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Electric Vehicles Charging Infrastructure in Israel

Implementation Policy and Technical Guidelines

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Foreword

The world energy sector in recent years entered a state of turmoil, as several key drivers of market progression shifted direction. Evidently, profound changes to additional established sectors seems to be picking up in pace; there are increasing indications that the ground transportation is on the cusp of such a paradigm shift, powered by technological disruption. The reincarnation of electric vehicles is a growing force, bound to profoundly influence both the energy and the transportation sectors, arguably faster than commonly anticipated.

On a local level, the state of Israel is also experiencing changes, with newly discovered energy resources and a surge of technological progress, but also with an impending crisis in its transportation system. While past attempts to introduce electric cars to the Israeli markets ultimately failed, recent change in global momentum coupled with Israel's needs and know-how, it is now time to go back to the drawing board.

As infrastructure is a closely tied aspect of transportation, it is undeniably critical in the case of electric transportation. The level of investments required and the extent of lifetime such infrastructure is planned for, mandate a systematic approach in planning both the appropriate technical implementation, nonetheless the suitable market structure to support it, with an adequate policy to facilitate them.

The purpose of this study is to provide decision-makers with guidelines for deployment of charging infrastructure for electric vehicles. It is based on a knowledge and lessons learned from international experience, adapted to the unique attributes and needs of Israel, through the use of designated a modelling tools and the methodical consultation with stakeholders.

At present, the dynamic and rapidly evolving market of electric vehicles is going through an exponential growth rate. We did our best to not only reflect the latest developments, but also foresee the implications of measures taken today in shaping the future landscape of electrified transportation. Yet, it is only to be expected that unforeseen developments will see this market materializing in unexpected ways.

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Abbreviations

AC	Alternating Current
BEV	Battery Electric Vehicle
BMS	Battery Management System
BSS	Battery Swap Stations
CO_2	Carbon Dioxide
CPO	Charge Point Operator
DC	Direct Current
DNO	Distribution Network Operator
DSO	Distribution System Operator
EV	Electric Vehicle (both BEV and PHEV)
EVSE	Electric Vehicle Supply Equipment
EVSP	Electric Vehicle Service Provider
GHG	Greenhouse gases
ICE	Internal Combustion Engine
kW	Kilowatt
kWh	Kilowatt-hour
MSP	Mobility service provider
OC	Opportunity Charging
OEM	Original Equipment Manufacturer
PAYG	Pay as you go
PHEV	Plug-in Hybrid Electric Vehicle
PPP	Public Private Partnership
SLA	Service-level agreement
ZEV	Zero Emission Vehicle

Executive summary

Introduction, objectives and methodology

Electrification of the transportation sector serves the goals of reducing oil-dependency, lowering harmful air pollution in densely populated areas and decreasing greenhouse gases emissions, through the superiority of electric drivetrains in energy efficiency, compared to the conventional internal combustion engines. Nonetheless, the electric batteries' lower energy density and lengthy charge time provide inferior utility compared with fuel-based drivetrains, resulting in "range anxiety". Coupled with EVs prohibitive upfront cost, there are substantial market impediments for electric mobility. However, with ongoing improvements in battery range and costs, **the main barrier for EV adoption remains the charging infrastructure availability**. It is essential to avoid overlooking the country-specific and even municipal-level situation, as differences in population spatial dispersal, transportation sector profile, utilities market structure, grid properties and even climate may have profound implications over the appropriate charging infrastructure deployment scheme. The potential benefits in the transition onto more diverse energy sources for transportation, as well as the possible pitfalls and many variables involved, call for a deep investigation into the best policies and practices suitable for the case of Israeli implementation plans.

The objectives of the research are to review the best practices for the deployment of electric vehicle (EV) charging infrastructure, specify optimal models for the Israeli case, and provide actionable guidelines for implementation. **The focus of the research is public infrastructure for passenger electric vehicles and Light Commercial Vehicles** (LCV), which represents the vast majority of the national vehicles fleet. Whereas passenger cars and LCVs commonly rely on home and work charging on off-street parking spaces, such solutions in many cases are either insufficient or simply inapplicable, calling for a publicly-available charging solution. Unlike private charging, public and semi-public charging proves to be of higher complexity, as it may involve more stakeholders and operate under one of many models and market structures; moreover, being a public service mandates a careful consideration of policy and regulation that best serves the greater interest of the public, where there might be some inherent conflicts.

This paper consists of three distinct parts, each based on different methodologies used to draw meaningful insights about field of electric vehicle charging in general, and specifically to shape policy guidelines for the development of this market in Israel:

Part I: Best Practices provides an overview of operational aspect of EV charging, and an international best practices review made of a deep dive analysis of the charging market in the United Kingdom, Ireland, the Netherlands, and the United States of America.

Part II: Stakeholders Feedback entails a summary of findings from a stakeholders' roundtable event which was held as part of the research, based on a methodical discussion regarding the challenges faced in the introduction of EVs and the related charging infrastructure into the Israeli market at scale, as well as brainstorming for possible solutions.

Part III: Charging in Israel explores the prospects of development for the Israeli EV and charging markets, building on an analysis of the status quo in local private transportation sector, a mapping of the related stakeholders in the public and private sectors, and an adoption forecast for EVs and charging infrastructure into the 2020-2025 timeframe.

Operational aspects

Types of EV

In general, electric vehicles can be divided into two main categories:

- **Battery electric vehicles (BEV)** are powered only by their battery and have an electric range that varies between roughly 100 to 500 km.
- **Plug-in hybrid electric vehicles (PHEV)** have a battery with an electric drivetrain, as well as an internal combustion engine (ICE). The all-electric range is roughly 40-60 kilometers, and when the battery charge is low the ICE can be used to either recharge the battery, assist the electric motor, or directly drive the vehicle.

Technical standards

In charging EVs, a distinction is made between "types" of the plug and socket and the charging "mode". Charging modes are differentiated by maximum charging speeds, and communication capabilities. The different modes are applicable on diverse types of plugs or socket-outlets. Standards for the vehicle side of the charging cable are determined by the origin of the vehicle.

Charging mode	Communication	Charging regulation	Maximum current	Maximum power	
				1 phase	3 phases
Mode 1	Not necessary	On board EV	16 A	3.7 kW	11 kW
Mode 2	Only control on charging cable, not bidirectional	On board EV	32 A	7.4 kW	22 kW
Mode 3	Between vehicle and EVSE compulsory	On board EV	70 A	16.1 kW	44 kW
Mode 4	Between vehicle and EVSE compulsory	Off board EV	400A (DC)	240 (DC)	

Normal charging with alternating current (AC) uses either Type 1, 2 or 3 for low to moderate charging rates. For fast charging with direct current (DC), either the CHAdeMO or Combined Charging System (CCS, or COMBO) are used. Where Type 1, 2 & 3 and CHAdeMO require a dedicated inlet in the vehicle, often leading to two separate inlets (for normal and fast charging), CCS supports both AC and DC charging using the same plug and a single inlet in the vehicle.

Types of charging locations and use

A distinction can be made between home charging (sometimes called private charging, on private domain), semi-public, public, and fast charging (22 kW or more). Workplace charging typically takes place at a private or semi-public location, while on-route fast charging along highways would typically be public. Among these options, charging at home and work are widely seen as the preferable solution for EV charging worldwide, and with vehicles typically used for average commuter trips of 20-30 km it should be sufficient. However, servicing visitors and EV drivers without private charging options requires public charging. Fast charging enables longer journeys, but currently takes a small share of the total charging worldwide.

Smart charging

A significant increase in number of EVs is expected to have a big impact over the electric grid. Smart charging allows drivers to charge their car during off-peak hours with lower kWh prices. It offers the opportunity to mitigate energy peaks on the grid of intermittent energy supply from renewable sources through matching energy demand and supply, and using the EVs battery to store energy during peak production and return this energy during peak demand (known as Vehicle-to-Grid, V2G). Utilizing stationary EVs as a storage facility has a value when otherwise needed investments in grid capacity could be avoided. The savings translate to lower costs for all electricity users.

Interoperability and billing

It is ultimately the *user experience* that has the most influence over the adoption of change by the general public. The process of charging should be such that warrants a "friction free charging", meaning that an EV driver should always be assured to be able to charge at any publicly accessible charger, with minimal hustle or uncertainty. This notion includes the availability of relevant information about charging points' location, current status, charging rates (power-wise and cost-wise), and without cumbersome procedures of authentication, billing, disengagement and so on – where the user's ease of use and should be a top priority.

Mobility service providers (MSPs) handle the charging subscription with accompanying charge card and/or app and payment for the charge session, and may provide services such as 'social charging', information about the availability of charge points or the state of charge of your car. In some countries Clearing Houses take the role of connecting different Charge Point Operators (CPOs) and/or MSPs, offering a platform for the exchange of roaming authorization, charge transactions and charge point information data, without requiring bilateral agreements.

From the perspective of the EV driver, interoperability is to be able to charge everywhere at any time with one identification method, regardless the brand or type of the charging station operator and service provider. Therefore EVs, charging facilities and additional services need to be compatible with each other, in order to promote widespread adoption of EVs and to reduce the different regulatory, commercial or political barriers.

Besides the two standard billing models –prepaid and postpaid, the EV owner can also be billed for the purchase of charging services via billing structures such as fixed monthly fee with a certain contracted energy use, or yearly subscription fee and an additional use fee for each charging session.

Business case

While costs of home chargers vary at about €300-€1,500, public chargers are more expensive with costs of about several thousand euros, as public chargers are designed with superior robustness, to allow them to withstand more demanding operational environment. Installation of public chargers entails additional cost components as these involve more intense roadwork, setup etc., compared to garage wall-mounted charging point.

Based on indications from the well-developed market of the Netherlands, the initial cost to install an AC public charger with 2 sockets is about €3,000-4,000 (€1,500-2,000 per charging point), and the running cost for a charger with annual sales of 2,000-8,000 kWh amounts to €930-1,280 per year, respectively. Costs of entry-level 50kW DC fast chargers range from €15,000 to €30,000 for the hardware, with costs of grid connections and construction varying widely, averaging at a total cost for a highway location fast charging station with 2 chargers at about €250,000. The rate between the operational expenditure (OPEX) to capital expenditure (CAPEX), as well as the variability with respect to sales volume, goes to show the importance of charger utilization (i.e. sales) for the business case of public charging.

Global uptake

There are four main barriers for the adoption of EVs: price, total cost of ownership (TCO), range, and infrastructure. The first three barriers are mainly subjected to global technological developments, and while subsidies can mitigate them to some extent, they will be dealt-with even without government intervention and are projected get overcome by 2024 through improvements in charging power and battery capacity and cost. With commercial drivers with high mileage potentially already today at TCO cost parity between EV and ICE, for private drivers in small cars this may take as long as until 2026. As for the charging infrastructure barrier however, countries and municipalities play an important role, by which rollout policies determine the charging availability for EV users.

Market trend

To this date, almost all major OEMs and car brands are committing to electrification of their offerings. By the end of 2016, there were over 2 million EVs on the world's roads, with over 750,000 EV sales that year of which 60% were BEVs. The projected EV deployment scenarios for 2030 are very dependent on global and local policy, battery price and the development of other alternative fuels, buy under any scenario projections reflect significant numbers of EVs in the passenger vehicle stock in 2030.

The global number of charging points – both private and public – was estimated to reach 1.45 million in 2015, of which 190,000 (or 13%) were public charging points. That same year, global public charging displayed growth rates similar to those of the global EV stock (71% and 78%, respectively). The number of publicly available chargers per EV differs a lot per country. A selection of the largest electric car markets indicates that in 2015 the number of EVs per slow public charging point outlet fell in the range of 5 to 15 with a global average of 7.8, and a global average of 45 EVs per public fast charging point (of which 27 were BEVs). The range of variability across countries is much wider for fast-charging infrastructure.

Practices analysis

An in-depth analysis of the policies in place for EVs and charging infrastructure was carried out for the United Kingdom, Ireland, The Netherlands and the United States. These countries were chosen in light of the distinct properties founds in their EV markets, differing on the market model they have for charging infrastructure, the different approach on how to organize EV policy, and the status-quo of EVs and infrastructure uptake.

Market models for charging infrastructure

Two main market models of ownership and operation of EV charging infrastructure can be distinguished: The **integrated model**, in which the charging infrastructure is integrated in the DNO’s (regulated) activities and asset base, which is responsible for the distribution of energy, operation and maintenance of the charging stations, with retail either provided by the DNO or by independent market parties; and the **independent model** where market parties deploy the charging stations independently from the DNO, which has the regulated task to connect the charging points to the grid – just as with any household – but several market parties run the activities to provide the e-mobility user with power.

Comparative analysis

A comparative analysis of the characteristics of the EV scene in the reviewed countries is given in the next table.

Country	United Kingdom (2017)	Ireland (2017)	The Netherlands (2017)	United States (2017)
BEV stock	45,623 (33%); 0.54%	1,948 (73%); 0.47%	21,115 (18%); 1.92%	297,000 (53%); 0.50%
PHEV stock	92,057 (67%); 1.36%	739 (27%); 0.25%	98,217 (82%); 0.28%	266,600 (47%); 0.40%
Total EV stock	**137,680**; **1.9%**	**2,687; 0.7%**	**119,332; 2.2%**	**563,700; 0.9%**
# normal charge points	11,497 (81%)	837 (83%)	32,120 (98%)	40,862 (87%)
# Fast charge points	2,759 (19%, 60 per 1,000 BEVs)	172 (17%, 88 per 1,000 BEVs)	755 (2%, 36 per 1,000 BEVs)	6,266 (13%, 21 per 1,000 BEVs)
Total charge points	**14,256 (104 per 1,000 EVs)**	**1,009 (376 per 1,000 EVs)**	**32,875 (275 per 1,000 EVs)**	**47,128 (84 per 1,000 EVs)**
EVs incentives				
Public charging incentives				 (excluding VW funds for Electrify America program)
Fast charging incentives				
Charging market model	Independent	Integrated	Independent	Independent
Public charging organization	By local authorities, over discrete platforms	By the grid operator	By local authorities, over open-access platform	By charging networks operators and property owners on discrete platforms
# private operators of public charging	5-10	0-5	15-20	10 networks, many property owners
EV market overview	The progressive EV market in the UK is substantially supported by the government's extensive and pragmatic approach to support the growth of both the vehicles as well as charging infrastructure. The UK uses a unique version of the independent e-mobility model for charging infrastructure, and outstandingly has a large number and variety of active stakeholders in the sector.	Characterized by reminiscent of centralized electricity market structure (much in the same way as in Israel), Ireland operates an integrated infrastructure model in which the Distribution System Operator (DSO) integrates the charging infrastructure into their main activities in the electricity sector.	One of the front-runners on realizing EV-charging infrastructure, The Netherlands has an independent e-mobility model were market parties deploy the charging stations independent from the DSO (distribution network operator). Incentives and subsidies are applied as stimulants for innovation, competition, and development of new companies.	propelled by strong incentives at the federal level, the independent US market enjoys a wealth of supportive programs and policy momentum, is also characterized by a great degree of variance in local regulatory framework and adoption in the different states. The commercial sector is well developed and highly competitive, yet suffers from fragmentation resulted by the bottom-up market evolution legacy.
Policy scope	Long term strategy	No defined plans	Five-year plans	On a specific-topic basis
Organization of EV policy	Office for Low Emission Vehicles, a cooperation of multiple ministries	Sustainable Energy Authority of Ireland (SEAI)	One coordinating ministry	Presidential directives, congress laws (acts), several ministries programs

Key lessons learned

These lessons are presented as actionable guidelines, categorized under the topics of Electric vehicles, Public charging infrastructure, fast charging and Organization & communication. To explore specific topics further in depth, see the Lessons learned sections under each country.

Electric vehicles

Incentivize in order to lower TCO

Introduction of incentives proved to be a meaningful catalyst for public EV adoption. All the reviewed countries incentivized electric vehicles and charging infrastructure, each in different ways, improving the TCO. It is important to plan ahead the fadeout of incentives, in order to avoid market uncertainty and shocks to adoption rates.

Differ incentives between BEV and PHEV

Applying same-level incentives for both BEVs and PHEVs might result in a significantly uneven uptake allocation between these alternatives. In the Netherlands, similar tax exemptions to BEVs and PHEVs resulted in about 85% of EVs sold being PHEVs, a relatively high share compared to most other countries. In the other countries, incentives allocation based on weighting the share of electric-only range, battery capacities or tailpipe emissions resulted in a relative balance in market shares with higher rates of BEVs.

Set training programs

Professional personnel including technicians, electricians and emergency forces should undergo dedicated training to familiarize them and allow them to gain experience with EVs an EVSE. Increasing number of automotive technicians will need to know how to safely and effectively service and repair EVs, electricians should be provided with specific training on charging station installation and the relevant national electrical codes, and emergency units should be trained to identify an EV, disable its systems and learn appropriate fire control.

Public charging infrastructure

Provide an exit strategy when funding public charging

Initial deployment of public charging requires subsidizing, especially when aiming to provide wide coverage of the public charging network – nevertheless, it is important to facilitate profitable business models for private investments in charging at scale. Cities in the Netherlands tendered charging infrastructure with their own funding, with contracts focused on improving the business case to lower costs for the city and EV users. In the UK, cities and regions received government funds without a clear exit strategy for when subsidies end, making them dependent on more subsidies. In the US, local governments support property owners in deployment of public chargers using measures aimed at improving the business case of their properties and the services they offer.

An integrated model results in higher costs for public charging infrastructure

An integrated model with the DSO operating public chargers results on the long term in high public investments, lack of competition, higher inefficacy in deployment, lack of innovation and no driver for improvements in the business case.

Mandate national interoperability of charging services

Regulatory measures should be shaped to facilitate publicly-accessible charging, and maintain principles of competitiveness and uniformity. In the UK and US, cities and regions did not demand interoperability in their tenders, unlike municipalities in the Netherlands did. Requirement of interoperability led CPOs and MSPs to a start a foundation to organize interoperability, enabling EV-users to charge everywhere with using a single authentication and payment method, such as one card or app. Lack of mandated interoperability resulted in a fragmented market, which negatively impacts the EV drivers' experience.

Provide uniform charge point requirements

When funding public charging infrastructure for local authorities provide certain uniform requirements on the public charge points, providing scale up of CPs, consistent user experience, efficient application & connection process and lower costs. In the Netherlands, this did not happen because of individual cities making their own specific requirements.

Start with demand driven placement of public CPs

Deployment schemes for public charging should target to mitigate uncertainties regarding demand and its implications, as well as maintain flexibility to accommodate adjustments in EV adoption, travel patterns and charging technology changes. Placement of a CPs upon request of an electric driver assures usage of the charge point, which is essential to the business case of public charging and ease of use for drivers. This placement strategy also provides charging certainty for EV users and is therefore important for the EV sales of OEMs.

Incentivize private and semi-public charge points as well

Charging in semi-public locations is a crucial part of charging market, as it accounts for a large share of vehicles' parking duration. Charging at multi-unit residential, workplace, and other shared parking sites is faces by challenges of cost, fairness, ownership, administration and legal issues, and necessitates dedicated regulatory framework. Incentivizing private and semi-public charge points can lower the need for public charge points which are more expensive and have impact on public space, and also stimulates the EV uptake due to improved TCO.

Realize standards and protocols

Realize clear standards for EVs, charging and communication in line with European or worldwide standards. This creates an open and competitive market which serves the customer.

Fast charging

Tender simple and long-term contracts for fast charging

In the Netherlands, the Ministry of infrastructure released 15-year valid licenses for fast charging (with hardly any requirements) along the highways, resulting in a thorough fast charging network at zero costs for the government. The city of London also tendered fast charging. The city is responsible for extra investments in the local electricity grid.

Tender fast charging sites to avoid 'land grab'

To avoid one operator exploiting all fast chargers (UK), the tendering of separate locations in an early market stage is recommended. Public fast charging stations siting should be planned to reduce range concerns for EVs, by allowing them to complete long range and inter-city trips.

Organization & communication

Define clear EV targets

Setting a clear and realistic yet ambitious target for number of EVs from the onset, results in a national and international benchmark and confirmation of a long-term view, helping to move the focus of the discussion to policy implementation and providing an outlook to stakeholders. Likewise, forming a local Master Plan that identifies EVs as part of the local transportation strategy is a foundational step for communities.

Set a national plan for EV infrastructure (public and private)

A national plan for infrastructure helps regions and big cities without knowledge and experience. The national government can take a role in standardization and knowledge transfer. In the Netherlands lack of plan resulted in different infrastructural models and big differences in numbers of chargers within cities and regions, whereas in the UK the plan includes all aspects of EV and infrastructure. In the US, efforts to promote charging stations installation are sometimes not fully leveraged due to lack of communication and coordination among potential partners about availability of incentives and existing public charging stations.

EV communication on a national level is necessary to create awareness

Setting clear targets, delivering an EV-plan and investing in infrastructure is not enough. Communication on these targets and the 'why' of EV, creates awareness, stimulates action and gives insight, transparency and trust to the market, which is necessary for investments especially in public infrastructure. Public communication regarding EVs should emphasis their economic advantage in total cost of ownership, the superior driving experience and the available incentives, along with the environmental benefits.

Create a EV forum including all stakeholders

Create a stakeholders' forum for EV-policy including businesses, universities, research institutes, the DSO and (local) governments. Creating wide EV support and action plans at national and political level.

Identify and encourage EV 'champions'

Successful initiatives to deploy charging stations are typically led by an internal champion either on the demand side or the supply side. Local government officials and personnel play a critical role in establishing a supportive policy environment for EVs and in implementation.

Stakeholders feedback

In order to facilitate an effective stakeholders feedback, a unique methodology for experts' consultation was developed. The workshop included 32 experts from the government, local municipalities, commercial parties, entrepreneurs, cars importers and representative from the academia. While both national and local level barriers were pointed out, more emphasis was placed over barriers and responsibility for the solutions at the national level.

Challenging business case, the top national-level barrier, is closely tied with the lack of market which was also noted as a barrier for charging. These barriers imply that the infancy of the charging market is hampered by the economics of its limited scale. This calls for a government support in the form of financial backing, as well as in "soft" policy measures to compensate early-adopters and strike more confidence in the commercial sector to expand its efforts in forming this market. As currently the public charging market is virtually inexistent, supporting it with both budget allocation and soft incentives would be negligible in financial terms but could prove to have a huge effect over business risk and consumer psychology.

Issues of availability of public space and its usage are critically important at the municipal level, as this is where ultimately most of the public charging is expected to take place. Competition over parking and curb space is already fierce, amplifying the need to clearly highlight the benefits of EVs replacing ICEs in densely-populated urban areas, as well as the pathways to allow deployment of charging infrastructure in a way that does not impair the utility the residents receive from their city. Careful planning and forethought, coupled with sensible rollout models, should assist in smoother integration of EVs into municipal transportation systems, without unwarranted investments and unneeded interference in the cityscape.

The replacement of oil with electricity for transportation creates a new load demand source for an infrastructure which was not originally designed to handle it. This is challenge for the national electric grid, just as much as it is for local distribution systems, both commonly characterized by old and capacity-constrained infrastructure which are excessively costly to upgrade or replace. While this is not a cause of immediate concern with the current penetration rate of EVs, future-proofing new construction is an obviously needed measure, as well as the consideration of advanced technological solutions – especially utility- and local-level energy storage (for which there is significant Israeli know-how).

As of yet, the regulatory framework for public charging has not matured, reflected by the ambiguity as for the roles of the stakeholders, the market structure rules that shape their business models, and the technical standards and operational norms by which they are required to operate. Globally, these topics are being addressed in ever-growing number of countries, but while convergence of standards provide a path to follow, there are still divergence in approaches for market structure, taxation and regulatory leeway. Principle concepts of open access, accordance with internationally recognized standards, clear and accessible regulation, and shaping the scope of competitiveness in the value chain will go a long way in removing uncertainties.

Charging in Israel

Households

Israel has a population of over 8.5 million and a population growth rate which is the second highest in the OECD at 1.9% average growth in 2012-2014. Over 93% of the 2.37 million household are in urban localities, with 35% of households residing in one of Israel's eight major cities. Yet, 54.9% of employees commute to a workplace out of their locality. Two thirds of household own at least one car, and almost a quarter of households own two cars or more. On average, 12% of household's consumption expenditures is spent over vehicles. These indicators highlight the dominancy of private car ownership even given the extremely high urbanization level. Considering that EVs are often touted as an urban commuter or second car alternatives, the households' car ownership data alludes to the potential market size for EVs in Israel. Yet, looking at other countries as a benchmark for the level of motorization (i.e. the number of vehicles per residents), Israel is much less motorized than most developed nations, arguably leaving ample room for additional growth in its vehicle fleet.

Travel

Compared to other OECD countries, Israel ranked the highest in terms of annual vehicle-kilometers per road network length. While the total travel distance increases, the share of privately owned car in vehicle kilometers further increases as well. The average annual kilometers traveled per car was 16,300 km in 2015, with significantly higher than average travel by fleet cars. The annual travel distance is tightly correlated with the age of the vehicle, with newer cars (up to 4 years old) averaging at 20,500 km per year. The average age of a private car in Israel stands consistently around 6.7 years. Again, compared to OECD countries, Israel has nearly the highest annual distance travelled per vehicle, accentuated by the disproportion to its size. As a point of note, where the average annual travel for a private car in 2016 was 14,447km, PHEVs exceeded the average by as much as 44%.

Fleet

Out of the total 3.09 million motor vehicles in Israel in 2015, 2.58 million were private vehicles, and growing at a significant rate; that year, private cars (excluding taxis) accounted for about 83% of the total number of vehicles in Israel. Japan and South Korea are the most dominant production country of origin, even more so in new car sales. Cars sales in Israel has seen record-breaking sales numbers year over year, with 2016 reaching as high as 286K new cars deliveries, presenting a surge of 35% increase in sales over the prior 3 years, especially in the SUV segment. The general car sales increase trend is arguably fueled by record-low interest rates, coupled with overall strong economy conditions; nonetheless, some also see the lack of adequate public transportation services as driver for private cars sales increase, along with the higher share of government investment in road infrastructure development, as opposed to lagging investments in public transportation.

EVs and EVSE

To date, there are less than thousand private BEV cars on Israel roads, most of which are the remnants of the cars sold by Better Place, followed by only a handful of BEVs sales until 2017 which has seen a reintroduction of BEV offerings, with 3 models available to customers (Nissan LEAF, Renault Zoe and BMW i3). Sales of BEVs that year have reinstated and reached 112 units sold; however, the majority of sales (about 100 Zoe's) are attributed to the BEV car sharing fleet by Car2Go. At the turn of 2018, there are indications the more BEV models are expected to get debuted in the Israeli market, with more mainstream and longer-range models. In addition, there are several thousands of PHEVs on the roads as well, with about 20 PHEV models on sale – most of which are from high-end brands, accredited to the tax discounts PHEVs receive, as well as the inherent higher costs of this type of drivetrain. A noteworthy trend is the private import of PHEVs, which accounts to several hundreds of cars out of the 1,000 privately imported cars in 2016.

In much the same way, public charging EVSE had an unsteady development. There are an estimated 150 public and semi-public charging points available in the country, typically located at city and commercial parking lots. As for private chargers, BEVs currently sold include a mode 3 charger installation by a 3rd party as part of the package, and importers follow through with BEV sales only to customers who have access to charger-enabled private parking.

EV Policy

EVs in Israel enjoy significantly reduced purchase tax rates, further accentuated in the light of the high base purchase tax for ICE cars, which at a current rate of 83% is among the highest in OECD countries (OECD, 2016). The purchase tax for BEV is 10% and for PHEV 20%, and both also receive a tax-value discount over car safety systems, resulting in a possible effective discount of few additional percent. In addition, employees who make use of company car which is an EV (either BEV or PHEV) receive a fairly significant discount on value-of-use tax of 990 ILS per month (Israel Tax Authority). Yet, as sales number shown, the tax incentives had little to no effect over BEVs, while at the same time did boost sales of PHEVs.

As an active implementation policy, the Ministry of Environmental Protection allocated a budget of 8.6M ILS for the cities in the Haifa District for supporting an EV car-share array, which started operating in late 2017 and is set to eventually include 160 EVs (Renault Zoe cars), with designated free parking and charging spaces. Under additional set of programs, a budget of 23M ILS was given as subsidy for the purchase of 62 electric city buses by several public transportation operators around Israel. The Ministry of Energy publicly announced in January

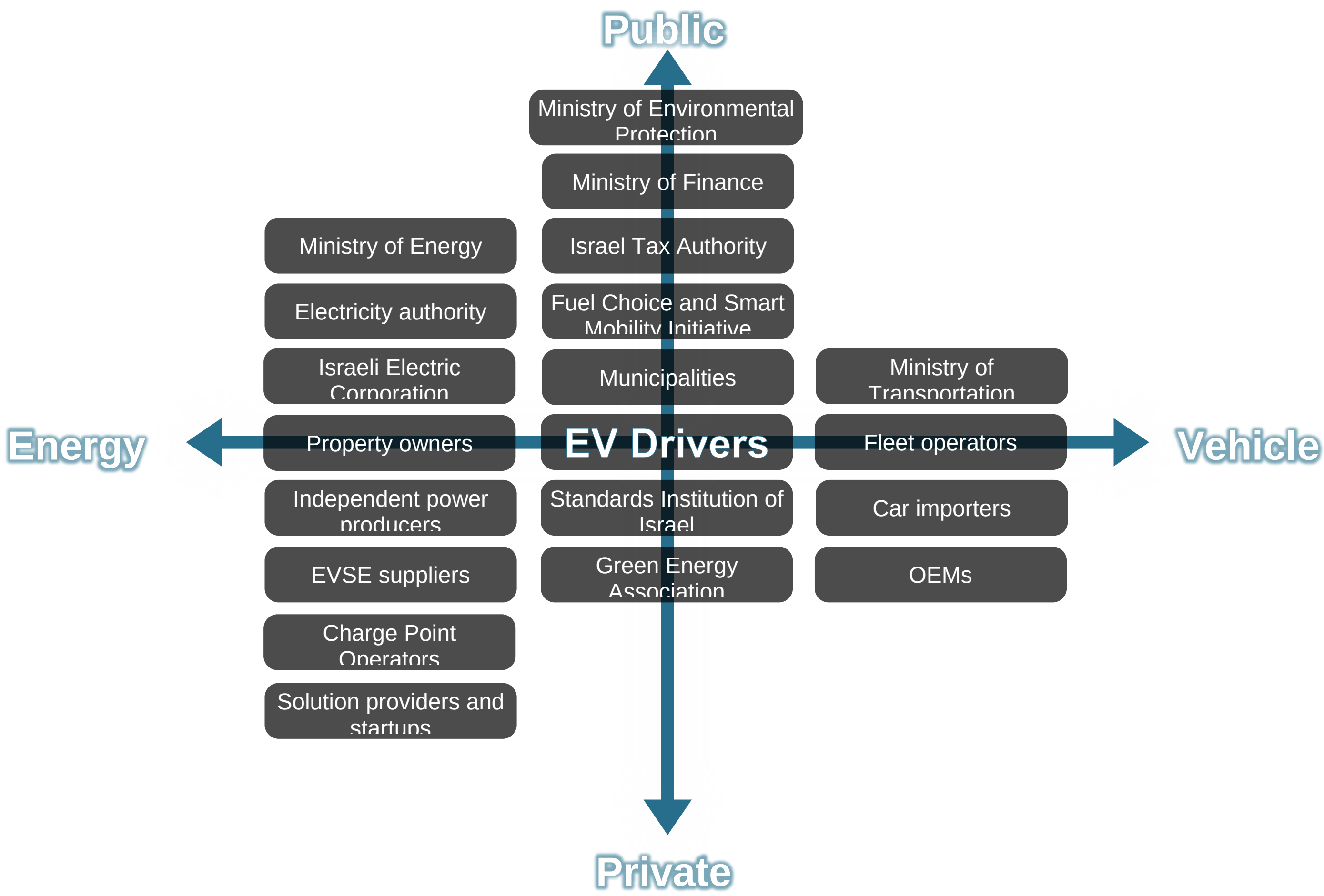
2018 that its policy is to fully withdrawal from gasoline use in Israel by 2030, noting actions taken to set the required regulation to facilitate public charging by private providers, as well as plans to support the deployment of several thousands of charging stations (with an estimated budget of 25M ILS). Efforts to remove barriers and promote market implementation of EVs are orchestrated by the Fuel Choices and Smart Mobility Initiative unit of the Prime Minister's Office, which operates as an inter-ministry integrator to coordinate measures, programs and projects to facilitate the alternative and smart mobility agenda, in both the public and private sectors, as well as with international partners.

Electricity sector

Historically, the Israeli electricity market is dominated by the vertically-integrated government-owned Israeli Electric Corporation (IEC), and regulated by the Electricity Authorities (alternately called Public Utility Authority – Electricity, PUA). In recent years the electricity generation segment is opening up to increasing share of independent power producers (IPPs), transforming electricity into a more competitive market. About 97% of Israeli electricity generation fuel mix is fossil-fuel based, increasingly so by domestic natural gas.

Stakeholders

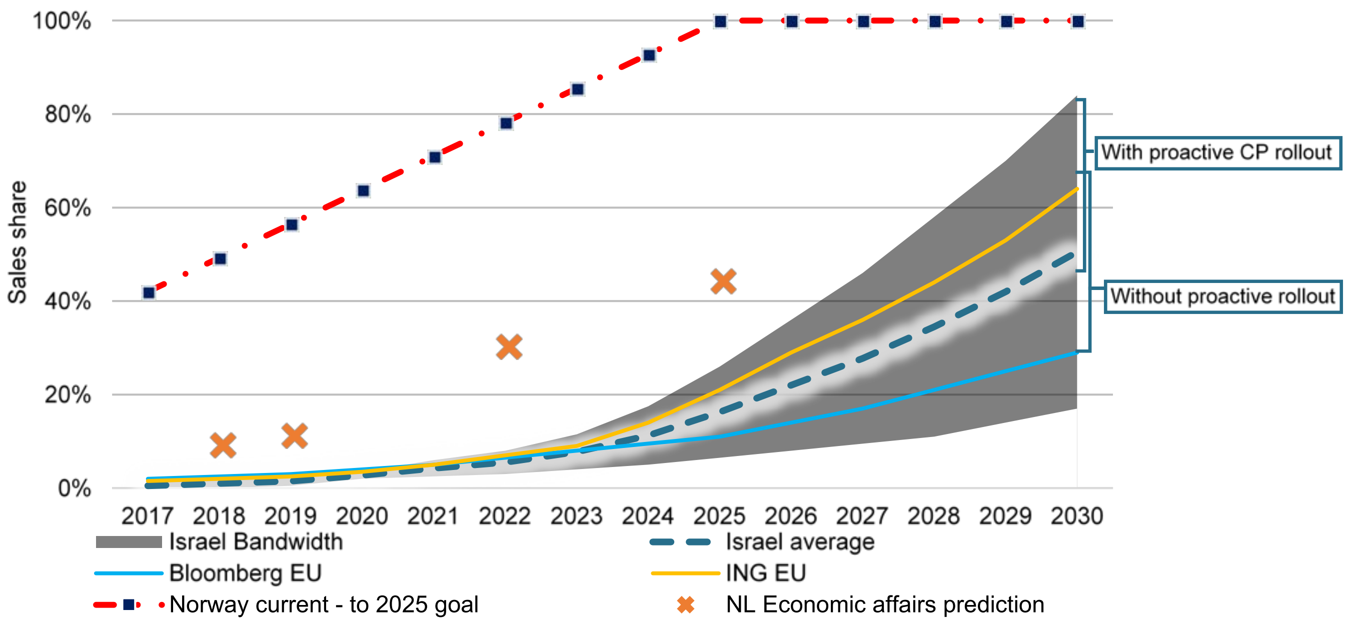
Examining the scope of stakeholders which are related to EVs and EV charging, each can be classified as either a user, a provider, or a regulator – or any combination of those. Every consumer of transportation (i.e. everyone) are potential users; suppliers of hardware, services, data and property access are providers; entities with authority can both support and moderate in roles of regulators. Alternately, stakeholders can be placed along two axes – one being the public vs. private axis, and the other being Energy vs. Vehicle



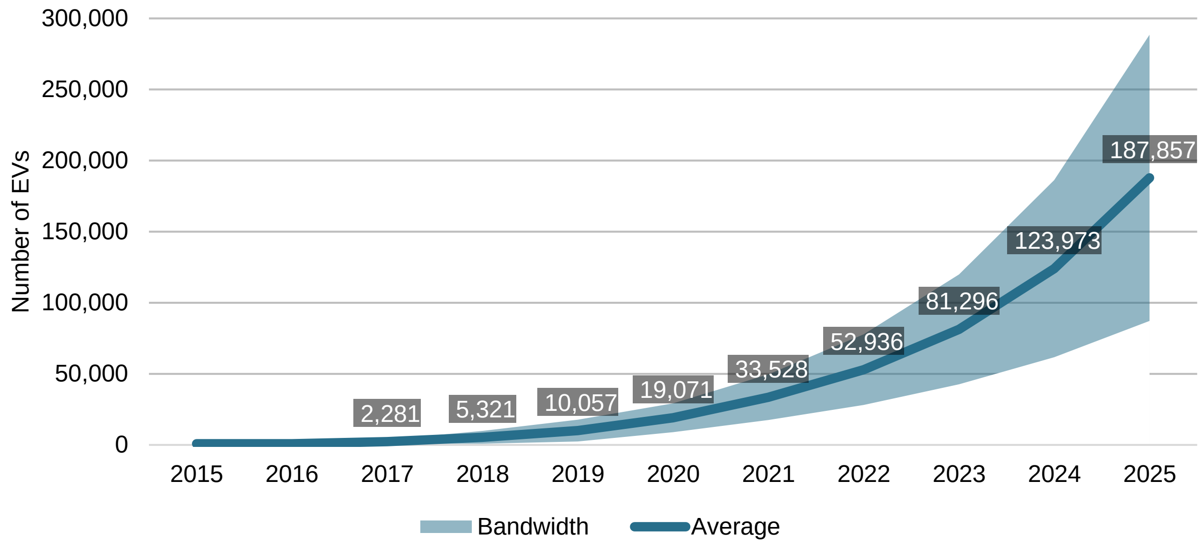
Adoption forecast

For the following forecast analysis of EV adoption in Israel, *slow* and *fast* scenarios were defined, in order to determine the range of uptake rate until 2030. These scenarios represent a relatively conservative approach. Both the Netherlands and Norway – two of the frontrunners on EV adoption – have set their prospects and goals significantly higher than the Israel fast scenario. The prediction assumptions consider no current EV sales in Israel, and the rate remains lower than EU scenarios until 2021; after 2021, TCO starts playing a role in EV sales, lag in sales doesn't continue, but the scenarios diverge due to tech and policy paths.

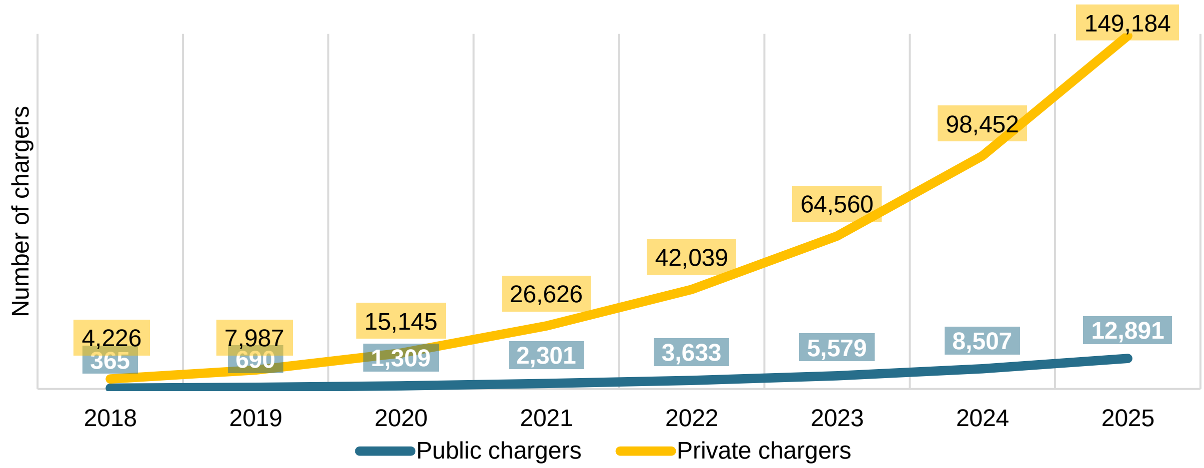
Israeli EV uptake is predicted to reach a sales market share of 2% to 4% (3% avg.) in 2020, 6.5% to 26% (16% avg.) in 2025 and 17% to 84% (51% avg.) by 2030.

