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best practices in electric mobility

INCLUSIVE AND SUSTAINABLE INDUSTRIAL DEVELOPMENT

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best practices in electric mobility

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Abbreviations

AC	Alternating current
ASEAN	Association of Southeast Asian Nations
AT&C	Aggregate technical & commercial
BEV	Battery electric vehicle
CDFI	Community Development Financial Institution
CLMV	Cambodia, Lao PDR, Myanmar and Viet Nam
DC	Direct current
EV	Electric vehicle
EVSE	Electric vehicle supply equipment
GEF	Global Environment Facility
GHG	Greenhouse gas
HEV	Hybrid electric vehicle
ICE	internal combustion engine
ISID	inclusive and sustainable industrial development
IMPT	Indonesia, Malaysia, the Philippines, Thailand
IRENA	International Renewable Energy Agency
LCO	Lithium cobalt oxide
LDV	Light duty vehicle
LFP	Lithium-iron-phosphate
Li-ion	Lithium-ion
NCA	Nickel-cobalt-aluminium
NMC	Nickel-manganese-cobalt
NiMH	Nickel-metal hydride
OEM	Original equipment manufacturer
PHEV	Plug-in hybrid electric vehicle
PHV	Plug-in hybrid
PLDV	Passenger light duty vehicle
PLEV	Personal light electric vehicle
PPP	Public-private partnership
R&D	Research and development
RE	Renewable energy
RFID	Radio-frequency identification
RGGI	Regional Greenhouse Gas Initiative
ROEV	Roaming for EV charging
SIDS	Small island developing states
TCO	Total cost of ownership
VAT	Value added tax
V2G	Vehicle-to-grid
ZEV	Zero-emission vehicle

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About this publication

This paper was prepared by PricewaterhouseCoopers (PwC) Pvt. Ltd for the United Nations Industrial Development Organization (UNIDO) to provide a global assessment of practices, challenges, drivers and emerging best practices in major electric vehicle (EV) markets. The paper has been informed by the Expert Group Meeting “Smart Mobility for Smart Cities”, held in Vienna by UNIDO in September 2019, which presented findings on the current state of the market, including best practices, infrastructure, technologies and business models.

It examines key lessons learned across countries on integrating the power sector with transport and incorporating electric mobility into the urban planning concept of transit-oriented development. The paper draws on examples from a range of policy initiatives and programmes, including the UNIDO e-mobility programme, which is currently being implemented in China, Malaysia and South Africa with the backing of the Global Environment Facility (GEF).

It presents a set of recommendations on the way forward, which will be of use to policymakers and industry in devising future programmes. Lessons learned from the information gathered will also be incorporated into the design and further development of UNIDO’s electric mobility programme, enabling the Organization to respond with increasing effectiveness to the growing demand for services in this area.

Executive summary

The world is on the cusp of a transport revolution as more and more countries step up efforts to convert their transportation systems to electric. The push to cut greenhouse gas (GHG) emissions as part of the Paris Agreement is putting the spotlight on the highly polluting transport sector. To meet the targets, emissions must peak around 2020 and fall 9 per cent by 2030. If powered by renewable energy (RE), electric vehicles can play an important role in helping to reach this target.

Although the COVID-19 pandemic has created global uncertainty, there are some early indications that the move towards electric mobility will persist this decade. An opportunity exists to include measures supporting EV adoption as part of countries COVID-19 recovery measures. Supporting the growth of the sector will also contribute directly to achieving a plethora of development goals, including SDG 13 on climate action and SDG 3 on good health and well-being. The huge investment in infrastructure and technology required to build an EV ecosystem will provide new green jobs and business opportunities, contributing to progress on poverty reduction, decent work and sustainable cities.

The United Nations Industrial Development Organization (UNIDO) is carrying out programmes to help countries to accelerate the shift to more sustainable transport systems in order to meet these sustainable development goals. In response to growing member interest to expand and further develop EV programmes, UNIDO convened an Expert Panel Meeting, "Smart Mobility for Smart Cities", in September 2019 to examine market trends, share best practices and lessons learned, and to assess the challenges ahead.

This paper explores the findings from the meeting, including lessons learned from UNIDO's EV programmes in China, Malaysia and South Africa and lays out recommendations for countries wishing to implement new EV programmes and for future UNIDO work in this area.

Demand for EVs is growing with many drivers

In terms of growth, the EV market has expanded rapidly in recent years. In 2018, the number of electric passenger cars reached more than 5 million,[1] an increase of 2 million over the previous year. China is the largest market in volume of sales, with Norway leading the way in market share of EVs in new vehicle sales. China and the United States have the largest number of public electric vehicle supply equipment (EVSE) installations and growth looks sets to continue.

[1] International Energy Agency (IEA) (2019). *Global EV Outlook 2019: Scaling up the transition to electric mobility*. IEA, Paris.

Uncertainty around oil prices is also giving new momentum to e-vehicle programmes as countries aim to reduce oil imports and boost energy security. At the same time, battery prices have tumbled by 75 per cent over the past decade, which has drastically cut the overall cost of battery electric vehicles (BEVs). This, along with improvements in battery design and charging technology, is making previously uneconomical technologies viable.

The drivers for e-mobility are presented in the following infographic:

FIGURE 1. DRIVERS OF EV ADOPTION

Reduction in battery prices	Evolving battery technology	Evolving charging methods	Increase in renewables	Rising crude oil prices	Increasing government support

However, such disruptive moments are not without risk. Trade relations are likely to change with the new technology presenting opportunities for green trade deals, cutting the cost of imports. But this could be impeded by countries with a strong automobile base seeking to protect their industry. As the EV market grows a sharp fall in the value of oil could trigger economic shocks as government receipts fall, while new geopolitical battlegrounds could emerge over access to metal and mineral resources required to power EV batteries, most of which are held in countries with poor governance records.

Barriers to mass EV adoption remain

In addition to this, there are many economic, regulatory, technical and informational challenges that must be addressed by all stakeholders in order to achieve the transition to electric mobility, as highlighted below.

FIGURE 2. KEY BARRIERS TO EV ADOPTION

Economic barriers
- High upfront EV cost
- Business viability issues

Regulatory barriers
- Characterization of EV charging activity
- Tariff-related issues

Technical barriers
- Charger standards and protocol issues
- Grid stability issues
- Battery performance issues

Informational barriers
- Lack of awareness
- Range anxiety

Many governments across a range of countries have implemented varying policies and programmes to encourage the shift to electric mobility. Lessons can be drawn from these examples, which provide essential guidance on the support needed to create a sustainable EV sector for the future.

FIGURE 3. POLICY RECOMMENDATIONS FOR ELECTRIC MOBILITY

1. Develop national policies and roadmaps
2. Support infrastructure and technology development
3. Enable business models for deployment
4. Create financial mechanisms targeting electric mobility

Develop national policies and roadmaps

First among the findings is the need for a well-defined roadmap or strategy for countries to achieve electric mobility. It should have clear objectives for deployment of EVs and EVSE and should involve private and public stakeholders from the outset to ensure their active participation. For successful implementation, governments should take concrete legislative action and establish stringent monitoring mechanisms. There also needs to be close involvement from local government at city and state level to supplement the initiatives taken by central government. Due to the high capital cost of EVs, financial incentives are also necessary. The most effective incentives reduce the upfront cost of EVs and can be easily accessed by consumers. Additionally, communication campaigns will be crucial in explaining the benefits of EVs to the end consumer.

Support infrastructure and technology development

In terms of EV ecosystem infrastructure, there is a strong case for encouraging the involvement of utilities in providing a network of charging stations. In places where utilities have been allowed to set up charging infrastructure, as in the case of California, investment in EVSE has increased, suggesting that private sector participation could help to speed up the development of infrastructure.

Smart charging and vehicle-to-grid (V2G) can help utilities manage EV load at times of peak demand. Countries should enable smart charging to take advantage of EVs in grid management. Additionally, countries should also allow charging activity to be considered as a service rather than resale of electricity to enable private-sector investment into the sector.

EVs can enable the transition to renewable energy as their batteries can act as storage for the power generated by RE sources. This would mitigate the concern that the rise in electric vehicles is merely transferring pollution to power plants as significant amounts of electricity is still produced by fossil fuel-based thermal power plants.

Cutting emissions is also behind the idea of transit-oriented development (TOD), which is a concept in urban development and planning that encourages public transport. It focuses on the creation of pedestrian-oriented pathways with easy connectivity to transit services to the rest of the city from transport hubs such as metro stations and bus stands. Given the expected growth in shared mobility services, governments should enable electrifying public transport services, car fleets and personal use vehicles to electric at such hubs as part of the drive to lower emissions.

In relation to EV technology itself, progress is moving at a quick pace, with faster charging methods and higher capacity batteries. But much of the development has so far been fragmented, hampering ease of use and leading to multiple payment mechanisms. To support the growth of the EV sector, interoperability of the charging stations will be essential, ensuring that EV users have easy access to a robust, uniform charging network.

Enable business models for deployment

As EVSE business models are highly dependent on the utilization of the charging station, incentives must be provided in the short term until the business is viable for private players to invest. Additionally, there is no fixed EV to EVSE ratio in regions where there are a considerable number of EVs. It is essential for countries developing their plan to consider the residential and personal chargers while deciding on the number of EVSE installations. Without new business models emerging that create new relationships between private drivers, fleet managers, city managers, energy providers, the auto industry and central government, it will be difficult to scale up electric vehicles.

Demand aggregation or bulk procurement is one of the most common models followed for adoption of electric vehicles for a public or private fleet. Outright purchase and collaborative procurement are among a number of popular demand aggregation methods. In order to minimize maintenance and operating costs, some agencies also prefer leasing the vehicles in their fleet. Electric vehicle car sharing is also gaining popularity as it reduces some of the downsides to owning a vehicle, such as parking charges and fuel and maintenance costs. In addition, as shared cars have greater average driving distance per day compared to an owned car, the payback period for owning an electric car reduces significantly.

In the area of charging infrastructure, governments are employing several business models. In China, a government agency installed a substantial number of fast charging stations in order to overcome the hurdle of range anxiety in the minds of EV owners. Battery swapping stations are also becoming a popular concept. Swapping stations provide reduced charging times as well as increased battery life.

Create financial mechanisms targeting electric mobility

Lastly, innovative financing mechanisms are required to mobilize the e-mobility ecosystem. Some of the common financing mechanisms for EVs and related charging infrastructure are low interest rate loans, feebate mechanisms, green bonds, and microloans. Sometimes, multibank arrangements, operated by a group of banks to pool funding and provide lending, are also undertaken. Small business microloans can also be used to fund the e-mobility ecosystem. Microloans are small business loans offered at attractive interest rates to help businesses access capital for items like machinery or fixtures. These loans can facilitate funding for electric vehicle charging equipment and installation costs.

It is clear that governments need to take concrete action to encourage electric mobility to take advantage of the benefits of the technology, which include cost savings, greater energy security, lower pollution and falling emissions. But making the leap from fledgling to mainstream will require high levels of cooperation between countries and regions. Experiences from across the world and the understanding gained from them are already providing a blueprint for future development and should to be incorporated into future programmes.

Accelerating the scale-up and adoption of electric mobility

As a specialized agency of the United Nations mandated to promote and accelerate inclusive and sustainable industrial development (ISID), UNIDO is well placed to support countries in their transition towards electrification of transport systems. Through its technical cooperation services, the Organization is assisting governments in building up their electric fleets, developing appropriate charging infrastructures, and providing skills and training to support improvements in areas such as in battery technologies. Deploying its policy advisory and knowledge transfer services, UNIDO can contribute to establishing sustainable transport strategies, designing market guidelines and raising awareness in order to drive the move to carbon-free transport necessary to meet the Sustainable Development Goals.

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1. Overview of global electric mobility

Over the last few years, the electric mobility market has been the subject of lively discussions due to new, more powerful, rechargeable batteries and the high volatility on international markets. The uncertainty created by the COVID-19 pandemic has added to the discussion, although there is some early indication that the move towards electric mobility will persist through the decade. Some countries are exploring how measures to increase EV adoption can be included as part of COVID-19 economic recovery packages as EVs are seen to support meeting strategic objectives such as reducing dependency on oil, more efficient energy transformation, significant CO_2 reductions and lowering emissions from transport.

The transportation sector emits almost a quarter of all energy-related CO_2 emissions. Road vehicles – car, trucks, buses, two- and three-wheelers – account for over three-quarters of transport emissions and remain the fastest-growing sector. On current trends the global passenger car fleet is set to double by 2050, with most of the growth taking place in developing markets where policies to curb emissions are often lacking.

To meet the objectives of the Paris Agreement and the 2030 Agenda for Sustainable Development, direct transport emissions must peak around 2020 and then decrease by over 9 per cent by 2030. To achieve such a fall will require urgent action to improve public transport, scale up non-motorized transport and put cleaner, more efficient modes of transport on the roads. If the integration of mobility with the electricity sector and digital technologies is developed in tandem with renewable and efficient energy supplies, along with flexible options on grid management, electric vehicles (EVs) could prove to be the silver bullet. EVs are efficient, low-carbon, quiet and able to improve grid reliability, making them a crucial part of global efforts to cut fossil fuel dependency, improve air quality and decarbonize the economy.

Supporting the growth of the sector will contribute directly to achieving progress on SDG 13 on climate action, SDG 3 on good health and well-being, SDG 7 on affordable and clean energy and SDG 12 on responsible production and consumption.

The huge investment in infrastructure and technology required to build an EV ecosystem will also provide new green jobs, business opportunities, improved access to services and scope for technological innovation, which will contribute to progress on a wider range of development goals including poverty reduction, decent work, industry and sustainable cities.

The United Nations Industrial Development Organization (UNIDO) is carrying out programmes to help countries to accelerate the shift to more sustainable transport systems in order to meet these sustainable development goals. In response to growing member interest to expand and further develop EV programmes, UNIDO convened an Expert Panel Meeting, "Smart Mobility for Smart Cities", in September 2019 to examine market trends, share best practices and lessons learned, and to assess the challenges ahead.

This paper will explore the findings from the meeting, including lessons learned from UNIDO's EV programmes in China, Malaysia and South Africa. It will also lay out recommendations for countries wishing to implement new EV programmes and for future UNIDO work in this area.

1.1. The electric mobility landscape

Electric vehicles

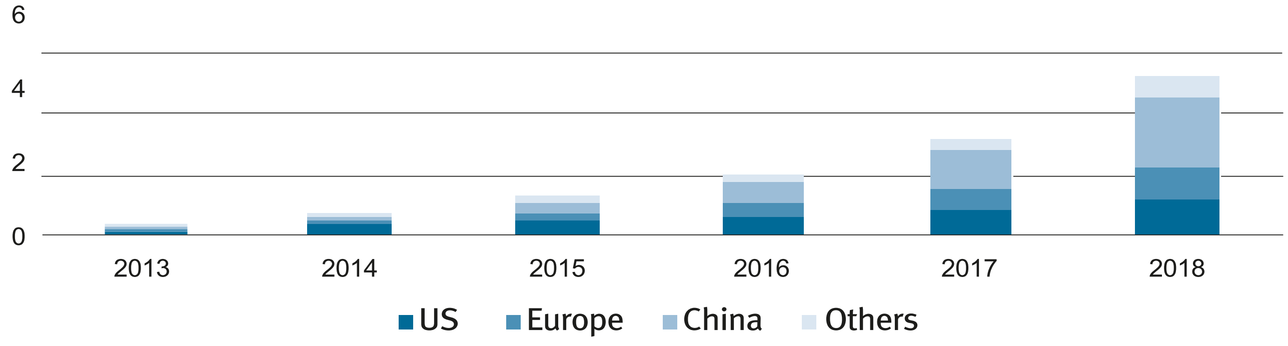
There are three main types of electric vehicles. Battery electric vehicles (BEVs) which are fully electric with rechargeable batteries as the sole means of energy storage; plug-in hybrid electric vehicles (PHEVs), which recharge through both regenerative braking and "plugging in" to an external electric power source; and hybrid electric vehicles (HEVs), which use both gasoline and electricity, with the electric battery charged by the internal combustion engine (ICE).

The different types of EVs are further categorized into light duty (cars, motorcycles, scooters, two-, three-, or four wheelers) and heavy duty vehicles (buses and trucks). Other transport modes such as two-wheelers and buses are also becoming electric. In 2018, the global stock of two-wheelers was about 260 million and 460,000 electric buses were operating on international roads.

The total number of electric cars in the world crossed the 5 million mark in 2018,[2] an increase of about 2 million over the previous year. China is the leader in electric car sales, followed by Europe and the United States. China has the largest fleet of electric light commercial vehicles (LCVs), with 57 per cent of the world's stock. Norway has the highest share of electric cars in its transport sector, with sales at 46 per cent.

