferries projects in Denmark. Biking is very important in Denmark and e-biking continues to grow, in 2018 it moved well beyond 10 % of bike sales.

With policy strategies and grant schemes since 2008, Denmark was one of the first mover countries in introducing battery electric cars and hydrogen and fuel cell-based transport in a testing and demonstration context, from 2012, also in deployment mode.

Incentive programmes broadly focused on electric applications in passenger cars, buses, vans, garbage trucks etc, including charging infrastructure. Private and public fleets together with city car sharing systems have been a main priority. In the private segment, commuters and families with more than one car, have been another important focus area. Denmark is actively represented and participating in a broad palette of regional, international and EU programmes, ranging from charging and roaming standards, cross bordering and highway charging corridors and smart grid projects to e-mobility as service and as an energy efficient and environmentally friendly form of transport. Hydrogen programmes have especially focused on R&D in fuel cells and deployment of a Danish network of hydrogen filling stations.

Broad political agreements governed the development. The 2008 energy agreement continued the decarbonising of the energy system and initiated the first programmes for electric mobility and charging infrastructure. The broad political energy agreements from 2012 set out the ambitious targets for the energy system in 2020 and 2050 and also initiated new e-mobility and charging infrastructure programmes with focus on deployment vehicles and infrastructure for alternative fuels, mainly electricity but also hydrogen and biogas.

In the transport sector two political agreements in 2009 and 2014 focused on a Green Transport Policy and financial support for green solutions in the public transport sector (2009), for research in alternative fuel technologies, and for small-scale tests of electricity and CNG vehicles (2013). These funds and programmes largely ended in 2015, with projects running until their project's periods end, typically within 3-5 years. A small scheme of 1,6 million USD funds new fuel cell vehicles and infrastructure in 2018.

The support for green transport provided by the government has helped regional and municipal authorities to develop initiatives promoting e-mobility like Copenhagen Electric and the Municipality of Copenhagen.

In 2016, Copenhagen City published a new climate plan aiming at making the city the first CO_2-neutral capital by 2025, including the public transport sector. The plan contains objectives, main activities and initiatives adopted by the City Council to be implemented to achieve this goal.

25.1.2 Taxation

Until 1 January 2016, battery electric vehicles (BEV) were exempted from the relatively high registration tax on passenger cars (VAT was applied). Thus, exemption was a strong incentive, which - together with national and regional activities - brought Denmark into the e-mobility forefront. The taxation system lead to disproportionate incentive towards expensive BEVs and rather high shares of sales.

A progressive reduction of the tax exemption was decided in 2015, starting from 2016 and with full taxation phased in by 2020. The detailed phase-in steps were initially 20 % in 2016, 40 % in 2017, 65 % in 2018, 90 % in 2019 and 100 % in 2020.

This dropped sales of BEVs in 2016, with taxphased in with a 20 % first step. Due to low EV sales, taxation was changed again with 2 political agreements in 2017.

New Political Agreement as per 18 April 2017:

- EV tax stay 20 % for the next 5.000 EVs or latest to the end of 2018
- EV purchase tax 40 % in 2019, 65 % in 2021, 90 % in 2021, 100 % from 2022
- New (2017-2021) BEV and PHEV purchase tax rebate of 225 USD/kWh battery, max 45 kWh (10,000 USD)
- 2019 tax exemption (0,124 USD/kWh) of commercial charging, in 2020 full tax
- Energy tax exemption for charging e-buses extended to 2023 or longer
- Grants for Hydrogen filling stations: 5 million DKK (0,7 million USD) 2017-2018

New Car Taxation Political Agreement as per 3 October 2017:

- Vehicle purchase tax reduced from 105 to 85 %, high tax maintained at 150 %
- Cut between low and high tax is moved from (16,900 USD) to (29,300 USD)
- Bonus/Malus from 16 to 20 km/l gasoline and 18 to 22 km/l diesel
- Malus raised from 1,000 DKK/l to 6,000 DKK/l (150 USD – 900 USD); Bonus still 4,000 DKK/l (600 USD)

Effects generally:

- Cheap ICE cars get a bit more expensive, expensive cars get cheaper, also HEV
- Lower cost EVs not much more expensive, high cost EVs more expensive

- Consumer reaction on tax exemption removed end of 2015 has been dramatic
- Taxation changes in 2017 did not change this, but slightly upward trend

Due to low numbers of EVs and PHEVs sold a new taxation was agreed late 2018:

- The politically agreed increase of EV taxes from turn of the year, is postponed
- EVs under 400,000 DKK (~ 60,000 USD) will still have to pay 20 % in 2019 of the registration tax, and in 2020 it is increased to 40 %
- In return, a basic deduction of 40,000 DKK (6,000 USD) is introduced in 2019, which in 2020 will be raised to 77,500 DKK (11,650 USD)
- Registration tax on EVs below DKK 400,000 is around zero in 2019 and 2020
- After 2020, normal high registration tax will be phased in until 2023
- EVs over 400,000 DKK pay tax in 2019-2020 but less than conventional cars
- The fee on plug-hybrid cars will be phased in the same way

Basically, this means, that registration tax on all non-premium EVs and PHEVs will be low in 2019 and 2020 (25 % VAT is still applied).

25.2 HEVs, PHEVs and EVs on the Road

The 2018 EV and PHEV passenger car stock increased to approx. 9,800 EVs and 5,200 PHEVs, totalling approx. 15,000 units. In 2018, new passenger EV registrations increased to approx. 1,500 EV units and 3,100 PHEV units, totalling 3,600.

Table 1: Distribution and sales of EVs, PHEVs and HEVs in 2018 (Data source: DEA)

Fleet Totals on 31 December 2018				
Vehicle Type	**EVs**	**HEVs**	**PHEVs**	**FCVs**
Quadricycles[a]	237	0	0	0
Passenger vehicles[b]	9,801	24,970	5,164	83
Commercial vehicles[c]	669	1,688	232	0
Buses[d]	7	0	0	0
Trucks[e]	7	0	0	4
Totals without bicycles	**10,721**	**26,658**	**5,396**	**87**

Total Sales during 2018				
Vehicle Type	**EVs**	**HEVs**	**PHEVs**	**FCVs**
Quadricycles[a]	60	0	0	0
Passenger vehicles[b]	1,485	8,665	3,128	6
Commercial vehicles[c]	190	397	31	0
Buses[d]	2	0	0	0
Trucks[e]	3	0	0	0
Totals without bicycles	**1,740**	**8,953**	**3,159**	**6**

n.a. = not available
[a] UNECE categories L6-L7
[b] UNECE categories M1
[c] UNECE categories M2-M3
[d] UNECE categories N1
[e] UNECE categories N2-N3

25.3 Charging Infrastructure or EVSE

Denmark has a very well developed public charging infrastructure, thanks to several e-mobility providers including, CLEVER, E.ON, and Tesla. Combined, these companies provide publicly accessible recharging networks countrywide.

The Danish Road Directorate has conducted tenders to establish public charging infrastructures at rest stops on the national Danish highway system. E.ON and CLEVER have deployed fast chargers on these sites, while Tesla has deployed a network of superchargers close to the highway system.

A large range of projects regarding charging infrastructure has taken place in Denmark. One of the latest are danish E-mobility Service Provider Clever and German E.ON forming a joint venture for building and operating ultra-fast chargers along the freeways throughout Scandinavia. “Ultra-Fast Charging Venture Scandinavia” will aim to connect cities in Denmark, Norway and Sweden with a total of 48 ultra-fast charging sites. The joint venture is fulfilling a promise to the European Commission’s Connecting Europe Facility (CEF) programme to build 28 co-financed sites in Denmark and Sweden. In addition, the joint venture will deploy 20 sites in Norway outside of the funding scope.

The joint venture will be a charge point operator, where the partners share the vision to provide more ultra-fast charging stations and better customer experience for drivers of electrical vehicles across borders. In 2020, all 48 sites are planned to be operational. E-mobility customers of Clever, E.ON and third party operators will get access to the charging stations. The joint venture has opened their first ultra-fast chargers in Halsskov, Denmark, followed by several new sites in both

Denmark, Sweden and Norway in 2019. The first large flagship site will be close to Fredericia opening in Q1 2019.

In terms of interoperability, all quick chargers in Denmark today are multi-standard types (CHAdeMO, CCS and Mennekes type 2) and are connected to backend systems which allow billing of customers based on actual consumption of kWh.

E.ON and CLEVER's business models are primarily based on customer subscriptions of the company's recharging infrastructure (with a monthly subscription fee) and charges for energy consumption. Both e-mobility providers also offer non-subscription based recharging services.

Table 2: Information on charging infrastructure in 2018 (Data source: DEA)

Charging Infrastructure on 31 December 2018	
Chargers	**Quantity**
AC Level 1 Chargers	n.a.
AC Level 2 Chargers	1,078
CHAdeMO	155
CCS	155
Tesla	94
UFC- ultra fast chargers (+100 kW)	4
Totals	**1,486**

25.4 EV Demonstration Projects

Since 2008, the Danish Energy Agency (DEA), the Danish Road Safety Agency and the Danish Road Directorate administrated several programmes to support deployment of EV, PHEV and hydrogen transport and infrastructure in the Danish transport sector. Funds have been used for projects for companies, public bodies, and private consumers to familiarize themselves with EVs etc. and build synergies between stakeholders to support deployment of alternative fuel infrastructure.

Electric Car-Sharing Schemes in Denmark

Denmark hosts several electric car-sharing services:

- *DriveNow* operates in Copenhagen with an electric fleet of 400 BMW i3s to be booked by app. Pricing include rates per minute, daily or monthly subscriptions.
- *GreenMobility* operates in Copenhagen with + 400 Renault ZOEs booked and accessed by app. Pricing include minute rates, daily or monthly subscriptions.

- *Let's Go* is a non-profit operator in several Danish cities, with electric cars in the fleet. Let's Go is a membership-based organisation, with dedicated parking. Members pay based on time and distance travelled.

Partnerships with the public sector, and funding from the Danish Energy Agency and The Capital Region of Denmark for public charging infrastructure, has helped expand the operational zone of these schemes, for example to serve hospitals.

Electric Buses in Danish Public Transport

Movia is the Public Transport Authority (PTA) in East Denmark including the Copenhagen area, started using electric buses in 2009-2014, with 11 all-electric 8 m buses. In 2014-2015, Movia tested two 12 m depot-charged electric BYD buses. In 2016-2019, Movia and Copenhagen are testing opportunity-charged electric Finnish Linkker buses.

Movia has decided that all bus operation must be fossil-free by 2030. To meet the fossil-free bus fleet goal by 2030, all new bus operation starting from 2018 and forward must be fossil-free – or prepared for fossil-free operation.

Copenhagen published a new climate plan in 2016, aiming at making the city the first CO_2-neutral capital by 2025, including the public transport sector. It contains objectives, activities and initiatives adopted by the City Council.

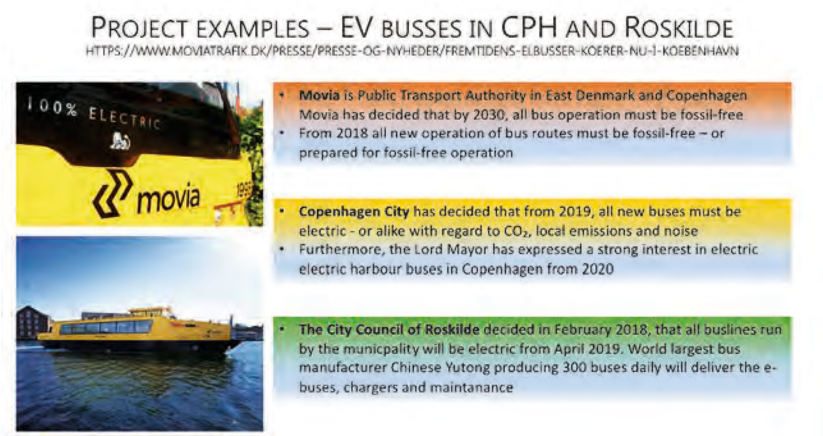

Figure 4: Project examples, e-buses in CPH and Roskilde

For public bus, the goal is to shift the bus fleet to all-electric buses. City Council has decided that from 2019 onward, all new city buses must be electric - or perform alike on CO_2 emission, local emissions and noise. Furthermore, from

January 2020 the old diesel harbour buses will be phased out and there will be five new harbour buses, all of which operate on electricity.

The City Council of Roskilde decided in February 2018, that all buslines run by the municipality to be electric from April 2019.

Parker Project - V2G Cars Providing Energy System Services

The Parker project builds on two previous Danish projects, the EDISON and Nikola projects, which have founded the understanding the electric vehicle's potential for balancing the Danish power system. Parker represents the next technology readiness level by allowing balancing services to be applied to a fleet of electric vehicles.

Parker works together with the world's first commercial pilot of series produced V2G cars providing system services to ensure market adoption, applicability and re-usability to power systems in Denmark and elsewhere.

Figure 5: Project examples, "Parker" project

25.5 Outlook

- DK world leader in greening energy systems, gCO_2/kWh 550 g in 2006 to below 200 g in 2017 (2018 not available yet)
- Record breaking strong energy system, RE shares and ambitious targets
- DK first mover with EV policy strategies and grant schemes since 2008
- Very strong charging infrastructure with several operators
- Challenging EV taxation from 2016, but increasing sales in 2018
- Applications in fleets, buses, ships, bicycle, etc. increases

- Exciting projects show that DK is an ideal test bed for interplay between e-mobility, smart energy system, renewable energy and energy storage
- Cities, regions and commercial players are very active in many projects
- Electric buses in DK potential positive commercial businesses case due to lower energy cost (twice as expensive, three times more energy efficient)
- E-Trucks are not taxed
- General elections in 2019 and climate issues including EV is high on the agenda
- The Government has called for 1 million electric cars and plug in hybrids in 2030 and a phase out of diesel and gasoline passenger cars
- The government has announced a new climate plan to implement this after the 2019 general elections

26 Finland

26.1 Major Developments in 2018

26.1.1 Continuing Growth in EV Sales

Year 2018 showed a continuing growth in EV sales, with plug-in hybrids leading the sales with a clear margin. In total 5,708 new electric vehicles were sold in 2018, including 776 battery electric vehicles (16 % of the sales). The growth year-over-year was 129 %, which is following the trend from 2016 and 2017 with over 100 % annual growth.

The total fleet of EVs in Finland at the end of 2018 is 15,499, including both plug-in hybrids and battery electric vehicles. The imports of used EV's also increased during 2018, consisting of one third of all new registrations. The market share of new passenger EVs sold during 2018 was 4.7 % of all new registrations.

Currently, most of the EV's are concentrated in the capital Helsinki region and around larger cities. 44 % of plug-in hybrids and 42 % of battery electric vehicles are in the capital region.

26.1.2 New Policies to Accelerate Growth

New incentives were introduced in 2018 to further increase the growth of the EV market. There are now three different subsidies for building charging infrastructure.

- Subsidy for public smart charging and fast charging stations. Subsidy rate for fast chargers is 35 %, and for normal chargers 30 %. The subsidy requires the chargers to support smart charging, and to provide an open data interface for monitoring the charger's availability and condition.
- Tender for alternative fuels infrastructure, including biogas vehicle refueling and electric vehicle charging. Subsidy is available for commercial, municipal or community provided infrastructure. The total annual amount available for the tendering is 3 million EUR. The first round of tendering was performed in October 2018.
- Subsidy for housing companies for building EV charging infrastructure. In the year 2018 budget, 1.5 million EUR was reserved for the first year. The

subsidy 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.

In addition to charging infrastructure subsidies, a new purchase incentive was introduced from the beginning of 2018, targeted at private persons buying or leasing an electric vehicle. The subsidy is granted for a purchase or at least 3 year lease of a battery electric vehicles, with a maximum purchase price of 50,000.00 EUR, including taxes. The amount of the subsidy is 2,000.00 EUR. Import vehicles are excluded. A total of 6 million EUR is reserved for the subsidy, including also conversion subsidy to convert gasoline and diesel powered vehicles to run on gas or ethanol.

26.1.3 New Research Results

The Prime Minister's office procured a research, coordinated by VTT Technology Research Centre of Finland (VTT), for identifying cost effective means for advancing the electric vehicle market. The research included identifying obstacles in home charging and the EVSE market situation, an electric vehicle market review, and system dynamics modelling of identified incentives for advancing the EV market. According to the modelling performed by VTT, the current incentives are leading into reaching the government's energy and climate strategy goal of 250,000 EV's by 2030. By taking into use multiple new incentives, it would be possible to double the number of EV's by 2030.

Tampere University of Technology, in collaboration with ETH Zürich, modelled the potential for BEVs in Finland and in Switzerland, according to the current passenger vehicle usage needs[48]. The study found out that 85 % of the current car trips could already be performed using BEV's, utilizing the current vehicle models and charging infrastructure.

The Finnish Innovation Fund Sitra funded a research[49] performed by McKinsey & Company on finding cost-effective emission pathways for Finland for 2030. The research was suggesting large-scale electrification of the transport sector to be the most cost-effective single method to cut emissions. With a fleet of 800,000 EVs (including BEVs and PHEVs) in 2030, the emissions abatement would reach 4.6 $MtCO_2$, with a cost of -90 EUR/tCO_2.

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48 Tampere University of Technology, „Anxiety vs reality – Sufficiency of battery electric vehicle range in Switzerland and Finland", https://tutcris.tut.fi/portal/files/ 16484199/1_s2.0_S1361920917310295_main.pdf

49 Sitra, „Cost-efficient emission reduction pathway to 2030 for Finland: Opportunities in electrification and beyond", https://media.sitra.fi/2018/11/30103309/cost-efficient-emission-reduction-pathway-to-2030-for-finland1.pdf

The Ministry of Transport and Communications in Finland released a proposal for an action program[50] for carbon-free transport by 2045, based on the work by Transport Climate Policy working group. The report is assessing different means, including incentives and restrictions, to promote low- or zero-emission mobility. The report is suggesting to stop sales of gasoline and diesel powered vehicles by 2035. In this report the most effective methods for advancing the EV market were found to be the EV purchase price subsidies and increasing the taxation on fossil-based fuels.

26.1.4 Charging at Work Gets a Fixed Tax Benefit Value

Charging at work has been considered as a taxable benefit, if the employer has been providing employees charging for EVs. To be able to charge at work, the value of the charged electricity has been required to be paid back to the employer, which has required either electricity measurements at charging stations or utilizing commercial charging service providers. This had proven to be complicating the arrangement for workplace charging, and inhibiting the uptake of charging points at workplaces.

A new law is going to be set in practice from the beginning of 2019, where the workplace charging benefit has been valued at a fixed value of 30 EUR. This is expected to simplify the workplace charging arrangement.

26.2 HEVs, PHEVs and EVs on the Road

Finland has statistics readily available for HEV, PHEV and BEV passenger vehicles, but for example bus and truck HEVs are not classified separately. For example hybrid buses are currently classified in diesel category. For passenger vehicles, statistics is available also for the HEV segment.

Tesla was maintaining the market leader position in battery electric vehicles in 2018, with Nissan following as second. In total these two brands held two thirds of the new electric vehicle market. In plug-in hybrids, Volvo was the market leader in 2018. Figure 1 shows the distribution of the sales according to brand in the battery electric vehicles section, and Figure 2 shows the sales distribution in PHEVs.

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[50] Ministry of Transport and Communications, ”Toimenpideohjelma hiilettömään liikenteeseen 2045 Liikenteen ilmastopolitiikan työryhmän loppuraportti”, 2018, http://julkaisut.valtioneuvosto.fi/handle/10024/161210

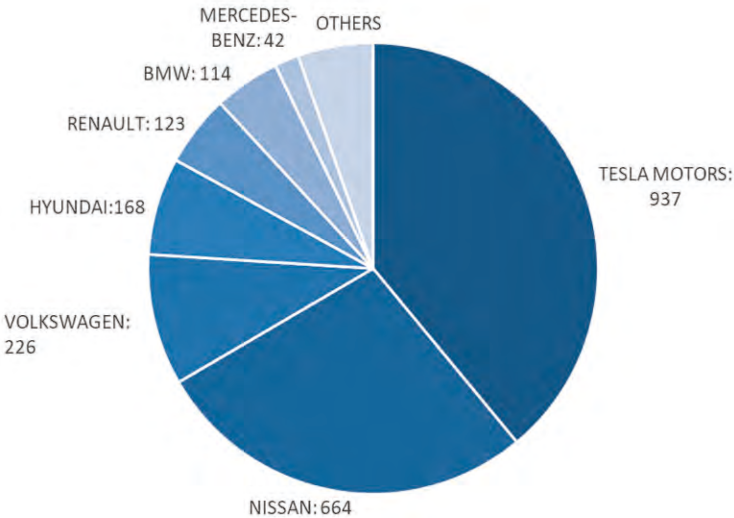

Figure 1: Number of newly registered passenger BEVs for specific OEMs (Source: Technology Industries of Finland)

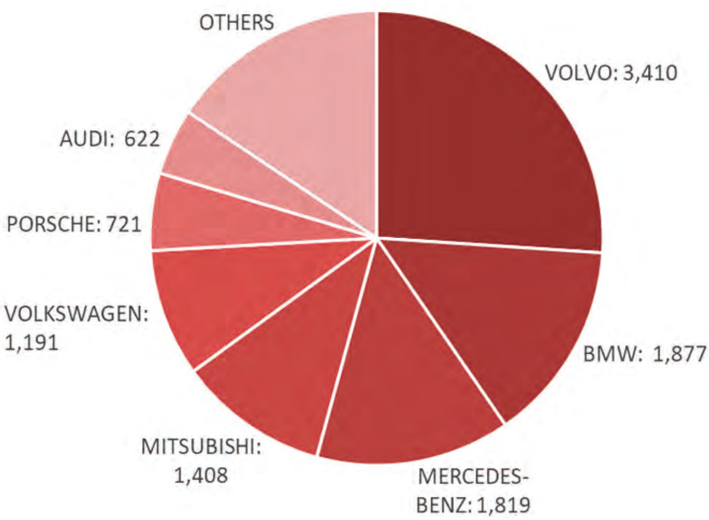

Figure 2: Number of newly registered passenger PHEVs for specific OEMs (Source: Technology Industries of Finland)

Table 1: Distribution and sales of EVs, PHEVs and HEVs in 2018 (Data source: Traficom, Autoalan tiedotuskeskus)

Fleet Totals on 31 December 2018					
Vehicle Type	**EVs**	**HEVs**	**PHEVs**	**FCVs**	**Total[h]**
Bicycles	n.a.	n.a.	n.a.	n.a.	n.a.
Mopeds[a]	1,211	0	0	0	125,381
Motorbikes[b]	43	0	0	0	154,323
Quadricycles[c]	144	0	0	0	15,347
Passenger vehicles[d]	2,404	40,374	13,095	1	2,696,334
Commercial vehicles[f]	256	n.a.	29	0	325,656
Buses[e]	21	n.a.	0	0	12,481
Trucks[g]	2	n.a.	0	0	96,169
Totals without bicycles	**4,081**	**40,374**	**13,124**	**1**	**3,425,691**

Total Sales during 2018					
Vehicle Type	**EVs**	**HEVs**	**PHEVs**	**FCVs**	**Total[h]**
Bicycles	n.a.	n.a.	n.a.	n.a.	n.a.
Mopeds[a]	474	0	0	0	4,927
Motorbikes[b]	10	0	0	0	3,307
Quadricycles[c]	16	0	0	0	242
Passenger vehicles[d]	776	11,855	4,932	0	120,499
Commercial vehicles[f]	46	n.a.	9	0	15,515
Buses[e]	1	n.a.	n.a.	0	475
Trucks[g]	1	n.a.	n.a.	0	3,897
Totals without bicycles	**1,324**	**11,855**	**4,941**	**0**	**148,862**

n.a. = not available
[a] UNECE categories L1-L2
[b] UNECE categories L1-L5
[c] UNECE categories L6-L7
[d] UNECE categories M1
[e] UNECE categories M2-M3
[f] UNECE categories N1
[g] UNECE categories N2-N3
[h] Including both conventional and alternative technologies

Table 2: Available vehicles and prices (Data source: VTT Technology Research Centre of Finland, “Cost-effective means for advancing electric vehicle market in Finland - GASELLI final report”, 2018)

Market-Price Comparison of Selected EVs and PHEVs in Finland	
Available Passenger Vehicles	**Untaxed, Unsubsidized Sales Price (in EUR*)**
Audi A3 e-tron	32,048
Audi Q7 e-tron Quattro	77,749
BMW 225xe	31,598
BMW 330e	37,395
BMW 530e iPerformance	48,605
BMW i3 94Ah	32,654
BMW i8	123,921
Hyundai Ioniq electric	28,722
Jaguar I-Pace	65,874
KIA Soul EV	27,572
KIA Niro plug-in	28,487
KIA Optima plug-in	34,343
Mercedes Benz GLC 350e 4Matic	47,716
Mini Countryman S E ALL4	31,929
Mitsubishi Outlander PHEV	38,208
Nissan e-NV200 evalia	33,975
Nissan Leaf Acenta 40kWh	29,588
Porsche Panamera 4 E-Hybrid	96,908
Renault Kangoo Z.E.1	25,130
Renault Twizy 45 Life2	9,126
Renault Zoe R903	26,067
Smart Fortwo Electric Drive4	20,180
Tesla Model S 75D	71,836
Tesla Model X 75D	77,437
Toyota Prius Plug-In Lounge	31,147
VW e-Golf	33,219
VW e-up!	22,645
VW Golf GTE	32,602
VW Passat GTE	38,087
Audi A3 e-tron	32,048

*The vehicle untaxed prices have been retrieved by first deducting the value added tax (24 %) and then the vehicle registration tax (3,3 % in 2018 for <50 gCO_2/km) from the vehicle prices collected for VTT's report. Pricing for Renault Twizy and Kangoo was obtained from Renault (www.renault.fi).

26.3 Charging Infrastructure

The numbers of chargers in Table 3 include the number of chargers, which may have multiple charging points. The total number of AC Level 2 charging points is 1,811 and CCS / CHAdeMO charging points 272 pcs. CCS and CHAdeMO have not been separated, as most of the chargers in Finland are dual output chargers. Also, individual charging points at Tesla Superchargers have not been listed, but the number of Supercharger locations is mentioned.

Growth for chargers year-over-year in 2018 was 50 %. Growth in AC level 2 charging points was even higher with 86 %. Approximately half of the charging points are in the three major growth areas in the capital Helsinki region, Tampere region, and Turku region.

Table 3: Information on charging infrastructure in 2018 (Data source: Technology Industries of Finland, Q4/2018 e-mobility update report)

Charging Infrastructure on 31 December 2018	
Chargers	**Quantity**
AC Level 1 Chargers	n.a.
AC Level 2 Chargers	722
CHAdeMO	131
CCS	131
Tesla	7
Inductive Charging	n.a.
Totals	**991**

26.4 EV Demonstration Projects

Light Electric Vehicles

At the end of 2018, the Finnish postal service Posti had approximately 450 light electric vehicles for postal deliveries, 200 of which were light 3-wheel freight scooters, and the rest were electric assisted trolleys. The vehicles have been delivered by the Swiss company Kyburz.

Electric Trucks

Niinivirta European Cargo Oy has currently the only two registered electric delivery trucks in Finland. Both vehicles are conversion vehicles, built by Emoss, and are used in city logistics in Tampere and Helsinki.

Electric Buses

Pilot demonstrations with all-electric buses are continuing in four cities; Helsinki, Espoo, Tampere, and Turku. In the Helsinki metropolitan area, the Helsinki Regional Transport Authority's (HSL) introduced the first two electric buses in Espoo in spring 2016. Since then, eight more buses have been introduced on three different lines in Helsinki. The buses are manufactured by the Finnish company Linkker Oy, and fast charging of 300 kW is provided at terminals or at end stops of the routes. All buses are equipped with roof-mounted pantographs.

Turku Region Public Transport Föli has adopted their first all-electric buses in autumn 2016. The six electric buses were supplied by the Linkker. With the charging system, the total value of the procurement is approximately 3.8 million EUR. The Ministry of Employment and the Economy has granted approximately 1 million EUR in investment aid for the implementation of the system.

The electric buses are running on line 1 of Turku City Transport, which operates on the route Harbour–Market Square–Airport. During rush hours, two diesel-powered buses are operated alongside the electric buses. Turku Energia provides quick-charge stations with inverted pantographs for the electric buses at the harbour and the airport. Turku Energia has also implemented the charging equipment at the operator's bus depot for night-time charging. The agreement includes a service agreement for the buses and charging equipment for a period of seven years.

In the city of Tampere, the operation with electric buses started in the end of 2017. Four buses manufactured by Solaris are running on line 2. The buses are equipped with roof-mounted pantographs, and besides fast-charging at the terminal, slow-charging is provided at the depot.

26.5 Outlook

Passenger Vehicles

Taking the WLTP test method into use caused some disturbance in the passenger car market, especially in the PHEV market. This did not affect the BEV market, which has maintained a steady, yet a bit slower growth. It is expected that the whole EV market will get up to speed again in 2019, and a similar growth as in

2018 is expected also in 2019. Most of the hurdles in the growth are expected to be related to the still high purchase cost, low production volumes, and long delivery times of the current vehicles, and in arranging home charging in housing companies.

The most interesting new vehicles for the Finnish market in 2019 are the Tesla Model 3, Hyundai Kona electric and Kia e-Niro and the new Nissan Leaf e+.

Electric Buses

The Helsinki Regional Transport Authority's (HSL) vision is to power a third of its fleet in the Helsinki metropolitan area with electricity by 2025. In 2019, the number of electric buses will increase as 35 new all-electric buses will be introduced in Helsinki. At least five more buses are expected in the beginning of 2020.

The strategic goal of the City of Turku is to become carbon neutral by 2040, which requires ambitious climate and environmental measures. In fact, the city aims to purposefully increase the share of electric equipment in public transport and outsourced services (taxis, transport services, the city's own equipment).

27 France

27.1 Major Developments in 2018

27.1.1 The National Conference on Mobility

Launched by Élisabeth Borne, Minister for Transport, the National Conference on Mobility is a wide consultation addressed to all the actors of the territory and aiming at preparing the Mobility Law, drafted in the first half of 2018.

Spread over three months, the National Conference on Mobility aimed to identify the priority needs and expectations of all citizens around mobility by paying particular attention to the transport of everyday life, and to rural areas. For this, users, local authorities, operators, economic actors and NGOs from all over the country were invited to participate and bring out new solutions.

27.1.2 The Mobility Law

Following the National Conference on Mobility, the Mobility Law was presented by the Minister of Ecology François de Rugy and the Minister of Transport Élisabeth Borne to the Council of Ministers on 26 November 2018.

According to the expectations of the Government, this project must respond to four major challenges:

- The lack of solutions in many rural territories;
- The environmental and climatic emergency, which calls to change our behavior;
- The difficulties of having an infrastructure policy turned towards funding of major projects;
- A revolution of innovation and practices, which is a great opportunity.

27.1.3 Low Emissions Zone

France is still behind other European countries in the setting up of Low Emissions Zones: more than 220 zones are deployed in Europe compared to three in France at the end of 2018.

For those reasons, the Mobility Law will carry the ambition to see these areas spread to other French cities, particularly those with concentrations of air pollutants regularly exceeded. It will give local communities the means to implement them easily and in a way adapted to each situation.

The law will require all agglomerations with more than 100,000 inhabitants and those affected by an Atmospheric Protection Plan to assess the possibilities of setting up a Low Emission Zone. Agglomerations affected by regular violations of air quality standards will be required to establish a Low Emissions Zone before 31 December 2020.

The State will accompany this initiative and aims to achieve the implementation of Low Emission Zone in all cities for which air quality issues are highest in the near future.

27.1.4 Air Quality Certificates: Crit'Air

The air quality certificate is a self-adhesive sticker to stick on the vehicle, which indicates its environmental class according to its emissions of atmospheric pollutants.

There are six classes of certificates. The air quality certificate promotes the least polluting vehicles by:

- Favorable parking arrangements;
- Privileged traffic conditions;
- Possibility of driving in Low Emissions Zones.

The air quality certificate can be used by local authorities to ensure that the least polluting vehicles benefit from privileged parking conditions or can enter into low Emissions Zones.

27.1.5 The Ecological Bonus

The bonus system aims to reward purchasers of new cars or vans emitting from 0 to 20 grams of CO_2 per kilometer, through long-term purchases or lease financing (two years and more). The bonus system was set up in 2008 and is reviewed annually in order to adapt to the evolution of the offer of low-emission vehicles.

The bonus applies to new vehicles belonging to the category of passenger cars, vans and specialized motorized vehicles, as well as to two- or three-wheeled vehicles and quadricycles. Vehicles eligible for the bonus may be registered by individuals or by companies.

Used vehicles are not eligible but vehicles that have been leased for a long time are. The amount of the aid is 27 % of the vehicle's acquisition cost, plus if necessary the cost of the battery if it is rented. The amount of the aid is capped at 6,000 EUR. If you scrap an old vehicle, you can benefit from the conversion premium under certain conditions.

27.1.6 The Conversion Premium

In addition to the bonus, the destruction of certain old vehicles entitles you to the payment of a conversion premium for the purchase of a new or used vehicle under certain conditions:

- 2,500 EUR, for the purchase of a new BEV or PHEV, without condition of income
- 1,000 EUR (2,500 EUR for a non-taxable household), for the purchase of an EV or PHEV used car
- 1,000 EUR (2,000 EUR for a non-taxable household), for the purchase of a Crit'air 1 thermal vehicle or some PHEV emitting less than 122 g CO_2/km
- 2,000 EUR for a non-taxable household, for the purchase of a Crit'air 2 thermal vehicle emitting less than 122 g CO_2/km
- 4,000 or 5,000 EUR (doubling the premium), for non-taxable persons working more than 30 km from their home, or who travel more than 12,000 km per year for professional reasons
- 100 EUR (1,100 EUR for a non-taxable household), for the purchase of a new two-wheelers, motorized three-wheelers or electric quadricycle.

27.1.7 The Ecological Malus

The ecological malus is a first registration tax on the most emitting vehicles of carbon dioxide.

The ecological malus aims to encourage consumers to acquire new passenger cars emitting the least CO_2 via a registration tax. This tax aims to cut global warming by reducing greenhouse gas emissions from transport. The scale of the penalty is progressive: the higher the CO_2 emissions of the vehicle, the higher the penalty.

The bonus-malus automobile scheme is designed to balance the amount of aid paid under the bonus and the conversion premium by the amount of revenue from the malus levied on passenger cars with the highest CO_2 emissions. Thus, revenues from the malus, due by buyers of passenger cars emitting the most amount of CO_2 per km, are entirely dedicated to financing aid for the acquisition of the most virtuous vehicles, including cars and electric vans.

27.2 HEVs, PHEVs and EVs on the Road

27.2.1 Electric Passenger Cars

The electric vehicle market set records in 2018! The electrified light vehicle segment is approaching 40,000 units over the year, with exactly 39,158 registered registrations. This represents an increase of + 27 % compared to 2017 and a market share of around 1.5 %.

In 2018, once again Renault ZOE is leading the segment with 17,038 registrations (+ 11.76 % compared to 2017). The ZOE represents 54.86 % of all registrations in the segment.

The Nissan LEAF keeps second place of the ranking with 4,668 registrations, an increase of + 96.05 %, thanks to the new version available since spring 2018.

Finally, the Smart ForTwo ED climbs one step and comes third in the podium (1,278 units, + 36.25 %). In addition, there are 1,148 BMW i3s with a range extender (+ 6.99 %).

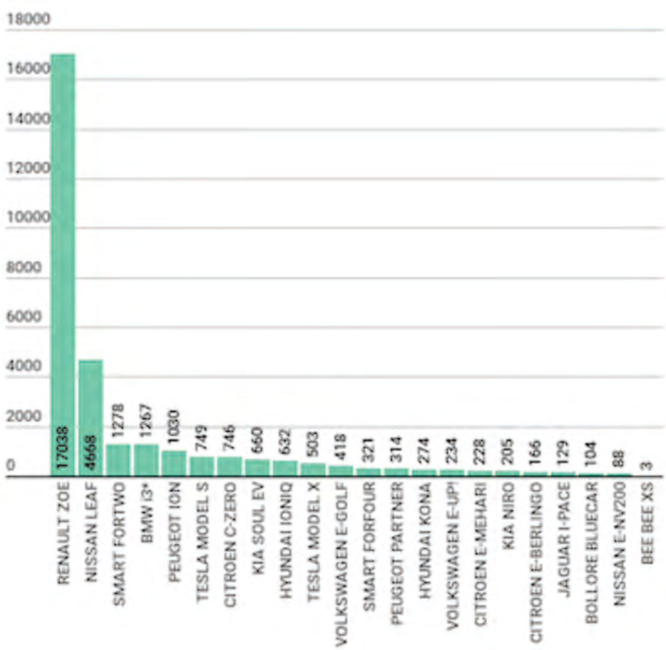

Figure 1: 2018 BEV sales for passenger cars (Source: AVERE)

27.2.2 Electric Light Commercial Vehicles

The electric light utility market is also up to 34.80 % in 2018, with 8,103 new registrations. In total, the electrified models represent 1.77 % of the segment over the year. The French manufacturers are cruising to the top of the podium and the ranking of the first three registered models did not move compared to 2017.

Thus, Renault retains the first places with 4,176 new Kangoo ZE (+ 64.02 %, 51.54 % market share) and 973 ZOE (+ 44.15 %). The Peugeot Partner remains in third place with 649 registrations (- 1.67 %).

Table 1: Distribution and sales of EVs, PHEVs and HEVs in 2018 in France (Data source: AVERE)

Fleet Totals on 31 December 2018				
Vehicle Type	**EVs**	**HEVs**	**PHEVs**	**FCVs**
2/3-Wheelers[a,b]	24,450	n.a.	n.a.	n.a.
Passenger vehicles[c]	126,990	408,590	38,730	80
Commercial vehicles[e]	40,380	n.a.	n.a.	40
Buses[d]	490	1,660	n.a.	n.a.
Trucks[f]	40,470	n.a.	n.a.	n.a.
Totals without bicycles	**232,780**	**410,250**	**38,730**	**120**

Total Sales during 2018				
Vehicle Type	**EVs**	**HEVs**	**PHEVs**	**FCVs**
2/3-Wheelers[a,b]	13,000	n.a.	n.a.	n.a.
Passenger vehicles[c]	32,200	91,700	14,500	10
Commercial vehicles[e]	8,100	n.a.	n.a.	n.a.
Buses[d]	90	270	n.a.	n.a.
Totals without bicycles	**53,390**	**91,970**	**14,500**	**10**

n.a. = not available
[a] UNECE categories L1-L2
[b] UNECE categories L1-L5
[c] UNECE categories M1
[d] UNECE categories M2-M3
[e] UNECE categories N1
[f] UNECE categories N2-N3

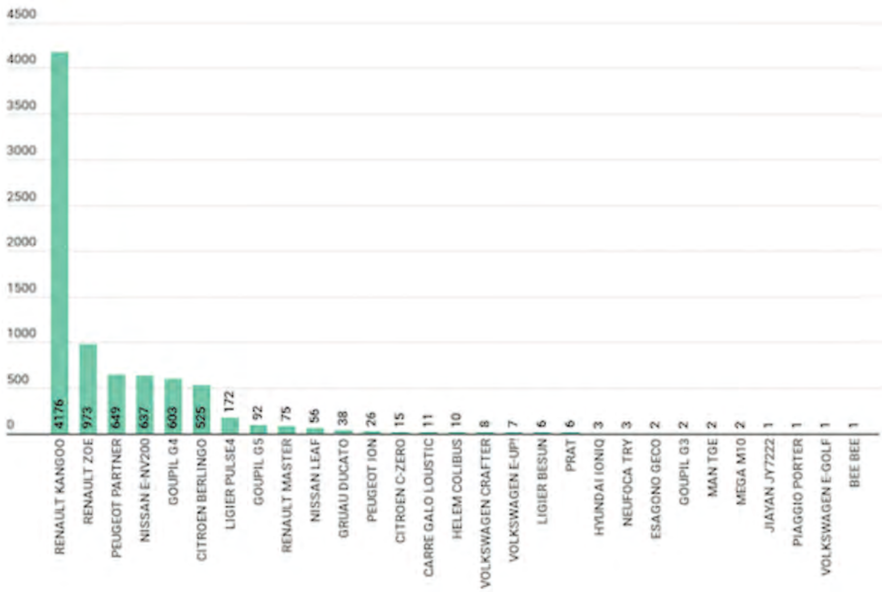

Figure 2: 2018 BEV sales for Light Commercial Vehicles (Source: AVERE)

Table 2: Available vehicles and prices in France in 2018

Market-Price Comparison of Selected EVs and PHEVs in France	
Available Passenger Vehicles	**Untaxed, Unsubsidized Sales Price (in EUR)**
BMW Serie I	38,865
Bollore Bluecar	18,217
BYD E6	25,000
Citroën C Zero	26,900
Ford Focus	32,900
KIA Soul	36,117
Lumeneo Neoma	44,012
Mia	23,658
Mini	29,872
Mitsubishi i-MiEV	33,980
Nissan Leaf	26,900
Nissan NV 2000	26,600
Peugeot iOn	23,257
Renault Fluence	25,156
Renault ZOE	87,987
Smart ForTwo	n.a.