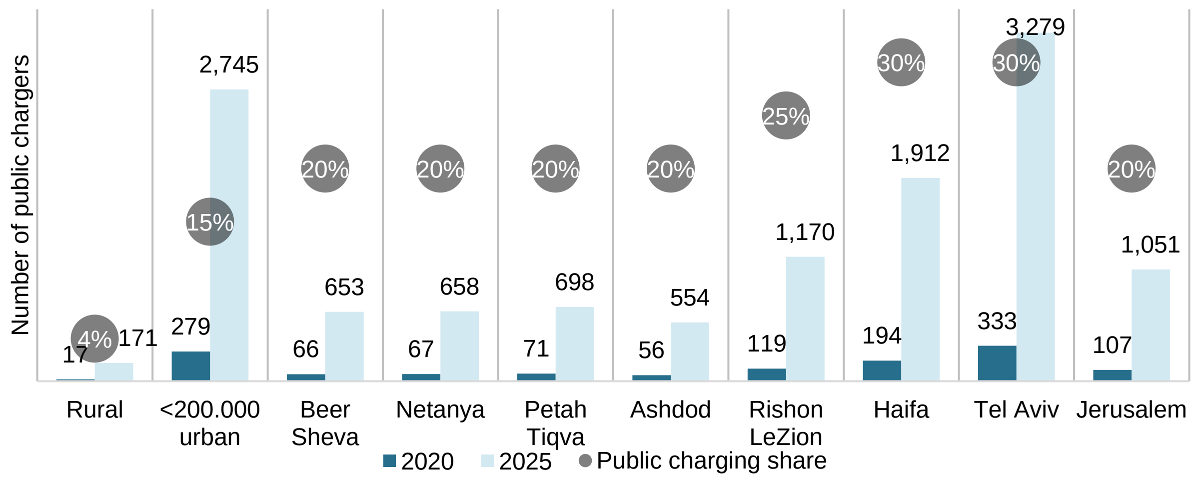


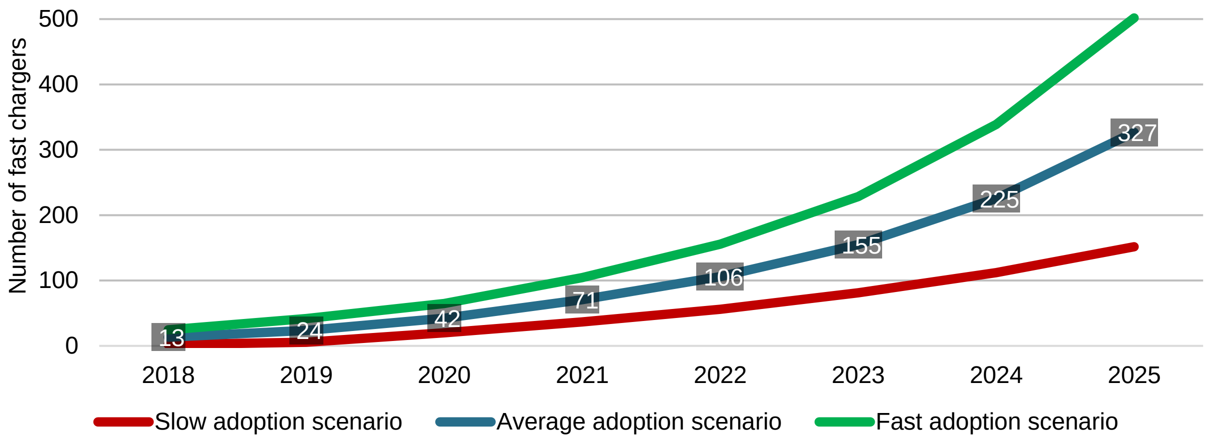
By 2020 the number of EVs in Israel is expected to be about 9,000 to 29,000, accounting for 0.3% to 0.9% of the total fleet that year (avg. of 19,000 and 0.6%, respectively). By 2025 the number of EVs in Israel is expected to reach 87,000 to 288,000, accounting for 2.3% to 7.7% of the total vehicle fleet that year (avg. of 188,000 and 5.0%, respectively).



The estimated national share of public charging points is 14.7%. **The demand prediction shows that tens of thousands of public charging stations are needed within less than a decade**. **By 2020 there are 15,145 private chargers and 1,309 public chargers (or 2,618 public charging points) are needed, and by 2025 there are 149,184 private chargers and 12,891 public chargers (or 25,782 public charging points) needed.** Municipalities can expect demand for hundreds up to thousands of public charging stations within less than a decade, with Tel Aviv, Haifa, Jerusalem and Rishon LeZion in demand for over 100 public chargers by 2020. **The predicted demand for fast chargers is for 20 to 65 (42 avg.) fast chargers required by 2020, and 152 to 502 (327 avg.) fast chargers required by 2025**.







Conclusions and recommendations

Israel is a small, highly urbanized and densely populated country. It is characterized by a high dependency on private car commute, high vehicle travel distance and a growing car market with high demand – despite high taxes and market prices. The country has no meaningful domestic oil production, but does have an abundancy of natural gas, ample potential to harvest solar energy, attractive electricity rates and EV tax incentives. Given those circumstances, **Israel serves as a prime candidate for high rates of EV adoption**.

Based on findings in this study, the following conclusions and recommendations are given for the realization policy of large-scale adoption of electric vehicles and the required charging infrastructure:

1. Ensure policy coordination and infrastructure rollout plan

- Set one coordinating ministry to take lead in EV Infrastructure strategy and development
- Develop an Infrastructure rollout plan with clear and compelling targets in relation to national EV sales targets, including identification of the best charging locations (in both highways and cities)
- Coordinate national, regional and municipal infrastructure policies
- Provide adaptive programming to cope and respond to a rapidly evolving EV market

2. Support all charging methods and standard requirements

- Take an integrated approach considering all types of charging – including home, work, public and fast charging
- Standardize requirements for charging, in terms of safety, interoperability, customer interaction, open access etc.
- Develop building codes for new commercial and residential construction to enable easy charger installation

3. Facilitate strong stakeholder cooperation

- Install a high-level multi-actor EV taskforce, where representatives from national and local policy, automotive industry, energy sector, science and SME cooperate
- Assure strong involvement of IEC to develop smart charging techniques to alleviate additional load on electricity grid and possibilities for V2G
- Support entrepreneurship and innovations projects to build leading companies
- Combine uptake of EV with increased renewable energy production

4. Build strong market development

- Build towards a fully commercial charging operator model from the start
- Provide initial financial support for CPOs to spark early investment and offer new companies possibilities to enter the new market
- Develop a tariff and pricing structure that balances attractive use for customers and the business case for the CPO

5. Promote extensive communication and education

- Generate promotion of EV and infrastructure to build EV awareness and outreach towards potential EV customers
- Organize constant learning and make use of existing lessons learned

1. Introduction

The growth of modern economies is literally fueled by an increase in their energy consumption. The hallmarks of developed nations are sprawling, modern cities, driven by pulsating grids of electricity and transport as their life force. While recent times has seen a shift in the electric power sector's fuel mix towards and increasing share of sustainable energy, this has yet to be the case in transport. While transportation accounts for 19% of the world's total energy demand, with 95% of its energy consumption being sourced from oil, transportation is the mainstay consumer of oil, with a share of over 55% of the world's oil consumption in 2015 (see **Figure 1**). Of about 95 million of barrels per day (Mb/d) of global oil demand in 2015, cars and other light duty vehicles account for 19 Mb/d. (BP, 2017)

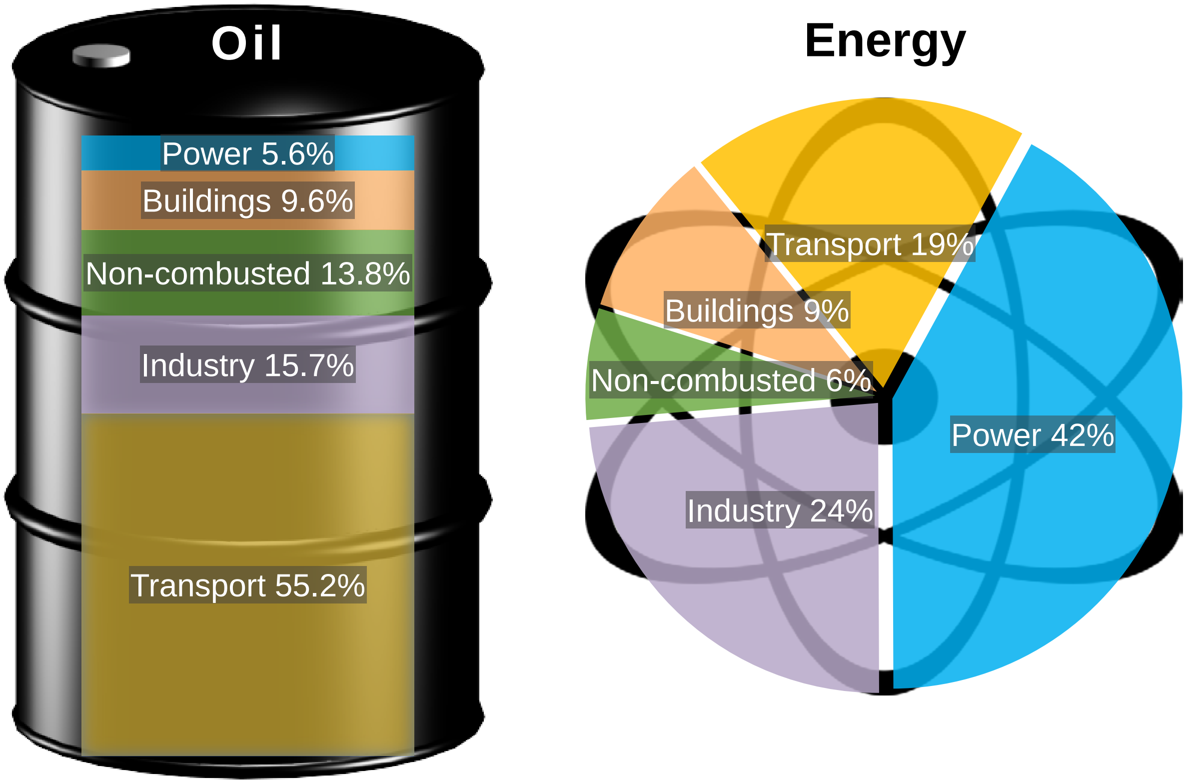


Figure 1. World oil and total energy consumption by sector, 2015. Adapted from BP *(2017)*.

The electrification of the transportation sector serves the overarching goals of reducing oil-dependency, lowering harmful air pollution in densely populated areas and decreasing greenhouse gases emissions (Ayalon, Flicstein, & Shtibelman, 2013). This is achieved through the intrinsic superiority of electric drivetrains in terms of energy conversion efficiency, compared to the conventional internal combustion engines (ICEs), also accounting for scale advantages of centralized electricity generation as opposed to vehicles' on-board ICE. Nonetheless, the electric batteries' lower energy density and lengthy charge time provide inferior utility compared with fuel-based drivetrains. These characteristics result in drivers' so called "range anxiety", where users feel – and occasionally are – limited in drive distances and the availability of charge points in their destinations. Coupled with EVs prohibitive upfront cost, there are substantial market impediments for the proliferation of electric mobility (e-mobility) into the transportation sector.

The strategic plan of the Fuel Choices and Smart Mobility Initiative of Israel's Prime Minister's Office, which aims at reducing the share of crude oil in the transportation sector by 60% by 2025, attribute a significant share of the alternatives to electrical mobility. There are also additional potential gains to be had for a larger share of EVs and plug-in hybrid electric vehicles (PHEVs) in the country's fleet, in terms of running costs and environmental externalities (Ayalon, Liebes, Rosental, & Gabay, 2014). With the ongoing incremental improvements in battery range and costs – which amounts to roughly 1/3 of the vehicle's cost – the main barrier for EV adoption remains the charging infrastructure availability.

While the introduction of any kind of alternative for the decades-long oil-based fueling infrastructure and its entrenched stakeholders may seem to have very low probability of success, it is important to note that electricity is already much the same, with virtually almost every household and building connected to the grid. It is also acknowledged that utilities are positioned to take pivotal role in the mitigation of their own share in the fossil-energy negative implications, through the transformation of the transportation sector into a more electricity-based one, with multiple gains to be had on their part (NRDC, 2016).

The International Transport Forum (ITF) at the OECD (Lindberg & Fridstrøm, 2015) has recently set forth an analysis of the policy strategies for vehicle electrification in the OECD countries, of which Israel is a member, and explores policy options and their implication on a broad scale. Based on an estimated cost for charging infrastructure of €1500 to €2500 per vehicle (with just 50% home charging) (McKinsey, 2010), and the assumptions of 10% annual car fleet renewal rate with 10% of this replacement by EV, the ITF study estimated that the investment required in public charging infrastructure in Israel will be €37m by 2020. Israel is also noted as one of the countries where subsidizing a charging infrastructure by an increase in ICE vehicle registration tax has relatively negligible impact, amounting to an increase of 2% in taxes. It is also important to realize that since EVs are about 3 times as efficient as ICE vehicles, their introduction into the fleet changes the tax base at the proportional rate, calling for a prudent taxation policy reevaluation, with an impending opportunity to correct economic distortions with unpriced market externalities.

However, it is essential to avoid overlooking the country-specific and even municipal -level situation, as differences in population spatial dispersal, transportation sector profile, utilities market structure, grid properties and even climate may have profound implications over the appropriate charging infrastructure deployment scheme.

There are multiple methods for charging, but in general there are 2 major types of charging points: fast charging (ranging from less than half an hour up to 2 hours), and slow charging (at rates usually requiring an overnight charging). These also vary in terms of capacities, grid connection requirements and cost (Lindberg & Fridstrøm, 2015). Consequently, different countries have a wide range of EVs sub-category shares, as well as charging "mix". For instance, in the Netherlands, PHEVs account for the majority of chargeable vehicles, with a rising market share, while in California the split is roughly 50/50 between battery electric vehicles (BEVs) and PHEVs (ICCT, 2014). As for charging, there is a rate of almost 50% slow charges per EV in the Netherlands, 20% in the US and 10% in Japan, implying an adequate rate of non-residential charger per BEV in the wide range of 8% to 30%; for fast chargers, the rate is 1% in the Netherlands, 0.3% in the US and 3% in Japan (IEA, 2013).

The potential benefits in the transition onto more diverse energy sources for transportation, as well as the possible pitfalls and many variables involved, call for a deep investigation into the best policies and practices suitable for the case of Israeli implementation plans.

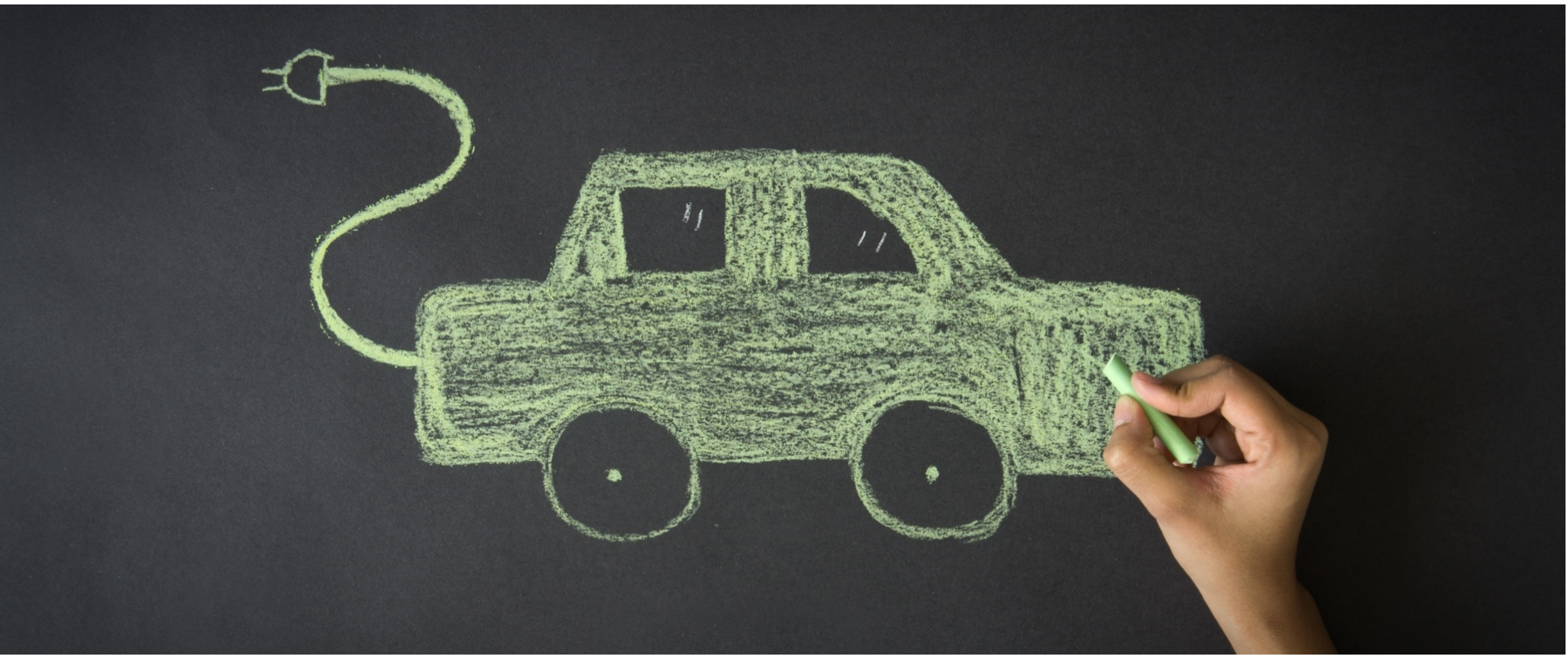
2. Objectives

The objectives of the research are to review the best practices for the deployment of electric vehicle (EV) charging infrastructure, specify optimal models for the Israeli case, and provide actionable guidelines for implementation.

Considering the role of the transportation sector in national aspects of energy, economy, resiliency and environment, a contemplated process of choosing the right implementation methods would have a profound and continues effect, especially in light of the life expectancy of the involved infrastructures. The design of the study is aimed to serve as a practical tool for policy-makers and other stakeholders alike in their development plans for handling the expected propagation of EVs in Israel for the short and medium term, for the very least.

The focus of the research is on *public* infrastructure for passenger electric vehicles and Light Commercial Vehicles (LCV). This segment of transportation represents the vast majority of the national vehicles fleet in terms of numbers. Whereas passenger cars and LCVs commonly rely on home and work charging on off-street parking spaces, such solutions in many cases are either insufficient or simply inapplicable, calling for a publicly-available charging solution. Unlike private charging, public and semi-public (publicly accessible, on private property) proves to be of higher complexity, as it may involve more stakeholders and operate under one of many models and market structures; moreover, being a public service mandates a careful consideration of policy and regulation that best serves the greater interest of the public, where there might be some inherent conflicts.

It should be noted that while quite inseparable, this study focuses on the *charging infrastructure*, rather than on the *electric vehicles* themselves, the latter being a rapidly evolving field shaped by international market forces, which is less susceptible to influence by local policy. Other means of electric transportation – i.e. heavy-duty vehicles, rail etc. – are characterized by fundamentally different attribute than private passenger transport, and consequently the strategy for realizing charging infrastructure for them is completely different and driven by other considerations altogether.



3. Methodology

This paper consists of three distinct parts, each based on different methodologies used to draw meaningful insights about field of electric vehicle charging in general, and specifically to shape policy guidelines for the development of this market in Israel.

Part I: Best Practices provides an overview of operational aspect of EV charging, and an international best practices review made of a deep dive analysis of the charging market in the United Kingdom, Ireland, the Netherlands, and the United States of America. The selected countries represent progressive EV charging infrastructures, yet each has taken a unique approach and different policies to advance this mobility alternative. The difference in policies and their implementation provides guidance as for the suitable strategies for realization of charging infrastructure in Israel.

- **Key method: Comprehensive review** – a collection of information about key aspects of the evolving field of EVs and charging markets. Further details are reviewed on a local level for the selected sample countries, including market models to realize charging infrastructure, incentives and policies, national targets and goals, municipal strategies for contracting, stakeholders' roles and motivations, technical and regulatory challenges, and lessons learned. The review is based on literature including scientific publications, governmental papers and industry reports, as well as personal communication and interviews with key position holders in the selected countries and in Israel.

Part II: Stakeholders Feedback entails a summary of findings from a stakeholders' roundtable event which was held as part of the research, prompting an engaging and methodical discussion regarding the challenges faced in the introduction of EVs and the related charging infrastructure into the Israeli market at scale, as well as brainstorming for possible solutions. The methodical stakeholders' consultation process clearly highlighted the topmost barriers, solutions and the actors responsible for providing them.

- **Key method: Active workshop –** to facilitate an effective stakeholders feedback, a unique methodology for experts' consultation was developed. The workshop hosted a panel of representatives from government offices, municipalities, the electricity and transportation sectors, charging solutions developers and providers, and other consultant and experts from related fields.

Part III: Charging in Israel explores the prospects of development for the Israeli EV and charging markets, building on an analysis of the status quo in local private transportation sector, a mapping of the related stakeholders in the public and private sectors, and an adoption forecast for EVs and charging infrastructure into the 2020-2025 timeframe.

- **Key method: Forecasting model –** employing a dedicated model to develop scenarios and forecasts for EV share and charging demand, based on indicators of population, economics and transportation data at the national and municipal level.

Last in the paper is the **Conclusions and recommendations** section, which provides the main takeaways of actionable recommendations aimed at decision makers to consider when shaping policies for the realization of a developed EV market in Israel.

Part I: Best Practices

4. Operational aspects

The distinct attribute of electricity-driven vehicles over conventional ICE requires a change of mindset regarding their on-going operation, as well as the required infrastructure to support it. As the deployment of EVs is still in its infancy, there are still several technical approaches in charging them, each at a different level of maturity, as well as actual market usage. The following chapter covers the dominant technologies, standards and operational aspect involved with EVs, and describes their application in the market.

4.1. Types of EV

Many types of electric vehicles exist – all with different specifications for the drivetrain technology, electric driving range, and driving characteristics. In general, electric vehicles can be divided into two main categories:

- **Battery electric vehicles (BEV) –** BEVs are powered only by their battery and have an electric range that varies between roughly 100 to 500 km (Tesla Model S). The average range is about 150-200 km.
- **Plug-in hybrid electric vehicles (PHEV) –** PHEVs have a battery with an electric drivetrain, as well as an internal combustion engine (ICE). The all-electric range is roughly 40-60 kilometers. When the battery charge is low, depending on the specific drivetrain design, the ICE can be used to either recharge the battery when depleted, assist the electric motor during higher loads, or directly drive the vehicle, or any combination of the above.

Technology development for both PHEVs and BEVs has only seen a first wave of investment by most original equipment manufacturers (OEMs), resulting in an initial limited selection of models. As markets expand, more R&D will be needed. The electric car stock has been growing since 2010 at an increasing rate, crossing the one million units mark during 2015, with a BEV uptake slightly ahead of PHEV uptake (see **Figure 2**).

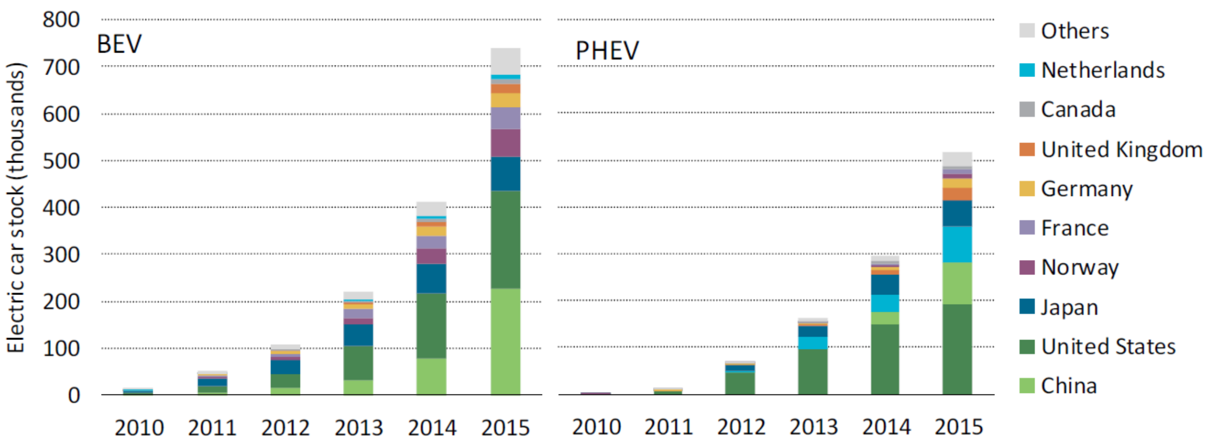


Figure 2. Global stock of electric cars (BEV and PHEV). Reprinted from IEA *(2016)*.

Figure 3 describes changes in electric range of popular electric vehicle models in the period of 2013-2016 and the estimated range improvements for 2016-2018. An electric range of more than 250 miles (400 kilometers) is expected for popular models; currently Tesla already offers different models providing this range (ICCT, 2016).

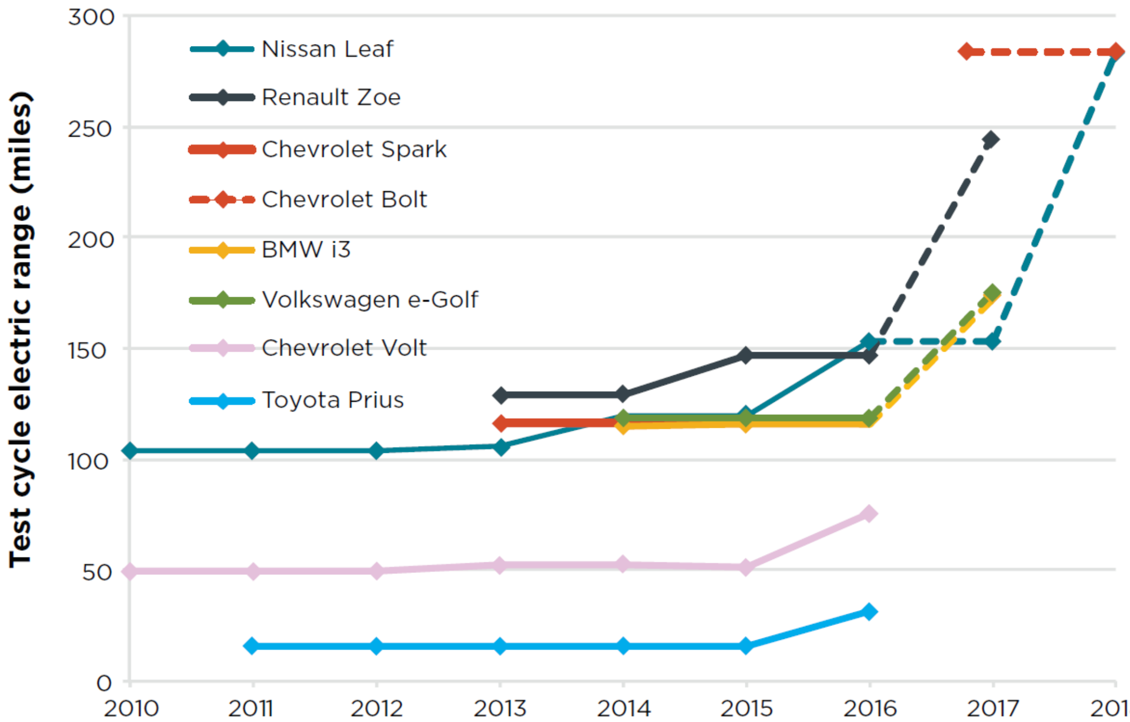


Figure 3. Electric range of current and announced popular electric vehicle models. Reprinted from International Council on Clean Transportation *(2016)*.

4.2. Technical standards

In standardization of charging EVs, a distinction is made between "types" of the plug and socket and the charging "mode". The charging modes differentiate themselves in relation to maximum charging speeds, and communication capabilities. Standards for the vehicle side of the charging cable are determined by the origin of the vehicle. The Israeli standardization – set by the Standards Institution of Israel (SII) – mirrors the European IEC standards in place without significant modifications, with the purpose of maintaining international accordance.

Charging modes

The International Electro-technical Commission defines the charging modes in IEC 61851-1, an international standard for conductive charging systems (IEC, 2017). The different modes are applicable on diverse types of plugs or socket-outlets. Due to safety concerns Mode 1 is prohibited for use in Israel. **Table 1** provides an overview of the four charging modes and their characteristics.

Table 1. Charging modes. Adapted from Jiménez et. al *(2015)*.

Charging mode	Communication	Charging regulation	Maximum current	Maximum power	
				1 phase	3 phases
Mode 1	Not necessary	On board EV	16 A	3.7 kW	11 kW
Mode 2	Only control on charging cable, not bidirectional	On board EV	32 A	7.4 kW	22 kW
Mode 3	Between vehicle and EVSE compulsory	On board EV	70 A	16.1 kW	44 kW
Mode 4	Between vehicle and EVSE compulsory	Off board EV	400A (DC)	240 (DC)	

Types of sockets and plugs

The type of plugs and sockets used for charging are mostly determined by the make of the vehicles, in light of the necessary compatibility between EV, plug and socket. Normal charging with alternating current (AC) uses either Type 1, 2 and 3 for low to moderate charging rates. For fast charging with direct current (DC), either the CHAdeMO or Combined Charging System (CCS, or COMBO) are used.

As of May 2015, CHAdeMO was the most used standard for fast charging, with 5,737 charging points installed all around the world, of which 3,087 in Japan, 1,661 in Europe, 934 in the USA and 55 in other countries (Jiménez et. al, 2015). European companies, including Audi, BMW, Daimler, Ford, General Motors, Porsche and Volkswagen developed the CCS in order to accommodate both normal (AC) and fast (DC) charging. Where Type 1, 2 & 3 and CHAdeMO require a dedicated inlet in the vehicle, often leading to two separate inlets (one for normal charging and one for fast charging), CCS supports both AC and DC charging using the same plug and a single inlet in the vehicle. A multi-standard for fast charging that combines CHAdeMO and CCS is in development in Europe. Additionally, there is a notable distinction of sockets vs. fixed cable at the charging point end. In the US, all public CPs have a fixed cable, while in Europe normal CPs only have sockets and the cable is provided by each vehicle and connected on both ends. In all cases, fast charging stations have a fixed cable because of safety requirements for high voltages.

Table 2 summarizes the most common types of plugs and sockets for electric vehicles.

Table 2. Types of sockets and plugs for charging.

Normal charging (AC)		Origin	Rated power
Type 1 'Yazaki' socket		**Japan** **USA** *(uses a separate standard - JSAE 1772 - due to difference in voltage standards)*	• Normal charging • Up to **7.4 kW** (32A, 1 phase) • Includes vehicle to charge point communication • Smart grid capable
Type 2 'Mennekes' socket		**Europe** (Germany)	• Normal and semi-fast charging • Up to 44 kW (63A, 3 phase) • Includes vehicle to charge point communication • Smart grid capable
Type 3 'le grand' socket		**France** **Italy**	• Up to **22 kW** (32A, 3 phase)
Fast charging (DC)			
CHAdeMO		**Japan**	• Fast charging • **50 kW up to 150 kW** (DC)
Normal (AC) or fast (DC) charging			
Combined Charging System (CCS)		Europe	• Normal and semi-fast charging **43 kW** (AC) • Fast charging **50 kW up to 150 kW** (DC)

Stakeholders' perspectives

Stakeholders might have diverging interests regarding the eventual charging standard(s). Such interests and consequently the preferred standards differ between stakeholder groups but also within the groups. Most notably this goes for the car manufacturers. The main difference is found between the stakeholders on the infrastructure side (e.g. grid operators, electricity providers) and the car manufacturers.

- From an infrastructure perspective, it is preferable to install regular and semi-fast AC chargers, as these are relatively cheap and require relatively modest grid connections. These chargers can charge a car in about 8 and 2 hours, respectively.
- From a car manufacturer's perspective DC charging is more interesting, as it provides a way to charge a car within half an hour and requires only minimal investments in the vehicle end (Pfeiffer & Bach, 2014).

4.3. Types of charging locations and use

A distinction can be made between home charging (sometimes called private charging, on private domain), semi-public, public, and fast charging (22 kW or more). Workplace charging typically takes place at a private or semi-public location, while on-route fast charging along highways would typically be public.

Among these options, charging at home and work are widely seen as the preferable solution for EV charging worldwide, and with vehicles typically used for average commuter trips of 20-30 km it should be sufficient. However, servicing visitors and EV drivers without private charging options requires public charging. Fast charging enables longer journeys, but currently takes a small share of the total charging worldwide.

The common types of charging and their characteristics are as follows:

- **Home / private**
  - Charging on private ground
  - Overnight and during weekends (minimum of 4-8 hours)
  - Done with either charging station or an existing standard 16A socket
  - Requires certified installation or inspection to ensure safety
- **Semi-public**
  - Charging at public locations on private ground (e.g. retail locations, office buildings, parking at apartment blocks)
  - Includes some workplace charging (office buildings may have discount contract with energy provider)
  - Retail stores may offer free charging as a service to customers
- **Public**
  - Services for visitors or EV drivers without private charging options
  - Requires dedicated parking places at a public charging station
  - Increases EV visibility
  - Involves various stakeholders
  - Charging station requires robust outdoor setup with payment system and a separate grid connection
  - High installation and operation costs

- **Fast charging**
  - Enables longer travel distances
  - Setup is similar to existing networks of gas stations, with charging stations at intervals of 50-75 km in and around cities with many EVs
  - Can be provided as a service at supermarkets, highway restaurants etc.
  - Typically, higher speed of charging than at other locations

Figure 4 describes the prioritization of charging types, based on location, needs and the required EVSE.

Figure 4. Three-dimensional charging pyramid – hierarchy of opportunities and needs. Reprinted from *(Santini, Zhou, Elango, Xu, & Guensler, 2014)*

4.4. High power charging

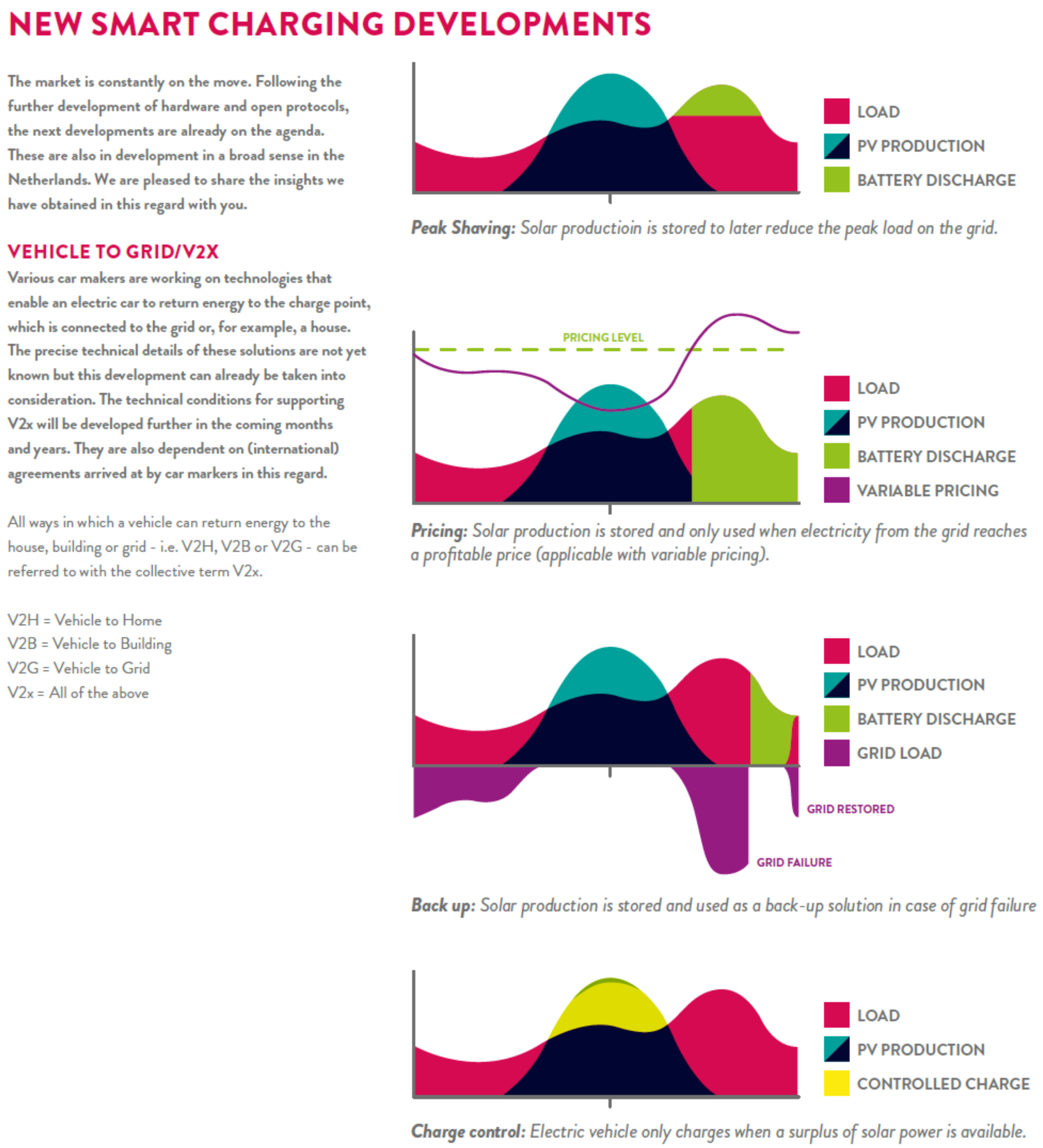
Currently, on-route fast chargers have sockets of approximately 50 kW. It takes 20-30 minutes on average to charge EV batteries up to 80% with this voltage. This enables EV drivers to travel over longer distances in case their destination is not reachable on a single charged battery. Higher voltage chargers are currently being developed by various car- and charge point manufacturers. These companies are aiming for both 150 kW and 350 kW chargers for the coming years. The first 150 kW chargers are expected to become available already in 2017. Charging EV's with 150 kW takes approximately 10 minutes to charge the battery up to 80%. Up until now, it is still unknown when the first EVs that can charge at 150 kW will be available on the market.

Some of the major car manufacturers took the initiative to develop the first 'ultra-fast chargers', chargers with a voltage of 350 kW. These chargers have the ability to charge an EV 100 times faster than a 'normal' charge point, taking only a few minutes to charge an EV up to 80%. A joint venture of VW, Audi, Porsche, BMW, Daimler and Ford's European division is planning to realize a network of 400 of these ultra-quick chargers throughout Europe in 2020 (similar to the Tesla fast charge network). As of yet, no car manufacturer is offering an EV that can charge with this voltage. However, the joint venture wishes to be prepared for the future and participate on the EV developments: charging EVs quicker and EVs with higher battery capacity.

4.5. Smart charging

A significant increase in number of EVs is expected to have a big impact over the electric grid. To balance peak loads and fluctuating energy supplies, a new EV charging market model could emerge. Smart grids combined with solar- and wind energy can contribute to these challenges ahead. Flexible charging of EVs can make a significant contribution to this need for flexibility (Movares, 2016). In general, three stakeholders have an interest in smart charging of EVs (Beeton & Meyer, 2015):

- **Energy producers and suppliers:** Affordable energy storage is increasingly viewed as the key enabler for large-scale renewable energy. The intermittent and variable supply characteristics of renewable energy resources creates significant challenges for their integration into the grid, since over-supply isn't easily stored and under-supply isn't easily managed (yet). As more EVs are adopted and made available as a supplementary storage resource alongside stationary facilities, the growing and flexible storage capacity will facilitate larger amounts of renewables. Use of this storage capacity will likely align with peak demand periods when electricity prices are higher, typically in the early morning and when people return from work in the late afternoon to early evening. Peak production of renewable energy is during the day, when solar energy production is at its highest, resulting in cheaper energy; it also relates well with traditional fossil fuel generation, which experience low loads in night times. This cheaper energy can be stored in the batteries of stationary EVs and return towards the grid when energy prices are higher (during peak demands). When the peak period is over, the EV can recharge during the night.
- **Consumer:** Smart charging offers e-drivers the technology that enables them easy and convenient charging management. Currently, most e-drivers charge their cars at the moment they arrive at home, during the so called peak hours. Peak hour energy prices are higher, since demand is high. Smart charging offers e-drivers the opportunity to charge their cars during off-peak periods with lower kWh prices. This way, drivers can use smart charging to program their EV to start charging at the onset of the off-peak hours, resulting in lower electricity costs and thus maximizing benefits.
- **Distribution System Operator (DNO):** Smart charging offers the DNO the opportunity to mitigate energy peaks on the grid of intermittent energy supply from renewable sources, using the battery of EVs to store energy during peak production hours and return this energy during peak demand periods. This use of EVs as an energy storage is known as Vehicle-to-Grid (V2G). Utilizing stationary EVs as a storage facility has a value when otherwise needed investments in grid capacity could be avoided, as well as facilitates renewable energy integration through matching energy demand and supply. The savings translate to lower costs for all electricity users. This model is illustrated in **Figure 5**.