[2] IEA, *Global EV Outlook* 2019.

FIGURE 4. ELECTRIC CAR STOCK (BEV AND PHEV) 2013-18 (IN MILLIONS)

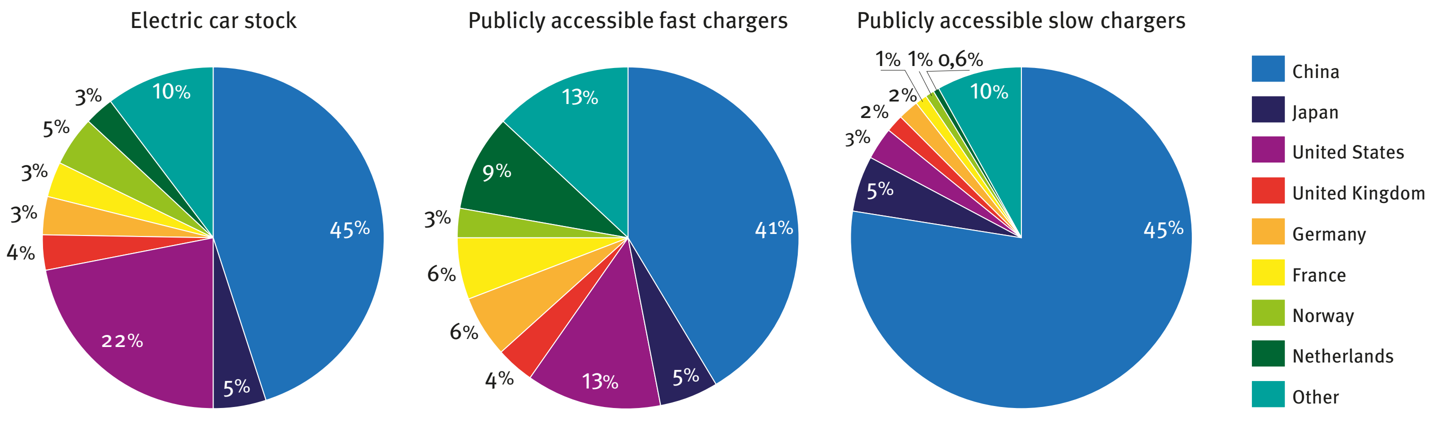


Source: Adapted from IEA (2019), *Tracking Transport*, IEA, Paris https://www.iea.org/reports/tracking-transport-2019

Charging infrastructure

China and Japan have the maximum number of chargers installed to cater for the available number of electric vehicles (EVs). China had around 130,508 alternating current (AC) chargers and 83,395 fast direct current (DC) chargers installed as of 2017. The chart below provides a snapshot of the number of publicly accessible AC and DC chargers by country for the year 2017. As is clear from the chart, China has by far the highest number of both AC and DC chargers, mainly due to the Government's aggressive deployment policies and rebates. By contrast, countries such as Norway and Sweden focus more on home-based charging, which explains their low number of public chargers.

FIGURE 5. EVSE DEPLOYMENT



Source: Adapted from IEA (2019). Global EV Outlook 2019

1.2. Key barriers in EV adoption

Mobility is set to change dramatically in the coming years as electric vehicles and networks to support them look set to grow quickly; however, there is a long way to go before this paradigm shift in transport becomes a reality. The market for EVs is still in its infancy and many barriers need to be overcome before they become a common mode of transportation.
These include the following:

FIGURE 6. KEY BARRIERS TO EV ADOPTION

Economic barriers	Regulatory barriers	Technical barriers	Informational barriers
■ High upfront EV cost ■ Business viability issues	■ Characterization of EV charging activity ■ Tariff-related issues	■ Charger standards and protocol issues ■ Grid stability issues ■ Battery performance issues	■ Lack of awareness ■ Range anxiety

1.2.1. Economic barriers

Purchase price of EVs

EVs have a higher price tag than conventional internal combustion engine (ICE) cars, mainly due to the cost of the battery, making them less attractive to many potential consumers.

Business viability issues

Even though EVs have very low operating costs, fleet operators that use traditional ICE vehicles will face higher capital costs to replace them with EVs. It is difficult to offer EVs at the same rate as ICE vehicles or even deploy the vehicles at a higher cost.
Under current market conditions, it is challenging to construct a profitable business case for public EV charging stations for several reasons. These include high initial investments, low and uncertain near-term demand for public charging and the high cost of electricity to public charging stations as compared to home charging. As the penetration of electric vehicles is very low, utilization of initial charging stations would also be low, resulting in higher total cost of ownership (TCO) and lower revenues for the charging station operators/owners.

1.2.2. Regulatory barriers

Characterization of EV charging activity

The characterization of EV charging activity either as the sale of electricity or as a service has been a major point of contention. Internationally, the majority of countries have characterized EV charging as a service, and hence, have kept the market open for all the players without the requirement of obtaining a licence from government authorities.

Tariff issues

For public charging stations, the cost of electricity constitutes a major component of the overall cost of charging electric vehicles. It may range from 30 per cent to 60 per cent of the total cost depending upon the price of components, such as equipment, land and the electricity tariff. If charging stations are charged the tariff applicable for commercial use, which is generally higher than the average cost of supply in order to subsidize various categories of consumers and high aggregate technical and commercial (AT&C) losses, it would force them to charge high rates to consumers. This would make electric vehicles less attractive than ICE vehicles under the present scenario, due to the currently higher initial cost of EVs compared to ICE vehicles.

1.2.3. Technical barriers

Charger standards and protocols

There is no single agreed charger standard in many countries, which results in a lack of interoperability.

Grid stability issues

Normal EV charging behaviour will put extra load pressure on the grid at peak hours. Charging profiles on traditional or “unmanaged” EV charging stations (primarily residential and office premises) typically see peaks in the midday and early evening periods, which overlap with peak loads on the grid. EV charging during peak demand hours carries the risks related with the management of electricity distribution networks. Hence, utilities are likely to become increasingly concerned with managing the charging activity of electric vehicles in order to avoid any adverse impact on the electricity grid. Higher EV uptake would need to be supported by the strengthening of the distribution & sub- transmission network. However, EVs can have a positive impact on grid stability if EV charging is done during off-peak hours.

Battery performance issues

While lithium-ion (Li-ion) batteries are the most suited to this application, there have been concerns about their safety in high temperatures and their life cycle.

1.2.4. Informational barriers

Awareness

There is lack of awareness about electric vehicles, their performance, and the incentives and regulations in place for their use.

Range anxiety

The range of e-cars is limited by the size of the battery, and is generally smaller than that of ICE cars. Range anxiety is one of the most significant barriers to the rapid uptake of electric vehicles.

2. Drivers of EV adoption

Globally, the market drivers required for the transition to an electric mobility ecosystem across developed and developing nations are illustrated below:

FIGURE 7. DRIVERS OF EV ADOPTION

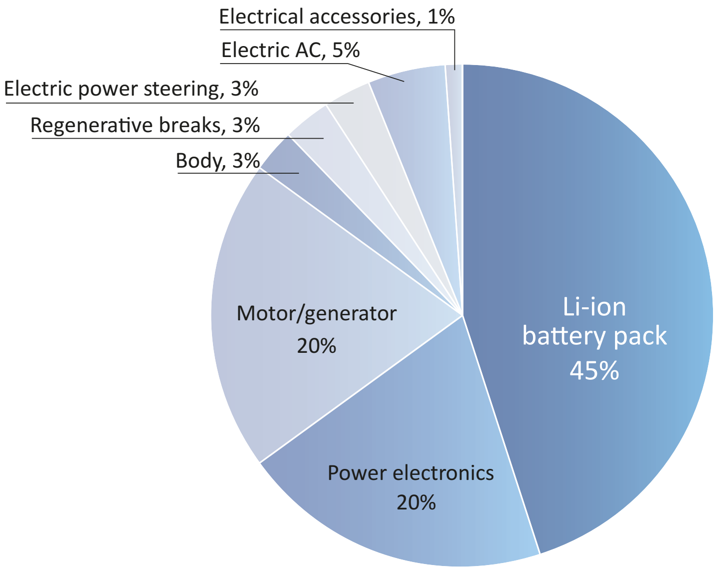
Reduction in battery prices	Evolving battery technology	Evolving charging methods	Increase in renewables	Rising crude oil prices	Increasing government support

2.1. Reduction in battery prices

The comparatively higher cost of electric vehicles has held the market back from fully competing with conventional vehicles. The cost of batteries is the primary factor behind the higher retail price for EVs. The battery cost contributes as much as 45 to 50 per cent of the total average BEV cost.

The figure below illustrates the cost breakdown of a fully electric vehicle. A Li-ion battery pack costs around 45 per cent of the total cost of a BEV.

FIGURE 8. COST BREAKDOWN OF BEV

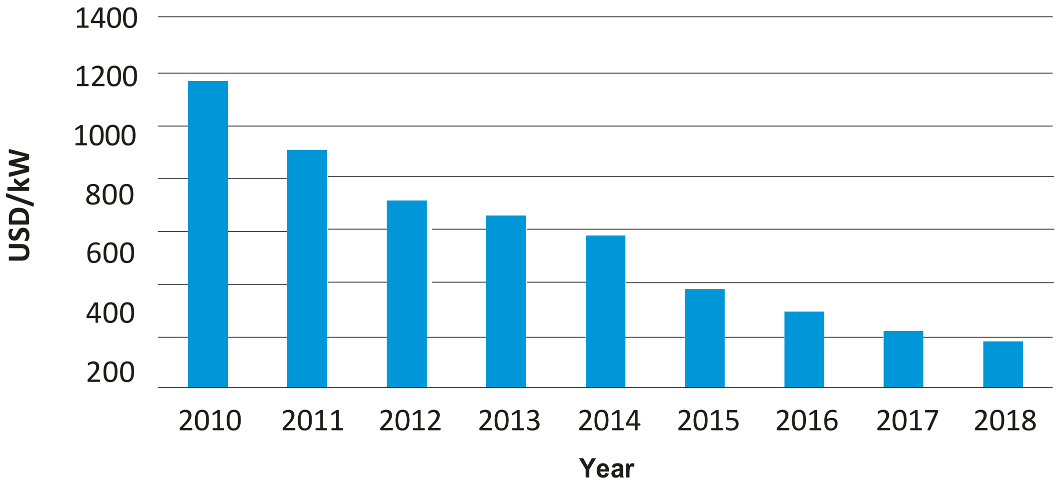


Source: PwC analysis adapted from IRENA cost data. https://www.irena.org/costs/Charts/Electric-vehicles

However, battery prices have plummeted by as much as 75 per cent over the past decade, drastically reducing their contribution to the overall BEV cost. Over the course of 2019 prices for lithium-ion battery modules tumbled below $200 per kilowatt-hour (kWh), enabling previously uneconomical applications such as battery storage-enabled solar powered EV charging stations to surge.

The figure below presents the BNEF (Bloomberg New Energy Finance) Li-ion battery price survey from 2010 to 2018.

FIGURE 9. FALLING LITHIUM-ION BATTERY PRICES



Source: Adapted from BloombergNEF (2019). *A Behind the Scenes Take on Lithium-ion Batteries*. https://about.bnef.com/blog/behind-scenes-take-lithium-ion-battery-prices/

2.2. Evolving battery technology

As a result of design improvements and falling prices, the electric car market began to accept the newer technology. Battery original equipment manufacturers (OEMs) have moved in the past few years from lead acid or nickel metal hydride (NiMH) batteries towards Li-ion technology for transportation purposes thanks in large part to the significant improvement in Li-ion battery performance. Figure 4 presents a concise comparative analysis among different types of prevalent battery technologies used for powering electric vehicles.

Initially, Li-ion batteries were considered unsuitable for large-scale storage (required in electric vehicles) due to their limited capacity, which led to reduced supply of the batteries. Slowly, over the years, as technology progressed and new Li-ion battery packs started to come in (Li-phosphate and Li-nano phosphate batteries), suppliers started to take interest and slowly the technology began to take off.

FIGURE 10. FALLING LI-ION BATTERY PRICES

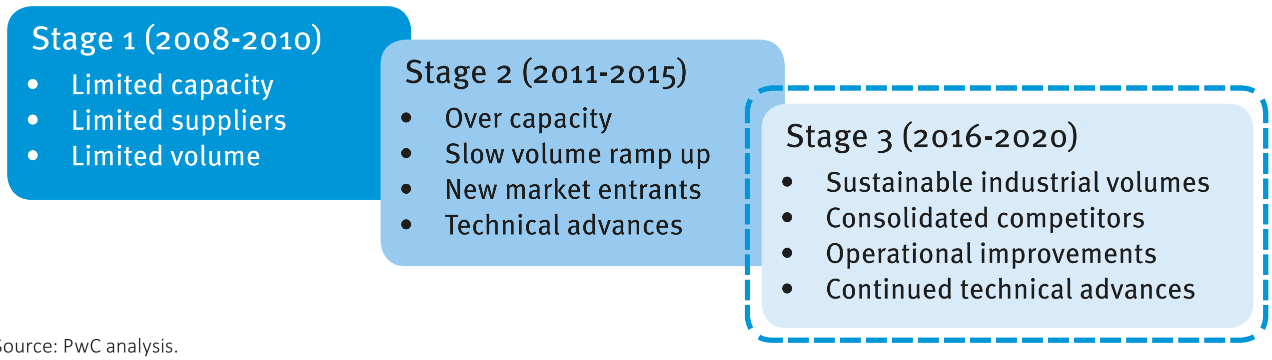
	Lithium Li-Ion	Nickel Metal Hybride (NMH)	Nickel Cadmium	Lead Acid
ADVANTAGES	High energy density No memory effect Low discharge No maintenance Long lifespan	Good energy density Low memory effect No environment issues Good safety Good lifespan	Very good power density Rapid recharge Inexpensive Long lifespan	Good power density No memory effect Low discharge (40% year) Inexpensive, easy to manufacture
DISADVANTAGES	Safety (sensible to °C, overload) Stability Expensive	Risk of overheating No use at -0 °C High self discharge (3 months) Expensive	Memory effect Low capacity High self discharge Environmental concerns	Low energy density No fast charge (8-16 h) Short lifespan Environmental concerns Required charged storage
APPLICATIONS	Hybrid / electric vehicles Mobile phones Laptops	Yesterday's Hybrid vehicles Consumer electronics	Low end consumer goods Standby power	Conventional car batteries Emergency lighting Back-up power

Source: Adapted from Cellerite (2019). *Battery technology / chemistry*. https://www.cellerite.com/post/battery-technology-chemistry.

Li-ion also evolved as new market entrants such as NiMH and other alternatives started to prosper. Finally, from 2016 onwards, Li-ion batteries were ready for use in transportation thanks to technological improvements and commercial affordability.

Figure 11 explains the three stages of Li-ion battery development between 2008 and 2020.

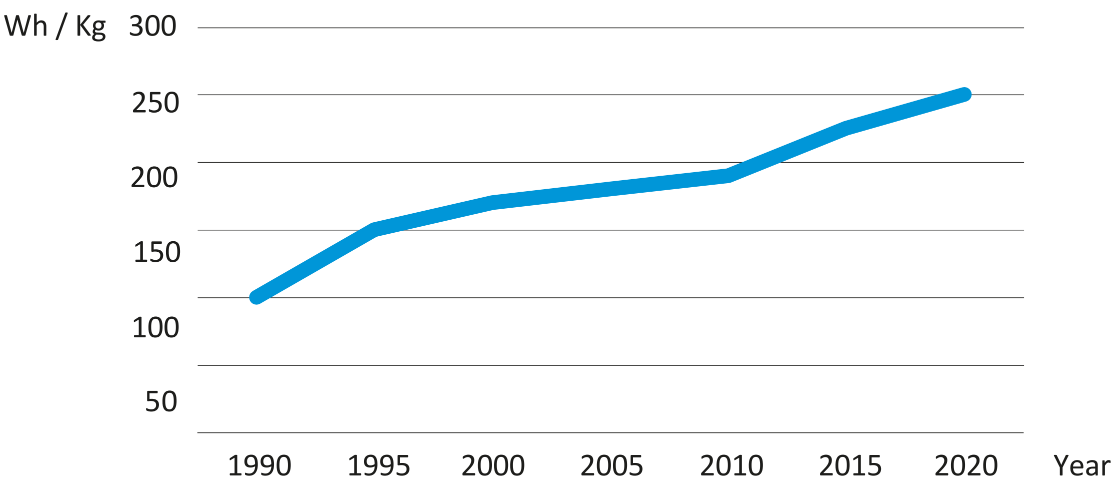
FIGURE 11. STAGES OF LI-ION BATTERY DEVELOPMENT



Source: PwC analysis.