Tesla Model S	37,590
Tesla Roadster	23,260
Think City	38,865
Volkswagen Golf	18,217
Volkswagen IP	25,000
Volvo C30E	26,900

n.a. = not available

27.3 Charging Infrastructure or EVSE

Table 3: Information on charging infrastructure in 2018 in France (Data source: AVERE)

Charging Infrastructure on 31 December 2018	
Chargers	**Quantity**
AC Level 1 and 2 Chargers	22,569
CHAdeMO	n.a.
CCS	n.a.
Tesla	68
Inductive Charging	n.a.
Totals	**22,637**

28 Germany

28.1 Major Developments in 2018

Back in 2007, the German government declared the promotion of electric mobility to be a decisive building block for climate protection in its Integrated Energy and Climate Programme. In 2009, the "National Development Plan for Electric Mobility" was the key framework for action. The "Electromobility Government Programme" of 2011 finally formulated the strategy and instruments that are still relevant today. The aim is to develop Germany into a leading market and provider of electric mobility.

By 2020, one million electric vehicles are to be driven on Germany's roads. By 2030, this figure is expected to rise to six million. The four federal government departments responsible for electric mobility, BMWi, BMVI, BMU and BMBF, have intensified their support for electric mobility and are supporting a large number of model projects and research projects.

German / European Battery Cell Production Initiated

In November 2018, the German Minister of Economic Affairs Peter Altmaier had promised one billion EUR for setting up a German and European battery cell production. According to the BMWi, the aim is to forge a network for the production of battery cells of the latest generations together with other European states and to supply about 30 % of the global demand for battery cells by 2030 from German and European production sites. In February 2019, the call for funding was published. So far, more than 30 companies expressed their interest and applied for the call, amongst others BASF, VW, PSA, BMW and Northvolt.

"In Germany and Europe, we need competitive, innovative and environmentally friendly battery cell production. Our own know-how on this part of the value chain is crucial for the future market success of our companies. Therefore, we will flank the entrepreneurial initiatives", says Minister of Economic Affairs Peter Altmaier. Recently, the French government promised to contribute 700 million EUR.

National Platform "Future of Mobility" Launched

The goal is affordable, sustainable and climate-friendly mobility. On 26 September 2018, the members of the steering committee met for the first time at the constituent meeting of the new Future of Mobility platform at the Federal Ministry of Transport and Digital Infrastructure. Under the leadership of the Ministry, six working groups will develop cross-modal solutions for sustainable, affordable and climate-friendly mobility. Chairman of the new platform is Henning Kagermann, former chairman of the National Platform for Electric Mobility.

On 29 March 2019, the platform presented first recommendations for a sustainable mobility of the future in six fields of action and, with a systematic assessment of the respective CO_2 reduction potentials and calculations of target scenarios, demonstrated that the transport sector target for 2030 (CO_2 emission reduction to 95 to 98 million tonnes) can in principle be achieved. The fields of action are:

- Change to alternative powertrain technologies for cars and trucks
- Further increase in efficiency of cars and trucks
- Regenerative fuels
- Strengthening of rail passenger transport, bus, bicycle and pedestrian traffic
- Strengthening of rail freight transport and inland navigation
- Digitalization

The biggest potential for savings is seen in heavy transport with more efficient trucks and commercial vehicles though alternative drive technologies. As an additional incentive for freight forwarders, the truck toll should be scaled according to fuel consumption.

In the passenger car sector, the switch to electric vehicles is propagated. This is to be achieved by further continuation of the purchase incentive, promoting climate-friendly company cars and the expansion of charging infrastructure that has also been accelerated by subsidies in the long term.

Federal Transport Minister Andreas Scheuer wants to increase the share of electric cars through a support programme for private charging stations. The budget till 2020, already should intend one billion EUR in addition to promote charging points and the private installation of charging points by one half of the costs.

Quotas as well as bonus-malus-schemes for electric vehicles are not intended. Instead, regenerative and synthetic fuels are being pursued as a means of reducing CO_2 emissions.

28.1.1 Policies and Financial Support

Tax Relief for Electric Company Cars

In 2018, the German government decided to introduce a new tax incentive for the use of company cars with electric or plug-in hybrid drive[51]. The monetary benefits for the private use of an electric company car will be virtually halved from 2019 on. In future, only half the gross list price will in future be used as the basis for calculating the imputed income. So far, employees have had to pay tax on the non-cash benefit at 1 % of the total gross list price (including special equipment) if they also use a company car privately. When the vehicle is used from home to work, another 0.03 % is added per kilometre driven. The new rules only apply for a limited period from 1 January 2019 to 31 December 2021, but it also applies to older BEVs or PHEVs, independent of the time the vehicle was purchased or leased by the company and initial registration is not a prerequisite. However for the application of the new regulation (halving of the gross list price), the first transfer of the motor vehicle to an employee for private use is decisive. This first transfer must have taken place after 31 December 2018[52]. The tax revenue shortfall is estimated at 1.96 billion EUR[53].

Purchase Premiums to Promote the Sale of Electrically Powered Vehicles

In 2016, the "*Umweltbonus*[54]"-programme has started. The Federal Government has set the goal of promoting the sale of new electric vehicles with the help of an environmental bonus. This will make a significant contribution to reducing air pollution while at the same time increasing demand for environmentally friendly

[51] Maximum 50 g CO_2/km or electric range of more than 40 km

[52] BMF v. 19.12.2018 - IV C 5 - S 2334/14/10002-07

[53] https://www.electrive.net/2018/08/01/regierung-segnet-05-regel-fuer-elektro-dienstwagen-ab/

[54] http://www.bafa.de/SharedDocs/Downloads/DE/Energie/emob_merkblatt_antrag.pdf?__blob=publicationFile&v=5

electric vehicles by at least 300,000 vehicles. The subsidy supports the rapid market penetration of electrically powered vehicles[55]. The purchase of PEV is supported with 4,000 EUR for BEV and 3,000 EUR for PHEV (half of the amount is to be paid by the OEM). A budget of 600 million EUR has been provided. The incentive will end when the budget has been spent, or at latest at the end of June 2019. According to the German Press Agency, government circles are "seriously considering" extending the premium beyond the summer.

Until the end of February 2019 a total of 103,079 applications have been handed in which distributes among the vehicle categories as follows[56]:

- 67,014 for BEV
- 36,014 for PHEV
- 51 for FCEV

The subsidy is restricted to BEV, FCV or PHEV (CO_2 emission ≤ 50 g CO_2/km) listed by the Federal Office for Economic Affairs and Export Control [57]. Requirements include[58]:

- initial vehicle registration
- category M1, N1 or N2[59] vehicles (L-category vehicles are excluded)
- models with a net list price ≤ 60,000 EUR (basic version)

Among the Top10 applications per manufacturer there are 19 % for BMW, about 15 % each for Volkswagen and Renault, closely followed by Smart with 13 %. The vast majority of applications were submitted by private individuals and companies: 44 % and 54 % respectively. The most popular models were Renault Zoe (12,187 – 18 % of Top10), BMW i3 (9,239) and Smart ForTwo EQ (7,953) closely followed by VW e-Golf, Streetscooter Work and Audi A3 e-tron.

Electric Mobility Act

The Electric Mobility Act (EmoG), which was drawn up under the auspices of BMVI and BMU and came into force on 12 June 2015, pursues the goal of

[55] https://www.bafa.de/DE/Energie/Energieeffizienz/Elektromobilitaet/elektromobilitaet_node.html

[56] https://www.bafa.de/SharedDocs/Downloads/DE/Energie/emob_zwischenbilanz.pdf?__blob=publicationFile&v=40

[57] http://www.bafa.de/SharedDocs/Downloads/DE/Energie/emob_liste_foerderfaehige_fahrzeuge.pdf?__blob=publicationFile&v=8

[58] https://www.bafa.de/SharedDocs/Downloads/DE/Energie/emob_liste_foerderfaehige_fahrzeuge.pdf?__blob=publicationFile&v=63

[59] if covered by a category B driver's license

granting electrically powered vehicles special privileges in road traffic. These include, for example, the allocation of special parking spaces at charging stations in public spaces, the reduction or waiver of parking fees and the exemption from certain access restrictions. The vehicles are specially marked with (so-called "e-plates") for better verifiability.

Today, the EmoG is an important component of the Federal Government's promotion of the market ramp-up of electrically powered vehicles. More than 100 cities and municipalities are currently making use of the legal possibilities for giving priority to such vehicles. A recent external evaluation report shows that the implementation of the Electric Mobility Act has a positive effect on the number of existing and new registrations of electric vehicles[60.] According to this report, the municipalities generally rate the EmoG positively. The EmoG makes it possible for municipalities to implement certain privileges for qualified electric vehicles in a context-sensitive manner. The EmoG is often used as a building block within the municipal transport concept. Parking on public roads and the reduction or remission of parking fees are the most common applications. The release of special tracks is very rarely used and often not considered practicable. The municipalities would like to create regulations in the future that make it attractive for inner-city delivery traffic to use electric vehicles.

Support in Setting up Charging Infrastructure

In 2016, the federal regulation defining technical requirements for the installation and operation of public charging stations, the so-called "Ladesäulenverordnung (LSV)" entered into force. It transposes EU regulation into national law and supports an accelerated implementation of charging infrastructure. Central element of the regulation is the specification of standardised plugs and socket-outlets according to IEC 62196. Depending on charging power, type 2 (> 3.6 kW) or Combo 2 (>22 kW) connections are mandatory for new charging stations. In 2017, minimum payment standards have been set with the amendment of the charge point rules in 2017 [61] securing the non-discriminating access to charging infrastructures [62].

50 Million for Electric Mobility in Cities

On 22 November 2018, Andreas Scheuer, Federal Minister for Transport and Digital Infrastructure, presented additional subsidy notes amounting to around 50

[60] https://www.bmu.de/themen/luft-laerm-verkehr/verkehr/elektromobilitaet/

[61] https://www.umwelt-online.de/PDFBR/2017/0256_2D17.pdf

[62] http://www.bmwi.de/Redaktion/DE/Dossier/elektromobilitaet.html

million EUR for municipal electric mobility projects. The funding is granted under the “Clean air emergency programme 2017-2020”. 2,000 e-vehicles and over 1,100 charging facilities can become operational this way. Under the federal programme for charging infrastructure, proposals for over 15,000 charging points have been approved and therefore the number of existing charging points has been more than doubled.[63]

28.1.2 Automotive Industry

At the end of 2018, 30 PEV models were available from German manufacturers[64] with the aim to increase the number of electrified models to 100 until 2020, investing about 40 billion EUR in electric mobility. The German automobile industry expects that battery electric vehicles will have a world market share of about 25 % in 2030, hybrid electric vehicles (including PHEVs) will reach 37 %.

The portfolio covers all segments from small cars to large sports utility vehicles and luxury cars. The majority of electric vehicles made in Germany are PHEV. Six BEV models were available in 2018. However, all German manufacturers announce the introduction of more battery electric vehicle models for the future.

Audis plan is to deduct ten billion EUR from combustion technology and invest in electric mobility by 2022, the company has also announced seven new electric vehicles, three purely electric for market launch in 2019 and 2020 (e-tron series). A cooperation with Porsche aims at realizing a common platform for autonomous and electrified vehicles as well as a joint development of key components. In addition, Audi is also driving the development of fuel cell technology with the h-tron models, now in its sixth generation, with a first small series planned for 2020. In addition to electrification, Audi is also pursuing the development of low-CO_2 or -neutral fuels with the “e-fuels” strategy.

BMW uses the "Efficient Dynamics" label to mark electrified models and pursues the goal of zero emission mobility in the long term. On the one hand, conventional powertrains will be further optimized, on the other hand hybrid vehicles will be introduced to the market, especially in the larger vehicle segments, thereby increasing the electric power output continuously. In addition, BMW has already developed the electric vehicle i3 and the plug-in hybrids i8 from scratch, both are manufactured in Leipzig. From the year 2020, electric vehicles will be produced for the mass market - with the aim of offering a total of 25 electrified models in 2025 (12 of which are purely electric). BMW also formed a partnership with

63 Sourcce: https://www.now-gmbh.de/en/news/press/50-million-for-electric-mobility-in-cities

64 vda.de

Toyota to conduct joint research on battery technologies. In 2021, BMW plans a small series of fuel cell vehicles and from 2025 on, they shall generally be offered to a broad client base.

Daimler is one of the pioneers in the development of fuel cell technology, which is still part of the Daimler strategy. At the IAA 2017, the GLC F-Cell presented a pre-series fuel cell plug-in vehicle, which was launched into the market in 2018. Under the EQ brand, the company bundles activities for smart electric mobility, while “CASE” (Connected, Autonomous, Shared & Service and Electric Drive) comprises the cornerstones of the company's strategy for developing the mobility of the future. By the year 2022, more than ten purely electric vehicles will be available within the EQ family, with investments amounting to 10 billion EUR planned for this purpose. 15-25 % of vehicle production is to be purely electric at this time. In addition to the development of alternative drive concepts, the optimization of the conventional powertrain is also a key element for short- to medium-term emission reduction.

According to media reports, every second new car sold by Porsche will have an electric drive by 2023. The mission e (Taycan) presented at the IAA 2015 is expected to be available in the market in 2019, followed by a purely electric SUV. In addition, Porsche plans to introduce its own fast charging technology on an 800 V basis, which is able to charge the battery within 15 minutes up to 80 %.

By 2022, Volkswagen has announced investments of around 34 billion EUR in the development of electric vehicles, new mobility services, autonomous driving and digititalization - with the aim of selling one million electric vehicles by 2025. According to the “Roadmap E” 80 new electrified models are to be offered by 2025, of which 50 purely electric and 30 plug-in hybrids. By 2030, all of the Group's 300 models worldwide will be available with at least one electrified version. Comprised under the Volkswagen I.D. brand, the company’s electric mobility activities shall lead to the market launch of competitive battery electric vehicles from 2020 on, which will then be manufactured in Zwickau.

28.1.3 EV Demonstration Projects

FastCharge Project Demonstrates Charging With up to 450 kW

As part of the FastCharge research project launched in July 2016, BMW, Porsche, Allego, Phoenix Contact and Siemens have succeeded in boosting the charging capacity to a remarkable 450 kW. The project was started to explore the “technical and physical limits of all components and systems involved in charging” and to target charging capacities of up to 450 kW. The aim was to make charging as fast and convenient as today's refuelling. With the inauguration of a prototype charging system on the A8 motorway between Ulm and Augsburg, the consortium led by BMW proved that charging times of less than three minutes are possible for the first 100 kilometres of range - at least with two research vehicles, which of course had to be made receptive to such charging performance for the first time.[65]

Largest Model Project for Green Hydrogen Mobility Now Underway

With the "eFarm" project, Germany's largest green hydrogen mobility project to date has started. The GP JOULE group of companies is jointly establishing a hydrogen infrastructure in North Frisia, from production and processing to fleet utilisation. The project will create supply security for 100 % green, regionally-produced hydrogen for citizens and companies wishing to purchase a hydrogen vehicle. As part of the National Innovation Programme Hydrogen and Fuel Cell Technology, the Federal Ministry of Transport and Digital Infrastructure (BMVI) has approved investment support totalling 8 million EUR for the establishment of five hydrogen production sites, two hydrogen refuelling stations in Husum and Niebüll, as well as the procurement of two fuel cell buses and five fuel cell passenger vehicles.[66]

28.2 HEVs, PHEVs and EVs on the Road

New car sales in Germany in 2018 have cumulated to 3,435,778. This was a slight decline of -0.2 % compared to the previous year. BEV sales experienced a strong growth of +43.9 % year-on-year from 25,056 to 36,062. HEV sales increased by 76 % to 130,258[67]. PHEV sales increased by 7 % year-on-year from 29,436 in 2017 to 31,442. The largest increase compared with the previous year was recorded for passenger cars with the bivalent drive type of gasoline or compressed natural gas. It was +305.3 %. New registrations of diesel-powered passenger cars fell by -16.9 %, down to a share of 32.3 %. The number of new registrations of gasoline-powered passenger cars rose to over 2.14 million, a share of 62.4 %[68].

As of 1 January 2019, 57.3 million motorised vehicles were on the road in Germany, including 47.1 million passenger cars, 4.4 million motor bikes, 3.4 million trucks and 80,519 buses.

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[65] Ref.: https://www.electrive.net/2018/12/13/fastcharge-projekt-demonstriert-laden-mit-bis-zu-450-kw/

[66] Ref.: https://www.now-gmbh.de/en/news/press/largest-model-project-for-green-hydrogen-mobility-now-underway

[67] Including PHEV

[68] Numbers taken from Kraftfahrt-Bundesamt (KBA) - Federal Motor Transport Authority, www.kba.de, last accessed 24th March 2019

The stock of BEV amounted to 112,119 (53,861 in 2017), that of HEV to 275,380 (236,710 in 2017). This corresponds to a year-on-year growth of 208 % and 116 %, respectively. With 6,360 sold units the Renault Zoe was the most popular BEV in 2018. It is followed by the VW Golf (5,743), Smart Fortwo (4,204) and BMWi3 (3,792).

Table 1: Distribution and sales of EVs, PHEVs and HEVs in 2018 in Germany (Data source: Kraftfahrtbundesamt, KBA)

Fleet Totals on 31 December 2018					
Vehicle Type	**EVs**	**HEVs**	**PHEVs**	**FCVs**	**Total[d]**
Passenger vehicles[a]	83,175	274,414	66,997	372	47,095,784
Buses[b]	228	567	1	11	80,519
Trucks[c]	17,598	118	13	1	3,149,263

n.a. = not available
[a] UNECE categories M1
[b] UNECE categories M2-M3
[c] UNECE categories N1-N3 (incl. lightweight commercial vehicles)
[d] Including both conventional and alternative technologies

Table 2: Non-exhaustive list of available vehicles and prices (Data source: various, incl. OEM websites, auto motor sport Autokatalog 2019 and ADAC vehicle database; all websites accessed March 2019)

Market-Price Comparison of Selected EVs and PHEVs in Germany	
Available Passenger Vehicles	**Untaxed, Unsubsidized Sales Price (in EUR)**
Renault Twizy 45	6,950
Renault Twizy	7,650
Peugeot Partner Electric Kastenwagen L1	21,290
Citroën C-ZERO Model 2018	21,800
Peugeot i-On Modell 2018	21,800
smart EQ fortwo (Modell 2017 / BR453)	21,940
Peugeot Partner Electric Kastenwagen L2	22,340
smart EQ forfour (Modell 2017 / BR453)	22,600
Volkswagen e-up!	23,570
Hyundai IONIQ 1.6l Gdi Hybrid	24,800
smart EQ fortwo cabrio (Modell 2017 / BR453)	25,200
Citroën E-Mehari	25,270
Kia Soul EV, Plug (30 kWh)	29,490

Hyundai IONIQ 1.6l Gdi Plug-in-Hybrid	29,900
Renault ZOE 22 kWh	29,900
Kia Soul EV, Play	31,390
Hyundai IONIQ Elektro TREND	33,300
Renault ZOE Z.E. 41 kWh Life (incl. battery)	34,100
Nissan e-NV200 Kastenwagen, Pro	34,105
Kia e-Niro 136 Edition 7 (12/2018)	34,290
Hyundai KONA Elektro Trend (100kW, 39.2 kWh)	34,600
Nissan LEAF ZE1 MY19 40 kWh	35,800
Renault ZOE Z.E, 41 kWh Limited (incl. battery)	35,900
Volkswagen e-Golf	35,900
Kia e-Niro 136 Vision (12/2018)	37,290
Toyota Prius Plug-in Hybrid	37,550
Renault Kangoo Maxi Z.E. 33	37,985
BMW i3 (120Ah)	38,000
Kia e-Niro 204 Edition 7 (12/2018)	38,090
Hyundai KONA Elektro Style (100kW, 39.2 kWh)	38,100
Hyundai KONA Elektro Trend (150kW, 64 kWh)	39,000
Opel Ampera-e	39,330
BMW 225xe Act. Tourer iPerf. xDrive Plug-in-Hybrid	39,650
Kia e-Niro 136 Spirit (12/2018)	40,290
Streetscooter Work	40,400
BMW i3s (120Ah)	41,600
Hyundai KONA Elektro Style (150kW, 64 kWh)	42,500
Kia e-Niro 204 Vision (12/2018)	42,790
Opel Ampera-e Plus	42,990
Nissan e-NV200 Kombi (40 kWh)	43,433
Kia e-Niro 204 Spirit (12/2018)	44,790
Hyundai KONA Elektro Premium (150kW, 64 kWh)	45,600
Opel Ampera-e Ultimate	48,385
Tesla Model 3 Long-Range Dual Motor AWD	53,800
BMW 530e iPerformance Plug-in-Hybrid	56,000
Tesla Model 3 Performance Dual Motor AWD	64,600
Hyundai ix35 Fuel Cell (until 4/18)	65,450
Hyundai Nexo Fuel Cell	69,000
Jaguar I-Pace (X590)	77,850

Toyota Mirai Fuel Cell	78,600
Kia e-Niro 204 Spirit (12/2018)	44,790
Audi e-tron 55 quattro (available 03/19)	79,900
Tesla Model S Maximum Range	88,730
Tesla Model X Maximum Range	90,400
Tesla Model X 75D	95,300
Tesla Model S Performance	96,880
BMW 740e iPerformance Plug-in-Hybrid	97,900
BMW 740Le iPerformance Plug-in-Hybrid	103,300
BMW 740Le iPerformance Plug-in-Hybrid xdrive	106,700
BMW i8 Coupé	138,000
BMW i8 Roadster	155,000

28.3 Charging Infrastructure or EVSE

At the end of December 2018, over 16,100 public and semi-public charging points are registered in the BDEW charging station register - 12 % of which are fast chargers. At the end of July there were only around 13,500 charging points. This is an increase of more than 2,600 charge points - i.e. 20 % - within five months.[69]

Since April 2017, the Federal Network Agency[70] 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. The map is published under the URL: http://www.bundesnetzagentur.de/ladesaeulenkarte. The map shows the charging stations of all operators who have successfully completed the notification procedure of the Federal Network Agency and agreed to publication on the Internet. At the beginning of 2019, the map contained 13,147 charging points, of which 11,620 are normal and 1,527 are fast charging points at a total of 6,600 publicly accessible charging facilities. Following the publication of the overview map, the number of reported charging points more than tripled in the last year[71].

[69] https://www.bdew.de/presse/presseinformationen/ueber-16100-oeffentliche-ladepunkte-deutschland/

[70] The Federal Network Agency (German: Bundesnetzagentur or BNetzA) is the German regulatory office for electricity, gas, telecommunications, post and railway markets. It is a federal government agency of the German Federal Ministry of Economics and Technology and headquartered in Bonn, Germany

[71] ttps://www.bundesnetzagentur.de/SharedDocs/Pressemitteilungen/DE/2019/20190111_Ladesaeulenkarte.html

Consumers Can Now Check Billing of Their Charges.

Unlike fuel filling stations, charging points for electric vehicles generally do not issue receipts. The Federal Network Agency is expanding its interactive charge point map with so-called Public Keys. With these, consumers now have the opportunity to check the correctness of the e-mobility provider's bill. The public keys printed on the chargers can be entered by the user into a verifying software provided by the e-mobility provider. With this, the user can check whether the measured values shown in his invoice correspond to the actual measurement results and originate from the charging point at which the car was charged.[72]

Full-Coverage Network of Chargers on Motorways

In 2018, Germany reached the world's first nationwide network of chargers on motorways, each with several DC charging points at over 400 locations. Charging with higher power, which is already used in the first charging stations, leads to a significant reduction in charging time. Overall, the German charging network with AC and DC charging points is becoming more and more closely meshed[73].

Germany: World's Largest Increase in H_2 Filling Stations

As of 15March 2019, there were 62 hydrogen fueling stations in Germany[74]. A total of 48 publicly accessible hydrogen filling stations were put into operation worldwide in 2018, 17 of them in Germany. Nine new locations were added in Japan in 2018 and ten in the USA (including six in California). Japan (96) still has the largest number of public H2 filling stations, ahead of Germany (60) and the USA (42)[75].

28.4 Outlook

Permission for Last Mile Electric Vehicles to Participate in Traffic on Public Roads

In a global view alternative and new mobility concepts today are more and more characterized through personal light electric vehicles (PLEV). In a small deployable radius they offer a way to bridge the gap between short distances or in

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[72] https://www.bundesnetzagentur.de/SharedDocs/Pressemitteilungen/DE/2019/20190111_Ladesaeulenkarte.html

[73] Ref.: Nationale Plattform Elektromobilität, Fortschrittsbericht 2018, Mai 2018.

[74] https://h2.live/news/679

[75] Ref.: https://www.electrive.net/2019/02/15/brd-erlebt-weltweit-groessten-zuwachs-an-h2-tankstellen/

the last mile within multimodal transport chains. The participation of these vehicles (e.g. mono-wheelers, electric scooters or skateboards) in public road traffic has not yet been regulated in Germany but is now about to be legalized. As of February 2019 a draft of the regulation has been submitted to the Federal Council for approval. It regulates the use of the vehicles on traffic areas by maximum design speed between 6 and 20 km / h. The adoption of the regulation planned in spring will pave the way for more diverse means of transport and will open a large market.

By 2020, 100 PEV Models From German OEM Expected

By 2020, there will be 100 electric vehicle models from German manufacturers on the market. The further expansion of a comprehensive portfolio of vehicle models

has been announced and is being implemented. In addition to the already existing range of vehicles of the German vehicle manufacturers suitable for everyday use, all suppliers expand the number of their available vehicle models.

29 Ireland

29.1 Major Developments in 2018

EV sales grew by 112 % from 2017 to 2018. Several new models entered the market in 2018. Traditionally BEVs have represented the larger share of EVs sold in Ireland. However, this has become increasingly challenged as the number and range of PHEVs available is steadily increasing. In the BEV market, there is still not enough depth and variety to the vehicles on offer. The Leaf and the Ioniq represent the most prominent BEV options in the Irish market.

The Government established the Low Emissions Vehicle (LEV) Task Force introduced new subsidies for EVs which stimulated substantial growth in the market in 2018.

29.1.1 Policies and Incentives

The primary support mechanisms for the EV market include a capital grant of up to 5,000 EUR and Vehicle Registration Tax relief of up to 5,000 EUR for BEVs. PHEVs receive the same grant amount but only receive VRT relief of up to 2,500 EUR. Accelerated Capital Allowances are provided to commercial purchasers of EVs.

The Government introduced additional subsidies in 2018 including a 600 EUR grant for Domestic charge points, up to 50 % reduction in tolls for EVs and relief from Benefit in Kind tax for company owned BEVs capped at 50,000 EUR. Together these have proven very effective.

In addition, the Government established a 500 million EUR "Climate Action Fund" which is expected to provide funds for fast charging infrastructure.

29.2 HEVs, PHEVs and EVs on the Road

The cumulative number of Passenger EVs (BEV and PHEV) on Irish roads was 8,600 vehicles as of the end of 2018. Imports of vehicles from the UK were significant again in 2018 with good exchange rate and availability of low cost EVs being a key factor.

Table 1: Distribution and sales of EVs, PHEVs and HEVs in 2018 (Data source: SEAI)

Fleet Totals on 31 December 2018				
Vehicle Type	**EVs**	**HEVs**	**PHEVs**	**Total[d]**
Motorbikes[a]	33	15	0	40,198
Passenger vehicles[b]	4,565	32,271	2,797	2,128,548
Buses[c]	0	0	0	12,498
Commercial vehicles[d]	167	60	10	317,724

Total Sales during 2018				
Vehicle Type	**EVs**	**HEVs**	**PHEVs**	**Total[d]**
Motorbikes[a]	7	0	0	1,556
Passenger vehicles[b]	1,242	6,644	715	121,575
Buses[c]	n.a.	n.a.	n.a.	558
Commercial vehicles[d]	67	0	2	25,459

n.a. = not available
[a] UNECE categories L1-L5
[b] UNECE categories M1
[c] UNECE categories M2-M3
[d] UNECE categories N1
[e] Including both conventional and alternative technologies

29.3 Charging Infrastructure

Table 1 indicates the current number of chargers available at publically accessible locations in the Republic of Ireland. Development activity was relatively low for the national infrastructure in 2018 apart from replacement of early unreliable infrastructure with more reliable units. Some CHAdeMO only Fast Chargers have also been changed out with triple headed units which supply CCS and Fast AC along with Chademo. Tesla have introduced a number of superfast charger stops around the country with little fanfare.

Charging infrastructure is also available in Northern Ireland and drivers may roam between and readily access the infrastructure in both parts of Ireland.

ESB also introduced an enhanced charge point management system, now powered by infrastructure software provider Driivz. The system allows ESB to monitor the availability of the charge point network and to remotely operate charge point units in the field, as well as the ability to carry out fault diagnoses and repair. Furthermore, the system feeds real time information into the charge point map and app enabling drivers to better plan their journey.

Figure 1: Charging infrastructure future ownership and operation under discussion in 2017 and 2018 (Source: ESB Ecars)

Table 2: Available vehicles and prices in Ireland (Data source: SEAI - basic entry level price show for each model)

Market-Price Comparison of Selected EVs and PHEVs in Ireland	
Available Passenger Vehicles	**Untaxed, Unsubsidized Sales Price in EUR)**
Mitsubishi i-MIEV	28,095
Mitsubishi Outlander PHEV	35,137
Nissan Leaf 30kWh	30,073
Nissan ENV200	23,411
Renault Fluence	20,139
Renault Kangoo Van ZE	20,000
Renault Zoe	15,514
Citroen C-Zero	25,183
BMW i3 BEV	30,668
BMW i8 PHEV	101,342
BMW 225xe PHEV	35,131
BMW 330e PHEV	33,880
VW eGolf	30,216
VW Golf GTE PHEV	33,431
VW Passat GTE PHEV	34,349
Audi A3 E-Tron PHEV	33,431
Volvo V60 PHEV	47,807
Volvo XC90 PHEV	58,045

29.4 Outlook

The LEV Task Force recommended many new supports for EVs in its report to the Government in 2018, most of which were implemented in 2018 and are expected to continue in 2019. The Climate Action Fund is expected to provide 10 million EUR of capital support towards 150 kW fast charging stations around the country. In addition to this, there is significant private investment expected to happen for charging infrastructure on private and public properties. Building regulations are expected to be examined to see what modifications are needed to encourage the development of the EV market.

30 Italy

30.1 Major Developments in 2018

In general, 2018 was a year of recession for the car market in Italy. Statistic data show a reduction of global car sales compared with the previous year but, whilst on the one hand there was a substantial decrease in diesel car sales, on the other hand sales of alternatively-powered cars increased. In particular, hybrid and electric cars have gained market shares.

At the end of the year, Fiat Chrysler Automotive (FCA), the main national car manufacturer, announced the first installation of the full battery electric vehicle platform which will be used on the new version of the model Fiat 500 and may be globally used on other models.

Other important developments come from the proposal for the Integrated Nation Plan for Energy and Climate, submitted by the Italian government to the European Union at the end of December, which gives a prominent role to the strategies for cleaner transport in the general context of de-carbonization, and the 2019 Budget Law that introduces direct incentives for purchasing hybrid and electric vehicles.

30.1.1 Legislation, Funding, Incentives and Taxation

In 2018, support measures for e-mobility were decided at local level and don't provide direct incentives for buying electric and hybrid vehicles but rather a reduction of circulation costs. The reduction of the annual circulation tax (ownership tax) is among the most widely used types of indirect incentives: usually, electric vehicles are exempt from the annual circulation tax for a period of five years from the date of first registration and after this five-year period they benefit from a 75 % reduction of the tax rate applied to equivalent petrol vehicles. Some regions extend the period of this reduction for the whole life of the vehicle, other regions distinguish battery electric vehicles from plug-in hybrid electric vehicles. In some municipalities, electric vehicles have free access to limited traffic areas and/or free parking in reserved parking areas. Certain municipalities are going to introduce more and more strict driving bans for diesel vehicles: Florence in 2020 and Rome in 2024 (driving ban in city centre), Milan in 2025 (driving ban throughout the city). There are also cases of direct incentives: the Autonomous

Province of Trento provides a direct incentive for purchasing a plug-in hybrid electric vehicle (4,000 EUR incentive) or a battery electric vehicle (6,000 EUR incentive). The Friuli Venezia Giulia region allocated 1,4 million EUR for replacing old cars: the region offers a contribution from 3,000 to 5,000 EUR for scrapping petrol (category Euro 0 or Euro 1) or diesel (category from Euro 0 to Euro 3) cars and purchasing “green” cars. The Veneto region allocated 500,000 EUR to provide contributions for scrapping and replacing most polluting cars (petrol cars Euro 0 and Euro 1, diesel cars from Euro 0 to Euro 3) with alternative fuel cars: a 2,000 or 3,500 EUR incentive respectively for purchasing bi-fuel or hybrid and electric cars. The Emilia Romagna region allocated 3 million EUR to improve the quality of air: people residing in this region, who bought hybrid cars during 2018, will receive a three years contribution corresponding to the amount of the ownership tax for a mid-size car, up to a maximum of 191 EUR per year. In addition, the region purchased electric buses, next-generation trains, and spent 2.4 million EUR to buy 103 electric cars for the public administration.

In February, the Program Agreement between the Ministry of Infrastructures and Transport and the regions to install electric vehicle charging stations was published. These installations will take 72.2 million EUR and the Ministry will provide a co-funding amounting to 27.7 million EUR. The financial resources will be provided to the regions and used by them to implement the National Plan for Electric Charging Infrastructure (PNIRE). The Apulia region published a tender for purchasing and installing domestic electric charging points supplied by renewable sources. The non-repayable contribution amounts to 80 % of purchase and installation costs, up to a maximum of 1,500 EUR. The Sardinia region allocated 15 million EUR for installing 650 electric vehicle charging stations: 50 “fast” charging stations (supply power higher than 22 kW), 300 “quick” charging stations (supply power between 7 and 22 kW) and 300 “slow” charging stations (supply power between 3 and 7 kW). Further, municipalities have the possibility for purchasing electric vehicles to be used in their fleet. The Calabria region published an announcement of funding the installation of 58 electric vehicle charging stations located in 52 localities. With a financing of 940,000 EUR, this Plan will enable the installation of the first electric vehicle charging infrastructure in the region.

Finally, local administrations must include in their own Building Regulation a rule which requires new buildings to have the predisposition for electric vehicle charging stations.

The Ministry of Economic Development is supporting program agreements and research and development projects for hybrid and electric retrofit of conventional engines as well as the production of new cleaner vehicles.

In 2018, the government worked for the preparation of the 2019 Budget Law, which introduces a bonus of up to 6,000 EUR and a malus of up to 2,500 EUR for purchasing new cars as from 1 January. The bonus/malus system is based on the value of CO_2 emissions per kilometer. This amendment allocates 300 million EUR annually for the years from 2019 to 2021. Those who register a new electric, hybrid or natural gas car will receive a contribution up to 6,000 EUR, but those who register a car fueled by conventional polluting fuels will pay a tax of up to 2,500 EUR. This tax will not be applied to town cars and special purpose vehicles. Finally, the law includes a 50 % fiscal deduction on the costs incurred in purchasing and installing charging stations for electric and hybrid vehicles from 1 March 2019 to 31 December 2021. In the first few months of 2019, this measure will be followed by the Strategic Plan for Sustainable Mobility containing operative indications on public transport to meet the 2030 national targets.

At the end of December 2018, the proposal for the National Integrated Plan on Energy and Climate was submitted by the government to the European Commission. It provides actions to promote alternative fuels and reduce polluting emissions from transport: increased funding to replace old buses for public transport with electric and natural gas fuelled vehicles (estimated 2,000 buses per year during the period 2019-2033), obligation for public administration to buy alternative fuel vehicles and to facilitate registrations of low-emissions vehicles, also by progressively reviewing the taxation system (ownership tax, fuel tax and so on), environmental bonus/malus for purchasing new cars and fiscal deduction for installing electric vehicle charging stations as required by the 2019 Budget Law, to increase refueling points for alternative fuels. The plan also mentions experimental measures to allow charging stations to be used for the "Vehicle to Grid" service. New national regulations to promote wide diffusion of electric and hybrid vehicles in the cities are also under consideration by the government: free access to limited traffic areas, priority lanes and reserved parking lots. The main target of this policy is to meet 21.6 % as the share of energy from renewable energetic sources in the energy gross final consumptions for the transport sector. Electric cars will account for up to 6 % of the main target. Relating to public fleet, the plan aims to increase the requirements provided by the European Directive on Alternative Fuels Infrastructure: in high pollution provinces, the share of alternative fuel vehicles will be at least 30 % by 2022, 50 % by 2025 and 85 % by 2030. Further, the government plans to allocate 10 million EUR (80 % will be reserved to the Carabinieri Corps) for purchasing about 220 electric or hybrid cars to be used for surveillance activities in protected natural areas. As of 2021, urban plans for sustainable mobility will be compulsory for metropolitan cities, municipalities with over 100,000 inhabitants and towns with high rates of pollution. Relating to infrastructure, more than 300 fast and ultra fast electric vehicle charging stations (in addition to those required by the PNIRE) at roads and motorways fuel stations are mentioned under the Program “Connecting Europe Facility”.

Other proposals for investment programs are under consideration, e. g.: the “Toward Electrification” program to develop products and processes for new electric cars, the “E-Smart 4.0” program relating to next generation tires for electric and autonomous vehicles, the “Battery Swapping Eco-System” program about the battery-replacement.

More ambition in de-carbonization, incentives for sustainable mobility, involvement of public administration are in the plans of the Ministry of Environment too.

The Ministry of Infrastructures and Transport is considering a number of measures for a sustainable and safe mobility, e-mobility in airports, bikes on the priority lanes, and electric scooters on the motorways.

More and more, Italy bets on hydrogen as the future energy carrier, especially for transport and integration of renewable sources into the electric system. In fact, Italy is between the signatories of the “Hydrogen Initiative”, the European initiative aimed to increase technological and financial efforts for new hydrogen production and storage solutions in different applications, including those relating to transport. Further, the Ministry of the Interior published the “Technical regulation of fire preventing to design, build and operate hydrogen distribution plants for automotive applications” by which Italy aligns itself with the international standards for hydrogen car fuelling stations.

