GSMP

GLOBAL SUSTAINABLE MOBILITY PARTNERSHIP

Driving zero emission mobility solutions for all

# Policies for a mature, flourishing & equitable EV charging ecosystem

Prepared for the International ZEV Alliance

**1st November 2021**

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# Executive Summary

## Scope

Global Sustainable Mobility Partnership (GSMP) members Cenex NL, Cenex UK, Forth, TERI and uYilo were commissioned by the International Zero-Emission Vehicle (ZEV) Alliance to create a vision for a charging infrastructure ecosystem that could efficiently, equitably and conveniently serve the diverse needs of all Electric Vehicle (EV) applications in the mass market.

The specific objectives of the study were to:

- Provide an update on charging deployments and the development of users' needs;
- Describe how different types of chargers can serve the full ZEV market;
- Analyse the financial viability of public charging in major markets;
- Review charging needs and equitability challenges in urban and rural areas;
- Examine emerging solutions for commercial vehicles; and
- Recommend possible policies and best-practice to address the points raised above.

## Current Status

The current deployment of EV charging infrastructure varies dramatically by continent and local factors. An increasing number of internal combustion engine bans mean that EV uptake is expected to accelerate in the coming decade. Charger installations are also expected to follow-suit. Around 16 to 23 million public chargers are projected to be installed by 2030 from a baseline of around 1.3m at the end of 2020. Although supply chains are expanding and standards are taking effect, no market is working fully effectively and so policy interventions are likely to continue to be needed.

International workshops run by the GSMP identified EV user groups which can be divided between those who can charge privately and those who cannot. In the latter group, five segments were identified globally as important segments for policy focus: private vehicles, fleets & staff, rural drivers, high mileage local vehicles and long haul.

Research into the ZEV Alliance markets indicates that the most mature charging ecosystems match user segments with charging locations and charger types. It is recommended that this is used to target potential policies and evaluate the impact they might have.

| **Location** | **Private** | | **Public** | | | |
|---|---|---|---|---|---|---|
| | Residential | Commercial | Roadside | Destination | Hub | Travel Corridor |
| **Segment** | Private vehicles | Fleets & staff | Private vehicles, high mileage local | Private vehicle, rural Long haul | Fleets & staff, high mileage local | Fleets & staff<br>Rural<br>Long haul |

| | **Slow** | **Standard** | **Fast** | **Rapid** | **Ultra-Rapid** |
|---|---|---|---|---|---|
| **Location** | Private residential<br>Public roadside | Private residential<br>Private commercial<br>Public roadside | Private commercial<br>Public destination | Private commercial<br>Public destination<br>Public hub | Public hub<br>Public travel corridor |

## Building a Charging Ecosystem

Mature and flourishing charging ecosystems are concluded to be more likely to exist if the following features are present:

- Specific government focus in the form of a dedicated Transport or Energy brief;
- An infrastructure strategy that gives direction and shapes business investment;
- Targets that flexibly adapt to local nuances to determine charger numbers, types, standards and availability; and
- Formal consumer representation to ensure advocacy and drivers' voices are heard.

In the case of ZEV Alliance members, many of these building blocks are already in-place.

The same international stakeholders highlighted the barriers that industry participants believe remain and potential policy solutions as follows:

- Public charger (un)reliability – must be guaranteed through technical and contractual means, and be visible to users to build up confidence in the network;
- Interoperability – protocols, payment, pricing structures and access must be harmonised within jurisdictions as well as allowing cross-border travel;
- Lack of coordinated policy – best-practice must be shared between and across different government levels with clear national expectations for the roles of each party;
- Electricity network constraints – significant work must be done to share data, deploy innovative storage technologies, build EV expertise in the network operators, mandate proactive investment to increase capacity, and fund upgrades; and
- Poor business case – targeted and more consistent funding must be made available to ensure a just and swift transition.

In countries where these are not currently present, it is recommended that these high-level points and the specific proposals put forward in Section 3.3 (page 17) are formulated into a policy agenda to underpin the flourishing of the charging ecosystem.