NEW SMART CHARGING DEVELOPMENTS

The market is constantly on the move. Following the further development of hardware and open protocols, the next developments are already on the agenda. These are also in development in a broad sense in the Netherlands. We are pleased to share the insights we have obtained in this regard with you.

VEHICLE TO GRID/V2X

Various car makers are working on technologies that enable an electric car to return energy to the charge point, which is connected to the grid or, for example, a house. The precise technical details of these solutions are not yet known but this development can already be taken into consideration. The technical conditions for supporting V2x will be developed further in the coming months and years. They are also dependent on (international) agreements arrived at by car markers in this regard.

All ways in which a vehicle can return energy to the house, building or grid - i.e. V2H, V2B or V2G - can be referred to with the collective term V2x.

V2H = Vehicle to Home
V2B = Vehicle to Building
V2G = Vehicle to Grid
V2x = All of the above

Figure 5. Smart charging application models. Reprinted from *(Living Lab Smart Charging, 2017)*.

4.6. Wireless charging

Wireless charging is still operating at a few pilot locations and is not yet commercially viable. To enable inductive wireless charging, two magnetic coils are necessary between which the energy transfer will take place. One of the coils is located in the ground and is connected to a power source. The other coil is installed in the vehicle and is connected to both the charging system and the battery of the car. Energy is transferred through a magnetic field between the two coils: from the coil in the ground to the coil in the car. (see **Figure 6**).

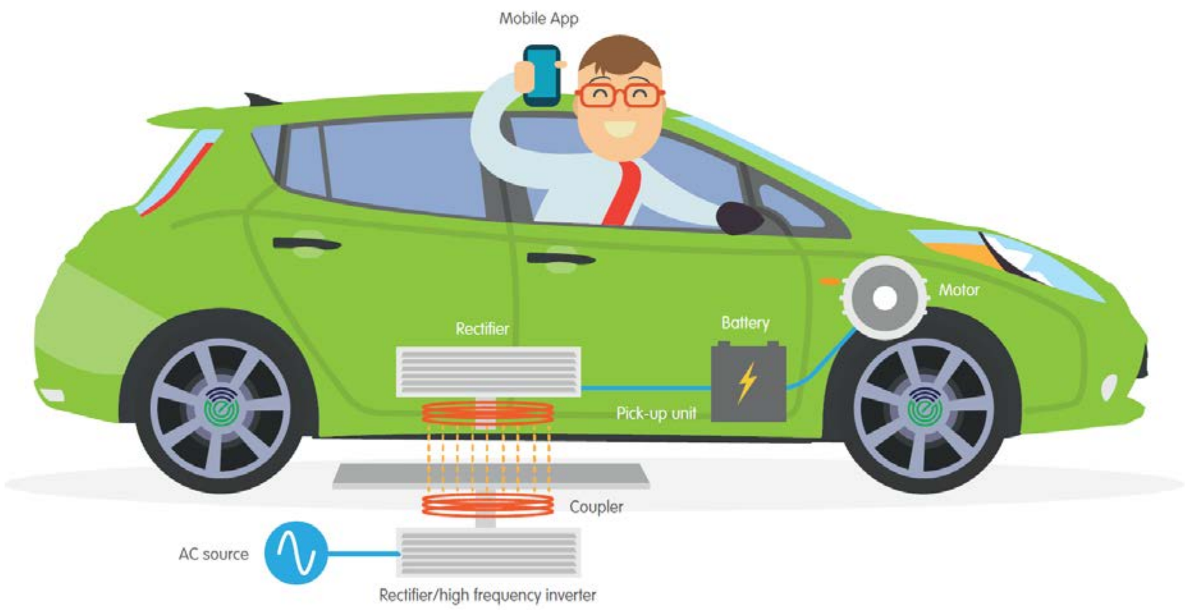


Figure 6. The concept of wireless charging. Reprinted from *(Rotterdam, 2017)*.

Dynamic charging

The concept of dynamic charging is a subcategory of wireless inductive charging, where charging takes places while the vehicle is moving. Using coils embedded in roads and dedicated receivers on the vehicle side, EVs can charge as they stay in transit. The most likely introduction of dynamic charging into real-world applications are through buses traveling on public transportation routes, especially equipped with charging coils for that purpose. Apart from saving time spent at stationary charging points, the benefits of this technology are the extended driving ranges it provides, or alternately the possibility to use smaller capacity batteries. Adversely, it requires a substantial infrastructure investment, and is naturally very location-specific.

Standardization

Unlike charging with a cable, for which various international standards have already been established, the standardization and normalization for induction charging is still in its early stages. An international taskforce, The SAE Wireless Power Transfer (WPT) and Alignment Taskforce, has been working on a standard for wireless charging up to 7 kW: the SAE J2954. Eight OEMs have committed to work with the taskforce to provide vehicles for collaborative WPT testing planned to begin in third quarter 2017, scheduled complete in 2018. The SAE Wireless Power Transfer (WPT) and Alignment Taskforce is underway with defining vehicle and infrastructure hardware and software to be able to automatically park and charge autonomous vehicles (Green Car Congress, 2017).

4.7. Battery swapping

Addressing the challenge of prohibitive charging duration, replacing the vehicle's depleted battery with a freshly charged one in a dedicated swapping station was conceived as a solution for long-range trips of EVs. Battery swapping has been piloted on a small scale, but has lost much of its appeal since the bankruptcy in 2013 of Better Place, the company that installed ~55 battery swapping stations in Denmark and Israel.

In practice, OEMs have not adopted the technology, and almost none of the new BEV models being introduced support battery swapping. One exception to this is Tesla, which has demonstrated battery swapping capability for its Model S; however, following about two years of operating a pilot program with a battery swapping station in the US, it appears that the company has abandoned the concept, stating low driver interest as the culprit (Korosec, 2015).

With issues of excessive investments cost in the swapping stations and battery ownership, countered by increased performance of fast charging, deemed the battery swapping as an unattractive solution by both e-drivers and charging providers. Nonetheless, there may be a case for battery swap for commercial fleets of EVs.

4.8. Interoperability and billing

As with all intersections between technology and human behavior, it is ultimately the *user experience* that has the most influence over the adoption of change by the general public. In order to provision EV as a positive proposition, the process of charging should be such that warrants a "friction free charging". Essentially, this means that an EV driver should always be assured to be able to charge when and where needed, and with minimal hustle or uncertainty. This notion is reflected in the ability to charge at any publicly accessible charger, as well as in the availability of relevant information about charging points' location, current status, charging rates (both power-wise, and cost-wise), etc. It is crucially also accentuated in the actual process of charging itself – eliminating needs for cumbersome procedures of authentication, billing, disengagement and so on – where the user's ease of use and should be a top priority.

Mobility service providers (MSPs) offer mobility products and services. They handle the charging subscription in these cases, accompanying a charge card and/or app, and payment for the charge session. Additional services can be added, such as ‘social charging’ (sharing charge points with your neighbors), information about the availability of charge points or the state of charge of your car, etc.

In some countries Clearing Houses take a role. The Clearing Houses connect different Charge Point Operators (CPOs) and/or MSPs. A clearing house offers a platform for the exchange of roaming authorization, charge transactions and charge point information data (without different entities having to make bilateral agreements). Transactions between the customer, MSP and CPO are facilitated via the clearing house.

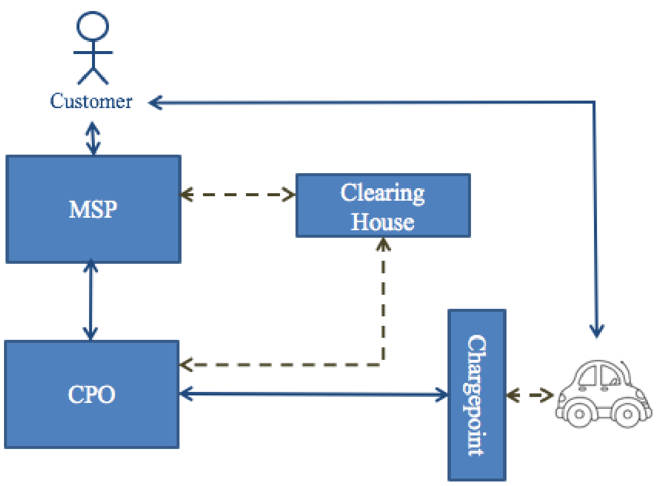


Figure 7. Interfaces and their relations involved in charging interoperability.

Interoperability

From the perspective of the EV driver, interoperability is to be able to charge everywhere at any time with one single card or other identification method, regardless the brand or type of the charging station operator and service provider. Technically, this is facilitated through a myriad of communication protocols and technical standardization between the participating actors who assume the different market roles in the charging network (see **Figure 8**).

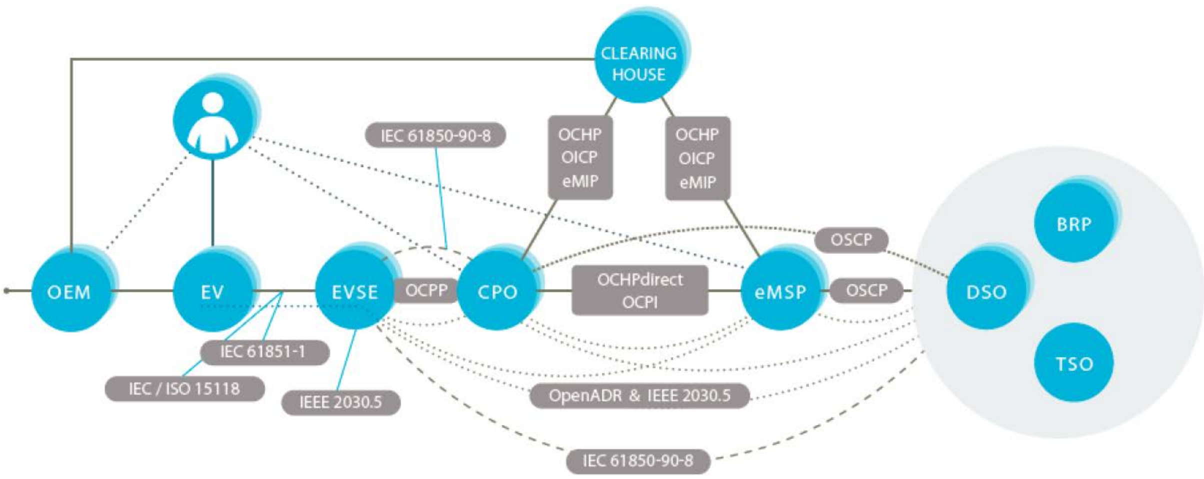


Figure 8. Protocols and market roles in the charging network. Reprinted from *(ElaadNL, 2016)*.

For the purpose of a fluent and efficient transition towards sustainable mobility, it is important that interoperability becomes mainstream and standardized. Therefore EVs, charging facilities and additional services need to be compatible with each other, in order to promote widespread adoption of EVs and to reduce the different regulatory, commercial or political barriers.

Billing models

Different types of payment systems are developed in order to facilitate billing methods for the users of charging services (Beeton & Meyer, 2015):

- **Free:** The simplest billing strategy is unmetered, free charging for the e-driver. In practice, different stakeholders (e.g. municipalities, cities, commercial businesses and pilot projects) are often offering electricity free of charge to vehicle owners. Commercial businesses like Lidl, McDonalds, Holiday Inn and various shopping centers follow the free charging model as a mean of marketing, as well as a service to their customers. However, it is not expected that local governments and other stakeholders can keep offering free charging when the number of EVs increases. The city of Amsterdam, for example, has already abandoned the principle of free charging from April 2012.

- **Pre-paid**: electricity used for charging electric vehicles can be paid for in advance, before the actual charging process takes place. This category of payment methods is referred to as 'prepaid' since it entails a financial transaction pre-charging. Different types of prepaid methods are used. Examples:
  - **Subscription:** the e-driver pays a fixed amount beforehand in order to have unlimited access to certain charge points for a certain period of time.
  - **Pay as you go (PAYG):** The e-driver pays in advance to obtain a level of credit. After charging, this credit is debited and the remaining balance is determined.
  - **Cash:** The e-driver insert cash into the charging device. The respective amount of electricity, in accordance to the cash payment, is transferred to the EV.

- **Post-paid**: payment after the charging process has taken place. This payment method relates to payments via cash, card, mobile and the electricity bill. Examples:
  - **Cash:** The e-driver pays cash afterwards charging the EV. This payment is method is somewhat similar with current payment methods at petrol stations.
  - **Card:** The e-driver pays for the electricity by using his credit/debit card. Also, similar like current payment method at petrol stations.
  - **Mobile:** Same as with the card option, only using mobile device for authentication.
  - **Domestic electricity bill:** Since most home chargers already have a domestic electricity account, domestic energy usage is added to the domestic electricity bill.

Besides the two standard billing models – i.e. prepaid and postpaid billing – the vehicle owner can also be billed for the purchase of charging services via different combined billing structures. The EV owner can have a billing contract with an EV service provider, where they pay a fixed monthly fee and retrieves a certain contracted energy use in return; if the user exceeds the set amount of electricity, they are charged for it on top of the contracted amount. Another example is a yearly subscription fee and an additional use fee for each charging session.

4.9. Business case

While costs of private (i.e. home) chargers vary at about €300-€1,500, depending on specification, features and make, public chargers are generally more expensive with costs of about couple thousand euros for European models, with price quotes of up to $6,000 for US models, and there have been indications that local hardware developed and/or assembled in Israel fall within the lower end of that range (all AC chargers). The higher costs are to be expected, as public chargers are designed with superior robustness, to allow them to withstand more demanding operational environment.

Correspondingly, the installation of public chargers entails additional cost components as these involve more intense roadwork, setup etc., compared to garage wall-mounted charging point. Evidently, installation costs vary to a great degree based on numerus factors – including local workforce costs, contracting terms, municipal regulation, roll out scheme, road and grid infrastructure – all of which tend to sum into a cost which well exceeds to the cost of the charger hardware in its own. Moreover, there appears to be learning curve by which localities where ample experience in the installation process was gained, exhibit a more streamlined installation process coupled with slimmer costs. Initial recent experience in pricing installation costs in Israel of over $7,500 (~ €6,000) per charger.

Following are the cost components for public chargers, based on indications from the Netherlands, where the market is well developed already and ahead in the learning curve with over 7 years of experience:

- The initial cost to install an AC public charger with 2 sockets is about €3,000-4,000 (€1,500-2,000 per charging point). The running cost for a charger with annual sales of 2,000-8,000 kWh amounts to €930-1,280 per year, respectively. (see **Table 3**).

- Costs of entry-level 50kW DC fast chargers range from €15,000 to €30,000 for the hardware, with costs of grid connections and construction varying widely. A total cost of fast charging station on a highway location with 2 chargers averages at about €250,000.

Table 3. Cost components for public chargers in the Netherlands.

Capital expenditure – initial cost		**Operational expenditure – yearly running cost**	
Charger hardware (AC, 2 sockets)	€ 1,000-2,000	Maintenance	€ 275
Rollout management (application services, location management)	€ 550	User service	€ 25
Parking layout (signage, paint job)	€ 450	Communication	€ 75
Grid connection	€ 655	Grid connection	€ 210
Installation	€ 400	Insurance	€ 25
		Fixed Opex per charger /year	**€610**
		Electricity cost (excl. tax) /kWh	€ 0.06
		Energy tax /kWh	€ 0.1
		Energy cost /year (2,000-8,000 kWh sales)	**€ 320-1,280**
Total CAPEX per charger	**€ 3,055-4,055**	**Total OPEX per charger /year**	**€ 930-1,890**

The rate between the operational expenditure (OPEX) to capital expenditure (CAPEX), as well as the variability with respect to sales volume, goes to show the importance of charger utilization (i.e. sales) for the business case of public charging.

Public chargers in the US are quoted to generally cost between $5,000 for a level 2 AC charger up to $50,000 for installed fast DC charger, compared to $1M to $2M for the installation of a gasoline station (Schoettle & Sivak, 2017; Fitzgerald & Nelder, 2017).

5. Global uptake

Since 2010, electric vehicles sales have started to grow exponentially, in part due to increasingly stringent emission standards for 2020 towards 2025 by American, European and Chinese governments. This growth is facilitated by improvements in battery chemistry and lower battery price, expected to forge ahead and continue to drive global adoption in the foreseeable future.

5.1. Adoption barriers

In general terms, there are 4 main barriers for the future adoption of EVs:

1. **Purchase price**
2. **Total cost of ownership** (TCO)
3. **Range**
4. **Infrastructure**

The first three barriers are mainly subjected to global technological developments and will be dealt with even without government intervention; while subsidies can mitigate these barriers to some extent in the short term, it is projected they are overcome by 2024 through improvements in charging power and battery capacity and cost. As for the charging infrastructure barrier however, countries and municipalities play an important role, by which rollout policies determine the charging availability for EV users. (ING, 2017).

5.2. Growth premise

Technological developments improve performance and cost of EVs at a fast rate. Specifically, battery price, lifetime and energy density are improving year-over-year (ING, 2017; BNEF, 2017). Already today, the advantages of EVs over ICE vehicles are cheaper operation and maintenance, more powerful drive, a user-friendly experience, quieter ride, superior safety (due to structural robustness and better crumble zone), no tailpipe emissions and a more sustainable well-to-wheel energy efficiency and environmental impact.

Cost parity between EVs and ICEs differ per country, as well as depending on factors such as driving patterns and driver type. As the trend of said improvements continues, additional sectors and use-cases are expected to reach this parity state. With commercial drivers with high mileage potentially already today at TCO cost parity between EV and ICE, for private drivers in small cars this may take as long as until 2026 (see **Figure 9**).

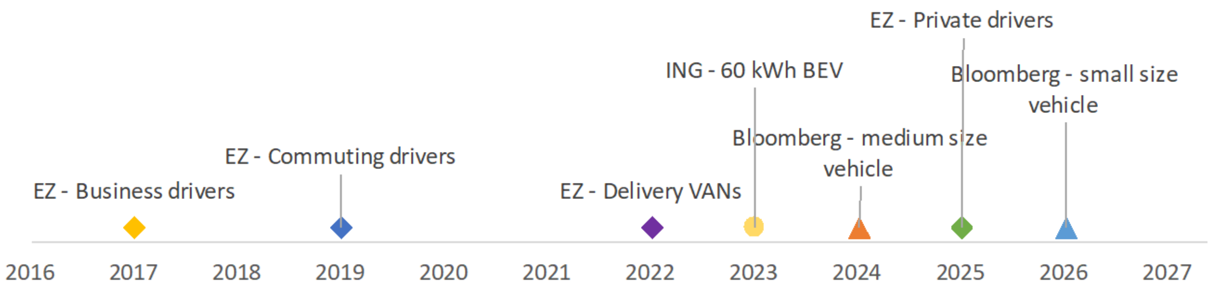


Figure 9. Expert predictions for cost parity for certain types of drivers in the EU and in the Netherlands (EZ - Dutch Ministry of Economic Affairs). Source: EVConsult, adapted from *(Ecofys, 2016; ING, 2017; BNEF, 2017)*.

5.3. Market trend

Whereas merely a couple of years ago, only and handful of car OEMs were developing EVs, nowadays is seems that not a week goes by without another news of long-term commitment to the EV future being made by an industry player. To this date, almost all major OEMs and car brands are committing to electrification of their offerings. Some highlight examples include Volvo declaring all model to be electrified from 2019 (Autocar, 2017), Volkswagen targeting 30% of vehicles sold in 2025 to be electric (Forbes, 2016), Hyudai-Kia with plans for 8 fully electric models by 2022 and a dedicated EV platform (Green Car Reports, 2017), the wide-scale rollout of EVs by the Renault-Nissan-Mitsubishi Alliance (Renault, 2018), as well as commitments by GM, Ford, BMW, Daimler, Honda, Jaguar and Toyota, among others.

By the end of 2016, there were over 2 million EVs on the world's roads, with over 750,000 EV sales that year of which 60% were BEVs (see **Figure 10**) (IEA, 2017). And notable standout was Norway, which saw more than 19% of new cars sales attributed to EVs in 2015 (see **Figure 11**), further surpassed in the couple following years.

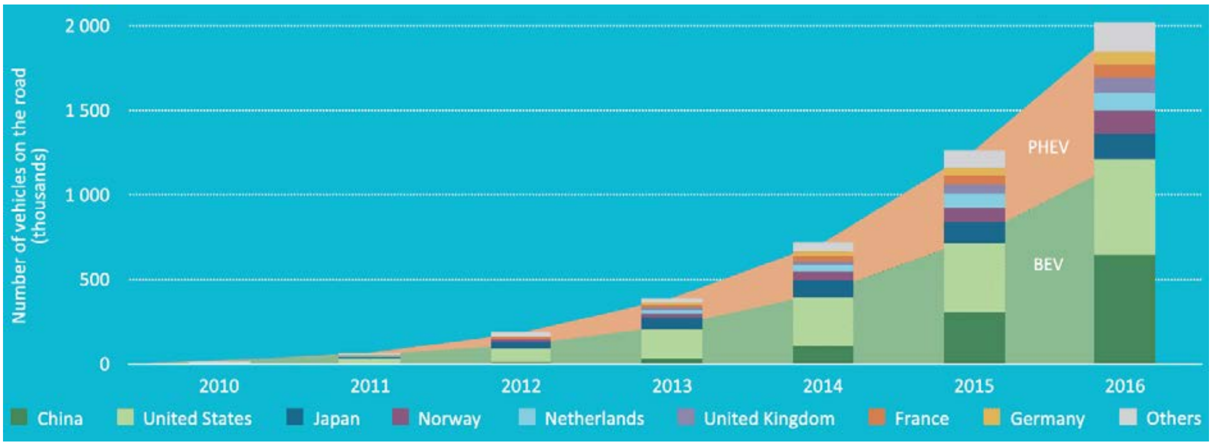


Figure 10. Evolution of the global electric car stock (BEV and PHEV), 2010-2016.Reprinted from *(IEA, 2017).*

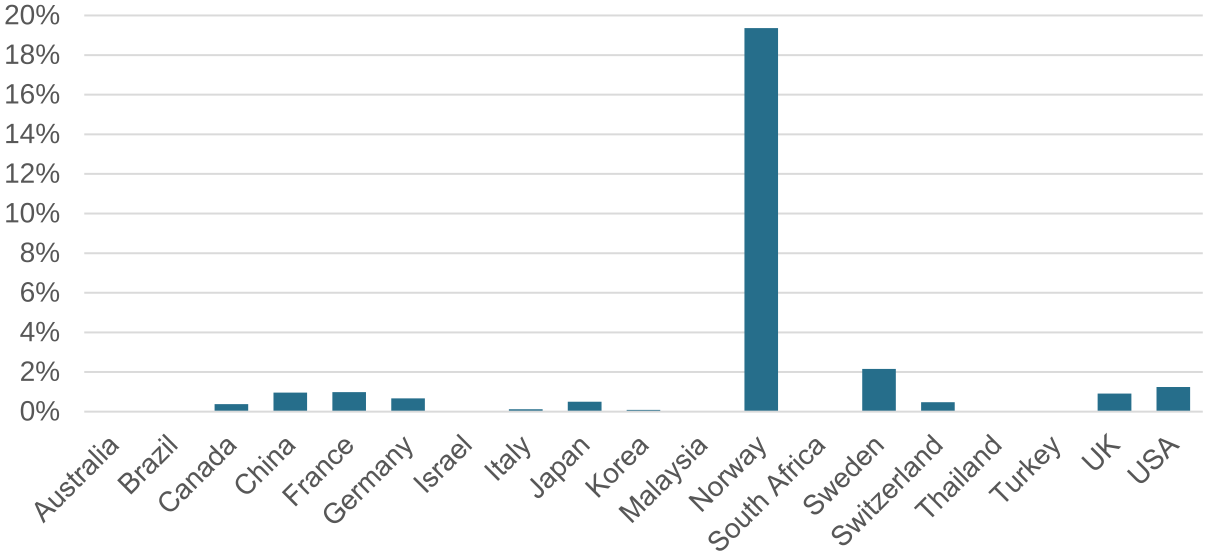


Figure 11. EV sales as a percent of total vehicles sales in 2015 for select countries. Adapted from *(EIA, 2017)*.

The projected EV deployment scenarios for 2030 are very dependent on global and local policy, battery price and the development of other alternative fuels. In any scenario, projections reflect significant numbers of EVs in the passenger vehicle stock in 2030 (see **Figure 12**).

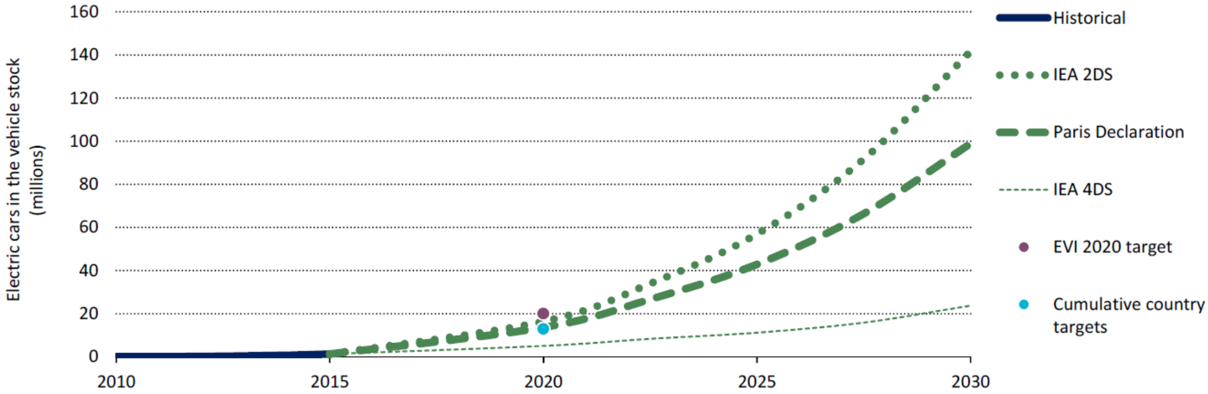


Figure 12. Deployment scenarios for the stock of electric cars to 2030. Reprinted from IEA *(2016)*.

The global number of charging points – both private and public – was estimated to reach 1.45 million in 2015, of which 190,000 (or 13%) were public charging points (see **Figure 13**). That same year, global public charging displayed growth rates similar to those of the global EV stock (71% and 78%, respectively) (IEA, 2016).

The number of publicly available chargers per EV differs a lot per country. A selection of the largest electric car markets indicates that in 2015 the number of EVs per slow public charging point outlet fell in the range of 5 to 15 with a global average of 7.8, and a global average of 45 EVs per public fast charging point (of which 27 were BEVs) (see **Figure 14**). The range of variability across countries is much wider for fast-charging infrastructure, and there are sizeable differences when this indicator is calculated only accounting for BEVs.

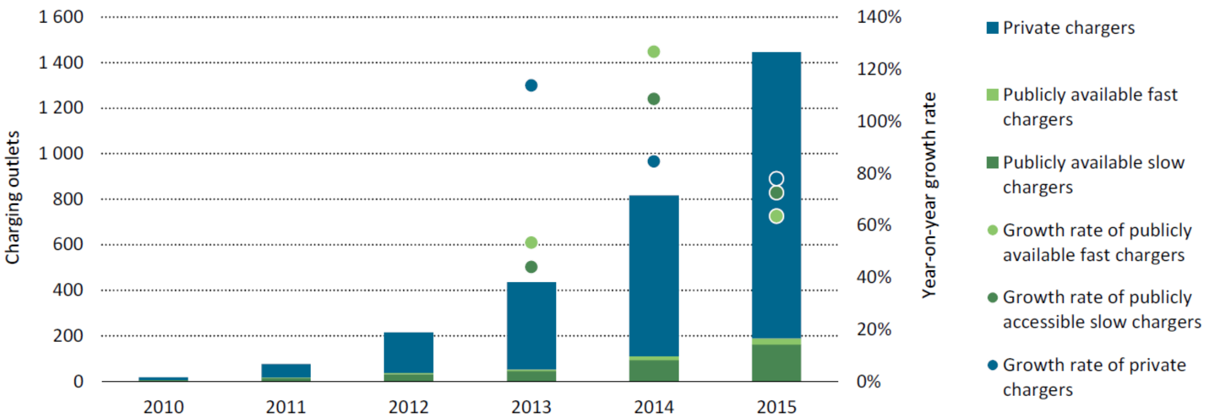


Figure 13. Global deployment of public and private charging stations, 2010-2015. Reprinted from IEA *(2016)*.

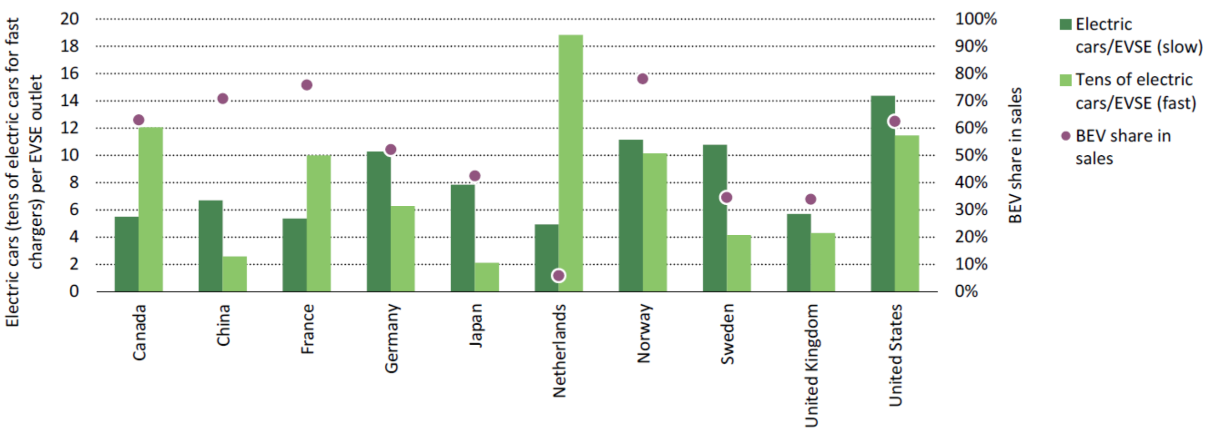


Figure 14. Electric cars/EVSE stock ratio for slow and fast publicly available chargers and share of BEVs in total electric car stock, 2015. Reprinted from IEA *(2016)*.

6. Practices analysis

The following next chapters provide an in-depth analysis of the policies in place for EVs and charging infrastructure in the United Kingdom, Ireland, The Netherlands and the United States. These countries were chosen in light of the distinct properties founds in their EV markets. Generally, they differ on a few important aspects: the market model they have for charging infrastructure, the different approach on how to organize EV policy, and the status-quo of EVs and infrastructure uptake.

6.1. Market models for charging infrastructure

Two main market models of ownership and operation of EV charging infrastructure can be distinguished (Zhu et. al., 2016):

- **The integrated model**: also known as the integrated DNO model, e.g. as in Ireland, in which the charging infrastructure is integrated in the DNO's (regulated) activities and asset base. The DNO is responsible for the distribution of the energy and also for operation and maintenance of the charging stations. Retail of energy and services can be provided by the DNO, but also by independent (new) market parties.
- **The independent model**: used in the Netherlands and the United Kingdom, market parties deploy the charging stations independently from the DNO. The DNO has the regulated task to connect the charging points to the grid – just as with any household – but several market parties run the activities to provide the e-mobility user with power.

6.2. Analysis structure

For each country, the following aspects of EVs and charging infrastructure are discussed:

Introduction

An overview of the country's EV and charging infrastructure status quo.

Drivers and objectives

The country's motivation and goals for pursuing adoption of EVs, underlying their EV policy.

Policy and incentives

An overview of enacted policies and incentives in place for EVs. These are divided into four distinct categories of incentives (van der Steen, Van Schelven, Kotter, van Twist, & van Deventer MPA, 2015):

- **Organizational:** Governmental actions that provides the physical ability to act directly to achieve policy goals, including the allocation of means, capital, resources and the physical infrastructure needed to act. Includes:
  - Government or public authorities acting as a launching customer
  - Degree of freedom for business models (commercial charging rates / revenues etc.)
- **Financial:** policy instruments involving either the handing out or taking away of material resources (cash or kind), in order to incentivize or disincentive behavior by subjects. E.g.:
  - Purchase grants

- Tax benefits
- Subsidies
- Government funding for research

- **Regulatory:** laws and directives designed to mandate, enable, incentivize, limit or otherwise direct subjects to act according to policy goals, including:
  - Legal requirements
  - Local parking legislation
  - Legal benefits (permission to drive on bus lanes, parking permits)
  - Legislation of standards
  - Technical requirements (for interoperability, open source systems etc.)

- **Communicational:** instruments that influence the value chain of charging infrastructure through the communication of arguments and persuasion, including:
  - Government information campaigns
  - Education
  - Change of awareness and consumer behavior

Apart from the categorization of incentives, they are differentiate based on their desired effect (e.g. more electric vehicles, more charging infrastructure, etc.), as it targets electric vehicles, private charging, public charging, semi-public charging or fast charging.

Governance and stakeholder roles

Since a sizeable share of the inhabitants lives in urban areas with limited access to private parking spaces, public charging infrastructure will be needed for e-drivers. As public authorities have the authority over public areas, each country has its own structure of public charging infrastructure, with different stakeholders assuming one or more roles in the public domain, subjected to governance by differing authority bodies.

To understand the organization of public charging infrastructure, an overview of the most important stakeholders is necessary. The role different stakeholders take, the influence they have and their interest on public charging can have impact on the public charging landscape (e.g. costs and business case, types of charging, mapping of chargers, amount of innovation etc.).

Lessons learned

Each country case in concluded with key takeaways.

7. United Kingdom

Title:
United Kingdom

Capital:
London

Population:
65.081.000

Gross Domestic Product (in billion EUR) :
€ 2.927,95

Total land area (km2):
244.820 km2

Passenger cars:
28.500.000

Highway (km):
3.555 km

Gross Domestic Product Capita (in EUR):
€ 44.989

Reprinted from EAFO (2018).

7.1. Introduction

The United Kingdom (UK) actively started their EV policy in 2010, setting financial subsidies for electric cars and the organization of charging infrastructure. From 2013 the sales of electric vehicles began to rise in the UK. While only around 500 electric cars per month were registered during the first half of 2014, this has risen to an average of almost 3,000 per month in 2016. By the end of 2017, there were 137,680 passenger EVs in the UK, of which 45,623 were BEVs and 92,057 PHEVs, together gaining a 1.9% market share that year (see **Figure 15**); there were also 4,282 LCVs (EAFO, 2018). As for publicly accessible charging positions, in 2017 there were 11,497 normal charge points in the UK (< 22kW) and 2,759 fast charging points (see **Figure 16**), or 104 public charging points per 1,000 EVs (EAFO, 2018). The UK has an independent infrastructure model in which the infrastructure is organized by private entities separate from the DNO.

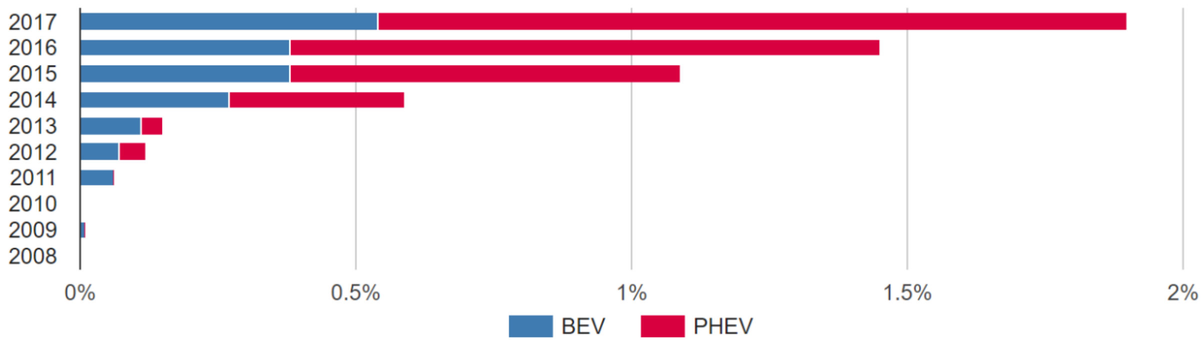


Figure 15. EV market share in the UK. Reprinted from EAFO *(2018)*.

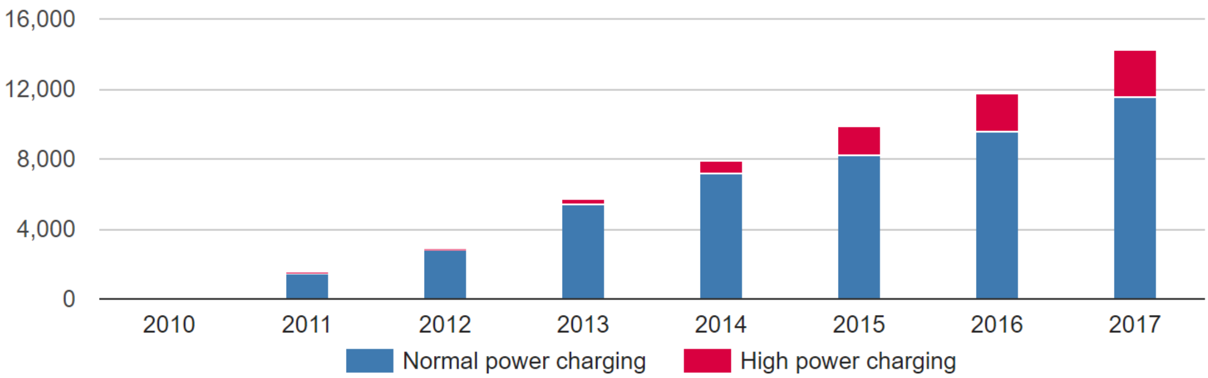


Figure 16. Number of publicly accessible charging positions in the UK. Reprinted from EAFO *(2018)*.

7.2. Drivers and objectives

The UK government has the following drivers underlying their EV policy:

- The UK has set itself the legally binding target of reducing total greenhouse gases (GHG) emissions by 80% relative to 1990 levels by 2050, of which transport is a major contributor. In order to fulfil its domestic and EU obligations, the UK is committed to supporting the development and deployment of low carbon vehicles, particularly EVs.
- Poor air quality reduces life expectancy in the UK by an average of six months and costs the economy an estimated £16 billion annually. Plug in vehicles emit little or no pollution at point of use and are a long-term solution to air quality problems (OLEV & GSR, 2015).
- Create world class skills and facilities for the development and manufacturing of electric vehicle technologies and export vehicles globally. Make the UK the best place in Europe for the automotive sector to invest (OLEV, 2016).

To realize these ambitions, the UK founded the Office of Low Emission Vehicles (OLEV). OLEV is a cooperation of – and funded by – the Department for Transport (DfT), Business, Innovation and Skills (BIS), and the Department of Energy and Climate Change (DECC). The core purpose of OLEV is to support the early market for plug-in and other ultra-low emission vehicles (ULEVs). To fulfill this mission, OLEV set the following objectives:

- Create a network of supporting infrastructure that ensures electric vehicles are an attractive customer proposition;
- Develop a smarter electricity grid that maximizes the benefits to vehicle owners and the electricity system from the shift to EVs;
- Make sure that by 2050 almost all cars and vans in the UK are EVs, with the UK automotive industry at the forefront of the design, development and manufacturing of these EVs.

7.3. Policy and incentives

Organizational, financial, regulatory and communicational measures the UK government and OLEV used since 2010 to support the uptake of electric vehicles. Both measures directed at EVs and measures directed at charging infrastructure are noted.

Organizational

Governmental actions that provides the physical ability to act directly to achieve policy goals, including the allocation of means, capital, resources and the physical infrastructure needed to act

- **Office for Low Emission Vehicles (OLEV)**
  OLEV is a cross-government industry-endorsed team, with the core purpose of supporting the early market for plug-in and other ultra-low emission vehicles (ULEVs). Working to combine policy and funding streams in order to simplify policy development and delivery for ULEVs, OLEV employs people and funding from the Departments for Transport (DfT), Business, Innovation and Skills (BIS), and Energy and Climate Change (DECC).