The figure below illustrates how the Li-ion battery energy density increased over the past two decades.

FIGURE 12. LI-ION BATTERY ENERGY DENSITY



Source: https://www.omicsonline.org/articles-images/advances-automobile-engineering- Lithium-ion-batteries-6-164-g003.png

2.3. Evolving EVSE technology

Today's technology supports two charging methods: an AC on-board charger (slow and fast charging) and a DC off-board charger (fast charging), as illustrated in the figure below.

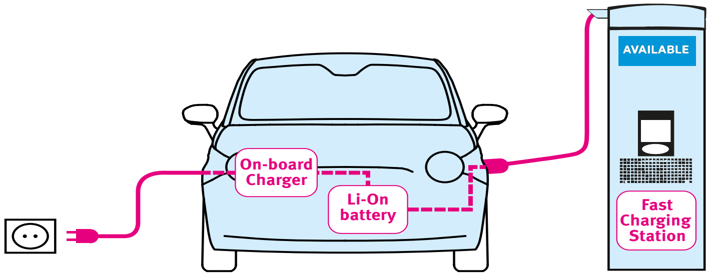


FIGURE 13. CHARGING METHODS FOR EVS

Source: Image adapted from ABB.

At home or at work locations, vehicles are typically charged using an AC wall box, which takes about eight hours. When on the road, people can use public AC charge posts or DC fast chargers, depending on their needs and the type of electric vehicle. DC fast chargers typically cost more than AC slow chargers, but charging time per session is considerably lower in the case of DC charging as DC chargers produce much more power. This difference in service capability results in higher overall return on investment from DC fast chargers. DC fast chargers also ensure efficient use of high-cost parking spaces in urban areas. Hence, deployment of fast charging networks is one of the most critical requirements for rapid deployment of electric vehicles.

BOX 1.

CASE STUDY

China's fast DC charger deployment

Many stakeholders in China, including the Government, local government and utilities, have been active in quickly building a fast DC charging infrastructure network in the country. Fast charging infrastructure deployment resulted in huge electric vehicle uptake:

- In 2017, China had around 83,000 publically accessible fast chargers and 130,000 publically accessible slow chargers.
- That same year, China had the largest electric car stock at 40 per cent of the global total, with an auto market share of 0.2 per cent.
- Electric cars sold on the Chinese market more than doubled the amount delivered in the United States, the second-largest electric car market globally.

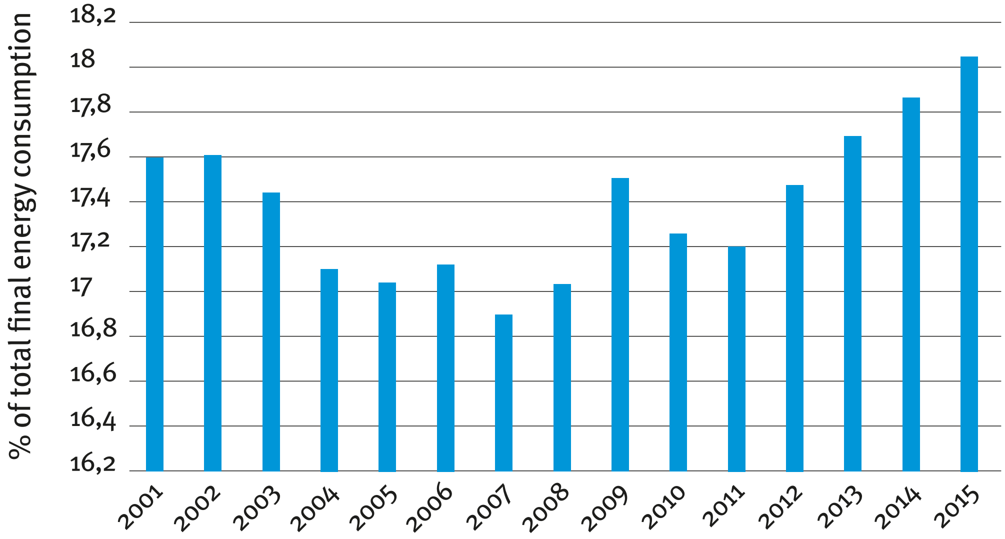
2.4. Promotion of renewable energy

A rapid global transition towards renewable energy continues apace, thanks to rapidly tumbling prices, technology enhancements and an increasingly supportive policy environment. According to International Renewable Energy Agency (IRENA) figures, global renewable energy generation capacity reached 2,351 gigawatts (GW) by the end of 2018, up 8 per cent on the year.

Renewable energy generated from hydropower plants made up approximately half of the global renewable generation mix,[3] while wind and solar together accounted for the majority of the remaining capacity at 44 per cent of the global mix.

The figure below shows the proportion of renewable electricity generation in the global energy mix from 2001 to 2015.[4]

FIGURE 14. GLOBAL RENEWABLE ENERGY CONSUMPTION



The growing generation of RE fits perfectly with the e-mobility ecosystem. Electricity used for powering batteries can be fuelled from renewable-based energy to make the transport ecosystem carbon-free. Therefore, promoting renewable energy would give huge impetus to the deployment of electric vehicles.

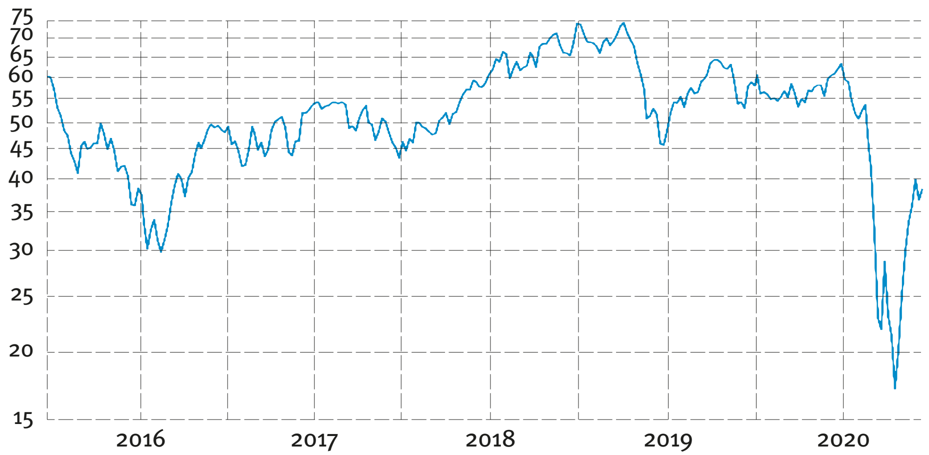
[3] International Renewable Energy Agency (2019). *Renewable Capacity Highlights 2019*.

[4] World Bank Open Data.

2.5. Crude oil prices

Prior to the onset of the COVID-19 pandemic, rising crude oil prices had been a driver for the adoption of electric vehicles. It remains to be seen the extent to which crude oil prices will be a driver of EV adoption as economies recover.

FIGURE 15. HISTORICAL CRUDE OIL PRICES



Source: Macrotrends.net. Crude oil prices 2016-2020

2.6. Government support

More than 160 countries declared their Intended Nationally Determined Contributions (INDCs) to reduce GHG emissions as a part of the preparation for COP21 Paris Climate Conference in December 2015. A majority of the nations identified transport as a key sector for reducing emissions.[5] Focusing on the types of vehicles and fuels used in the sector, there was a heavy emphasis on the need to convert to electric vehicles. Additionally, initiatives have been developed to accelerate the deployment of EVs, such as the EV30@30 Campaign launched at the eighth Clean Energy Ministerial held in Beijing in 2017. Including countries such as Canada, China, Finland, India and Norway, the campaign has set an objective of reaching a minimum 30 per cent sales share for EVs by 2030.

Since the introduction of electric vehicles, governments around the world have taken several steps at national and local level to promote electric mobility. Many governments have adopted various programmes and are increasingly striving to develop the EV market and the associated charging infrastructure through a combination of subsidies, grants and public-private partnerships (PPPs).

[5] German Corporation for International Cooperation (GIZ) (2017). *Transport in Nationally Determined Contributions (NDCs), Lessons learnt from rapidly motorizing countries*.

BOX 2.

OPPORTUNITIES FOR ELECTRIC MOBILITY IN SMALL ISLAND DEVELOPING STATES (SIDS)

SIDS are heavily dependent on fossil fuels for electricity generation and transport. SIDS are also more vulnerable to changes in the environment as they are small in size, have fewer resources and are more likely to be affected by natural disasters.

SIDS can leverage the benefits of EVs to maintain the ecological balance of the environment and reduce costs. A detailed review of the potential opportunities and benefits of EV adoption in SIDS is highlighted below:

Short distances to travel

- This eliminates the range anxiety of EVs.

Reducing pollution

- With almost zero tailpipe emissions, EVs would drastically cut the level of GHG emissions from transport.

Reduce dependency on fossil fuels

- Deploying EVs would reduce the requirement of fossil fuels for transport, cutting down the level of fossil fuel imports across the nations.

Increasing renewable energy

- SIDS have to preserve ecological balance, thus EVs with technologies such as vehicle-to-grid (V2G) and second-life batteries can reduce the environmental impact across the states.
- SIDS usually have an abundance of sun and wind that can be used to produce electricity, but EV batteries could also work as backup in the event of natural disasters.

BOX 3.

CASE STUDY

Barbados-based Megapower

Barbados-based Megapower has increased the numbers of EVs in the Caribbean region. The company provides EVs, charging infrastructure and solar energy, selling over 200 EVs and 50 charging stations in Barbados since 2013. It is integrating renewable energy into EV networks by setting up solar carports, which combine solar power with charging stations. The company also sells used EV batteries that can be used for energy storage of renewable power.

3. Geopolitical implications for EV adoption

A rapid transition to EVs would increase the risk of disruption, especially against the current backdrop of rising trade barriers and resource nationalism. Geopolitical repercussions would be likely to be felt in a number of areas, including international trade, energy security and competition over strategic resources. In each case they could act as a catalyst for greater cooperation or as a source of conflict. In addition to geopolitical effects, there would also be potential human security implications, the evolution of which could be hard to predict. One such example is the resulting dramatic loss of oil tax revenue in producing countries, which would also hit investors and consumers.

3.1. International trade

- **Rise of green free trade agreements:** EV costs must fall rapidly if sales are to grow to deliver a transport sector compliant with targets and mandates set by various countries. Fast growth requires an expansion of global supply chains, regulatory cohesion and market integration, which could prompt a rise in green free trade agreements.
- **Strategic trade tensions:** Countries with an automobile manufacturing base will need to accelerate their transition to electric mobility. If they are not able to adapt to the new technology, they risk losing market share and car-making jobs. To protect domestic industries, they could raise import tariffs on EVs, which would affect global trade and the uptake of EVs.

3.2. Energy security

- **Reduction of revenue in oil states:** Electrification could result in reduced public revenues from oil in producing countries, many of which are in regions already at risk of instability. If EV batteries overtake oil as as geopolitical drivers, the world will look very different.
- **Transnational energy infrastructure:** China is investing heavily in EVs and the Belt and Road Initiative to reduce its reliance on the United States for protection of oil supply chains. It is also a way to bring Chinese EVs and clean energy to the global market. The European Union, China and Japan want to avoid the impact of volatile oil markets on economic growth. This could all lead to a faster phasing out of combustion vehicles.

3.3. Access to strategic resources

- **Increased competition for rare-earth elements:** The need for cobalt, nickel, lithium and other minerals could lead to increased competition for access to them.
- **Regional instability:** The largest reserves of metals and minerals required for battery production are found in weak states with poor governance records. Investment in resource extraction could lead to environmental degradation, civil unrest and instability.[6]

3.4. Economic shocks and financial instability

The adoption of EVs could wipe out $19 trillion in revenue from the oil industry by 2040. This in turn would mean lower tax revenues for governments reliant on the oil industry. Lower oil industry revenues would also lead to poor returns for institutional investors, including pension funds, bringing a decline in institutional investment in oil, which would make the industry less able to raise capital.[7]

[6] Clean Energy Ministerial (CEM) (n.d). *EV 30@30 Campaign*. http://www.cleanenergyministerial.org/campaign-clean-energy-ministerial/ev3030-campaign

[7] Aurora Energy Research (2018). *The adoption of EVs could wipe out $19 trillion in revenue from Oil Industry by 2040*. https://www.auroraer.com/wp-content/uploads/2018/05/Aurora-Press-Technology-drives-transi on-to-a-low-carbon-future-22051.docx.pdf

4. Policy initiatives in electric mobility

Many governments have recognized the benefits provided by electric vehicles and have implemented a variety of policies aimed at transitioning the base of their respective automobile sectors from conventional fossil fuel to electricity. These policies act as a guide for the multiple stakeholders involved in the transition to act to encourage the shift to electric mobility. Initiatives implemented to date have been designed to overcome a range of barriers affecting the uptake of electric mobility, such as high initial cost of vehicles, range anxiety, high charging times and consumer awareness, thus enabling many countries to successfully deploy electric vehicles. This section aims to discuss the key findings from some of these policy initiatives.

4.1. Electric mobility policies: some examples from around the world

As a first step towards the transition of the automotive sector to electric, many countries establish a national roadmap or policy to implement e-mobility. A national roadmap is a vision document that defines a set target and the proposed strategies to support the expansion of the EV market.

FIGURE 16. COMPONENTS OF AN E-MOBILITY BLUEPRINT

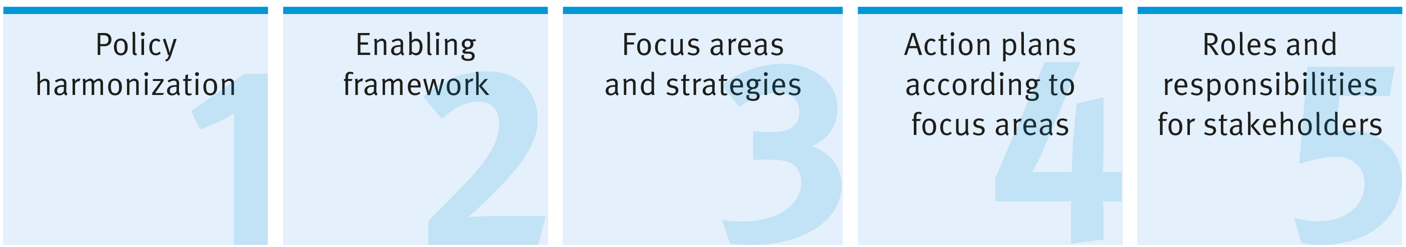


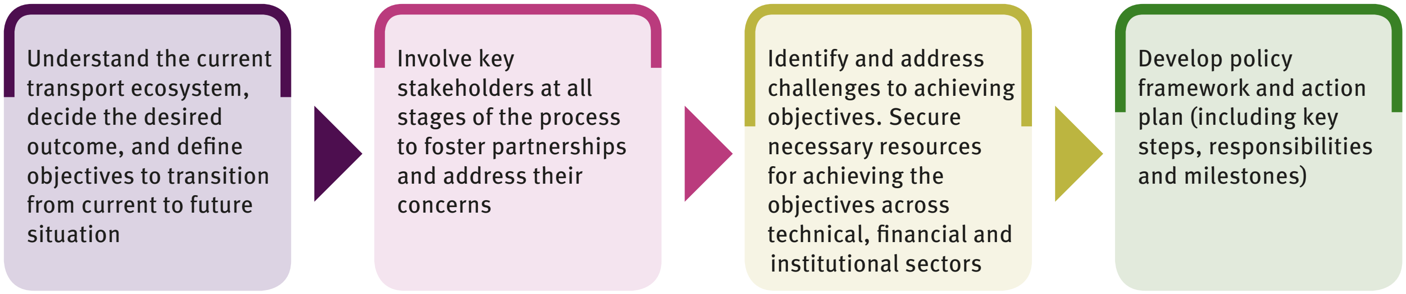
TABLE 1. ELECTRIC MOBILITY POLICIES

Title	Country	Key features
The National Electromobility Development Plan, 2009	Germany	The German Federal Government included electromobility as a major component of its Integrated Energy and Climate Programme (2007). E-mobility goals contained within the programme were then formed the basis of the National Electromobility Development Plan developed in August 2009. The plan was drafted by all relevant industries and represents Germany's approach to electric mobility as a cross sectoral initiative. It envisaged that Germany would become the lead market and provider of electromobility by the end of 2020, with 1 million electric vehicles on the road. This target has been pushed back to 2022. Proposed measures include financial incentives, R&D, development of an enabling framework, integration of renewables and standardization of technology.
2014 Automobile Industry Strategy	Japan	Japan has included electric vehicles in its strategic plans since the 1970s. The 2014 Automobile Industry Strategy is the latest plan to set out a roadmap for achieving electric mobility. It includes a target for next-generation vehicles and electric vehicles as a share of the passenger vehicle market. It also contains a strategy to promote next-generation vehicles and increase research & development and human resources.
Zero-Emission Vehicle Executive Order, 2018	California, USA	In 2018, then Governor of California Edmund G. Brown Jr. signed an executive order commanding all state entities to work with the private sector and all appropriate levels of government to put at least five zero-emission vehicles (ZEVs) on Californian roads by 2030. It also called for 200 hydrogen fueling stations and 250,000 ZEV chargers, including 10,000 direct current fast chargers by 2025.
National Environment Strategy 2020	Lao, PDR	The vision of the country's Environmentally Sustainable Transport (EST) Strategy is to "manage and promote land transport to be convenient, connected, safe, modern, barrier free, sustainable and environment friendly." The first goal of the action plan is the promotion of goods and passenger transportation using electricity, domestic energy and low-emission energy.