30.1.2 Research

For several years, the National Research Council of Italy (CNR) has been studying the development of an integrated system between electric mobility and energy production from renewable energetic sources and storage. The application of this study is the integration of alternative sustainable mobility systems, Intelligent Transport System (ITS) by the means of an ICT platform directed to systems, infrastructures and electric vehicles, fuel cell and hybrid (fuel cell and battery) vehicles. Another area of study is the management of energetic flows inside the hybrid propeller: it gives information to build simulation models of the energetic flows and pollutants generation. This study wants to define and experimentally evaluate the best control strategies for the optimal management of the propulsion system. Finally, CNR studies the different types of energy storage systems (batteries and supercapacitors) for electric vehicles.

In 2018, the Italian National Agency on New Technologies, Energy and Sustainable Economic Development (ENEA) continued its activities relating to the

"Sustainable Electric Mobility" project, included in the National Research Program for the Electrical System founded by the Ministry of Economic Development. These activities include studies and researches to realize support instruments for planning and/or evaluating electric mobility and developing innovative technologies for charging infrastructures, especially the investigation of the impacts of electric mobility on the transport system in urban context and the development of useful instruments for Local Public Transport (LPT) companies or local administrations. Here is a list of the activities made by ENEA in 2018:

- Research activity on an innovative system for local public transport. In such a system, as shown in Figure 1, the bus is equipped with a hybrid storage system: supercapacitors (SCs) and batteries, SCs are used to supply the powertrain during the route, while the batteries are used to supply the auxiliaries systems and the powertrain itself during transfer from the garage to the bus terminal and in case of emergency. The charging connection is automated by a pantograph and the charging station is also equipped with SCs. The SCs on board can be charged very quickly (less than 30 s) at the bus stop by a simple energy transfer between the SCs in the charging station and the ones on board, without any electronic device interposed, but only an inductance. The SCs in the stations can be slowly charged by the grid in the time before the next bus arrival. This simple and cheap way makes it possible to perform a flash charge without demanding high power from the power grid that is not strongly affected by the charging service.

Figure 1: Storage system on board the bus (left), bus equipped with pantograph (middle) and electric schematic of the charging station (Source: ENEA)

- Studies on dynamic wireless charging, in terms of system design and implementation on a little size experimental vehicle. In cooperation with the University of Padova, a new "Double D" coil system, operating at 85 kHz, has been designed and characterized through numerical simulation, in the perspective of the realization of a physical dynamic wireless power transfer prototype. The complete prototype consists of three coils on the ground (truck coils) and a coil on the vehicle (pick-up coil). Three power signal generation systems and a power signal receiving system were designed and realized to supply the truck coils and to manage the power signal received by the pick-up coil in order to charge the batteries on the vehicle. The compliance to the fixed requirements was checked on a laboratory bench: the transferred power was 3.3 ± 0.4 kW, measured during the movement of the pick-up coil on the truck coils. The power efficiency was > 90 %.

- ENEA realized the "Better Electric Solutions for public Transport" system, a software to make technical-economic feasibility studies for electric supply of urban buses and provide the optimal configuration of electric charging infrastructure, and the "E-Mobility Simulation" system for public and private decision-makers to support a more correct and sustainable diffusion of e-mobility in urban contexts.
- Risk analysis and management of the residual risk for batteries in electric vehicles. Even if batteries and their management systems are subject to safety tests, the risk analysis (and experience) show that there is the possibility of undesired events. In cooperation with the Italian National Fire Corp and with universities, Hazard Analysis on battery packs were performed – including Battery Management System contribution – with Failure Mode and Effect Analysis, Hazard and Operability Analysis and Layer of Protection Analysis techniques; some thermal abuse test campaign on Nickel Manganese Cobalt (NMC) pouch cells and pack, an example of which is shown in Figure 2, followed by the test of the main extinguish agents; a cone calorimeter campaign of test on 18650 NMC cells to evaluate the Heat Release Rate and other abuse tests, making chemical characterization before and after the test. These studies give the information needed to manage the worst case that may be the consequence of failure of safety systems during vehicle use and recharge, crash situations, the thermal project of rechargeable electric energy storage systems and/or low reliability of their components. The research group headed by ENEA is also interested to collect accidents information that have involved Lithium-ion batteries during their life cycle and recall news from the market of portable, domestic and EV apparatus: the study of these events is very important for the improvement of prevention systems and our knowledge about the abuse behavior of batteries, rechargeable electric energy storage systems.
- Studies on the ageing of battery cells (commercial NMC - graphite, non-commercial NMC - Lithium Titanium Oxide) and development of data-based models to predict the life duration for a given duty cycle.

"Ricerca sul Sistema Energetico" (RSE), another main research institute, together with CNR and ENEA, has been working on electric mobility for several years, not only vehicles but especially their impacts on the grid and the optimization of mobility in the context of the wider energetic scenario.

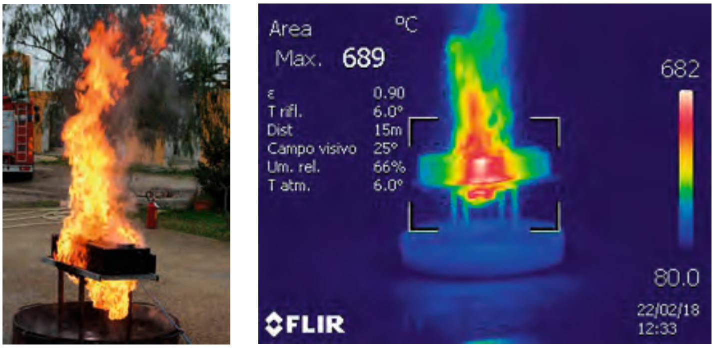

Figure 2: Thermal abuse test on battery pack (Source: Italian National Fire Corp.)

In June, RSE published the dossier "Le auto elettriche nella rete"[76] where the potential impact of several million electric vehicles on the medium and low voltage electric energy distribution system is analyzed. Some previous studies had already assured about energy availability and the complete reliability of the transmission grid for supporting a substantial increase of the electric vehicle fleet. The dossier shows how, in case of a great increase of electric vehicles used by local public transport companies, the current load of the low voltage grid in Italy seems perfectly capable to support a progressive increase of electric vehicles, while an adjustment of the medium voltage grid (consistent, both in time and investments, with the increase of public transport) seems to be necessary. Relating to private transport, batteries of electric vehicles can be considered as a "flexible load": in fact, in urban use these vehicles are stopped (then available for charging) for 90 – 95 % of the time and the daily covered distances are rather small (a few tens of kilometers). The simulations show that the current electric energy distribution grids are significantly "underused" and then perfectly capable to satisfy the demand, it is enough to provide users with the right information about off-peak charging to avoid new power peaks.

30.2 HEVs, PHEVs and EVs on the Road

In general, 2018 was a year of recession for the car market in Italy. Compared to the previous year, statistic data show a reduction by 3.1 % of global car sales. Referring to the month of October, UNRAE's data confirm a 27 % decrease in diesel car sales while, referring to the period from January to October, a 10.6 % decrease is shown. On the other side, sales of alternatively-powered vehicles increased. In October, sales of hybrid electric cars increased by 27.3 % while the registrations of plug-in hybrid electric cars increased by 82.1 % and the ones of

[76] https://www.dossierse.it/archivio/06-le-auto-elettriche-nella-rete/dossier

battery electric cars increased by 149.8 %. In the first ten months, sales of hybrid electric cars increased by 31.3 % while the registrations of plug-in hybrid electric vehicles increased by 68.5 % and the ones of battery electric cars by 150 %. Relating to the global car market, in the first ten months, hybrid electric cars accounted for 4.2 % of the total car sales, plug-in hybrid electric cars for 0.2 % and battery electric cars for 0.3 %.

Without abandoning the production of diesel vehicles, FCA Group bets on clean vehicles: FCA plant at Mirafiori will manufacture the full electric version of the model Fiat 500 for the European market, whose first deliveries will be ready by 2020. Most of the new models planned by FCA will have full, hybrid or plug-in electric versions.

Table 2 illustrates the cars available in the market of passenger battery electric vehicles, hybrid electric vehicles and plug-in hybrid electric vehicles from different manufacturers. Nissan Leaf was the most popular battery electric vehicle in Italy, followed by Smart Fortwo, Renault Zoe, Tesla S, Tesla X, BMW i3, Smart Forfour, Volkswagen Golf, Citroen C-Zero, and Jaguar I-Pace while, relating to hybrid vehicles, the most popular was Toyota Yaris followed by Toyota C-HR, Toyota RAV4, Toyota Auris, Kia Niro, Suzuki Swift, Suzuki Ignis, Lexus NX, Ford Mondeo, Hyundai Ioniq.

Table 1: Distribution and sales of EVs, PHEVs and HEVs in 2018 (Data source: Traficom, Autoalan tiedotuskeskus)

Fleet Totals on 31 December 2018					
Vehicle Type	**EVs**	**HEVs**	**PHEVs**	**FCVs**	**Total[h]**
Bicycles	500,000[i]	n.a.		n.a.	3,500,000[i]
Mopeds[a]	n.a.	n.a.		n.a.	1,950,000[i]
Motorbikes[b]	n.a.	n.a.		n.a.	6,689,911[i]
Quadricycles[c]	n.a.	n.a.		n.a.	n.a.
Passenger vehicles[d]	7,469[l]	177,583[l]		1[p]	38,520,321[m]
Commercial vehicles[f]	4,045[l]	638[l]		n.a.	3,555,849[l]
Buses[e]	n.a.	n.a.		13[p]	99,100[m]
Trucks[g]	27[l]	1[l]		n.a.	527,499[l]
Totals without bicycles	**11,541**	**178,222**		**14**	**51,342,680**

Total Sales during 2018					
Vehicle Type	EVs	HEVs	PHEVs	FCVs	Total[h]
Bicycles	148,000[l]	n.a.	n.a.	n.a.	1,688,000[l]
Mopeds[a]	2,928[l]	n.a.	n.a.	n.a.	20,923[l]
Motorbikes[b]	648[l]	n.a.	n.a.	n.a.	219,465[l]
Quadricycles[c]	654[l]	n.a.	n.a.	n.a.	5,555[l]
Passenger vehicles[d]	4,997[o]	81,892[o]	4,734[o]	n.a.	1,910,025
Commercial vehicles[f]	n.a.	n.a.	n.a.	n.a.	181,590[o]
Buses[e]	n.a.	n.a.	n.a.	n.a.	4,584[o]
Trucks[g]	n.a.	n.a.	n.a.	n.a.	46,176[o]
Totals without bicycles	**9,227**	**81,892**	**4,734**	**n.a.**	**2,388,318**

n.a. = not available
[a] UNECE categories L1-L2
[b] UNECE categories L1-L5
[c] UNECE categories L6-L7
[d] UNECE categories M1
[e] UNECE categories M2-M3
[f] UNECE categories N1
[g] UNECE categories N2-N3
[h] Including both conventional and alternative technologies
[i] Source: ANCMA
[l] Source: ENEA elaboration on data ACI
[m] Source: ACI
[n] Power heads not included
[o] Source: ACEA
[p] Source: ENEA

Table 2: Available vehicles and prices in the Netherlands (Data source: https://ev-database.nl, January 2019)

Market-Price Comparison of Selected BEVs and PHEVs in Italy	
Available Passenger Vehicles	**Unsubsidized Sales Price (in EUR)**
Audi A3 SPB e-tron (petrol-electric plug-in hybrid)	39,850÷41,450
Audi A4 2.0 TFSI (petrol-electric hybrid)	40,400÷52,800
Audi A5 SPB 2.0 TFSI (petrol-electric hybrid)	41,680÷64,330
Audi A6 40 2.0 TDI S tronic (diesel-electric hybrid)	53,850÷59,550
Audi A6 45 3.0 TDI quattro tiptronic (diesel-electric hybrid)	60,400÷66,100
Audi A6 50 3.0 TDI quattro tiptronic (diesel-electric hybrid)	62,100÷67,800
Audi A6 Avant 40 2.0 TDI S tronic (diesel-electric hybrid)	56,250÷61,950
Audi A6 Avant 45 3.0 TDI quattro tiptronic (diesel-electric hybrid)	62,800÷68,500

Audi A6 Avant 50 3.0 TDI quattro tiptronic (diesel-electric hybrid)	64,500÷70,200
Audi A7 SPB 40 2.0TDI S tronic (diesel-electric hybrid)	62,600÷66,550
Audi A7 SPB 45 3.0TDI quattro tiptronic (diesel-electric hybrid)	69,900÷73,850
Audi A7 SPB 50 3.0TDI quattro tiptronic (diesel-electric hybrid)	72,900÷76,850
Audi A8 50 TDI 3.0 quattro tiptronic (diesel-electric hybrid)	93,800÷101,100
Audi A8 55 TDI 3.0 quattro tiptronic (petrol-electric hybrid)	95,800÷103,100
Audi Q7 45 TDI quattro tiptronic (diesel-electric hybrid)	64,250÷75,150
Audi Q7 50 TDI quattro tiptronic (diesel-electric hybrid)	69,750÷78,650
Audi Q7 E-TRON (diesel-electric plug-in hybrid)	87,000÷91,180
Audi Q8 (diesel-electric hybrid)	78,450÷86,500
BMW 530e (petrol-electric plug-in hybrid)	59,150÷67,950
BMW 740e (petrol-electric plug-in hybrid)	101,400
BMW 225xe Active Tourer (petrol-electric plug-in hybrid)	38,350
BMW i8 (petrol-electric plug-in hybrid)	147,600÷163,400
BMW i3 (electric)	39,900÷46,300
CITROEN C-Zero (electric)	30,741
CITROEN E-Mehari (electric)	27,300÷28,200
DS 5 (diesel-electric hybrid)	50,600
Ferrari LaFerrari Aperta (petrol-electric hybrid)	1,860,001
Ford Mondeo (petrol-electric hybrid)	42,100
Honda NSX (petrol-electric hybrid)	201,000
Honda CR-V 2.0 Hev (petrol-electric hybrid)	32,900÷44,500
Hyundai Ioniq (petrol-electric plug-in hybrid)	34,650÷37,300
Hyundai Ioniq (petrol-electric hybrid)	26,050÷30,300
Hyundai Kona (electric)	36,400÷45,400
Hyundai Tucson (diesel-electric hybrid)	40,400
Infiniti Q50 (petrol-electric hybrid)	51,990÷63,400
Infiniti Q70 (petrol-electric hybrid)	63,450÷66,400
Jaguar I-Pace (electric)	79,790÷104,390
KIA Optima (petrol-electric plug-in hybrid)	44,000÷45,750
KIA Niro (petrol-electric hybrid)	25,500÷30,500
KIA Niro (petrol-electric plug-in hybrid)	36,700
KIA Sportage (diesel-electric hybrid)	36,000÷38,500
Land Rover Range Rover Sport (petrol-electric plug-in hybrid)	91,200÷112,500
Land Rover Range Rover (petrol-electric plug-in hybrid)	124,000÷206,100
Lexus CT (petrol-electric hybrid)	32,100÷37,400

Lexus IS (petrol-electric hybrid)	41,300÷51,300
Lexus LS (petrol-electric hybrid)	105,000÷140,000
Lexus RC (petrol-electric hybrid)	49,800÷53,300
Lexus LC (petrol-electric hybrid)	105,500÷120,500
Lexus UX (petrol-electric hybrid)	37,900÷49,900
Lexus NX (petrol-electric hybrid)	47,800÷59,250
Lexus RX (petrol-electric hybrid)	69,500÷81,150
Mercedes C 200 BERLINA (petrol-electric hybrid)	42,494÷53,985
Mercedes C 200 STATION (petrol-electric hybrid)	44,374÷55,365
Mercedes C 200 COUPE’ (petrol-electric hybrid)	46,977÷57,367
Mercedes C 200 CABRIO (petrol-electric hybrid)	56,219÷65,149
Mercedes E 350 (petrol-electric hybrid)	65,455÷77,623
Mercedes E 53 (petrol-electric hybrid)	93,073÷97,394
Mercedes S 450 (petrol-electric hybrid)	106,210÷119,980
Mercedes S 500 (petrol-electric hybrid)	124,750
Mercedes CLS 450 (petrol-electric hybrid)	80,380÷92,540
Mercedes CLS 53 (petrol-electric hybrid)	109,510
Mercedes GT COUPE’ (petrol-electric hybrid)	99,775÷119,417
MINI Countryman (petrol-electric plug-in hybrid)	39,100÷42,700
Mitsubishi i-MiEV (electric)	29,900
Nissan Leaf (electric)	34,370÷ 39,790
Nissan NV200 Evalia (electric)	42,990÷ 44,300
Peugeot iOn (electric)	28,151
Peugeot Partner Tepee (electric)	33,000
Porsche Panamera 2.9 E-Hybrid (petrol-electric plug-in hybrid)	115,751÷123,437
Porsche Panamera 4.0 E-Hybrid (petrol-electric plug-in hybrid)	194,197÷207,983
Porsche Cayenne (petrol-electric plug-in hybrid)	95,923
Renault ZOE (electric)	26,300÷ 36,200
Smart fortwo COUPE’ (electric)	24,198÷ 28,298
Smart fortwo CABRIO (electric)	27,548÷31,548
Smart forfour (electric)	24,748÷29,748
Suzuki Swift (petrol-electric hybrid)	18,890÷19,290
Suzuki Baleno (petrol-electric hybrid)	17,600
Suzuki Ignis (petrol-electric hybrid)	16,950÷19,350
Tesla Model S 75 kWh (electric)	90,980
Tesla Model S 100 kWh (electric)	114,480÷152,330

Tesla Model X 75 kWh (electric)	98,830
Tesla Model X 100 kWh (electric)	118,980÷161,730
Toyota Yaris (petrol-electric hybrid)	19,600÷22,450
Toyota Auris (petrol-electric hybrid)	24,500÷30,800
Toyota Prius (petrol-electric plug-in hybrid)	41,650
Toyota Prius (petrol-electric hybrid)	29,500÷36,050
Toyota C-HR (petrol-electric hybrid)	28,850÷34500
Toyota RAV4 (petrol-electric hybrid)	34,100÷41,650
VW e-up! (electric)	28,450
VW e-Golf (electric)	40,100
Volvo V60 (petrol-electric plug-in hybrid)	62,970÷63,170
Volvo S90 (petrol-electric plug-in hybrid)	71,150÷77,180
Volvo V90 (petrol-electric plug-in hybrid)	74,110÷80,140
Volvo XC60 (petrol-electric plug-in hybrid)	69,500
Volvo XC90 (petrol-electric plug-in hybrid)	79,900÷120,400

30.3 Charging Infrastructure or EVSE

The PNIRE defines the national strategy for the widespread diffusion of electric vehicle charging infrastructure, with a target of 4,500 ÷ 13,000 slow/accelerated charging points and more than 2,000 ÷ 6,000 fast charging stations on the national territory by 2020, giving priority to urban areas which belong to metropolitan cities and, successively, suburban areas, extra-urban roads, state roads and highways. By the means of the Program Agreement between the Ministry of Infrastructures and Transport and the Regions (Basilicata, Calabria, Campania, Emilia Romagna, Friuli Venezia Giulia, Lazio, Liguria, Lombardy, Marche, Piedmont, Apulia, Sardinia, Sicily, Tuscany, Umbria, Valle d'Aosta, Veneto, and the autonomous provinces of Trento and Bolzano) the installation of electric vehicle charging stations required by the PNIRE is continuing and at the moment several charging points have been installed.

In 2017, Enel launched its plan to provide Italy with an appropriate charging infrastructure. Targets for Enel's plan are shown in Figure 3 and resumed as follows:

- 2,700 charging points by 2018
- 7,000 charging stations by 2020
- 14,000 charging stations by 2022

Enel will use from 100 to 300 million EUR, resulting from company investment, European founds and drivers' contribute, this is not going to be a part of electricity tariff and a burden on electricity bills. An agreement between the European Investment Bank (BEI) and Enel X Mobility for funding Enel's plan was signed in 2018: Enel X Mobility will receive a 115 million EUR total funding lasting 10 years which will support about 50 % of the total investment. This financial action falls under one of BEI's main action streams that is financing projects on innovation and sustainable mobility against climate change.

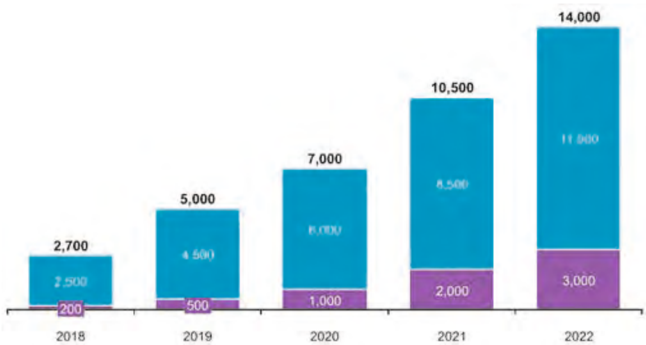

Figure 3: Enel's Plan for electric vehicle charging stations – numbers in blue are representing fast chargers and the purple ones, ultra-fast and superchargers (Source: Enel X)

As a consequence of this, a general upward trend is registered but, on the other side, the inventory of charging infrastructures is particularly complicated: the results, to the best of actual abilities, has been obtained by the European Alternative Fuel Observatory's (EAFO) website and are resumed in Table 3.

Table 3: Information on charging infrastructure in 2018 (Data source: ENEA elaboration on data from EAFO web site, CIVES for Tesla superchargers)

Public Charging Infrastructure on 31 December 2018	
Chargers	**Quantity**
AC Level 1 & 2 Chargers (≤ 22 kW)	2,860
CHAdeMO, CCS and Tesla Superchargers (> 22 kW)	702
Totals	**3,562**

30.4 EV Demonstration Projects

The Italian start-up Daze Technology made "DazePlug", shown in Figure 4, an innovative automatic charging device for electric cars, which wants to be a valid alternative to the wireless charging, with the same costs but greater energy efficiency, because the physical connection between plug and socket is not affected by the energy losses which are typical of wireless charging systems. Charging power is actually limited to 7.2 kW, but it will be increased up to 44 kW soon and up to 150 kW in the future.

Figure 4: automated conductive charging system “DazePlug” (Source: Daze Technology S.r.l.)

Enel X, the Company of Enel Group with strong roots in the energy field and an open strategy geared towards digitalization, sustainability, innovation, and the consultancy PricewaterhouseCoopers have signed a memorandum of understanding for developing e-mobility in companies, which includes a preliminary step of studies and analysis followed by pilot projects on the ground. The experimental phase will be made on PricewaterhouseCoopers’ car fleet. Further, PricewaterhouseCoopers will make its skills on e-mobility and fleet management available to Enel X to develop innovative solutions for the company fleet.

Twelve Italian Municipalities take part in “Simpla” (Sustainable Integrated Multi-sector PLAnning), an international project funded by the Program Horizon 2020 of the European Union, aimed to provide guidelines for harmonizing municipal strategic plans and test their application.

Several projects on sustainable transport, affecting Italian companies, have received European funding under the Program “Connecting Europe Facility”: “Ambra-Electrify Europe” by Enel X, which also involves Austria, Spain, and Romania (cost 70.75 million EUR, European Union’s support 14.15 million EUR, ending 31 December 2022), “Multi-E”, which wants to provide a network of compressed natural gas filling stations and electric vehicle charging stations in Slovenia, Italy, Slovakia, and Hungary (cost 64.53 million EUR, European Union’s support 12.9 million EUR, ending 31 December 2023).

The Italian Regulatory Authority for Energy, Networks and the Environment has approved the Pilot Project for Mixed Authorized Virtual Units: storage systems for e-mobility are comparable to other storage systems with regards to the grid connection points by the means of which the charge/discharge takes place, so this project qualifies as an enabler of “vehicle to grid” technology to the market of ancillary services.

30.5 Outlook

A recent analysis made by the consulting company PricewaterhouseCoopers (PwC) estimates a high improvement of electric cars in Italy, as illustrated in Figure 5. The trend would see the electric vehicles fleet to increase from 15,000 vehicles today up to 0.5 million vehicles (baseline scenario) or even 1.5 million (optimistic scenario) by 2025. This trend will be supported by several drivers, such as the 72 % reduction of CO_2 emissions, the greater efficiency than petrol cars, the range increase, the flexibility due to charging infrastructure and the battery cost, which is expected to fall by 60 % until 2025 to meet the cost equality between petrol and electric cars.

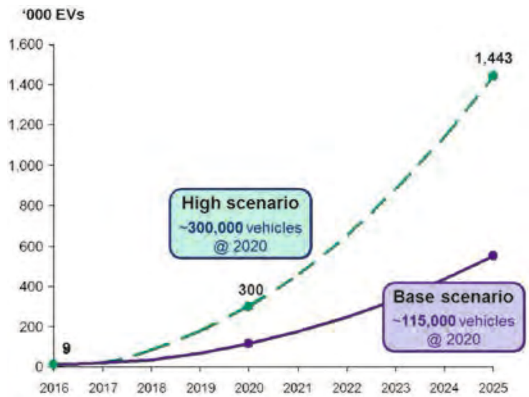

Figure 5: electric vehicles outlook (Source: PwC AutoFacts®)

The National Integrated Plan on Energy and Climate estimates that, in a vision to 2030, about 6 million electric chargeable vehicles will be circulating in Italy, more than 1.5 million of which will be fully battery fuelled.

According to projections by the European Association of Electric Transmission Operators ENTSO-E, the stock of electric vehicles in 2030 will be between 4.3 and 6.2 million, and the forecast given in the study "E-Mobility Revolution – Impacts on Italy and its industrial value chain: Italy's agenda, 2017" by Enel and The European House – Ambrosetti, show a range between 2 and 9 million electric vehicles depending on various scenarios of diffusion.

With increasing electric fleets, the energy consumptions will increase too. Terna, the grid operator which manages the high voltage Italian transmission grid, has analyzed different Italian scenarios of e-mobility and, with reference to a mean value of 6.5 million electric vehicles in 2030, estimates that the impact on electric energy demand should be relatively low, up to 5 %.

31 Norway

31.1 Major Developments in 2018

Three major milestones for the development of the EV market were reached for Norway in 2018. First of all, the total number of BEVs in the fleet passed 200,000, of which 97 % were passenger vehicles and 3 % were commercial vehicles. Secondly, the BEV share of the fleet was 7.2 % with a further 3.4 % being PHEVs (96,000) so that more than 1 out of 10 passenger vehicles in Norway now have a plug and can run on grid electricity. Thirdly, the BEV market share of new vehicle sales reached 31 %, and with PHEVs accounting for 18 % plus a large share of BEVs being imported second hand, 50 % of the vehicles that where imported to Norway in 2018 had a plug, which is another world's first. The Battery Electric Commercial Vehicle market is less developed due to fever incentives, but the market share more than doubled to 4.6 % in 2018 and the share of the fleet reached 1.1 %. The range and charge time barriers are larger for commercial activities than for consumers (Figenbaum 2018). Heavy duty trucks are still a rare sight, only 13 where in the fleet at the end of 2018. The same goes for buses with 42 registered, of which 10 are minibuses. There are also 5 fuel cell buses on the road. FCEVs are very low in numbers, only 143 are registered, and the market has been turbulent since, with the major hydrogen station operator going bankrupt in 2018.

In December, the first fast charger was put in service in Finnmark, Norway's most northern province. All of Norway's provinces now have fast chargers. The installation of the first Ultra-fast chargers was also accomplished although they are not yet operating at the full power until the cables can be upgraded. The total number of installed fast chargers is about 1,100, plus 562 Tesla Superchargers.

Oslo is the European Environmental Capital of the year in 2019. The efforts to reduce emissions from public transport within the city has therefore received a boost. Public transport is controlled by provincial authorities through tenders that private bus companies compete for. The public transport operator in Oslo, Ruter, issued change orders to existing tenders in 2018, so that there will be a rollout of 70 Battery Electric Buses in the city centre in 2019. In addition, Oslo has decided to electrify three large ferries that traffic the inner parts of the Oslofjord, thus saving 6,000 tons of CO_2[77]. In 2018, it was decided to install shore power for the international car ferries that go from Oslo to Denmark. The installation opened on the 8th of January 2019.

Two battery electric ferries were put into use for a fully battery electric car ferry service on the west-coast of Norway, and more than 60 electric ferries are under development, and will be put into service in the coming years.

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

Norway has very large incentives for BEVs. BEVs and FCEVs are exempted from the registration tax and the Value Added Tax (VAT) which are levied on fossil fuel powered vehicles upon purchase. These exemptions make BEVs the cheapest option in most vehicle segments. In addition, BEVs have a much lower annual tax, and several driver privileges with substantial economic value, such as exemption from toll roads and reduced parking charges. An overview of the incentives is shown in Table 1. The incentives and the BEV policy is stable but a gradual revision of some of the user privileges has started. The user privileges include reduced parking charges and ferry rates, road toll exemption, much lower energy taxes, and access to bus lanes. The toll road exemption is being phased out as the Parliament decided in 2017, that BEVs can be levied 50 % of the rate that ICEVs pay. The same goes for parking charges and ferry rates. None of the toll road companies introduced charges in 2018, but several consider doing so in 2019. Parking charges however have been introduced in many municipalities already. Access to bus lanes have been restricted to BEVs with at least one passenger in addition to the driver in the rush hours in some areas around Oslo. FCEVs have had the same incentives as BEVs, but has the added advantage of still being 100 % exempted from parking charges and toll roads, and FCEVs still have unrestricted access to bus lanes.

Norway is not part of the European Union but closely connected through the European Economic Area agreement (EEA). In December 2018, the Norwegian Parliament decided that Norway should incorporate the EU legislation for fleet average CO_2-emission, requiring a fleet average of 95 g CO_2/km for new vehicles sold in 2021, into the Norwegian legislation. The regulation became part of the Norwegian law from 01.01.2019[78] and will make the Norwegian BEV market more

[77] https://www.aftenposten.no/osloby/i/7lvAMK/Betaler-millioner-for-a-gjore-Nesoddbatene-miljovennlige-allerede-i-2019

[78] https://www.regjeringen.no/no/sub/eos-notatbasen/notatene/2014/apr/co2-utslipp-for-personbiler-endringsbestemmelser/id2433597/

attractive for vehicle producers as the BEV sales in Norway, will count towards the 95 g / km target for 2021.

Table 1: Relative advantage of different BEV incentives in Norway, Figenbaum (2018)

Incentives	Intro year	BEV buyers - relative advantage	Future plans
Fiscal incentives: Reduction of purchase price/yearly cost gives competitive prices			
Exemption from registration tax	1990 / 1996	The tax is based on ICEV emissions and weight. Example ICEV taxes: VW Up 3000 EUR. VW Golf: 6000 EUR	To be continued until 2020
VAT exemption	2001	Vehicles competing with BEVs are levied a VAT of 25% on sales price	To be continued until 2020
Reduced annual tax	1996/ 2004	BEVs and hydrogen vehicles 46 EUR (2019-figures). Diesel rate: 288-336 EUR	To be continued indefinitely
Reduced company car tax	2000	The company-car tax is lower but BEVs are seldom company cars	This incentive was up for revision in 2017/18 but remained unchanged
Exemption from reregistration tax	2018	Change of ownership tax: ICEVs 0-3 year-old vehicles +1200 kg: 610 EUR, 4-11 years 370 EUR	
Direct subsidies to users: Reduction of variable costs and help solving range challenges			
Free toll roads	1997	In Oslo users save 600-1000 EUR / year. Some places savings exceed 2,500 EUR	Law revised so that rates for battery electric vehicles in toll roads and ferries will be decided by local governments, up to a maximum rate of 50 % of the ICEV rate
Reduced fares on ferries	2009	Similar to toll roads saving money for those using car ferries	
Financial support normal chargers	2009	Reduce investors risk, reduce users range anxiety, expand usage	A national plan for charging infrastructure shall be developed
Financial support for fast chargers	2011	More fast-charging stations influences BEV km driven & market shares	ENOVA* support fast chargers along major corridors. City fast charging left to commercial actors
Electricity tax: 0.0162 EUR / kWh. Much less than fuel taxes per km		Gasoline road use tax: 0.54 EUR / litre Gasoline CO_2-tax:0.12 EUR / litre ; for Diesel: 0.39 + 0.14 EUR / litre respectively**	Road use tax to be continued until it can be replaced by GPS road pricing

User privileges: Reduction of time costs and providing users with relative advantages			
Access to bus lanes	2003 / 2005	BEV users save time driving to work in the bus lane during rush hours	Local authorities have given the authority to introduce restrictions if BEVs delay buses
Free parking	1999	Users get a parking space where these are expensive and save time looking for a space	Local authorities can since 2017 introduce parking chargers up to 50% of the ICEV rates
Free charging (some places)		Not regulated by national law, but often bundled with free municipal parking	Local authorities and parking operators decide whether this incentive will continue

* ENOVA, a Government agency, supports the introduction of energy saving and climate gas reduction technologies in Norway. In the transportation sector it supports charging infrastructure and refuelling infrastructure for alternative fuels.
**Source: https://www.skatteetaten.no/bedrift-og-organisasjon/ avgifter/saravgifter/om/ mineralske-produkter/

The research on EVs follows a four-pronged path; (1) research on batteries and battery materials, (2) research on hydrogen components such as fuel cells and storage systems, (3) research on system solutions especially for maritime applications, and (4) social sciences based interdisciplinary research on users, markets and policies. The budget for research allocated to these areas increased from 9 million to 12 million Euros between 2017 and 2018. The Mobility Zero Emission Energy Solutions (MoZEES) research centre focusing on battery electric and hydrogen solutions for heavy duty vehicles, vessels and railways was established as a collaboration between several leading Norwegian Research Institutes in 2017.

31.2 HEVs, PHEVs and EVs on the Road

The total BEV fleet passed 200,000 in December 2018, of which 97 % were passenger vehicles and 3 % were commercial vehicles. The BEV share of the passenger vehicle fleet reached 7.1 % with a further 3.5 % being PHEVs (96,000). More than 10 % of the total fleet can therefore use grid electricity for propulsion. The best-selling BEV in 2018 was the Nissan Leaf, which also became the best-selling model overall, regardless of propulsion system. The BEV fleet grew 41 % between 2018 and 2017. The most numerous BEVs in the fleet are Nissan Leaf (49,823), Volkswagen E-Golf (31,883), BMW i3 (19,749), and Tesla Model S/X (30,106).

The other vehicle groups lag far behind. The share of BEVs in the fleet of commercial vehicles reached 1.1 %. Battery Electric Buses and Trucks are at a test and demonstration stage with 42 and 13 registrations respectively. The obvious reason for these low numbers are the general development in the auto-industry where buses and trucks lags behind passenger vehicles in the development.

FCEVs are very low in numbers, although the purchase incentives are the same as for BEVs, and there are now more user privileges for FCEVs than for BEVs. FCEVs however rely on public infrastructure for hydrogen, which is very scarce, whereas BEVs can be charged wherever electricity is available. Electricity is cheaper to run on than hydrogen and the selection of vehicles is much larger for BEVs than FCEVs.

Passenger BEVs reached a market share of new vehicles sales of 31.2 % with 46,092 sales. PHEVs and HEVs accounted for another18 % and 11 % respectively. The share of BEVs in the commercial vehicle segment increased from 2.1 % in 2017 to 4.6 % in 2018. In addition, 11,899 second hand passenger BEVs and 150 battery electric commercial vehicles were imported from various countries, partly to circumvent that Norwegian sales volumes have not counted towards the EU fleet average target for CO_2-emissions. A large share of these vehicles were one-day registrations in EU countries. The total market share for BEVs and PHEVs reached 50 % in 2018, when adding second hand imports to new vehicle sales. Table 3 shows the price and availability of BEVs in the Norwegian market.

The market for PHEVs was 9 % lower in 2018 than in 2017. A reason for this development could be that more long range BEVs came on the market in 2017. Another reason ist hat several popular PHEV models were removed from the market due to complications from the introduction of the WLTP test. VW PHEVs and Audi PHEVs are for instance not available for purchase (apart from vehicles in stock) in the beginning of 2019, and thus not in the price list in Table 4. These brands stood for 19 % of the PHEV sales in 2018.

Table 2: Distribution and sales of EVs, PHEVs and HEVs in 2018 in Norway (Data source: Data obtained from the national vehicle registry 31 December 2018, Norwegian Public Roads Administration)

Fleet Totals on 31 December 2018					
Vehicle Type	**BEVs**	**HEVs**	**PHEVs**	**FCVs**	**Total[h]**
Bicycles	175,000[(I)]	0	0	0	n.a.
Mopeds[a]	1,385	0	0	0	163,494
Motorbikes[b]	181	0	0	0	180,085
Quadricycles[c]	1,444	0	0	0	12,444
Passenger vehicles[d]	194,900	93,048	95,993	143	2,749,680
Commercial vehicles[f]	5,305	59	29	1	476,264
Buses[e]	42	151	1	5	15,632

Trucks[g]	13	18	2		71,877
Totals without bicycles	**203,270**	**93,276**	**96,025**	**149**	**3,669,476**

Total Sales during 2018					
Vehicle Type	**BEVs**	**HEVs**	**PHEVs**	**FCVs**	**Total[h]**
Bicycles	61,185[(II)]	0	0	0	396,673[(II)]
Mopeds[a]	309[(III)]	0	0	0	3,643[(V)]
Motorbikes[b]	29[(III)]	0	0	0	8,435[(V)]
Quadricycles[c]	162[(III)]	0	0	0	n.a.[(IV)]
Passenger vehicles[d]	46,092[(V)]	16,323[(V)]	26,546[(V)]	51[(V)]	147,929[(V)]
Commercial vehicles[f]	1,603[(V)]	16[(III)]	0	0	34,640[(V)]
Buses[e]	6[(III)]	78[(III)]	0	0	1,026[(V)]
Trucks[g]	12[(III)]	2[(III)]	0	0	7,068[(V)]
Totals without bicycles	**48,213**	**16,419**	**26,546**	**51**	**202,741**

n.a. = not available
[a] UNECE categories L1-L2
[b] UNECE categories L1-L5
[c] UNECE categories L6-L7
[d] UNECE categories M1
[e] UNECE categories M2-M3
[f] UNECE categories N1
[g] UNECE categories N2-N3
[h] Including both conventional and alternative technologies
[(I)] Based on the sum of sales data collected by the Norwegian EV association for 2014-2016, and import statistics from Statistics Norway for 2017 and 2018, collected by Ydersbond et al 2019 (forthcoming)
[(II)] Norway, Table 08799: External trade in goods, by commodity number (HS) and country 1988M01 - 2018M12.
[(III)] Including both conventional and alternative technologies
[(IV)] Included in motorbikes
[(V)] Source: OFVAS, http://www.ofvas.no/bilsalget-i-2018/bilsalget-i-2018-article866-788.html
Included in motorbikes

Table 3: Available vehicles and prices in Norway in 2018 (Data sources for BEVs and FCEVs: https://www.vegvesen.no/Kjoretoy/Kjop+og+salg/Nybilvelger (status 15 January 2019); PHEVs: OFVAS status 17 January 2019). Prices includes 245 EUR scrappage fee; 1 EUR = 9.8 NOK)

Market-Price Comparison of Selected BEVs, PHEVs and FCEV in Norway	
Available Passenger Vehicles	**Untaxed, Unsubsidized Sales Price (in EUR)**
Audi e-tron 55	65,467 to 88,452
BMW i3 120 Ah	31,531 to 39,684
BMW i3s 120 Ah	35,194 to 42,327
Citroen Berlingo	22,814
Citroen C-Zero	14,733
Hyundai Ioniq Electric	24,898 to 27,449
Hyundai Kona Electric	33,163
Jaguar I-Pace	65,301 to 78,056
KIA e-Niro First edition	37,816
KIA Soul EV	25,520 to 27,051
Mitsubishi i-MIEV	15,296
Nissan e-NV200 40 kWh 5-7 seats	32,551 to 33,776
Nissan Leaf 40kWh	27,755 to 31,224
Nissan Leaf 62 kWh 3.ZERO e+	38,061
Opel Ampera e-premium	35,704
Peugeot iOn	16,694
Peugeot Partner Tepee	22,806
Renault Kangoo Z.E. Maxi 5 seats	27,388
Renault Twizy Intens	9,184
Renault Zoe 40 R90 Life	25,000
Renault Zoe 40 R110 Intens	27,551
Smart EQ ForFour	18,357 to 20,398
Smart EQ ForTwo	17,337 to 19,378
Tesla Model S 100D 4WD	84,255
Tesla Model X 100D 4WD	88,582
VW e-Golf	33,286
VW e-up!	19,592 to 21,561
BMW 2-series 225xe Active Tourer	30,983 to 33,148
BMW 5-series 530e iPerformance	43,581 to 44,674
BMW 7-series 740e	77,852
BMW i8 Coupe	110,963

Hyundai Ioniq PHEV	23,200 to 25,241
Kia Niro	24,947 to 29,858
Kia Optima PHEV	33,029
Mercedes Benz E300e PHEV	43,077
Mercedes Benz E300de PHEV	44,923 to 45,579
Mercedes Benz S 560e PHEV Long	92,111
Mini Countryman	29,241 to 38,931
Mitsubishi Outlander PHEV	35,050 to 39,924
Toyota Prius Plug-In Lounge	26,302 to 27,951
Volvo S90	49,860 to 53,448
Volvo V60	48,984
VolvoXC60	55,869 to 59,633
Volvo XC90	64,345 to 68,834
Hyundai Nexo Fuelcell Panorama FCEV	58,674
Toyota Mirai Executive FCEV	57,041

n.a. = not available

31.3 Charging Infrastructure

More than 9 out of 10 current BEV owners can charge their vehicle at home in a private parking space and 42 % use a dedicated wall box EVSE for charging[79], whereas only 9 % of PHEV owners use this type of charging connection[80]. Based on these percentages, the installed number of private wall box EVSE charge stations passed 90,000 by the end of 2018.