- **Plugged-in places [since 2010]**
  A framework of projects which was designed to take different approaches to setting up plug-in vehicle charging schemes, aided by match funding from OLEV. There are eight Plugged in Places (PIPs) projects located across the UK, purposed at exploring the effectiveness of different strategies, locations and charge point types. Examples of such schemes are the Charge Your Car network in the North-East of England and Source London in the greater London area (now the network of Bolloré).

- **Advanced Propulsion Centre (APC) [since 2013]**

  The UK government supports low emission vehicle R&D through the Advanced Propulsion Centre, a public-private partnership of a £1 billion, ten-year commitment between government and the automotive industry, focusing on developing low-carbon vehicle technologies. (APC, 2017)

- **Go Ultra Low City Scheme [since 2014]**
  A scheme introduced by the national government to promote local EV incentives, offering £40M (~ €50M) to 2-4 cities, to be invested in various EV incentives such as bus lane access, EV car sharing support, charging infrastructure investments and parking policies.

- **Ultra-Low Emission Vehicle Taxi Scheme [since 2014]**
  Through the ULEV Taxi Scheme, £20M (~ €25M) will be available to local authorities that support the uptake of low emission vehicles in the taxi fleet.

- **Modern Transport Bill [since 2017]**
  The Modern Transport Bill, announced by the queen, is UK's push to be at the forefront of the international transport technology revolution: developing driverless cars and launching a commercial spaceport. Electrification of transport is one of the goals integrated in the bill, including charging infrastructure.

- **Grant schemes charging infrastructure [2016-2018]**
  OLEV has allocated £2.5m of funding for 16/17 and 17/18 for on-street residential charging projects, available to local authorities for eligible projects, on a first come, first-served basis. There are schemes for home and work charging as well.

Financial

Policy instruments involving either the handing out or taking away of material resources (cash or kind), in order to incentivize or disincentive behavior by subjects

- **Plugged-in Places program [2010-2013]**
  The Plugged-in Places program complemented the subsidy of home chargers with funding for public and semi-public charging infrastructure until 2013 (30 million), where the government matched private investments in charging infrastructure with public funds. Roughly 5,500 charging points were installed under the program, 65% of which are publicly accessible, with free charging until 2014, later shifting onto park and charge fee model.

- **Plug-in grant [2011]**
  A subsidy that covered 25% of the eligible cars' (BEVs, PHEVs and FCEVs) list price, up to £5,000 (~€6,200) at the point of purchase.

- **Plug-in Van grant [2015]**
  20% of the list price up to a maximum of £8,000.

- **Plug-in grant [2015-2020]**
  Incentive raised to 35% of vehicle value, capped at £5,000 (in favor of lower priced EVs). In late 2015 the scheme was extended into 2018 and the level of grant was reduced to £2,500-£4,500 for cars, depending on CO2 emissions and zero emission range. £200M have been secured for the plug-in car grant for 2015-2020. (GOV.UK).

- **EV Homecharge Scheme [until 2016]**
  The Electric Vehicle Homecharge Scheme subsidizes the installation of private chargers in the UK. EV owners could apply for this subsidy, which covered a maximum of 75% or £700 (~€873) of the total installation cost.

- **Budget allocation for charging infrastructures [2015-2020]**
  For this timeframe, £32M (~ €40M) are allocated for charging, of which £15M (~ €19M) are assigned to the EV Homecharge Scheme, £8M (~ €10M) to public charging infrastructure, and £9M (~€11M) to other infrastructure investments.

Regulatory

Laws and directives designed to mandate, enable, incentivize, limit or otherwise direct subjects to act according to policy goals

- **Taxi regulations [2018]**
  From 2018 only zero emission capable taxis with a minimum of 30 miles range are allowed, targeted at a full zero emission in the future.

- **Vehicle Excise Duty**
  Cars with CO2 emissions of up to 100 g/km are exempt from annual ownership taxes, which can otherwise reach upwards of €600; taxes on the private use of company cars are also determined based on the vehicle's CO2 emissions rating.

Communicational

Instruments that influence the value chain of charging infrastructure through the communication of arguments and persuasion, including information and education

- **The Office for Low Emission Vehicles (OLEV) [2015-2020]**
  OLEV's website provides useful information for consumers, including guidance and calculators for EV and charging infrastructure incentives, playing an important role in consumer outreach and education.

- **ULEV Readiness [2014-2015]**
  The UK government allocated £5 million (~€6 million) during 2014 to 2015 for the electrification of its own fleet under the ULEV Readiness Project. The project included a fleet review to identify the most suitable vehicles to be replaced with EVs and then provides fully subsidized two-year lease agreements for EVs.

7.4. Governance and stakeholder roles

In the UK the infrastructure is tendered by lower governments (cities, regions or municipalities) and the operation of infrastructure is done by private parties that subcontract their energy supplier, charge points operator (CPO) etc. The grid operator realizes the grid connection as a public entity. **Figure 17** illustrates the different roles in public charging, and **Table 4** describes which stakeholders take those roles.

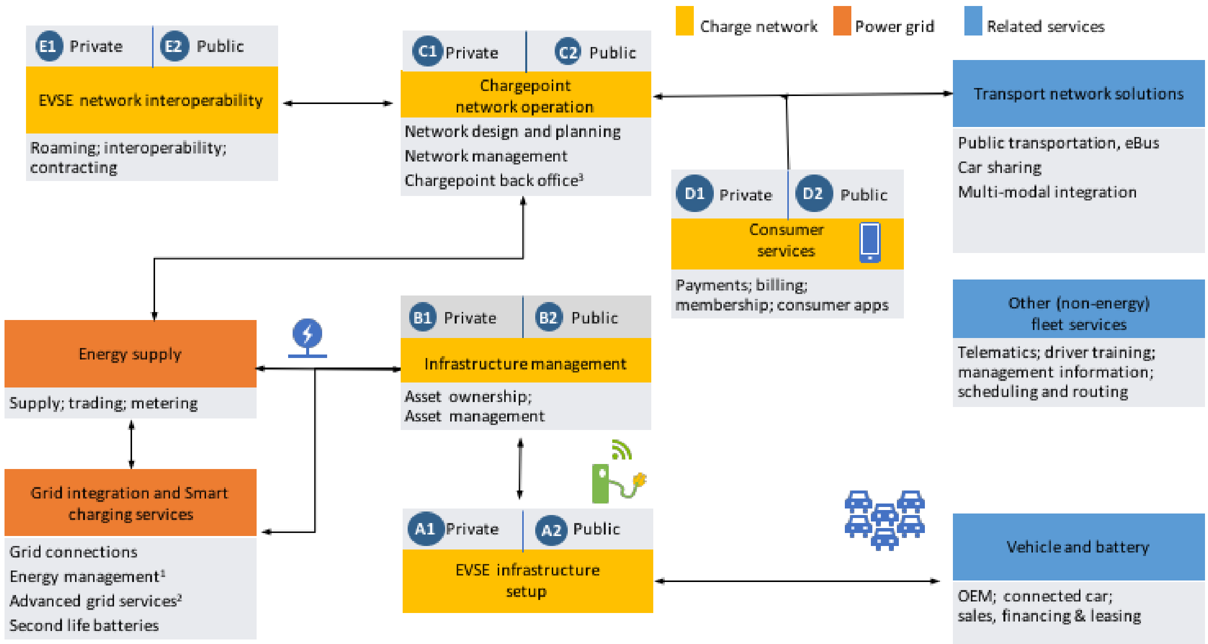


Figure 17. Charging stakeholders map for the UK.

Table 4. Charging stakeholders roles in the UK.

	Position on public charging infrastructure
A1	Mostly English manufacturers, often subcontractors of CPOs.
A2	Standardization and certification: mostly public under European legislation (IEC standards). English authorities set basic requirements for grid connection and testing of public chargers.
B1	Since 2014 asset management is done by private parties, mostly energy companies or big contractors. Often A1, B1 and C1 are organized by these parties with different subcontractors (e.g. the manufacturers).
B2	Municipalities or operators legally own the infrastructure. Municipalities often tender the public charging infrastructure (A1–D1). During the contracting term, most responsibilities are for the contracting party.
C1	Often same party as B1 (energy companies, big contractors) take the role of CPO (charge point operator). They take most of the (financial) risks and responsibilities for exploiting chargers during the contracting term.
C2	Municipalities make up charging policies, the framework of the network design (e.g. demand response, only for EVs with more than 40 km range)
D1	There are only few separate EVSPs (Electric Vehicle Service Providers) in the UK. They offer billing services providing access to multiple charging networks from different operators, by making bilateral agreements with CPOs. The EVSPs are small and cover only a part of the charging networks, so there is no total interoperability. In other areas (e.g. London) billing and other consumer services are organized by the locally operating CPO.
D2	Non-public.
E1	There is no national interoperability between chargers in different UK regions. Interoperability within regions is often organized by "pay as you go" or by the CPO itself.
E2	None public

Case study: the city of London

As one of the eight Plugged-in Places projects, London's city-wide charging network Source London was originally led by the local government body Transport for London (TfL), a private-public consortium of partners from the public and private sector. Source London received £9.3M (~€11.5M) from the Department for Transport, with matching funding from TfL (TfL, 2013). The IT infrastructure was developed for TfL by Siemens. In 2014 the charging network was sold to Bolloré Group, which manages the Source London network including more than 1,300 public charging points.

London was also awarded £13M (~€16M) as part of the Go Ultra-Low City Scheme in early 2016, to be invested in charging infrastructure and priority parking for EVs, among other measures (GOV.UK, 2016). Based on the award, the TfL, London Councils and the Greater London Authority (GLA) announced an allocation of £4.48M to 25 London boroughs for the installation of up to 1,500 new standard speed (level 2) on-street charging points – effectively doubling the number of CPs throughout the city (TfL, 2017).

In a tender for fast charging in the city, a longlist of operators was selected, but it's up to the boroughs to makes the final operator selection. TfL takes care of the locations for 10 years, as well as the grid connection. The commercial operator and the city share costs, and once the operator turns a certain level of profit the city also receives a share; the maximum charging price rate is set for 5 years. TfL's investments in grid capacity in order to accommodate 300 fast chargers is set to cost £18M.

Status quo

- Currently 1,500 CPs sockets across 27 boroughs
- Plan to expand network to 6,000 CPs by 2018 through organizing a new tender by TfL
- CPs are mostly 3-7kW
- Bolloré (IER) responsible for maintenance/ replacement
- Separate membership and RFID card required for every CPO
- Pay as you go (credit card)

Challenges

- **Parking:**
  - 83% population in some boroughs have no off-street parking
  - Existing high demand for on street parking
  - Political pressure from residents and businesses not to remove existing on-street parking provision

- **Interoperability:**
  - Near field technologies a preferred over RFID cards (no real interoperability).
  - Many providers with different cards.

- **Governance:**
  - 33 boroughs with different priorities and political make up.
  - Two tiers of regional and local governments lead to a convoluted decision-making process.
  - Tender for public charging is separate for residential (public charging for residents only), for car clubs (sharing) and for taxi. This makes the system very inefficient.
  - Source London and TfL have no control over critical items like price/ access for everybody / SLAs and parking fees, mainly because governance has been difficult since the start.

7.5. Lessons learned

Purchase subsidies for electric vehicles

High upfront costs of EVs are a key barrier for the uptake of EV's. The Plug-in Car Grant was considered an important factor in the purchase decision of 85% of ULEV buyers (OLEV, 2016).

Home charging

Subsidy scheme for (connected) home charger was used by charge point operators to make deals with car dealers / leasing companies providing "free chargers" to consumers. This increased the adoption of home chargers.

Governance public charging network

The Source London network was Initially owned by Transport for London. When funding for the chargers ended, many chargers were not maintained and malfunctioned, causing bad publicity and unhappy EV drivers. In 2014, the whole network was sold to Bolloré, a private entity. It's important to define the governance structure for the project from the beginning and gain buy-in from all the key stakeholders. Establish mechanisms for regular, open, honest communications amongst key project stakeholders. (OLEV, 2013).

Business case

The business case is central to the development of the plug-in vehicle charging scheme. Upfront thought should be put into the payment model and how the project is going to be funded. The goals of the project should be linked to policy development and be long ranging enough to ensure they endure over time.

Public charger Placing strategy

A separate placing strategy is needed for different groups e.g. the domestic, workplace and publicly accessible charge points markets or for public and private sector hosts. Separate funding requirements and mechanisms may also be attached to each of these groups. The project team shortlisted sites based on analysis of the target markets, driving and parking patterns and customer dwell times and then conduct feasibility analysis of the grid network capacity and installation requirements. These considerations would need to be balanced before a site is agreed. (OLEV, 2013).

Grid operator

Working closely with the grid operator on grid capability can be a major benefit. In the UK there can be a huge variation in costs for a grid connection depending on location. Working with the DNO and utilizing grid maps can be effective in short-listing locations and identifying the most cost-effective sites. This is more evident for rapid chargers or where multiple chargers are located together. (OLEV, 2013).

Interoperability

There is no national interoperability between charging operators in different UK regions, so an e-driver needs several membership cards to have access to different networks. Interoperability between regions is often organized by "pay as you go" or by the CPO itself. One of the reasons for lacking interoperability is that tendering bodies (public entities) did not prescribe interoperability as a requirement in their tenders.

- Weigh up the pros and cons of providing below-cost or free services to gain early adopters and think ahead about how transition to payment models can be achieved effectively.

- Consider the benefits of a pay-as-you-go scheme; lower barriers to entry for users and ease of interoperability with adjacent charging networks (OLEV, 2013).

Organization

- The UK has a clear, long term strategy for EV with specific targets until 2020. This roadmap is the bases for the EV incentive program.
- The foundation of OLEV in cooperation with multiple ministries makes a shared vision possible, incorporating all perspectives (energy, infrastructure, transport, climate, business), as well as creates one clear organization responsible and accessible for all other public and private entities on the subject of EV.
- The use of the Plugged-in Places program stimulated EV in 8 regions and made realization of infrastructure possible in an early stage, breaking the “chicken and egg problem” in which EV’s won’t be sold because they are not able to charge. One of the disadvantages of this approach was that other areas that missed out on the program felled behind in EV and infrastructure developments. These regional differences became more visible over time.

8. Ireland

Title: Ireland	**Total land area (km2):** 70.273 km2
Capital: Dublin	**Passenger cars:** 1.985.000
Population: 4.630.000	**Highway (km):** 1.200 km
Gross Domestic Product (in billion EUR) : € 246,11	**Gross Domestic Product Capita (in EUR):** € 53.156

Reprinted from EAFO (2018).

8.1. Introduction

By the end of 2017, there were 2,687 passenger car EVs in Ireland, of which 1,948 were BEVs and 739 PHEVs, together gaining a 0.7% market share that year (see **Figure 18**); there were also 152 LCVs (EAFO, 2018). As for publicly accessible charging positions, in 2017 there were 837 normal charge points, and 172 fast charging points (see **Figure 19**), or about 376 public charging points per 1,000 EVs (EAFO, 2018). Noteworthy is that almost 700 public charging points were already deployed by 2014 – while there were only about 500 EVs on Irish roads at that time.

Ireland follows an *integrated infrastructure* model, where the charging infrastructure is in hands of e-Cars, a full subsidiary of the Electric Supply Board (ESB). ESB is Ireland's distribution network operator (DNO), but also operates part of the power stations in the country, acting as an energy supplier. Historically, ESB had a monopoly over the Irish power market. Presently, ESB operates with different entities: in a public role as DNO, and as a commercial semi-state concern in a liberalized and competitive energy supply market. e-Cars tenders the chargers and instalment but does the operation of the charging infrastructure itself.

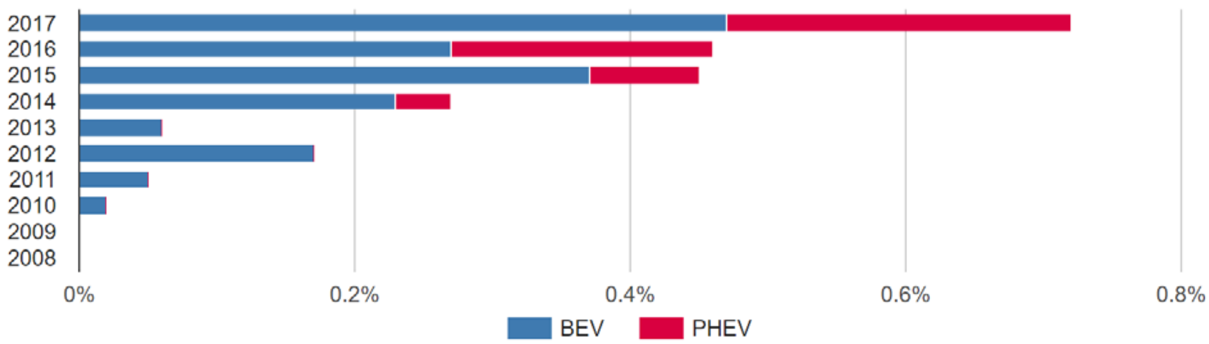


Figure 18. EV market share in Ireland. Reprinted from EAFO *(2018)*.

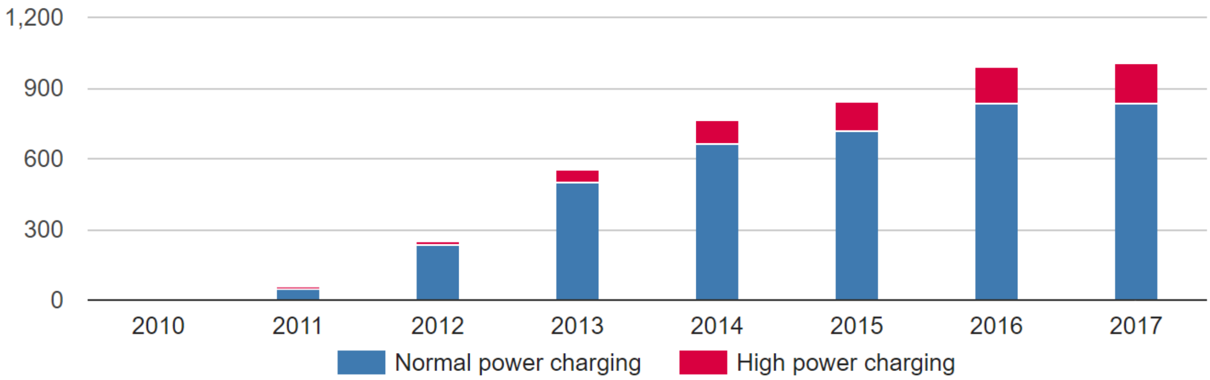


Figure 19. Number of publicly accessible charging positions in Ireland. Reprinted from EAFO *(2018)*.

8.2. Drivers and objectives

With an abundance of accessible wind and ocean energy, and distances from the capital city to key neighboring cities ranging from 170km to 260km, Ireland is well suited to become an early adopter of electric vehicle technology.

Transport accounts for a sizable chunk of the Ireland's total primary energy consumption, with 42% of the total final consumption placing it as the country's largest energy consuming sector, almost entirely dependent on oil (SEAI, 2016) (see **Figure 20**). Increasing oil scarcity, oil price volatility and environmental concerns are driving a search for an alternative means of powering the transport system, drivers for the electric vehicle roadmap of Ireland (SEAI, 2017).

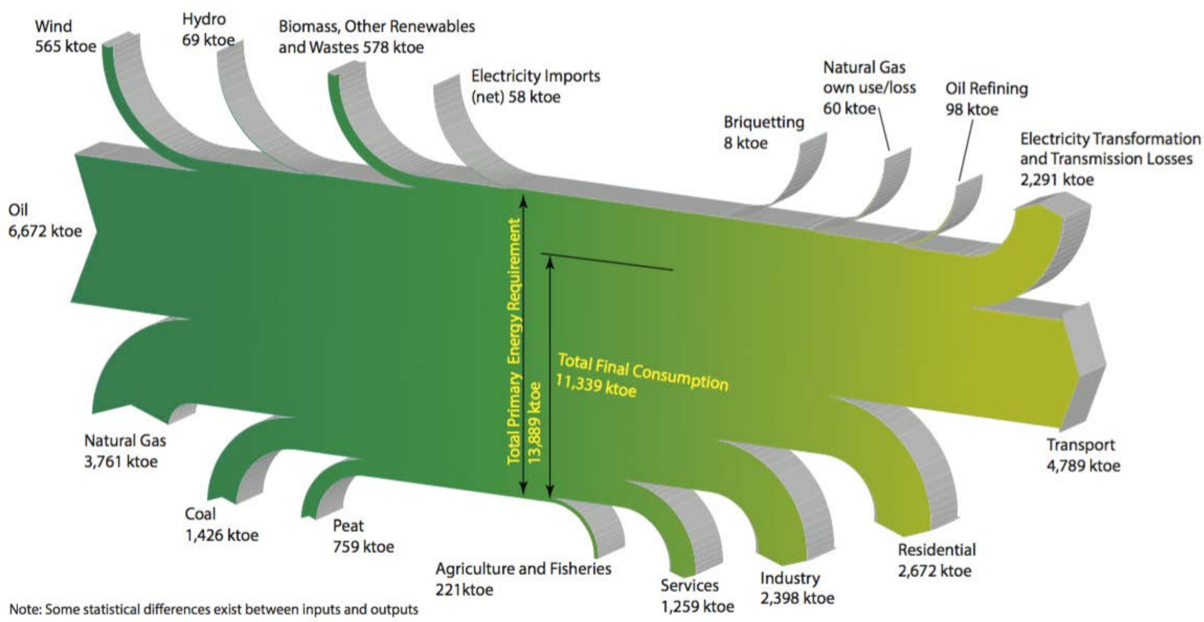


Figure 20. Ireland's energy flow, 2015. Reprinted from SEAI *(2016)*.

Ireland's target under the Renewable Energy Supply Directive is to ensure that 10% of its transport energy comes from renewable sources by 2020. Renewable energy is on the rise in Ireland, reaching a 16.7% share of the electricity generation fuel mix in 2015, with natural gas as the biggest energy source of the sector covering 42.2% at a downward trend in the preceding 5 years (SEAI, 2016).

As the volume of EVs begins to grow, a significant rise in the contribution of wind power in transport is expected. Ireland has substantial resources of wind and ocean energy. By storing these intermittent supplies of wind and ocean power, highly efficient EVs therefore offer Ireland the opportunity to supply a significant proportion of its transport energy needs from its own energy resources while substantially reducing the associated CO_2 footprint. This has the potential to significantly displace imports of petrol and diesel (SEAI, 2017).

The sustainable energy authority of Ireland designed an Electric Vehicles Roadmap, offering a vision of how the Irish market for electric vehicles could develop up to the year 2050 (SEAI, 2017). Ireland's target is to achieve 10% EV usage by 2020 amounting to 230,000 vehicles on the road, and 2.9 million electric vehicles on the road by 2050, with renewables powering up to 50% of the passenger vehicle segment by that year. The expected impact of EVs on energy efficiency, fossil fuel imports, CO_2 emissions, and electricity demand is significant. CO_2 emissions for the passenger car fleet are forecasted to reduce by about 80% with respect to 2011 emissions, despite a significantly larger fleet size.

8.3. Policy and incentives

Organizational, financial, regulatory and communicational measures the Irish government used since 2010 to stimulate the uptake of electric vehicles (ESB, SEAI). Measures directed at EVs and measures directed at charging infrastructure are noted separately.

Organizational

Governmental actions that provides the physical ability to act directly to achieve policy goals, including the allocation of means, capital, resources and the physical infrastructure needed to act

- **ESB eCars [since 2010]**
  eCars was established in 2010 by the Electric Supply Board (ESB) to roll out charging infrastructure for electric vehicles across Ireland, and to support the introduction and demand for electric vehicles nationally. ESB acts as the launching authority. The first 30 fast charge points were rolled-out by eCars in 2011. Networks (NIE Networks).

- **Green eMotion initiative [since 2012]**
  The Green eMotion is consortium of 42 partners from the industry, the energy sector, electric vehicle manufacturers, municipalities, universities and research institutions. These organizations joined forces to explore the conditions needed for a Europe-wide electromobility. Green eMotion's main objectives include setting a framework for pan-European interoperable electromobility which is commonly accepted, user-friendly and scalable; Integrate smart grid developments, innovative ICT solutions and different types of EUs various urban mobility concepts; Enable a European wide market place for electromobility to allow for roaming; and providing a unique knowledge base

- **Northern Ireland Plugged in Places (PiP) [2015]**
  As part of the original Plugged in Places (PiP) project, the Northern Ireland Electricity (NIE) Networks – which owns the region's transmission and distribution grid – installed a network of 334 public charging points across Northern Ireland. e-Cars assumed responsibility over managing the operation, maintenance and development of charging assets on behalf of NIE Networks, with the latter maintaining ownership of the charging stations as part of their electricity distribution network. (ESB, 2018).

Financial

Policy instruments involving either the handing out or taking away of material resources (cash or kind), in order to incentivize or disincentive behavior by subjects

- **Electric Vehicle Grant Scheme [since 2008]**
  - **2008-2010:** The Sustainable Energy Authority of Ireland (SEAI) regulate grants which entitles BEVs and PHEVs with a reduction of up to €2,500 off the registration tax.
  - **2009:** The Irish Government, ESB and the Renault-Nissan Alliance agreed on a partnership to position Ireland as a European leader in electric transport, including the start of the electric vehicle grant scheme and the import of the Nissan Leaf (ESB, 2018).
  - **Until 2013:** To make Ireland an early adopter of EVs the government offered a grant and an exemption from vehicle registration tax (VRT) relief for purchasers of BEVs or PHEVs, until December 2012.
  - **2013:** €5,000 government subsidy for each plug-in electric car
  - **2014-2017:**
    - €5,000 government subsidy for each plug-in electric car (PHEV and BEV)
    - VRT reduction €5,000 for BEV (extended to end of 2021)
    - VRT reduction €2,500 for PHEV (extended to end of 2018)
    - BEV motor vehicle tax is only €120 per year, the lowest rate of motor tax in Ireland
    - Electricity from all public chargers is free

  (SIMI, 2017) (SEAI, 2017)

- **EV Home Charge Scheme [2014-2017]**

  The first 2,000 electric cars registered in Ireland are eligible for a free installation of a home charging point, worth about €1,000.

- **International Green Electric Highways [2014]**

  A Project led by ESB and partly funded by the EC, in which a network of fast charge points was rolled out throughout the Republic of Ireland and Northern Ireland.

Regulatory

Laws and directives designed to mandate, enable, incentivize, limit or otherwise direct subjects to act according to policy goals

- **EU legislation**

  Ireland follows the European legislation regarding the EV sector as a standard.

- **Free parking**

  Parking a BEV is free in numerous Irish municipalities.

Communicational

Instruments that influence the value chain of charging infrastructure through the communication of arguments and persuasion, including information and education

- **ESB campaign [2011]**

  ESB started an information campaign since the introduction of the first EV's in the country. This campaign started with great fanfare, but nowadays its much less intense.

- **OEMs campaign [2014-2015]**

  Multiple OEMs, most noteworthy Renault-Nissan, Mitsubishi Motors, Toyota and Peugeot Citroën, started a major campaign to promote the uptake of EV's in the country.

8.4. Governance and stakeholder roles

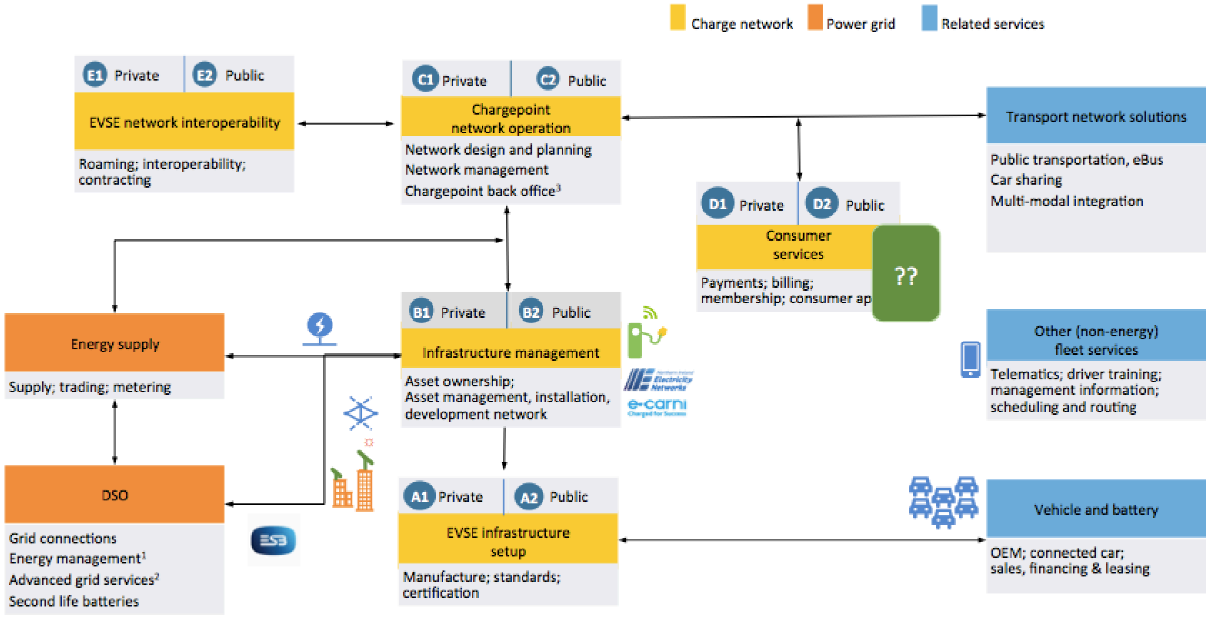
From the onset, the infrastructure in Ireland has been in the hands of e-Cars, a full subsidiary of ESB – Ireland's grid operator. ESB tenders the charging hardware and installation, but does the operation itself. Following a public consultation, the Commission for Energy Regulation (CER) decided to allow ESB to recover €25M through its distribution use tariffs for carrying out an extensive EV charging pilot program (CER, 2014). In light of Irelands targets EV targets, the program's objectives were to evaluate the positive and negative impact of EV charging over the electric grid, and specifically those associated with the distribution system. Moreover, the program was purposed so that its assets could be sold in the future, following the logic that considering the high cost of infrastructure, innovation and competition is needed in the charging infrastructure sector. This is in line with the Alternative Fuels Infrastructure Directive from the European Union, which mandates national governments to ensure that adequate publicly available EV charging infrastructure is provided, and that "The establishment and operation of recharging points for electric vehicles should be developed as a competitive market with open access to all parties interested in rolling-out or operating recharging infrastructures". ESB's eCars supports the view that the provision of publicly accessible EV charging infrastructure should be delivered on a competitive basis, rather than as a regulated monopoly, and would seek to accommodate and promote competition. (ESB, 2016).

Four options for the ownership of the charging infrastructure for electric vehicles are now being evaluated:

1. Assets become part of the Regulatory Asset Base (RAB) of ESB;
2. Sale of charging infrastructure via a public tender in a single lot to a third party, with a possible contractual obligation to prevent disaggregation;
3. Sales of charging infrastructure via public tender in multiple lots to third parties, i.e. multiple owners;
4. Maintain ESB's eCars ownership, with no future regulation of user cost recovery tariff and no additional regulatory support. As part of this arrangement, ESB eCars would operate the system on a commercial basis.

The CER has decided that any infrastructure developed over the course of the pilot will not be added to ESBNs Regulated Asset Base (RAB) at this point. A solution to the liberalization of the market model to a more independent infrastructure model has not been found yet.

The current stakeholder field in Ireland is described below, with **Figure 21** illustrating the different roles in public charging, and **Table 5** describing which stakeholders take those roles.



1. Time-of-use tariff optimisation, peak demand shaving, wholesale energy optimisation, BEMS / site load integration
2. Power quality management, demand response, balancing services, distributed generation integration, grid storage integration, vehicle-to-grid
3. Access control, chargepoint management, fault identification, data management

Figure 21. Charging stakeholders map for Ireland.

Table 5. Charging stakeholders roles in Ireland.

	Position on public charging infrastructure
A1	Only subcontractors of ESB
A2	eCars (an ESB subsidiary) is the sole network operator and is responsible for the infrastructure setup and hiring private contractors to install chargers in public space. There's only one Irish EVSE manufacturer (EC Charging), who enjoyed a long and productive relationship with eCars since its foundation in 2010, with the rollout of the national infrastructure. As for standardization and certification, chargers comply with all Irish and European specification standards, and the embedded communication system complies with OCPP.
B1	Only subcontractors of ESB
B2	ESB owns the infrastructure assets, pending to a government decision on their future. Municipalities tender public charging infrastructure in accordance and cooperation with ESB.
C1	Only subcontractors of ESB
C2	The Department of Communications, Climate Action and Environment set the EV and charging policies, with inputs from the Department of Transport, Tourism and Sport and consultation advice by ESB. The network design framework is produced by ESB (e.g. demand response, only for EVs with more than 40 km range), with aims to provide rapid charging every 30 km along major routes. Usually ESB identifies sites of interest prior to approaching potential hosts to establish a contract, though sometimes a host initiates the contact with ESB; in any case, potential hosts normally look to ESB to provide the charge point and don't want the charger connected to their metered power supply, but this is slowly changing as vehicle numbers increase. ESB takes the role of CPO, as well as most of the (financial) risks and responsibilities for chargers' utilization during the contracting term.
D1	Electric vehicle service providers (EVSPs) offer subscriptions to e-drivers and delivering interoperability (the possibility to charge everywhere) in return, using an RIFD card for

	authentication in the transaction. Currently, only one operator operates in Ireland, but more will/can join in the future. This interoperability also applies in Northern Ireland. NIE (Northern Ireland) are a separate legal entity and work within a separate jurisdiction, with a different currency. The RFID cards are issued with different branding, but drivers from either side of the border can use their cards on both sides, with the back-office system supporting both currencies.
D2	-
E1	Pending to the Commission for Energy Regulation (CER) decision, new operator(s) may get to utilize the existing infrastructure and back office, with interoperability set as mandatory under all market models, and a free competitive market as another key objective.
E2	The back-office system implemented by ESB is set up for multiple charging operators.

8.5. Lessons learned

Incentives EV and charging infrastructure

In Ireland, the sales of EV was slow compared to the readiness of the infrastructure, in part due to lacking availability of EV models. Since the business case of charging infrastructure is based on the sales of kWh's to electric drivers, a low number of EVs makes a good business case for chargers impossible. Also, the placement of chargers which are not being used in public space has a negative effect on the image of electric transport. **Charging infrastructure development must go hand in hand with a package of EV incentives and EV growth.**

Integrated charging infrastructure model

The integrated model where the grid operator is also the operator of all public charging infrastructure through a subsidiary, means that the costs for the subsidiary and its operation are paid by all the grid operator's customers. This has both advantages and disadvantages:

- **Advantages:**
  - There is one single point of contact for OEMs and governmental bodies.
  - There is one single point of contact for consumers if they are looking for EV information, charging stations installation and charging services in the public domain.
  - Concentrated R&D efforts working with multiple stakeholders
  - Unified approach for charging station installation and permitting process with public entities (cities/ regions) and commercial site owners.
  - A publicly owned "trusted advisor" for policy makers
  - There are no issues with interoperability of charging services due to the fact that only one CPO is active in this market.

- **Disadvantages:**
  - There is no free choice of service or energy providers for consumers
  - There is no incentive for other companies to research and develop innovative solutions for charging infrastructure or related services
  - There is no competition in public charging and no incentive for continuous improvement of the business case of public charging to lower costs for the governments and the e-driver. Pricing for consumers is only influenced by subsidies.
  - There is one party that set all standards for the charging model; municipalities have no choice but to comply with this model.

Interoperability

All chargers are interoperable due to the fact that only one CPO is active in the market.

Business case

There is less drive for innovation and cost reduction with just one operator. The cost of investment and operation of the charging network is funded by the ratepayers, until a viable business model emerges.

International Cooperation

The decision to join the largest EU funded EV project has enabled ESB to take a leadership role in the development of the EV standards and in preparation for EV uptake by the electricity grid.

9. The Netherlands

Title: Netherlands	**Total land area (km2):** 41.543 km2
Capital: Amsterdam	**Passenger cars:** 8.000.000
Population: 16.933.000	**Highway (km):** 2.274 km
Gross Domestic Product (in billion EUR) : € 868,62	**Gross Domestic Product Capita (in EUR):** € 51.297

Reprinted from EAFO (2018).

9.1. Introduction

By the end of 2017, there were 119,332 passenger car EVs in the Netherlands, of which 21,115 were BEVs and 98,217 PHEVs, together accounting for a 2.2% market share – a steep drop from a record 9.9% merely two years before, with PHEVs sales plummeting while at the same time BEVs sales continue to show steady growth (see **Figure 22**); there were also 2,210 LCVs (EAFO, 2018). As for publicly accessible charging positions, in 2017 there were 32,120 normal charge points, and 755 fast charging points (see **Figure 23**), or about 275 public charging points per 1,000 EVs (EAFO, 2018).

The Dutch charging market operates under an independent infrastructure model.

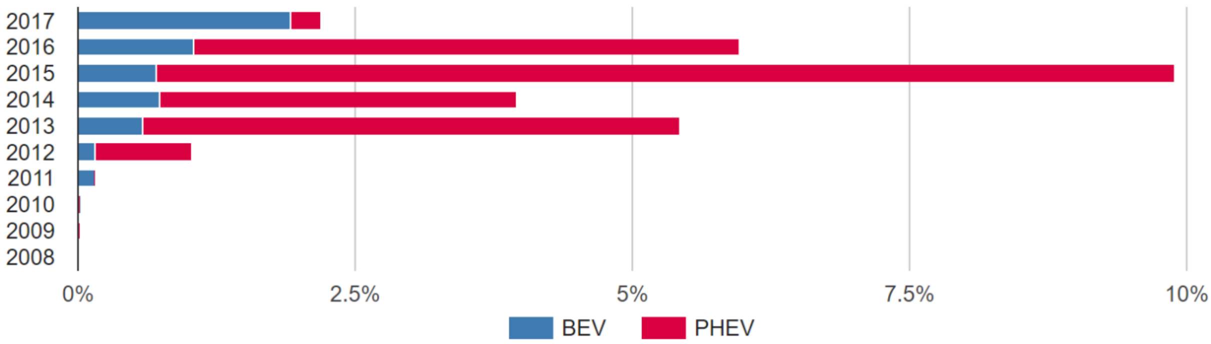


Figure 22. EV market share in the Netherlands. Reprinted from EAFO *(2018)*.

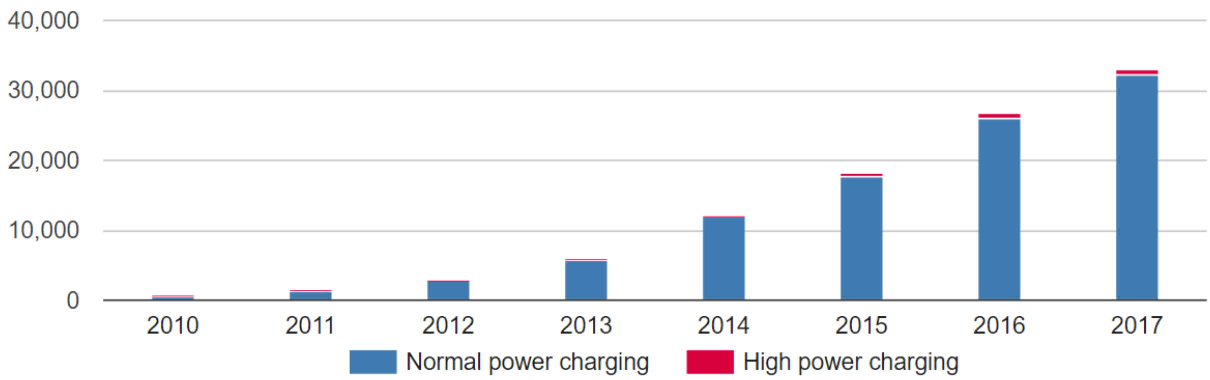


Figure 23. Number of publicly accessible charging positions in the Netherlands. Reprinted from EAFO *(2018)*.