4.1.1. **Set a well-defined electric mobility roadmap**

According to the IEA, the policy pathway towards sustainable transport begins with the development of a policy framework and action plan. The steps included in the planning stage are defined below:

FIGURE 17. KEY ELEMENTS OF POLICY FORMULATION



Japan has a successful track record in implementing electric mobility roadmaps. The country saw the need for electric mobility as early as 1976, when the Ministry of International Trade and Industry (MITI) established a basic market expansion plan for battery-powered electric vehicles.[8] The plan was comprehensive and clear with a strategy for all stakeholders, which brought together Government departments, municipalities and companies in their efforts to achieve electric mobility. The plan was regularly reviewed and updated according to the market environment. The release of the plan was followed by swift action by stakeholders, which resulted in the achievement of the set targets. For example, Government agencies initiated programmes to fund R&D of new technologies for 10 years over different phases, the Japanese Electric Vehicle Association launched leasing programmes and OEMs started the development of hybrid electric vehicles (HEVs) and EVs.

In 2016, the number of electric car charging points in the country surpassed the number of petrol stations.[9] Japan is also the home of the first mass produced EV, the eNissan Leaf, which has sold 360,000[10] units around the world since 2014. In 2018, Japan had sold a total of 49,750 BEV and PHEV cars, of which approximately half were BEVs.

California is leading the change to electric vehicles in the United States thanks to action at local government level, where extensive policies to ramp up electric vehicle conversion have led to the proliferation of EVs across the region.

[8] Max Åhman (2006). *Government policy and the development of electric vehicles in Japan*. Energy Policy 34 (March) pp 433-443.

[9] Statista (2016). *Japan Has More Electric Car Charging Points Than Gas Stations*. https://www.statista.com/chart/4815/japan-has-more-electric-car-charging-points-than-gas-stations/

[10] Centre for Solar Energy and Hydrogen Research Baden-Württemberg (2019). *Global E-car Count Up from 3.4 to 5.6 Million.* https://www.zsw-bw.de/en/newsroom/news/news-detail/news/detail/News/global-e-car-count-up-from-34-to-56-million.html

Germany, however, has seen less success in meeting its electric mobility targets. The German Federal Government included electromobility as a major component of the Integrated Energy and Climate Programme (2007). Building on this, the National Electromobility.

The Development Plan was created in August 2009. The plan was drafted with the involvement of all relevant industries and represents Germany's approach to electric mobility as a cross sectoral initiative. The plan envisaged that Germany would become the lead market and provider of electromobility with 1 million electric vehicles on the road by the end of 2020. Proposed measures include financial incentives, R&D, development of an enabling framework, integration of renewables, standardization of technology.

The case of Germany stresses the need for effective legislation. In the absence of effective local authority laws and initiatives, it is difficult to implement a change in the transport sector. The Electric Mobility Act brought into force in 2015 provides for privileges such as special parking spots, lowering of charges and permission for EVs to be driven in the bus lanes. The decision on which privileges should be extended to EVs is made by the local authority. However, the incentives have been implemented in fewer than 1 per cent of local authority areas.[11] Hence, the policy has not been utilized to its maximum potential and has impacted the adoption of electric mobility in the country.

Germany has delayed its goal of having 1 million electric vehicles on the roads from 2020 to 2022. Although the National Electromobility Development Plan led the various Government departments to take out policies, orders and laws to enable electric mobility in the country, the initiatives were delayed. An environmental bonus that provides for an environmental subsidy Of €4,000 for BEVs and €3,000 for PHEVs was implemented in 2016. A total of 131,000[12] electric vehicles were registered in Germany up till December 31, 2017.

Without appropriate strategies in place for focal points, there has been lack of development of action plans and priority projects, especially those that can be implemented by the Lao Government.

It is essential for countries to set a clear and well-defined roadmap or strategy for implementing electric mobility. The roadmap should be prepared in cooperation with the stakeholders and should assign roles and responsibilities to each of them. It

[11] German National Platform for Electric Mobility (2018). *Progress Report 2018 – Market ramp-up phase*. http://nationale-plattform-elektromobilitaet.de/fileadmin/user_upload/Redaktion/Publikationen/NPE_Progress_Report_2018.pdf

[12] Ibid.

should also be followed by concrete legislative action. The implementation of the strategies needs to be monitored and evaluated at regular intervals to ensure that the goals are achieved.

4.2. Supporting the deployment of EVs

The focus of this section is to discuss the key lessons from government policy initiatives aimed at increasing the uptake of electric vehicles.

4.2.1. Administration of strategy implementation at the sub-national level

It is often, but not always, the case that national governments set a vision for countries to transform their transport sectors; however, due to the division of powers, sub-national or local governments are often responsible for implementation, or have control of key areas of implementation, such as planning approvals or enforcing local laws. As such, the process of designing policies and legislation, and the assignment of responsibilities and resources, necessitates a careful examination. To this end, stakeholders (both internal and external to government) identification and consultation, is crucial step that needs to be undertaken early on in the policy development process (please see below).

FIGURE 18. THE ROLE OF SUB-NATIONALS

Providing free parking and access to high capacity lanes	Providing additional financial and non-financial incentives	Spreading awareness about electric mobility with citizens	Setting up EV procurement programmes and mandates for themselves and their suppliers

California makes a case for exemplary action at a local level. The majority of electric vehicles in the United States are deployed in the state, which has provided financial and non-financial incentives in addition to those put forward at federal government level. These incentives have set specific and clear targets for deployment of EVs in the state.

At the same time, the case of Germany, highlighted above in section 4.1, demonstrates potential pitfalls when local authorities fail to take a lead. Only 1 per cent of local administrations implemented directives agreed under the 2015 Electric Mobility Act, which has led to a slower uptake of electric vehicles than envisaged.

4.2.2. **Involve stakeholders in policy formation and implementation**

While the benefits of electric mobility are well known, it may not be in the business interest of the stakeholder to pledge future actions to achieve the targets set out by the state. For example, the purchase of electric buses may be an initiative devised by the environment ministry, while the procurement of the buses is the responsibility of the transport ministry, which might not have the budget required. Interacting with stakeholders will help policymakers understand their needs and also receive feedback and input on the initiatives undertaken.

The needs of some of the stakeholders are identified below:

FIGURE 19. NEEDS OF EV STAKEHOLDERS

EV private consumers	Fleet operators	Grid distribution companies	EVSE operators	Car sharing operators
EVSE network	Profitable business model and EVSE network	Avoid congestion of the grid	Profitable business	Parking spaces from municipalities

In the process of deploying EVs, it is essential to involve all stakeholders in the planning and execution of the policies and programmes. Addressing the needs of the stakeholders and finding solutions to alleviate their concerns in a collaborative manner is necessary for successful implementation of national strategies.

An effective way to engage with stakeholders is to create a multi-stakeholder task force for electric mobility at national and local level. The task force can take part in all stages of the transition, such as planning, implementing, monitoring and taking corrective action.

4.2.3. **Set clear targets for implementation of electric mobility**

In order to achieve the visions set out in country roadmaps, it is essential to set clear targets for roll-out of EVs and EVSE. Tangible and defined goals will help to direct the state and other stakeholders towards the appropriate level of operations and action. Setting targets also acts as an effective tool to monitor the progress of electric mobility in the country. Intermediate targets may also be set that will provide timely reality checks, allowing any required changes in policy and initiatives to be taken up accordingly.

Many countries have established well-defined deployment targets for transitioning to electric mobility with timelines set for achieving the objectives.

Examples of a number of country targets are shown in the following table.

TABLE 2. EXAMPLES OF E-MOBILITY TARGETS

Target	City/ Country	Key features
100 per cent electric vehicle sales in light duty vehicles (LDVs) and public bus segments by 2025	Norway	In 2017, the Norwegian Parliament set a goal for the country to phase out gasoline vehicles for passenger buses and cars by 2025.
1 million electric vehicles on the road by 2020	Germany	As a part of the National Electromobility Development Plan, Germany has committed to having 1 million EVs deployed in the country by 2020, later extended to 2022.
1 million EVs and plug-in hybrids (PHVs) by 2020	Japan	As a part of the EVs and PHVs roadmap to 2020 laid out by the Ministry of Economy, Trade and Industry (METI).
30 per cent EV sales share by 2030	India	As a part of the EV30@30 Campaign, India has signed up to achieve 30 per cent EV sales share by 2030.
1.5 million ZEVs on Californian roads by 2025, on the path to 5 million ZEVs by 2030.	California	An executive order was signed by the Governor of California in January of 2018 to set a target and focus multi-stakeholder efforts on achieving it.

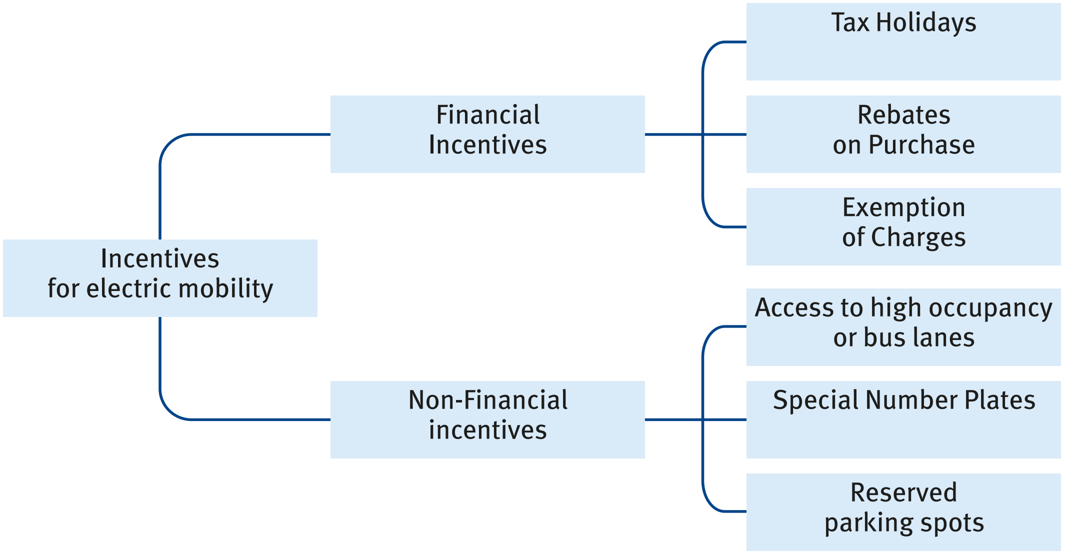
Source: PwC analysis

4.2.4. **Incentives should be specific and easily accessible**

A major challenge with electric vehicles is the high initial cost that restricts the rapid proliferation of the technology. In order to tackle this, countries can provide a variety of incentives to bring the cost of purchasing an electric vehicle down towards that of a conventional gasoline/ICE powered vehicle.

The incentives can be segregated into the categories shown in the next figure.

FIGURE 20. TYPES OF INCENTIVES FOR EVS



Source: PwC analysis

Financial incentives are a necessary to encourage the use of electric vehicles. These incentives will be necessary until the cost of EVs vehicles are on a par with ICE vehicles.

In 2018, a total of 46 per cent[13] of new car sales in Norway were electric, making the country the global leader in terms of market share of electric cars. The significant rise in the number of electric vehicles on the roads has been achieved through the provision of financial and non-financial incentives to consumers wishing to buy an EV. A snapshot of the incentives is provided below.[14]

[13] IEA (2019). *Global EV Outlook 2019*.

[14] European Climate Initiative (2018). *Incentives for Electric Vehicles in Norway*. https://www.euki.de/wp-content/uploads/2018/09/fact-sheet-incentives-for-electric-vehicles-no.pdf.

TABLE 3. NORWAY'S INCENTIVES FOR E-MOBILITY

Title	Key features
Exemption from registration tax, 1990	Norway charges an import or registration tax for all cars which can reach about €10,000 or more depending on the CO2 emissions. BEVs are completely exempt from this tax.
Exemption from road tax, 1996	BEV's were charged a lower annual road tax in Norway.
Exemption from 25 per cent VAT on purchase, 2001 and lease, 2015	BEVs are exempt from paying 25 per cent VAT charged at the time of purchasing or when leasing an electric vehicle.
Reduced company car tax, 2000	To calculate tax for BEVs used as a company car, the cost was reduced to 50 per cent. Since 2018, this has been reduced further to 40 per cent.
Free municipal parking	Local governments have been able to decide incentives from 2010, however most EVs have free parking in the country. This may be subject to change given the growing number of EVs.
No charges on toll roads	Road tolls are mostly exempt for EVs in Norway. This exemption may be phased out, however it will still continue to be less than 50 per cent of the charge for ICE vehicles.
No charges on ferries	BEVs are exempt from ferry charges.
Access to bus lanes	BEVs have access to bus lanes in most towns and cities of Norway. The programme was launched in 2003 in Oslo. However, from 2015 it requires carpooling with at least one passenger during rush hour. From 2017, local governments have been free to decide on incentives.
Introduction of special registration plates	BEVs have different number plates that have a prefix 'EL' or 'EK' for easy identification.

BOX 4.

KEY PRINCIPLES OF INCENTIVE PROGRAMMES

According to a paper conducted for the International Zero-Emission Vehicle Alliance, the following key principles support the optimal design of electric vehicle incentives:

- Move incentives up front to the vehicle purchase and make their value visible to dealers and prospective consumers
- Make the value of incentives crystal clear to consumers and dealers
- Ensure the incentives are available to the full target market
- Commit to durable incentives that allow manufactures, dealers, public outreach campaigns, and consumer to rely on them for several years

Reference: Yang, Z., Slowik, P., Lutsey, N,. & S. Searle (2016). *Principles for Effective Electric Vehicle Incentive Design*. International Council on Clean Transportation.

4.2.5. Spread awareness about EVs

As electric vehicles present a new technology to consumers, it is essential that accurate and reliable information about the technology reaches them. As a part of encouraging electric vehicles, many governments undertake awareness programmes to spread relevant information. Along with educating prospective consumers about the benefits of EVs, it is also necessary to inform them about the incentives provided to encourage their purchase. The following methods of raising awareness are recommended.

FIGURE 21. METHODS OF RAISING AWARENESS FOR E-MOBILITY

Online information

- It is beneficial to create a dedicated website to spread awareness about electric mobility.
- In the United Kingdom, for example the "Go Ultra Low" initiative provides information about all vehicles running on alternate fuels. It takes a few clicks to learn everything about the vehicles and the laws in the country.
- Information can be provided on social networking sites such as Facebook, LinkedIn, Instagram and Twitter to targeted customers.

Public events

- In the United States, National Drive Electric Week is held once a year and has events all over the country.

Targeted promotion material

- Specific government departments can create leaflets and brochures elucidating the programmes and the steps required to apply for certain privileges.
- For example: utilities can provide stepwise procedures to apply for an EV charger connection, while municipalities can provide information for requirements to access free parking spots and access lanes.

Labelling

- Many countries offer different number plates for electric vehicles with "zero-emission" signage.

Source: PwC analysis

Governments can collaborate with OEMs to spread awareness about the vehicles as is done in the Go Ultra Low campaign in the United Kingdom. A sustained programme with multiple methods of outreach and funding from governments is most effective. A survey of BEV owners in Norway proved that effective online sources of information were the EV association, blogs, media, dealers and friends.

4.3. Supporting the convergence of the energy and transport sectors

Electric mobility will lead to a paradigm shift in the “refuelling” of vehicles. Electric vehicle batteries are required to be charged periodically, leading to the need for a robust charging network. The key role in this transition will be played by power utilities. Electric mobility is a great business opportunity for power utilities as a growing network of consumers will help increase revenues. The power utilities also play a pivotal role in providing clean energy to electric vehicles. The GHG emission reductions that are associated with electric vehicles are dependent on the energy mix of the country, with higher levels of RE in electricity generation bringing a larger reduction in GHG. EVs also facilitate a shift to RE as the batteries can store renewable power. In this section we analyze the policies that are required to maximize the convergence of energy and transport sectors.