Public charging consists of AC level 2 chargers with type 2 connectors rated for 3.6-22 kW charge power, as well as some older installations with Schuco domestic type sockets. Most fast chargers are equipped with both a CCS and a CHAdeMO cable, but only one of these can be used at a time. A small number of fast chargers are single standard CHAdeMO or CCS. The best estimate is therefore that there are 1,100 fast chargers in Norway, of which about 95 % are dual standard CCS CHAdeMO chargers.

Ionity installed 23 CCS chargers prepared for 150 kW charge power in four locations in 2018[81]. Another operator installed two double 150 kW chargers in one

[79] Nordbakke S., Figenbaum E. 2019. Forthcoming

[80] Figenbaum E., Kolbenstvedt M. 2016. Learning from Norwegian Battery Electric and Plug-in Hybrid Vehicle users. Results from a survey of vehicle owners. Institute of Transport Economics. TØI report 1492/2016

[81] Personal communication with the Norwegian EV association 17 January 2019

location. None of these can actually charge at 150 kW until a charge cable upgrade has been carried out. In addition, there are a couple older chargers rated at 100-120 kW. Table 5 shows the estimated numbers of different types of charging infrastructure.

Table 4: Public charging infrastructure in 2018 in Norway (Data source: www.nobil.no)

Charging Infrastructure on 31 December 2018	
Chargers	**Quantity**
AC Mode 2 Charger 230 V domestic in cable EVSE(I)	4,057
AC Mode 3 Chargers 230 V Type 2 connector(II)	4,275
CHAdeMO(III)	1,104
CCS(IV)	1,064
Tesla	562
Inductive Charging	0
Totals	**11,098**

(I) According to IEC 62196
(II) CCS and Chademo chargers cannot be added together. 95 % of chargers are equipped with both types of cable, but the charger can only supply power to one at a time
(III) from ENOVA, a Government agency
(IV) https://www.skatteetaten.no/bedrift-og-organisasjon/avgifter/saravgifter/om/mineralske-produkter/

31.4 EV Demonstration Projects

The BEV activities in Norway are mostly fully commercial and in the passenger vehicle market the early majority buyer group is reached. The government has put in place incentives and support programs that private companies respond to by developing their businesses and introducing new business concepts and models. Therefore, there are few if any “demonstration projects”. In this section, an overview of different types of commercial activities will therefore be presented. Most of these are within new mobility services.

NSB, a national railroad operator, together with GreenMobility, is putting in place a fleet of 250 Renault Zoe BEVs in a free-floating car sharing scheme in Oslo, starting up from January 2019[82]. Existing car sharing schemes such as “Bilkollektivet”[83] has introduced some BEVs, e-bikes and e-cargo-bikes in their fleet. Hyre[84] and Nabobil[85] are App-based broker services also renting out BEVs. Owners of vehicles can rent out vehicles to private and business customers in a

[82] NSB press release: https://www.nsb.no/om-nsb/for-presse/pressemeldinger/na-er-nsbs-bybiler-her

[83] https://bilkollektivet.no/nb/

[84] https://www.hyre.no/

[85] https://nabobil.no/

safe manner with a special insurance included in these services. Move About[86] offers car sharing pools for businesses as well as traditional car sharing for consumers.

Battery Electric Buses have been tested out in the city of Oslo with three bus companies operating two buses each. Several challenges have been encountered in establishing OppCharge charge spots in dense city areas, and the added height of E-buses caused problems on one route in Oslo[87].

31.5 Outlook

The BEV market in Norway will remain strong through 2019. The major purchase incentives, i.e. the exemption from registration taxes and the VAT, remains in place. Purchasing a BEV makes economic sense to consumers and in addition provides access to attractive money saving driving privileges. A number of new attractive BEV models and variants of existing models will come onto the market, also in market segments without previous offerings, which should increase demand further.

The PHEV market could get an upswing when new models with longer range in E-mode becomes available, although BEVs will be cheaper than PHEVs in all market segments due to the incentive structure. A question is if PHEV sales will be additional to or replace some BEV sales or if new long range BEVs will attract some of the PHEV buyers.

In the commercial vehicle segment, the market share could increase with the availability of longer range and also larger Battery Electric LCVs.

A major development within public transport will be a definitive breakthrough for Battery Electric Buses, which will enter regular service in Oslo (76 buses), Trondheim (35 buses), and Drammen (6 buses), and the province of Akershus (39 buses). The cities of Lillehammer and Tromsø will each test out two E-buses for two years starting in 2019.

Within the maritime sector there are several passenger vessels and car ferries under conversion to Battery Electric propulsion. A hydrogen ferry is also being developed.

[86] http://www.moveabout.no/Hjem

[87] Interviews with bus operators and public transport entities conducted in the MoZEES project

32 The Netherlands

32.1 Major Developments in 2018

By 2030, only zero emission cars will be sold in the Netherlands. That is the ambition of the Dutch government. With this goal in mind, businesses, social institutions, knowledge institutions and the government all work together in the Formula E-Team, the Dutch public-private platform to promote e-mobility and accelerate the transition to electric vehicles. The aim is to help meet the climate targets and, in addition, to take advantage of the associated economic opportunities.

And their efforts were successful in 2018. The number of fully electric passenger cars more than doubled, hundreds of electric buses were taken in daily operations and more and more electric taxis drive around in cities. Dutch companies are active abroad and can make good use of the experience gained in their home market.

Policy-wise, a draft National Climate Agreement was presented, with a proposal for several extra measures to stimulate e-mobility.

32.1.1 Policy Developments

A large part of 2018 was taken up by preparations towards a National Climate Agreement. Five Sectoral 'tables' were established, for Industry, Agriculture and Land Use, the Built Environment, Electricity and Mobility; participants of the tables were many relevant stakeholders from market parties, NGOs and research institutes. Local and national governments were also represented. These tables had to draft sectoral plans to reach 'their share' of the CO_2 emissions reduction in 2030. The Dutch government wants to reduce greenhouse gas emissions by 49 % in 2030. For the mobility sector this comes to an additional 7.3 Mton of CO_2 emissions that have to be reduced by 2030.

There were several 'sub tables' at which subthemes were discussed (for mobility on innovative fuels, logistics, etc). The Formula E-Team functioned as the e-mobility sub table. In the mobility chapter of the draft National Climate Agreement, the proposals for e-mobility measures are good for half of the needed CO_2 emissions reduction for mobility by 2030. Next to an ongoing focus on stringent CO_2 standards (both national and in relation to the European Union), the proposed measures are:

- Financial and fiscal stimulation:
  - Exemption of purchase tax and (national) road tax for zero emission vehicles until 2025
  - Lower surcharge on income tax for company cars compared to conventional vehicles until 2025
  - Purchase subsidy for private customers from 2021 to 2030
- National Agenda on Charging Infrastructure:
  - Jointly drawn up by municipalities, provinces, national government, DSOs and sectoral organizations
  - Contains agreements between parties that lead to national (fast) charging infrastructure coverage for the growing number of electric vehicles
  - Agreements focus on these themes: acceleration of charging infrastructure, open protocols and price transparency, smart grids, innovation and charging infrastructure for logistics
- Accompanying measures from private parties and local government:
  - Activities that lower the threshold to switch to e-driving
  - Measures in the field of communication, battery check and guarantee for second-hand cars, e-leasing, e-car sharing and e-scooters.

At the end of December 2018, the draft agreement was presented. In the first quarter of 2019, the Netherlands Environmental Assessment Agency (PBL) will calculate costs and effects of all measures. After that, the national government will decide which measures will be introduced and made into national policy.

The Ministries of Infrastructure and Water Management and Economic Affairs and Climate Policy, LomboXnet and the province of Utrecht are the Dutch partners in the European Commission's Innovation Deal 'From E-Mobility to Recycling: the Virtuous Loop of the Electric Vehicle'. Other signatories are the European Commission and from France: the Ministries for the Ecological and Inclusive Transition and Economy & Finance, Renault s.a.s. and Bouygues. This Innovation Deal will address the problem of recycling and re-use of electric vehicle batteries.

In February 2018, the State Secretary for Infrastructure and Water Management, Ms Stientje van Veldhoven, signed the Citydeal Shared E-mobility in Urban

Planning and Development[88], together with representatives of the Ministry of the Interior and Kingdom Relations, seven cities, a province and several private parties. In three years the municipalities of Amsterdam, The Hague, Rotterdam, Utrecht, Amstelveen, Amersfoort and Apeldoorn will welcome more shared electric cars. Each city will experiment and gain experience with the deployment of shared electric cars for innovative housing projects. The electricity is supplied by local solar panels and the car battery is used to temporarily store surplus electricity.

Figure 1: Parties in the Citydeal Shared E-mobility in Urban Planning and Development (Source: Agenda Stad, photographer Valerie Kuypers)

In an administrative agreement, 32 municipalities together with the Ministry of Infrastructure and Water Management have agreed to make their dedicated social support transport fully zero emission by 2025. Social support transport is the transport of elderly, school children, and people with a physical or mental condition that incapacitates them for independent travel.

32.1.2 Financial and Fiscal Incentives

As part of the Green Deal on Publicly Accessible Charging Infrastructure, the national government has committed a total of 7.2 million EUR to contribute to the installing of public charging points by municipalities. In the period mid-2015 to mid-2018 a gradually decreasing contribution per pole was granted, on the

[88] https://youtu.be/Zi-cDR18wN8

condition that the municipality contributed the same amount per pole and that a market party also contributed. As a result of this Green Deal, 250 municipalities requested a contribution for 8,847 public charging poles.

The main driver behind the increase of electric vehicles in the Netherlands is fiscal stimulation. The focus is on stimulating zero emission vehicles, tax measures for plug-in hybrid vehicles will gradually be reduced to the same level as conventional cars. The package will stay more or less the same until 2021. Table 1 provides an overview of the incentives that were in place in 2018.

Table 1: Fiscal incentives in the Netherlands in 2018

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 CO_2 emissions and 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 CO_2 emissions and amounts of registration tax.
Road tax	Zero emission cars are exempt from paying road tax. Plug-in hybrid cars < 51 gr CO_2 / km pay half tariff (up to 2020). For conventional cars this tax is 400 to 1,200 EUR (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 4 or 22 % of the catalogue value on the taxable income. For zero emission cars this percentage is 4 %. For all other cars, including plug-in hybrid cars, it is 22 %.
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 < 31 gr CO_2 / km (no diesel engine) are on the list of deductible investments, as are the accompanying charging points.

32.1.3 Market Developments

At the end of 2018, more than 1,500 zero emission taxis drove in the Netherlands. Of these the vast majority (1,498) were battery electric vehicles and five were fuel cell electric vehicles. The most striking example are the over 300 electric taxis at Schiphol Airport (already since 2014) but electric taxis are nowadays employed in all Dutch provinces. The municipality of Amsterdam has a subsidy scheme for electric taxis and makes popular taxi stands only available for clean taxis – and starting in 2021 these can only be entered by zero emission taxis. In Rotterdam electric taxis (and small e-buses and e-trucks) have free access to a number of bus lanes. Other privileges in Rotterdam include expanded inner city accessibility slots for zero emission distribution vehicles.

Quite a number of provinces and municipalities have added electric buses to their public transport fleets in 2018. Europe's largest electric bus fleet drives at and around Schiphol Airport, where from 1 April 2018 100 electric articulated VDL Citea SLFA buses were put in service by Connexxion, Transport Region Amsterdam and Schiphol. The operational availability of the buses has been maximized through an optimized rapid charging concept, using 23 Heliox rapid chargers (450 kW) and 84 Heliox depot chargers (30 kW). The concession will expand to 258 zero emission buses in 2021.

Figure 2: VDL Citea SLFA electric bus at Schiphol airport (Source: VDL Bus & Coach bv)

Other Dutch cities/regions with electric buses include Alkmaar, Waterland, Haarlem, Amersfoort, Almere, Dordrecht, Gorinchem, The Hague, Maastricht, Venlo, Eindhoven, Den Bosch, Utrecht, Friesland, Groningen, and Drenthe. The transport authorities of Amsterdam and Rotterdam have ordered electric buses. In addition to some foreign bus brands and VDLs Citea buses, the Ebusco 2.1 electric bus also is deployed in Dutch public transport regions.

The provinces of Gelderland and Overijssel will install 4,500 new charging points in 43 municipalities – a quadruplication of the current number of charging points in these regions. The new charging points will be used for the largest practical test on smart charging ever, in cooperation with EV drivers.

The fast charging coverage of the Netherlands is continually being rolled out, more and more also at other locations than just along highways. Nuon will place fast chargers at all Dutch McDonalds branches with McDrive and started with installing the first 168 fast charging poles in 2018. Fastned has started a pilot with fast chargers at Albert Heijn XL supermarket locations.

The Ministry of Defense, on behalf of the central government, has concluded several contracts with car suppliers to deliver official cars. In 2020, 20 % of governmental official cars should be zero emission, and in 2030 100 %. Rijkswaterstaat, part of the Ministry of Infrastructure and Water Management and responsible for the design, construction, management and maintenance of the main infrastructure facilities in the Netherlands, is the first national governmental body in the Netherlands to deploy electric passenger cars at a large-scale. They have replaced 100 diesel cars by 100 electric cars.

Figure 3: Rijkswaterstaat electric car fleet (Source: Rijkswaterstaat)

32.1.4 Innovation and Research

The Innovation and Acceleration Programme Electric Mobility (IAP), an integral research- and innovation programme initiated by the Formula E-Team to strengthen the Dutch frontrunners position in electric driving, has officially started. Under it is a network of 200 associated companies, knowledge institutes and authorities. High on the initial agenda are these subjects: heavy duty commercial vehicles, light electric vehicles, charging infrastructure and energy market.

The Netherlands Knowledge Platform for Public Charging Infrastructure (NKL) has presented its annual benchmark of the costs associated with public charging. Use of public charging stations is rising steadily – 2018 saw a 15 % increase. While the average cost for a new charging station is still falling, market forecasts for 2025-2030 predict a more moderate drop. The priority now is to further develop and professionalize the market to ensure it can cope with the expected growth of electric transport. Currently, the research concludes, the primary focus should be a shift towards topics such as creating a standardized application procedure and ensuring the availability of sufficient technical personnel.

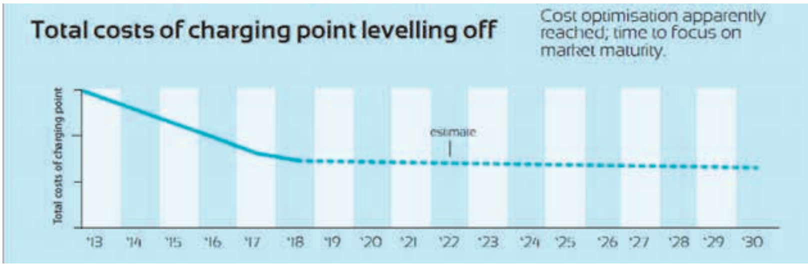

Figure 4: Cost development of public charging points (Source: www.nklnederland.com)

The Dutch Living Lab on Smart Charging organized a Smart Charging Challenge. In this Hackathon of 28 hours students and experts jointly considered several challenges in the field of smart charging. It led to four winning views on the integration of renewable energy and electric vehicles:

1) Synchronize daily planning and activities of employees with time-slots for smart charging their cars

2) Autonomous electric vehicles charged outside the city center and batteries used to balance the energy grid

3) Speech controlled charging making the car buying and selling energy on its own when it is needed and when it is profitable, and

4) Reservation of cheapest or most renewable energy-using charging locations.

The Dutch DSOs have agreed to continue their cooperation in e-mobility for five more years with Knowledge and Innovation Centre ElaadNL. Prime focal points will be smart charging, issues such as intelligent charging systems, rules and the combination with local renewables. In April 2018, ElaadNL opened a test lab in Arnhem. The testing location has all types of public charging poles that are used in the Netherlands, a fast charger, a stream of chargers, a neighborhood battery used for energy storage and two lamp posts with charging possibility. New electric cars can thus be tested on their interaction with Dutch charging options, related to smart charging, power quality and interoperability.

ElaadNL experts have researched the ISO 15118-standard for communication between electric car and charging pole. In the publication ‘Exploring the Public Key Infrastructure for ISO 15118 in the EV Charging Ecosystem” they explain the protocol and conclude that smart charging can be helped by the ISO standard, because it adds user information to the EV ecosystem. They argue for an open system.

Figure 5: Opening of ElaadNL test lab (Source: ElaadNL, photographer Kevin Hagens)

32.2 EVs, PHEVs and HEVs on the Road

The number of Battery Electric Vehicles (BEVs) in the Netherlands grew considerably in 2018, as is shown in Figure 6 and Table 2. Between December 2017 and December 2018, the number of full electric cars more than doubled. At the end of 2017, there were 21,115 BEV passenger cars and at the end of 2018, the number was 44,984 – an increase of 113 %.

The electric passenger car fleet is gradually becoming more full electric. BEVs made up 31.5% at the end of 2018, whereas at the end of 2017 only 17.6% of all electric passenger vehicles were BEVs.

At the end of 2018, there were 50 Fuel Cell Electric Vehicles (FCEVs), passenger cars, in the Netherlands, compared to 41 FCEVs at the end of 2017.

The total number of Plug-in Hybrid Electric Vehicles (PHEVs) in the Dutch fleet decreased a bit over the year, by 0.5 %, to 97,702 passenger cars at the end of 2018. New PHEVs were still registered, but some older ones were exported, thus resulting in a slightly negative fleet balance.

Over the year 2018, 6.5 % of total new passenger car registrations were electric. Of these, the majority was fully electric - 5.6 %; 0.9% of new registrations were PHEVs. In 2017, only 2.6 % of new registrations were electric vehicles.

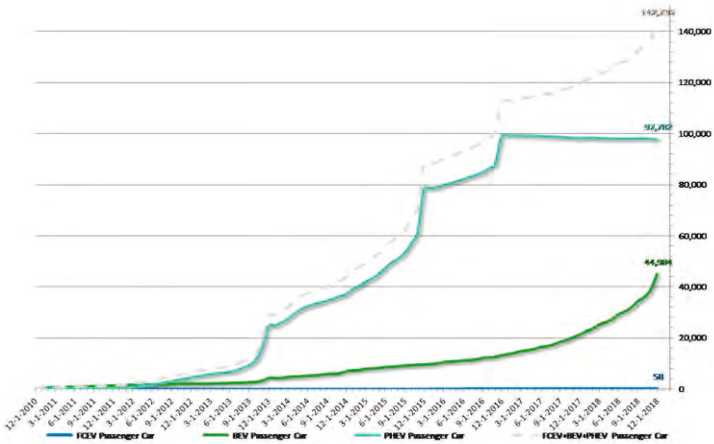

Figure 6: Development in the number of electric vehicles in the Netherlands 2010-2018 (fleet) (Source: Dutch Road Authority, edited by RVO.nl)

In the total Dutch fleet of passenger cars, electric vehicles (BEV, FCEV and PHEV) accounted for 1.6 % in December 2018. There were 180,562 HEVs on the road at the end of December 2018, an increase of 14 % compared to the end of December 2017.

Table 1: Distribution and sales of EVs, PHEVs and HEVs in 2018 (Data source: Dutch Road Authority, edited by RVO.nl; fleet totals: CBS except buses: CROW; 2018 new registration totals: BOVAG/RAI, Bicycles: GFK/BOVAG)

Fleet Totals on 31 December 2018					
Vehicle Type	**EVs**	**HEVs**	**PHEVs**	**FCVs**	**Total[h]**
Bicycles	n.a.	n.a.	n.a.	n.a.	~22,900,000
Mopeds[a]	32,647[(I)]	n.a.	n.a.	n.a.	1,211,522
Motorbikes[b]	608	n.a.	n.a.	n.a.	661,639
Quadricycles[c]	1,634	n.a.	n.a.	n.a.	n.a.
Passenger vehicles[d]	44,984	180,562	97,702	50	8,373,244
Commercial vehicles[f]	3,196	n.a.	n.a.	n.a.	883,350
Buses[e]	436[(II)]	n.a.	n.a.	7	5,147
Trucks[g]	92	n.a.	n.a.	2	139,656
Totals without bicycles	**83,597**	**180,562**	**97,702**	**59**	**11,274,558**

Total Sales / Registrations during 2018					
Vehicle Type	**EVs**	**HEVs**	**PHEVs**	**FCVs**	**Total[h]**
Bicycles	409,000	n.a.	n.a.	n.a.	1,011,000
Mopeds[a]	8,419[(III)]	n.a.	n.a.	n.a.	59,791
Motorbikes[b]	212	n.a.	n.a.	n.a.	13,104
Quadricycles[c]	222	n.a.	n.a.	n.a.	n.a.
Passenger vehicles[d]	25,065	28,109	4,094	14	447,367
Commercial vehicles[f]	1,012	n.a.	n.a.	n.a.	79,171
Buses[e]	108[(II)]	n.a.	n.a.	2	n.a.
Trucks[g]	16	n.a.	n.a.	n.a.	16,533
Totals without bicycles	**35,054**	**28,109**	**4,094**	**16**	**562,166**

n.a. = not available
[a] UNECE categories L1-L2
[b] UNECE categories L1-L5
[c] UNECE categories L6-L7
[d] UNECE categories M1
[e] UNECE categories M2-M3
[f] UNECE categories N1
[g] UNECE categories N2-N3
[h] Including both conventional and alternative technologies
[(I)] Including 377 L1 speed pedelecs
[(II)] Including trolley buses
[(III)] Including 1,523 L1 speed pedelecs

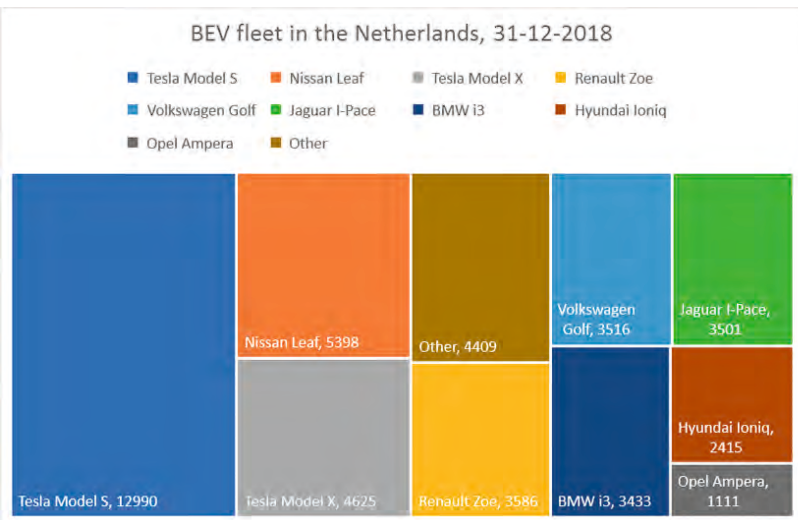

Figure 7: BEV fleet in the Netherlands, 31 December 2018 (Source: Dutch Road Authority, edited by RVO.nl)

In 2018, the top 3 of most popular new registered BEV passenger cars consisted of: Tesla Model S (4,962 cars), Jaguar I-Pace (3,501 cars) and Nissan Leaf (3,275 cars). Figure 7 illustrates the car models in the total BEV passenger car fleet in the Netherlands.

The top 3 of most popular registered new PHEVs were Audi A3 Sportback e-tron (222 cars), Volkswagen Passat (142 cars) and Volkswagen Golf (42 cars). Figure 8 shows the car models in the total Dutch PHEV passenger car fleet.

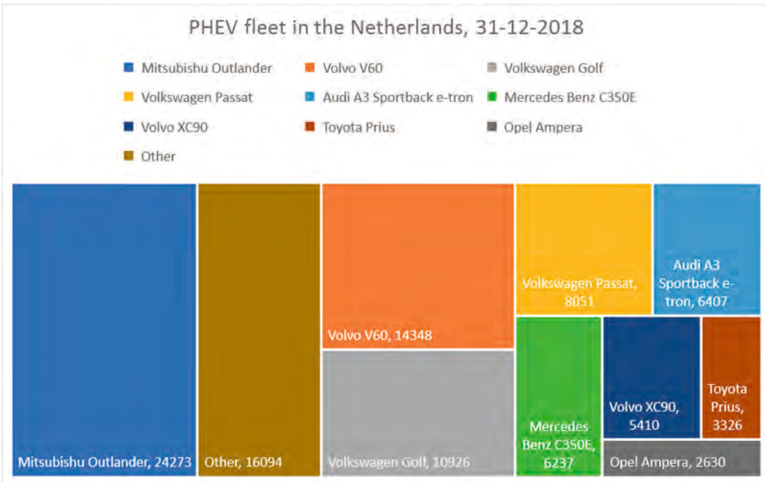

Figure 8: PHEV fleet in the Netherlands, 31 December 2018 (Source: Dutch Road Authority, edited by RVO.nl)

Table 3: Available vehicles and prices in the Netherlands (Data source: https://ev-database.nl, January 2019)

Market-Price Comparison of Selected BEVs and PHEVs in the Netherlands	
Available Passenger Vehicles	**Unsubsidized Sales Price (in EUR; prices include 21 % VAT)**
Audi A3 Sportpack e-tron	42,975
Audi e-tron	84,100
BMW i3	41,994
BMW i3s	45,693
BMW 225xe iPerformance	43,565
BMW 530e iPerformance	63,601
BMW 740e	100,848
BMW i3s Range Extender	49,120
BMW i3 Range Extender	45,433

Citroën E-Berlingo Multispace	31,670
Citroen C-Zero	22,360
Hyundai IONIQ Electric	33,995
Hyundai IONIQ Plug-in	29,995
Hyundai KONA Electric	39,195
Jaguar I-Pace	80,810
Kia e-Niro	42,510
Kia Niro PHEV	35,345
Kia Optima Plug-In Hybrid	41,475
KIA Soul EV	36,335
Land Rover Range Rover P400e PHEV	133,240
Land Rover Range Rover Sport P400e PHEV	101,150
Mercedes GLE 500e Plug-In	93,879
Mini Countryman Cooper SE ALL4	40,700
Mitsubishi I-MIEV	27,615
Mitsubishi Outlander PHEV	35,990
Nissan e-NV200 Evalia	41,990
Nissan Leaf	37,290
Opel Ampera-e	46,699
Peugeot iOn	22,360
Peugeot Partner Tepee Electric	30,470
Porsche Cayenne E-Hybrid	106,000
Porsche Panamera 4 E-Hybrid	117,600
Renault Kangoo Maxi ZE 33	37,806
Renault Zoe R110	35,090
Renault Zoe R90	32,890
Renault Zoe R90 Entry	30,390
Smart EQ forfour	24,050
Smart EQ fortwo cabrio	27,043
Smart EQ fortwo coupe	23,760
Tesla Model S 100D	113,320
Tesla Model S P100D	151,020
Tesla Model X 100D	117,820
Tesla Model X P100D	160,220
Toyota Prius Plug-in Hybrid	37,995
Volkswagen e-Golf	39,680

Volkswagen e-Up!	24,860
Volkswagen Golf GTE	41,050
Volkswagen Passat GTE	45,570
Volkswagen Passat GTE Variant	47,170
Volvo s90 T8 Twin-Engine	65,995
Volvo V60 T8 Twin Engine	58,995
Volvo V90 T8 Twin-Engine	68,995
Volvo XC-60 T8 Twin-Engine	68,995
Volvo XC-90 T8 Twin Engine	79,995

32.3 Charging Infrastructure or EVSE

The Netherlands has a well-developed charging network, as is illustrated in Figure 9, that shows the division of charging points over the provinces. The provinces of South-Holland, North-Holland, Brabant, and Utrecht (also the most populated parts of the Netherlands) have the highest charging infrastructure density.

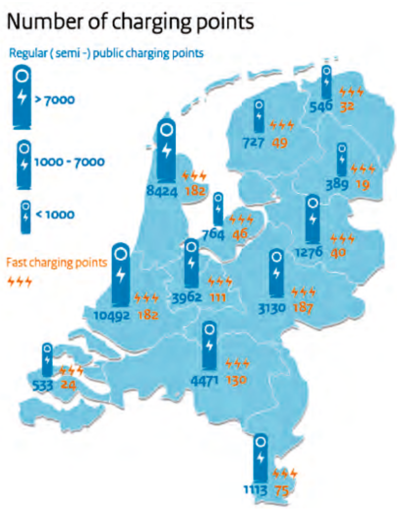

Figure 9: Division of (semi) public regular and fast charging points in the Netherlands (Source: oplaadpalen.nl, edited by RVO.nl)

Table 4 gives the number of charging points at the end of December 2018. Fast charging can be done at 186 locations, mostly along highways, but also some in cities. At the end of 2018, there were an estimated 100,000 private charging points in the Netherlands.

Table 4: Information on charging infrastructure in the Netherlands in 2018 (Source: oplaadpalen.nl, edited by RVO.nl)

Charging Infrastructure on 31 December 2018	
Chargers	**Quantity**
AC Level 1 Charging points (> 3.7 kW)	2,928
AC Level 2 Charging points (3.7 kW – 22 kW)	32,924
Fast charging points (22 kW – 120 kW)	818
Super charging points (> 120 kW)	265
Inductive Charging	1 bus line (Utrecht)
Totals	**36,936**

All charging is interoperable in the Netherlands, as has been the case since 2011. The Open Charge Point Interface (OCPI) protocol, an independent roaming protocol for providers of charging infrastructure and services, was designed in the Netherlands for this purpose. It provides information about location, real-time availability, prices, and real-time billing, as well as mobile access of chargers.

The Dutch government, knowledge institutes and companies together call for the use of open standards and protocols in charging infrastructure, so as to stimulate innovation and global access – thus stimulating EV uptake.

32.4 EV Demonstration Projects

There is a great number of projects going on. This is only a small selection.

The Dutch TSO TenneT, responsible for maintaining grid balance, and energy aggregator Vandebron are involved in a flexibility pilot that uses blockchain technology for smart charging. Vandebron supplies electricity to TenneT that comes from the charging sessions of clients driving Teslas. Depending on the grid balancing situation, TenneT can request to start or stop the charging process, considering the wishes of the drivers, who get financially compensated. Vandebron developed an algorithm to manage the charging.

The Smart Solar Charging project demonstrated an important first at Utrecht. 20 electric cars were jointly charged by solar power after dark. With this demonstration, 20 charging points, 200 solar panels and a large storage battery were officially taken into operation. The 400 kW and 800 kWh batteries have enough capacity to fully charge, 20 electric vehicles simultaneously. Even if the sun does not shine.

Through the demonstration programme for climate related innovations in transport (DKTI-Transport, running 2017-2021), a subsidy scheme aimed at transport solutions with low or zero CO_2 emissions, several projects on electric driving were supported. These reached from large scale demonstration projects targeting freight transport using electric trucks and delivery vans to interesting niche projects in areas such as development and demonstration of electric vehicles for waste collection and concrete mixing. Two examples of projects:

- Online retailer Picnic is to set up large scale retail operations with electric N1 vehicles, implementing a smart grid and charging infrastructure to maximize the cost efficient and sustainable use of electricity.
- DAF Trucks and VDL have jointly developed the CF Electric truck, that will be used by the supermarket chain Jumbo to supply its supermarkets in the south of the Netherlands. The vehicle is based on the DAF CF and is electrically operated using VDL's E-Power Technology. The truck is developed for road haulage up to 37 tonnes in urban areas.

Figure 10: DAF CF Electric truck for Jumbo supermarkets (Source: DAF Trucks N.V. Eindhoven)

Together with German and Dutch partners, the province of Groningen started the innovation project "Kontactlo(o)s Laden". The aim is to realize innovative and sustainable solutions to wirelessly charge e-bikes, e-scooters and self-driving vehicles. 13 participants develop and test innovative charging systems. One of the plans is to build a wireless charging system into a bicycle garage.

32.5 Outlook

By summer 2019, the National Climate Agreement will be ready, and it will be clear what extra measures will be taken until 2025 to stimulate the uptake of electric driving.

The market is anxiously looking forward to more affordable electric cars and electric car models with larger battery capacities. But already now long waiting lists exist in the Netherlands and other countries for customers ordering electric cars. To accommodate the expected growth in electric driving, a speed up of car manufacturers' production processes is needed.

In 2019, the EU-Programme Support Action (PSA) on ID-issuing will start. The PSA aims at the collection of data on location/availability of alternative fuels infrastructure and ensuring a process to set-up an effective, EU-wide coordination mechanism to assign unique identification codes to charge point operators and e-mobility service providers. It focuses on unlocking and making data available on a European level. 15 countries are participating in this PSA: NL (coordinator), BE, LU, ES, FR, AT, DE, PL, LT, HU, EL, CZ, SI, PT, HR.

In May 2019, the EVS32 will take place in Lyon in France. The Netherlands will be present with a large Dutch pavilion where Dutch experiences and solutions in zero emission mobility can be found.

33 Republic of Korea

33.1 Major Developments in 2018

33.1.1 Comparison of Driving Performance of Hyundai-Kona EV and Kia-Niro EV

The comparison between the performance of Kona EV and Niro EV, which has the best single-charge driving distance among the electric vehicles produced and sold in Korea, shows that both cars have the same battery capacity (64 kWh) and motor output (150.0 kW). However, the Kona EV has an empty vehicle weight of 1,685 kg, which is lighter than the empty vehicle weight of the NiroEV (1,755 kg), so it is slightly different from the single-charge driving distance amongst the cars. It has a driving distance of 406 km for a Kona EV and 385 km for a Niro EV. However, the government-certified electricity consumption efficiency is 5.8 km / kWh for the Niro EV, which is 0.2 kWh higher than the Kona EV. Both vehicles are expected to show higher consumption efficiency in cruising.

The driving distance at low temperatures was 310.2 km for the Kona EV. In the case of NiroEV it was 349 km for the models with the heat pump and 303.8 km for the models with the exception of the heat pump.

Figure 1: Kona EV and KIA Niro EV (Source: Hyundai)

33.1.2 Hyundai Motor Company's Hydrogen Electric Trucks: Export Issues to Europe

Hyundai Motor Co. and a Swiss hydrogen energy company, H2Energy signed a memorandum of understanding (MOU) at the “Internationale Automobile Ausstellung” (IAA Commercial Vehicles 2018) in Hannover, Germany to deliver 1,000 hydrogen electric large refrigerated and regular van trucks from 2019 to 2023. H2Energy is a Swiss company that produces and supplies hydrogen and will provide hydrogen powered trucks supplied by Hyundai Motor through lease to seven members of H2Energy (four oil refineries and three food chains).

Figure 2: Hyundai Motor Company's hydrogen electric truck (Source: Hyundai)

Based on the XCIENT(Commercial Truck), Hyundai Motor is developing a large-sized hydrogen-electric truck with 9,745 mm the whole length, 2,550 mm overall width and 3,730 mm overall height depending on European local regulations. The main dimension of the hydrogen-electric trucks under development is the single-charge driving distance 400 km range, the charging time is seven minutes, and eight tanks (350 bar) will be equipped. Also, the fuel cell is a new fuel cell system used in Nexo, two parallel connections are equipped with a 190 kW class system. It is equipped with a motor that produces 350 kW power. In addition to its performance, safety devices such as Front Collision Prevention Assistance(FCA) and Lane Departure Warning (LDW) are also equipped for safety.

33.1.3 Securing the Next-Generation Technology of LG Chem

LG Chem invested in Enervate, US start-up, to secure next-generation battery technology to improve the running distance and the rapid charge rate of electric vehicles.

Currently, the battery industry is developing silicon anode materials as a next-generation technology for increasing battery energy density. Silicon has about a four times larger capacity than graphite, which is a conventional anode material, so it can increase the battery energy density and improve the running distance of an electric car. It also helps to improve the charging speed and the low-temperature charging performance. However, due to the technological limitation, which is the silicon contents serious disadvantage that expanding the volume during charging and discharging performance, the silicon content in the anode material remains within 5 %.

Figure 3: Enervate's battery with named "HD ENERGY" (Source: Enevate)

Enervate is a company that develops lithium-ion battery technology based on silicon anode materials. Enervate is developing anode materials with more than 70 % of silicon as the main component now. Lithium-ion batteries with this technology can be charged up to 75 % in 5 minutes, increase the energy density compared to existing electric car batteries, and can be safely charged at minus 40°C because it is not casted out lithium metal even at low-temperature high-speed charging. This technology can shorten the charge time of the electric car to a level of a conventional internal combustion engine cars, and solve the inconvenience of electric vehicles such as running distance, cost, and safety.

33.1.4 New policies, legislation, incentives, funding, research, taxation, etc.

Subsidy Policies Changes in 2019

According to the Ministry of Environment, instead of lowering EV subsidies per vehicle so that many people can receive subsidies for electric vehicles, the number of supplying vehicles will increase in 2019.

The Ministry of Environment adjusted the EV subsidy up to 9 million won in 2019, while the number of subscriptions increased to 42,000. Comparing with subsidy policies of 2018, the subsidy increased to 58.3 % and supply target increased to 50 %. This means that the government decided lowering EV subsidies per vehicle so that many people can receive subsidies for electric vehicles, but the number of supplying vehicles will increase.