9.2. Drivers and objectives

The drivers of the Dutch Plan of Action "speeding up electric transportation 2011 – 2015" are as follows:

- Strengthening the economic position of the Netherlands
- Strong competition position by acting as a testing ground for EV, possible because county is suitable for EV (flat, short distances, densely populated urban areas).
- Creating employment (e.g. IT, services, battery development, R&D etc.)
- Accounts to energy security
- Transition from fossil fuels to sustainable energy
- Batteries in EV's can serve as storage for growing amount of (volatile) sustainable energy
- Being a frontrunner in the rapidly emerging EV sector ('early market')
- Impulse for the Dutch R&D sector
- Climate targets & air quality in cities (CO_2 and NO_x).
- Implement the "Sustainable Fuel Vision" of Ministry of Infrastructure & Environment in order to unite the Dutch climate goals with mobility and society

The plan defines the following objectives:

- Stimulate roll out of EVs to 20.000 EVs in 2015 and the needed infrastructure.
- Growing the potential for revenue around EV (green growth)
- Stimulating innovation on the area of EV
- Policy goal: no more ICE vehicles sold from 2025 onwards
- Stimulate roll out of EVs:

Table 6. Rollout predictions for EVs in The Netherlands in 2020, 2025.

Predictor	EVs in 2020	EVs in 2025
Economic Affairs, 2011 (SER, 2014)	200,000	1,000,000
TUE 2015 (Steinbuch, 2016)	323,212 (183,513 BEVs)	1,522,165 (1,142,674 BEVs)
Ecofys en TUE 2016 (Ecofys, 2016)	275,972 (126,302 BEVs)	1,460,926 (880,110 BEVs)

9.3. Policy and Incentives

Organizational, financial, regulatory and communicational measures the Dutch government and used since 2009 to support the uptake of electric vehicles. Measures directed at EVs and measures directed at charging infrastructure are noted separately.

Organizational

Governmental actions that provides the physical ability to act directly to achieve policy goals, including the allocation of means, capital, resources and the physical infrastructure needed to act

- **Foundation of Elaad [2009]**
  An initiative of Dutch DNOs, Elaad was founded with the purpose to achieve a total of 10,000 public charging points. From 2009 to early 2014 it has realized a network of approximately 3,000 public charging points. The Dutch grid operators financed Elaad.

- **Air Quality program [2010]**
  The rollout of first public chargers by tenders throughout various big cities in the Netherlands was funded by air quality programs. The second stage started in 2013, with rollout of public charge points throughout various municipalities, conurbations and regions/provinces.

- **Car sharing scheme [2011]**
  Delivery of 300 electric Smarts by Daimler in Amsterdam to promote electric transport, which was the first full electric scheme in the world. Members of Car2Go Amsterdam can use these cars between set borders and can park the cars for free within the city limits of Amsterdam and conurbation. Car2Go is co-financed by the city of Amsterdam, in order to raise awareness.

- **Fast charging infrastructure [2012]**
  RWS (Rijkswaterstaat, part of the Ministry of Infrastructure and Environment) started issuing licenses to market parties to install fast chargers and offer electricity at rest areas along the Dutch motorways at gas stations, truck stops and service stations. In total 6 parties requested the possibility to place fast chargers on 249 spots alongside the entire motorway. Currently there are 612 charge points at fast chargers in The Netherlands (approximately 200 fast charging stations).

- **National knowledge platform for charging infrastructure [2014]**
  The NKL (national knowledge platform for charging infrastructure) was founded to increase collaboration between various organizations, with a primary goal of lowering the cost of public charging infrastructure through joint projects. By increasing information exchange, research and support of various initiatives, the NKL seeks to strengthen the position of the Netherlands in the EV sector. NKL is funded by the Dutch government and DNOs (NKL, n.d.)

- **Infrastructure rollout [2016]**
  Rollout of charge points via the largest tenders so far. A region, a province or a large city is the tendering authority; smaller municipalities can join these tenders freely but have no influence on the tender terms. Due to this cooperation's economy of scale, the prices for the realization of charge points decrease so quickly that the support of public financing is sometimes no longer necessary.

Financial

Policy instruments involving either the handing out or taking away of material resources (cash or kind), in order to incentivize or disincentive behavior by subjects

- **Tax exemptions [2011-2017]**
  - **2011-2013:** Total exemption of registration fee and road taxes for both BEVs and PHEVs (if they emit less than 95 g/km for Diesel or 110 g/km for gasoline)
  - **2014-2016:** Registration fee was exempted for BEVs and set at EUR 6/gCO_2/km for PHEVs.
  - **Since 2017:** BEVs are exempted from the ownership tax, and PHEVs receive 50% discount (about 400 to 1,200 EUR for conventional cars). BEVs remained exempted from registration fee, which was raised to EUR 20/gCO_2/km for PHEVs. Private use of company car is set at 4% for BEVs, while for PHEVs the fee was increased to 22%, the same as for conventional cars. The government decided to equalize PHEV to conventional cars, as experience showed that most PHEV drive the bigger part of their journey on their ICE engine, and so equalizing their taxation with ICE cars prevented an unintended incentive

  (RVO.nl, 2017; EAFO, 2018; IEA, 2017).

- **Green Deal Charging Infrastructure [2011]**
  The Green Deal Charging Infrastructure is a cooperation between the government, municipalities and private parties, which installs public chargers and contributes a third of the costs in order to finance the financial gap in the business case. 15,000 charging stations in private and semi-private domains were installed. (RVO.nl, 2017).

- **Privileges EV [2011-2017]**
  A scheme for free parking and charging

- **Rotterdam programs [2013-2014]**
  - €1,450 subsidy to install home charger using green energy
  - Scrappage program to remove old, polluting vehicles to improve air quality
  - €2,500 incentive for entrepreneurs to replace the old vehicles with BEV vehicles (first 5,000 applicants)

- **Purchase subsidy [2014]**
  €3,000 subsidy for purchase of BEV taxis and delivery vans

- **Green Deal Public Charging Infrastructure [2015-2018]**
  Like the Green Deal Charging Infrastructure 2011, bodies (often municipalities or regional bodies) tendering charging infrastructure can request Green Deal funding, as long as they fund a third of the project cost themselves and that another third is funded by the private sector, with the government contributing the other third in order to finance the financial gap in the charging infrastructure business case. The Ministry of Economic Affairs allocated €5.7M to deploy the charging infrastructure, up to 2018.

Regulatory

Laws and directives designed to mandate, enable, incentivize, limit or otherwise direct subjects to act according to policy goals

- **Environmental zones in city centers [since 2007]**
  First major implementation of environmental zones within city centers in order to improve the air quality. Only vehicles (e.g. heavy-duty trucks, passenger cars) that emit less than

a certain threshold are allowed in the city center. Each city sets their own emission levels. The emission levels get stricter over time.

- **Parking regulations**
  - Parking spaces reserved for BEV/PHEV on designated parking lots
  - 1-year free parking in several big cities
  - Free parking with Car2Go in Amsterdam

Communicational

Instruments that influence the value chain of charging infrastructure through the communication of arguments and persuasion, including information and education

- **Formula E-Team [2009-2017]**
  The Formula E-Team (FET) is a public-private partnership between businesses, universities, research institutions and the government, created to accelerate the EV uptake in the Netherlands. With members including automotive associations, ministries, foundations and environmental cooperation, the goal of this taskforce is to make the Netherlands the testing ground and a world forerunner regarding EVs and EV technology (RVO.nl, 2017). Prince Maurits, a cousin of the King of the Netherlands, took lead of the FET to further promote EV in the Netherlands (Groen7, 2012)In 2010 the FET team submitted the "Action plan driving electric" report to the prime minister, which was later embraced by the cabinet leading to the establishment of EV tax benefits schemes. In 2011, FET took part in the implementation of the first Green Deals, with the help of the government and private parties.

- **RVO (Netherlands Enterprise Agency) [since 2009]**
  RVO takes multiple actions to stimulate Green Growth in the electric transport sector. The agency issues publications (both Dutch and international) to elaborate, promote and distribute EV knowledge to help lower governmental bodies to realize infrastructure and to stimulate investments and innovation in the private sector. RVO also organizes exchange programs (Partners for International Business, PIB) on EV, inform about subsidies, and on the growth of EV and infrastructure. (RVO.nl, 2017).

9.4. Governance and stakeholder roles

In 2009 the city of Amsterdam was the first to place chargers in the public domain. Big cities have taken an active role in promoting electric transport and realizing public infrastructure through tenders and local measures and incentives to stimulate EV (e.g. subsidies, Car2Go, the electrification of their own fleets, taxi etc.).

Next to the first initiative of the cities, Elaad was founded in 2009: an initiative of DNOs in the Netherlands. The purpose of Elaad was to achieve a total of 10,000 public charging points. From 2009 to early 2014 it has realized a network of approximately 3,000 public charging points. Whether the realization of public charging infrastructure is a commercial job or falls below the statutory duties of the DNOs, has been under discussion. The Ministry of Economic Affairs decided that competitive activities should have no place in the regulated domain of the network operator. That is why since August 2014, ElaadNL operates as knowledge and innovation center in the field of charging infrastructure and coordinates cooperation between DNOs and other public and private entities on behalf of operators involved (Kwink groep, 2016). Cities and provinces tender public charging infrastructure since 2011 on larger scale.

Private entities, like energy companies and contractors, operates these chargers. The case study of Arnhem hereafter gives more insight in how this public- private cooperation is organized.

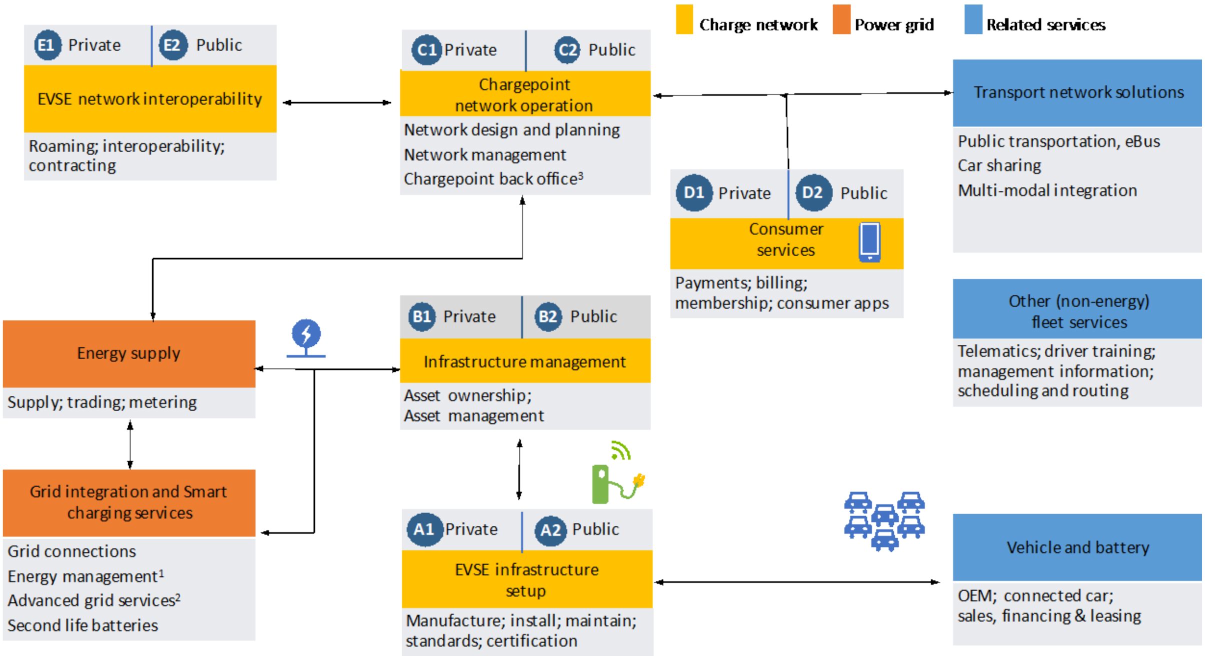


Figure 24. Charging stakeholders map for the Netherlands.

Table 7. Charging stakeholders roles in the Netherlands.

	Position on public charging infrastructure
A1	Mostly Dutch manufacturers, often subcontractors of CPOs
A2	Standardization and certification: mostly public under European legislation (IEC), national legislation. Dutch grid operators designed basic requirements for correct grid connection & testing of public chargers.
B1	Asset management is since 2013 only done by private parties: mostly energy companies or big contractors. Often A1, B1 and C1 are organized by these parties with different subcontractors (e.g. the manufacturer).
B2	Municipalities legally own the infrastructure. They often tender the public charging infrastructure (A1 – E1). During the contracting term, most responsibilities are for the contracting party.
C1	Often same party ass B1 (energy companies, big contractors) take the role of CPO (charge point operator). They take most of the (financial) risks and responsibilities for exploiting chargers during the contracting term.
C2	Municipalities make up charging policies, the framework of the network design (e.g. demand response, only for EVs with more than 40 km range)
D1	MSPs (Mobility Service Providers) offer subscriptions to e-drivers and delivering 'interoperability' (the possibility to charge everywhere) in return.
D2	Non-public.
E1	National interoperability is organized through the Central Registry Interoperability (CIR) and is managed by the non-commercial association eViolin to which all CPOs and EVSPs are connected (eViolin, 2018).

Case study: The City of Arnhem

Introduction

The city of Arnhem finalized its second successful tender for public charging infrastructure using the innovative Best Value Procurement (BVP) approach. The main idea behind the BVP method is to contribute to a free market and select the contractor offering the highest quality instead of only the lowest price (City of Arnhem, 2016).

Providing public charging services

Although the business case for public charging in the Netherlands has become more attractive, high public charging prices still results without support from the local or national government. To keep stimulating electric mobility, in 2015 the city of Arnhem organized a second tender for public charging infrastructure. The tender involves a commissioning period for chargers of 2-3 years and an operation period of the infrastructure of 4-8 years.

Tender objectives

The city aims to stimulate electric transportation for four reasons: 1) improve local air quality, 2) reduce CO_2 emissions, 3) reduce noise, and 4) strengthen the local sustainable economy. With the recognition of the (future) demand for public charging infrastructure, the city defined three main objectives for the tender:

- To facilitate charging infrastructure for e-drivers without private parking possibilities
- To unburden the city from the organization and responsibilities related to public charging within the city
- To find a contractor that proactively searches for and experiments with smart-charging solutions and future-ready technologies and reduces the impact of public charging on public space.

Tender procedure

The tender was a public European tender for a concession of public charging services for electric vehicles in the city of Arnhem. These services include construction, maintenance, operation and exploitation of public charging stations. Because traditional tender methodologies focus primarily on price, the city decided to follow the Best Value Procurement (BVP) methodology. This allowed focus on quality and let the market come up with solutions based on their expertise and the public charging demand.

Scope

The tender included public charging services and everything that is necessary to enable EV owners to charge publicly. Additionally, it included an option to take over several existing charging locations that are currently property of the city. The responsibilities of the contractor are listed below:

- A charging point is to be realized within 10 weeks after location confirmation and the acknowledgement of complementing permits
- If the charging location applicant (e-driver) satisfies certain criteria* the contractor must approve the application
- Delivering continuous and professional charging services
- The organization of requesting permits, announcements and grid connections
- Management of the request and realization scheme for charge points
- The required communication concerning the construction of charging locations
- The delivery of data (usage and availability of the charging infrastructure network)
- Communication towards users and transparency regarding price and charging regulations
- Arranging the back office for billing of the charging services

* The criteria defined by the city are: 1) the applicant does not have private property to charge its electric vehicle, 2) the applicant either lives in the city or works there for at least 18 hours per week.

Key to the above demands is that the operationalization of it is *not* prescribed. Applicants are expected to design their own market model based on their expertise, the market demand and the state of technology. This is typical in BVP tenders, in which a common analogy is that the applicants are mountain guides (experts) with the city being tourists taking a hiking tour - the city knows which mountain it wants to climb but it does not plan the route; after all, the mountain guide has experience and can determine which route best fits the situation, avoiding difficult passages and raging rivers.

Scope (continued)

The length of the concession agreement is set at a maximum of 10 years. Only during the first two years (the commissioning period) the contractor is responsible for the development of new public charging locations. The city has the possibility to extend this commissioning period with one year. Accordingly, the contractor operates its infrastructure for an additional 4-8 years. This structure has two major advantages:

- It allows the contractor to build a business case for the charging services for a period of ten years
- The city has the possibility to employ a different contractor and define another tender contract after two years

Program requirements

The city defined a list of demands for the public charging services, divided into six categories:

1. Charging services
- Charging services should be suitable for all electric vehicles at around 3.5kW
- Charging services comply with international standards
- The grid connection of the charging location is contracted by the contractor
- Only sustainable produced electricity is used for the charging services
- Minimum impact on public space (color, shape, integration)
- The construction work when realizing a charging location occurs within one day

2. Operation and availability
- The charging objects are in a well-maintained state at the end of the concession agreement
- The availability of the charging locations is real-time publically available
- A minimum down time of 1% per month
- Malfunctions are addressed and repaired within 2 hours after being reported (24hrs a day)
- The plug can be unplugged from distance on request of the EV-owner
- The charging service starts within at most 8 seconds after identification
- A user can connect within 2 minutes after a previous user disconnected

3. Charging tariff
- A maximum kWh price is defined by the city
- The charging price is clearly communicated to the EV-owners

4. Ownership and transfer
- After the concession period the public charging services are to be transferred to the city or another party without additional costs
- The contractor is obliged to cooperate in the transfer at the end of the concession agreement
- Suppliers of the charging infrastructure are to provide maintenance for a minimum of 3 years after termination of the concession agreement
- Charging objects and related systems (such as software) are free of any property rights and should operate according to the OCPP 1.5 protocol
- All complementary documentation is provided by the contractor at termination of the concession agreement

5. Data and performance reports
- The city is owner of all data regarding the public charging services
- The contractor provides monthly performance (usage and malfunctions) reports

6. Grid operator
- The grid connection of the charging locations is in accordance with the demands of the grid operator

Procurement methodology

The applicant receiving the most points in the procurement will enter the verification trajectory. Each application is reviewed by a committee consisting of three members: a council advisor from the city's department of public quality, an administrator from the city's department of product administration and a senior advisor from EVConsult. In the procurement, a maximum of 85 points on can be received on quality and 40 points on price. The points on quality can be earned with four distinct plans of action (see table below) and during the interviews.

PROCUREMENT CRITERIUM	MAXIMUM POINTS
Quality	**85**
Plan 1: Charging solution	25
Plan 2: Organization and financing	20
Plan 3: Services for EV-owners	10
Plan 4: Risk assessment and value added	10
Presentation and interviews	20
Price	**40**
Price per charging location at charging tariff of €0,28	7
Price per charging location at charging tariff of €0,30	20
Price per charging location at charging tariff of €0,32	7
Price per charging location at charging tariff of €0,34	2
Price per charging location at charging tariff of €0,36	2
Price for removal of charging location	2

Verification procedure and tender closure

A three-week verification trajectory is meant for the city and the applicant to get to know each other and agree on the charging solution proposed by the applicant. If the charging solution or the applicant does not satisfy the city's demands, the city can decide to choose another applicant. For Arnhem the verification trajectory was completed successfully. It revealed the temporary results and a few weeks later the contract was made definite.

9.5. Lessons learned

Tax exemptions

Both the BEV's and PHEV's gained the same tax exemptions. This resulted in a high uptake of EV's in the Netherlands and accompanying this, a strong growth of chargers. The side effect of this financial incentive was that people in the Netherlands mostly bought or leased PHEV's, with a limited range of electric kilometers. Target groups, mostly business people, drive over 50 km a day. When the battery turned empty, the PHEV return to the inefficient ICE engine. Most companies now oblige their employees to drive their PHEVs electric. The government changed their incentive with a focus on BEVs now more BEVs will be brought on the market by OEMs.

Economic development and business potential

As part of the national EV policy to stimulate 'green growth' several manufacturers of charging equipment and providers of charging services have emerged in the Netherlands. The success of these start-up firms is positively correlated to the success of EVs, particularly with regard to short-term success. For these companies, it is important for incentives to be continued and for clear directives to be developed with regard to permits for charging points.

The employment in the EV sector grew by 25% to 3,200 jobs in 2014, especially in construction of custom vehicles, charging infrastructure and smart grids. Electric transport supplies in 2014 (estimation of bank ING): 3,200 (FTEs), €820M of production and €260M added value to the Dutch economy. Private investors offer leading start-up companies in the semi-public and private charging infrastructure sector funding to scale up. Dutch companies are increasingly active internationally. Especially in charging infrastructure, services and construction vehicles (buses) are Dutch companies operating abroad (see **Figure 25**) (RVO.nl, RebelGroup, EVConsult, 2015).

Figure 25. Type of actors active in the Dutch EV sector in 2008, 2011 and 2014 *(RVO.nl, RebelGroup, EVConsult, 2015)*

Public support for charging infrastructure

The Dutch government supports the realization of public charging infrastructure. The larger cities in the Netherlands have demonstrated their willingness to co-finance hundreds of public charge points. Besides such direct financial support, the national government has taken away regulatory hurdles (e.g. easier permit procedures for installation), support cost reductions (e.g. allowing 'simpler' solutions to metering), and by making the business case more interesting to investors (e.g. flexible energy tariffs to enable the use of EVs as energy buffers) (Bakker, 2013).

Business case

The program of the NKL (National Knowledge Platform) brings together all stakeholders in the field of electric mobility to improve the business case of public charging. The NKL also monitors the development of the business case. The cost of public charging infrastructure decreased in 2016 by approximately 30% since 2013. The main causes for this cost decrease were standardization of the charger and the placement process, more scale and reduced maintenance costs through increased quality of the charger. The average selling price of electricity on public chargers went up with 12%. The use of the public chargers has increased by 70% to around 8.5 kWh / day. Together these improvements led to a big improvement of the business case (NKL, 2016).

Independent Grid Operation

The foundation of Elaad by regional DNOs, organizing placement of public chargers led to a first network of public chargers without cities and municipalities to invest in an early stage of the market. The downside of this approach was a more reactive attitude of municipalities, since it was unclear for a long period of time who was responsible for organizing public chargers and who was allowed to operate public chargers and get revenue out of it. Private entities took the opportunity when big cities started tendering to get into the field of public charging. Still there are uncertainties coming from unclear regulations on who is entitled to operate charging stations (e.g. the subsidiaries of DNOs). To keep development of the public charging market up to speed roles and responsibilities need to be clear from start.

Parking pressure

Elaad placed their chargers on strategic spots in municipalities, not having a direct user to charge there. This led to chargers not being used, which had a negative impact on the image of EV and unnecessary increasing the parking pressure. This led to a new approach: installing public chargers only when there is a direct need from an e-driver, so utilization is guaranteed and parking pressure is not unnecessary increased. This improves the business case of public charging and the image of EV. Also, potential e-drivers have the assurance they will be able to charge using this approach, knowing that they can request a public charger if they meet the required criteria (e.g. having an EV, no private parking place available etc.)

Interoperability

In the Netherlands interoperability was required by the cities in all tenders. This requirement led to the foundation of E-Violin in which all CPOs and MSPs are cooperating together to organize interoperability.

Fast charging

The national highway authority (RWS, part of the Ministry of Infrastructure & Environment) a nationwide fast-charging network established by a number of firms that have been granted concessions to operate such stations along the Dutch highways.

Lessons learned:

- The authority gave out more than 200 concessions (with an exclusive right for use of the location of 15 years) for Fast-charging locations along the national highways. Without any additional funding from the authority all locations are now being exploited by companies who made their own long-term investments in fast charging.
- Splitting up the concession in different batches so multiple companies have a change of winning locations and stimulate competition.

10. United States

Population:
326,626,000

Land area:
9,147,593 sq km

Gross domestic product:
$19.36 trillion ($59,500 per capita)

Installed electricity generating capacity:
1.074 billion kW

Electricity capacity from renewable sources:
10.7% + 7.4% hydroelectric

Paved Roadways:
4,304,715 km (incl. 76,334 km expressways)

Light-duty vehicles:
189,619,308 (short wheelbase)

Figure 26. Map and key statistics for the US. Image reprinted and data adapted from CIA *(2018)*, BTS *(2018)*.

10.1. Introduction

EV sales in the US started to pick off in 2011, as better car models, infrastructure and incentives came together and presented the market with an improved value proposition (see **Figure 27**). While PHEV sales were somewhat held back in 2015 – arguably associated with low fuel prices that year – the sales of BEV in the US shows consistent year over year growth (see **Figure 28**) (AFDC, 2017). As of 2016, there were about 563,700 EVs in the US, of which over 297,000 were BEVs and over 266,600 PHEVs (see **Figure 29**) (IEA, 2017).

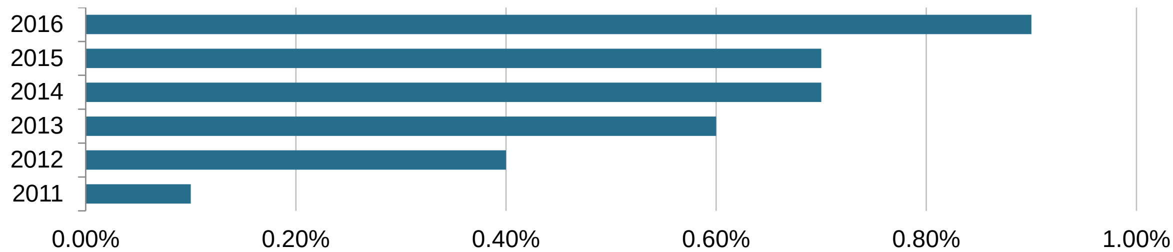


Figure 27. EV market share in the US. Adapted from ORNL *(2017)*.

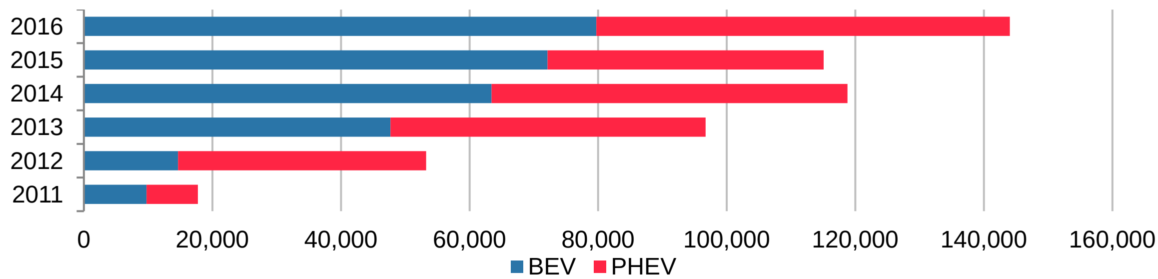


Figure 28. EV sales in the US. Adapted from AFDC *(2017)*.

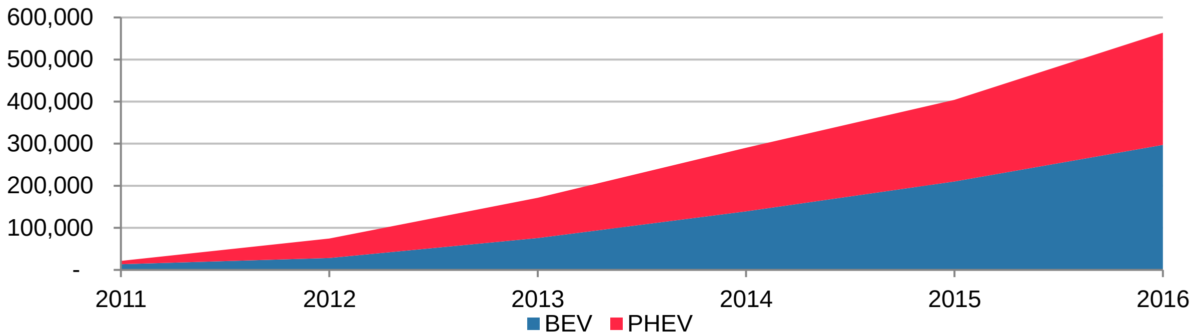


Figure 29. EV stock in the US. Adapted from IEA *(2017)*.

Hand in hand with the growth in number of EVs on US roads, the availability of public charging infrastructure experienced a rapid growth in deployment as well, reaching 35,089 normal charging points and as much as 5,384 fast charging point in 2016 (see **Figure 30**), or about 72 public charging points per 1,000 EVs (IEA, 2017).

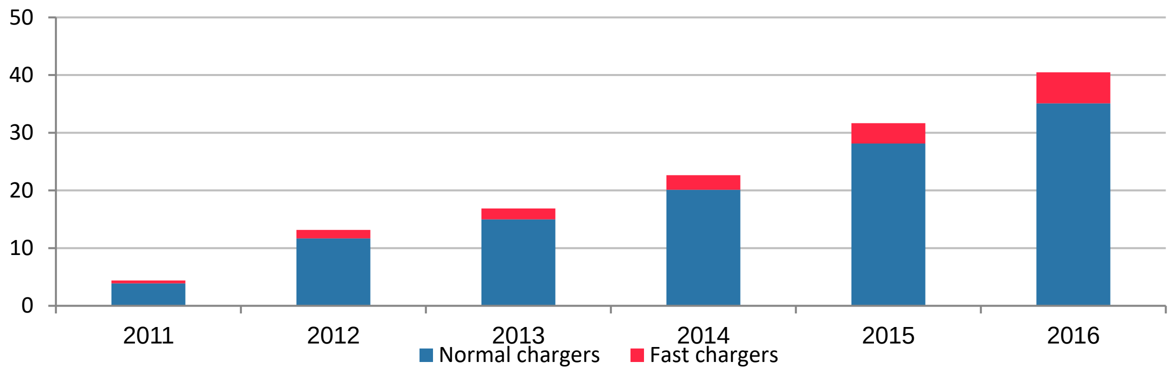


Figure 30. Number of public charging points in the US. Adapted from IEA *(2017)*.

As of February 2018, there were already 17,200 public EV charging stations (with over 47,100 charging points), of which 13,387 were associated with one of the 10 network operators (see **Figure 31**) (AFDC, 2018). While public charging stations can be found in each of the US states (see **Figure 32**), their distribution between states varies greatly – over 14,200 stations are located in the state of California, with Texas having the second-largest deployment with over 2,400 (see **Figure 33**). This could be attributed to the corresponding variation in EV supportive measures on the state level, showcasing the influence those can have over market adoption; in addition, it correlates well with the states' populations sizes (Schoettle & Sivak, 2017).

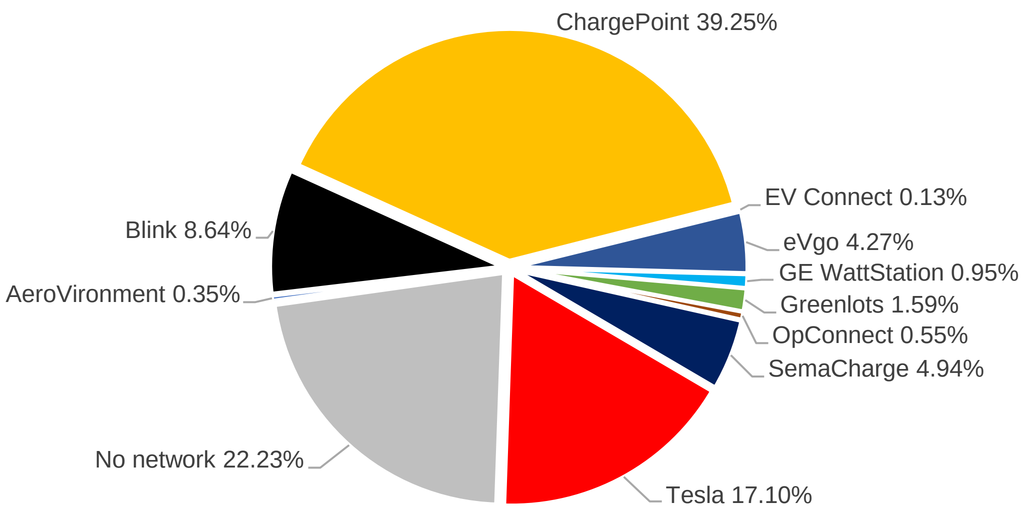


Figure 31. Share of network operators in number of public charging stations. Adapted from AFDC *(2018)*.

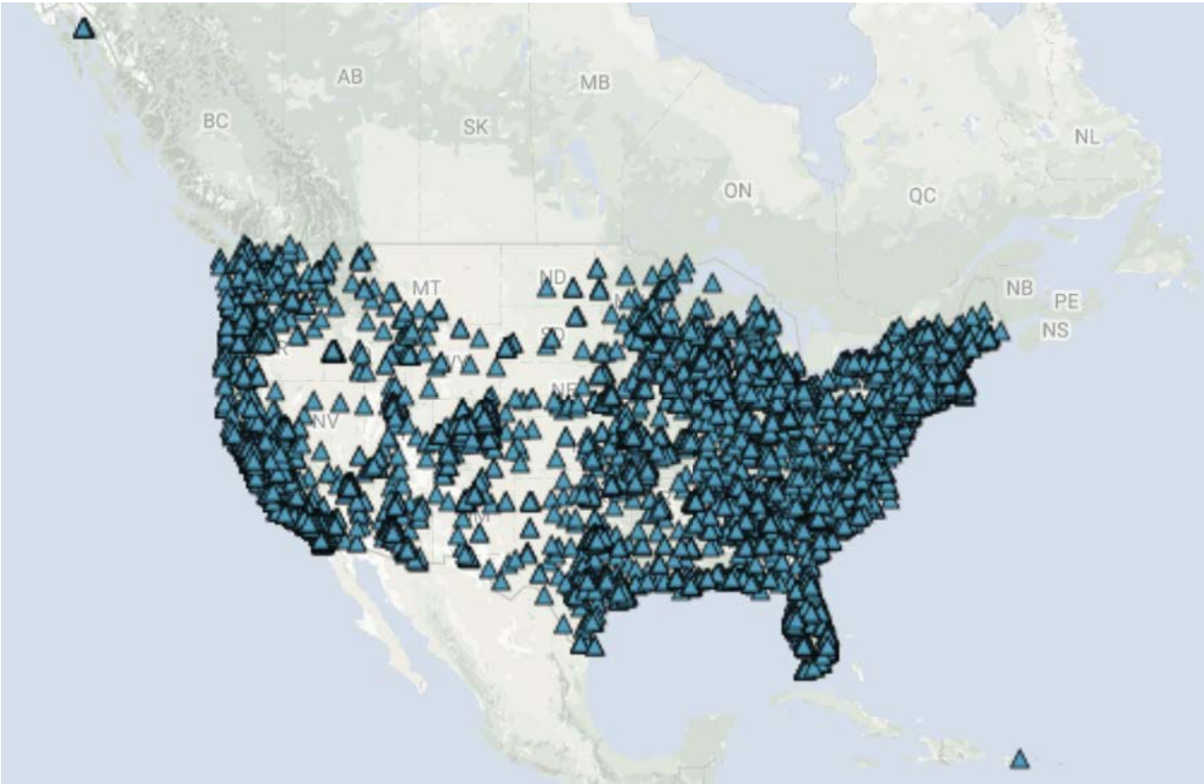


Figure 32. Locations of public charging stations in the US. Reprinted from AFDC *(2018)*.

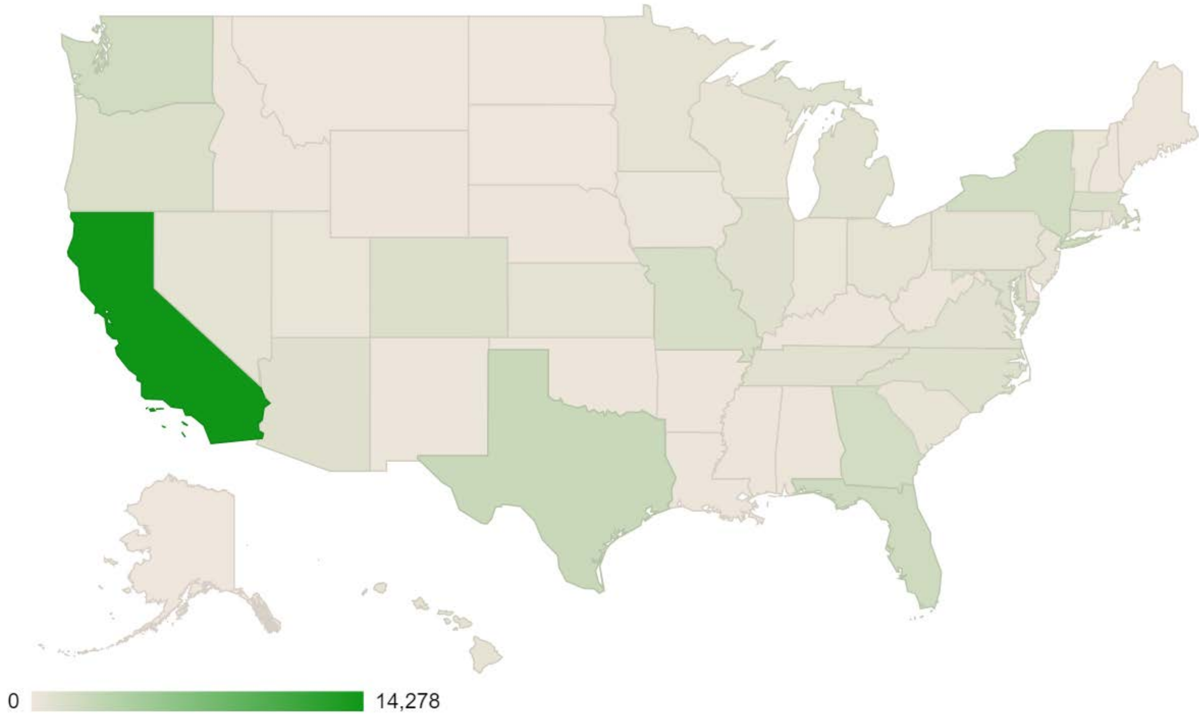


Figure 33. Density map of number of public EV charging stations in the US, by state. Reprinted from AFDC *(2018)*.

The US charging operates in an independent model, stemming from its bottom-up development evolution without directive oversight and planning, resulting in lacking interoperability and difficulty in implementation of cross-network measures and programs such as managed charging, local incentives schemes and projects (Fitzgerald & Nelder, 2017).

10.2. Drivers and objectives

- The Alternative Motor Fuels Act of 1988 and the Clean Air Act Amendments of 1990, which encouraged the production and use of alternative fuel vehicles (AFVs) and the reduction of vehicle emissions. The enactment of the Energy Policy Act (EPAct) in 1992 required certain vehicle fleets to acquire AFVs.
- US aims to advance its economic, environmental, and energy security by supporting local actions to cut petroleum use in transportation. (DOE, 2017)
- The Clean Cities program's goal is saving 2.5 billion of gallons (~9.5B of litters) of oil per year, by 2020 (DOE, 2017).
- One of the strongest drivers for the introduction of EVs to the US market are the Corporate Average Fuel Economy (CAFE) standards, which continuously push for improvement in fuel economy.

10.3. Policy and Incentives

In the US, not only that the federal government has as many as 26 direct and indirectly-related EV policies and laws in place, all but 3 US states have additional local policy measures (including incentives), with the noteworthy standout of the state of California with 56 EV-related laws and incentives in place (as of May 2017) (Schoettle & Sivak, 2017).

Following is a sample of key federal organizational, financial, regulatory and communicational measures the US government uses to support the uptake of electric vehicles. Both measures directed at EVs and measures directed at charging infrastructure are noted.

Organizational

Governmental actions that provides the physical ability to act directly to achieve policy goals, including the allocation of means, capital, resources and the physical infrastructure needed to act

- **Clean Cities [1993-2020]**
  As part of the DOE's Vehicle Technologies Office created to provide technical and financial information to EPAct-regulated and voluntary adopters fleets, the Clean Cities program is working to develop partnerships, publications and toolsets which support implementations efforts to reduce oil dependence in transportation. The program targets both the national and the local level, with almost 100 local coalitions of nearly 15,000 businesses, fuel companies, fleet owners, local government and community organizations stakeholders, led by a local Clean Cities coordinator. Each coalition's coordinator creates projects and activities that are best suited for the locality's challenges and opportunities. Clean Cities has already awarded almost $400 million and leveraged additional $800 million in matching funds and contributions through its funding opportunities for hundreds of projects across the US, including the introduction of EVs into public and private fleets. (DOE, 2017).

Financial

Policy instruments involving either the handing out or taking away of material resources (cash or kind), in order to incentivize or disincentive behavior by subjects

- **Plug-In Electric Drive Vehicle Tax Credit [since 2010]**
  Plug-in Electric Vehicles, including passenger vehicles and light trucks, which were acquired after 2009 receive a tax credit of $2,500, plus $417 for vehicles powered by a battery with at least 5 kWh, plus additional $417 per kWh beyond that, with a total allowed credit for a vehicle limited to $7,500. Once a manufacturer hits cumulative sales of 200,000 EVs the credit phases out gradually over a year. (IRS, 2017).

- **Two-Wheeled Plug-In Electric Drive Motor Vehicle Tax Credit [until 2017]**
  Two-wheeled plug-in electric drive vehicle with a battery of at least 2.5 kWh of capacity, which are intended for road use and can drive at least 45 miles per hour, are eligible for a 10% credit of the cost of the vehicle, up to $2,500.