4.3.1. Allow utilities to own EVSE

In many countries, utilities are not allowed to own EVSE. Thus, even though the number of electric vehicles is increasing, utilities are not yet playing an active role in the deployment of charging infrastructure in those countries. It is considered easier for a utility to install charging stations using taxpayers’ money, without expecting a return in the near future. In cases where utilities have been allowed to install charging infrastructure there has been some resistance from the private sector for hampering their profitability.[15]

However, as heavy regulations may hamper the fast development of charging infrastructure, it may be preferable to allow utilities to install charging infrastructure in partnership with the private sector. As an example, in 2015, the California Public Utilities Commission lifted a four-year ban on utilities from investing in public charging infrastructure. The lifting of the ban was considered necessary to unlock potential investment and accelerate the setting up of charging infrastructure for the state to meet its EV targets. Surprisingly, the decision was supported by the private industry as long as they would still be allowed to participate as it increased the overall EV market.[16]

4.3.2. Reduce carbon emissions from the power sector

A reduction in emissions through EVs is directly related to the energy mix of the electricity sector in the country. Efforts to reduce carbon emissions at the point of electricity generation will further strengthen countries’ endeavours to reduce emissions.

[15] Myriam Alexander-Kearns, Miranda Peterson & Alison Cassady (2016). *The Impact of Vehicle Automation on Carbon Emissions*. Center for American Progress.

[16] Center for Strategic and International Studies (2016). *Utility Involvement in Electric Vehicle Charging Infrastructure*. https://www.csis.org/analysis/utility-involvement-electric-vehicle-charging-infrastructure-california-vanguard.

A lowering of carbon emissions from the electricity sector will significantly improve the impact of electric vehicles on the environment. A number of governments have already brought in regulations to encourage lower emissions from the sector. The most effective policies are highlighted in the following table.

TABLE 4. EFFECTIVE POLICIES FOR REDUCING CARBON EMISSIONS

Type of initiative	Example
Renewable portfolio standards	A 45 per cent reduction in CO_2 pollution has been achieved by the Regional Greenhouse Gas Initiative (RGGI) in nine states of the United States.[17]
Cap and trade programmes	The European Union uses a cap and trade programme to restrict CO_2 emissions from power plants.
Carbon tax	The Government of Japan charges a tax per ton of CO_2 emitted.

4.3.3. Enable smart charging

There is a risk that charging of electric vehicles will increase the peak demand of electricity. As a general practice, an EV user will charge his vehicle when he returns from work. This is around the same time that electricity demand will peak from the residential sector. To avoid this, owners may be encouraged to charge EVs during the day. Additionally, electric vehicles have an on-board battery that can be used for various grid stability processes. In addition to providing a backup for the grid, electric vehicles can also support RE integration into the grid. In the case of solar power, the electricity is generated during daytime. To initiate a change in consumer behaviour, dynamic pricing is seen as an effective tool. Thus, electricity at peak times may be offered at a higher price and when there is availability of RE power, such as solar, it may be charged at a lower rate to reduce the charging at peak times.

To enable such dynamic pricing and smart charging it is important that national legislations make the technology for it compulsory. In the United Kingdom, from July 2019, only charge points installed at home that utilize smart technology will be eligible for funding from the Government.

[17] Congressional Research Services (2019). The *Regional Greenhouse Gas Initiative: Background, Impacts and Selected Issues*. https://crsreports.congress.gov/product/pdf/R/R41836.

Governments set the following requirements:

FIGURE 22. GOVERNMENT REQUIREMENTS FOR SMART CHARGING

- Two-way electronic communications with a third party
- React to the communication by changing charging or discharging rate
- Record and monitor the charge point's own energy usage
- Comply with energy efficiency standards
- Require protocols to be open

4.4. Supporting transit-oriented development

Transit-oriented development (TOD) is a concept in urban development and planning that aims to encourage public transport. It focuses on transport hubs such as metro stations and envisages the creation of pedestrian-oriented paths with easy connectivity to transit services to the rest of the city. The increase of public transport and new business models involve car sharing, electrifying fleets and mobility as a service. The key lessons learned from in policy initiatives to support TOD are highlighted in this section.

4.4.1. Electrify ride-hailing services

Ride-hailing services like Uber, Lyft, Didi and Ola are becoming the new modes of transport in many countries. They encourage sharing their services with multiple riders travelling together from point to point. Since they will form a significant portion of shared mobility, governments must initiate action to encourage the services to shift their vehicles to electric. This can be carried out in the following ways:

FIGURE 23. REGULATIONS FOR ELECTRIFYING RIDE-HAILING SERVICES

Fleet regulations	Financial incentives	Exemption from charges
States may come up with their version of fleet-based ZEV regulation	Ride-hailing, fleet-specific financial incentives	Exemption from charges such as tolls and permissions that are levied on commercial vehicles

In 2018, California introduced legislation that instructs state agencies to develop regulations that reduce the per passenger mile emissions of transportation network companies, which must include company-specific targets for EV adoption.

4.4.2. **Allow EVs in last mile connectivity**

Most cities now have an intra-city metro network that connects all major locations. It is the travel from the metro stations to the destination that needs to be electrified. In Southeast Asian countries this sector is dominated by rickshaws or tuk-tuks. Legislation should be passed to ensure these vehicles are converted to electric. Additionally, personal light electric vehicles (PLEVs) that consist of electric kick scooters and mono-wheelers should be considered as a solution to the last mile of travel. Germany and the UK are working towards legalizing PLEVs in the last mile of travel.

5. Analysis of infrastructure and technology requirements for EV adoption

An essential requirement for electric vehicles to run effectively is easy access to a convenient and reliable recharging facility. Range anxiety and lack of charging infrastructure can be a huge deterrent to uptake of electric vehicles.[18] In contrast to the conventional ICE vehicles, where refuelling at a petrol station is the only option, EVs can be charged in residences or offices.

While slow charging at home may be convenient and common for EV users, it is the public charging infrastructure that can reinforce confidence in consumers to shift to electric mobility. Studies have shown that the availability of a strong network of EVSE in a country is a far greater incentive for potential buyers of EVs than rebates and subsidies.[19] In the following sections we analyze the infrastructure and technology requirements for electric mobility and look at initiatives required to bring them to the market.

5.1. Enable interoperability of charging stations

The development of electric vehicles has been fragmented across the world, which has led to the availability of multiple technologies for charging the vehicles. To encourage further rapid growth of the EV sector, the development of standardized charging station protocols will be necessary.

Research has already shown that in the absence of an effective charger network, even high subsidies on EVs cannot lead to market success.[20] While the standards for physical plugs have been accepted, the development of payment mechanisms, backend communication and power supply standards are less developed. This leads to EV consumers taking multiple memberships and using various payment mechanisms to access public charging networks.

To enable ease of use, it is essential to establish a single platform for payments across countries and to allow interoperability of chargers. This requires considerable planning and consolidation. The Netherlands has been able to integrate all its public chargers and some private charging stations so that they can be used and paid for with a single radio-frequency identification (RFID) card.

[18] Harrison, G., and C. Thiel. (2016). *An exploratory policy analysis of electric vehicle sales competition and sensitivity to infrastructure in Europe*. Technol. Forecast. Soc. Change. http://dx.doi.org/10.1016/j.techfore.2016.08.007.

[19] Yu, Z., Li, S. & L. Tong. (2016). *Market dynamics and indirect network effects in electric vehicle diffusion*. Transportation Research Part D: Transport and Environment. Volume 47 (August) pp 336-356.

[20] Harrison, G., and C. Thiel. (2016).

TABLE 5. INTEROPERABILITY INITIATIVES IN THE UNITED STATES

Government initiatives	Private sector initiatives
California passed the **Interoperability Electric Vehicle Charging Stations Open Access Act (California Senate, 2013)**, which ensures interoperability of charging stations in the state. This has led to the state being a frontrunner in adopting electric mobility.	The **Roaming for EV Charging (ROEV) association** was cofounded by BMW, Nissan and the three largest charging platforms in the US: Chargepoint; CarCharging/Blink; and EVgo. The association aims to advance interoperability in the country and its goal is to provide drivers with accessible and convenient charging stations and networks across North America.

Source: PwC analysis

5.2. Incentives should be given in the short term

To build an effective EVSE network, Many governments and local utilities provide rebates or tax incentives to encourage the installation of EVSE to help build up an effective network to support the growth of the EV market. These incentives act as a key enabler for installation of charging infrastructure.

Private players need to be incentivized to install charging stations as the utilization of public charging infrastructure is directly related to the number of electric vehicles in use in the country. As already established, countries need to set up an EVSE network to increase the uptake of electric vehicles. Thus, in the short term, utilization of the chargers will be low and will not make a profitable investment for private players. In the long term, with an increase in electric vehicles, public charging infrastructure will become a profitable investment and will be implemented by the private sector. Governments may also encourage private participation and innovative business models by inviting private players through tenders to set up charging infrastructure in the country, as done by the Netherlands through public procurement tenders for EVSE that are open to all players.

TABLE 6. INCENTIVES FOR EV CHARGING INFRASTRUCTURE

Belgium	**Tax incentives** • When a charging point is installed outside a private dwelling, the owner is entitled to a 40 per cent tax deduction up to a maximum of €260. • There is additional deductibility of 13.5 per cent on the investment in charging infrastructure for companies under corporate tax law.
Netherlands	**Tax incentives** • Customers and companies that create charging points on private space are entitled to receive a discount of €500 per charging point. • The Rotterdam Electric Programme supported the first 1,000 EV owners in the city with an electric charging point. On private property, a charging point is also partly subsidized.
Norway	**Local benefits ("non-fiscal incentives")** • EV users can use public charging infrastructure for free. • The Government of Norway has granted €11.9 million for new recharging stations.
UK	**PIPs (Plugged-in-Places)** • The programme is intended to support the development and consumer uptake of EVs by creating electric car hubs in six key British city or city regions with the installation of charging points at various locations.
United States, California	**Rebates/subsidies** • **PEV Home Charger Deployment Program**. The programme provides incentives for residents who purchase new PEVs and install Level 2 EV charging stations from qualified vendors. • **PEV Charging Rate Reduction**. Southern California Edison (SCE) offers a discounted rate to customers for electricity used to charge EVs. Two rate schedules are available for PEV charging during on- and off-peak hours. • **Commercial loans**. Small business loans are available up to $500,000 on the installation of EV charging infrastructure. There is a rebate of 50 per cent of the loan under certain conditions.

Source: PwC analysis

5.3. Appropriate ratio of public EVSE to EVs needs to be decided

The ratio of electric vehicle chargers to the number of electric vehicles varies across the world. At the same time, the number of EVSE installations depends on the type of chargers available in residences and offices. In cities where there is easy access to charging at home, there will be smaller demand for public charging stations. An analysis of countries such as China, the Netherlands, Norway and the United States, which lead in adoption of large-scale electric mobility, suggests there is no uniformity in the ratio of EVSE to EVs. According to an analysis done of several metropolitan areas in the following countries, the ratio of EVs to charge points was found out to be as follows:

FIGURE 24. RATIO OF EVS TO EVSE

China	The Netherlands	California	Norway
3-11 EVs/charge point	3-6 EVs/charge point	25-30 EVs/charge point	14-17 EVs/charge point

Source: PwC Analysis

Countries looking to establish a target for EVSE should model their cities according to the markets with increased deployment of EVs. The plan for setting up public and private charging infrastructure in a city should also incorporate the urban infrastructure already available.

5.4. EVSE should be incorporated into building code regulations

Every country needs to build a plan for charging infrastructure ratio as defined in the previous section. Based on the requirement for chargers in public and private buildings, building codes applied to new build and buildings in need of refurbishment should contain specific requirements for the incorporation of charging points.

EVSE requires robust electrical connections and infrastructure to be installed in existing building units. Reworking the electrical connection in multi-unit dwellings or commercial buildings is required while setting up the charging infrastructure, which is a tedious process. However, while constructing new buildings, it is easier to have the requisite electrical work installed. Thus, many countries have updated the regulations for new or refurbished buildings to incorporate the need for EVSE charging. From 2015, as part of the Green Buildings Standards Code, California mandated that 3 per cent of all parking locations in commercial buildings should have infrastructure that includes a dedicated panel and circuit capacity for installation of EVSE.

In Europe, every new or refurbished building has been required to incorporate a charging point from 2019 onwards, which will help the uptake of electric mobility.

5.5. Characterization of the role of electricity

The characterization of EV charging activity, either as the sale of electricity or as a service, has been a major point of contention. Classifying the activity of charging an EV as a resale of power can severely restrict the installation of EVSE. Therefore, it is essential that charging of EVs is defined as a service. Internationally, the majority of countries have characterized EV charging as a service, and hence, have kept the market open for all the players without the requirement to obtain a licence.

In Japan, under the Electricity Business Act the EV charging business is a specified part of the supply section. The Act was fully liberalized in April 2016. Since then all entities have been allowed to engage in the retail electricity business, including supplying electricity to low-voltage consumers, by registering as electricity retailers.

Most US states treat EV charging as a service, including California where the Californian Public Utility found that EV charging by stations did not constitute resale of electricity.

5.6. Smart charging should be encouraged

Smart charging is a way of vehicle grid integration that optimizes the charging of EVs taking into consideration the distribution grid constraints, incorporation of renewable energy and EV users' flexibility. Smart charging enables the management of EV loads by communicating with the grid. Under this method, the grid communicates with the EV to monitor and manage the charging process in the most beneficial manner. In this way, EVs not only assist in avoiding peaks on the local grid but can also support the integration of renewables in the grid. Different types of smart charging that can be employed to reap the benefits are described below.

FIGURE 25. TYPES OF SMART CHARGING

Time-of-use pricing

- This is the simplest form of smart charging as it does not require any communication between the grid and the EV. The timing of charging in response to the rates via a smart charger on the EV or EVSE can be utilized to reduce peak demand and also reduce costs for customers.

Basic control

- On/off of charging for grid congestion management.

Unidirectional controlled (V1G)

- In this method, vehicles or charging infrastructure control the rate of charging.

Vehicle-to-grid (V2G)

- In this form of smart charging, the utility utilizes the EV battery during discharge mode to reduce peak loads.

Vehicle to home/building

- The EV is used as a backup power supply for the residential grid.

Dynamic pricing

- EVSE embedded meters and the prices reflect the real time cost of energy and the grid at small intervals.

Source: Adapted from IRENA (2019). *Innovation Outlook: Smart charging for electric vehicles*. International Renewable Energy Agency, Abu Dhabi.

Smart charging has emerged as one of the most effective ways in which to harness the power of EVs and to reduce their impact on the grid. It can be utilized to encourage renewable energy integration into power generation for many countries. The only disadvantage with smart charging is the effect on battery life due to frequent charging and discharging. However, many studies have proved that there is no visible impact of V2G on battery life.

5.7. Battery technology

Improvements in battery technology have been a key enabler to the electric mobility ecosystem. The EV market is currently dominated by Li-ion batteries. The cost of the batteries at the end of 2018 was approximately $175/kWh, down from around $1,160/kWh in 2010.[21] Li-ion batteries are at the time of writing the most commonly used batteries but there are question marks over their safety. There are also doubts over future availability due to the rising cost of cobalt, which is a significant component of the batteries. As a result, battery chemistries for electric vehicles are moving towards nickel-rich chemistries instead.

A significant amount of R&D is being undertaken in battery technology to improve energy density of batteries and to reduce costs. While it is assumed lithium-ion batteries will continue to dominate the market for some time, the following battery subchemistries are currently in use:

TABLE 7. BATTERY SUBCHEMISTRY

Battery subchemistry	Uses
LFP (lithium-iron-phosphate)	75 per cent of China's fleet of buses use LFP subchemistries, which appear to have the best compromise between safety, cost and performance.[22]
NMC (nickel-manganese- cobalt)	NMC is used in batteries for Nissan Leaf, BMW i3 and other EVs.
NCA (nickel-cobalt-aluminium)	NCA has high energy and power density, but is not stable at high temperatures. Tesla uses NCA subchemistry in its cells, delivering an impressive specific energy of 3.4Ah per cell, or 248 Watt-hours per kilogram.

Source: PwC analysis

[21] BloombergNEF (2019). *A Behind the Scenes Take on Lithium-ion Batteries*. https://about.bnef.com/blog/behind-scenes-take-lithium-ion-battery-prices/

[22] IRENA (2019). *Innovation Outlook: Smart charging for electric vehicles*. International Renewable Energy Agency, Abu Dhabi.