Table 1: Subsidy for cars and small EV (1,272 KRW = 1 EUR)

Type	Manufacturer	Vehicle type	Government subsidy support amount (10k KRW)
Passenger car	Hyundai	Kona (basic)	900 (7,070 EUR)
		Kona (Economic)	900 (7,070 EUR)
		IONIQ (18, HP)	847 (6,650 EUR)
		IONIQ (18, PTC)	841 (6,610 EUR)
	Kia	Niro EV (HP)	900 (7,070 EUR)
		Niro EV (PTC)	900 (7,070 EUR)
		SOUL EV (18, HP)	778 (6,110 EUR)
	Renault Samsung	SM3 Z.E (`18)	756 (5,940 EUR)
	BMW	I3 94ah(`18)	818 (6,430 EUR)
	GM	Volt EV	900 (7,070 EUR)
	Tesla	Model S 75D	900 (7,070 EUR)
		Model S 90D	900 (7,070 EUR)
		Model S 100D	900 (7,070 EUR)
		Model S P100D	900 (7,070 EUR)
Small EV	Renault Samsung	TWIZY	420 (3,300 EUR)
	Dae-Chang motors	DANIGO	420 (3,300 EUR)
	Ssemisisco	D2	420 (3,300 EUR)

The government has provided many benefits for EV owners to improve the supply rate of electric vehicles. And, in fact, benefits are contributing to the improvement of the electric vehicle supply rate. For electric vehicles, the government offers the following benefits:

- Reduction of highway toll by 50 %
- Public parking 50 % discount
- Exemption from electricity base fee
- Discounted rapid charge rate of 173.8 won (44 % reduction)

In addition, the government plans to maintain subsidies for hydrogen and electric vehicles by 2022 but will adjust subsidy prices as follows:

- Difference in price between internal combustion engine
- Core component development
- Supply condition etc.

Table 2: Diffusion goals and support benefits

EV	2018	2019	Remarks
Supply target	20,000 unit	42,000	50 % Increase
Government subsidy budget	240 billion unit	380 billion unit	58.3 % Increase
• Subsidies by car type declined as subsidy support changed • Adjusted up to 9 million won depending on battery capacity and mileage (fuel economy)			

Table 3: 2019 Electric vehicle subsidies by local government

City	Support Unit Price in 2018 (10k KRW)	Support Unit Price in 2019 (10k KRW)
Seoul	500 (3,920 EUR)	450 (3,531 EUR)
Busan	500 (3,920 EUR)	500 (3,920 EUR)
Daegu	600 (4,710 EUR)	600 (4,710 UR)
Incheon	600 (4,710 EUR)	500 (3,920 EUR)
Gwangju	700 (5,490 EUR)	600 (4,710 EUR)
Daejeon	700 (5,490 EUR)	700 (5,490 EUR)
Ulsan	500 (3,920 EUR)	600 (4,710 EUR)
Sejong	700 (5,490 EUR)	600 (4,710 EUR)
Gyeonggi-do	500 (3,920 EUR)	500~700 (3,920~5,490 EUR)
Gangwon-do	640 (5,020 EUR)	640~940 (5,028~7,385 EUR)
Chungcheongbuk-do	800~1000 (6,280~7,850 EUR)	800 (6,280 EUR)
Chungcheongnam-do	800~1000 (6,280~7,850 EUR)	800~1000 (6,280~7,850 EUR)
Jeollabuk-do	600 (4,710 EUR)	600 (4,710 EUR)
Jeollanam-do	440~1100 (3,450~8,640 EUR)	600~800 (4,710~6,280 EUR)
Gyeongsangbuk-do	600~1000 (4,710~7,850 EUR)	600~1000 (4,710~7,850 EUR)
Gyeongsangnam-do	600~900 (4,710~7,070 EUR)	600~800 (4,710~6,280 EUR)
Jeju	600 (4,710 EUR)	500 (3,920 EUR)

33.2 Charging Infrastructure or EVSE

In Republic of Korea, electric vehicles are being actively promoted. With the spread of electric cars, charging stations are also increasing. But the perception of electric cars is not good. As reasons for that, the shortage of chargers, the inconvenience of using chargers, and the long charging time were ranked high. To solve these inconveniences and expand the charging infrastructure, the government announced that it would install 100 kW chargers in post offices, public libraries and police stations.

To solve the inconvenience of using these chargers with high failure rates and high inconvenience, we decided to replace the old chargers in 2018, with 1,070 high-speed 100 kW chargers, .

In 2018, the Ministry of Environment and eight private operators cooperated to make all chargers available with a single membership card for the convenience of customers. In addition, the navigation and map of major websites showed the real-time operating status of the chargers. In 2018, AC Level 2 Charge increased by 607 and Fast Charger increased by 1,715 compared to 2017.

Table 4: Information on charging infrastructure in 2018 (Data source: The Ministry of Environment)

Charging Infrastructure on 31 December 2018	
Chargers	**Quantity**
AC Level 2 Chargers	5,432
Fast Chargers	3,858
Totals	**9,290**

33.3 HEVs, PHEVs and EVs on the Road

Electric Vehicle Distribution Status in 2018

By 2018, a total of 23 million vehicles have been registered in the Republic of Korea. Among these registered vehicles, 461,733 vehicles were electric or PHEV, HEV vehicles. Passenger vehicles increased by 114,696 compared to the previous year. Buses and medium and heavy weigh trucks were increased by 186.

Table 4: Distribution and sales of EVs, PHEVs and HEVs in 2018 (Data source: Ministry of Land, Infrastructure and transport in January 2018)

Fleet Totals on 31 December 2018				
Vehicle Type	**EVs**	**HEVs**	**PHEVs**	**FCVs**
Passenger vehicles[a]	55,417	404,759	n.a.	893
Buses[b]	279	325	n.a.	0
Trucks[c]	60	n/a	n.a.	0
Totals without bicycles	**55,756**	**405,084**	**n.a.**	**893**

n.a. = not available
[a] UNECE categories M1
[b] UNECE categories M2-M3
[c] UNECE categories N2-N3

Table 5: Available vehicles and prices in Republic of Korea

Market-Price Comparison of Selected BEVs and PHEVs in Korea	
Available Passenger Vehicles	**Unsubsidized Sales Price (in KRW and EUR, in brackets)**
Hyundai Kona Electric	47~49 million (max. 38,500)
Hyundai Ionic Electric	39~42 million (max. 33,000)
KIA Niro EV	48~50 million (max. 39,250)

KIA Soul EV	43 million (33,750)
Renault Samsung Motors SM3 Z.E.	39~41 million (max. 32,180)
Renault Samsung Motors Twizy	15~15.5 million (12,170)
GM Chevrolet BOLT EV	46~49 million (max. 38,500)
BMW i3 94ah	59~65 million (max. 51,000)
Tesla Model S 90D	116 million (91,000)

34 Spain

34.1 Major Developments in 2018

34.1.1 VEA Strategy 2014-2020

On 26 June 2015, the Spanish National Government approved an Agreement of knowledge about a new National Strategy to promote Energy Alternative Vehicles in Spain for the period 2014-2020 (VEA Strategy).

Three main guidelines are considered in VEA Strategy: to promote R&D and industrialization measures regarding vehicles, components and infrastructure, to promote the demand of alternative energy vehicles and communication campaigns and to promote recharging and refueling networks for alternative energy vehicles.

VEA Strategy is congruent with the objectives of the Directive 2014/94/EU of 22 October 2014, relative to promotion of infrastructure of alternative fuels and technologies. This strategy stablishes 30 key actions to place Spain as a reference country for the alternative energies applied to transport sector: Electric, Liquid Petroleum Gas (LPG), Natural Gas, Biofuels and Hydrogen vehicles, focusing on industrial development, in order to meet energy and environmental challenges.

34.1.2 Spanish National Policy Framework (MAN)

Directive 2014/94/EU of 22 October 2014 establishes that each Member State shall adopt a national policy framework for the development of the market as regards as alternative fuels in the transport sector and the deployment of the relevant infrastructure and notify them to the European Commission before the 18 November 2016.

Directive 2014/94/EU was transposed into Spanish normative through Royal Decree 639/2016 of 9 December, and the Spanish National policy framework (Marco de Acción Nacional-MAN), consistent with the VEA Strategy 2014-2020 and establishing an objective of 150,000 electric vehicles by 2020, was notified on time to the EC.

34.1.3 VEA Website

In the frame of the VEA Strategy, the VEA website was created, a Government official site for sharing relevant information of the different alternative fuels and technologies in the transport sector. On this website, a database of alternative vehicles is also available where users can search the different models of vehicles available in the Spanish market and technical information of them.

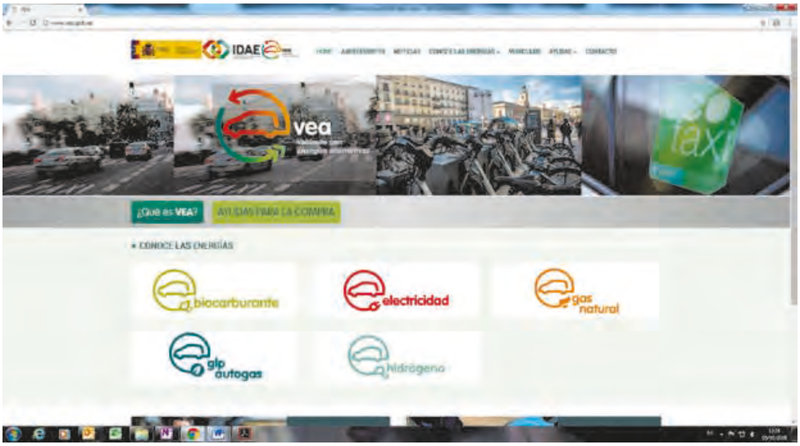

Figure 1: Website of VEA (Source: http://www.vea.gob.es)

MOVALT Plans: National Incentives Plans for the Acquisition of Alternative Vehicles and to Promote EV Charging Infrastructure

"Plan MOVALT Vehicles", an incentives program for alternative vehicles acquisition at National scale, was funded with an allocated budget of 20 million EUR and it was running effectively from 13 December 2017 to 30 June 2018.

Plan MOVALT Vehicles finally supported the acquisition of 2,977 alternative energy vehicles, powered by Electricity, NG and LPG energies, from which a number of 1,583 were electric vehicles (1,286 BEVs; and 297 EREVs/PHEVs), with a final budget amount of 6,921,500 EUR applied to them.

"Plan MOVALT Infrastructure": an incentives program for alternative vehicles acquisition at National scale, was funded with an allocated budget of 20 million EUR and it was running effectively from 23 January 2018 to 31 December 2018. The evaluation of the applications will end by the 30

June 2019. At the end of 2018 and in the frame of Plan MOVALT Infrastructure, there were presented a number of 588 applications for incentives.

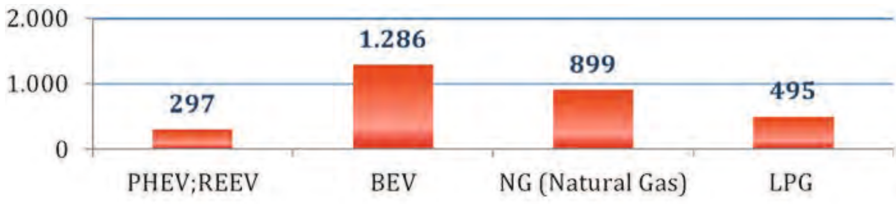

Figure 2: MOVALT Vehicles: vehicles acquired per alternative energies

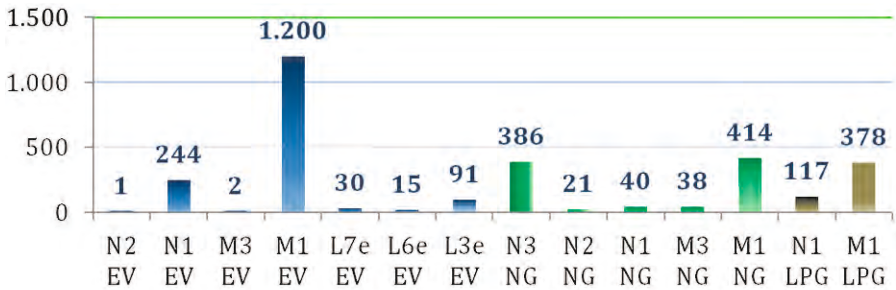

Figure 3: MOVALT Vehicles: vehicles acquired by alternative energies and categories

National Framework to 2030

The Spanish Government is currently working in the National Integrated Plan for Energy and Climate and a National Climate Change Law to set the energy and climate strategic goals up to 2030. In this context, the electrification of the transport sector is one of the main issues with ambitious and challenging targets.

Table 1: MOVALT Infrastructure: charging points related type of use (provisional data at 31 December 2018)

Type of use of the charging points (public vs private access)						
Access	**Applications**	**%**	**Charging points**	**%**	**Budget (EUR)**	**%**
Public	392	66.7	976	63.3	18,026,577	90.3
Private	196	33.3	566	36.7	1,940,285	9.7
Total	**588**	**100**	**1,542**	**100**	**19,966,862**	**100**

Table 2: MOVALT Infrastructure: charging points related charging power (provisional data at 31 December 2018)

Charging type of the charging points (power)				
Charging type (power)	**Applications**	**%**	**Reserved budget (EUR)**	**%**
Normal (7-15 kW)	197	33.5	1,133,790	5.7
Semi-quick (15-40 kW)	201	34.2	3,659,317	18.3
Fast (40-100 kW)	189	32.1	14,834,289	74.3
Ultra-fast (> 100 kW)-buses	1	0.2	339,466	1.7
Total	**588**	**100**	**19,966,863**	**100**

34.2 HEVs, PHEVs and EVs on the Road

In the year 2018, there were registered a number of 22,586 electric vehicles in Spain, considering BEVs, PHEVs and REEVs, which doubles 2017's figures, with a number of 11,160 EVs registrations. This increase was supported by National incentives programs for EVs acquisition (Plan MOVALT Vehicles) and also by other incentive programs at regional and local scales.

In the specific case of electric passenger cars (BEVs, PHEV/EREVs), this category had a market penetration of 0.9 % during 2018. Considering both, electric and hybrid electric vehicles (HEVs), resulted in a market penetration of 6.2 %.

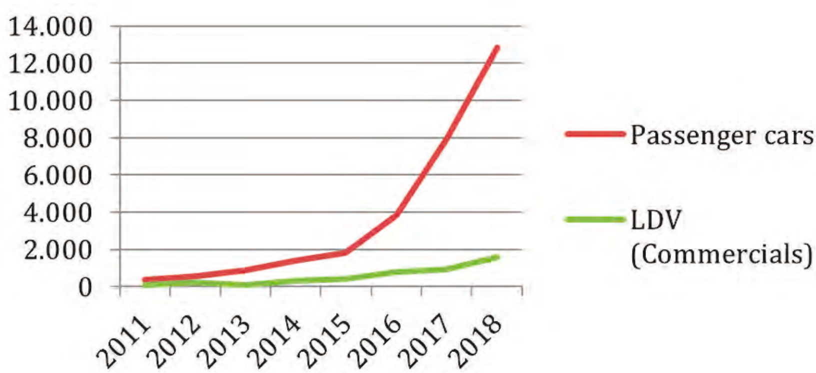

Figure 4: EVs market evolution (annual sales of cars –M1- and vans –N1-) in Spain

Focusing on *conventional hybrid vehicles*, the huge increase of the hybrid passenger car registrations along the recent years 2016 to 2018 is remarkable, with a total number of 76,009 registrations during the year of 2018, coming from a total of 7,759 registrations during the year of 2015 (almost ten times the figures of 2015). It is remarkable that, at a National scale, there have not any incentives programs running for the acquisition of these vehicles over the last years, but this is more than compensated by the impact of the new Environmental car labelling and the measures implemented for clean air in regions and cities.

Electric Vehicles (BEVs, PHEVS and REEVs) fleet in Spain at the end of 2018, resulted in a total number of 56,540, which more than doubles the figures of 2017, accounting a number of 24,817 EVs.

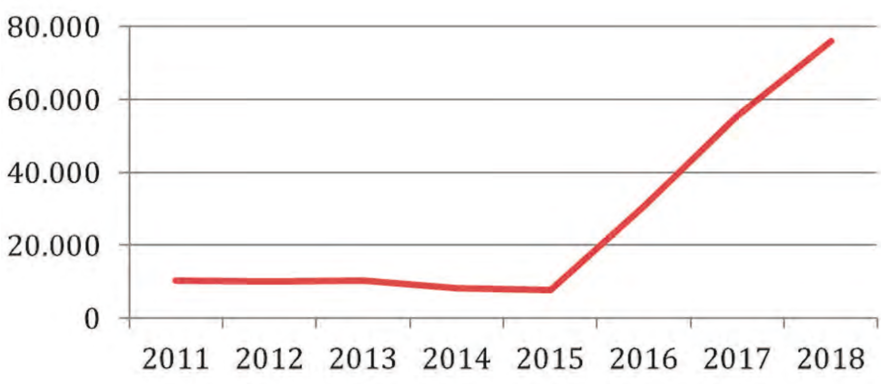

Figure 5: HEVs market evolution (annual sales of passenger cars –M1-) in Spain

Table 1: Distribution and sales of EVs, PHEVs and HEVs in 2018 in Spain (Data source: IDAE, based on registrations of Spanish Traffic Authorities, DGT)

Fleet Totals on 31 December 2018					
Vehicle Type	**EVs**	**HEVs**	**PHEVs**	**FCVs**	**Total[h]**
Bicycles	300,000	0	0	0	~30,000,000[i]
Mopeds[a]	8,878	0	0	0	1,881,797
Motorbikes[b]	10,499	36	0	0	3,427,155
Quadricycles[c]	3,286	0	0	0	117,184
Passenger vehicles[d]	16,113	238,257	12,692	1	24,138,555
Commercial vehicles[f]	4,826	37	8	0	4,083,876
Buses[e]	99	537	58	0	65,364
Trucks[g]	68	167	13	0	917,261
Totals without bicycles	**43,769**	**239,034**	**12,771**	**1**	**34,631,192**

Total Sales during 2018					
Vehicle Type	EVs	HEVs	PHEVs	FCVs	Total[h]
Bicycles	100,000	0	0	0	1,140,000[i]
Mopeds[a]	4,336	0	0	0	17,416
Motorbikes[b]	3,516	0	0	0	164,313
Quadricycles[c]	221	0	0	0	2,928
Passenger vehicles[d]	6,602	76,099	6,257	1	1,424,738
Commercial vehicles[f]	1,575	2	4	0	171,387
Buses[e]	53	182	8	0	3,848
Trucks[g]	12	90	2	0	40,036
Totals without bicycles	**16,315**	**76,373**	**6,271**	**1**	**1,824,666**

n.a. = not available
[a] UNECE categories L1-L2
[b] UNECE categories L1-L5
[c] UNECE categories L6-L7
[d] UNECE categories M1
[e] UNECE categories M2-M3
[f] UNECE categories N1
[g] UNECE categories N2-N3
[h] Including both conventional and alternative technologies
[i] Estimated data at the end of 2018 (Source AMBE -Spanish Association of Bicycles and Brands)

34.3 Charging Infrastructure or EVSE

Package of Urgent Measures for Energy Transition and Consumer Protection: Liberalization of the Public Recharging Activity (National Level)

In the year 2011, a national normative (Royal Decree 647/2011) was approved which establishes that public infrastructure service for charging electric vehicles should be operated by authorized “Charging operators”, which had to deal with special requirements. In this way and at the end of 2017, there were officially registered a number of 58 charging operators, which deployed a total of 278 public charging stations for EVs in different cities all over the national territory.

On 5 October 2018, the Council of Ministers approved a Royal Decree-Law 15/2018 on urgent measures for energy transition and consumer protection. The Plenary of the Congress of the Deputies of 18 October 2018, validated the RD-law by an absolute majority, also approving its processing as a draft law by way of urgency. Among other urgent measures, the “Charging operator” role was removed, as it turned out, in its practical application, to be excessive rigid and discouraging for the public recharging activity.

This new normative has opened the activity to any consumer and must be registered by regional administrations in an official register for the appropriate control and follow up of their activity and also, communicated to the Ministry for Ecological Transition. The regulation for this registration should be prepared in the next six months. This normative represents a measure oriented to reach the objectives of the VEA Strategy, focused on the deployment of alternative energy vehicles.

At the end of 2018, an estimated amount of more than 5,000 charging points exist in Spain, which means an approximated ratio of 11 electric vehicles registered in Spain per charging point.

Barcelona City Council (Local Level)

The Barcelona City Council has deployed an electric recharging network of nearly 1,200 points, being the operator and owner of the infrastructure within its ”Strategy for the promotion of electric mobility in the city of Barcelona”[89], that defines lines of action for the period of 2018-2024.

Madrid City Council (Local Level)

In November 2018, the City of Madrid made a call for tenders to transfer charging points to holders entities with free access locations, thus avoiding to devote public land to charging infrastructure.

34.4 EV Demonstration Projects

Aigües de Barcelona

Aigües de Barcelona is the Company which manages the services related water distribution in the city of Barcelona and also other 36 cities all over its metropolitan area.

Since 2011, Aigües de Barcelona is progressive electrifying its vehicle fleet, counting actually with a number of 132 electric vehicles (from its total number of 240 fleet vehicles).

[89] https://bcnroc.ajuntament.barcelona.cat/jspui/bitstream/11703/109244/1/180309_MG%20Estrat%C3%A8gia%20VE_CEUM.PDF

Aigües de Barcelona is also currently developing with “CitySensia”, an interactive Platform for citizen’s information on air quality, with information in real time about air quality parameters through receptors installed in the electric vehicles of the fleet, which allows knowing which city zones are more sensible to pollutants and their evolution figures.

EMT Madrid

Since January 2018, it is working in Madrid a bus line (line 76) fully operated be electric buses that are charged by inductive recharging systems. This initiative was launched by Madrid City Council in the framework of its “Plan A” for Air Quality.

To achieve that, 5 Hybrid buses (CGN Tempus Castrosúa) were transformed, by ETRA Technology Group, into pure electric buses and prepared for inductive recharging. This system combines partial recharging with connectors with inductive recharging through a subsoil inductor component. Inductive recharging systems are placed at the beginning of the line, where in less than 8 minutes batteries are fully recharged.

Similar initiatives were placed in other European cities, like Manheim, Braunschweig and Berlin (Germany), and Bruges (Belgium).

Electric buses acquisition plan: Apart from this initiative, Madrid Bus Transport Company (EMT) acquired 15 electric buses and 18 mini buses during 2018 and plans to incorporate other 40 electric buses between 2019 and 2020, with the objective of a total of 78 electric buses at the end of 2020.

Other interesting initiative promoted by EMT is “Electro-EMT” project, which consist in the deployment of fast charging systems placed in different parking lots all over the city of Madrid, as a new mobility service. These recharging systems can be reserved and used through its correspondent smartphone application. Currently prices for recharging vehicles are around 0,40 EUR/kWh.

35 Sweden

35.1 Major Developments in 2018

Sweden has the largest market share of plug-in electric vehicles (PEVs) in the EU (EAFO, 2018)[90] and is third globally (IEA, 2018)[91]. In January 2018, the world's most ambitious climate law entered into force in Sweden. The overreaching target is for Sweden to reach net zero greenhouse gas emissions by 2045. The law requires all policy areas, not only environment, climate, transport and energy, to contribute to achieve the targets. The transport sector has an intermediate target to reduce its GHG emissions by 70 % compared to 2010by 2030. Electrification, biofuels and a more transport-efficient society has been pointed out as key enablers to reach these goals[92].

In July 2018, a bonus- malus scheme replaced the PEV rebate programme, which was introduced in 2012. The bonus-malus scheme enhanced the PEV sales the second half of 2018 and sales were over 10 % each month. On the total, the share of PEVs in new-sales over 8 % in 2018 and the number of PEVs were almost 70,000 vehicles[93].

In addition to the investment scheme Klimatklivet – the Climate Leap, which was introduced in 2015, a private home-charger support scheme was introduced in 2018. Private households are the main target group but one charging point could also be granted to a cooperative. For many PEV owners in multi-family dwellings, it was difficult to reach the consensus need to apply through Klimatklivet.

The public charging infrastructure in Sweden has developed significantly during 2018, from approximately 4.600 charging points to almost 7.000. Many of these have been granted support through the investment scheme Klimatklivet, the Climate leap, which by the end of 2018 in total had granted investment support to

90 European Alternative Fuel Observatory, 2018

91 IEA, Nordic EV Outlook, 2018

92 http://www.energimyndigheten.se/nyhetsarkiv/2017/strategisk-plan-for-hur-transportsektorn-ska-bli-fossilfri/

93 Power cicle – Plug-in electric vehicles in Sweden, 2019

over 30,000 charging points. 22,000 of these are non-public charging points and 8,000 are public[94].

Since 2016, regional public transport authorities have been granted purchase subsidies for electric buses but in 2018 this scheme also entitled private transport companies the purchase rebate.

There are no local or regional policies to promote PEVs in Sweden but in 2018, the government decided to assign the municipalities the governance regarding environmental zones. As of 1 January 2020, current regulations on environmental zones are complemented by two new types of stricter environmental zones and then municipalities may decide whether to introduce environmental zones[95].

35.1.1 Demand Side Policies

There have been different demand-side policies for more environmentally friendly-vehicles since 2006. Between 2006-2009, Sweden had a general green car purchase subsidy and in 2012, the first PEV specific purchase subsidy was introduced. Between 2012 and June 2018, a super green rebate was granted to newly registered plug-in passenger vehicles. In July 2018, the PEV purchase rebate scheme was replaced by a bonus-malus scheme.

Bonus-Malus Scheme

In July 2018, the first bonus-malus scheme for light duty vehicles in Sweden was introduced. Battery electric vehicles (BEVs) and fuel cell vehicles (FCV) are eligible the maximum bonus, which is 6,000 EUR. For plug-in electric vehicles (PHEVs), the bonus decreases linearly until 60 grams of carbon dioxide (CO_2) and 1,000 EUR. Vehicles with emission levels over 95 grams of CO_2 are penalised with a malus in relation to the emission level up to 140 grams of CO_2. Unlike the PEV rebate scheme, bonus-malus also include light duty vans, which is an important improvement for many fleet vehicles.

Vehicle Tax

In parallel to the introduction of the Bonus-malus scheme, the vehicle tax system was revised. Previously, PEVs was tax exempted for the first 5 years but since July 2018 the tax exemption lasts for only 3 years.

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[94] Naturvårdsverket – The Swedish Environmental protection agency. 2019 https://www.naturvardsverket.se/Stod-i-miljoarbetet/Bidrag/Klimatklivet/Resultat-for-Klimatklivet/

[95] Swedish Government, 2018 https://www.regeringen.se/pressmeddelanden/2018/08/forordningsandringar-om-miljozoner/

Reduced Value of Fringe Benefits

Company cars can reduce the value of fringe benefits for PEVs compared to the equivalent, conventional fossil-fuelled car. After adjustment, the value of fringe benefits is reduced by 40 %, to a maximum of 1,000 EUR.

Given the PEV deployment among company cars, it constitutes for 75 % of the PEV ownerships, this has probably been the most important incentive to promote the use of PEVs in Sweden.

Support to E-Bikes, LEVs and E-Boats

In January 2018, the Swedish government introduced a purchase rebate to e-bikes and light electric vehicles (LEVs). In June 2018, the support scheme also came to include electric outboard motors for boats. The budget for 2018 was 35 million EUR and each rebate comprised 25 % of the cost up to 1,000 EUR. Most of the budget in 2018, almost 30 million EUR, were granted for the purchase of e-bikes.

35.1.2 Charging Infrastructure Policies

Klimatklivet – The Climate Leap

In September 2015, the Swedish government launched the investment support scheme Klimatklivet, the *Climate Leap*[96]. Klimatklivet is a general investment support scheme, not specifically aiming for charging infrastructure deployment, granting up to 50 % of the investment cost. Between 2015 and 2018, about two-thirds of the applications granted investments support were to deploy charging infrastructure. Approximately 30.000 charging points had been granted support. The majority, 22.000 charging points, are non-public installations for company fleet vehicles or for residents in multi-family dwellings. Other measures that have been granted investment support through Klimatklivet were for example bike garages, biogas production plants, LBG refuelling stations.

Home-Charging Support Scheme

In 2017, the Swedish government decided on a home-charging support scheme. From 1 February 2018, private households are subsidized up to 1,000 EUR or by 50 %, when installing an EVSE at their home[97]. By the end of 2018, 3,060 home-

[96] https://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/forordning-2015517-om-stod-till-lokala_sfs-2015-517

[97] https://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/forordning-20171318-om-bidrag-till_sfs-2017-1318

chargers had been granted support. The interest for the scheme increased over the year and almost 45 % of the home-chargers was investment support in December.

Additional Charging Infrastructure Along Bigger Roads

Klimatklivet has contributed to the expansion of the fast charging corridors along several roads, but Sweden is a widespread country and there are roads where the market drivers currently are not enough. Therefore, the Swedish Government commissioned the Swedish Transport Agency to investigate possible public measures to improve the market conditions in these areas[98]. The report concludes that approximately another 70 fast-chargers, with at least 50 kW, where needed for a nation-wide coverage in Sweden. The report suggests a procurement scheme, similar to the Norwegian model, to achieve the proposed deployment[99].

35.1.3 Incentives for Public Transport

EV Bus Rebate

In 2016, the Government introduced a purchase subsidy specifically targeting electric buses. In the beginning, battery electric and plug-in hybrid buses could be granted rebate. In 2017, fuel cell buses using renewable hydrogen were also included in the scheme. In 2018, the EV bus scheme expanded to also entitle private transport companies to the purchase rebate.

35.1.4 Research and Demonstration

Electromobility R&D and Swedish industrial policy interact to put fossil-free vehicles and vessels to the market. Sweden is an automotive country, with a broad portfolio of passenger cars, heavy-duty vehicles, construction machinery, vessels and marine engines, and the scope of the electric mobility in Sweden include all segments.

35.2 HEVs, PHEVs and EVs on the Road

Sweden has the largest global market share in the EU (EAFO, 2018) and the third largest globally (IEA, 2018). In 2018, PEVs constituted 8.1 % of the new-car sales (Bil Sweden, 2019). The total stock of PEVs in Sweden is almost 70,000, see

[98] http://www.regeringen.se/regeringsuppdrag/2018/01/uppdrag-om-laddinfrastruktur-langs-storre-vagar/

[99] https://trafikverket.ineko.se/Files/en-US/48899/Ineko.Product.RelatedFiles/2018_172_infrastruktur_for_snabbladdning_langs_storre_vagar_regeringsuppdrag.pdf

Figure 1. Twelve Swedish cities have today introduced in total 95 electric buses, many as a part of a broader EV strategy.

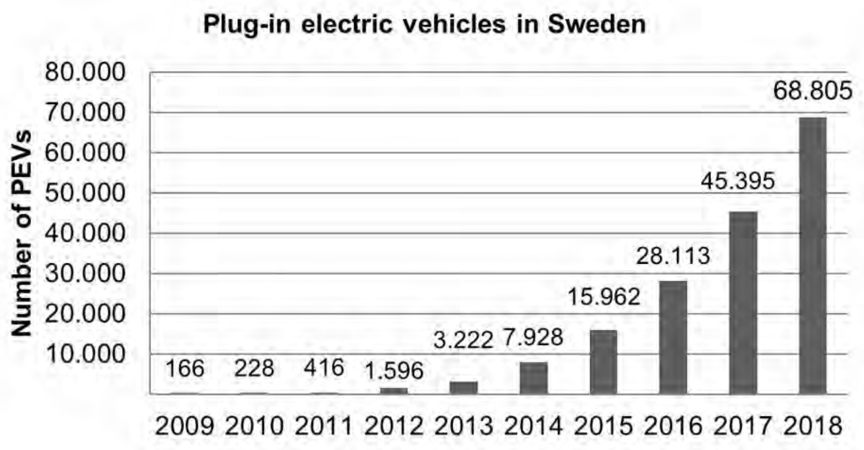

Figure1: The number of plug-in electric vehicles in Sweden between 2009 and 2018 (Source: Power circle, 2019, Plug-in electric vehicles in Sweden)

There are no regional or local policies to promote PEVs, only variable levels of engagement. The cities and regions in Sweden with a high PEV uptake have often worked consistently with PEV promotion and EVSE deployment activities for many years.

Even though the conditions for PEVs in Sweden are more favorable outside the dense cities, the three largest metropolitan areas – Stockholm, Gothenburg, and Malmö – comprise 75 % of the PEVs in Sweden. The highest uptake of PEVs in Sweden is found in Stockholm. Approximately half of the PEV stock is registered here (33,290).

In 2018, approximately 65 % of the new-car sales in Sweden were fleet vehicles or company cars. The setup for company cars in Sweden ranges from financing models where the employer pays for all costs of the car and the employee is just taxed for the benefit, to operational leasing models where the employee pays for all costs for the car with a gross salary deduction. Given the PEV deployment among company cars, it constitutes for about 75 % of the PEV ownerships, this has probably been the most important incentive to promote the use of PEVs in Sweden.

Governmental fleets are governed by certain procurement policies in Sweden, which force them to particularly consider climate factors when acquiring cars and vans or other mobility services. The public procurement policies in Sweden does also promote an increased use of renewable fuels, such as sustainable biofuels and electricity.

Table 1: Distribution and sales of EVs, PHEVs and HEVs in 2018 (Data source: BilSweden, 2019, the Swedish Transport Administration, 2019, Hydrogen Sweden, 2019)

Fleet Totals on 31 December 2018					
Vehicle Type	**EVs**	**HEVs**	**PHEVs**	**FCVs**	**Total[f]**
Quadricycles[a]	251	n.a.			251
Passenger vehicles[b]	16,664	90,273	49,394	42	4,870,783
Commercial vehicles[d]	2,661	52	9	0	572,075
Buses[c]	100	137	0	14,378	n.a.
Trucks[e]	4	28	0	0	83,977
Totals without bicycles	**19,680**	**90,490**	**49,403**	**14,420**	**5,527,086**

Total Sales during 2018					
Vehicle Type	**EVs**	**HEVs**	**PHEVs**	**FCVs**	**Total[f]**
Quadricycles[a]	32	n.a.	n.a.	n.a.	n.a.
Passenger vehicles[b]	7,147	21,020	21,811	5	365,535
Commercial vehicles[d]	2,465	52	9	0	56,617
Buses[d]	42	15	8	0	931
Trucks[e]	3	2	0	0	6,205
Totals without bicycles	**9,689**	**21,089**	**21,828**	**5**	**429,288**

n.a. = not available
[a] UNECE categories L6-L7
[b] UNECE categories M1
[c] UNECE categories M2-M3
[d] UNECE categories N1
[e] UNECE categories N2-N3
[f] Including both conventional and alternative technologies

Table 2: The top 15 selling PEVs in Sweden and prices (Data source: the public website www.miljofordon.se, accessed on 24 January 2019)

Market-Price Comparison of Selected BEVs and PHEVs in Sweden	
Available Passenger Vehicles	**Taxed (25 % VAT) but Unsubsidized Sales Price (in EUR)**
BMW 530e	53,050
BMW I3 (BEV)	37,500
Hyundai IONIQ BE 16	39,790
KIA Niro PHEV	31,870

KIA Optima PHEV	40,490
MINI Countryman Cooper S	39,900
Mitsubishi Oitlander PHEV	39,990
Nissan Leaf	37,990
Renault Zoe	32,990
Tesla Model S	79,800
VOLVO S/V90N Plug-in hybrid	55,490
VOLVO V60 N Plug-in hybrid	54,890
VOLVO XC60N Plug-in hybrid	60,280
VW E-Golf	40,990
VW Passat GTE	42,600

35.3 Charging Infrastructure or EVSE

The Swedish market for charging infrastructure is completely deregulated, which enables almost anyone to become a charging point operator (CPO). This has created an ecosystem of charging infrastructure benefits from interactions between private and public efforts to deploy EVSE.

A non-public charging point is often considered as the enabler to switch from a conventional vehicle to a PEV. The cold climate in Sweden implies an extensive deployment of block heaters and other power outlets (foremost standard household outlets, Schuko) to precondition the vehicles during the winter. This infrastructure amounts of more than 600,000 outlets and even though it is rudimentary, hence not adapted to power loads over several hours, it constitutes an excellent foundation for cost-effective EVSE upgrades, both at private houses but also in public parking lots.

Since 2015, Klimatklivet has granted support to 22,000 non-public charging points and the home-charging scheme added another 3,060 non-public charging points during 2018.

The public charging infrastructure in Sweden today is the result of public and private actions, sometimes in joint forces, and constitute about 7,000 charging outlets at almost 1,700 charging stations[100], see Figure 2a. Klimatklivet have granted support to about 8,000 public charging points. Figure 2b shows the locations of granted charging points with a charging power below 23 kW, entitled in Sweden as destination charging. Klimatklivet has also granted support to DC fast chargers, for example along motorways. See Figure 2c.

[100] www.nobil.no Accessed 2019-01-25

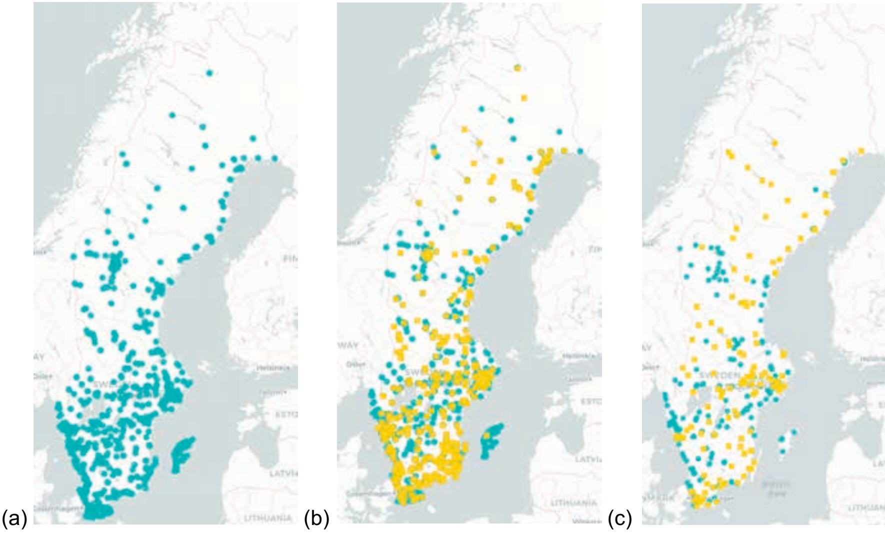

Figure 2: Public charging EVSE infrastructure in compliance with the EU standard, blue=existing yellow=granted support through Klimatklivet ; (a) existing EVSE (b) EVSE < 23kW (c) 50 kW DC

Table 3: Information on charging infrastructure in December 2018 (Data source: nobil.no)

Charging Infrastructure on 31 December 2018	
Chargers	**Quantity**
AC Level 1	2,050
AC Level 2 (≤22,2 kW)	4,000
CHAdeMO	350
CCS	350
Tesla	250
Totals	**7,000**

35.4 EV Demonstration Projects

Sweden continues to develop electric road systems (ERS). Today, two pre-commercial procurement projects are running. One system works with pantographs on public roads, which was launched in 2017. In 2018, a system that uses a rail in the road to charge a vehicle was augurated. Not only are the technologies demonstrated, but also for example the business models surrounding the electric road systems are investigated.

This section will present two interesting demonstration projects, but the Swedish public R&I portfolio is broad. During 2018, there has been an increased focus on maritime applications and freight.

Northvolt Battery Pilot Production

In 2018, an increased effort was made for a complete European circular value chain around batteries. In February 2018, a decision was made to support Northvolt AB with a maximum of 14.6 million EUR for the implementation of the project, Northvolt Pilot Production, which is expected to lead to a pilot plant for battery cell production in Västerås. The project is a step towards getting a complete European circular value chain around batteries, everything from mining to recycling.