- **Public Transportation Innovation [2015-2020]**
  Under the Fixing America's Surface Transportation (FAST) Act, entities from all sectors – public, commercial, NGO, higher education – are eligible to receive funding assistance for research, demonstration, and deployment projects involving low or zero emission public transportation vehicles. Government cost share of projects under this section can be up to 50% to 80% (depending on it content), and the budget allocated for the program is a total of $140M for years 2015-2020. (FTA, 2016)

- **Alternative Fuel Infrastructure Tax Credit [until 2017]**
  Equipment for fueling alternative fuels – including electricity, but not limited to – is eligible for a tax credit of 30% of the cost (excluding permitting and inspection expenses, allowed to be used for multiple sites), up to $30,000. Consumers who purchased qualified residential fueling equipment may receive a tax credit of up to $1,000.

- **Electrify America program**
  Following the emissions fraud by Volkswagen, the OEM reached a settlement with the California Air Resources Board (CARB) by which VW will fund the Electrify America program with a $2 billion investment spread over the next 10 years. The program and will fund zero emission-vehicle infrastructure and education programs, with $800 million invested in California and the remaining $1.2 billion to be invested in the rest of the states. (Fitzgerald & Nelder, 2017).

- **Airport Zero Emission Vehicle (ZEV) and Infrastructure Incentives**
  The Zero Emissions Airport Vehicle and Infrastructure Pilot Program provides airports with funding for up to 50% of the cost to acquire ZEVs and install supporting infrastructure for them, limited only to road vehicles for the airports' operational fleet (FAA, 2017).

- **Improved Energy Technology Loans**
  The U.S. DOE's Loan Guarantee Program supports projects of early commercial use of advanced technologies, which reduce air pollution and GHG emissions. The program is not aimed at R&D projects, and projects may include the deployment of fueling infrastructure with the associated hardware and software. The loan guarantees can reach up to 100% of the amount of the loan, with loan guarantees of over 80% requiring that the loan is issued and funded by the Treasury Department's Federal Financing Bank. (LPO).

Regulatory

Laws and directives designed to mandate, enable, incentivize, limit or otherwise direct subjects to act according to policy goals

- **Vehicle Incremental Cost Allocation**
  Through numerous federal laws, federal fleets are required to obtain 75 percent of their light-duty annual acquisitions as alternative fuel vehicles (AFVs) in Metropolitan Statistical Areas. These alternative fuels include biodiesel, electricity, hydrogen, denatured alcohol, methanol, natural gas and propane. The U.S. General Services Administration (GSA) and other federal agencies that procure vehicles for federal fleets must allocate the incremental cost of purchasing AFVs across the entire fleet it procures. (GSA, 2017).

- **Procurement Preference for Electric and Hybrid Electric Vehicles**
  The U.S. Department of Defense (DOD) is required set regulations that give a preference for leasing or procuring EVs or PHEVs, excluding tactical and combat vehicles.

- **Electric Vehicle Charging on Federal Property**
  Any federal agency may install or provide through a contract with a vendor electric vehicle supply equipment (EVSE) for federal employees and others authorized to park at their facilities to charge their privately-owned vehicles. Employees and other users must pay to reimburse federal agencies for the EVSE procurement, installation, and use.

- **High Occupancy Vehicle (HOV) Lane Exemption**
  States can exempt alternative fuel vehicles and EV from HOV lane requirements within the state. States are also allowed to establish programs allowing low-emission and energy-efficient vehicles to pay a toll to access HOV lanes. Vehicles must be certified by the Environmental Protection Agency (EPA) and appropriately labeled for use in HOV lanes, with the Department of Transportation (DOT) responsible for planning and implementing HOV programs. States that adopt these requirements are responsible for enforcement and vehicle labeling.

Communicational

Instruments that influence the value chain of charging infrastructure through the communication of arguments and persuasion, including information and education

- **Alternative Fuels Data Center [since 1991]**
  The Alternative Fuels Data Center (AFDC) was established by the DOE with the mission to collect, analyze, and distribute data regarding alternative and advanced transportation fuels, vehicles, and technologies. The AFDC is operated and managed by the National Renewable Energy Laboratory (NREL). It gathers and analyzes information on the fuel consumption, emissions, operation, and durability of alternative fuel vehicles, and provides unbiased, accurate information on alternative fuels and vehicles to government agencies, private industry, research institutions, and other interested organizations.

- **FuelEconomy.gov**
  DOE's Office of Energy Efficiency and Renewable Energy operates the FuelEconomy.gov website, which provides consumers with fuel economy information and decision tools for purchasing a vehicle, using data provided by the EPA. It includes information on fuel economy, emissions, and energy impact of light-duty vehicles, as well as tips for drivers on maximizing fuel efficiency. FuelEconomy.gov was establish in order fulfill DOE and EPA's responsibility under the Energy Policy Act of 1992 to provide accurate fuel economy

information to consumers, as well as the DOE's requirement under the 1975 Energy Policy and Conservation Act to publish and distribute an annual fuel economy guide.

- **EV Everywhere Grand Challenge [2012-2022]**
Declared by the US president in 2012, the EV Everywhere Grand Challenge sets the goals of creating a parity between plug-in electric vehicles and gasoline-powered vehicles in terms of affordability and convenience. Both technical and deployment goals where set, setting the path for a wide range of programs and activities to achieve them, encompassing R&D, policy, organizational and educational measures. (DOE, 2013)

- **Workplace Charging Challenge [2013-2018]**
Under the EV Everywhere Grand Challenge scheme, the DOE Launched the Workplace Charging Challenge with the goal of increasing the number of US employer offering workplace charging by tenfold. To achieve this goal, the DOE aims to partner with 500 organizations who commit to provide charging stations to their employees, with some 400 employers already partnered by the end of 2016 from a wide variety of sectors including utility, healthcare, education, commercial, industrial, and all levels of government. Employers joining the Challenge are provided with assistance, informational resources, guidance, and recognition for their implementations accomplishments. (DOE/EE, 2013).

10.4. Governance and stakeholder roles

The US federal governance system of the is unique in the sense that on the one hand, the national government holds powerful means of control with which it may implement strategic policy, while on the other hand State and local governments exercise a great degree of freedom in policy-making within their respective jurisdiction. This balance of power and autonomy is evident in the way the federal government set forth strong and extensive incentives and programs – resulting in some of the most progressive EV policies in the world – whereas different states vary greatly with their commitment and application of EV policies; where some states remained laggards in adoption, others outpaced the national progress by setting an aggressively positive policy stance.

Consequently, in the US, EVSE installations must comply with both local, state, and national codes and regulations, and permitting requirements by local building, fire, environmental, and electrical inspecting authorities vary. Zoning, codes (including permitting), and parking ordinances are regulatory tools of state and local governments, which can be applied to promote EV readiness in their communities. They each relate to different potential aspect of EV charging, and so a synergy of measures can prove to be most effective in the adoption and deployment of EVSE.

- **Zoning:** should not restrict the deployment of EVSE and can even incentivize or require its implementation.

- **Codes:** can specify requirements for certain features in new construction and provide permitting or inspection protocols.

- **Parking Ordinances:** Parking regulation and enforcement is typically a shared responsibility in municipalities, requiring participation of departments of transportation, law enforcement, public works, permitting, and other key players in the management of transportation and traffic.

It is important to note that more often than not, it is apparent that regulators refrain from targeting a specific solution (e.g. BEVs), but rather prefer to maintain a solution-agnostic approach by which the policies provide means to an end (e.g. lower emissions) – but not the path to get there.

Also noteworthy is that unlike Ireland and The Netherlands – and to a bigger extant than the UK – US is home to several car OEMs, most of which are prominent and veteran players in the international automotive sector. The constitutive part in history of the American auto industry is of great national importance in the US, and although its glory days are arguably long gone, the sheer number of jobs it provides and the crucial reliance of the US economy over its vehicles cannot be overlooked when examining the context of US policies and market dynamics.

On the other end of the plug, US electric utilities are increasingly strained by weakening demand, tightening environmental regulation and deteriorating and obsolete infrastructure. For utilities, EVs present an opportunity to potentially becoming a non-organic growth market with significant demand, as well as facilitators of advanced grid services which are a central part of the go-to strategy for many of these entities. Subsequently, utilities seek regulatory leeway to allow them to seize the EV opportunity by opting to promote a range of programs, from dedicated charging tariffs through rate-funded chargers' deployment.

Case study: The West Coast Green Highway

The West Coast Green Highway is a collaborative effort by the US states of California, Oregon and Washington, as well as the Canadian province of British Columbia to promote a sustainable transportation over a stretch of over 2,100 km of interstate and highway roads, from British Columbia to Baja California – "BC to BC". Under this initiative, the West Coast Electric Highway project is a network of DC fast charging stations deployed every 40 to 80 kilometres along the route, enabling EVs to make long distance inter-city travel. On the local level the project is headed by the respective states' departments of transportation, in collaboration with industry partners. Each station also includes level 2 EVSE, and while most provide CHAdeMo EVSE, the newer locations also offer CCS.

(Washington State Department of Transportation, 2014).

10.5. Lessons learned

The following lessons learned are based over key insights that were gathered from the first 16 EV readiness projects from across the US, performed under the Clean Cities Community Readiness and Planning for Plug-In Electric Vehicles and Charging Infrastructure program (C2ES, 2014).

Regulation and Policy

Regulatory measures should be shaped to facilitate publicly-accessible charging, and maintain principles of competitiveness, uniformity and streamlined procedures

- Mandating interoperability is needed to avoid lack of compatibility among charging station payment methods, communications, and fast-charging standards.
- Regulation over the sale and resale of electricity, or alternately sale of charging services and which party may assume what role, should be clearly defined.
- Charging in semi-public locations is a crucial part of charging market, as it accounts for a large share of vehicles' parking duration. Charging at multi-unit residential, workplace, and other shared parking sites is faces by challenges of cost, fairness, ownership, administration and legal issues, and necessitates dedicated regulatory framework.
- Local governments have a critical role in the development of public and private charging due to their authority over zoning, parking, signage and building codes, which can present barriers to development, but also opportunities through ordinances to proactively support charging stations installation (e.g. density bonuses for charging stations, or requirements for a percentage of parking spaces to be outfitted with or prewired for charging stations in new multi-unit residential, commercial, industrial, or large parking lot construction).
- Procedures for residential, workplace and public charger installations should to be kept affordable, uniform, streamlined and simple, with clear zoning rules for station siting.
- Signage of charging stations should be uniform and clearly visible.
- Enforcement of charging-only public charging parking spaces requires new ordinances.
- The extent of short-term reductions in fuel tax revenues over the switch from gasoline to electricity is overestimated. While improving ICEs fuel economy potentially reduces taxation revenues needed to fund road infrastructure, increasing share of EVs will further decrease it, undermining the viability of fuel tax as a funding resource. Suggested solutions such as EV-specific taxes, fuel-neutral tax over mileage and taxes over electricity used for charging – all raise concerns over negative impact on EV sales, consumer privacy and prohibitive metering mechanisms.
- Policy-making should consider concerns that public financial subsidies and other incentives such as dedicated parking spaces for EVs will be used disproportionately by higher income individuals and households.

Business case

Initial deployment of public charging requires subsidizing especially when aiming to provide wide coverage of the public charging network – nevertheless, it is important to facilitate profitable business models for private investments in charging at scale

- It is difficult to form a successful business case for charging stations, due to low utilization rates in early EV market stages, high upfront and maintenance costs coupled with low margins on electricity sales, excessive demand charge rates over electricity for fast chargers, and the limited freedom in shaping services and pricing due to regulation.
- Alternative electricity structures could be set in place to mitigate charging impacts over the grid, as well as stimulate EV adoption through cost reductions to consumers. These may be realized by a time of use (TOU) rate structure which encourages demand shift to off-peak hours, facilitated by smart meters.
- In multi-unit residences costs of charging stations installation can be covered by individual residents, collectively through homeowner associations, by the building owner, or by a third-party charging service provider. Electricity use may be charged directly to individual residents by connecting stations to their electricity meters or stations may be connected to a common meter, and based on usage fees billed to the EV owner.
- Developers of new multi-unit residences and commercial buildings can be encouraged to offer charging by tax credits, subsidy, zoning incentives and sustainable building credits.

Awareness and outreach

Public communication regarding EVs should emphasis their economic advantage in total cost of ownership, the superior driving experience and the available incentives

- Despite the lower fuel and maintenance costs of EVs, their higher upfront cost of tends to be prohibitive to consumers, who are usually not considering the total cost of ownership (TCO) as part of their purchasing decision.
- Consumers have limited knowledge of EV models, their performance, safety, economics,
- Efforts to promote charging stations installation are not fully leveraged due to lack of communication and coordination among potential partners about available incentives, and of the availability of existing public charging stations.
- Successful initiatives to deploy charging stations at shared parking locations are typically led by an internal champion either on the demand side (a resident or an employee seeking access to charging) or the supply side (a building developer, a facility manager, or an employer seeking to offer charging).
- Local government officials and personnel play a critical role in establishing a supportive policy environment for EVs and in implementing those policies.
- Public and private fleets are promising EV markets since fleets have known and predictable driving patterns and needs, are analytical about the total cost of ownership, and can usually deploy private charging stations and utilize each with multiple vehicles.
- Regions with a significant tourism industry and environmentally minded travelers, should consider incorporating EVs into the travel experience as part of a sustainable program to reduce environmental impacts of tourism and support local charging stations deployment.

Planning and readiness

Deployment schemes for public charging should target to mitigate uncertainties regarding demand and its implications, as well as provide best practices guidelines for implementation

- Forming a local Master Plan that identifies EVs as part of the local transportation strategy is a foundational step for communities.
- Deployment plans for charging stations should be kept flexible in order to accommodate adjustments in EV adoption, travel patterns and charging technology changes.
- When planning public charging station deployment, it is also critically important to understand the proportion of private residential, fleet, and workplace charging stations.
- Public planners and private investors in public charging stations face uncertainty about the expected future level of demand, utilization rates, locations, optimal level of charging power, and share of BEVs versus PHEVs (with BEVs posing a greater strain on the grid).
- Long charging times at highly utilized public charging stations can be a deterring inconvenience to drivers who might need to wait for others to finish to start their charge.
- There is limited experience about best practices for planning parking sites with public charging stations, to ensure they are functional, safe, low-cost efficient and accessible, including accessibility for the disabled.
- Public fast charging stations siting should be planned to reduce range concerns for EVs, by allowing them to complete long range and inter-city trips.
- There is uncertainty regarding electricity demand and the strain over the distribution grid from high concentrations clusters of EVs and from fast-charging stations. Analyses performed in the US indicated that at the projected adoption rates no substantial grid impacts could be expected; only at significantly higher adoption rates such as 20% of vehicles, local residential distribution systems were found to be the first grid component to experience stress.
- Electric utilities unaware of or uncertain about the numbers and locations of incoming demand from new EVs, as well as for the effectiveness of time-of-use (TOU) electricity rates in mitigating electricity demand spikes from charging. Setting notification protocols by which utilities are updated with communication about market adoption of EVs and charging stations installation, may assist them in preparation and planning.
- There are challenges in planning and deploying the infrastructure needed to capitalize on the potential benefits from Vehicle-To-Building (V2B) and Vehicle-To-Grid (V2G).

Training

Professional personnel including technicians, electricians and emergency forces should undergo dedicated training to familiarize them and allow them to gain experience with EVs an EVSE

- An increasing number of automotive technicians will need to know how to safely and effectively service and repair EVs as the market grows.
- Electricians should be provided with specific training on charging station installation in order to familiarize them with the charging equipment's relevant national electrical codes, as well as gain experience in safe and efficient equipment installation.
- Emergency units should be trained to ensures awareness to topics such as how to identify an EV, how to disable electrical systems and confirm that the vehicle is turned off, where batteries are located, and fire control considerations.

11. Practices summary

Concluding Part I: Best Practices, is a summary of findings from the reviewed countries, providing a collection of the insights gathered as well as a comparative analysis of the characteristics of the EV scene in these countries.

11.1. Key lessons learned

Following are the highlight lessons learned from the review of the EV market development in the United Kingdom, Ireland, The Netherlands and the United States. These lessons are presented as actionable guidelines, categorized under the topics of Electric vehicles, Public charging infrastructure, fast charging and Organization & communication. To explore specific topics further in depth, see the Lessons learned sections under each country.

Electric vehicles

Incentivize in order to lower TCO

Introduction of incentives proved to be a meaningful catalyst for public EV adoption. All the reviewed countries incentivized electric vehicles and charging infrastructure, each in different ways, improving the TCO. In the UK and the Netherlands most (tax) benefits were directed towards lease cars, being a suitable target group for electric vehicles in the early development stage of EV. Currently a shift towards second hand cars and private use is starting in the Netherlands. The US set a regressive mechanism to incentivize early adopters and front-runner OEMs, with diminishing support as the market evolves. It is important to plan ahead the fadeout of incentives, in order to avoid market uncertainty and shocks to adoption rates.

Differ incentives between BEV and PHEV

Applying same-level incentives for both BEVs and PHEVs might result in a significantly uneven uptake allocation between these alternatives. In the Netherlands, similar tax exemptions to BEVs and PHEVs resulted in about 85% of EVs sold being PHEVs, a relatively high share compared to most other countries, potentially displacing BEVs and delivering overall less clean kilometers driven, as well as negative publicity. In the other countries, incentives allocation based on weighting the share of electric-only range, battery capacities or tailpipe emissions resulted in a relative balance in market shares with higher rates of BEVs.

Set training programs

Professional personnel including technicians, electricians and emergency forces should undergo dedicated training to familiarize them and allow them to gain experience with EVs an EVSE. An increasing number of automotive technicians will need to know how to safely and effectively service and repair EVs as the market grows, electricians should be provided with specific training on charging station installation to familiarize them with the relevant national electrical codes, and emergency units should be trained to identify an EV, learn to disable its electrical systems and learn fire control considerations

Public charging infrastructure

Provide an exit strategy when funding public charging

Initial deployment of public charging requires subsidizing, especially when aiming to provide wide coverage of the public charging network – nevertheless, it is important to facilitate profitable business models for private investments in charging at scale. As problem owner (air quality) and responsible party for the public domain, cities in the Netherlands tendered charging infrastructure with their own air-quality funding. As investors, they designed contracts focused on improving the business case to get costs for the city and EV-user down. In the UK, cities or regions received money from the government without a clear exit strategy on what happens after the subsidy ends, making the city dependent on the subsidy again. An alternative could be e.g. a decreasing subsidy. In the US, local governments support property owners in deployment of public chargers using measures aimed at improving the business case of their properties and the services they offer.

An integrated model results in higher costs for public charging infrastructure

An integrated model with the DSO operating public chargers results on the long term in high public investments, lack of competition, higher inefficacy in deployment, lack of innovation and no driver for improvements in the business case.

Mandate national interoperability of charging services

Regulatory measures should be shaped to facilitate publicly-accessible charging, and maintain principles of competitiveness and uniformity. In the UK and US, cities and regions did not demand interoperability in their tenders, unlike municipalities in the Netherlands did. Requirement of interoperability led CPOs and MSPs to a start a foundation to organize interoperability, enabling EV-users to charge everywhere with using a single authentication and payment method, such as one card or app. Lack of mandated interoperability resulted in a fragmented market, which negatively impacts the EV drivers' experience.

Provide uniform charge point requirements

When funding public charging infrastructure for local authorities provide certain uniform requirements on the public charge points, providing scale up of CPs, consistent user experience, efficient application & connection process and lower costs. In the Netherlands, this did not happen because of individual cities making their own specific requirements.

Start with demand driven placement of public CPs

Deployment schemes for public charging should target to mitigate uncertainties regarding demand and its implications, as well as maintain flexibility to accommodate adjustments in EV adoption, travel patterns and charging technology changes. Placement of a CPs upon request of an electric driver assures usage of the charge point, which is essential to the business case of public charging and ease of use for drivers. This placement strategy also provides charging certainty for EV users and is therefore important for the EV sales of OEMs.

Incentivize private and semi-public charge points as well

Charging in semi-public locations is a crucial part of charging market, as it accounts for a large share of vehicles' parking duration. Charging at multi-unit residential, workplace, and other shared parking sites is faces by challenges of cost, fairness, ownership, administration and legal issues, and necessitates dedicated regulatory framework. Incentivizing private and semi-public charge points can lower the need for public charge points which are more expensive and have impact on public space. This measure also stimulates the EV uptake because it improves the TCO of an EV.

Realize standards and protocols

Realize clear standards for EVs, charging and communication in line with European or worldwide standards. In the Netherlands, the foundation of grid operator takes a role in this, as is the case in Ireland. In the UK this is mostly organized by OLEV. In the US, responsibilities are shared between the DOE, EPA and DOT. This creates an open and competitive market which serves the customer.

Fast charging

Tender simple and long-term contracts for fast charging

In the Netherlands, the Ministry of infrastructure released 15-year valid licenses for fast charging (with hardly any requirements) along the highways, resulting in a thorough fast charging network at zero costs for the government. The city of London also tendered fast charging. The city is responsible for extra investments in the local electricity grid.

Tender fast charging sites to avoid 'land grab'

To avoid one operator exploiting all fast chargers (UK), the tendering of separate locations in an early market stage is recommended. Public fast charging stations siting should be planned to reduce range concerns for EVs, by allowing them to complete long range and inter-city trips.

Organization & communication

Define clear EV targets

Setting a clear and realistic yet ambitious target for number of EVs from the onset, results in a national and international benchmark and confirmation of a long-term view, helping to move the focus of the discussion to policy implementation and providing an outlook to stakeholders. Likewise, forming a local Master Plan that identifies EVs as part of the local transportation strategy is a foundational step for communities.

Set a national plan for EV infrastructure (public and private)

A national plan for infrastructure helps regions and big cities without knowledge and experience. The national government can take a role in standardization and knowledge transfer. In the Netherlands there was no plan, resulting in different infrastructural models and big differences in numbers of chargers within cities and regions, whereas in the UK the plan includes all aspects of EV and infrastructure. In the US, in some cases efforts to promote charging stations installation are not fully leveraged due to lack of communication and coordination among potential partners about available incentives, and of the availability of existing public charging stations.

EV communication on a national level is necessary to create awareness

Setting clear targets, delivering an EV-plan and investing in infrastructure is not enough. Communication on these targets and the 'why' of EV, creates awareness, stimulates action and gives insight, transparency and trust to the market, which is necessary for investments especially in public infrastructure. Public communication regarding EVs should emphasis their economic advantage in total cost of ownership, the superior driving experience and the available incentives, along with the environmental benefits.

Create a EV forum including all stakeholders

Create a stakeholders' forum for EV-policy including businesses, universities, research institutes, the DSO and (local) governments. Creating wide EV support and action plans at national and political level.

Identify and encourage EV 'champions'

Successful initiatives to deploy charging stations are typically led by an internal champion either on the demand side or the supply side. Local government officials and personnel play a critical role in establishing a supportive policy environment for EVs and in implementation.

11.2. Comparative analysis

Table 8. Comparative analysis of the EV and charging markets in the UK, Ireland, The Netherlands and the US.

Country	United Kingdom (2017)	Ireland (2017)	The Netherlands (2017)	United States (2017)
BEV stock; market share	45,623 (33%); 0.54%	1,948 (73%); 0.47%	21,115 (18%); 1.92%	297,000 (53%); 0.50%
PHEV stock; market share	92,057 (67%); 1.36%	739 (27%); 0.25%	98,217 (82%); 0.28%	266,600 (47%); 0.40%
Total EV stock; mkt. share	**137,680**; **1.9%**	**2,687; 0.7%**	**119,332; 2.2%**	**563,700; 0.9%**
# normal charge points	11,497 (81%)	837 (83%)	32,120 (98%)	40,862 (87%)
# Fast charge points	2,759 (19%, 60 per 1,000 BEVs)	172 (17%, 88 per 1,000 BEVs)	755 (2%, 36 per 1,000 BEVs)	6,266 (13%, 21 per 1,000 BEVs)
Total charge points	**14,256 (104 per 1,000 EVs)**	**1,009 (376 per 1,000 EVs)**	**32,875 (275 per 1,000 EVs)**	**47,128 (84 per 1,000 EVs)**
EVs incentives				
Public charging incentives				 (excluding VW funds for Electrify America program)
Fast charging incentives				
Charging market model	Independent	Integrated	Independent	Independent
Public charging organization	By local authorities, over discrete platforms	By the grid operator	By local authorities, over open-access platform	By charging networks operators and property owners on discrete platforms
# private operators of public charging	5-10	0-5	15-20	10 networks, many property owners
EV market overview	The progressive EV market in the UK is substantially supported by the government's extensive and pragmatic approach to support the growth of both the vehicles as well as charging infrastructure. The UK uses a unique version of the independent e-mobility model for charging infrastructure, and outstandingly has a large number and variety of active stakeholders in the sector.	Characterized by reminiscent of centralized electricity market structure (much in the same way as in Israel), Ireland operates an integrated infrastructure model in which the Distribution System Operator (DSO) integrates the charging infrastructure into their main activities in the electricity sector.	One of the front-runners on realizing EV-charging infrastructure, The Netherlands has an independent e-mobility model were market parties deploy the charging stations independent from the DSO (distribution network operator). Incentives and subsidies are applied as stimulants for innovation, competition, and development of new companies.	propelled by strong incentives at the federal level, the independent US market enjoys a wealth of supportive programs and policy momentum, is also characterized by a great degree of variance in local regulatory framework and adoption in the different states. The commercial sector is well developed and highly competitive, yet suffers from fragmentation resulted by the bottom-up market evolution legacy.
Policy scope	Long term strategy	No defined plans	Five-year plans	On a specific-topic basis
Organization of EV policy	Office for Low Emission Vehicles, a cooperation of multiple ministries	Sustainable Energy Authority of Ireland (SEAI)	One coordinating ministry	Presidential directives, congress laws (acts), several ministries programs

Part II: Stakeholders Feedback

12. Introduction

As part of the study, the research team held a gathering of stakeholders for an active workshop. In the event, interim findings of the research were presented, prompting an engaging and methodical discussion regarding the challenges faced in the introduction of EVs and the related charging infrastructure into the Israeli market at scale, as well as brainstorming for possible solutions.

13. Methodology

In order to facilitate an effective stakeholders feedback, a unique methodology for experts' consultation was developed. The workshop, held on 15/6/17, included 32 experts from the government, local municipalities, commercial parties, entrepreneurs, cars importers and representative from the academia (see **Appendix I: Stakeholders workshop participants**).

Stages in the experts' consultation:

1. **Stakeholders classification**
   Participants were classified into 3 categories of actors:
   - **Central government:** ministries, regulators, NGOs (12 representatives)
   - **Local government:** municipalities, regional associations (4 representatives)
   - **Commercial:** companies, importers, suppliers, consultants, academia (16)

   Each category was assigned with a designated color sticker.

2. **Teams assignment**
   Participants were assigned to four groups of 7-9 experts each, predetermined in advance to form a balanced mix representation of the above categories.

3. **Barriers mapping**
   The first round of the consultation included mapping barriers for infrastructure and its deployment.
   - Each experts group was asked to state 3-5 national-level barriers and 3-5 local / municipal-level barriers.
   - Each group participant than opted to use their respective colored sticker in case they indeed perceived the barrier raised within the group as such.
   - Each barrier was than rated according accumulated stickers votes it received, with higher sticker count denoting a more crucial and significant barrier.
   - Barriers from all groups were unified into a single list, with their aggregated rating. The top 3 national and top 3 municipal barriers were selected to proceed to the solutions round.

4. **Solutions brainstorming**
   In a second round, each group suggested possible solutions for the top barriers as well as designated a responsible "owner" among the stakeholders for the barrier solution.

5. **Concluding discussion**
   Solutions were collected from all groups and debated over a general discussion

14. Results

The process of charting the challenges faced by public EV charging surfaced barriers that are all resulted from the inception of a new market, which is understandably expected. Moreover, as the introduction EVs in general disrupt long-standing sectors and the business models they rely on, the paradigm shift it involves affects infrastructures which were previously not directly related to transportation and its value chain; the potential and pitfalls it transpires necessitate rethinking by all the stakeholders in the scene. The methodical stakeholders' consultation process clearly highlighted the topmost barriers, solutions and the actors responsible for providing them. The barriers where classified into 8 distinct categories, with votes tallied together from all the four teams.

1) Challenging business case

31 votes (22 national, 9 local; 3 of 4 teams)

Barrier description:
The economic viability of charging infrastructure is questionable, and there are no clear funding sources for deployment of either normal rate charging (AC) or fast charging (DC). There are no financial incentives for building infrastructure, and in some cases the allocation of public parking spaces may result in loss of revenues for municipalities.

Suggested solutions:
- **Government support for initial deployment through direct funding, subsidies and contracting**
- **Innovation program to drive down cost of charger and installation**
- **Setting long-term government policy**

Responsibility:
Ministry of Energy, Ministry of Finance (Tax authority, Planning administration), Ministry of Transportation, Ministry of Environmental Protection

2) Public space use and availability

31 votes (7 national, 24 local; 4 of 4 teams)

Barrier description:
There is scarcity of vacant parking spaces in densely-populated areas, and allocation of dedicated parking spaces for EVs will further exacerbate the parking demand pressure. Additionally, charging points and their required auxiliary electrical cabinets take valuable space on already crowded sidewalks. Installation of private chargers on public space is prohibited.

Suggested solutions:
- **Allocate dedicated parking spaces for EVs in public lots, based on demand so utilization is guaranteed**
- **Incentivize sharing private parking with charging when not in use by the owner**
- **Detailed planning by municipalities to accommodate present physical infrastructure**
- **Mandate open access as an obligatory regulation**
- **Plan to accommodate commuter charging outside the city center at alternative locations**

Responsibility:
Municipalities, Ministry of Finance (Planning administration), the Electricity Authority (PUA)

3) Lacking grid readiness

22 votes (11 national, 11 local; 3 of 4 teams)

Barrier description:
The current electricity grid is not designed to support the in increased demand loads of large-scale charging of EVs in the future. On the national and regional level, at a later stage this may overstrain the grid's capacity during peak demand hours and seasons, especially in the case of fast and superfast DC charging (50kw-400kw). Similarly, on the local level the distribution grid in public spaces also cannot support additional extensive power demand required for city-wide charging.

Suggested solutions:

- **Start Pilot programs to test grid impact with real EV's and consumers in practice**
- **Promote development of technological solutions (e.g. energy storage and smart charging) to mitigate excessive loads on the grid**
- **Mandate laying the groundwork for charging in new-construction buildings**

Responsibility:
Ministry of Energy, Municipalities, Ministry of Finance (Planning administration), private sector

4) Market structure & open access framework

21 votes (21 national, 0 local; 3 of 4 teams)

Barrier description:
Currently there is no established framework for interoperability, to enable open access for all users, transaction clearance between charging operators and flexible electricity procurement. There is no policy in place over charging tariffs, rates, billing and contracting. The roles of IEC, private power producers, municipalities and CPOs are not yet defined in the context of public EV charging.

Suggested solutions:

- **Mandate open access as an obligatory regulation**
- **Strictly follow universal norms and international standards**
- **Form and set regulation for charging-related process, the roles of the parties involved and the binding conditions under which they may operate**

Responsibility:
Ministry of Energy, the Electricity Authority (PUA), the Standards Institution of Israel (SII)

5) Lack in standards, regulation and clear policy

14-28* votes (14-28* national, 0 local; 2 of 4 teams)

***** *one team noted four different barriers under this topic tag; the lower total accounts for only one barrier from that team with the highest number of votes, the higher total accounts for counting votes of all three barriers separately*

Barrier description:
No set standards for the installation, operation and management of charging points, coupled with absence of policy in terms of national goals, taxation and market structure – all result in market uncertainty for the long-term. Moreover, there's knowledge gap in the private sector as for the regulation in the field.

Suggested solutions:

- **Long term policy on number of EV's and chargers should be set by the government**

- **Strictly follow universal norms and international standards**
- **Compose a guidebook for installation of charging points in the different settings (i.e. by municipalities, in workplaces and at home)**
- **Set clear and publicly accessible regulation**

Responsibility:
Ministry of Energy, the Electricity Authority (PUA), Ministry of Finance (Tax authority, Planning administration)

6) Lack of market

13 votes *(13 national, 0 local; 2 of 4 teams)*

Barrier description:
The "chicken and egg" dependency cycle of charging points and vehicles to use them impedes the proliferation of EVs at scale and the viability of the EV charging market.

Suggested solutions:
- **Provision non-financial "soft" incentives, including exclusive access to low-emission zones, parking priority and dedicated allocation, and access to public transportation lanes with a clear timeline**
- **Mandate public institutions (including e.g. taxis and driving instructors) to procure EVs at a set share of their vehicles fleets, at an increasing rate**
- **Promote education and campaigning for public awareness**

Responsibility:
Government Ministries, municipalities

7) Lack of administrative integration

11 votes *(7 national, 4 local; 2 of 4 teams)*

Barrier description:
The multitude of the authorities involved and their oversight of holistic considerations hinder the ability to plan on the metropolitan level.

Suggested solutions:
- **Appoint an integrator to reduce red tape and coordinate the related public bodies**
- **Allocate funds to implementation projects**

Responsibility:
The Fuel Choices and Smart Mobility Initiative

8) Lack of motivation for municipalities

11 votes (5 national, 6 local; 2 of 4 teams)

Barrier description:
In light of competing topics in their agendas, municipalities have limited incentives to prioritize EV charging and investments required for its infrastructure.

Suggested solutions:
- **Raise awareness to the benefits of EVs in municipalities by government offices**
- **Campaigning and education**

Responsibility:
Ministry of Transportation, the Fuel Choices and Smart Mobility Initiative

15. Discussion

While both national and local level barriers were pointed out, more emphasis over the national level barriers is apparent from the votes, as well as from the responsibility for the solutions.

Challenging business case, the top national-level barrier, is closely tied with the lack of market which was also noted as a barrier for charging. These barriers imply that the infancy of the charging market is hampered by the economics of its limited scale. This calls for a government support in the form of financial backing, as well as in "soft" policy measures to compensate early-adopters and strike more confidence in the commercial sector to expand its efforts in forming this market. As currently the public charging market is virtually inexistent, supporting it with both budget allocation and soft incentives would be negligible in financial terms but could prove to have a huge effect over business risk and consumer psychology.

Issues of availability of public space and its usage are critically important at the municipal level, as this is where ultimately most of the public charging is expected to take place. Competition over parking and curb space is already fierce, amplifying the need to clearly highlight the benefits of EVs replacing ICEs in densely-populated urban areas, as well as the pathways to allow deployment of charging infrastructure in a way that does not impair the utility the residents receive from their city. Careful planning and forethought, coupled with sensible rollout models, should assist in smoother integration of EVs into municipal transportation systems, without unwarranted investments and unneeded interference in the cityscape.

The replacement of oil with electricity for transportation creates a new load demand source for an infrastructure which was not originally designed to handle it. This is challenge for the national electric grid, just as much as it is for local distribution systems, both commonly characterized by old and capacity-constrained infrastructure which are excessively costly to upgrade or replace. While this is not a cause of immediate concern with the current penetration rate of EVs, future-proofing new construction is an obviously needed measure, as well as the consideration of advanced technological solutions – especially utility- and local-level energy storage (for which there is significant Israeli know-how).

As of yet, the regulatory framework for public charging has not matured, reflected by the ambiguity as for the roles of the stakeholders, the market structure rules that shape their business models, and the technical standards and operational norms by which they are required to operate. Globally, these topics are being addressed in ever-growing number of countries, but while convergence of standards provide a path to follow, there are still divergence in approaches for market structure, taxation and regulatory leeway. Principle concepts of open access, accordance with internationally recognized standards, clear and accessible regulation, and shaping the scope of competitiveness in the value chain will go a long way in removing uncertainties.

In summary, all the raised barriers call for a clearly defined policy, from national long-term goals all the way down to technical guidelines.

Part III: Charging in Israel

16. Israel overview

At the underlying basis of charting a projection of the development path for EVs in Israel, are the characteristics of the market and its recent historic trends. The following overview provides an analysis which covers key social, economic, transportation and energy indicators which can be found directly related to deployment of electric vehicles in Israel.

16.1. Households

The state of Israel is a densely populated, highly urbanized country. Covering 22,072 km^2 (20,770 km^2 excluding disputed territories), it has a population of over 8.5 million, projected to reach about 11.4 million by 2035 (see **Figure 34**). With a population growth rate which is the second highest in the OECD – 1.9% average growth in 2012-2014 – the organic population growth plays a crucial role in projections for the Israeli market. (CBS, 2013; CBS, 2017; OECD, 2016).

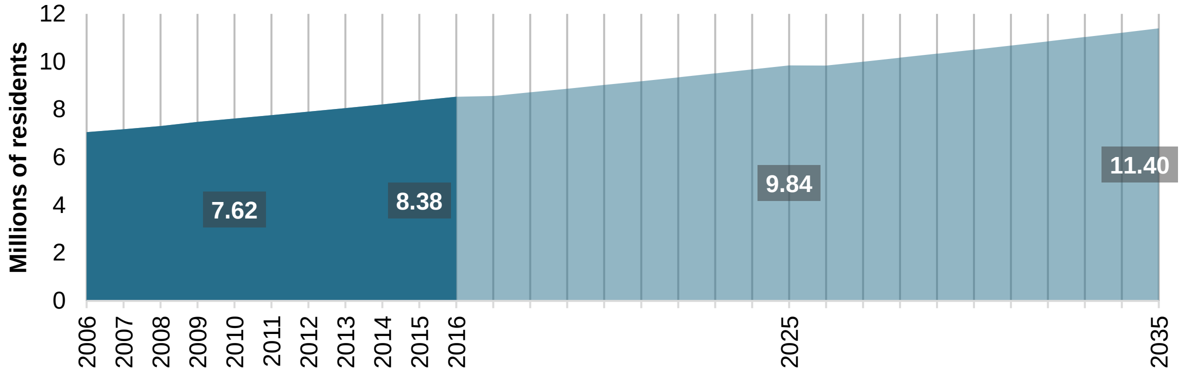


Figure 34. Israel's population, data and projection (millions of residents). Population data adapted from CBS *(2017)*, projection from CBS *(2013)*.

Over 93% of the 2.37 million household are in urban localities, with 35% of households residing in one of Israel's eight major cities. Yet, 54.9% of employees commute to a workplace out of their locality. Two thirds of household own at least one car, and almost a quarter of households own two cars or more (see **Figure 35**) (CBS, 2016). On average, 12% of household's consumption expenditures is spent over vehicles.

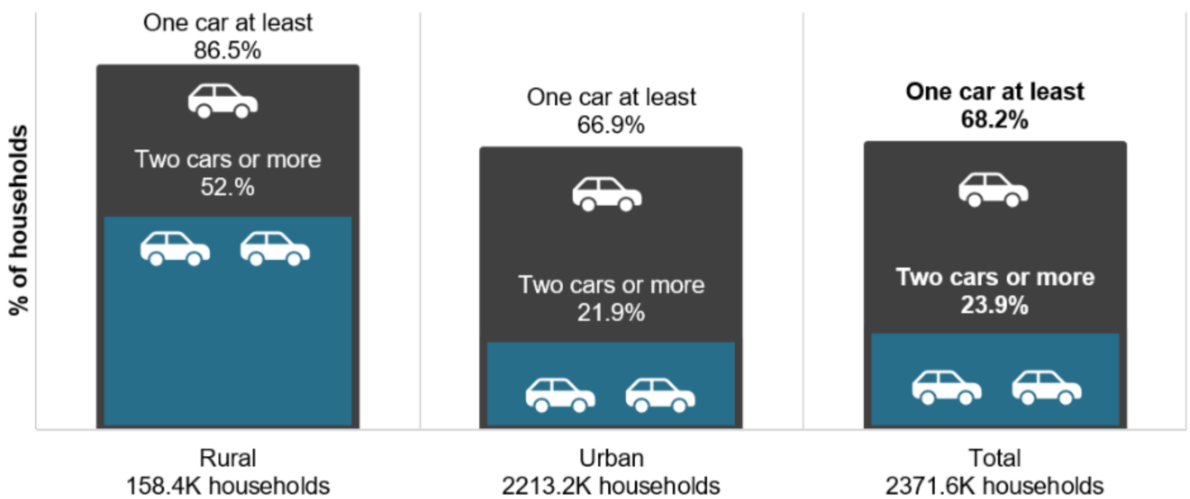


Figure 35. Household ownership of cars, by type of locality. Adapted from CBS *(2016)*.

These indicators highlight the dominancy of private car ownership even given the extremely high urbanization level. Considering that EVs are often touted as an urban commuter or second car alternatives, the households' car ownership data alludes to the potential market size for EVs in Israel.