6. Analysis of business models

Without fresh business models emerging that create new relationships between private drivers, fleet managers, city managers, energy providers, the auto industry and central government, it will be difficult to scale up electric vehicles. Electric mobility business models can bring together three important sectors that have previously operated separately, namely: the auto industry, the power sector and transport infrastructure. It is essential that new e-mobility business models are investigated in order to help establish the vital ecosystem needed for the development of electric vehicles. Comparative experience among different countries can provide valuable lessons for governments on the best practices required to create business opportunities and provide financing in this sector. In this section, we analyze the key lessons learned from a variety of business models across the world.

6.1. Bulk aggregation for fleets

Any public or private entity that procures electric vehicles or related infrastructure in large quantities can be identified as an EV aggregator. Bulk procurement provides an impetus for vehicle manufacturers, charging infrastructure companies, fleet operators, service providers and industry to gain efficiencies of scale and drive down costs. Three inter-linked aggregation strategies that could become prevalent in the current market in order to make aggregation collaborative and cost-efficient are presented below:

TABLE 8. STRATEGIES FOR DEMAND AGGREGATION

Demand aggregation strategy	Product category
Aggregating the demand for public transport at city/ multiple city level	E-rickshaws and electric buses
Aggregating the demand for private and commercial transport at city/multiple city level	Passenger light duty vehicles [PLDVs] including passenger cars and taxis
Aggregating the demand for government officials	Vehicles for public-sector establishments

Source: PwC analysis

Below are the cases for demand aggregation for procurement of electric vehicles and chargers.

FIGURE 26.

EXAMPLES TO ENCOURAGE THE ELECTRIFICATION OF FLEETS AND DEMAND AGGREGATION

1. **Government fleets**: Energy Efficiency Services Limited (EESL) is a joint venture between four national public-sector enterprises set up under the Indian Ministry of Power. EESL issued tenders for procurement of 10,000 electric cars and 5,000 EV chargers. Upon procurement, EVs were leased out to Government organizations at the same rate charged to hire petrol and diesel cars. EV chargers were installed on the premises of the organizations. This bulk procurement resulted in bringing down the costs of EVs and chargers by more than 30 per cent. EESL is now planning to deploy public chargers too.
2. **Police fleets:** The Los Angeles Police Department switched 260 fleet vehicles to EVs. Charging infrastructure deployment is being integrated with solar power generation.
3. **Public fleets**: The four largest cities on US west coast, Los Angeles, Seattle, San Francisco, and Portland, purchased 24,000 electric vehicles for their municipal fleets. The city of New Bedford, Massachusetts, procured 23 Nissan EVs using state incentives and federal tax credit. The US Navy Department also purchased 400-600 EVs from Ford Motor Company.

The best model for procurement of EVs for fleets is yet to emerge. Instead, fleet aggregators are taking a variety of approaches towards EV procurement.

Outright purchase: Outright purchase of vehicles is the most common model for adoption of vehicles in fleets.

Collaborative procurement: It refers to a process where a number of entities combine their EV procurements into a single bid request. In 2013, eight state governors (including New York) signed a Memorandum of Understanding (MoU) committing to coordinated action on state EV programmes.

Closed-end leasing: In a closed-end leasing, both the lease term and monthly payments are fixed. The lessor sets limitations on mileage and wear and tear, and maintenance and repairs are built into the contract. At the end of the lease term, the lessee has no obligations to make additional payment, provided the vehicle did not exceed maximum mileage or other terms. The lessor then takes responsibility for the vehicle.

New York State Energy Research and Development Authority (NYSERDA) (2018). *EV Procurement Review for Public Fleets*. NYSERDA Report 18-07. Albany, NY.

Open-end leasing: Open-end leasing tends to be common in private fleets. An open-end lease places the risk for fluctuations in the vehicle's value on the lessee. At the end of the lease period, if the vehicle sells for less than its depreciated value, the lessee must pay the difference. A significant determinant of costs for both open- and closed-end leases is the value at the end of the lease term. All else being equal, a vehicle that sells near its original purchase price will be less expensive to lease than one that depreciates more quickly.

BOX 5.

EXAMPLES OF EV LEASING

The City of New Bedford is currently leasing 19 Nissan Leafs, which represents more than 25 per cent of the city's "general use" fleet. The vehicles are leased through a dealer already on the state contract who offers a three-year lease term. This model works best for New Bedford as it reduces the administrative burden on local government.

6.2. E-car sharing

In this business model, the car is used by the subscriber for commuting but during the rest of the day it is available for regular car-sharing customers. This way the utilization of each car increases, customers avoid the risk of vehicle ownership and the cost of the car is distributed among multiple users. The residual value problem is also addressed by assuming that the car is retained within the business until its salvage value is zero. With a car-sharing offer, which includes a suitable mix of electric and ICE cars, any travel or distance need can be met. The car-sharing offer ultimately dispenses with the need of car ownership altogether.

The subscription fee is based on the daily driving distance of the subscriber. When the daily driving distance is less than 50 km, the subscription fee can easily compete with the cost of owning an ICE car. If the daily range exceeds 50 km, the depreciation of the electric car will make the subscription fee too high for it to be able to compete with ICE car ownership. If the distance limit in the battery warranty were increased to 120,000 km, the subscription fee would be able to compete with car ownership up to a daily driving distance of 70 km.

best practices in electric mobility

BOX 6.

EXAMPLES OF ELECTRIC CAR SHARING

The Lithuanian electric car-sharing service, Spark, has officially launched in Romania with the deployment of 50 cars in Bucharest. The fleet consists of Nissan Leaf and Renault Zoe electric cars. The minimum rental time is 12 minutes. The service area, however, is Bucharest, so anybody outside the city's vicinity must bring the car back or else pay extra.

6.3. State-led charging models

Through its "Ten Cities, Thousand Vehicles" programme launched in 2009, the Government of China used cities to test out local programmes, which were later rolled out into a national initiative. Different business models employed by different cities are covered in brief below:

BOX 7.

CASE STUDY

China's "Ten-cities, Thousand Vehicles" programme

State leadership model: Beijing

- Reduced vehicle taxes and granted licence plate lottery exemptions.
- 3 EV industrial campuses were established to promote R&D in EV technologies and attract leading automakers, battery makers, and other industry players.
- Tie-ups and joint ventures were set up between private entities and government, such as a joint venture between Beijing Yanqing district government and state-owned vehicle manufacturer BAIC Foton to deploy EV taxis.

Platform-led business innovation model: Shanghai

- Adopted rental model borrowed from Bremen, Germany.
- Set up international EV demonstration zone, called EVZONE, for testing and piloting the EV model to test innovations in vehicle performance, route design, and charging facility distribution; and to provide a site for auto manufacturer R&D collaboration. EVZONE to establish EV leasing stations in busy areas where consumers can lease an EV with a membership card.

BOX 7.

Cooperative commercialization model: Shenzhen

- Shenzhen local government has fostered a financial leasing model with state-owned enterprises such as Potevio New Energy.
- Potevio retained ownership of the bus batteries, leased them to Shenzhen Bus Company, and offered loan guarantees for the bus capital cost. Moreover, because of support from the local government and manufacturer BYD, Potevio was able to buy the batteries at a subsidized price.

Flexible rental model: Hangzhou

- People could rent the car or the battery separately.
- Provided free battery rental for three years or up to 60,000 km for people who purchase EV cars.

Fast-charging model: Chongqing

- Unlike other pilot cities that adopted battery swapping (Shenzhen and Hangzhou) or slow charging stations (Beijing and Shanghai), Chongqing was able to pilot more grid intensive fast-charging EV technology due to its proximity to the robust Three Gorges Dam Power Grid.
- In addition, because of the large number of hilly areas in the city, Chongqing was less able to install battery-swapping stations which require flat areas.

Source: Marquis, C, Zhang H, & L. Zhou (2013). *China's Quest to Adopt Electric Vehicles*. Stanford Social Innovation Review.

6.4. Battery swapping

This business model compensates the high cost component of the electric battery compared to the vehicle price. Charging times are also reduced by a substantial amount. In addition, due to controlled charging conditions, batteries last for longer charging cycles. Swapping requires a compatible interface between the vehicle and swapping station. The battery swapping provider has a contract with the customer, which contains the automated swapping of discharged to charged batteries for the electric vehicle. The swapping provider follows his/her own optimized charging strategies. Whereas, the customer possesses a battery for a temporary period.

BOX 8.

CASE STUDY

Better Place battery swapping stations in Israel

Better Place, an Israeli startup company, set out to build a network of battery swapping stations.
Under the concept, the consumer buys an electric car (a Renault Fluence ZE sedan in this case), to drive to a Better Place station and swaps the empty battery with a fully charged one in about the same time it takes to put gas in a conventional car. The consumer then pays for the electricity used per mile on a subscription model.
The Better Place initiative failed to succeed for a number of key reasons:

- Better Place only ever established a few dozen battery-swapping stations in Israel and Denmark due to the high cost of robot-operated battery swapping.
- The batteries were compatible only with Renault Fluence sedan cars.
- Large Fluence sedans were not popular among buyers in those countries, who tend to prefer smaller vehicles.

Source: Dvir, D. & O. Emet (2016). *Better Place – Revolutionary Idea: The Vision and Reality*. Coller School of Management, Tel Aviv University.

BOX 9.

CASE STUDY

Gogoro battery swapping stations in Taiwan

- Gogoro is a Taiwan-based company that develops and sells electric scooters and battery swapping infrastructure.
- It has set-up GoStations, which are ATM-sized vending machines where depleted batteries can be readily swapped for fully charged batteries.
- The electric scooters are also cloud connected and transmit the vehicle and battery data to the swapping stations.
- Gogoro has sold over 34,000 scooters, which, combined with its rental efforts, have led to customers travelling over 100 million km to date — and saving an apparent 4.1 million litres of petrol that would otherwise have been used.

Source: Wired. (2017). *The Electric Scooter Maker Hoping to Change the World Lands in Japan*. Retrieved from wired.com: https://www.wired.com/story/gogoro-electric-scooters-japan/

6.5. The second life of batteries

An EV needs to be replaced when the capacity reduces to 70 to 80 per cent but the batteries can still be utilized for energy storage systems. Used EV batteries can be deployed in a variety of ways, including rooftop solar storage, solar streetlight applications and backup power for telecom towers. This extends the useful life of the battery by another 10 years before they need to be disposed. Utilizing the second life of the battery also leads to a way for an EV owner to monetize the investment. A few applications of EV batteries after they have completed their useful life for EVs are highlighted below:

FIGURE 27. APPLICATION FOR SECOND LIFE OF EV BATTERIES

Using old EV batteries for energy storage

- Nissan, Eaton and The Mobility House have developed an energy storage system that makes the energy management of the Amsterdam Arena in the Netherlands more efficient, sustainable and reliable.
- The system uses Eaton's bidirectional inverters and the equivalent of 280 Nissan Leaf batteries stored in racks.
- It will be used for backup power during major events replacing diesel generators in the future, assisting utilities during periods of high demand and grid stabilization services

Recycling old EV batteries to power streetlights

- Nissan's "The Reborn Light" initiative uses old batteries from the Nissan Leaf electric vehicle to ease the burden on Japan's electrical grid.
- The former car battery lives in the base of the light, powering an array of high-efficiency LEDs at the top.
- The battery recharges each day, but it's not plugged into the electrical grid. Instead, Nissan uses solar panels on the light to ready the batteries for nighttime uses solar panels on the light to ready the batteries for nighttime.

Used electric car batteries in data centres

- French data centre web hosting company Webaxys is using an energy storage system at its headquarters in Normandy based on used batteries from EVs by Nissan Motor.
- The system, designed by Nissan and Eaton, will help the facility take advantage of RE, whose intermittent availability requires energy storage for effective use.
- GM is powering its data centres with old Chevrolet Volt EV batteries.

Application in RE storage using recycled batteries

- Second-life batteries from Renault electric vehicles will be used to store the fluctuating supply of energy produced by solar and wind farms on the Portuguese island of Porto Santo.
- Stored as soon as it is produced, this energy is recovered by the grid as and when needed to meet local demand

Source: PwC analysis

7. Analysis of financing approaches

The financing of electric mobility is usually done in three main areas:

FIGURE 28. FINANCING OF E-MOBILITY

FINANCIAL INCENTIVES	Financial incentives are provided to EV consumers for procuring EVs The incentives are also provided to EVSE operators Governments and the private sector spend on conducting R&D
PROCUREMENT	Procurement of EVs and EVSE by governments, fleet operators
POLICY	Government and multilateral agencies spend on policy preparation and implementation

Source: PwC analysis

Some of the common financing mechanisms for EVs and related charging infrastructure are discussed below.

7.1. Global financing mechanisms

Global financing mechanisms, such as the Global Environment Facility (GEF) and the Green Climate Fund (GCF), consist of governments, international institutions, the private sector and other organizations that provide grants and funding for programmes critical to conserving the environment. The reduction of GHG emissions is a focal point of such programmes. Some of the areas targeted by the programmes are highlighted below:

FIGURE 29. GEF FOCAL AREAS

Promoting innovation	Policy planning	Demonstration projects	Capacity building

7.2. Low interest rate loans

These are the easiest type of financial instruments on the market for customers to understand. The terms and conditions are generally simple and allow for loan appraisal and comparison with other lending institutions. The low interest loan is easy to manage as loans are the standard “business-as-usual” type of finance provided to customers. The low interest loan is of particular interest to charging station operators and other charging businesses as similar preferential instruments are not available from commercial banks due to perceived risks associated with EVs.

7.3. Revolving loan fund (RLF)

A RLF is fundamentally a source of money from which low-cost loans are made to borrowers consistent with standard, prudent lending practices. As the borrowers repay loans, the money is returned to the RLF to make additional loans. In that manner, the RLF becomes an ongoing or “revolving” financial tool. Governments can use RLFs to finance EV-related projects. Public-sector institutions have been the major borrowers of these RLFs globally. Typically, the interest and fees paid by the borrowers support RLF administration costs and the fund’s capital base remains intact.

BOX 10.

EXAMPLE OF A REVOLVING LOAN FUND

- The United States American Recovery and Reinvestment Act (ARRA) provided funding of $3.1 billion for the State Energy Program (SEP).
- The Recovery Act encouraged the creation of long-term funding mechanisms such as RLF in order to extend the impact of ARRA funds. In this regard, many states applied for ARRA funding and have set up RLFs for financing energy efficiency projects.

7.4. Feebate mechanisms

Feebates are special financing structures which generally present a revenue neutral policy regime to incentivize a positive technology like low carbon transport. Fees applied in the form of increased taxes and duties on ICE vehicles can be used to provide purchase incentives for electric vehicles.

BOX 11.

EXAMPLE OF A FEEBATE MECHANISM

- The California's Clean Vehicle Rebate Project imposed a fee of up to $2,500 on new, high-carbon-emitting vehicles.
- It then provided rebates on the fee to buyers of new low-emission vehicles.

7.5. Green bonds

Green bonds are created to fund projects that have positive environmental and/or climate benefits. These are debt instruments that allow investors to invest in sustainable projects while offering issuers affordable funding to finance these projects. However, verification of the use and environmental impact of any proceeds made must be strictly regulated and monitored by a third party.

BOX 12.

EXAMPLES OF GREEN BONDS

In March 2014, Toyota Financial Services issued the automotive industry's first asset-backed green bond. The bond took the form of $1.75 billion in securities, backed with US dealer income stream, to fund conventional loans and leases on sales of its hybrid ZEV models in the United States. Since then, the company has issued two more green bonds, the latest in May 2016, for $1.6 billion.

In March 2016, Hyundai Capital Services issued the Republic of Korea's first green bond. Worth $500 million, it was designed to finance the provision of loans and lease contracts for Hyundai and Kia hybrid and electric models. In May of the same year, Chinese car manufacturer Zhejiang Geely Holding Group issued $400 million in green bonds to build a factory north of London and finance the manufacturing of zero-emission taxis by its subsidiary London Taxi Company. The bonds issued were oversubscribed six times, demonstrating the high demand for these instruments.

7.6. Collaborative funds

A collaborative fund between government and private automakers could be explored in order to finance the transition to electric mobility.

BOX 13.

EXAMPLE OF A COLLABORATIVE FUND

In 2014, four private automakers - Toyota Motor Corporation, Nissan Motor Co., Ltd, Honda Motor Co., Ltd, and Mitsubishi Motors Corporation - announced a joint project to support the development of EV charging infrastructure by providing additional funding to supplement Government subsidies.