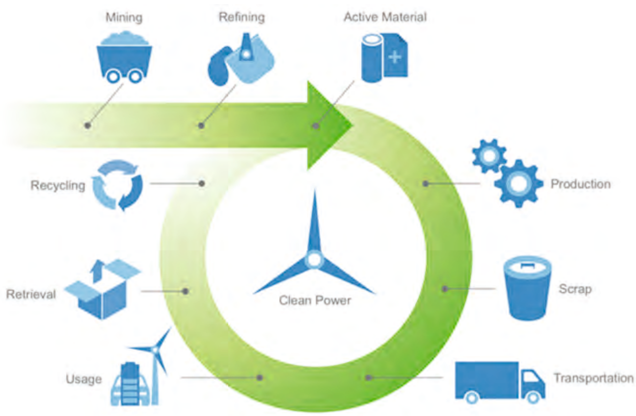

Figure 3: Northvolt, Circular value chain around batteries

Electric Site

During 2018, the Electric site project was finalised. In this project, Volvo Construction Equipment and Skanska have developed and tested several new electric construction and mining machines. Most noticeable perhaps is the HX concept, a battery electric, autonomous dump truck with 15 metric tons load capacity. The HX fleet is controlled by an automation system, and includes a safety system, which has been developed and evaluated as part of the project. Also an electric, 75 tons excavator has been developed. The results show that a production system, such as the one demonstrated in this project, has the potential of reducing CO_2 emissions by 95 as well as reducing the operating costs by 25 %.

Figure 4: Volvo HX02, a battery electric, autonomous dump truck with 15 metric tons load capacity

35.5 Outlook

Given the current policies, prognoses indicate a market share of about 13 % of PEVs among passenger cars in 2019. In the beginning of 2019, Sweden got a new government. Some of the current policies will probably be revised during 2019, but it is most likely that this will be done with the intention to boost the transition of the transport sector. One factor that currently determines the deployment of PEVs in Sweden is the availability of PHEVs in family-sized market segments. During 2018, the introduction of the WLTP implied a reduced number of PHEV models on the Swedish market, thus probably a bigger demand for PEVs than the 8 % market share. The supply of vehicles will continue to influence the Swedish market growth.

36 Switzerland

36.1 Major Developments in 2018

36.1.1 Electromobility Roadmap 2022

At the invitation of Federal Councillor Doris Leuthard, in December 2018, representatives of the automobile, electricity, property and fleet vehicle branches and their associations as well as representatives of the federal government, cantons, cities, and municipalities signed a joint roadmap[101] to promote electric mobility. The aim of the roadmap is to increase the proportion of electric vehicles (BEVs and PHEVs) among newly registered motor cars by 15 % by 2022.

More than 50 organisations and firms from various branches have worked together to produce concrete proposals for the roadmap and have elaborated measures within their own sphere of influence. Thanks to the strong commitment of all participants a comprehensive, broadly supported package to promote electric mobility in Switzerland could be elaborated. The Electromobility roadmap 2022 contains concrete measures divided into three priority fields of action: *successful market development for vehicles, optimal charging infrastructure and incentives and framework conditions*. These fields of action shall all be advanced jointly. Among the measures proposed are for example locating charging points in buildings, establishment of a national fast-charging network for electric vehicles, specific training and qualifications for tradespeople, adaptation of regulations and speedy market development of the vehicles. Synergy effects will be used and the impact of the measures increased through supplementary coordinatory measures and implementation of joint activities.

Implementation of the roadmap will start in January 2019 and it is open to further organisations and firms that also want to make a contribution to reaching the goals.

[101] www.roadmap2022.ch (available in German, French and Italian)

Figure 1: Federal Councillor Doris Leuthard signs the Electromobility roadmap 2022

36.1.2 Tendering Procedure for Fast-Charging Points at Motorway Service Stations

The Federal Roads Office (FEDRO) will ensure that a dense, nationwide network of high capacity fast-charging stations is established on the entire national road network in the next few years. To supplement the existing charging infrastructure at motorway service stations, from 1 January 2018, it will be legally possible to establish further charging points at suitable rest areas. To achieve this goal, a tendering procedure was initiated in 2018 to find operators for 100 rest areas (bundled as five packages each with 20 rest areas). FEDRA will finance the necessary electrical infrastructure to make it possible to establish the charging stations quickly. So about 160 charging stations will be made available at motorway service stations and rest areas, a network which will be among the densest and most powerful in the European area.

36.1.3 New Instruction Sheet on the Infrastructure in Buildings for Electric Vehicles

The Swiss Society of Engineers and Architects (SIA) elaborates standards, guidelines and recommendations which are binding on the Swiss building industry. A new instruction sheet SIA 2060 the society elaborated a new standard to improve the situation for electric mobility in the buildings sector (e.g., in apartment houses). This should ensure that electric mobility is given the proper consideration when new buildings or refurbishments are planned. Standardised recommendations were given in the information sheet and definite procedures elaborated for all stakeholders (engineers, architects, investors, building owners, and operators).

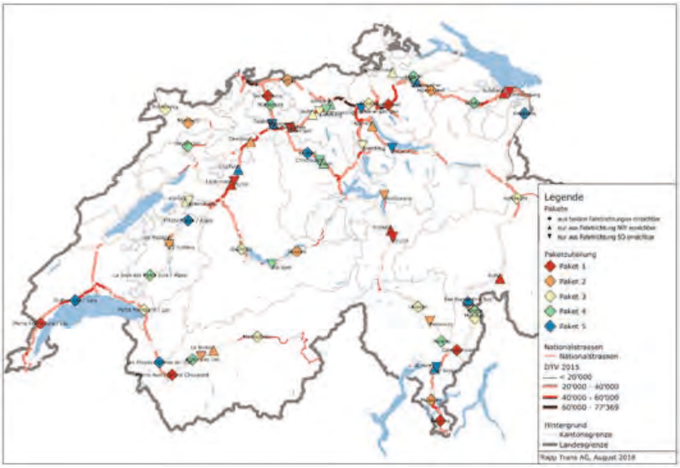

Figure 2: The five packages of fast-charging stations at motorway service stations in the tendering procedure

36.1.4 New Fact Sheet on the Environmental Impact of Private Vehicles

A new fact sheet[102] from SwissEnergy and the corresponding background report provide an overview of the environmental pollution caused by today's private vehicles as well as the vehicles of the future. The findings of the life cycle assessments indicate among other things levels of greenhouse gas emissions, primary energy consumption, particulate matter pollution, and emissions of atmospheric pollutants. The life cycle assessments present a clear picture: electric vehicles are only useful from the perspective of climate conservation if the electricity used as fuel originates from a source low in CO_2. That is the case in Switzerland today: the greenhouse gas emissions of a battery-powered car – "tanked up" with the current mixture of electricity – are only half the amount of a similar petrol driven car.

36.2 HEVs, PHEVs and EVs on the Road

At 299,600 private vehicles the number of new registrations in 2018 in Switzerland lay just under the 300,000 mark for the first time in seven years. In contrast to vehicles with conventional drive systems, the number of registrations of vehicles with alternative fuel has reached a new record at 21,552 vehicles with a market share of 7.2 % (market share in 2017: 5.6 %). More than half of these vehicles (11,272) were hybrid vehicles. In addition, 9,469 electric cars including plug in

[102] www.bfe.admin.ch > Efficiency > Alternative drives > Brochures and reports

hybrids came onto the road for the first time in 2018. This constitutes an increase of 12.9 %.

Table 1: Distribution and sales of EVs, PHEVs and HEVs in 2018 (estimated data)

Fleet Totals on 31 December 2018					
Vehicle Type	**EVs**	**HEVs**	**PHEVs**	**FCVs**	**Total[h]**
Mopeds[a]	8,965	5	0	0	n.a.
Motorbikes[b]	1,579	n.a.	n.a.	n.a.	n.a.
Quadricycles[c]	2,026	n.a.	n.a.	n.a.	n.a.
Passenger vehicles[d]	18,783	72,346	14,308	36	4,622,652
Commercial vehicles[f]	1,171	n.a.	n.a.	n.a.	n.a.
Buses[e]	21	117	0	2	n.a
Trucks[g]	27	22	0	1	n.a.
Totals without bicycles	**32,572**	**72,490**	**14,308**	**39**	**n.a.**

Total Sales during 2018					
Vehicle Type	**EVs**	**HEVs**	**PHEVs**	**FCVs**	**Total[h]**
Passenger vehicles[d]	5,110	11,272	4,359	n.a.	n.a.

n.a. = not available
[a] UNECE categories L1-L2
[b] UNECE categories L1-L5
[c] UNECE categories L6-L7
[d] UNECE categories M1
[e] UNECE categories M2-M3
[f] UNECE categories N1
[g] UNECE categories N2-N3
[h] Including both conventional and alternative technologies

In 2018, sales figures for e-scooters rose for the first time since 2012. With 1,555 new registrations e-scooters attained a market share of 3.5 %. This market niche has been reactivated by the Swiss Post on the one hand, by replacing the first three-wheeled motor cycles (Kyburz DXP) after seven years of use. The increase in the small e-motor cycle sector is due to sales growth experienced by Mobility. The vehicle sharing company took delivery of 200 Etrix S02s for its fleet. This demonstrates how as before individual actors dominate the e-scooter market today.

Table 2: Available vehicles and prices in Switzerland (Data source: data source: car dealers, official websites, EUR 1 = CHF 1.12)

Market-Price Comparison of Selected BEVs and PHEVs in Switzerland	
Available Passenger Vehicles	**Untaxed, Unsubsidized Sales Price (in EUR)**
Audi A3 e-tron	78,200
BMW i3	34,710
Citroen C-Zero	19,570
Hyundai Ioniq Elektro	33,480
KIA Soul EV AC	32,100
Mitsubishi i-MIEV	19,130
Mitsubishi Outlander PHEV	34,780
Nissan e-NV200 2.Zero Edition	38,870
Nissan Leaf Visia 40kWh	31,130
Peugeot iOn	19,570
Porsche Panamera 4 E-Hybrid	125,900
Renault Kangoo Z.E.1	33,530
Renault Twizy 45 Life2	13,130
Renault Zoe R903	31,010
Smart Fortwo Electric Drive4	21,050
Tesla Model S 75D	72,190
Tesla Model X 75D	77,850
Toyota Prius Plug-In Lounge	40,870
VW e-Golf	35,230
VW e-up!	26,620
VW Golf GTE	41,750

36.3 Charging Infrastructure or EVSE

By the end of 2018, 2,323 public charging locations with a total of over 5,800 charging points were registered in the Swiss national database.

Expansion of the public charging infrastructure in Switzerland is predominantly in the hands of the private sector. The federal government takes on a supportive role with respect to coordination and planning of this expansion. In 2018, two new projects were launched in this connection.

The federal government has determined that charging at the workplace is important to accelerate the market penetration of electric mobility. For this reason with the support of SwissEnergy the Swiss eMobility Association launched a project (charge4work) to provide neutral information and consulting services to promote the establishment of charging stations at the workplace and at business premises.

By establishing a national electric mobility data infrastructure (DIEMO), the Swiss Federal Office of Energy (SFOE), the Federal Office of Topography (swisstopo), and the operators of charging infrastructure for electric mobility jointly intend to create a publicly accessible data basis with real-time data. A high quality data basis is created which makes it possible to provide dynamic data (availability of the charging stations) by directly connecting the charging infrastructure operator to the federal spatial data infrastructure.

Table 3: Information on charging infrastructure in December 2018 (Data source: LEMnet.org)

Charging Infrastructure on 31 December 2018	
Chargers	**Quantity**
AC Level 1 Chargers (up to 3.7 kW)	850
AC Level 2 Chargers (up to 22 kW)	1,248
AC Fast Chargers (up to 43 kW)	186
CHAdeMO	224
CCS	208
Tesla	26
Inductive Charging	0
Totals	**2,323**

36.4 EV Demonstration Projects

36.4.1 Electric Buses

In 2018, new drive and charging systems were tested for public suburban buses in a number of demonstration projects. In Zurich the prototype of the “SwissTrolley plus” built by Carrosserie Hess AG (Figure 3) was tested in daily traffic. In contrast to conventional trolley buses, this bus is an electric bus fitted with a powerful battery, which is charged via the trolley wire. In the same way braking energy can be recuperated and fed to the battery irrespective of the condition of the network and current spikes in the network can be smoothed out. A number of cities including Bern (Switzerland) and Salzburg (Austria) have already ordered such vehicles.

Figure 3: The “SwissTrolley plus” in daily use in Zurich (Source: www.vbzonline.ch)

In Geneva this newly developed drive system is also being tested in a demonstration project. However, in this instance the battery is charged at fast-charging stations using the innovative “TOSA” system made by ABB Sécheron SA (Figure 4) that are installed at bus stops along the bus route. While passengers enter or leave the bus the battery is charged for 20 seconds through a flexible arm. The relatively small battery used leaves more room for passengers than conventional battery-driven buses. The TOSA system will in future be implemented in the French town of Nantes.

Figure 4: A TOSA bus approaches a bus stop equipped with a charging station (Source: www.ge.ch)

A variant of the TOSA system was also used in Bern for the first time in 2018. Charging takes place in this case through a pantograph at a charging station situated at the bus terminus (Figure 5). The battery capacity is sufficient for a number of round trips before it has to be recharged. In 2019, plans are afoot to realise this system in further Swiss cities.

Figure 5: TOSA variant with a pantographic charging system (Source: www.bernmobil.ch)

36.4.2 Electric Freight Vehicles

In the course of 2018, it was possible to gather further valuable experience from using electrical commercial vehicles in demonstration projects. In four towns in Switzerland (Lausanne, Murten, Neuchâtel, and Thun) prototypes of a 26 t electric waste collection vehicle made by Designwerk GmbH (Figure 6) were in daily use. In particular, because of the distinctive stop-and-go operation in this sector, electrification of urban waste collection leads to significant energy savings in comparison to diesel vehicles. In addition, a substantial reduction in noise and pollutant emissions is achieved. E-Force One AG is a further manufacturer in Switzerland that has successfully tested heavy electric trucks in real-life situations.

Figure 6: 26 t electric waste collection vehicle in Lausanne (Source: www.lausanne.ch)

In 2018, intensive test runs could also be made with the prototype of a 34 t hydrogen fuel cell drive made by Esoro AG (Figure 7). The vehicle equipped with the system tows trailers for Swiss retailer Coop and is tanked up at the first public hydrogen tank station in Switzerland at Hunzenschwil. On the basis of this initial positive demonstration the intention is to introduce further fuel cell trucks into Switzerland in future[103].

Figure 7: 34 t hydrogen fuel cell truck used by Coop (Source: www.esoro.ch)

[103] https://h2energy.ch/en/hyundai-motor-and-h2-energy-will-bring-the-worlds-first-fleet-of-fuel-cell-electric-truck-into-commercial-operation/

36.4.3 Electric Construction Machines

The largest electric vehicle in the world, a 110 t electric dumper truck, could be put into operation in 2018, and it is now deployed daily in a quarry (Figure 8). A fully laden Komatsu e-Dumper from Kuhn Schweiz AG (total weight 111 t) transports 60 t of lime and marl from the high-elevation extraction area to the permanently installed transport system. Energy recovered on the downhill (laden) run is stored in batteries, provided by Lithium Storage GmbH, and is used to power the uphill run. This means the vehicle only has to be charged at the charging station about once per week and leads to massive energy savings and substantial pollutant reduction.

Figure 8: 110 t electric dumper truck at work in a quarry (Source: www.edumper.ch)

Electrification of various classes of excavators was studied in a further demonstration project. In cooperation with Huppenkothen Baumaschinen AG, the company Suncar HK AG has developed electric drive systems for excavators between 2 t and 16 t in size and has tested them on real building sites (Figure 9). The intensive testing phase in 2018 delivered comprehensive findings about the potential of electric construction machines and these findings will flow into further development of such machines. In the meantime these electric excavators are now being used abroad in Austria, Germany, France, Norway, and Spain.

Figure 9: 16 t electric excavator deployed on a building site (Source: www.suncar-hk.com)

36.4.4 EV Batteries for Second Life Stationary Storage Systems

A demonstration project ended in 2018, in which a concept for second life batteries for stationary applications was developed and tested. The batteries, which originated from Swiss Post's electric delivery vehicles, were connected to provide storage capacity of 10 kWh and were used in addition to other places in a Swiss Post building (Figure 10). An intelligent battery management system was developed as part of the project and experiments were conducted to examine the economic viability of such second life storage systems.

Figure 10: Three-wheeled electric scooter manufactured by Kyburz AG and a second life storage system (Source: Swiss Post, Ecocentre, Langenbruck)

37 Turkey

37.1 Major Developments in 2018

Turkey's effort on national electric vehicle brand creation and surrounding mobility ecosystem development structured in 2018 by the consortium corporation named TOGG (Turkey's Automobile Initiative Group). The Union of Chambers & Commodity Exchanges of Turkey (TOBB) led the setup on 25 June 2018 and the consortium composed by equal shareholding of five domestic corporations.

Beside, numerous R&D Centers do research on automotive and electrification technologies in Turkey. Ford Otosan has unveiled a new electric and autonomous truck concept, F-Vision, at the IAA Commercial Vehicles 2018 in Hannover. Otosan did note that battery-powered early concept F-Vision will be equipped with level 4 autonomous driving. Also, Ford Transit Custom PHEV; targets a zero-emission range of 50 km and features the 1.0-litre petrol engine as a range extender scheduled for volume production in Kocaeli plant in 2019. The battery pack of Custom PHEV will also be produced in Turkey.

Figure 1: The Ford Otosan concept electric truck F-Vision (left), Anadolu Isuzu NPR10 EV electric truck (right) (Source: Otosan and Anadolu Isuzu)

IAA Commercial Vehicle 2018 was the meeting point for the electrified models of trucks and buses. The NPR 10 EV electric truck was developed by Anadolu Isuzu jointly with Altınay and Aselsan. The electric motor on the axle provides 1,500 Nm output torque and 335 hp maximum power for the NPR 10 EV. The company claims 110 km range by 4 hour charging for the electric truck. Temsa, a leading bus manufacturer in Turkey, introduced the 12 meters long Avenue Electron electric bus with a 230 km range and a total capacity of 85 passengers. At the same event, Avenue Electron featured a fast charging option. Atak and Jest electric minibuses, developed by Karsan with BMW collaboration, was another remarkable product at the IAA Commercial Vehicle show 2018. Eight meters inner-city M3 category bus “Atak Electric” has a range of up to 300 kilometers. Atak’s power relied on a 5 x 44 kWh battery pack and charging time for this battery pack was declared as being 2.5 hours. Another Karsan minibus, “Jest Electric” offers a range of up to 210 km based on the battery provided by BMW.

Figure 2: The Jest Electric minibus developed by Karsan with BMW collaboration (Source: Karsan)

AVL Turkey, AVL GmBH, and Ford Otosan signed a 3-year cooperation agreement on the development of platooning technologies on Otosan F-Max trucks. This cooperation will improve the emission levels, fuel economy (8-15 % reduction) and safety attributes of convoy trucks.

FEV Turkey branch started a joint project with the startup company KODECO in order to develop an autonomous electric vehicle, named Otomod, aiming at creating an alternative public transportation in universities, hospitals and airports. TUBITAK Technology and Innovation Grant Programmes Directorate (TEYDEB) is funding this project. Otomod will have a capacity of four seats with 45 km/h top speed and test drives of the prototype vehicles will be conducted in Istanbul Technical University Ayazağa campus. Besides, Gen Otomobil revealed their development efforts on TM-480 model. Prototype of the D-segment electric vehicle was showcased at the R&D and Innovation Summit in Istanbul in November 2018.

Figure 3: AVL Turkey, AVL GmBH and Otosan signed 3-year agreement on platooning technology development for F-Max truck (Source: Ford Otosan)

FEV Turkey branch started a joint project with the startup company KODECO in order to develop an autonomous electric vehicle, named Otomod, aiming at creating an alternative public transportation in universities, hospitals and airports. TUBITAK Technology and Innovation Grant Programmes Directorate (TEYDEB) is funding this project. Otomod will have a capacity of four seats with 45 km/h top speed and test drives of the prototype vehicles will be conducted in Istanbul Technical University Ayazağa campus. Besides, Gen Otomobil revealed their development efforts on TM-480 model. Prototype of the D-segment electric vehicle was showcased at the R&D and Innovation Summit in Istanbul in November 2018.

The Scientific and Technological Research Council of Turkey – Marmara Research Center (TUBITAK MRC), within the Automotive Excellence Center, also has continued component and system level electric and hybrid vehicle research & development activities in 2018. Electric vehicle components (electric motor, battery module, battery management system, inverter and electronic control units) development efforts continued in the scope of different projects and a wide range of vehicle applications. The functional prototype of high power density permanent magnet electric motor for electric vehicle applications was developed in 2018.

On the university side, the 13th Efficiency Challenge Electric Vehicle was held in August 2018. The competition, organized by TUBITAK Science and Society, aims to increase environmental awareness of students. University teams have had the chance to compete in the Autonomous category for the first time in the Efficiency Challenge history, Team AESK from Yıldız Technical University took the lead in this category, by completing the 120-meter mission path in 62 seconds.

Teams in Electromobile and Hydromobile categories were required to consume as little energy as possible and complete 30 laps and 20 laps, respectively. The Aydın University electro-mobility team won the electro-mobility competition and qualified for the Efficiency Record Award by consuming 730 Wh energy in 30 laps (60 km).

Figure 4: 13th Efficiency Challenge Electric Vehicle competition: Autonomous challenge (Source: TUBITAK)

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

Turkey adjusted special consumption taxes (SCT) in the automotive sector as the industry warned about significant sales and market shrinkage. A special consumption tax (SCT) reduction (15 %) was declared for passenger vehicles, motorbikes and commercial vehicles depending on the engine volume and/or electric motor power. The tax reduction declaration was announced on 31 October 2018 and lately extended to March 2019.

The Ministry of Treasure and Finance of Turkey also raised the upper price limits, higher taxes charged, on motor vehicles by 75 %. The lowest tax rate of 45 % levied on cars of under 1,600 cc applied to vehicles priced at as much as 70,000 Turkish liras, up from a previous level of 40,000 Turkish liras. Price bands at higher taxes applied to cars with the same or larger capacity engines also shifted upwards.

Policy instruments to support electrification of transportation to encourage the use of H&EV's and apparent tax advantages for full EV vehicles were valid during the year. The effects of tax advantages on the sales of EV vehicles were apparent in 2018, even with the important decrease on the total automotive market.

SCT exemption applied on motorbikes in 2018 covering the motorbikes below 250 cc and electric motorbikes with motor power lower than 20 kW.

Table 1 and Table 2 show the vehicle sales and SCT categories for initial new passenger vehicles, motorbikes and electric/ hybrid vehicles, respectively.

Table 1: Special consumption tax classification categories for new conventional and electric only vehicles in 2018 (Data source: Official Gazette of the Republic of Turkey)

Special Consumption Tax for Conventional and Electric Vehicles					
	Conventional			Electric Only	
Vehicle Type	Engine Cylinder Volume (cc)	Untaxed Price (₺)*	Special Consumption Tax (%)	Electric Motor Power (kW)	Special Consumption Tax (%)
Passenger Vehicle	<1,600	<70,000	45 (30**)	<85	3
		70,000-120,000	50 (35**)	85-120	7
		>120,000	60	≥120	15
	1,600-2,000	<100,000	100		
		>100,000	110		
	>2,000		160		
Motorbikes	<250		8 (0**)	<20	3(0**)
	>250		37	>20	37
*Currency: Turkish Lira (TRY); 31 December 2018 TCMB exchange rate: 1 USD = 5.28 TRY **Indicated tax values are valid until March 2019					

Table 2: SCT categories for new hybrid vehicles in 2018 (Data source: Official Gazette of the Republic of Turkey)

Special Consumption Tax for Hybrid Vehicles				
Vehicle Type	Engine Cylinder Volume (cc)	Electric Motor Power (kW)	Untaxed Price (₺)*	Special Consumption Tax (%)
Passenger Vehicle	≤1,600			60
	1,601 ≤1,800	≤ 50 kW		110
		> 50 kW	<85,000	45 (30**)
			85,000-135,000	50 (35**)
			>135,000	60
	1,801≤2,000			110
	2,001 ≤2,500	≤ 100 kW		160
		> 100 kW	<170,000	100
			>170,000	110
	>2,500 cc			160
Currency: Turkish Lira (TRY); 31 December 2018 TCMB exchange rate: 1 USD = 5.28 TRY **Indicated tax values are valid until March 2019				

37.2 HEVs, PHEVs and EVs on the Road

Fleet

In Turkey, the total number of road motor vehicles in traffic increased by 646,976 in 2018 compared to the previous year, the annual rise was lower than in recent years. The increase rate of electric vehicles on the road was remarkable, but the total fleet is still immature. The total number of fully electric vehicles in Turkey was still on three digit units at the end of 2018. There were 4054 units of hybrid and electric vehicles sold in 2018, but they still incorporate a negligible fraction of the total vehicle sales.

In 2018, a strong domination of 1,501-1,600 cc engine size was present among passenger cars (43.9 %) registered. Among all vehicles sold, passenger cars dominated with the 54.2 % of fleet total, followed by small trucks with 16.4 %. The average age of the total registered road motor vehicles slightly increased and became 13.4 years by the end of 2018. Table 3 shows the total vehicle fleet with respect to vehicle types from 2014 to 2018. Table 4 shows the sales of the new hybrid and electric vehicles collected by the Automotive Distributors Association (ODD).

Table 3: Total vehicle fleet according to the vehicle types between 2014 and 2018 (Data source: TURKSTAT Road Motor Vehicle Statistics, December 2018)

Fleet Totals on 31 December 2018 and in previous years					
Vehicle Type	**2014**	**2015**	**2016**	**2017**	**2018**
Passenger car	9,857,915	10,589,337	11,317,998	12,035,978	12,398,190
Minibus	427,264	449,213	463,933	478,618	487,527
Bus	211,200	217,056	220,361	221,885	218,523
Light commercial vehicle	3,062,479	3,255,299	3,442,483	3,642,625	3,755,580
Truck	773,728	804,319	825,334	838,718	845,462
Motorcycle	2,828,466	2,938,364	3,003,733	3,102,800	3,211,328
Special purpose vehicle	40,731	45,732	50,818	60,099	63,359
Tractor	1,626,938	1,695,152	1,765,764	1,838,222	1,885,952
Totals	**18,828,721**	**19,994,472**	**21,090,424**	**22,218,945**	**22,865,921**

Sales

In 2018, the automotive sector of Turkey was suffering a 35 % shrinkage despite the introduction of the SCT reductions. There were 486,321 passenger cars sold in 2018, as compared to 722,759 in 2017. In spite of the receiving higher share of sales with 96.10 % (467,693 units), the sale of vehicles with a maximum engine size of 1,600 cc suffered a loss of 32.7 %.

H&EV sales hardly experienced the market fall in 2018 compared to the conventional vehicles. Electric vehicle sales increased and almost doubled with sales of 155 units in 2018. Hybrid vehicle sales, with a total of 3,899 units in 2018, mainly concentrated on 1601 cc - 1800 cc engine range (> 50 kW electric motor) dominated by Toyota C-HR produced in Turkey.

Table 4: Passenger car market according to the engine/electric motor size between 2017 and 2018 (Data source: ODD Press Summary, December 2018)

Total Sales during 2018					
Engine Size	**Engine Type**	**2017* (end of Dec)**	**2018 (end of Dec)**	**SCT Tax Rates (%)**	**VAT Tax Rates (%)**
≤1,600 cc	Gas/ diesel	694,464	467,693	30 – 60*	18
>1,600 cc ≤2,000 cc	Gas/ diesel	21,568	13,202	100 -110	18
>2,000 cc	Gas/ diesel	2144	1,372	160	18
≤85 kW	Electric	55	80	3	18
>85 kW ≤120 kW	Electric	0	0	7	18
>120 kW	Electric	21	75	15	18
≤1,600 cc	Hybrid	464	550	60	18
>1,600 cc ≤1,800 cc (≤ 50 kW)	Hybrid		0	110	18
>1,601 cc ≤1,800 cc (> 50 kW)	Hybrid	3704	3011	30 – 60*	18
>1,801 cc ≤2,000 cc	Hybrid	63	59	110	18
>2,000 cc ≤2,500 cc (≤ 100 kW)	Hybrid	0	1	160	18
>2,000 cc ≤2,500 cc (> 100 kW)	Hybrid	266	265	100 - 110	18
>2,500 cc	Hybrid	10	13	160	18
Totals		**722,759**	**486,321**	**Tax Rates**	

* SCT tax rates applies as 45 %, 50 % and 60 % based on regulation as previously shown in Table 2. These rates deduced to 30 %, 35 % and 60 % respectively until March 2019
**Minor differences observed with ODD 2017 data, ODD 2018 data source is the master

When the passenger car market was examined according to average emission values in 2018, the percentage of cars with emission values between 120 g / km and 140 g/km continued to increase despite the significant decrease on the car sales. Passenger cars with emission values between 120 g/km and 140 g / km heavily slumped, but still led the sales with 39.84 %. Table 5 shows the passenger cars under 140 g / km CO_2 emissions that accounted for 80 % of the vehicle sales.

Table 5: Passenger car market according to average emission values in 2018 (Data source: ODD Press Summary, December 2018)

Passenger Car Sales during 2018 by Average Emission Values					
Average Emission Values of CO_2 (g/km)	31 December 2017*		31 December 2018		2018 / 2017
	Units	%	Units	%	%
<100 g/km	111,652	15.45	84,049	17.28	-24.72
≥100 to <120 g/km	324,232	44.86	193,733	39,84	-40.25
≥120 to <140 g/km	174,561	24.15	111,567	22.94	-36.09
≥140 to <160 g/km	92,508	12.80	81,728	16.81	-11.65
≥160 g/km	19,806	2.74	13,905	3.13	-23.03
Total	722,759	100.00	486,321	100.00	-32.71

* Minor differences observed on 2017 data, ODD 2018 source is the master

37.3 Charging Infrastructure or EVSE

The number of companies on the charging infrastructure market and the number of charging stations increased in 2018. In 2018, ZES (Zorlu Energy Solutions) company entered the market with charging stations in 23 different locations. ZES offers 61 vehicle slots for 100 kW DC fast charging and 22 kW AC charging options. Enerjisa, one of the main private companies on the energy sector in Turkey, incorporated Eşarj company and increased the charging capacity to 236 vehicles in 2018. Sharz.net company also entered the market and already established more than 40 stations mainly concentrated on the Marmara and Aegean regions.

New charging station installation efforts are targeting the shopping centers, parking areas operated by municipalities, hotels, public buildings, auto-dealers and EVSE providers. With these new charging locations that where introduced in 2018, the main travel routes throughout Turkey are significantly covered. Also, Metropolitan Municipality of Istanbul has started to build charging stations in open car parks through ISPARK. In addition, the number of stations offering fast charging options increased with the entrance of new infrastructure providers in 2018. There is no supercharger installed by Tesla Motors in Turkey, but the company announced the supercharger installation plans of 2019 across Europe, including Turkey.

Figure 5 shows the map of the charging stations that are provided by private companies throughout the country. Some examples of the active fast charging stations established by the new entrant companies can be seen in Figure 6.

Figure 5: Map of active charging stations throughout Turkey (Source: map retrieved from plugshare.com)

Figure 6: New fast charging stations examples constructed by ZES and Eşarj companies (Source: Zorlu Energy Solutions and Esarj)

38 United Kingdom

38.1 Major Developments in 2018

In a busy year, the highlight of the UK's involvement in developing the market for zero emission vehicles (ZEV) was the successful Global ZEV summit [104] held in Birmingham in September. The two-day event attracted high level delegates from national and sub-national Governments, industry, utilities, academics and NGO's and culminated in the signing of the Birmingham Declaration[105] 14 national and regional Governments committed to a zero emission future for transport.

At the COP24 in Katowice, the Birmingham Declaration was built on when 42 nations, 4 regional Governments, and 18 international and non-government organisations signed up to the Driving Change Together Partnership.[106]

Domestically, the UK's Office for Low Emission Vehicles took forward a number of new policies and programmes as well as managing their existing portfolio of demand and supply side support policies. 2018 saw a continued increase in the purchase of ultra low emission vehicles, the installation of domestic and publically accessible infrastructure.

July saw the publication of the UK's Road to Zero Strategy[107] and the underpinning Transport Energy Model[108]. This strategy sets out a clear pathway to zero emissions, and gives clarity and certainty to industry and driver alike. By 2030, the UK Government wants at least half of new cars sold, and as many as 70 %, to be ultra low emission. The UK Government has said it will end the sale of new petrol and diesel cars and vans by 2040. By 2040, it is expected the majority of new cars and vans sold will be 100 % zero emission and all new cars and vans will have significant zero emission capability. That will mean by 2050 almost

[104] https://www.gov.uk/government/topical-events/zero-emissions-vehicle-summit

[105] https://www.gov.uk/government/publications/zero-emission-vehicle-summit-the-birmingham-declaration

[106] https://cop24.gov.pl/presidency/initiatives/driving-change-together-partnership/

[107]https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/739460/road-to-zero.pdf

[108]https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/739462/transport-energy-model.pdf

every car and van in the UK will be zero emission. This transition is expected to be industry and consumer led, supported in the coming years by the measures set out in the Road to Zero Strategy. Progress will be reviewed in 2025 and the UK Government will consider what interventions are required if not enough progress is being made.

38.1.1 Vehicle Incentives

The UK Government provides grants to the purchase of qualifying ultra low emission vehicles including, cars, vans and HGVs, taxis, buses and powered two wheelers. At the Birmingham Summit the UK Government also announced its intention to support e-cargo bikes[109]. Details of how this support will work will be provided in due course.

The Plug-in Car Grant[110] which, to the end of February 2019, was reviewed during 2018. The result of this review[111] was announced in October. The changes to the grant announced today will mean that the grant rate for Category 1 vehicles will move from 4,500 GBP (5,276 EUR) to 3,500 GBP (4,103 EUR) and Category 2 and 3 vehicles will no longer be eligible for the grant. The plug-in car grant will be available until at least 2020. The regular review of the rates and criteria of the grant showed that it is effective and provides good value for money. That is why support is now focused on zero emission models such as the Nissan Leaf and the BMW i3.

The Plug-in Van Grant[112] (PIVG) provides 20 % of the price of a qualifying vehicle to a maximum grant amount of 8,000 GBP (9,380 EUR), or 20,000 GBP (23,450 EUR) for the first 200 large vans (3.5t+) or trucks. The UK Government has said that the PIVG will be maintained at current rates until at least April 2019.

The UK Government has provided 50 million GBP (~60 million EUR) to support the Plug-in Taxi Grant[113] programme. This grant will give licenced taxi drivers up to 7,500 GBP (8,793 EUR) off the price of a new vehicle. To date around 1,500 grants have been processed.

The Plug-in Motorcycle Grant [114]provides a grant of 20 % up to 1,500 (1,758 EUR) scooters & motorcycles are eligible for.

[109] https://www.gov.uk/government/news/funding-boost-for-green-last-mile-delivery-bikes

[110] https://www.gov.uk/plug-in-car-van-grants

[111] https://www.gov.uk/government/news/reformed-plug-in-car-grant-extended-into-next-decade

[112]https://www.gov.uk/plug-in-car-van-grants

[113] https://www.gov.uk/plug-in-car-van-grants

[114] https://www.gov.uk/plug-in-car-van-grants

The Ultra Low Emission Bus scheme , succesor to the Green Bus Fund[115], announced the winners of the second round[116] of funding in February 2019. Communities across the UK will benefit from greener journeys thanks to 263 new low emission buses, a 48 million GBP (56,280,000 EUR) investment from the Office for Low Emission Vehicles will fund new green vehicles and and the necessary recharging and re-fuelling infrastructure.

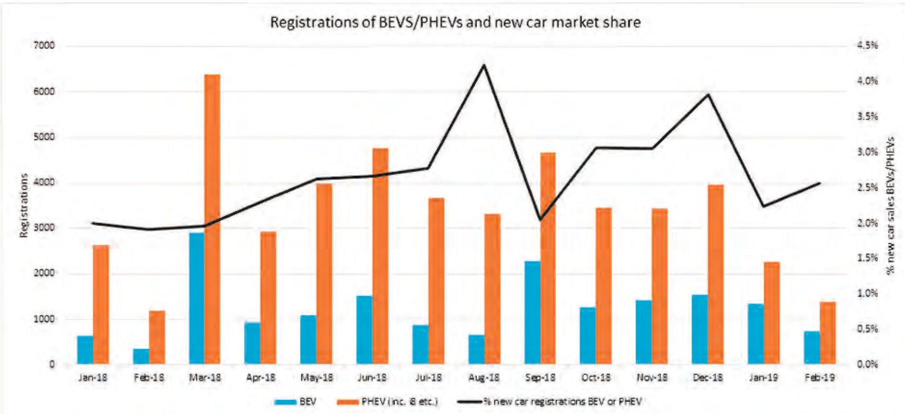

Figure 1: PICG Grant uptake Jan 2018 – Feb 2019 (Source: OLEV)

38.2 Charging Infrastructure or EVSE

The UK's vision is to have one of the best electric vehicle infrastructure networks in the world. This means current and prospective electric vehicle drivers are able to easily locate and access chargepoints that are affordable and secure. UK Government funding, policy and leadership, alongside private sector investment has supported the installation of more than 15,500 public chargepoints. This includes over 1,500 rapid chargepoints - one of the largest networks in Europe.

In order to meet the UK's 2040 ambition, it is recognised that we will need to install many more chargepoints at homes, workplaces and in public places. The UK Government also recognises that the consumer experience of public electric vehicle charging needs to improve.

Recharging an electric vehicle is fundamentally different to refuelling a petrol or diesel car. A key attraction of an electric vehicle is that they can be charged wherever they are parked if there is an electrical outlet. Studies indicate the vast majority of electric vehicle drivers charge at home. But there is also a role for

[115] https://www.gov.uk/government/publications/details-of-the-green-bus-fund

[116] https://www.gov.uk/government/publications/ultra-low-emission-bus-scheme-successful-bidders

workplace, destination, public charging, as well as charging at motorway service areas to facilitate longer journeys.

This is why the UK Government is taking a range of measures to support the installation of chargepoints in the UK. The UK is supporting people to charge their cars at home by providing up to 500 GBP (586 EUR) off the cost of installing a chargepoint at home through the Electric Vehicle Homecharge Scheme[117]. The Government has supported the installation of almost 100,000 domestic chargepoints. We have committed to maintaining the current grant level until March 2019, or until 30,000 installations. In addition we are putting in place plans to ensure that new homes we are building are electric vehicle ready. The UK Government plans to consult as soon as possible for introducing a requirement for every new home to have a chargepoint, where appropriate.

Providing support for those without offstreet parking is an essetial element of the UK offer. 28 local authorities have now applied for funding under the On-street Residential Chargepoint Scheme[118] with plans to install over a 1,000 chargepoints. The scheme provides grant funding to local authorities looking to install chargepoints for residents that lack off-street parking.

The Workplace Charging Scheme[119] offers up to 500 GPB (586 EUR) off the installation of charging sockets deployed at workplaces for consumers and fleets. More than 2,000 businesses have now applied for this scheme, and a further 4.2 million GBP (~5 million EUR) commitment until the end of 2018/19 could see over 8,000 sockets installed.

The UK Government has provided 40 million GBP (~ 47 million EUR) of funding via our Go Ultra Low City scheme to eight cities across the UK to support uptake of ultra low emission vehicles. To date, over 300 chargepoints have been installed as part of this scheme. Additional charging hubs will be installed across the country including in York and Milton Keynes.