Yet, looking at other countries as a benchmark for the level of motorization (i.e. the number of vehicles per residents), it appears that Israel is much less motorized than most developed nations, arguably leaving ample room for additional growth in its vehicle fleet (see **Figure 36**). Official estimations from almost two decades ago concluded that by 2020 motorization level will reach 340 private vehicles per 1000 people (and as much as 500 in some municipalities , mostly around the Tel-Aviv metropolitan area); based on population growth estimates, this implies a total fleet of 2.7 million private vehicle on the road by 2020 (Ministry of Transport and Road Safety, 1999). In reality, in 2017 the fleet had already exceeded this estimate reaching almost 2.86 million private vehicles, and motorization level has reached 325 private vehicles per 1,000 residents – remaining relatively low compared to the developed world (CBS, 2018). It should be noted that Israel has the highest youth dependency ratio among OECD countries at over 65% (UN, 2015), inferring that the effective number of drivers as a share of the population is lower, therefore capping the motorization level growth potential. Moreover, high distance traveled per vehicle and extreme road traffic density (discussed in the next section) further impedes the fleet's growth potential.

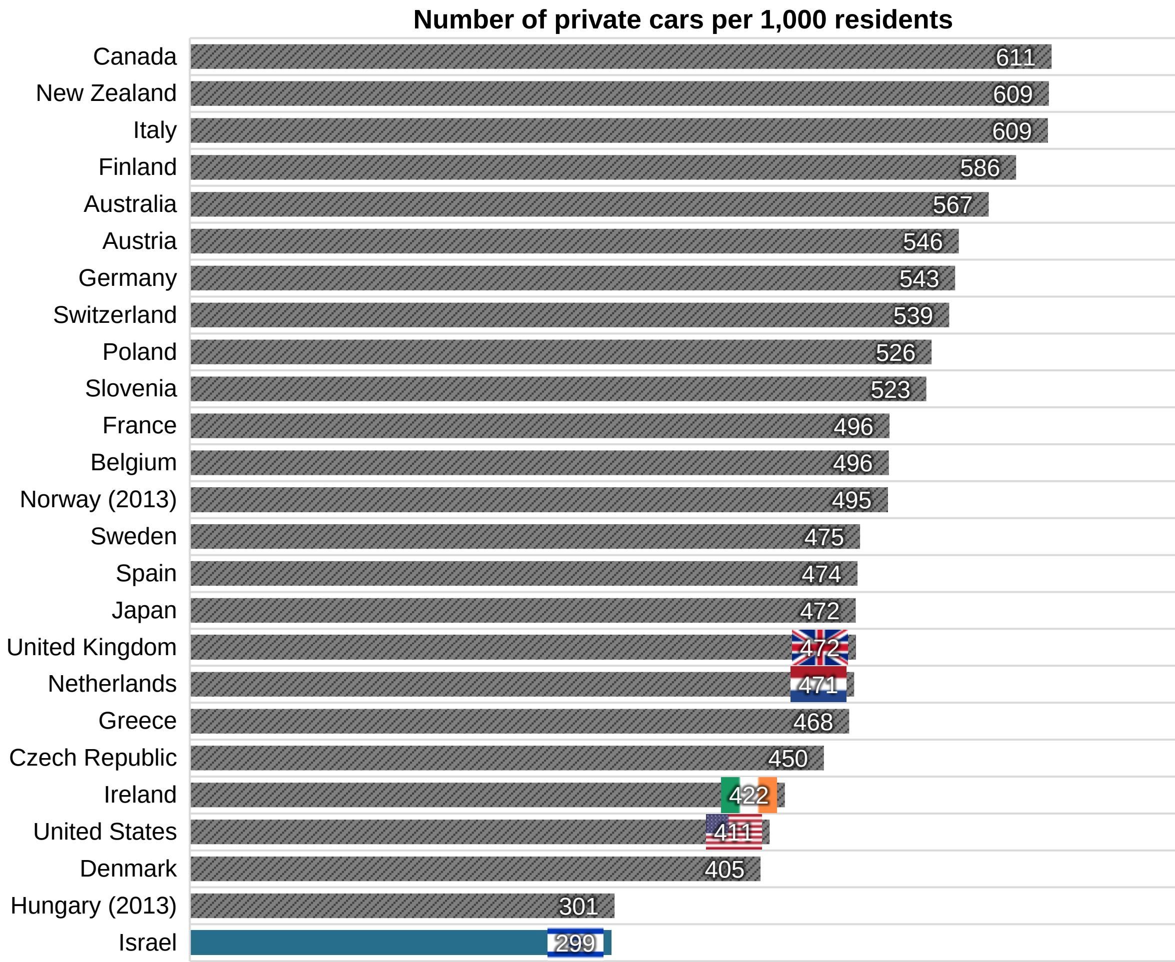


Figure 36. Level of motorization, international comparison (number of private cars per 1,000 residents). Adapted from CBS *(2016)*.

16.1. Travel

Israeli roads are expanding in length and area – especially so in recent years – however not at the same rate as the total kilometers traveled are. In the period of 2000 to 2015, the average annual growth rate of road length was 1.12%, of road area 2.45% and of cars distance travelled 2.95% (see **Figure 37**). A comparison to other OECD countries further validates the degree of traffic density in Israel, which ranked the highest in terms of annual vehicle-kilometers per road network length (see **Figure 38**) (OECD, 2016). While the total travel distance increases, the share of privately owned car in vehicle kilometers further increases as well (see **Figure 39**).

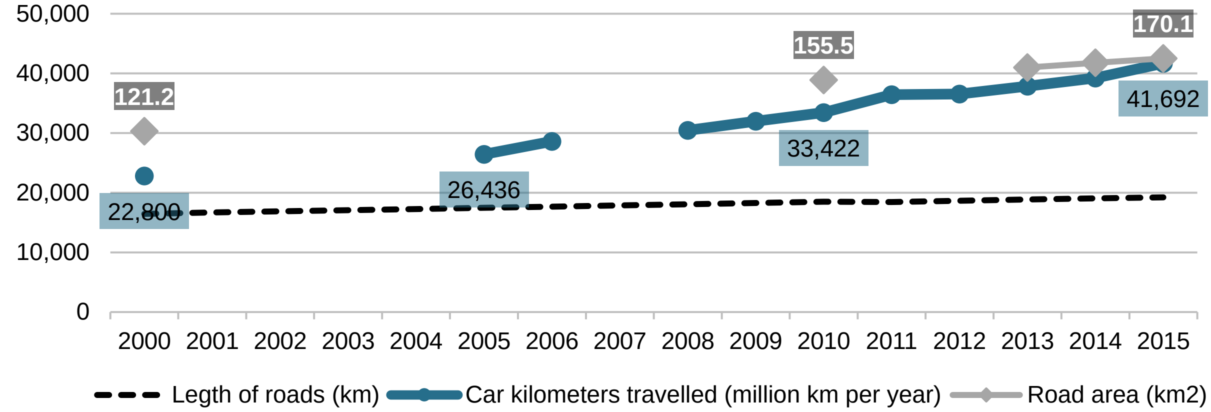


Figure 37. Change in Israeli road length, road area and annual total car kilometers traveled, 2000-2015. Adapted from CBS *(2016)*.

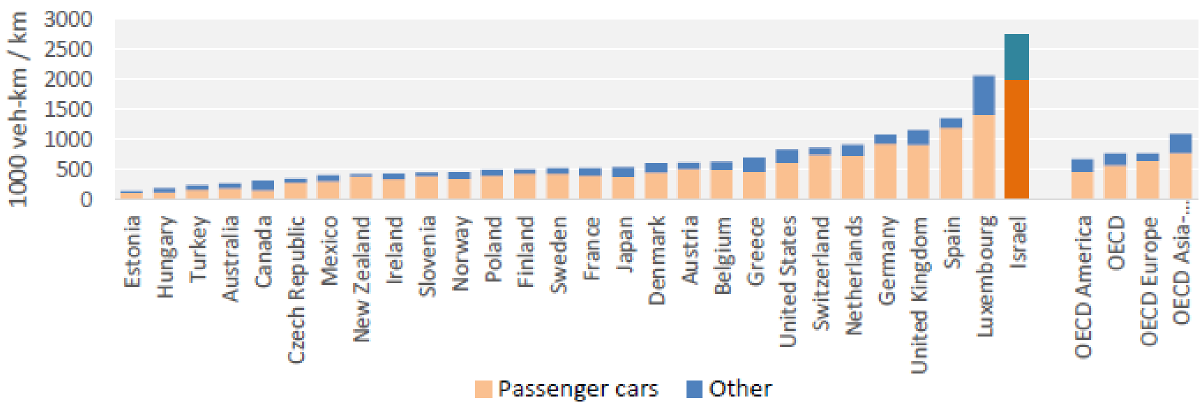


Figure 38. Road traffic density per network length in OECD countries. Reprinted from OECD *(2016)*.

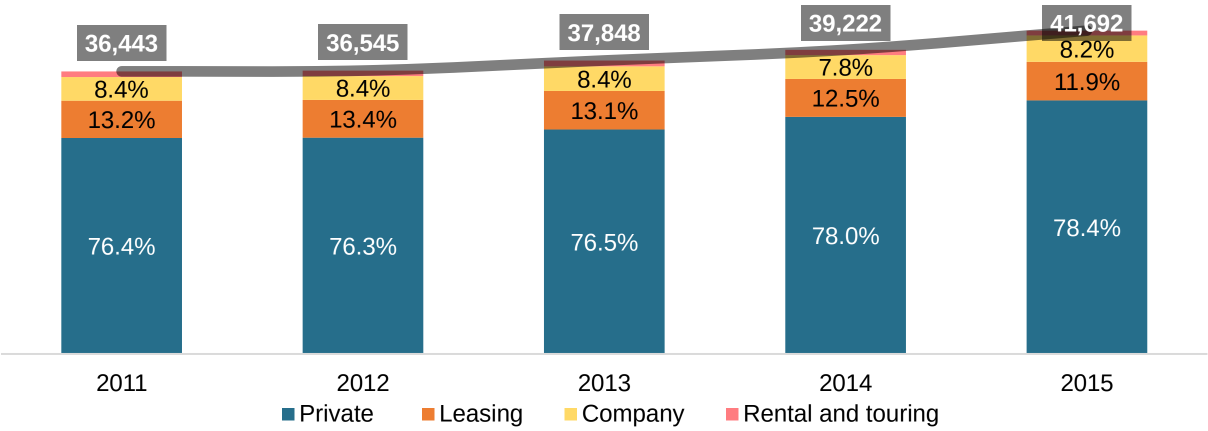


Figure 39. Total kilometers travelled, by ownership (Thousand km per year), 2011-2015. Adapted from CBS *(2016)*.

The average annual kilometers traveled per car was 16,300 km in 2015, with significantly higher than average travel by fleet cars (see **Figure 40**) (CBS, 2016). The annual travel distance is tightly correlated with the age of the vehicle, with newer cars (up to 4 years old) averaging at 20,500 km per year, and older models (10-21 years old) traveling on average 12,100 km a year; the average age of a private car in Israel stands consistently around 6.7 years (see **Figure 41**) (CBS, 2016). Again, compared to OECD countries, Israel has nearly the highest annual distance travelled per vehicle, accentuated by the disproportion to its size (see **Figure 42**) (OECD, 2016).

As a point of note, where the average annual travel for a private car in 2016 was 14,447km, PHEVs exceeded the average by as much as 44% (Israel Tax Authority, 2016).

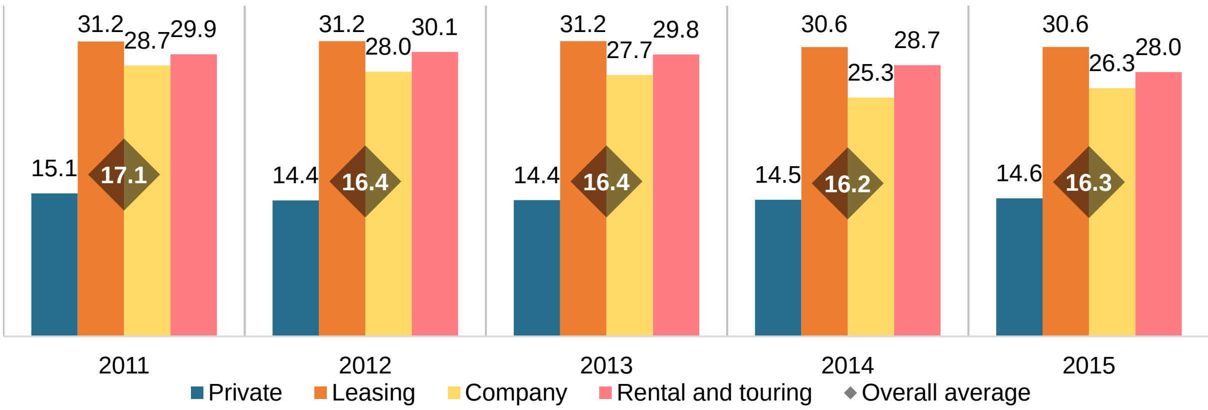


Figure 40. Average kilometers travelled per vehicle, by ownership type (Thousand km per year). Adapted from CBS *(2016)*.

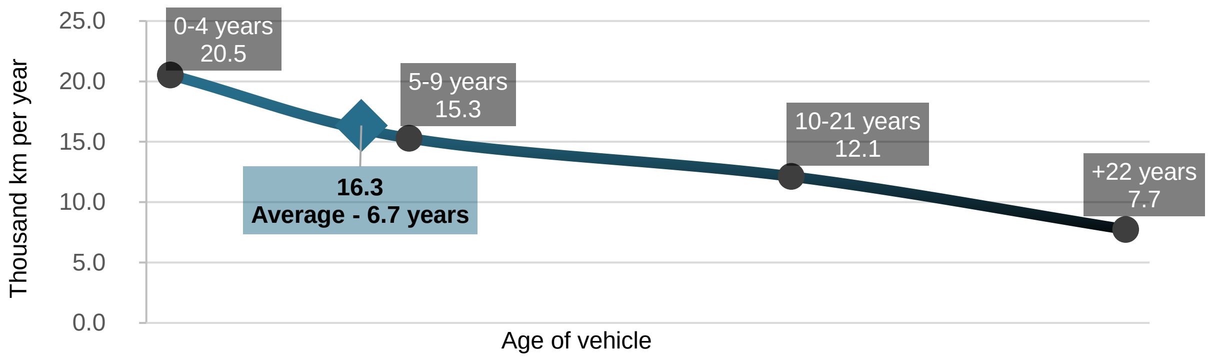


Figure 41. Private car average annual kilometers travelled, by age of vehicle (Thousand km per year). Adapted from CBS *(2016)*.

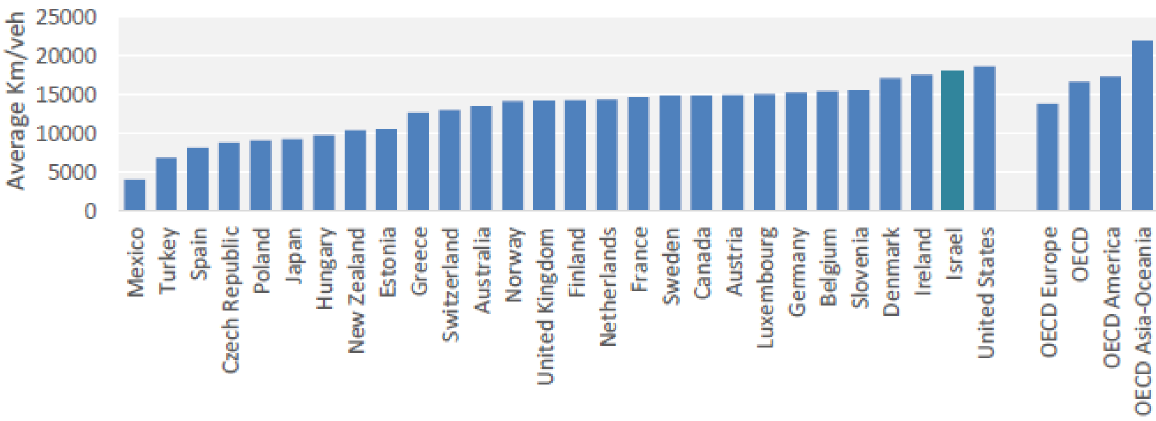


Figure 42. Annual average distance travelled per vehicle in OECD countries. Reprinted from OECD *(2016)*.

16.1. Fleet

Out of the total 3.09 million motor vehicles in Israel in 2015, 2.58 million were private vehicles, and growing at a significant rate; Japan and South Korea are the most dominant production country of origin in the Israeli private car fleet (see **Figure 43**). Of the licensed private cars in Israel in 2015, over 1.8M were up to 9 years old (see **Figure 44**). In that year, private cars (excluding taxis) accounted for about 83% of the total number of vehicles in Israel (CBS, 2016).

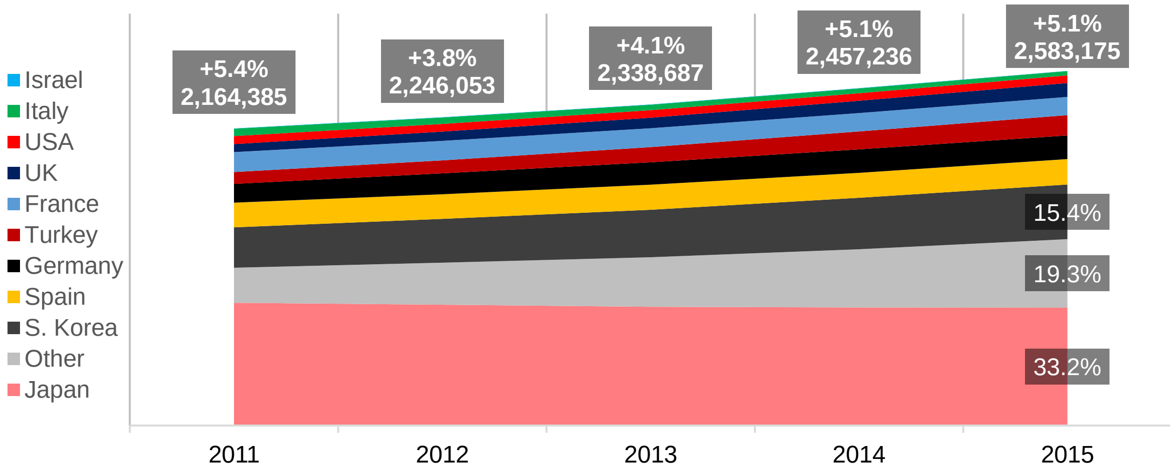


Figure 43. Size and growth (YoY) of Israeli private car fleet, by country of production, 2011-2015. Adapted from CBS *(2016)*.

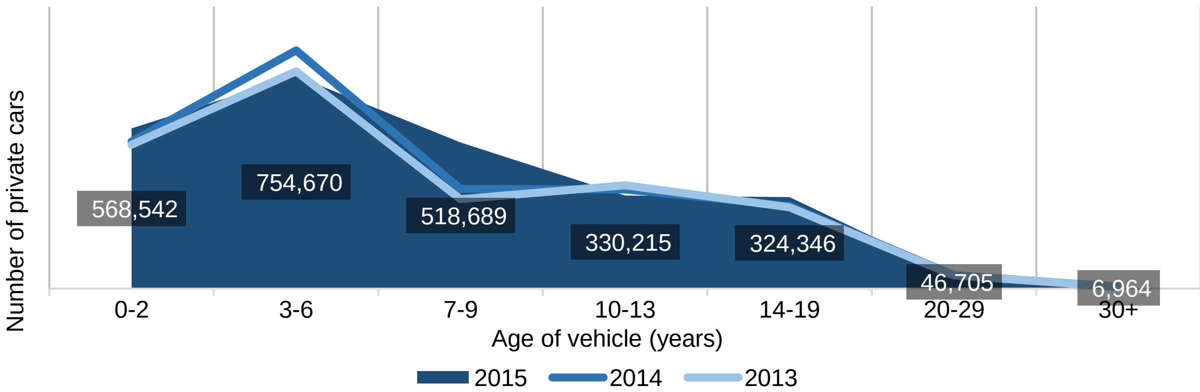


Figure 44. Absolute numbers of private cars, by age of vehicle (years). Adapted from CBS *(2016)*.

Cars sales in Israel has seen record-breaking sales numbers year over year, with 2016 reaching as high as 286K new cars deliveries, presenting a surge of 35% increase in sales over the last 3 years (Israel Tax Authority, 2016); sales in 2017 somewhat stagnated with a total of 282K cars sold (see **Figure 45**). Still, where private cars sales are losing momentum, other body-configuration cars continue to grow is sales – especially SUVs (Israel Vehicle Importers Association, 2018). The dominance of Japanese and South Korean models in new car sales is even more prominent than of the total fleet (see **Figure 46**). The total import value of private car in US dollars did not follow the same increase trend, arguable due to increasing share of lower-cost models, as well as strengthening Shekel exchange rate (see **Figure 47**).

The general car sales increase trend is arguably fueled by record-low interest rates, coupled with overall strong economy conditions; nonetheless, some also see the lack of adequate public transportation services as driver for private cars sales increase, along with the higher share of government investment in road infrastructure development, as opposed to lagging investments in public transportation.

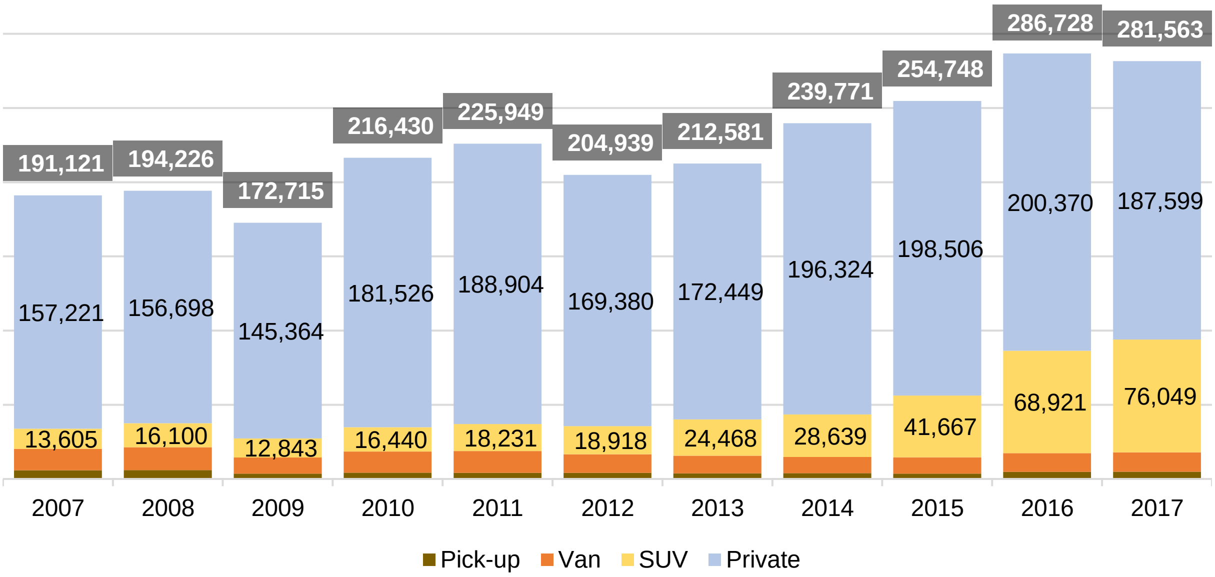


Figure 45. Vehicles registrations, by body type, 2007-2017. Adapted from Israel Vehicle Importers Association *(2018)*

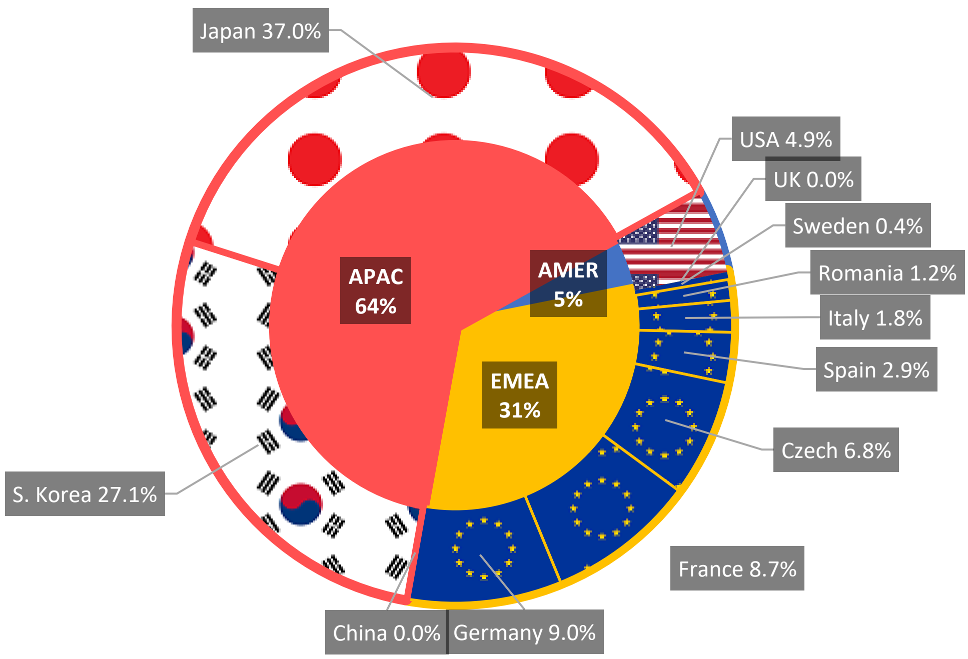


Figure 46. Vehicles registrations, by OEM country of origin, 2016. Adapted from Israel Vehicle Importers Association *(2018)*.

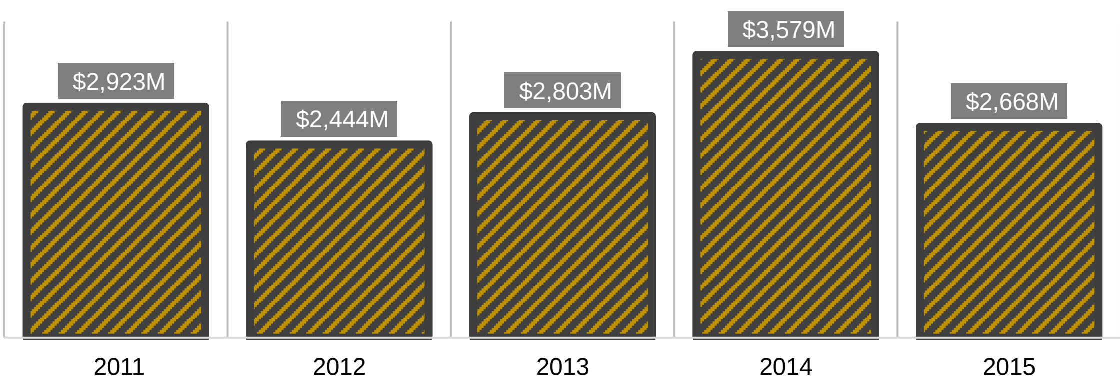


Figure 47. Import value of private cars (Million USD). Adapted from CBS *(2014)*.

16.2. EVs and EVSE

To date, there are less than thousand private BEV cars on Israeli roads. Most of the BEV stock are Renault Fluence cars, with nearly 1,000 units sold by Better Place between 2011 and 2013, some of which went through a scrappage program by the importer along with normal fleet degradation and decommissioning. In the years to follow, data is sparse but only a handful of BEVs were sold in the Israeli market, presumably several units of Nissan LEAF. 2017 has seen a reintroduction of BEV offerings, with 3 models available to customers (Nissan LEAF, Renault Zoe and BMW i3). Consequently, sales of BEVs that year have reinstated in more meaningful numbers, hitting 112 units sold; however, the majority of sales (about 100 Zoe's) are attributed to the BEV car sharing fleet by Car2Go. At the turn of 2018, there are indications the more BEV models are expected to get debuted in the Israeli market, with more mainstream and longer-range models. (CBS, 2017; CBS, 2018).

The data regarding the PHEVs fleet in Israel is scarce as well. Apparently, sales have picked up in recent couple of years or so, prompted by an increase in model offerings, with about 20 models from several brands; most models – and sales – are of higher-end brands, accredited to the tax discounts PHEVs receive, as well as the inherent higher costs of this type of drivetrain. About 0.02% of cars sold in 2016 were PHEVs, amounting to roughly about 5,000 cars. Added to that, is the noteworthy trend of privately imported PHEVs, accounting for an estimated several hundreds of cars out of the 1,000 privately imported cars in 2016. Since private imports are mostly of high-end cars (mainly SUVs and luxury sedans), the dominative share of PHEVs in private imports is also attributed to the discounted taxes they sustain, which in these car segments equates to discounts in the order of tens of thousands of dollars. (Israel Tax Authority, 2016).

Figure 48 presents the available formal data on EV sales in Israel between 2011 and 2017.

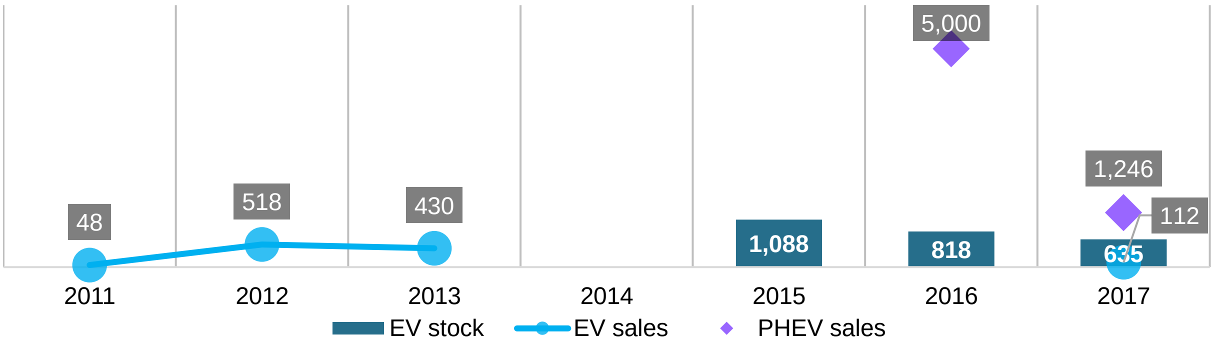


Figure 48. BEV and PHEV sales and stock in Israel. Adapted from CBS *(2017; 2018)*, Israel Tax Authority *(2016)*.

In much the same way, public charging EVSE had an unsteady development. There are an estimated 150 public and semi-public charging points available in the country, of which roughly two thirds are 2 charge point stations, most being remnants of Better Place's charging network, typically located at city and commercial parking lots. The remainder share are few dozens of semi-public charging points installed in recent months. As for private chargers, BEVs currently sold include a mode 3 charger installation by a 3rd party as part of the package. Understandably, importers are reluctant to sell BEV to customers who are unable to charge, and consequently sales are limited to customers who have access to private parking in which charger installation is viable. Charging requirement for PHEVs can generally be met by a mode 2 cable plugged into a dedicated heavy-duty wall socket, although some owners opt to use an adapter to plug into a regular-duty socket, creating a potential safety risk by doing so.

16.3. EV Policy

EVs in Israel enjoy significantly reduced purchase tax rates, further accentuated in the light of the high base purchase tax for ICE cars, which at a current rate of 83% is among the highest in OECD countries (OECD, 2016). The purchase tax for BEV is 10% and for PHEV 20%, and both also receive a tax-value discount over car safety systems (which applies to ICEs as well), resulting in a possible effective discount of few additional percent (Israel Tax Authority, 2016). In addition, employees who make use of company car which is an EV (either BEV or PHEV) receive a fairly significant discount on value-of-use tax of 990 ILS per month (Israel Tax Authority). Yet, as sales number shown, the tax incentives had little to no effect over BEVs, while at the same time did boost sales of PHEVs.

As an active implementation policy, the Ministry of Environmental Protection allocated a budget of 8.6M ILS for the cities of Haifa, Kiryat Bialik, Kiryat Yam and Nesher in the Haifa District for the purpose of supporting the establishment of an EV car-share array. The array started operating in late 2017 and is set to eventually include 160 EVs (Renault Zoe cars), with designated free parking and charging spaces (Ministry of Environmental Protection, 2016). Not only this initiative is expected to reduce ICE vehicles ownership and travel within the cities, it carries additional influential value by providing hands-on public exposure to the EV experience, a sizable boost to the EV market sales, and the future possibility of open access to the charging points. Under additional set of programs based on the same resources, a budget of 23M ILS was given as subsidy for the purchase of 62 electric city buses by several public transportation operators around Israel (Ministry of Environmental Protection, 2017). The project was funded in part from a 220M ILS budget the Keren Kayemeth LeIsrael – Jewish National Fund (KKL-JNF) allocated for environmental projects, which was allotted to the Ministry of Environmental Protection (Finance Committee, 2016). Based on this budget and the National Program for Lowering Air Pollution from Transportation, the Ministry commissioned several programs to support public transportation based on electric vehicles.

Looking forward, the Director General of the Ministry of Energy publicly announced in January 2018 that the policy of the Ministry is to fully withdrawal from gasoline use in Israel by 2030. He also noted actions taken by the Ministry and the Electricity Authority to set the required regulation to facilitate public charging by private providers, as well as plans to support the deployment of several thousands of charging stations (with an estimated budget of 25M ILS).

Efforts to remove barriers and promote market implementation of EVs and other means of alternative transportation solutions, are orchestrated by the Fuel Choices and Smart Mobility Initiative unit of the Prime Minister's Office. The Initiative operates as an inter-ministry integrator to coordinate measures, programs and projects to facilitate the alternative and smart mobility agenda, in both the public and private sectors, as well as with international partners.

16.4. Electricity sector

Historically, the Israeli electricity market is dominated by the vertically-integrated government-owned Israeli Electric Corporation (IEC), and regulated by the Electricity Authorities (alternately called Public Utility Authority – Electricity, PUA). In recent years the electricity generation segment is opening up to increasing share of independent power producers (IPPs), transforming electricity into a more competitive market. About 97% of Israeli electricity generation fuel mix is fossil-fuel based, increasingly so by domestic natural gas.

17. Stakeholders

17.1. Stakeholders mapping

By nature, the world of electric vehicles has interfaces to a wide range of sectors and players. Examining the scope of stakeholders which are related to EVs and EV charging, each can be classified as either a *user*, a *provider*, or a *regulator* – or any combination of those. Every consumer of transportation (i.e. everyone) are potential *users*; suppliers of hardware, services, data and property access are *providers*; entities with authority can both support and moderate in roles of *regulators*. Alternately, stakeholders can be placed along two axes – one being the *public* vs. *private* axis, and the other being *Energy* vs. *Vehicle* (see **Figure 49**). For any activity carried within the EV scene – either public, commercial or both – a coordination of a number of these stakeholders is required in order to achieve successful implementation, more so for projects or programs at large scale and complexity; it is imperative – as the international experience have shown – to create partnerships which consider the different viewpoints with regards to risks, benefits and authority of each of the involved players.

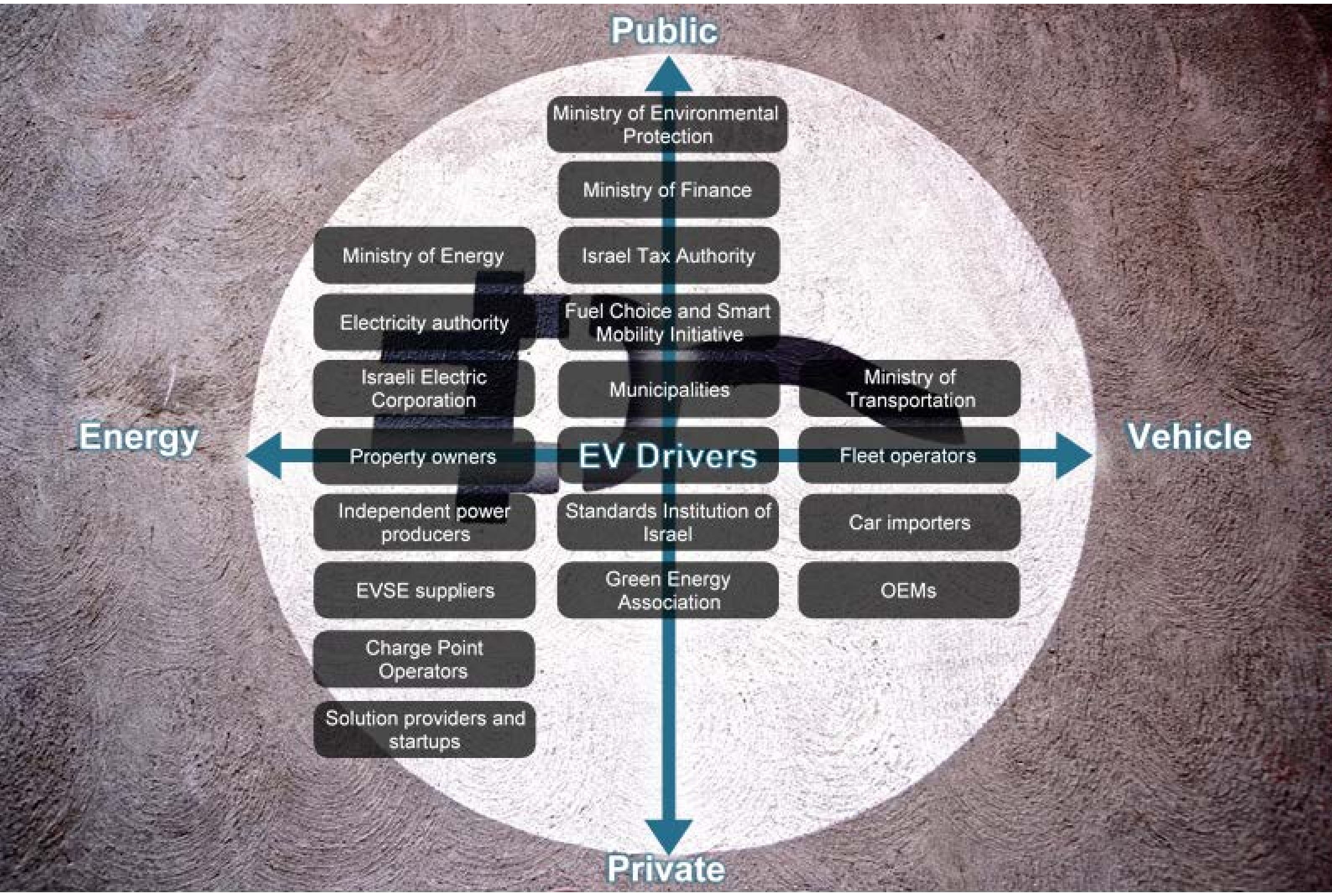


Figure 49. Mapping of EV and charging stakeholders, over axis of energy vs. vehilce and public vs. private.

17.2. Private stakeholders

Car importers and OEMs

While EVs might inherently undermine the importers' sales and servicing business model, they are aware that – similarly to world trend – an increase in the market share of EVs is inevitable. While having similar concerns, OEMs perceive EV models as strategic to their product line-up, boosting brand value while also serving to position the brand to gain future market share as the automotive landscape gets reshaped by EVs. Moreover, there is reason to believe that importers are subject to pressure from OEMs to EV sales target, if not in the immediate timeframe then short thereafter. Thus, importers appear to either take the high road and consider early entry as a long-term brand investment and a chance to gain head start and experience, or take a laggard strategy by which they wait for the market to shape before they join in.

One of the challenges car importers face with respect to sales of EVs, is that their target customers are mostly early adopters, who are tech savvy and highly knowledgeable of the product; such customers are demanding and require more attentive salesmen who are well-informed about the unique traits EVs. However, as overseas markets develop, the general gets increasingly aware of the topic - to the claim of one of the importers, a survey of over 500 participants revealed that about 35% of respondents are interested in an EV model, and 10% expressed purchase intent.

Charge Point Operators and EVSE suppliers

Charge point operators (CPOs) are the entities who provide the operational charging service, either directly to end-users or through a mediating retail service provider. CPOs range from operating over EVSE hardware they license for another owner, all the way to full vertical integration where the CPO manufactures charge points, installs them, manage the backend systems, takes care of maintainers and provide customer service – or anything in between.

Both international and local experience show that CPOs tend to be dominant champions in the local EV scene, serving at the same time as a knowledge source and a catalyst to promote the development of the market. The notable example to this is the Israeli-based Gnrgy – the company, which bought the EVSE from the Better Place default, is the single active CPO in Israel to date. It operates all the public and semi-public charging point in Israel, installs private chargers, as well as develops, manufactures and assembles it proprietary EVSE to both the local market and overseas market as an EVSE supplier. With operational experience it has gained, Gngry partakes in EV activities and projects in Israel, including standardization committee in the Standards Institution of Israel, discussions with municipalities and government officials, and EV implementation projects.