The automakers formed a joint entity, Nippon Charge Service, LLC, that provided financial support to cover one-third of the cost of installing charging equipment, while the remaining two-thirds was provided with support from the Development Bank of Japan Inc's "Fund for Japanese Industrial Competitiveness".

7.7. Multibank funding with a loan-loss reserve

Current funding for electric vehicles comes from a mix of local, state and national rebates, as well as cash and financing options from conventional institutions, such as banks or financing arms of automobile manufacturers. Some local credit unions have also started to provide loans for EVs and related charging infrastructure, but there is still a gap in private funding. A multibank arrangement, operated by a group of banks to pool funding and provide lending, could help overcoming this barrier.

Multibank community development corporations spread the risk among several lenders and are used to develop infrastructure and extend credit for small business loans, real estate development, and affordable housing construction. A similar structure could be applied to fund loans for electric vehicles in underserved communities. It could also serve as a platform for education on EVs and clean-driving initiatives while it provides credit to the population it serves.

7.8. Small business microloans

Microloans are small business loans offered at attractive interest rates to help businesses access capital for items like machinery or fixtures. These loans can facilitate funding for EV charging equipment and installation costs.

BOX 14.

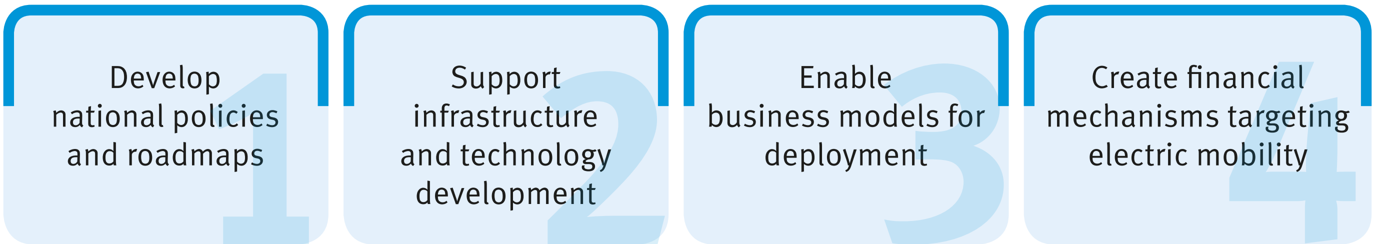
EXAMPLES OF MICROLOANS

One such micro lender is Texas-based LiftFund, founded in 1994. A highly regarded certified community development financial institution, or CDFI, it provides loans, financial education, and other financial services in underserved communities. The non-profit, which has expanded to operate in 13 states — Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, Missouri, New Mexico, Oklahoma, South Carolina, Tennessee, and Texas – counts regional and national banks, chambers of commerce, philanthropic foundations, local governments, and business and civic leaders among its backers.

8. Policy recommendations

Many countries are already adopting measures to shift their transportation sectors towards e-mobility. Growth in the sector will contribute to lower emissions from transportation and create new employment and business opportunities. But it will also be disruptive to business and industry given the scale of change required in supply chains and infrastructure. A list of recommendations for countries to consider when developing e-mobility strategies and policies is outlined below.

FIGURE 30. POLICY RECOMMENDATIONS FOR ELECTRIC MOBILITY



8.1. Develop national policies and roadmaps

To develop the electric mobility sector, countries should set coherent strategies in the form of national roadmaps. Strategies should include well defined, clear targets designed to integrate electric mobility into the existing ecosystem and ensure that all stakeholders are involved.

Policies and initiatives also need to actively engage local administrations as the implementing agencies working to deliver policies that lead countries towards lower emissions. It is also essential to engage with private and government stakeholders such as the automobile industry, the power sector and municipalities at each stage of planning and implementation. Stakeholders may have interests that conflict with national government objectives, which highlights the importance of bringing them on board without harming the sector. This could be done by setting up a task force on electric mobility that can guide policy decisions.

One tested method of raising the number of electric vehicles on the market is through providing financial and non-financial incentives. To be effective, incentives must be well targeted and should alleviate the incremental costs of acquiring an electric vehicle. The incentives should also be easily disbursed to the consumer by either reducing the upfront cost or being delivered shortly after purchase. National and local administrations need to spend considerable efforts to spread awareness about electric vehicles and the incentives provided by the government for them.

Electric mobility represents a significant opportunity for power utilities and integrating the two sectors will lead to significant synergies. Utilities should be allowed to set up EVSE and implement smart charging projects to incorporate renewable energy. Electric mobility should also be incorporated in types of transport required under transit-oriented development, such as last mile connectivity and ride-hailing services.

8.2. Support infrastructure and technology development

An integrated charging network is essential for the transition of the transport sector. One of the main challenges for the setting up of the charging stations is the multiple standards and communication methods available across the world. It is necessary to ensure interoperability of charging stations so that EV consumers have the ability the charge their electric car from any charger.

As is the case with electric vehicles, charging infrastructure needs to be incentivized too. Currently, due to the high cost of public charging stations and relatively small number of electric vehicles, it is not an attractive business investment. Governments need to incentivize the installation of charging stations until the cost economics of the operations become favourable to private players.

There is no set standard for the ratio of electric cars to public charging stations. Countries looking to establish a target for EVSE should learn from others with similar urban infrastructure. Charging infrastructure connections should also be made a prerequisite in the building codes for new and refurbished buildings. Many countries may classify EV charging as a resale of electricity, which could restrict the entry of private players into the business and might slow down the deployment of charging infrastructure. It is recommended that EV charging be classed as a service and not as a resale of electricity.

Smart charging has many advantages and can encourage power utilities to reduce the level of carbon emissions from their operations. It is recommended that countries should allow the flow of bidirectional current between EV batteries and the grid. Battery technology is constantly evolving and more research is required to create more sustainable and effective batteries.

8.3. Enable business models for deployment

Demand aggregation, or bulk procurement, is one of the most common models followed for the adoption of electric vehicles for a public or private fleet. Outright purchase and collaborative procurement are popular demand aggregation methods. However, some agencies prefer to lease vehicles to the fleet in order to avoid the inconvenience of operating and maintaining the vehicles. Under such as arrangement, known as a gross cost contract, the lessor has to pay a fixed, mutually agreed sum to the lessee in installments and the lessee takes care of operation and maintenance.

Electric car sharing is also gaining popularity. It reduces some of the less positive aspects of owning a car (such as parking charges and fuel costs). In addition, since shared cars are used more often with a higher average driving distance per day compared to an owned car, the payback period for owning an electric car is shorter.

In relation to charging infrastructure, governments are employing several business models to increase deployment. In China, a government agency installed a substantial number of fast charging stations in order to overcome the hurdle of range anxiety from the minds of EV owners. China experimented with 10 cities and deployed state-specific business models, playing on the state's strengths.

Battery swapping stations are also becoming popular. One successful case is in Taiwan where two-wheeler electric scooter maker Gogoro set up the Gogoro Energy Network, installing modular battery swapping infrastructure. Swapping stations provide reduced charging times as well as increased battery life.

8.4. Create financial mechanisms targeting electric mobility

Some of the common financing mechanisms for EVs and related charging infrastructure are: low interest rate loans; feebate mechanisms; green bonds; and microloans. Sometimes, multibank arrangements, operated by a group of banks to pool funding and provide lending, are also undertaken.

Multibank funding spreads the risk among several lenders and is used to develop infrastructure and extend credit for small business loans, real estate development, and affordable housing construction.

Small business microloans can also be used to fund the e-mobility ecosystem. Microloans are small business loans offered at attractive interest rates to help businesses access capital for items such as machinery or fixtures. These loans can facilitate funding for electric vehicle charging equipment and installation costs.

It is clear that governments need to take concrete action to encourage electric mobility to take advantage of the benefits of the technology. International cooperation is essential to develop the EV market. Experiences from across the world and the understanding gained from them have to be incorporated in further programmes across countries.

9. UNIDO’s e-mobility experience

It is clear there are strong drivers propelling the electric vehicle market forward, with countries such as China and Norway leading the way. The expected transition towards greater electrification of transport will dramatically change how energy is consumed and produced. With the right incentives, the rise in EVs will be central to the development of cleaner, more decentralized, smart energy systems and services. This shift, supported by a rise in power produced from RE sources, will contribute to cuts in GHG emissions.

Although the market has expanded dramatically in recent years, EV sales account for just a little over 2 per cent of global vehicle sales. In order to ensure that the transport sector contributes to meeting Paris Agreement emissions targets, sales must jump to at least 30 percent by 2030. To get there, many countries have significant barriers to overcome, such as a lack of charging infrastructure, a poor enabling environment, high technology costs, adaptation of industry value chains to integrate 4.0 technologies and strengthening of energy supply and distribution networks.

UNIDO is working to assist a number of countries in meeting these challenges so that economies and societies can reap the economic and environmental benefits of wider adoption, including new job creation, lower levels of air pollution and climate mitigation.

Based on information gathered at the Expert Group Meeting, this chapter will present snapshots of progress of UNIDO projects in China, Malaysia and South Africa and look at lessons learned to date and how UNIDO can further support countries to accelerate the adoption and scale-up of electric mobility.

9.1. **Case studies**

The case studies below highlight UNIDO’s work in China, Malaysia and South Africa. China has the world’s fastest growing use of electric vehicles, and it plans to make sure they are powered by sustainable energy sources. With funding from the GEF, UNIDO is providing technical assistance in a variety of areas including the implementation of different renewable energy technologies in charging stations in the cities of Shanghai and Yancheng. The plan is to evaluate which of them offer the best results and should be replicated throughout the country.

Malaysia is aiming for 10 per cent of its fleet be composed of electric vehicles by the end of 2020 as part of endeavours to cut GHG emissions from the transport sector. UNIDO is working with the country to promote the use of solar energy in charging stations. The adoption of charging stations powered by renewable energy sources is also expected to include Malaysia in the global chain of battery producers, as well as benefit the existing manufacturers of semiconductors and solar photovoltaic panels in the country by increasing the demand for their products.

In South Africa, UNIDO is helping to develop a policy framework to regulate and encourage the adoption of electric vehicles in the cities of Durban and Johannesburg, where particular attention was paid to the public transport system. The goal is to prove to other municipalities and the private sector that the technology is not only positive for the environment, but also economically and technically viable.

9.1.1. China

TABLE 9. PROJECT IN CHINA AT A GLANCE

Project title	Integrated adoption of New Energy Vehicles in China (UNIDO ID: 150157)
Goal	Support the greening of the transportation sector and automotive industry in China
Thematic areas	Safeguarding the environment
Donor	Global Environment Facility (GEF)
Project counterpart	Ministry of Industry and Information Technology (MIIT)
Budget	$ 9 million
Duration	2015-2020

Country context

China became the largest EV market in the world in 2015 with the highest number of PHEV and EV sales recorded. However, although it is a leader in electric mobility implementation, the country still struggles with the world's highest GHG emissions. It also has the largest renewable energy capacity globally, though that forms only a small portion of its power generation mix and is underutilized due to uneven generation patterns. While EVs remove tailpipe emissions, the pollution is shifted to the power generation process. By leveraging on the synergies of EVs and RE, there is a huge potential to drastically reduce GHG emissions.

Major barriers

The country can integrate RE with electric mobility in two ways: increasing the amount of renewable energy in the overall power grid and by setting up renewable energy microgrids to power EVs. The major barriers to increasing the renewable energy are:

FIGURE 31. MAJOR BARRIERS TO RENEWABLE ENERGY IN CHINA

Policy barriers	Capacity and knowledge of government officials	Technology and market barriers	Lack of awareness among the general public and industry
■ Lack of a national roadmap ■ No incentives or regulations ■ No standards ■ Lack of rules for national carbon policy for support of EV-RE integration ■ Lack of institutional coordination mechanisms	■ There is no knowledge about the a of RE with EVs in the public sector in China ■ No high quality material suitable for policymakers to convince them of the economic and technical viability of EV-RE	■ China does not have much experience in integrating the two sectors.	■ The general public is not aware of the need and potential of EV-RE ■ Even Industry players from power, vehicle and other sectors do not have any experience or information in the matter

Objectives

The project aims to facilitate and scale up the integration of renewable energy with electric vehicles in China, with the objective of reducing GHG emissions in the country. The outcomes envisaged at the end of the project are:

- Drafted and recommended policies, technical standards and guidelines that provide regulatory and planning elements, leading to the higher adoption of EV-RE integration schemes by city governments, vehicle manufacturers and consumers;
- Increased institutional capabilities and awareness of policymakers at national and local levels on the use of integrated EV – SG (smart grid) - RE systems;
- Two city-scale projects piloted, demonstrating the integration of EVs and RE as well as other foundational work to achieve large-scale EV-RE integration;
- Increased knowledge and capacity of business and consumer stakeholders, facilitating awareness, research and development, manufacturing, operation and maintenance of EV-RE integration.

Impact of the programme

The project increases the integration of electric vehicles with renewable energy sources in China. By setting the foundations of this integration with policy recommendations, training, awareness- raising and technology demonstrations, the project will ensure that the adoption of electric vehicles also becomes a driver for increasing access to sustainable energy sources in the country. Results of the project are expanded on below.

Increased stakeholder cooperation and dissemination of information

Integration of RE with the e-mobility sector is of paramount importance in China. The swift and efficient development and implementation of the EV-RE integration requires coordination among private and public stakeholders. The first International Smart Shared Mobility Congress (SMC 2018), held in Guangzhou, Guangdong Province, and the World New Energy Vehicle Conference 2019 held in Boao, Hainan Province, provided two such opportunities. The events brought together stakeholders from governments, international organizations, thinktanks and the private sector and led to declarations of shared development in China and internationally in e-mobility.

The focus of discussion at SMC 2018, which attracted over 600 delegates, was on electrification of transport, connectivity, shared mobility and autonomous driving. The congress helped to encourage the development of demonstration projects related to smart sharing and increased networking for smart mobility between China and the world.

At the World New Energy Vehicle Conference discussions centred on integrated development of automobiles, energy, transport, information and communication and smart city scenarios. The conference hosted over 1,800 participants from more than 18 countries and over 150 speakers. It was an important platform for gathering global innovators and developing high-quality products for the sectors. The GEF project and its outcomes were disseminated among the industry. The conference concluded with the declaration of the *Boao Consensus on New Energy Vehicles* between global new energy vehicle stakeholders in which participants committed to working together to develop technology in e-mobility with the aim of bringing electric vehicles to account for 50 per cent of annual global car sales by 2035.

Building stakeholder confidence in EV-RE integration

Both industry and the public sector lack experience and know-how on how to integrate renewable energy and electric vehicles into China's electric grid. Pilot programmes and demonstrations of smart charging and electric vehicles are building the confidence in investors, government departments and technology companies to replicate the projects and scale up the initiative. Both the International Smart Shared Mobility Congress and the World New Energy Vehicle Conference included test drives of new energy vehicles from technology companies.

To demonstrate the benefits of smart charging that can be leveraged with a larger number of electric vehicles, 15 smart charging stations and 200 smart charging piles have been installed in Shanghai. The number of electric buses has also been increased in Shanghai to 200. Additionally, 2 solar storage EV charging microgrids have also been constructed in the city with two more under construction. This will increase the awareness of technologies and will lead to replication of similar procurements in other cities across the country.

The programme has also demonstrated scaling up of the Shangai car sharing business model. As of the end of May 2019, the number of operating sites for EVCARD (a car sharing business model) in Shanghai was 1,021, and the number of electric vehicles operating in the network was 7,771, with a cumulative number of users exceeding 1.7 million.

Further demonstration projects that will boost the sector are envisaged in the following areas:

FIGURE 32. SUMMARY OF POTENTIAL DEMONSTRATION PROJECTS IN SHANGHAI

- Integration of EVs with power grid
- RE microgrids to enable distributed EV-RE integration
- V2G demonstration
- Business models to stimulate scale-up of China's EV fleet for RE-EV integration
- Demonstration of greater density of EV stationary charging stations for scale of EV-RE integration
- Demonstration of mobile charging stations
- Demonstrations of energy management systems for dispersed EVs and retired EV battery packs used for grid storage

It is imperative that these technologies are implemented through pilot projects so that information is disseminated and confidence is built among the industry and government stakeholders. Lessons learnt in the pilot programmes will be disseminated via capacity-building workshops.

Government institutional capacity-building

It is essential to educate the government officials working in public departments on the benefits of integrating the energy and EV sectors. In the World New Energy Vehicle Conference, the plenary sessions invited government representatives to conduct in-depth discussions on energy transformation, environmental protection and green development of the automotive industry, transformation and upgrading of the automobile industry and innovation and development.