The UK Government aims to encourage and leverage private sector investment to build and operate a self-sustaining public network supported by the right policy framework. In many cases, the market is better-placed than government to identify the right locations for chargepoints and it is essential that viable commercial models are in place to ensure continued maintenance and improvements to the

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[117] https://www.gov.uk/government/publications/customer-guidance-electric-vehicle-homecharge-scheme

[118] https://www.gov.uk/government/collections/government-grants-for-low-emission-vehicles#on-street-residential-chargepoint-scheme

[119] https://www.gov.uk/government/collections/government-grants-for-low-emission-vehicles#workplace-charging-scheme

network. Already, the vast majority of chargepoints now being installed are funded with private money and we want to see this trend continue.

That is why the UK Government have set up the 400 milllion GBP (469 million EUR) Charging Infrastructure Investment Fund[120] for investment into the public charging infrastructure. The Government will invest 200 million GBP (234,502,000 EUR) which will be matched by private investors to accelerate the roll out of public charging infrastructure. The fund will be managed and invested on a commercial basis by private sector partners.

Highways England are investing 15 million GBP[121] (17,587,600 EUR) to ensure there is a rapid chargepoint every 20 miles along motorways and major A roads in England by 2020.

The development of the market has to be supported by the right policy framework. This is why the the UK Government has put in force the Automated and Electric Vehicles Act[122]. This act gives the government new powers to improve the customer charging experience and increase provision of electric vehicle infrastructure. The legale powers include being able to:

- Require chargepoint operators to provide a common access method
- Require chargepoint operators to make information about their chargepoints freely available so that locating and accessing the charging network is straightforward and hassle free
- Set maintenance and reliability standards for public chargepoints

The Act also provides powers to ensure appropriate provision of chargepoints at motorway service areas and large fuel retailers enabling longer journeys and reducing range anxiety, if needed.

[120]https://www.gov.uk/government/publications/charging-infrastructure-investment-fund

[121] https://www.gov.uk/government/collections/road-investment-strategy

[122] http://www.legislation.gov.uk/ukpga/2018/18/contents/enacted

Table 1: Information on charging infrastructure in March 2019 (Data source: ZAP MAP)

Charging Infrastructure on 26 March 2019	
Chargers	**Quantity**
AC Level 2 Chargers	1,225
CHAdeMO	1,717
CCS	1,457
Tesla	339
Inductive Charging	0
Totals	**4,738**

38.3 Other Policy Support

Communications Campaign

The Go Ultra Low communications campaign[123] is now into its fifth year. This joint government-industry campaign aims to inform vehicle purchasers about the benefits of ULEVs and to dispel widespread myths. The aim of 'Go Ultra Low' simply is to provide all the facts and information motorist looking for to make an informed decision.

Go Ultra Low City Scheme

The 40 million GBP (46,900,300 EUR) Go Ultra Low Cities scheme is awarding funding to Milton Keynes, Nottingham, Bristol, and London to support them achieving Go Ultra Low exemplar status. Each of these cities will receive investment for pioneering initiatives to complement existing schemes and further incentivise purchase, increase use and enhance charging infrastructure, assisting them in becoming internationally outstanding examples for the promotion of ultra-low emission vehicles (ULEVs). In addition the Go Ultra Low Cities scheme is providing funding to Dundee, Oxford, York and North East regions to implement specific elements of their bids to support them in developing their low-emission transport strategies and enhance local charging infrastructure.

The measures being introduced by each of the cites is set out below please be aware that not all of the measures are currently in place:

- **Milton Keynes** – 9 million GBP (10,552,600 EUR)
  - Electric Vehicle (EV) Experience Centre 'one stop shop' in city centre (advice, promotion & short term loan of vehicles). Will have a

[123] https://www.goultralow.com/

Demonstration Fleet (20-30 EVs) and an Experience Fleet of 40 to 130 EVs
- Use of all bus lanes including same priority at lights as buses to be badged as Low Emission Lanes
- Opening up all 20,000 parking bays for free to EVs (with monitoring equipment to indicate when free)
- 30 additional dedicated car club EV bays within 6 months
- Two rapid charging hubs, 100 fast chargers and 200 charge points for on street charging

• **Nottinghamshire and Derby** – 6 million GBP (7,035,050 EUR)

- EVs able to use 22 km of bus lanes in low emission corridor running E-W through Nottingham city centre and out into the wider conurbation
- Discount parking rates for ULEVs
- Technology centre to promote new ULEV technologies, links with Robin Hood energy generating company (wholly owned by the council)
- ULEV business support programme – this includes guidance, onsite events, promotional activities, business workplace EV charging grants programme and procurement of a number of vans to offer businesses ‘try before you buy’ service
- 35 rapid and 195 fast charging units at key locations

• **Bristol** – 7 million GBP (8,207,560 EUR)

- Opening three High Occupancy Vehicles lanes in Bristol to ULEVs on two main routes to city centre and city ring road
- Creation of a Ultra Low Emission Zone (ULEZ) includes access only by low emission freight coupled with geo fencing initiative
- Community demonstrator cars & test drives (leases from 2-4 weeks) and local ambassadors and advocates to promote to new demographics
- Free residential parking for ULEVs.
- Up to four rapid charging hubs and 77 fast chargers for public and business use

• **London** - 13 million GBP (15,242,600 EUR)

- ‘Neighbourhoods of the Future’ to provide for and prioritise ULEVs to help normalise them, including:
- Hackney - 10-15 streets will ‘Go Electric’ with infrastructure (lighting columns etc.), EV parking bays
- Harrow - develop a Low Emission Zone to encourage ULEVs including priority traffic and parking management actions as part of large regeneration project

- Islington - consult on emissions based traffic restrictions backed by infrastructure, parking and car clubs offers
- Introduction of the world's first Ultra Low Emission Zone from September 2020
- London's Car Club strategy aims to have 1 million members by 2025 - retrofitting charging infrastructure into 1,000 car club bays
- Expand existing charging network and a new chargepoint delivery partnership providing a single point of call for residential properties.

Hydrogen for Transport Programme

The UK Government is clear that Hydrogen fuel cell electric vehicles (FCEVs) are an important technology for decarbonising road transport; and is supporting FCEVs and the necessary refuelling infrastructure. Since 2014 the Government has provided 5 million GBP(5,862,540 EUR) towards an initial network of 12 hydrogen refueling stations (HRS) and as the early nature of the market means vehicle costs are still high, 2 million GBP (2,345,020 EUR) has also been provided to support public and private sector fleets to become early adopters of FCEVs. 23 million GBP (26,967,700 EUR) additional funding is being provided to increase the uptake of FCEVs and expand the number of HRS. The Hydrogen for Transport Programme[124] (HTP) will provide support out until 2020 and is being run over two phases.

The winners of the first phase were announced in March 2018 supported by 9 million GBP (10,552,600 EUR) awarded to a successful project that will build four new and upgrade five existing hydrogen refueling stations as well as support the deployment of just under 200 FCEVs. In February 2019 the winners of the 14 million GBP (16,415,100 EUR) second phase of the Hydrogen for Transport Programme were announced. The winning projects expand the existing refuelling network into new locations, deploy additional vehicles in the UK including fuel cell buses, support decarbonisation and innovation and grow UK hydrogen supply chain and manufacturing.

Green Number Plates

The UK launched plans to consider the use of green number plates[125] for clean cars, vans, and taxis to promote awareness of ultra-low emission vehicles.

[124] https://www.gov.uk/government/news/23-million-boost-for-hydrogen-powered-vehicles-and-infrastructure

[125] https://www.gov.uk/government/news/green-number-plates-for-clean-vehicles

As well as promoting zero emission vehicles, green number plates could help support local incentives for electric vehicles such as access to bus or low emission vehicle lanes, electric charging bays or ultra-low-emission-zones.

The plans are part of a forthcoming government consultation announced today (9 September 2018) which will seek views on whether green plates could work in the UK, and if so, what they should look like.

Research and Development

The UK has awarded over 300 million GBP (351,752,000 EUR) in grants via Innovate UK into ultra low emission technologies. The Government has been supporting vehicle manufacturers, technology companies and academia in delivering a major programme of R&D into cleaner vehicle technologies. The programme is delivered via Innovate UK.

The UK Government, through the Advanced Propulsion Centre[126] (APC), Faraday Battery Challenge[127] and Connected and Autonomous Vehicles[128] (CAV) programmes, is supporting the development of low carbon and CAV technologies that will form the basis of future low carbon vehicle supply chains. The UK Government and industry have committed around 1 billion GBP (1.2 billion EUR) over 10 years to 2023 through the Advanced Propulsion Centre (APC), to research, develop and commercialise the next generation of low carbon technologies Since it was announced in July 2013, APC has awarded 44 collaborative R&D projects worth 741 million GBP (868,828,000 EUR).

The Government will commit 246 million GBP (288,437,000 EUR) to the Faraday Battery Challenge. This will ensure the UK builds on its strengths and leads the world in the design, development and manufacture of electric batteries. EPSRC has invested 55 million EUR (64,487,900 EUR) in the Faraday Institution.

Government is investing 250 million GBP (293,127,000 EUR) to position the UK at the global vanguard of the development, demonstration and deployment of CAVs. This includes collaborative R&D projects and capitalising on our renowned test tracks, and our competitive advantage, enabled through our open regulatory regime, of being able to test anywhere in the UK today.

[126] https://www.apcuk.co.uk/

[127] https://faraday.ac.uk/

[128] https://www.gov.uk/government/organisations/centre-for-connected-and-autonomous-vehicles

39 United States

39.1 Major Developments in 2018

The United States (U.S.) population continues to rely on vehicles for personal transportation. Cumulative 2018 national vehicle miles traveled (VMT) exceeded the 2017 figures by 0.4% (through October), reaching 2.7 trillion miles.[129] Sales of electric-drive vehicles in the U.S. increased in 2018, surpassing a cumulative total of 1 million PEVs since December 2010. During 2018, there were 50 plug-in electric vehicle (PEV) models sold, including both plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs); as well as 46 hybrid electric vehicle (HEV) models, for total sales of over 718,000 units.[130]

39.1.1 Industry and Market

Some major 2018 EV industry U.S. market developments include:

- GM plans to double its allocated resources for electric and autonomous vehicles in the next two years.[131] Honda and GM will partner to develop a next-generation battery system.[132]
- Ford plans to spend 11 billion USD on all-electric vehicles between 2018 and 2022. It plans 40 electrified vehicles by 2022, 16 BEVs and the rest PHEVs.[133]
- Mazda announced that by 2030, it expects that internal combustion engines combined with some form of electrification will account for 95 % of its vehicles and battery electric vehicles for the remaining 5 %.[134]

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[129] U.S. Federal Highway Administration. “Traffic Volume Trends - October 2018”,. October 2018

[130] Argonne National Laboratory, “Light Duty Electric Drive Vehicles Monthly Sales Updates“. Data sourced from Hybrid Cars monthly sales dashboards (Note: Post-June 2018 HEV sales are estimates)

[131] “General Motors Accelerates Transformation” General Motors Company. Accessed 11 January 2019

[132] “Honda Partners on General Motors’ Next Gen Battery Development.” media.gm.com, 7 June 2018

[133] “Ford Plans $11 Billion Investment, 40 Electrified Vehicles by 2022.” Reuters, 16 January 2018

[134] “Mazda Announces Electrification and Connectivity Strategies for Cars That Invigorate Mind and Body” Inside Mazda. Accessed 11 January 2019

- Daimler plans to develop over ten different all-electric vehicles by 2022, as well as the associated charging infrastructure (forming its "ecosystem")[135]
- Nissan unveiled its *Nissan Energy* system which allows its EVs to connect with energy systems for charging its batteries, or to feed energy back to power grids. The company will also develop new ways to reuse electric car batteries.[136]
- In 2019, every new Volvo will be electrified. By 2021, Volvo will have five new full EVs in its lineup, and by 2025, over one million of its EVs on the road.[137]
- The Volkswagen Group is proceeding with its transformation to e-mobility. Sixteen VW Group locations around the globe will produce battery-powered vehicles by the end of 2022.
- Tesla became the top seller of luxury cars in the U.S. In the small and midsize luxury car category, Tesla Model 3 sold more than twice that of the runner-up. From January to November 2018, Tesla Model 3 sold about 114,160 units.[138]
- Electric scooters made a debut in cities across the U.S. through several companies (e.g., Bird, Lime). An electric scooter is a two-wheeled kick scooter with an electric motor. A key related innovation is development of smartphone apps for its rental business model.[139]
- In addition to light-duty vehicle manufacturers, medium- and heavy-duty vehicle manufacturers also continue to enter the EV market. Daimler deployed its first all-electric truck (a medium-duty *Freightliner* eM2 106) and plans to deliver additional eM2 trucks as well as a small fleet of Class 8 *eCascadia* trucks to the U.S. west coast by 2019.[140] Volvo Trucks plans to begin demonstrations of all-electric VNR heavy-duty trucks in California in 2019, then larger-scale commercialization in North America in 2020.[141]

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135 "Plans for More than Ten Different All-Electric Vehicles by 2022: All Systems Are Go." marsMediaSite. Accessed 11 January 2019

136 "Nissan to Create Electric Vehicle 'Ecosystem'" Nissan Online Newsroom. Accessed 11 January 2019.

137 "Electric Car Initiative | Volvo Car USA" Accessed 11 January 2019

138 "2018 was an awesome year for Tesla" Clean Technica. Accessed 16 January 2019

139 "Electric scooters' sudden invasion of American cities, explained" Accessed 15 January 2019.

140 "Daimler Trucks North America Delivers Its First Battery-Electric Commercial Truck to Penske Truck Leasing" Daimler. Accessed 16 January 2019

141 "Volvo Trucks to Demonstrate Volvo VNR Electric Models in 2019 and Commercialize in 2020" Volvo. Accessed 16 January 2019

39.1.2 Policy and Government

Several different electric vehicle research and development funding opportunities were released in 2018, from both federal and state sources. Some prominent funding and policy initiatives are briefly summarized below:

- The U.S. Department of Energy (DOE) awarded 19 million USD in funding to 12 cost-shared research projects focused on batteries and vehicle electrification technologies to enable extreme fast charging (*DE-FOA-0001808*)[142].
- DOE also awarded 80 million USD for early-stage research of advanced vehicle technologies (*DE-FOA-0001919*)[143] to 42 projects including:
  - Electric Vehicle Charging R&D (15 million USD) projects to develop technologies to recharge multiple EVs at very high power levels; and software, controls, and hardware to provide physical and cybersecurity protection of EVs and their charging infrastructure.
  - Lithium-ion Battery Research (18 million USD) projects to develop cathode materials for next generation EV batteries that eliminate or significantly reduce the use of cobalt – an expensive, foreign-sourced critical material which could pose a supply risk in the future.
  - Technology Integration (27 million USD) projects to bring together key stakeholders, including those from the *Clean Cities* coalitions, in partnerships to provide data on the impact of mobility services and solutions through real-world testing and validation. The data, analysis, and insights from this work will fill critical information gaps to inform mobility research needs as well as near- and long-term transportation planning to maximize energy efficiency and affordability.
- DOE launched several new initiatives at the national laboratories including:
  - Laboratory Research to enable Next-Generation "Low Cobalt" or "No Cobalt" Cathodes (24 million USD over 3 years). Two National Laboratory teams, led by ANL and LBNL, will develop cathode materials that eliminate or significantly reduce the use of cobalt.
  - Launch of the Battery Recycling Prize (5.5 million USD) to develop and demonstrate profitable business and technology strategies to potentially collect 90 % of lithium-based batteries in the United States at the end of use (unlike lead-acid batteries, which are collected and recycled at a rate of 99 %, lithium-ion batteries are only collected and

[142] "Financial Opportunities: Funding Opportunity Exchange DE-FOA-0001808" EERE Funding Opportunity Exchange. Accessed 11 January 2019

[143] "Financial Opportunities: Funding Opportunity Exchange DE-FOA-0001919" EERE Funding Opportunity Exchange. Accessed 11 January 2019

recycled at less than 5 %) implement cost-effective, automated methods or technologies for separation and sorting of various collected battery types and sizes, develop cost-effective methods or technologies that will render lithium-based batteries safe or inert during storage, and investigate technologies that reduce the hazardous classification of lithium-based batteries in order to reduce shipping cost.

- Establishment of the Lithium-ion Battery Recycling R&D Center (15 million USD over 3 years) to support early-stage research at National Laboratories, U.S. universities and U.S. industry focused on the development of recycling processes to affordably recover critical materials from collected batteries. The Center includes the labs ANL, NREL, and ORNL and will develop and scale-up new processes to enable cost-effective recovery of multiple battery materials (cathode, anode, electrolyte salts, etc.) of current lithium based batteries and methods to re-introduce these materials into the material supply chain for future battery technologies. It will also investigate new electrode and cell designs that enable more effective material recovery at end-of-life. The value and impact of second-life applications also will be explored.

State level funding opportunities and initiatives include:

- California Governor Edmund G. Brown Jr. signed Executive Order B-48-18,[144] directing all state entities to work with the private sector and appropriate levels of government to put at least 5 million zero-emission vehicles (ZEVs) on California roads by 2030. The California Air Resources Board (CARB) voted to extend the *Low Carbon Fuel Standard* by ten years (to 2030) and to double its carbon intensity reduction target from 10 % to 20 %.[145] In addition, up to 29 million USD is now available through the *Southern California Incentive Project* (SCIP) to install charging stations in the counties of Los Angeles, Orange, Riverside, and San Bernardino. SCIP is an initiative of the *California Electric Vehicle Infrastructure Project* (CALeVIP).[146]
- Under a proposal submitted to the California Public Utilities Commission, San Diego Gas and Electric sought approval to build charging infrastructure

[144]"Executive Order B-48-18; Zero Emission Vehicles" BOMA California. Accessed 14 January 2019

[145]"CARB extends Low Carbon Fuel Standard by 10 years, doubles the intensity reduction target to 20%" Green Car Congress. Accessed 14 January 2019

[146]"Up to $29M available for public EV chargers in SoCal; SCIP accepting applications" Green Car Congress. Accessed 14 January 2019

to support deployment of about 3,000 medium and heavy-duty electric vehicles.[147]

- *Electrify America* announced its next 200-million USD investment in zero emission vehicle (ZEV) infrastructure as well as education and awareness in California. These plans are outlined in its *Cycle 2 California ZEV Investment Plan* which was submitted to CARB and approved in December 2018.[148]
- Maryland bill SB 1234 requires it to ensure that a percentage of the light-duty vehicles purchased for its vehicle fleet are zero-emission vehicles, over specific fiscal years. The legislation requires certain units of the state government to annually submit (by 1 December) to the General Assembly a report on the total number of light-duty vehicles and those of zero-emission, light-duty vehicles purchased over the prior 12 months.[149]
- Since New York State launched the Charge NY initiative (in late 2017), more than 5,750 consumers have received rebates to buy EVs. In addition, through EVolve NY, the New York Power Authority committed up to 250 million USD (through 2025) for initiatives to address key infrastructure and market gaps to the adoption of EVs throughout the state. EVolve NY helps accelerate the Governor's Charge NY 2.0 program to launch 10,000 EV charging stations by 2021.[150]
- Seattle, Washington Mayor Jenny Durkan released an executive order in September 2018, pledging to reduce the city's current 4,150-vehicle fleet by 10 % by 2020. Concurrent with that goal, the city aims to pursue electrification of future fleet vehicle purchases. Seattle plans to have a "fossil fuel-free fleet by 2030," according to an April 2018 executive order.[151]

[147]"SDG&E Seeks Approval to Build Charging Infrastructure to Support ~3,000 Medium/Heavy Electric Vehicles" Green Car Congress. Accessed January 11, 2019

[148]"Electrify America announces $200M Cycle 2 zero emission vehicle investment plan for California" Green Car Congress. Accessed Janyary 14, 2019

[149]"Procurement - State Vehicle Fleet - Zero-Emission Vehicles" General Assembly of Maryland. Accessed 14 January 2019

[150]"Evolve NYC" NY Power Authority. Accessed 14 January 2019

[151]"Mayor Durkan Signs Executive Order Eliminating 10% of the City's Car Fleet" Seattle Office of the Mayor. Accessed 16 January 2019

39.2 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 2018. It also includes an overview of the prices of the most popular-selling hybrid and electric vehicles. Figure 1 shows the 2018 sales for the top 9 U.S. market leaders. It is observed that HEV sales declined slightly to 356,853 in 2018[152] from 370,685 in 2017. There were 46 different models sold across 23 manufacturers. The top-selling models include Toyota Prius Liftback, Ford Fusion Hybrid, Toyota RAV4, and the Kira Niro, which account for 53 % of the U.S. HEV market. The Toyota Prius lineup shrank to 18 % of total market share (versus 24 % in 2017) as other manufacturers introduce new hybrids, but Toyota and Lexus together exceed half of the U.S. HEV market.

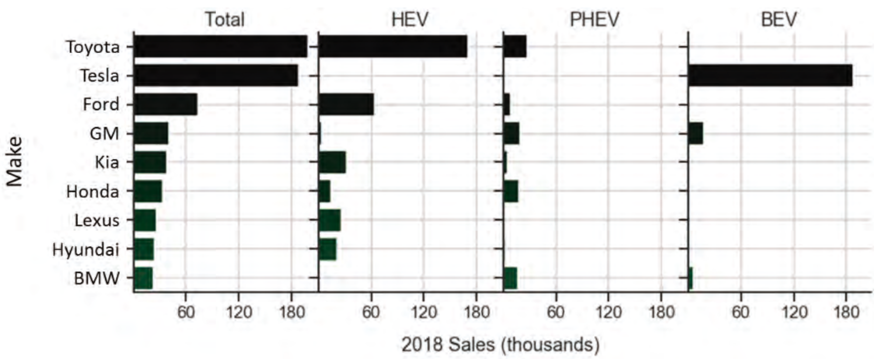


Figure 1: 2018 sales of electrified vehicles for market leaders (90 % of U.S. electrified vehicle sales). (Data source: Argonne National Laboratory, post-June 2018 HEV sales are estimated)

Figure 2 illustrates cumulative sales for HEVs, BEVs, and PHEVs over January – December 2018. It is observed that while the HEV and PHEV sales show a relatively steady profile, the BEV sales seem to show an upward trend during the second half of the year – this trend is primarily driven by increasing Tesla sales.

Figure 3 shows the evolution of the U.S. HEV market (over the past 14 years) for prominent manufacturers (only manufacturers with over 2 % of the market for a given year are included). The corresponding information for the PEV market (over the last nine years) appears in Figure 4.

152 Argonne National Laboratory, "Light Duty Electric Drive Vehicles Monthly Sales Updates". Data sourced from Hybrid Cars monthly sales dashboards (Note: Post-June 2018 HEV sales are estimates)

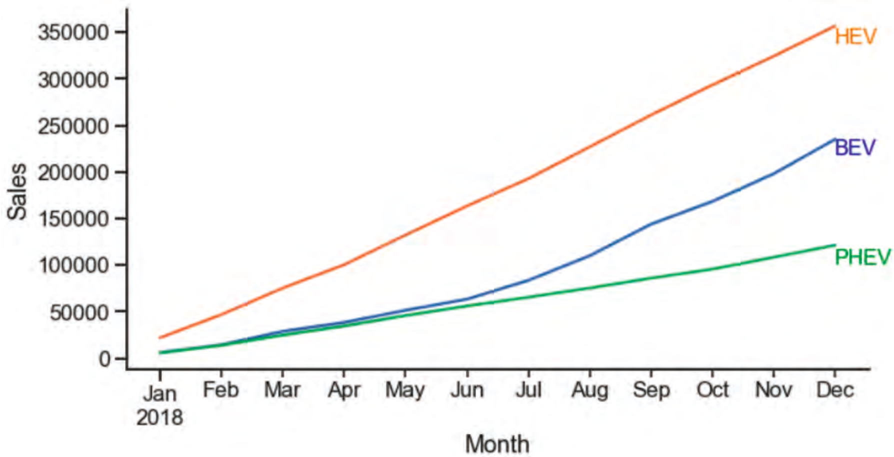


Figure 2: Cumulative sales of electrified vehicles in 2018, not including FCEVs. (Data source: Argonne National Laboratory, post-June 2018 HEV sales are estimated)

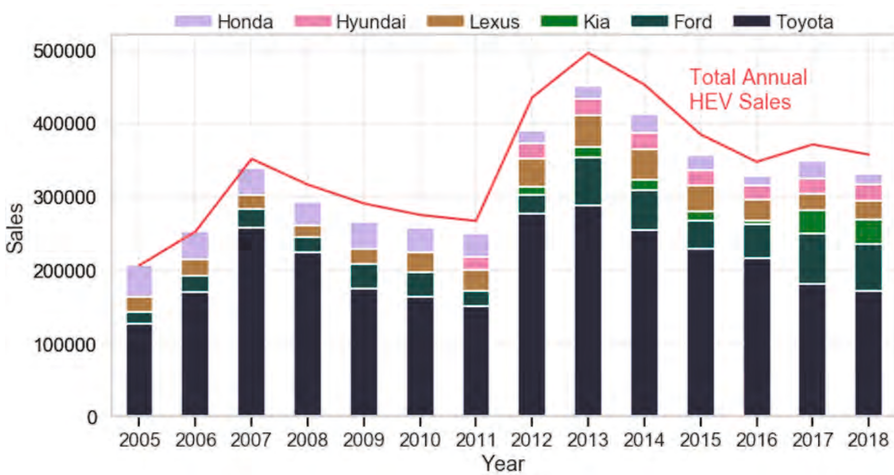


Figure 3: Evolution of the U.S. HEV market over time. Only OEMs with over 2 % of the HEV market are shown in detail (Data Source: Argonne National Laboratory; Post-June 2018 HEV sales are estimated)

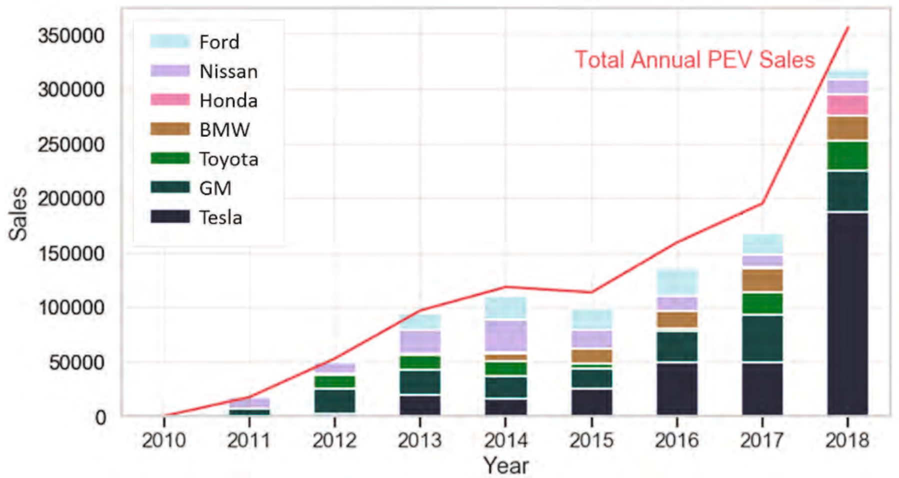


Figure 4: Evolution of the U.S. PEV market over time. Only OEMs with over 2 % of the PEV market are shown in detail (Data Source: Argonne National Laboratory)

In 2018, 50 PEV models were available for sale in the United States, including 20 all-electric (EV) models across 15 manufacturers and 30 plug-in hybrid EV (PHEV) models across 15 manufacturers. The total 2018 PEV sales reached around 360,000 units, nearly double the total sales in 2017. Eight of the PEV models sold over 10,000 units in 2018, including 5 BEVs and 3 PHEVs. The highest-selling 2018 models included the Tesla Model 3, Toyota Prius Prime, Tesla Model S, Tesla Model X, and Chevrolet Volt. Tesla, Chevrolet, Toyota, BMW, Honda, and Nissan cover over 85 % of the full 2018 U.S. PEV market.

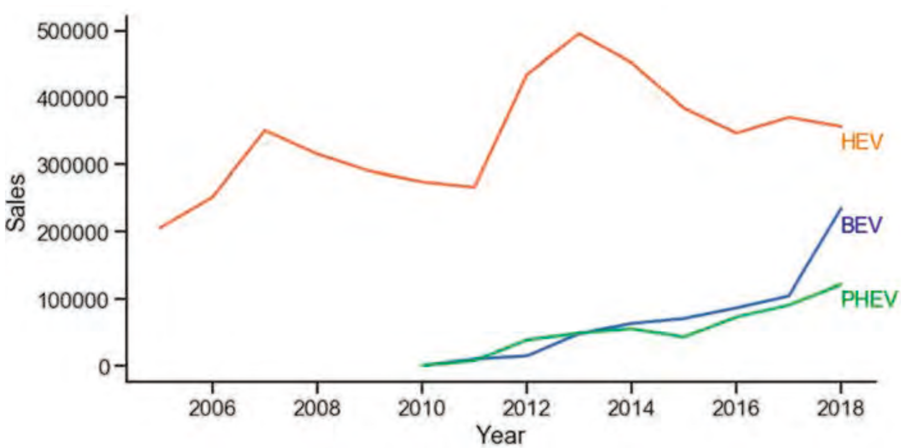


Figure 5: Annual U.S. electrified vehicle sales between 2010 and 2018. (Data Source: Argonne National Laboratory). Note: Post-June 2018 HEV sales are estimated

The 2018 sales data also demonstrate a large increase in Tesla's share of BEV sales; Tesla was responsible for 79 % of BEV sales in 2018 compared to 48 % in 2017. Figure 5 shows annual U.S. electrified vehicle sales over 2010-2018. It captures a spurt in the 2018 BEV sales (which had previously increased only at a rate similar to that for PHEV sales).

Table 2 provides estimated total stock and sales numbers for the electrified fleet, followed by a list of available vehicles and their respective prices in Table 3 for BEVs and PHEVs, respectively.

39.3 Charging Infrastructure or EVSE

Table 1 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. It is seen that from 2017 to 2018, the overall EV charging infrastructure availability in the U.S. grew steadily. The total number of available stations grew from 17,219 to 20,959, or by 22 %. This total increase reflects the respective 22 % and 17 % increases in the number of Level 2 and DC fast-charging stations, which more than offsets the 21 % decrease in Level 1 charging stations. The average number of plugs at each station increased by 5 % for Level 2 chargers and by 31 % for DC fast chargers from 2017 to 2018.

Table 1: Information on charging infrastructure in 2018, excluding non-public charging stations. Numbers represent the total installed stations while those in parentheses indicate the total number of available plugs. (Data source: U.S. DOE AFDC, accessed 7 January 2019)

Charging Infrastructure on 31 December 2018			
Chargers	**2017**	**2018**	**Change**
AC Level 1 Chargers	1,300 (2,604)	1,031 (2,029)	-21 % (-22 %)
AC Level 2 Chargers	15,639 (38,264)	19,008 (48,818)	+22 % (+28 %)
Fast Chargers	2,232 (6,267)	2,620 (9,626)	+17 % (+54 %)
Superchargers (incl. in Fast Chargers)	394 (2,831)	594 (5,413)	+51 % (+91 %)
Totals	**17,219 (47,135)**	**20,959 (60,535)**	**+22% (+28%)**

Figure 6 and Figure 7 show the state-level distribution of charging stations and EVSE plugs respectively for the U.S. California leads other states in the number of charging stations by an order of magnitude. This information is continuously collected by the U.S. DOE's Alternative Fuels Data Center (AFDC), and published on its website.[153]

[153] U.S. DOE Alternative Fuels Data Center Accessed 13 February 2018

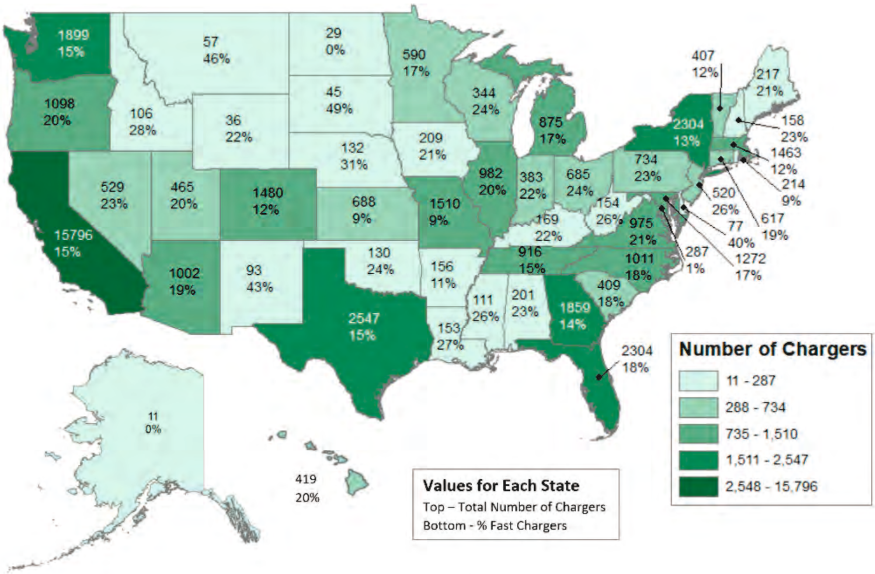


Figure 6: Level 2 and DC fast charge electric vehicle charging stations in the U.S. (Source: U.S. DOE Alternative Fuels Data Center)

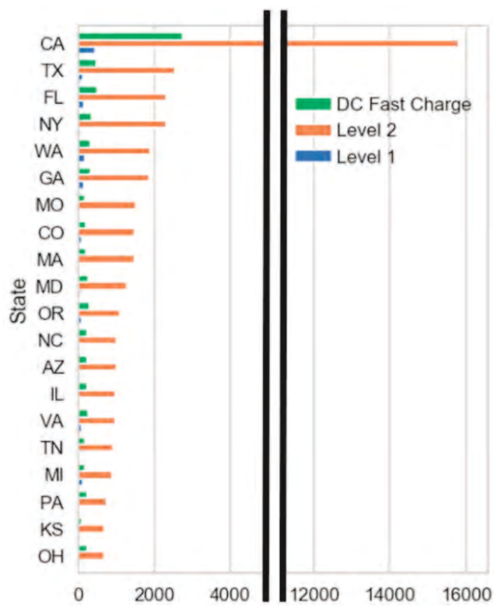


Figure 7: Number of EVSE plugs per U.S. State, grouped by charging level (Source and data: U.S. DOE AFDC, accessed 7 January 2019)

The Edison Electric Institute (EEI) and the Institute for Electric Innovation (IEI) estimated that 9.6 million charging ports will be required in the U.S. by 2030 to support EV sales. As shown in Figure 8, the vast majority of those will be needed for Level 2 home charging.[154]

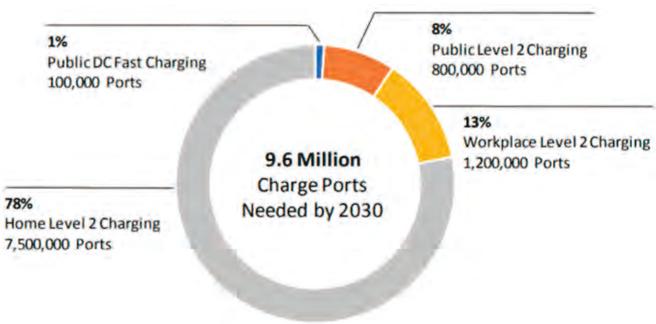


Figure 8: Projected EV charging infrastructure needs in 2030 (Source: EEI / IEI Forecast)

Over the next 10 years, Volkswagen's subsidiary Electrify America will invest 2 billion USD in ZEV infrastructure, access, and education programs in the U.S. This investment results from Volkswagen's emissions tests software settlement with U.S. federal regulators for diesel vehicles.[155] Electrify America is currently implementing the Cycle 1 National ZEV Investment Plan and Cycle 1 California ZEV Investment Plans. Over its first 30-month investment cycle (January 2017-June 2019), it will invest in ZEV infrastructure, education, and access to support increased adoption of ZEV technology.[156] It currently has 55 installed stations and 252 available plugs.

[154] Cooper, Adam, and Kellen Schefter. "Electric Vehicle Sales Forecast and the Charging Infrastructure Required Through 2030" November 2018

[155] "This is Volkswagen's Plan to Electrify America" AutoWeek. Accessed 16 January 2019

[156] "Our Investment Plan" Electrify America. Accessed 16 January 2019

Table 2: Distribution and sales of EVs, PHEVs and HEVs in 2018

Fleet Totals on 31 December 2018					
Vehicle Type	**EVs**	**HEVs**	**PHEVs**	**FCVs**	**Total[d]**
Passenger vehicles[a]	637,425	4,986,911	480,339	6,244	113,000,000
Light trucks[b]					133,000,00
Medium and Heavy Weight Trucks[c]	n.a.	n.a.	n.a.	n.a.	11,499,00

Total Sales during 2018					
Vehicle Type	**EVs**	**HEVs**	**PHEVs**	**FCVs**	**Total**
Electric Bicycles	260,000*	n.a.	n.a.	n.a.	n.a.
Passenger Vehicles[a]	212,723	356,853	114,683	2,662	5,304,985
Light trucks[b]	26,100		7,809	36	11,993,733
Medium and Heavy Weight Trucks[c]	n.a.	n.a.	n.a.	n.a.	732,000
Totals without bicycles	**238,823**	**356,853**	**122,492**	**2,653**	**18,030,718**

n.a. = not available

[a] U.S Cars – Data source: Argonne National Laboratory, “Light Duty Electric Drive Vehicles Monthly Sales Updates”. Data sourced from Hybrid Cars monthly sales dashboards. (Note: Post-June 2018 HEV sales are estimates)

[b] U.S. Class 1-2 Trucks (<10,000 lbs. GVWR) - Data source: Argonne National Laboratory, “Light Duty Electric Drive Vehicles Monthly Sales Updates”. Data sourced from Hybrid Cars monthly sales dashboards. (Note: Post-June 2018 HEV sales are estimates)

[c] U.S. Class 3-8 Trucks

[d] Including both conventional and alternative technologies – Fleet Totals obtained from the Oak Ridge National Laboratory Transportation Energy Data Book: Edition 37, “Quick Facts”, January 2019

*Estimate from the Light Electric Vehicle Association. Data is a 2017 estimate (latest available)

Table 3: Market-Price Comparison of Selected BEVs and PHEVs in the United States

Market-Price Comparison of Selected BEVs and PHEVs in the United States	
Available Passenger Vehicles (EVs)	**Untaxed, Unsubsidized Sales Price (in USD)**
BMW i3	44,450
Chevrolet Bolt	36,620
Fiat 500e	32,995
Ford Focus	29,120
Hyundai Ioniq	29,815
Jaguar I-Pace	69,500
Mercedes B250e	42,400
Nissan Leaf	29,990

Smart ED	23,900
Tesla Model 3	35,000
Tesla Model S 75D AWD	76,000
Tesla Model X 75D AWD	82,000
Mercedes B250e	42,400
Nissan Leaf	29,990
Smart ED	23,900
Tesla Model 3	35,000
Tesla Model S 75D AWD	76,000
Tesla Model X 75D AWD	82,000
Available Passenger Vehicles (PHEVs)	**Untaxed, Unsubsidized Sales Price (in USD)**
Audi A3 Sportback e-tron	39,500
BMW 330e	45,600
BMW 530e	53,400
BMW 740e	91,250
BMW i3 w/ Range Extender	48,300
BMW i8	147,500
BMW X5 xDrive 40e	63,750
Cadillac CT6	55,090
Chevrolet Volt	33,520
Chrysler Pacifica Hybrid	45,395
Ford C-Max Energi	24,120
Ford Fusion Energi	34,595
Honda Clarity PHEV	33,400
Hyundai Ioniq	25,350
Hyundai Sonata PHEV	25,500
Kia Niro	28,500
Kia Optima	35,390
Mercedes C350e	47,900
Mercedes GLC 350e	49,990
Mercedes GLE 550e	67,000
Mercedes S550e	97,525
Mini Countryman SE	31,895
Mitsubishi Outlander PHEV	34,595
Porsche Cayenne S-E	79,900
Porsche Panamera 4 E-Hybrid	102,900

Toyota Prius Prime	27,300
Volvo XC90 T8 PHEV	53,700
Volvo XC60 PHEV	39,800

39.4 Outlook

Global sales of light, medium, and heavy duty PEVs are estimated to continue growing according to revised forecasts from Bloomberg New Energy Finance which forecasts that EVs will become cheaper to make than gasoline vehicles and will globally sell 30 million units in 2030[157] Based on several independent forecasts, EEI and IEI estimated that U.S. annual EV sales will exceed 3.5 million vehicles by 2030. As indicated, this is supported by a broad industry consensus to increase electrification in the passenger vehicle market over the coming years.