As the local EV market develops, more CPOs are bound to emerge, including international enterprises. OEMs and importers may also want to expand the business into EVSE and the related service, to make up for lost share in their traditional business model. Alternately, given the regulatory clearance, independent power producers may want to take part in facilitating the consumption of their product by the new-comer market of EVs through deployment of charging networks.

Solution providers and startups

Despite the nascent status of the Israeli EV market, building on a developed ecosystem of world-known innovation, several startups and companies in Israel are targeting the EV sphere, each tackling a different challenging aspect faced by the transition to e-mobility. These represent only a fraction of the thriving and vibrant mobility-related tech sphere in Israel, made up of over 500 companies, thousands of entrepreneurs, and multiple R&D centers operated by multinational car OEMs and Tier 1 corporations.

Following are leading examples of EV-focused Israeli startup companies:

- **Driivz** – develops and operates management software for charging network as an electric vehicle services provider (EVSP) for major networks around the world, including The Netherlands, Ireland and the US. The system supports an increasing number of over 70 charger models, allowing remote control, maintenance, billing, smart charging applications, avoided emissions accounting and real-time troubleshooting. The company works closely with OCA, the developers of OCPP, and has been hailed as one the world leaders in charging network backend management solutions.
  http://driivz.com/
- **Electroad** – develops wireless electricity supply for EV's battery charging and motor driving, through coils embedded within the asphalt and receiver plates under the vehicle, controlled using discrete local wireless communication. The technology is patented and demonstrates high efficiency in dynamic supply of electricity (i.e. even while the receiving vehicle is on the move). Among the system's benefits are the lower costs of deployment and operation, as it carries significant economy of scale characteristics, and can be deployed at a rate as fast as 1km per night.
  https://www.electroad.me/
- **Chakratec** – develops a flywheel-based energy storage system, which can charge at a slow rate and then discharge at a high rate for fast DC charging applications, saving on infrastructure upgrades and enabling deployment of fast charging in remote areas with weaker local grid or within urban neighborhoods. The system can also provide frequency stabilization and other network services. The company is engaged with major European utilities in pilot programs in the continent.
  https://www.chakratec.com/
- **EV Meter** – develops a payment and management solutions for charging stations, as well as its own charging station with an integrated open payment solution and a public interface. The company, which is in part a subsidiary of the cashless payment services developer Nayax, develops both the hardware and software.
  http://evmeter.com/

18. Adoption forecast

In order to form comprehensive and well-informed policy for EV adoption in Israel, it is essential to establish a forecast which can provide an outlook on how the market is expected to evolve. This following section provide a forecast for the uptake of EVs in Israel, as well as the rollout of charging infrastructure.

18.1. Methodology

The forecast was built based on these stepping stones:

1. Definition of fast and slow scenarios to the share of EV sales in Israel until 2030, based on leading industry predictions with adaptation to Israel
2. Extrapolation of the number of new vehicles sold in Israel until 2030, based on historical sales and population growth data
3. Calculation of the expected number of EV sales the total expected EV stock, based on the EV share and new cars sold projections
4. Allocation of the projected EV stock over the major cities and urban/rural areas
5. Calculation of the private and public charging points demand per city/area
6. Calculation of the national fast charging demand

As the share between types of EV is greatly dependent on factors such as policy, market situation etc., for the sake of simplicity no distinction is made between EV types. Therefore, for the purpose of this forecast, EVs refer to both BEVs and PHEVs.

18.2. EV share

Analyses performed by leading industry experts predict an exponential growth rate for EV uptake in the coming decade or so. Bloomberg and ING recently predicted that by 2030 the EV share in total sales in the EU would reach 29% and 64%, respectively (BNEF, 2017; ING, 2017). While these predictions present a very similar outlook until 2023, after that year the Bloomberg prediction maintains a conservative scenario, relative to the ING one. Notably, both of these EU estimates include eastern-European countries, with about half of EU countries having an annual GDP per capita ranging from $12,000 to $34,000; in 2016, the GDP per capita in the European Union was $32,242, and in Israel $37,180 (see **Figure 50**) (World Bank Group, 2018).

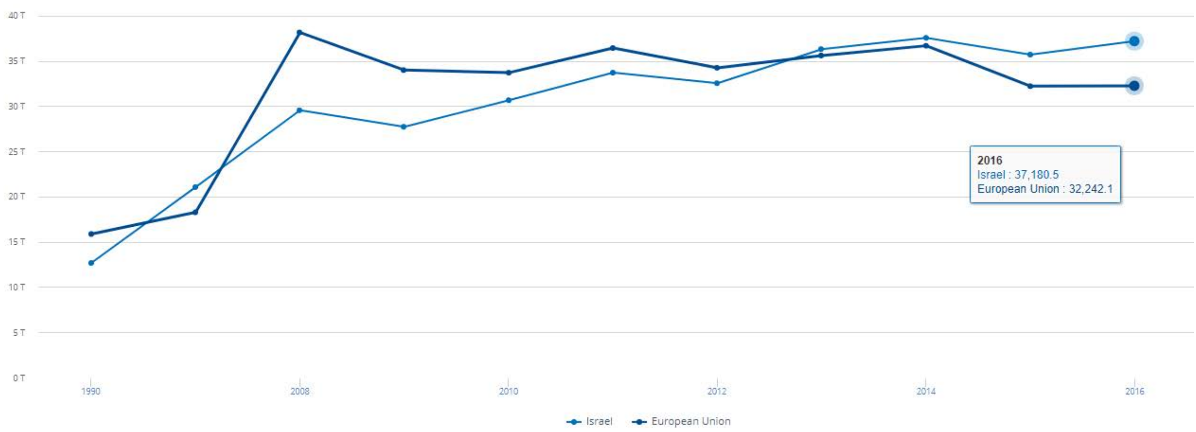


Figure 50. GDP per capita in the European Union and Israel 1990-2016. Reprinted from World Bank Group *(2018)*.

For the following forecast analysis of EV adoption in Israel, *slow* and *fast* scenarios were defined, in order to determine the range of uptake rate until 2030:

- **Slow** – 3 years behind Bloomberg EU prediction
- **Fast** – similar to ING EU prediction until 2020, and afterwards adoption rate exceeds it

These scenarios represent a relatively conservative approach. Both the Netherlands and Norway – two of the frontrunners on EV adoption with EV market shares of 2.2% and 39.2%, respectively (EAFO, 2018) – have set their prospects and goals significantly higher than the Israel fast scenario. The Israeli uptake prediction assumptions consider no current EV sales in Israel, and the rate remains lower than EU scenarios until 2021; after 2021, TCO starts playing a role in EV sales, lag in sales doesn't continue, but the scenarios diverge due to tech and policy paths. As adequate charging infrastructure is important for large scale EV rollout, the realization of proactive rollout policy is reflected accordingly.

Figure 51 describes the EV adoption prediction for Israel, compared to the Bloomberg and ING EU predictions, as well as the Netherlands and Norway goals. **Israeli EV uptake is predicted to reach a sales market share of 2% to 4% (3% avg.) in 2020, 6.5% to 26% (16% avg.) in 2025 and 17% to 84% (51% avg.) by 2030**.

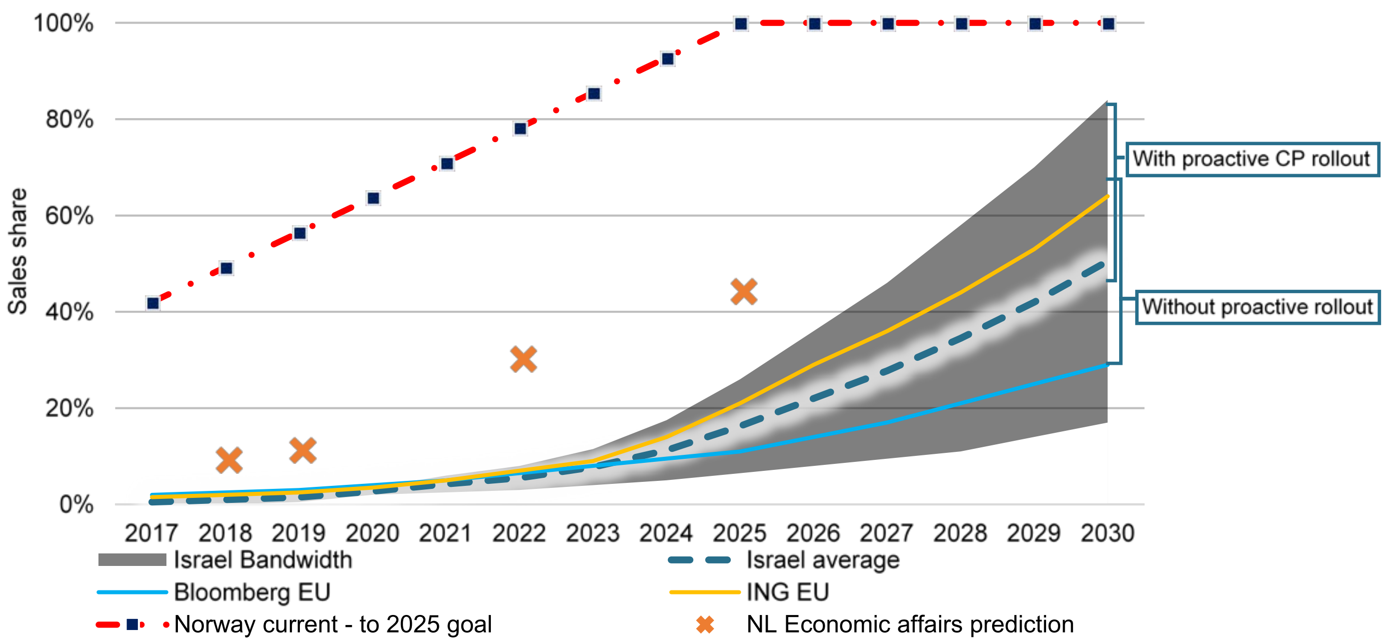


Figure 51. Predicted EV share of total new vehicle sales, until 2030.

18.3. Car sales

Historical data of population growth, level of motorization and vehicle sales in Israel were used to predict the number of vehicle sales from 2017 to 2030. Population growth prospect is based over a CBS projection (CBS, 2013), and the level of motorization prospect was linearly extrapolated from the historical data (CBS, 2017). Prospects of new vehicles sales were based on 2015-2016 average factored with the corresponding population growth and level of motorization in subsequent years. (see **Table 9**).

Table 9. Historical data and prospects of population, motorization level and new vehicles registrations for Israel.

	Year	Population (millions)	Level of motorization (cars/1,000 residents)	New vehicle registrations				
				Passenger car	SUV	Van	Pickup	Total
Historical	**2012**	7.91	284	169,380	18,918	12,500	4,141	**204,939**
	2013	8.06	290	172,449	24,468	11,862	3,802	**212,581**
	2014	8.22	299	196,324	28,639	10,897	3,911	**239,771**
	2015	8.38	307	198,506	41,667	10,996	3,579	**254,748**
	2016	8.54	314	200,370	68,921	12,681	4,756	**286,728**
Prospects	**2017**	8.57	322	205,937	70,836	11,787	4,038	**292,598**
	2018	8.72	329	214,428	73,756	11,787	4,038	**304,009**
	2019	8.87	337	223,153	76,757	11,787	4,038	**315,735**
	2020	9.03	344	232,117	79,841	11,787	4,038	**327,783**
	2021	9.19	352	241,327	83,009	11,787	4,038	**340,161**
	2022	9.35	359	250,788	86,263	11,787	4,038	**352,876**
	2023	9.51	367	260,506	89,606	11,787	4,038	**365,937**
	2024	9.68	374	270,488	93,039	11,787	4,038	**379,352**
	2025	9.84	382	280,739	96,565	11,787	4,038	**393,129**
	2026	9.84	389	286,028	98,385	11,787	4,038	**400,237**
	2027	10.00	397	296,346	101,934	11,787	4,038	**414,105**
	2028	10.16	404	306,927	105,573	11,787	4,038	**428,325**
	2029	10.33	412	317,775	109,305	11,787	4,038	**442,905**
	2030	10.50	419	328,898	113,131	11,787	4,038	**457,854**

18.4. EV sales

The prospected vehicle sales from above were multiplied with the *slow* and *fast* EV share scenarios in order to calculate the EV stock bandwidth for Israel until 2025. An equal adoption rate for the different body types of vehicles was assumed. (see **Figure 52**).

- **By 2020 the number of EVs in Israel is expected to be about 9,000 to 29,000, accounting for 0.3% to 0.9% of the total fleet that year (avg. of 19,000 and 0.6%, respectively).**
- **By 2025 the number of EVs in Israel is expected to reach 87,000 to 288,000, accounting for 2.3% to 7.7% of the total vehicle fleet that year (avg. of 188,000 and 5.0%, respectively)**.

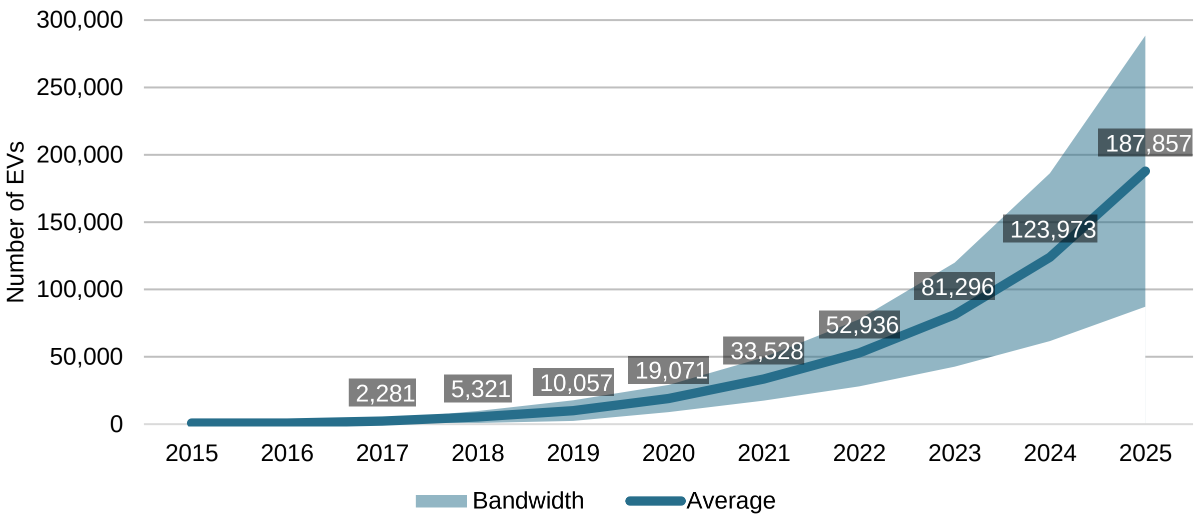


Figure 52. Predicted EV stock in Israel (incl. passenger cars, SUVs, vans and pickups), until 2025.

18.5. Regional adoption

With diverse attributes to different cities and regions, it is important to estimate the variance in EV adoption on a municipal and regional level as well. Therefore, an indication for the number of EVs in the major cities, urban areas and rural areas is also provided (see **Table 10**).

This indication is calculated by factoring the cities/areas share of the national population of the areas/cities with their relative income level. Factors were allocated based on EV adoption experience from the Netherlands and the EU in general, where EV adoption is found to be highly correlated to the residents' income level; a factor between 0.5 and 2.5 was used for the areas where the income is significantly higher or lower than the national average. Rural and urban areas in the EU show significantly lower EV adoption compared to city areas, therefore these areas were given a reduction factor of 0.5. Since the final shares do not sum up to 100%, the remainder was equally divided over all areas. The average of the EV sales in the fast and slow scenarios were used in this calculation.

Table 10. Predicted municipal adoption in the eight major cities and two area aggregates in Israel.

	Income per person	Population [share]	reasoning for factor [factor]	EV stock share	EVs in 2020	EVs in 2025
<200K urban	4,662 ₪/m.	[53.7%] 3,824,167	[0.5] Urban area	29.2%	5,574	54,909
Jerusalem	3,138 ₪/m.	[12.0%] 857,752	[0.5] low income	8.4%	1,601	15,768
Rural	5,811 ₪/m.	[8.9%] 632,000	[0.5] Rural area	6.8%	1,298	12,790
Tel Aviv	7,450 ₪/m.	[6.0%] 429,515	[2.5] very high income	17.5%	3,329	32,787
Haifa	6,016 ₪/m.	[3.9%] 277,993	[2.0] high income	10.2%	1,941	19,123
Rishon LeZion	5,376 ₪/m.	[3.4%] 242,320	[1.5] relative high income	7.5%	1,426	14,043
Petah Tiqva	5,228 ₪/m.	[3.2%] 228,170	[1.0]	5.6%	1,063	10,472
Ashdod	3,966 ₪/m.	[3.1%] 219,067	[0.66] relative low income	4.4%	843	8,305
Netanya	4,410 ₪/m.	[2.9%] 205,187	[1.0]	5.3%	1,002	9,865
Beer Sheva	4,496 ₪/m.	[2.8%] 202,495	[1.0]	5.2%	994	9,794

18.6. Charging demand

With the predicted number of EVs, an indication for the required public and private charging points can be given for Israel, as well as per area.

Based on international experience, the following assumptions were made:

- In rural areas 4% of EVs are not able to charge on private property and require public charging
- In urban areas 15% of EVs are not able to charge on private property and require public charging
- In city areas 20-30% of EVs are not able to charge on private property and require public charging (higher income cities assumed to have higher share of public chargers)
- An EV has either a public or a home charge point
- A public charger has two charge points and is shared by an average of 3 EVs
- A private charger has one charge point

Considering the share public charging in the different areas, the estimated national share of public charging points is 14.7%. **The public charging demand prediction for Israel shows that tens of thousands of public charging stations are needed within less than a decade.** By 2020 there are 15,145 private chargers and 1,309 public chargers (or 2,618 public charging points) are needed, and by 2025 there are 149,184 private chargers and 12,891 public chargers (or 25,782 public charging points) needed (all normal chargers, AC) (see **Figure 53**).

Municipalities can expect demand for hundreds up to thousands of public charging stations within less than a decade, with Tel Aviv, Haifa, Jerusalem and Rishon LeZion in demand for over 100 public chargers by 2020 (see **Figure 54**). Yet, even in cities demand for private chargers remains an order of magnitude larger than for public ones (see **Figure 55**).

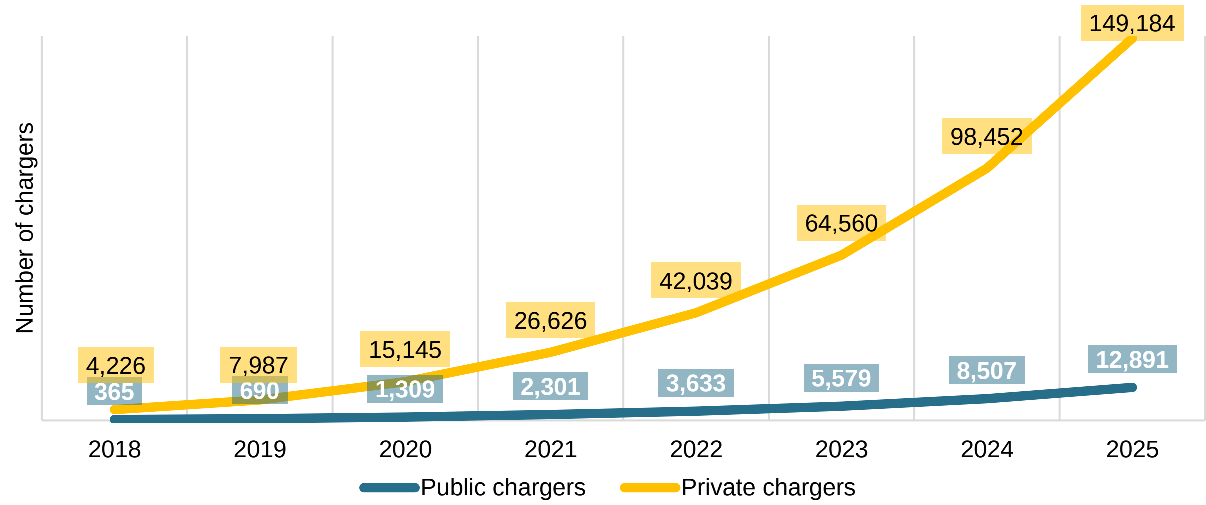


Figure 53. Predicted demand for public and private charging stations in Israel, until 2025.

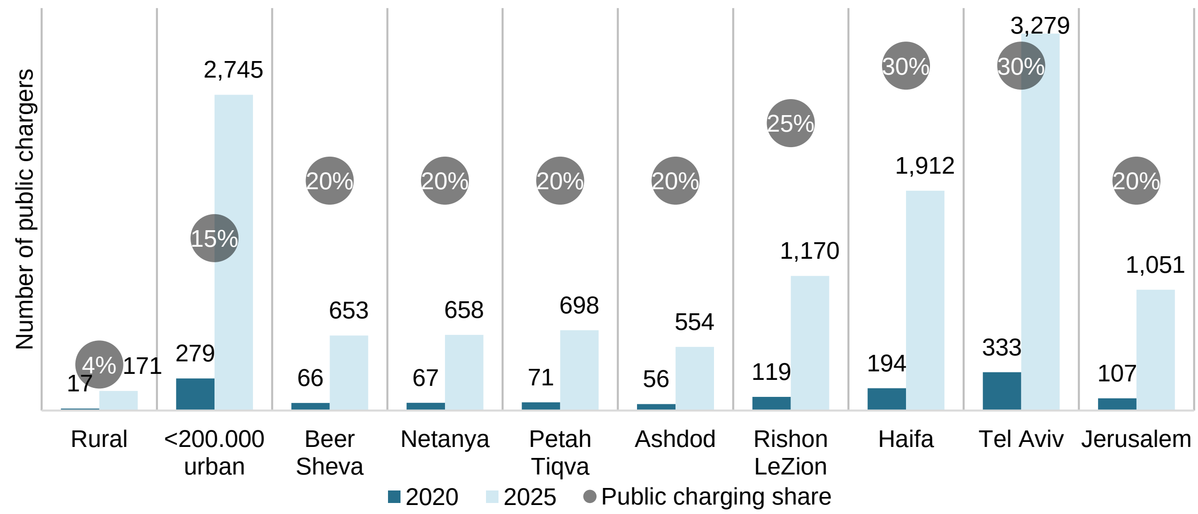


Figure 54. Predicted demand for AC public charging stations per city/region, in 2020 and 2025.

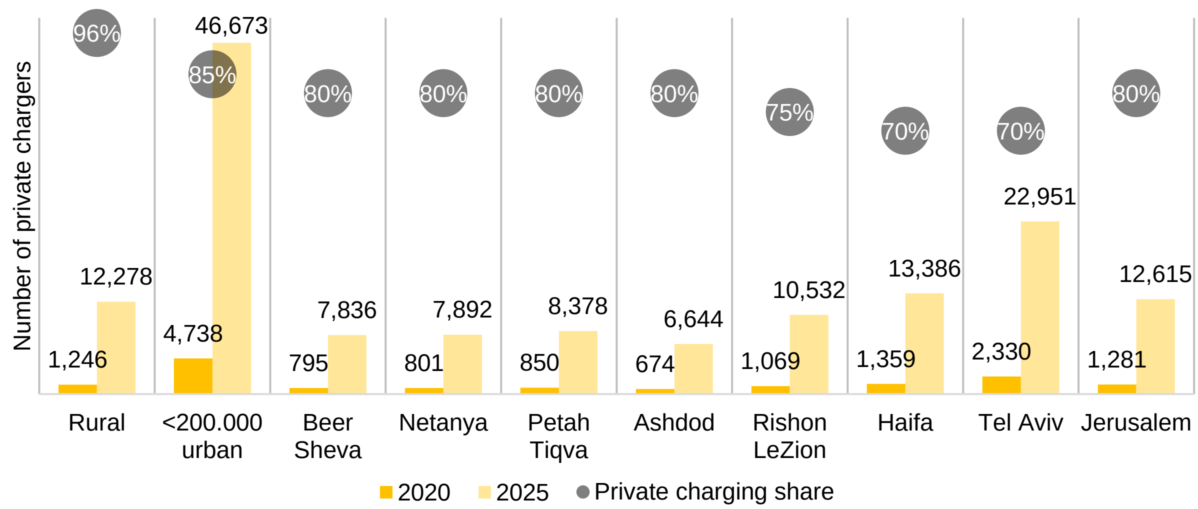


Figure 55. Predicted demand for private charging stations per city/region, in 2020 and 2025.

18.7. Fast charging

Since fast charging is a crucial part of the charging infrastructure – especially so on the national level and at the early development stages – it is also necessary to estimate the demand for it. Fast charging is not fully standardized yet, and faster charging speeds are undergoing rapid development. Currently, most BEVs can charge at 50 kW, with some capable of charging at 150 kW; most PHEV are not able to use fast charging. As 150 kW chargers are estimated to hit the market between 2018 and 2022, in the EU a joint venture of OEMs and CPOs is about to start a rollout of an EU wide 350 kW charging network, indicating the fast charging capabilities of upcoming EVs. As a benchmark for demand, with 755 fast chargers the Netherlands has less than 22 BEVs per fast charger and low utilization rates. A ratio of around 100-200 BEVs per fast charger is expected to result in a positive fast charging business case. However, as charging power increases, less chargers per EVs are expected to be required due to potential higher utilization rates.

For the demand estimate, the following assumptions were made:

- Since part of the EV fleet will be PHEVs, the fast charging demand was set at 400 EVs per fast charger
- The ratio reduces over time down to 600 EVs per charger (see **Figure 56**).
- All EVs are able to use fast charging

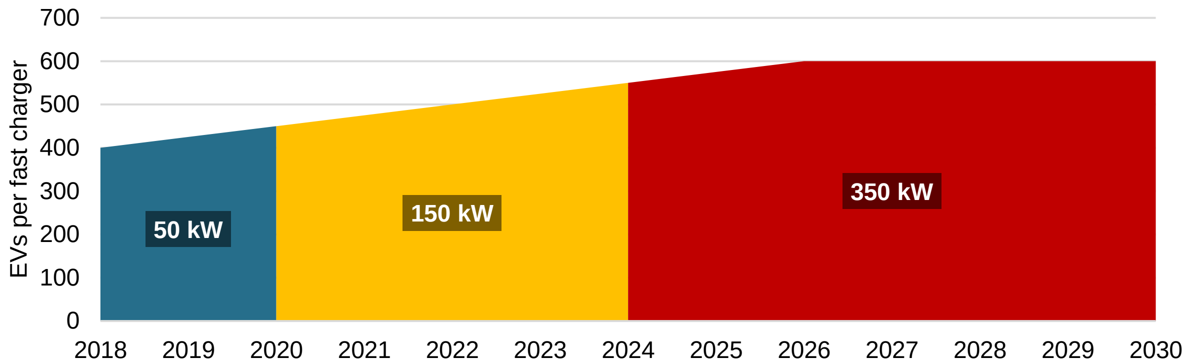


Figure 56. Ratio of EVs per fast chargers, as a function of charging power.

The predicted demand for fast chargers is for 20 to 65 (42 avg.) fast chargers required by 2020, and 152 to 502 (327 avg.) fast chargers required by 2025 (see **Figure 57**).

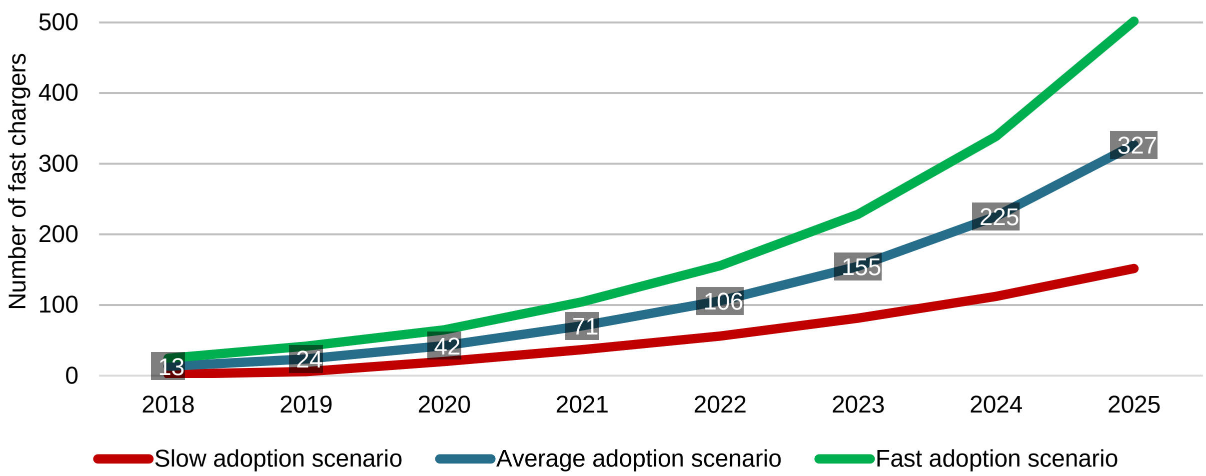


Figure 57. Predicted demand for fast charging stations in Israel, until 2025.

Locations guidelines

- Fast charging locations should have at least two chargers (one charger is not an attractive business offer to e-drivers)
- Roll out should first focus on nationwide coverage of the highway network, starting at routes with the highest traffic intensity
- When nationwide coverage is achieved, stations can be scaled up based on demand and a denser network can be realized (including city hubs)
- Until 2020 fast charging locations deployment should work towards coverage
- In 2025 deployment should both upscale of existing locations and densify the network

Based traffic density and gas station location, initial potential fast charging locations were identified (see **Figure 58**).

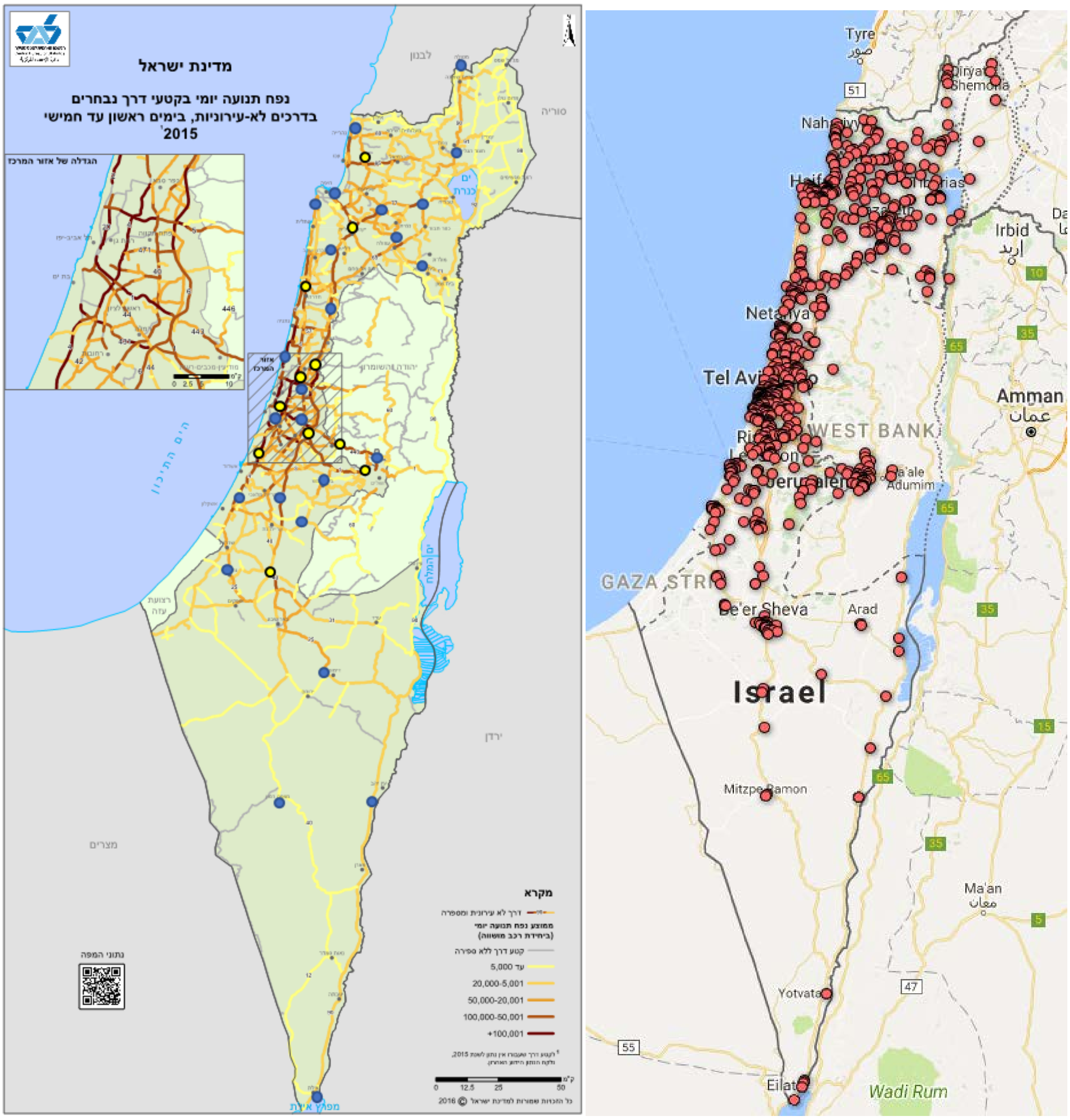


Figure 58. Initial potential fast charging locations over traffic density map (left) and current public gas stations (right). Modified over CBS *(2016)* and adapted from Fuel Administration *(2017)*, respectively.

19. Conclusions and recommendations

Israel is a small, highly urbanized and densely populated country. It is characterized by a high dependency on private car commute, high vehicle travel distance and a growing car market with high demand – despite high taxes and market prices. The country has no meaningful domestic oil production, but does have an abundancy of natural gas, ample potential to harvest solar energy, attractive electricity rates and EV tax incentives. Given those circumstances, **Israel serves as a prime candidate for high rates of EV adoption**.

Based on findings in this study, the following conclusions and recommendations are given for the realization policy of large-scale adoption of electric vehicles and the required charging infrastructure:

1. Ensure policy coordination and infrastructure rollout plan

- Set one coordinating ministry to take lead in EV Infrastructure strategy and development
- Develop an Infrastructure rollout plan with clear and compelling targets in relation to national EV sales targets, including identification of the best charging locations (in both highways and cities)
- Coordinate national, regional and municipal infrastructure policies
- Provide adaptive programming to cope and respond to a rapidly evolving EV market

2. Support all charging methods and standard requirements

- Take an integrated approach considering all types of charging – including home, work, public and fast charging
- Standardize requirements for charging, in terms of safety, interoperability, customer interaction, open access etc.
- Develop building codes for new commercial and residential construction to enable easy charger installation

3. Facilitate strong stakeholder cooperation

- Install a high-level multi-actor EV taskforce, where representatives from national and local policy, automotive industry, energy sector, science and SME cooperate
- Assure strong involvement of IEC to develop smart charging techniques to alleviate additional load on electricity grid and possibilities for V2G
- Support entrepreneurship and innovations projects to build leading companies
- Combine uptake of EV with increased renewable energy production

4. Build strong market development

- Build towards a fully commercial charging operator model from the start
- Provide initial financial support for CPOs to spark early investment and offer new companies possibilities to enter the new market
- Develop a tariff and pricing structure that balances attractive use for customers and the business case for the CPO

5. Promote extensive communication and education

- Generate promotion of EV and infrastructure to build EV awareness and outreach towards potential EV customers
- Organize constant learning and make use of existing lessons learned

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Appendix I: Stakeholders workshop participants

In the following list are the participants of the stakeholders' workshop. We wish to thank all participants for taking the time, contributing to the thought-process and sharing their invaluable insights.

Gideon Friedman	Ministry of Energy
Zvi Tamari	Ministry of Energy
Igor Stepensky	Electricity Administration
Noam Perlson	Public Utility Authority - Electricity
Tamar Adiel Zakai	Public Utility Authority - Electricity
Hagit Novo	Ministry of Environmental Protection
Uri Ziskind	Israel Tax Authority
Avi Blau	Ministry of Finance (consultant)
Zeev Shadmi	Ministry of Transportation
Idan Abudi	Ministry of Transportation
Anat Bonshtien	The Fuel Choices and Smart Mobility Initiative
Daniel Zucker	The Fuel Choices and Smart Mobility Initiative
Isaac Akerman	Standards Institution of Israel
Ilan Zilberman	Haifa Municipal Association
Vered Crispin Ramati	Tel Aviv Municipality
Alma Tsur-Revivo	Tel Aviv Municipality
Moti Pinhassi	Netanya Municipality
Udi Levin	Israel Electric Corporation
Itay Miron	Colmobil
Miki Zohar	Colmobil
Meir Ivgi	Champion Motors
Shai Moskovitch	Champion Motors
Avi Kenet	Carasso Motors
Yariv Kraiem	
Eyal Blum	Driivz
Ran Aloya	Gnrgy
Niso Hazan	EV Meter
Moshe Relles	EV Meter
Ilan Ben-David	Chakratec
Aviya Grosman	Greenspot
Gadi Schuster	Greenspot
Ziva Patir	Consultant
Rebecca Shliselberg	Consultant
Miriam Lev-On	The LEVON Group
Perry Lev-On	The LEVON Group
Roland Steinmetz	EVConsult
Roos van der Ploeg	EVConsult
Ofira Ayalon	Samuel Neaman Institute
Maayan Zerbib	Samuel Neaman Institute
Idan Liebes	Samuel Neaman Institute

Appendix II: Comparative data on available BEV models

Table 11. Comparative data on available BEV models in 2017. Adapted from *(Motor1, 2017; Push EVs, 2017)*.

	EPA (USA)		NEDC (EU)								
Vehicle	**Range (combined city & highway, km)**	**Efficiency (combined city & highway, kWh/100 km)**	**Range (km)**	**Efficiency (kWh/100 km)**	**Germany**	**Netherlands**	**Norway**	**Portugal**	**Spain**	**Sweden**	**UK**
2017 Tesla Model S AWD P100D	507	21.7									
2017 Tesla Model X AWD P100D	465	24.2									
2017 Tesla Model S AWD P90D	435	21.7									
2017 Tesla Model S AWD 75D	417	20.5	490		€84,470	€88,785	638,400 NOK	€90,200	€88,200	932,400 SEK	£66,500
2017 Tesla Model X AWD 90D	414	23.0									
2017 Tesla Model X AWD P90D	402	23.6									
2017 Chevrolet Bolt EV / Opel Ampera-e	383	17.4	520	14.5	€39,330		314,900 NOK				
2017 Tesla Model X AWD 75D	383	22.4									
2017 Tesla Model S AWD 60D	351	19.9	408								
Renault Zoe R90 (41 kWh battery)			403	13.3		€32,890	229,400 NOK	€32,710	€32,385		£23,770
Renault Zoe Q90 (41 kWh battery)			370	14.6							
2017 Volkswagen e-Golf	201	17.4	300	12.7	€35,900	€38,970	307,700 NOK	€40,463	€38,020	395,900 SEK	£32,190
2017 Hyundai Ioniq Electric	200	15.5	280	11.5	€33,300	€32,450	239,900 NOK		€29,400	331,900 SEK	£24,995
2017 Ford Focus Electric	185	19.3	225	16.4	€34,900		239,900 NOK				
2017 BMW i3 (94 Amp-hour battery)	183	18.0	312	12.6	€36,800	€38,769	273,100 NOK	€41,990	€37,400	364,700 SEK	£33,070
2018 Kia Soul Electric *	180	19.2	250	14.3			224,900 NOK			369,900 SEK	
2017 Nissan Leaf (30 kWh battery)	172	18.6	250	15	€31,265	€33,590	204,990 NOK	€22,340	€26,860	336,490 SEK	£25,790
Renault Zoe R240 (23.3 kWh battery)			240	13.3							
Renault Zoe Q210 (22 kWh battery)			210	14.6							
2017 Kia Soul Electric	150	19.9	212	14.7							
2017 Mercedes-Benz B250e	140	24.9									
2017 Fiat 500e	135	18.6									
2017 BMW i3 (60 Amp-hour battery)	130	16.8	190	12.9							
2016 Smart Fortwo ED Convertible/Coupe	109	19.9									
Volkswagen e-up!			160	11.7	€26,900	€27,491	214,500 NOK	€27,480	€28,050	279,900 SEK	£25,280
2017 Mitsubishi i-MiEV / Citroen C-Zero / Peugeot iOn	95	18.6	150	12.6							

** South Korean test cycle (similar to the EPA cycle)*

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