There is a need for coordination of different ministries to undertake policy action together in a holistic manner to encourage the sustainable development of the sector. Many programmes and pilots have been conducted in the country that have active involvement of multiple government stakeholders. A few workshops have already been undertaken for the inception of the programme itself and for the Shanghai demonstration project, with participation from central and local level government ministries, departments and associated offices. Further capacity-building workshops would lead to more informed decisions by policymakers on enabling EV-RE integration in the country.

Research and development in EV-RE integration

Due to the activities envisaged in the programme, multiple research and development initiatives have been undertaken. R&D in EV-RE integration will result in overcoming informational barriers and will lead to appropriate policy design, pilot programmes and business models for EV-RE China.

In preparation of a national level roadmap, research has already begun in the latest V2G practices and smart charging demonstration projects, future roadmap of new energy vehicles and energy mix of the country. This has included various interactions with OEMs and a series of seminars on distributed energy interaction, user-side microgrids and vehicle network coordination. Additionally, economic benefits have been analysed for smart charging in China, including the requirements and current data communication technology of Evs.

Research into potential uses of the battery following EV use are still at early stages around the world. Under this programme, a residual value assessment of the secondary use of retired EV batteries was undertaken for the demonstration projects. Additionally, technical standards and specifications on the fire protection system of the second life of the battery was also carried out.

9.1.2. Malaysia

TABLE 10. PROJECT IN MALAYSIA AT A GLANCE

Project title	Developing Energy Efficient Low Carbon Transport in Malaysia (UNIDO ID: 120309)
Goal	Promote the use of electric vehicles in Malaysia, cutting down greenhouse gas emissions in the country while supporting the development of its automotive industry
Thematic areas	Safeguarding the environment, advancing economic competitiveness
Donor	Federal Government of Malaysia, Global Environment Facility (GEF)
Project counterpart	Ministry of Energy, Science, Technology, Environment and Climate Change (MESTECC); Malaysian Green Technologies Corporation/PMU
Budget	$ 30,720,000 million ($ 28,720,000 co financing from Malaysian Government and $ 2,000,000 from GEF-5)
Duration	2015-2020

Country context

Malaysia’s demand for energy in the transport sector is high due to a growing population, automobile dependent growth in urban areas, subsidized fuel prices and the promotion of the automobile industry. Over the past decade, the transport sector has accounted for the largest share of the GHG emissions in the country. The automotive industry and market is highly developed, accounting for 28 per cent of new registrations in the ASEAN region for passenger cars. The transport sector predominantly consists of two-wheelers, which make up 46.6 per cent of all land transport vehicles.

Major barriers

Malaysia has undertaken many initiatives to encourage electric mobility in recent years. Some are still at the initial development stage but a few initiatives are being implemented and have begun to make visible inroads in the last three years. The key barriers to uptake of electric mobility in Malaysia are highlighted below:

FIGURE 33. MAJOR BARRIERS TO ELECTRIC MOBILITY ADOPTION IN MALAYSIA

Lack of in-depth coordination	Awareness barriers	Policy barriers	Infrastructure barriers
Lack of comprehensive co-ordination among stakeholders implementing initiatives. However, early implementation has been initiated by Greentech Malaysia and the Ministry of Energy, Science Technology, Environment and Climate Change.	General consumers still lack knowledge on EVs and the policies in place for their development, which has meant that policy application has been limited to two-wheeler fleet users such as the delivery companies and traffic police patrols.	There are few incentives in place for electric vehicles to encourage uptake among consumers and manufacturers. Current policy initiatives are more focused on HEVs and PHEVs.	To date, only 350 charging stations have been installed in Malaysia and there is a lack of testing facilities or support applications.

Objectives

The project has the following objectives in support of reducing transit sector GHG emissions:

- Improved policies and regulatory framework, strengthened institutional capacity, and enhanced awareness to catalyze and accelerate widespread use of EVs in Malaysia;
- Development and demonstration of infrastructure for EVs and local manufacturing capacity.

Impact of the programme

The project aims to help the country to develop a low-carbon transport sector. The project approach targets improvement in the policy and regulatory framework through developing national-level enabling policies, raising awareness and advancing institutional capacity-building. The project has demonstrated the integration of renewables and EVSEs by implementing installation and testing of charging stations that are based on renewable energy, supporting reductions in GHG emissions and air pollution from the transport sector.

Increased policy development and stakeholder development

Current policy initiatives have been effective in increasing the number of hybrid vehicles but have had negligible impact on the uptake of electric vehicles. Additionally, due to the fragmented development of electric mobility, there is a lack of coordination among stakeholders.

UNIDO is supporting the development of a Low Carbon Mobility Blueprint and Action Plan for land transportation in the country, which will be implemented by Greentech Malaysia and administered by MESTECC. The policy will present a holistic plan for Malaysia to adopt clean energy-based transport. Key ministries and agencies, transport associations, fuel suppliers and car manufacturers in Malaysia have all actively participated in the formulation of the plan via workshops and focus group discussions. These have helped in providing inputs to understand industry-specific barriers and the policy initiatives required to overcome them. Additionally, three workshops have been conducted with over 50 participants from wide backgrounds taking part, leading to constant support for the programme.

In addition, the results of a study to assess the energy and environmental landscape on Langkawi Island will be used to develop a Low Carbon Langkawi Island Plan. Greentech Malaysia has also started the development of standards and regulations for EV infrastructure. Based on the recently completed work on Low Carbon Mobility and Action Plan, MESTECC is currently collaborating with the Ministry of Transport and the Ministry of International Trade to draw up a joint cabinet paper on low carbon transportation in Malaysia for the consideration of the Government.

Increased interest in investment in EV Charging

Pilot demonstration projects for PV-based energy storage EV charger at the PLUS Highway and the PV-based energy storage BRT charger at Sunway Depot have succeeded in convincing direct beneficiaries on the potential for higher capacity replication of the system. The two demonstration projects differentiate from other EV chargers installed in the country because they are PV-based and integrated into the energy storage system. These projects have attracted the attention of the Electromagnetic Standard Development Committee under Standard Malaysia. Monash University, Malaysia Campus, has also explored the potential of scaling up the project in close collaboration with the BRT operator, Rapid Bus of Prasarana Group.

The PLUS Highway will see immediate replication within the project timeframe through the implementation of four additional PV-based chargers, whereas the BRT Sunway Depot is awaiting further funding in the project. Ten slow chargers have also been installed on the Langkawi Island. The demonstrations have been successful in providing the authorities and implementation agencies with the experience and confidence to scale up the technologies.

The demonstration projects are all linked to a centralized monitoring system under the ChargeV programme administered by Greentech Malaysia, which has so far installed 70 per cent of the 350 EV chargers installed in the country over the last three years. This monitoring system, albeit basic, will provide baseline data in the development of supporting infrastructure by the electric utility and tariff development for chargers by the energy commission. The system operated via an “app” has also enabled EV and PHEV owners to access availability of chargers for use.

Skills development and capacity-building for government

A National Occupational Standard has been developed for installation and maintenance of EV charging stations. This will lead to the creation of certified installers for EV charging stations. Greentech Malaysia is also currently developing the training needs, standard development and compliance regulation for EV value chains in Malaysia. The work is expected to identify the various training needs across the EV ecosystem and will be handed over to Skill Malaysia for further development of related EV competency training to be implemented by Greentech Malaysia soon.

9.1.3. South Africa

TABLE 11. PROJECT IN SOUTH AFRICA AT A GLANCE

Project title	Energy Efficient and Low-Carbon Transport in South Africa (UNIDO ID: 130281)
Goal	Promote energy and low-carbon transport contributing to low-carbon cities in South Africa
Thematic areas	Safeguarding the environment
Donor	Global Environment Facility (GEF)
Project counterpart	South African National Energy Development Institute (SANEDI); Department of Trade and Industry (DTI); Technology Innovation Agency (TIA); City of Durban; City of Johannesburg; Department of Environmental Affairs (DEA); Department of Transport (DoT); Department of Energy (DoE)
Budget	$ 9 million
Duration	2015-2020

Country context

South Africa's automotive sector is ranked 23rd in terms of manufacturing globally and is a key player in the international automotive value chain. Currently, road transport accounts for 91 per cent of emissions in the transport sector and electric vehicles could prove to be the most sustainable way to fight vehicular pollution. The South African EV market is still in its infancy, but electric vehicles are set to increase their presence on South African roads as more car manufacturers announce their intention to enter the industry in response to global trends. This increase is already evident. In 2016, there were around 200 EVs and 60 charging stations nationwide. This number has slowly but surely grown to 870 registered battery EV sales in April 2019 (excluding plug-in and battery hybrid electric vehicles, which are more popular). The charging infrastructure network has grown to 120 public charge points nationwide. Although motorcycle CO2 emissions are below that of cars, they emit high levels of black carbon, a potent short-lived climate pollutant. Addressing motorcycle emissions is a priority for improving air quality and reducing GHG emissions in Africa as a whole.

Major barriers

Although South Africa has undertaken many initiatives for encouraging electric mobility, developments are still in the initial pilot phase. The key barriers to uptake of electric mobility in South Africa are highlighted below:

FIGURE 34. MAJOR BARRIERS TO ELECTRIC MOBILITY ADOPTION IN SOUTH AFRICA

Lack of government and industry cooperation	Lack of awareness	Skills development and training	Lack of charging infrastructure
The stakeholders implementing electric mobility initiatives lack coordination. Industry support is crucial for the development of EV technology.	Consumers lack knowledge on EVs and have little awareness of EV policies.	Education and training of engineers and labourers is required in order to keep the EV market sustainable in South Africa.	Very few charging stations have been installed in South Africa and there is a lack of testing facilities, ancillary setvices, etc.

Objectives

The project's overall objectives are the promotion of the widespread use of EVs and non-motorized transport (NMT), and the development of the necessary infrastructure, as part of the Green Transport and Green Cities initiatives in South Africa. Expected outcomes at the end of the project are:

- Sustainable transport and urban policy and regulatory frameworks adopted and implemented;
- Increased investment in less GHG-intensive transport and urban systems.

Impact of the project

The project will accelerate the deployment of non-motorised and electric vehicles in its target areas of South Africa. It will contribute to South Africa's energy transition by promoting the use of renewable energies for transport. By moving away from fossil-fuels powered vehicles, South Africa should start to lessen its reliance on imported fossil fuels, boosting its energy security. The project also contributes to the reduction of the country's CO_2 emissions, having a positive impact on the environment and improving the air quality in cities.

Enablement of multi-stakeholder approach

South Africa's EV ecosystem comprises of various stakeholders, such as SANEDI, the dti, the uYilo E-Mobility Programme, the National Association of Automobile Manufacturers (NAAMSA), UNIDO and others, including government departments, skills development agencies, academia, policy and thought leadership influencers. The EV stakeholder pool continues to grow at a steady pace in South Africa. More government organizations with a transport, energy or climate change mandate are recognizing the need for electric mobility (preferably powered by renewable energy).

The focus has been on bringing private and public sectors under one roof to exchange policy and technical knowledge for emerging low-carbon transport technologies, the impact of such engagements is the implementation and planning of public awareness creation events hosted by private companies in support of government and vice versa. Examples include: the annual Electric Vehicle Industry Association Conference and Publication sponsored by UNIDO, the Sasol Solar Challenge, Eskom's (National Utility Entity) E-mobility Workshop, the Department of Transport's multi-stakeholder collaboration to promote green transport technologies and to grow the nation's EV charging point network. These events have also been useful information resources for the updating of policy to include EVs.

UNIDO's project initiated frequent conversations about the e-mobility ecosystem among relevant stakeholders due to multiple meetings, convenings and workshops, such as a workshop designed to initiate a macroeconomic study on EV adoption in South Africa and seminars such as South African National Energy Association (SANEA) dialogues on energy and mobility.

Increased industry engagement

In South Africa, the engagement of industry and government has been limited. However, since the inception of the Low Carbon Transport Project in South Africa (LCT-SA) Project, the Government has been very receptive towards the technological advancements in electric vehicles and battery technologies undertaken by the industry. Support from the Government in terms of incubation centres, incentives and conducive policies has made technology penetration a reality. The impact of industry and government engagements has led to increased commitment from the state, which in turn has had a positive effect on raising industry investment. The number of vehicle manufacturers offering EVs in South Africa has grown. Nissan was the sole provider of EVs at the inception of the project: today consumers have a choice between Nissan, BMW, Jaguar, Audi and Mercedes Benz for pure electric vehicles and even more options for hybrid vehicle models. EV charging infrastructure installers are also growing, offering a local competitive industry.

Awareness-raising and capacity-building

Various seminars, workshops and meetings have been organized by the LCT-SA project management unit in order to ensure proper knowledge about the need to transition to an e-mobility ecosystem and to highlight the benefits of electric vehicles. Awareness about EVs will help to allay concerns among end-users and should result in more adoption of EVs.

NMT supporting infrastructure pilots

The national uYilo E-Mobility Programme, as one of the stakeholders of the LCT-SA Project, has carried out a demonstration pilot as part of an electric bike-sharing project. Lessons learned from the uYilo and UP bike share schemes are being gathered to share knowledge with nine other cities for integrated and improved decision-making for NMT policy at the national level and implementation at the local level.

9.2. UNIDO's comparative advantage

UNIDO promotes inclusive and sustainable industrial development (ISID) to harness the full potential of industry's contribution to sustainable development. It means sharing the benefits of globalization so that no one is left behind, and making sure economies and societies thrive within a framework that is environmentally sustainable.

To accomplish this mission UNIDO carries out projects and programmes through four main functions:

- technical cooperation;
- analytical and research functions and policy advisory services;
- normative functions and standards and quality-related activities; and
- convening and partnerships for knowledge transfer, networking and industrial cooperation

The sections below show the functions through which UNIDO is able to deliver in the area of electric mobility and sustainable transport and where it can make an impact.

9.3. UNIDO's electric mobility services

UNIDO offers a range of services and expertise to support countries increase and accelerate their adoption of electric mobility. This includes policy advisory services and technical cooperation that targets the deployment of EVs and charging infrastructure, enabling grid stability and strengthening local capacity building and skills development.

FIGURE 35. SAMPLE OF UNIDO E-MOBILITY SERVICES

Policy advisory services

- Developing/reviewing national EV and sustainable transport policies and regulatory framework.
- Designing and planning EV-related tax incentives, incentive programmes and subsidy framework.
- Designing and planning of charger protocols and grid-related safety guidelines and standards.
- Creating guidelines on local manufacturing and assembling of electric vehicles.

Technical Cooperation

- Electric vehicle deployment
  - Mapping the agencies responsible for EV deployment.
  - Projecting the density of electric vehicles in the short, mid and long term.
  - Exploring innovative and cost-effective business models for EV deployment.
  - Recommending financial sourcing options for electric vehicles.
  - Providing bidding advisory services.
  - Developing guidelines for EV testing and certification.
- Charging infrastructure deployment
  - Examining different types of EVSE options and their suitability for each country, and assessing the size, roll-out cost and required number of charging stations of each type in different countries.
  - Selection of type of charging stations based on charging technology options.
  - Identification of the ideal locations for establishing charging stations based on owners' requirements, while taking into consideration the need for minimum additional investment in the power distribution network.
  - Assessment of applicable charger standards and protocols.
  - Evaluating suitable business models for EV charging in different country contexts based on cost-benefit analysis and potential to scale up electric mobility.
  - Developing an appropriate tariff framework which will allow cost recovery for capital invested in the charging stations and the growth of the electricity distribution network.
  - Developing a comprehensive roadmap to deploy charging stations in line with existing, if any, EV policies.
- Grid stability
  - Assessing the impact of projected electric vehicles on power utilities.
  - Assessing requirements for upgrading the power distribution network in line with EV charging needs.
- Capacity-building and skills development
  - EV technology (types of EV, clarification and specification discussion on EV chargers)
  - Basic electrical engineering - major components in an electric vehicle powertrain (vehicle dynamics, motor, electronic components).
  - EV batteries (lithium-ion battery design, battery charging methods and some aspects of battery pack design).
  - Battery management system (battery monitoring, automotive BMS)
  - Power source grid and renewables sources.
  - Safety for EV charging system (electrical safety, charging safety).

FIGURE 35. SAMPLE OF UNIDO E-MOBILITY SERVICES

Knowledge transfer

- Organizing exhibitions, workshops, and seminars on electric vehicles.
- Developing multi-stakeholder engagement platforms engaging both government and Industry
- Developing public awareness-raising programmes.
- Carrying out outreach and education campaigns.

9.4. What can UNIDO offer?

UNIDO welcomes the opportunity to discuss options for creating tailor-made support for electric mobility that meets local needs and the country's context. For questions and advice on the implementation of electric mobility projects, please feel free to get in touch with us at k.barunica@unido.org.

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