Electrification remains an integral feature of self-driving cars, as evidenced by ongoing test projects at Ford (currently testing it on the Fusion Hybrid), GM (testing on the Bolt EV), Uber (testing on Volvo's XC90 PHEV), Waymo (testing on Chrysler's Pacifica PHEV), and other auto industry members. If this technology achieves the performance and cost claimed by its advocates and remains EV-based, the share of electrified vehicle miles traveled could increase substantially.

[157] Bloomberg New Energy Finance. "Electric Vehicle Outlook 2018" Bloomberg NEF. Accessed 22 January 2019

40 Non-Member Countries

40.1 China

40.1.1 Major Developments in 2018

In 2018, the production and sales of new energy vehicles were 1.27 million units and 1.256 million units respectively, increased by 59.9 % and 61.7 % respectively over that of the same period of last year. Among them, the production and sales of battery electric vehicles were 986,000 units and 984,000 units respectively, increased by 47.9 % and 50.8 % respectively over that of the same period of last year; the production and sales of plug-in hybrid vehicles were 283,000 units and 271,000 units respectively, increased by 122 % and 118 % respectively over that of the same period of last year; fuel cell vehicle production and sales were 1,527 units.

The production and sales of battery electric passenger cars were 792,000 units and 788,000 units respectively, increased by 65.5 % and 68.4 % over that of the same period of last year; the production and sales of plug-in hybrid passenger vehicles were 278,000 units and 265,000 units respectively, increased by 143.3 % and 139.6 % over that of the same period of last year. The production and sales of battery electric commercial vehicles were 194,000 units and 196,000 units respectively, increased by 3 % and 6.3 % over that of the same period of last year. The production and sales of plug-in hybrid commercial vehicles were 6,000 units, decreased by 58 % over that of the same period of last year.

40.1.2 Policies and Incentives

In February 2018, the Ministry of Finance, National Development and Reform Commission, the Ministry of Industry and Information Technology, and the Ministry of Science and Technology jointly issued the *Notice of the four ministries and commissions on Adjusting and Improving the Financial Subsidy Policy for the Promotion and Application of New Energy Vehicles* (Cai-Jian [2018] No. 18, hereunder abbreviated as Subsidy Policy). The new Subsidy Policy further improves the energy density threshold requirements for battery electric passenger cars, non-fast charge battery electric buses and special vehicles traction battery systems according to the progress of traction battery technology, and encourage the application of high performance batteries. It improves the energy consumption requirements for complete new energy vehicles, encourages the promotion of the products of low energy consumption, and constantly improves the technology threshold for fuel cell vehicles.

For battery electric passenger cars, it is stated in the new Subsidy Policy that: Subsidy Amount of a Single Car = Mileage Subsidy Standard × Battery System Energy Density Adjustment Coefficient × Vehicle Energy Consumption Adjustment Coefficient. Unit battery power subsidy shall not exceed RMB 1,200/kWh. For Plug-in hybrid electric vehicle (including range-extended): Subsidy Amount of a Single Car = Mileage Subsidy Standard × Battery System Energy Density Adjustment Coefficient × Vehicle Fuel Consumption. The subsidy for a fuel cell electric vehicle is RMB 200,000 Yuan (approx. 26,500 EUR).

Table 1: Subsidy based on range in 2018 (Data source: Ministry of Finance, 10,000 RMB = 1,325 EUR)

Subsidy based on vehicle range in 2018	
Range	**Subsidy (RMB: Yuan)**
100km≤R＜150km	0
150km≤R＜200km	15,000
200km≤R＜250km	24,000
250km≤R＜300km	34,000
300km≤R＜400km	45,000
R≥400km	50,000
R≥50km for plug-in hybrid (including range-extended)	22,000

In July 2018, the State Council printed and distributed the Three-year Action Plan on Defending the Blue Sky, clarifying the general ideas, basic targets, main tasks, and assurance measures for atmospheric pollution prevention and control, proposing the schedule and roadmap for defending the blue sky. The focus lies on regions such as Beijing-Tianjin-Hebei and surrounding regions, the Yangtze River Delta region as well as the Fenhe and Weihe plain, to continuously implement prevention and control action of atmospheric pollution.

- Production and sales of new energy vehicle should reach approximately 2 million units as of 2020
- Accelerate and propel the use of new energy vehicles or clean energy vehicles for addition and update of public buses, environmental sanitation vehicles, postal service vehicles, taxis, shuttle buses, and light-duty logistic

distribution vehicles in urban built-up area, so that the use proportion reaches 80 % in key regions

- Mainly use new energy vehicles or clean energy vehicles for addition or replacement of operation vehicles in port, airport and railway goods yard in key regions
- By the end of 2020, replace all public buses in urban built-up areas with new energy vehicles in municipalities directly under the Central Government, provincial capital cities and cities directly under State planning in key regions
- Grant exemption from vehicle purchase tax to new energy vehicle meeting conditions, and continue to execute and optimize vehicle (vessel) tax deduction or exemption policy for energy saving and new energy vehicle (vessel)

40.1.3 Cities New Energy Car Sales of Major Manufacturers

The new energy car sales of major manufacturers were as follows. BYD was the champion, followed by BAIC BJEV and SAIC.

Table 2: New energy car sales of major manufacturers (Data source: manufacturers and CPCA)

New energy car sales in 2018	
Manufacturer	**Sales**
BYD	247,811
BAIC BJEV	158,012
SAIC passenger car	96,000
CHERY	90,537
CHANGAN	42,410
ZOTYE	33,872
ZD	15,336
JMEV	~50,000
JAC	63,671
Hubei	9,722
GAC NE	20,045
NIO	11,348

Table 3: Some available vehicles and prices in China (Data source: D1EV; 10,000 RMB = 1.325 EUR)

Market-Price Comparison of Selected BEVs and PHEVs in China	
Available Passenger Vehicles	**Untaxed, Unsubsidized Sales Price (in RMB, Yuan)**
BYD YUAN EV360	79,900 - 99,900
CHERY eQ	159,900 - 171,900
JAC iEV6E	118,500 - 158,800
BYD e5	220,700 - 230,700
BAIC BJEV EC series	59,800 - 61,800
BAIC BJEV EU series	129,900 - 161,900
ROEWE Ei5	128,800 - 158,800
GEELY EMGRAND EV	193,300 - 238,300
YOGOMO E XING	136,800
BAIC BJEV EX series	183,900 - 202,900
BYD TANG	239,900 - 329,900
BYD QIN DM	149,900 - 209,900
BMW 5 series	496,900 - 499,900
ROEWE ei6	201,800 - 222,800
BYD SONG DM	176,900 - 245,900
ROEWE eRX5	231,900 - 285,900
LYNK & CO 01	232,800 - 262,800

40.1.4 Charging Infrastructure or EVSE

According to the data submitted by companies and organizations of China Electric Vehicle Charging Infrastructure Promotion Alliance, by the end of 2018, there were 777,000 charging pillars, including 300,000 public charging pillars and 477,000 private charging pillars. The growth rate was 74.2 % compared to that of last year. Public charging pillars consisted of 170,000 AC charging pillars, 110,000 DC charging pillars and 500 AC and DC integrated charging pillars.

The construction of public charging infrastructure was concentrated. The number of public charging infrastructure in Beijing, Shanghai, Guangdong Province and other NEV development areas took 76.5 %.

40.1.5 Outlook

New energy vehicles developed fast in China. In future, the market share of new energy vehicles will keep growing. The subsidy for new energy vehicles will phase out. The financial policies will support the use of new energy vehicles to keep the steady growth of the industry. To fulfil the goal set by the *Three-year Action Plan on Defending the Blue Sky*, the local governments will formulate detailed policies and measures to promote new energy vehicles. The charging infrastructure construction will be improved further. It is expected to have an output of about 1.6 million new energy vehicles in 2019.

Table 4: Information on charging infrastructure in 2018 (Data source: China Electric Vehicle Charging infrastructure Promotion Alliance)

Top 10 cities/provinces regarding public charging pillar numbers	
City/Province	**Quantity**
Beijing	41,644
Shanghai	39,303
Guangdong	35,928
Jiangsu	30,333
Shandong	20,798
Zhejiang	14,226
Hebei	11,957
Tianjin	11,209
Anhui	10,228
Hubei	9,722

40.2 Japan

40.2.1 Targets

The Japanese Revitalization Strategy Revised in 2015 (Cabinet approval on 30 June 2015) states "(Next-generation automobiles) aim to increase the share of new automobiles accounted for by next-generation automobiles to between 50 % and 70 % by 2030". It followed the "2014 Automobile Industry Strategy" of the Ministry of Economy, Trade and Industry.

Table 1: Diffusion targets by types of vehicles (targets set by the METI)

	2018 Results	2030 Targets
Conventional Vehicles	62.22 %	30 ~ 50 %
Next-Generation Vehicles	37.78 %	50 ~ 70 %
Hybrid Vehicles	32.61 %	30 ~ 40 %
Electric Vehicles	0.53 %	20 ~ 30 %
Plug-in Hybrid Vehicles	0.60 %	20 ~ 30 %
Fuel-Cell Vehicles	0.01 %	~ 3 %
Clean Diesel Vehicles	4.02 %	5 ~ 10 %

In April 2018, the Ministry of Economy, Trade and Industry (METI) launched a Strategic Commission for the New Era of Automobiles, hosted by METI Minister Hiroshige Seko. Since then, the commission has been holding discussions on strategies that the Japanese automobile industry, amid dramatic changes in business environments surrounding automobiles, should take to lead global innovations and proactively contribute to solutions to global issues including climate change. In August 2018, METI released an interim report based on the commission's discussion results.

The report set a long-term goal that Japan should achieve by 2050, including:

- Advance the shift of vehicles produced by Japanese automakers in global markets to xEVs (electrified vehicles, including battery electric vehicles, plug in-hybrid electric vehicles, hybrid electric vehicles, and fuel cell electric vehicles)
- Bring about environmental performance at the world's highest level and
- Contribute to realizing a "Well-to-Wheel Zero Emission" policy (to reduce emissions of a vehicle's total emissions footprint to zero, from fuel and power production to automobile operation)

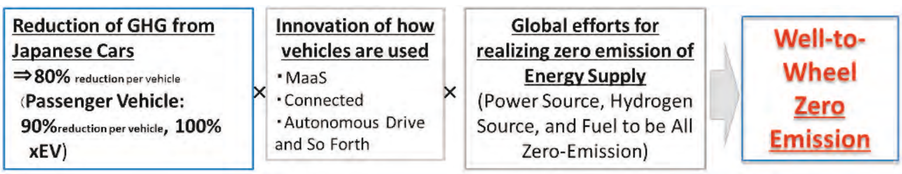
Moreover, the report set basic policies and concrete key actions to achieve these long-term goals.

Long-Term Goal (by the end of 2050)

- 80 % reduction of GHG emission per vehicles (90 % reduction for passenger vehicles, 100 % xEV) produced by Japanese automakers
- Realizing "Well-to-Wheel Zero Emission" in collaboration with global efforts to achieve zero emissions from energy supply and with innovation in how vehicles are used.

Strategy

- Three principles (OPEN Innovation, Cooperate GLOBAL issues, Establish SYSTEM) and key actions in the next five years



40.2.2 Clean Energy Vehicle Promotion Subsidy

A subsidy of passenger cars is available for electric vehicles (EVs), plug-in hybrid, vehicles (PHEVs), clean diesel vehicles (CDVs) and fuel-cell vehicles (FCVs).

- **EVs and PHVs**: up to 400,000 JPY (3,571 USD)
- **CDVs**: up to 150,000 JPY (1,339 USD)
- **FCVs**: up to 2,080,000 JPY (18,571 USD)

40.2.3 Taxation

EVs, PHVs, CDVs, and FCVs are exempt from paying "automobile acquisition tax" (local tax: registered vehicles: 3 %; light motor vehicles: 2 %) and "motor vehicle tonnage tax" (national tax at 1st & 2nd inspection) and "automobile tax" (local tax: partially exemption).

HEVs are partially exempt from paying "automobile acquisition tax" and "motor vehicle tonnage tax" and "automobile tax".

40.2.4 HEVs, PHEVs and EVs on the Road

As of the end of 2018, cumulative EVs/PHVs/FCVs sales were over 250,000 in Japan. In 2018, there were about 4.39 million newly registered passenger vehicles in Japan. Of this newly registered total sum, 1,431,980 were HEVs, 26,533 were EVs, 23,224 were PHEVs, and 612 were FCVs.

Table 2: Available vehicles and prices (Data source: Next generation vehicle promotion center; Currency Rate : 112 JPY = 1 USD)

Market-Price Comparison of Selected EVs and PHEVs in Japan	
Available Passenger Vehicles	**Untaxed, Unsubsidized Sales Price (in JPY and USD)**
Mitsubishi i-MIEV(2018 model)	2,730,000 ; 24,375
Mitsubishi Outlander PHEV(2019 model)	4,713,000 ; 42,080
Nissan Leaf S	2,917,000 ; 26,045
Porsche Panamera4 E-Hybrid	13,296,297 ; 118,717
Tesla Model S 75	8,296,296 ; 74,074
Toyota Prius Plug-in S	3,020,000 ; 26,964
VW Golf GTE	4,342,593 ; 38,773
VW Passat GTE	4,897,222 ; 43,725
Toyota MIRAI (FCV)	6,736,000 ; 60,143
Honda CLARITY FUELL CELL	7,104,000 ; 63,429
BMW i3	4,620,370 ; 41,253
BMW i8	18,787,037 ; 167,741
Volvo XC90	9,712,963 ; 86,723
Mercedes Benz GLC350 e 4MATIC	8,222,223 ; 73,413

40.2.5 Charging Infrastructure or EVSE

METI have provided to support charging infrastructure by a subsidy of "Promotion Project to Develop Charging Infrastructure for Next-generation Vehicles". As of the end of 2018, over 30,000 public charging stations including over 7,600 quick chargers were installed in Japan. Many private companies such as four Japanese car manufacturers' joint company[158] take an active role in installing quick chargers and normal chargers in response to the government.

[158] four car makers' joint company; - Toyota Motor Corporation, Nissan Motor Co., Ltd., Honda Motor Co., Ltd., and Mitsubishi Motors Corporation jointly established a new company in 2014, to promote the installation of chargers for electric-powered vehicles (PHVs, PHEVs, EVs) and to help build a charging network that offers more convenience to drivers who can use associated majority of public chargers by one membership cards in Japan

Table 3: Information on charging infrastructure in 2018 (Data source: Zenrin and Tesla)

Charging Infrastructure on 31 December 2017	
Chargers	**Quantity**
AC Level 1 Chargers	22,287
CHAdeMO	7,684
Superchargers	90
Totals	**30,061**

40.3 Morocco

40.3.1 Major Developments in 2018

Transport is the second polluting sector in Morocco and a major source of gas emissions; it is responsible for 15 % of the total emissions of the kingdom. The major problem is that the transport sector absorbs 35 % of national energy consumption including 50 % of petroleum products (Source: IRES).

For these reasons and because the transport remains an essential link in the development of the country's economy, the interest in electric mobility has increased over the past few years in Morocco. In addition, many automobile manufacturers commercialized their first modern electric models, proving that the electric drive is technically viable, environmentally friendly and affordable and it is a better solution in order to improve Moroccan economy.

In a few years, the Kingdom has become the leading automotive producer at the continental level with 340,000 vehicles a year. A total of 26 projects were approved in 2018 for a total investment of 1,300 million Euros in this sector. The Renault-Nissan-Mitsubishi Alliance recently announced the modernization and doubling of SOMACA's production capacity in Casablanca to reach 160,000 units by 2022 compared to 80,000 currently.

Morocco plans to reach 18,500 million Euros for export by 2025, with a production capacity of one million vehicles per year. (Source: Ministry of Equipment and Transport).

40.3.2 Continued Research, Development and Innovation

For several years the Research Institute in Solar Energy and New Energies (IRESEN) has been studying the development of an electric mobility/energy production integrated system from renewable sources/management. The application of this research and development works is the integration of alternative sustainable mobility systems, intelligent transport systems, charging infrastructures, and electric vehicles.

Another field is the experimental study of the impact of high temperatures in African countries on the charging process. It gives information to build simulation models of energetic flows inside the battery. This study wants to define and experimentally evaluate the best control strategies for optimal management of the battery during charging.

In 2018, IRESEN started working on innovative projects that focus in charging infrastructures, developing new innovative technologies, efficient and cheaper, especially for the African market. The institute launched new challenges in R&D, including studies and researches to realize support instruments for planning and/or evaluating electric mobility and developing new technologies, especially the investigation of the impacts of electric mobility on the transport system in urban context.

Otherwise, The PSA group, a French multinational manufacturer of automobiles and motorcycles sold under the Peugeot, Citroën, DS Automobiles, Opel, and Vauxhall Motors brands, signed an agreement with several academic institutions in Morocco to launch OpenLab, a research center where sustainable mobility systems will be explored for four years. The research center for sustainable mobility focus on electric mobility of the future for the development of electric traction chains adapted to African markets, renewable energies to promote the deployment of ecological and economic energy chains, seeking the best match between the supply chain needs of a production site and local constraints.

40.3.3 Initiative

Continuing the development of the automotive sector, Morocco has undertaken the development of the electric vehicle sector by addressing part of the value chain through an open partnership strategy at a worldwide level. It pushes for the opening of the market by launching first country field experiments on its territory. The COP22 in Morocco offered a unique opportunity to launch in Marrakech global dynamics of the electric vehicle following on the successful announcement of the global coalition of electric mobility in Paris by the Kingdom during COP21.

With support and heavy involvement of its international partners, industry and academia, Morocco is igniting the promotion of the creation of an International Association of Electric Mobility whose main objective would be the opening of the worldwide market.

In parallel to this approach, Morocco set up a tripartite operational cooperation between the Cities of Kénitra (Morocco), Ales (France) and Starkville (United States). These three Cities are intended to implement a real model of urban electric mobility and thereby be high level technology showcases.

To make this vision possible, a reflection is engaged with the General Direction of Taxes in the Kingdom in order to think about incentive measures and adapted taxation schemes. A specific ultra-modern environment shall be available to worldwide professional actors trough Green Tech Valley in Salé, a local HUB open to Africa.

40.3.4 HEVs, PHEVs and EVs on the Road

Only 78 electric cars are listed on the market in 2018, 0.02 % of the car fleet in Morocco (source: Federation of Energy). 1,000 fully electric hybrid vehicles, 10 electric buses and approximately 1,000 electric motorcycles. The most popular electric vehicles in Morocco are Renault ZOE.

The car supply in Morocco consists of 34 brands, marketed by importers/distributors. In 2017, three brands market models of electric cars in Morocco, namely Renault (Full electric: Twizy, Zoe, Kango ZE), Volvo (PHEV: XC90, XC60), Honda (PSHEV: insight), but in 2018 other brands have put on the market models of hybrid cars BMW, Hyundai, Porsh (source: Federation of Energy). Otherwise a first deployment of 20,000 units of the Chinese brand Yadea is planned through the self-service rental on Medina Bike stations and fleets of professionals and public administrations (Source: Federation of Energy).

On the Moroccan roads a difference in range of electric, hybrid and plug-in hybrid cars can be distinguished between Tesla owned by Moroccan immigrant citizens, Range Rover plug-in hybrids, Toyota hybrids, and Renault ZOE.

This diversity shows the progress of electric mobility in the Kingdom. But which imposes even more challenges regarding charging infrastructures.

Table 1: Distribution and sales of EVs, PHEVs and HEVs in 2018 (Data source: Federation of Energy)

Fleet Totals on 31 December 2018		
Vehicle Type	**EVs**	**PHEVs**
2- and 3-Wheelers[a]	1,000	
Passenger Vehicles[b]	1,078	
Buses and Minibuses[c]	10	10
Light commercial vehicles[d]	n.a.	
Medium and Heavy Weight Trucks[e]	10	n.a.
Totals	**2,108**	

n.a. = not available
[a] UNECE categories L1-L5
[b] UNECE categories M1
[c] UNECE categories M2-M3
[d] UNECE categories N1
[e] UNECE categories N2-N3

Table 2: Available vehicles and prices (Data source: Federation of Energy)

Market-Price Comparison of Selected EVs and PHEVs in Morocco	
Available Passenger Vehicles	**Untaxed, Unsubsidized Sales Price (in EUR)**
Toyota RAV4 Full hybrid	36,100
Renault Zoe R903	38,000
Toyota CHR Full hybrid	28,600
Toyota Yaris full hybrid	21,200
Volvo XC90 PHEV	79,500

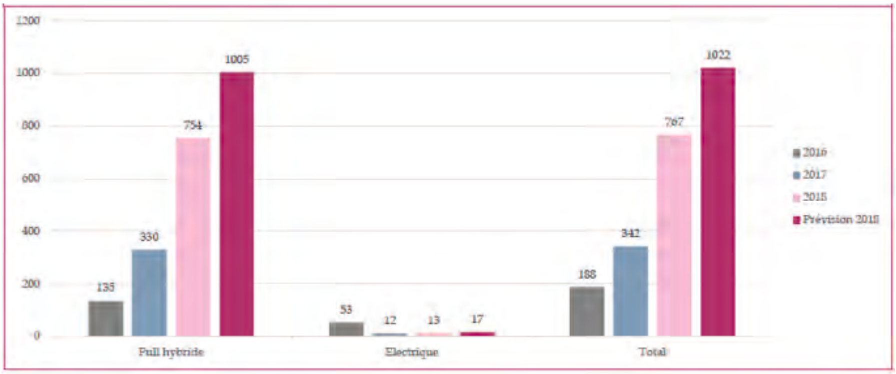


Figure 1: Illustration of the annual sales of fully hybrid and electric cars in Morocco (2016 – 2018) (Source: Federation of Energy)

40.3.5 Charging Infrastructure or EVSE

Getting an up-to-date overview on all charging points available in a country is not an easy task because this information is spread out over the different market players. For statistics on charging infrastructures in Morocco we refer to the website of Plug share and charge map.

Drivers of an electrical vehicle need much more detailed real-time information on the charging infrastructures: location, ways of access, availability, prices, etc. There is still a long way to go, because all this information is scattered over different databases/websites/apps at the moment and not always up-to-date and certainly not available in a standardized way. Thus, big improvements are needed in user-friendly access to charging infrastructures information.

Approximately 53 charging stations were installed including 37 at service stations on the Tangier-Agadir highway axis.

Figure 2: Illustration of the evolution of charging points in Morocco (2017 - 2018) by trimester, and the distribution of the type of charging stations (Source: www.charemap.com)

Table 2: Information on charging infrastructure in 2018 (Data source: Federation of Energy)

Charging Infrastructure on 31 January 2018	
Chargers	**Quantity**
AC Level 1 Chargers	11
AC Level 2 Chargers	24
CHAdeMO	15
CCS	3
Inductive Charging	n.a
Totals	53

40.3.6 EV Demonstration Projects

Green Miles

The Green miles project, which consists of equipping the Tangier-Agadir motorway axis with charging stations, is becoming a reality.

The project to install charging stations at Morocco’s highways is part of a global approach that does not just install the charging stations at resting air level. Indeed the installation of the terminals is done in parallel with the establishment of a system of intelligent communication between terminals, the installation of solar shading, to produce clean energy or the development of all kinds of innovative solutions that can help create the new ecosystem for electric mobility in the Kingdom. So through this project, the two main promoters, namelyIRESEN and Schneider Electric are trying to make fuel distributors and their various partners aware of the need to switch to renewable energies. What’s more, it would reduce their bills considerably.

Figure 3: Electric vehicle charging stations being implemented within Green Miles project (Source: IRESEN)

VTEEM

VTEEM, the result of the pilot project of the technological platform Marita Groupe / PSA / Renault / MSU is a company based in Kenitra, with its administrative headquarters and new district in Rabat.

They make electric vehicles available to their customers, that are adapted for the state service park, public or private establishments. VTEEM's vision is electric mobility at the service of Moroccan cities for a new model of sustainable and clean transport with an innovative sharing system consistent with the environmental objectives set in the framework of the Moroccan energy strategy.

This new concept has begun to flap by the provision of three electric vehicles for the transport of individuals using the application Careem in Rabat, but users find a problem to adapt with this new concept.

Rabat Sustainable Municipality

On 30 October 2018, the council of the Rabat-Agdal municipality officially announced the launching of an electric motorcycles fleet, for the transportation of employees during its forum Smartaro. The event presented the borough's "Smart" vision and the consecration of the first electric mobility pilot project in partnership with the Solar Cluster and SIE, with the support of GIZ.

In addition, the charging station was coupled with photovoltaic panels to recharge the two wheelers from renewable resources. In this context, several municipalities are beginning to take the initiative to replace their current fleet with 100 % electric vehicles.

40.3.7 Outlook

Morocco expects a real growth in the sale of electric vehicles in coming years. Currently, however, the market is in a period of transition, as companies and cities scale up to meet the demands. The demand for electrical vehicles comes with a few factors that require collaboration between cities and car owners. One of the differences between electric cars and traditional vehicles is that electric vehicles require public charging stations.

Thus, the government is planning on having several commissions integrating different research centers, industrialists and network managers to look at the ecosystem to put in place and establish a clear and precise roadmap.

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Vehicle Categories

In the "On the Road" sections of the country chapters, fleet numbers of motorized road vehicles are presented in a standardized table as much as possible. The definitions of the vehicle categories that are used in these tables are given below.

Table 1: Vehicle Categories

Vehicle	Description
2-Wheelers or "2- and 3- Wheelers"	This category includes e-bikes (two-wheeled vehicle with an electric motor and an appearance similar to that of a conventional bicycle and moped), pedelecs, e-mopeds and e-motorcycles (including e-scooters) running on two or three wheels. UNECE categories L1-L5.
Passenger Cars	Vehicle with a designated seating capacity of not more than 8 seats (in addition to the driver's seat). UNECE category M1.
Buses and Minibuses	Vehicle with a designated seating capacity of more than 8 seats in addition to the driver's seat. UNECE categories M2 and M3.
Light Commercial Vehicles	Commercial carrier vehicle with a gross vehicle weight of not more than 3.5 tons. This category includes commercial vans, pickup trucks and three-wheelers for goods or passenger transport. UNECE category N1.
Medium and Heavy Freight Trucks	Vehicle designed primarily for the transportation of property of equipment. UNECE categories N2 and N3.
Electric Vehicle	An electric vehicle (EV) is defined as any autonomous road vehicle exclusively with an electric powertrain drive and without any on-board electric generation capability. The term battery electric vehicle (BEV) is considered to be a synonymous term.
Hybrid Vehicle	A hybrid vehicle is one with at least two different energy converters and two different energy storage systems (on vehicle) for the purpose of vehicle propulsion. A hybrid electric vehicle (HEV), as defined by the 1990s IA-HEV Annex I, is a hybrid vehicle in which at least one of the energy stores, sources, or converters delivers electric energy. Other definitions of HEVs also exist but involve the same idea of different energy systems. Normally, the energy converters in an HEV are a battery pack, an electric machine or machines, and an internal combustion engine (ICE), although fuel cells may be used instead of an ICE. There are both parallel and series configuration HEVs.

Vehicle	Description
Plug-in hybrid electric vehicle	A plug-in hybrid electric vehicle (PHEV) is an HEV with a battery pack that has a relatively large amount of kilowatt-hours of storage capability. The battery is charged by plugging a vehicle cable into the electricity grid; thus, more than two fuels can be used to provide the energy propulsion.
Plug-in electric vehicle	A plug-in electric vehicle (PEV) is a vehicle that draws electricity from a battery and is capable of being charged from an external source. In this way, the PEV category includes both EVs and PHEVs.
Fuel cell (electric) vehicle	A fuel cell (electric) vehicle (FCV or FCEV) is a vehicle with an electric powertrain that uses the fuel cell as a source of the electricity to provide electric drive. FCVs may also include an electric storage system (ESS) and be HEVs or PHEVs, although an ESS is not technically necessary in an FCV.

Abbreviations

A	Ampere
AC	Alternating Current
ADEME	Agency for Environment and Energy Management (France)
AEV	All-Electric Vehicle
AFDC	Alternative Fuels Data Center (DOE)
AFV	Alternative Fuel Vehicle
ANR	Agence Nationale de la Recherche (France)
APC UK	Advanced Propulsion Centre United Kingdom
APN	Access Point Name
APU	Auxiliary Power Unit
AVEM	Avenir du Véhicule Electro-Mobile (France)
AVTA	Advanced Vehicle Testing Activity
AWD	All-Wheel Drive
A3PS	Austrian Agency for Alternative Propulsion Systems
BC	British Columbia
BDEW	German Association of Energy and Water Industries
BEV	Battery Electric Vehicle
BEVx	BEV with Auxiliary Power Unit
BFH	Bern University of Applied Sciences (Berner Fachhochschule)
BIS	Department for Business Innovation & Skills (United Kingdom)
BMLFUW	Federal Ministry of Agriculture (Austria)

BMVIT	Federal Ministry for Transport, Innovation, and Technology (Austria)
BMWFJ	Federal Ministry of Economy (Austria)
BOMA	Building Owners and Managers Association (British Columbia)
BSS	Battery-Swapping Station
CARB	California Air Resources Board
cc	Cubic Centimeter
CCS	Combined Charging Standard
CCZ	Congestion Charge Zone
CEA	Canadian Electricity Association
CEI-CIVES	Italian EV Association
CEIIA	Centre for Excellence and Innovation in the Auto Industry (Portugal)
CENELEC	European Committee for Electrotechnical Standardization
CERT	Committee on Energy Research and Technology (IEA)
CHF	Swiss Franc (currency)
CIRCE	Research Centre for Energy Resources and Consumption (Spain)
CNG	Compressed Natural Gas
CNR	National Research Council (Italy)
CO_2	Carbon Dioxide
CRD	Capital Region of Denmark
CRM	Customer Relationship Management
DC	Direct Current
DCFC	Direct Current Fast Charging
DEA	Danish Energy Agency (Denmark)

DLR	German Aerospace Center
DKK	Danish Crown (currency)
DMA	Derindere Motor Vehicles (Turkey)
DOE	U.S. Department of Energy
DOET	Dutch Organisation for Electric Transport
DPD	Dynamic Parcel Distribution
DSO	Distribution System Operator
ECV	Electric Commercial Vehicle
ED	Electric Drive
EET	European Ele-Drive Transportation Conference
eMI^3	eMobility ICT Interoperability Innovation Group (Belgium)
ENEA	Italian National Agency for New Technologies, Energy and Sustainable Economic Development
EnEl	Ente Nazionale per l'energia ELettrica
EPA	U.S. Environmental Protection Agency
EREV	Extended-Range Electric Vehicle
ERS	Electric Road System
ERTICO	European Road Transport Telematics Implementation Coordination
ESB	Electricity Supply Board (Ireland)
ETBE	Ethyl Tert-Butyl Ether
EU	European Union
EUL	EcoUrban Living (Finland)
EUR	Euro (currency; the standard "€" abbreviation is used in this report)
EUWP	Working Party on Energy End-Use Technologies (IEA) (this group was previously called the End-Use Working Party)
EV	Electric Vehicle

EVCIS	Electric Vehicle Charging Infra System (Korea)
EVE	Electric Vehicle Systems Program (Finland)
EVS	Electric Vehicle Symposium
EVSE	Electric Vehicle Supply Equipment
EVSP	Electric Vehicle Service Provider
EVX	(Global) Electric Vehicle Insight Exchange
ExCo	Executive Committee (IA-HEV)
FCV	Fuel Cell Vehicle (also called a Fuel Cell Electric Vehicle [FCEV])
FEUP	Faculdade de Engenharia da Universidade do Porto (Energy Faculty of the University of Porto) (Portugal)
FFV	Flex(ible) Fuel Vehicle
FHWA	Federal Highway Administration
g	Gram
GAMEP	Office for Electric Mobility (Portugal)
GEM	Global Electric Motorcars
GHG	Greenhouse Gas
GIS	Geographic Information System
GM	General Motors
h	Hour
HEV	Hybrid Electric Vehicle
HGV	Heavy Goods Vehicle
hp	Horsepower
HSL	Helsinki Region Transport
HSY	Helsinki Region Environmental Services Authority

HVO	Hydrotreated Vegetable Oil
H&EVs	Hybrid and Electric Vehicles
IA	Implementing Agreement (IEA)
IA-AMF	Implementing Agreement on Advanced Motor Fuels
IA-HEV	Implementing Agreement for Co-operation on Hybrid and Electric Vehicle Technologies and Programmes
ICE	Internal Combustion Engine
ICS	Inductive Charging System
ICT	Information and Communication Technology
IDAE	Institute for the Diversification and Saving of Energy (Spain)
IEA	International Energy Agency
IEC	International Electrotechnical Commission
IMA	Innovative Mobility Automobile GmbH (Germany)
Inc.	Incorporated
INESC	Instituto de Engenharia de Sistemas e Computadores do Porto (Institute for Systems and Computer Engineering of Porto) (Portugal)
INL	Idaho National Laboratory (DOE)
INTELI	Inteligência em Inovação (Portugal)
ISO	International Organization for Standardization
IT	Information Technology
ITS	Intelligent Transportation System
KAMA	Korea Automobile Manufacturers Association
KETEP	Korea Institute of Energy Technology Evaluation and Planning
kg	Kilogram
km	Kilometer

KORELATION	Cost – Range – Charging Stations (Kosten – Reichweite – Ladestationen) (e'mobile project)
KRW	South Korean Won (currency)
kton	Kiloton
kW	Kilowatt
kWh	Kilowatt-Hour
L	Liter (also spelled Litre)
LCA	Life-Cycle Assessment
LCV	Low-Carbon Vehicle
LDV	Light-Duty Vehicle
LEV	Light Electric Vehicle
Li	Lithium
LPG	Liquefied Petroleum Gas
MERGE	Mobile Energy Resources in Grids of Electricity (Europe)
METI	Ministry of Economy, Trade and Industry (Japan)
MIA	Environmental Investment Allowance (The Netherlands)
min	Minute
MIT	Massachusetts Institute of Technology
MOBI.E	Mobilidade Eléctrica (Portugal)
MOU	Memorandum of Understanding
mpg	Miles per Gallon
mph	Miles per Hour
MPV	Multipurpose Vehicle
MRC	Marmara Research Center (TÜBITAK, Turkey)
MSEK	Million Swedish Krona (currency)
MSRP	Manufacturer's Suggested Retail Price

MVEG	Motor Vehicle Emissions Group (Europe)
MW	Megawatt
MWh	Megawatt-Hour
n/a	Not Available. In the data tables, this abbreviation can mean either no reported data or the technology is not commercially available at present.
NEDC	New European Driving Cycle
NGV	Natural Gas Vehicle
N•m	Newton Meter
NPE	National Platform for Electromobility (Germany)
NRCan	Natural Resources Canada
NREL	National Renewable Energy Laboratory (DOE)
OA	Operating Agent
OCPP	Open Charge Point Protocol
ODD	Turkish Automotive Distributors Association (Turkey)
OECD	Organisation for Economic Co-operation and Development
OEM	Original Equipment Manufacturer
OERD	Office of Energy Research and Development (NRCan)
OLEV	Office for Low Emission Vehicles (United Kingdom)
OPEC	Organization of the Petroleum Exporting Countries
PCM	Phase-Charge Material
PFA	Automobile Sector Platform (France)
PHEV	Plug-in Hybrid Electric Vehicle
PHV	Plug-in Hybrid Vehicle
PIAM	Plan de Incentivos Autotaxi Madrid (Spain)

PIMA Aire	Plan de Impulso al Medio Ambiente (Spain)
PIP	Plugged-in Places (United Kingdom)
psi	Pound-Force per Square Inch
PV	Photovoltaic
QC	Quick Charging
RAI	Royalty Amsterdam International (The Netherlands)
RD	Royal Decree (Spain)
R&D	Research and Development
RD&D	Research, Development, and Deployment (also called Research, Development, and Demonstration)
RDW	Dutch Vehicle Authority
REV	Range Extender Vehicle
RFID	Radio Frequency Identification
RTC	Rotterdamse Taxi Centrale (The Netherlands)
RWE	Name of a German Electric Utility Company (originally Rheinisch-Westfälisches Elektrizitätswerk)
RWS	Rijkswaterstaat (The Netherlands)
SAE	Society of Automotive Engineers
SALK	Belgian Regional Strategic Action Plan (Belgium)
SCT	Special Consumption Tax (Turkey)
SEK	Swedish Krona (currency)
SFOE	Swiss Federal Office of Energy
SI	Système International (International System of Units)
SLF	Shredder Light Fractions
SME	Subject Matter Expert

STM	Société de Transport de Montréal (Canada)
SUV	Sport Utility Vehicle
SWOT	Strengths, Weaknesses, Opportunities, and Threats (a type of planning method or analysis)
t	Metric Ton or Tonne (1 t = 1,000 kg)
TCA	Taxi Centrale Amsterdam (The Netherlands)
TCG	Transport Contact Group (EUWP)
TCO	Total Cost of Ownership
TCP	Technology Collaboration Programme
Tekes	Finnish Funding Agency for Technology and Innovation
TNO	Netherlands Organisation for Applied Scientific Research
TOSA	Trolleybus Optimisation Système Alimentation (Switzerland)
TÜBİTAK	Scientific and Technological Research Council of Turkey
UGAP	Union des Groupements d'Achats Publics (Union of Public Purchasing Groups) (France)
UITP	International Association of Public Transport
ULEV	Ultra-Low Emission Vehicle
UK	United Kingdom
UPS	United Parcel Service (U.S.)
US	United States
U.S.	United States
USA	United States of America
USABC	United States Advanced Battery Consortium
V	Volt
VAMIL	Arbitrary Depreciation of Environmental Investments (The Netherlands)

VAT	Value-Added Tax
VITO	Vlaamse Instelling voor Technologisch Onderzoek (Flemish Institute for Technological Research) (Belgium)
vol-%	Percentage Based on Volume
VPN	Virtual Private Network
VRT	Vehicle Registration Tax
VSST	Vehicle and Systems Simulation and Testing (DOE)
VTO	Vehicle Technologies Office (DOE)
(ANR) VTT	Technical Research Centre of Finland (Valtion Teknillinen Tutkimuskeskus)
VW	Volkswagen
V2G	Vehicle-to-Grid
V2V	Vehicle-to-Vehicle
V2X	Bidirectional Charging
WCC	Workplace Charging Challenge (DOE)
Wh	Watt-Hour
WPT	Wireless Power Transfer
ZHAW	Zurich University of Applied Sciences

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