## Improving the Business Case for Public Charging

The business case for chargers was already noted by international stakeholders as a key barrier in the global deployment of charging infrastructure. Where public intervention is desired, governments and municipalities may use a range of ownership models to Own and Operate, subcontract to an External Operator, Lease land or let a Concession on public land. These distribute the investment, reputational and operational delivery risks, although it is recommended that contractual terms are sought to balance the financial and non-financial commitments.

| Ownership Model | Public Charging Locations | | | | Network Finance and Operation | | | |
|---|---|---|---|---|---|---|---|---|
| | Roadside | Destination | Travel corridor | Hub | Revenue | Risk | Service | Resource |
| Own & Operate | 5 | 3 | 3 | 2 | 5 | 1 | 5 | 1 |
| External Operator | 4 | 3 | 3 | 2 | 4 | 2 | 4 | 3 |
| Lease | 1 | 4 | 2 | 5 | 1 | 5 | 1 | 5 |
| Concession | 1 | 3 | 5 | 3 | 3 | 3 | 3 | 3 |

Analysis of the models summarised in the table above indicates that an Own and Operate approach is best for public roadside charging, although the External Operator comes a close second. Public destination charging can work fairly well under any model, whereas public hubs will be best under a lease model. The Concession approach most closely fits public travel corridor locations.

An outline business case was constructed for a hypothetical charger installation in the Netherlands, UK and US, using inputs specific to these markets to explore the business case for public charging. In all the scenarios tested, the Net Present Value of investing in public chargers increases with the power of the charger. However, the value available to the landowner diminishes if a Lease or Concession operating model is chosen.

A sensitivity analysis revealed that the tariff level has the strongest impact on NPV, followed by wholesale electricity costs and the number of charging sessions. Altering the number of chargers in an individual installation has the least strong impact of the variables analysed.

Taken in the round, there is an opportunity for governments and landowners to capture revenue, invest in lower-powered chargers for equitable access or maintain a balanced portfolio across both. Although it is noted that such actions are not required or desirable in all jurisdictions, there is a case for public intervention in charger deployment.

## Providing Equitable Access to Charging

With the case for public intervention strongly linked to equitable access, especially for the priority groups dependent on public charging, deeper analysis was conducted on how best to do this. Without some sort of public involvement, chargers will tend to be deployed in more affluent areas where EV ownership is higher. Whilst making equity the focus of policy in is likely to be more challenging in the short-term, it is recommended because it will yield better opportunities and outcomes in the long-term.

Community involvement is essential for the equitable approach, which is based upon a direct assessment of their needs and ongoing engagement with them to develop solutions. A suite of mobility equity indicators is suggested for use to measure the results.

| Goal #1<br>Increase Access to Mobility | Goal #2<br>Reduce Air Pollution | Goal #3<br>Enhance Economic Opportunity |
|---|---|---|
| 1. Affordability | 6. Clean Air and Positive Health Benefits | 9. Connectivity to Places of Employment, Education, Services, & Recreation |
| 2. Accessibility | 7. Reduction in Greenhouse Gases | 10. Fair Labor Practices |
| 3. Efficiency | 8. Reduction in Vehicle Miles Traveled | 11. Transportation-Related Employment Opportunities |
| 4. Reliability | | 12. Inclusive Local Business & Economic Activity |
| 5. Safety | | |

Delivering these may require direct funding of community efforts to ensure that historically underserved communities are not left out.

In urban locations, it is concluded that two locations are key to equitable success. Firstly, private residential charging. Specific proposals to target the lack of infrastructure through finance, information, EV-readiness programmes and other incentives are recommended in Section 5.3 (page 29). Where private residential charging is still not possible, public hubs are proposed as the best way to deliver equitable charging access. Here suggestions about alignment with existing community support programmes and strategic placement are put forward.

Considering rural locations, private residential locations are once again in the spotlight. However, here policies must streamline the installation process for those wishing to charge at home. Travel corridors are likely to be most valuable for rural drivers dependent on public charging. Co-location of these with amenities will boost the business case and provide economic activity for the immediate community. Similarly, policies to encourage points of interest and key destinations to be equipped with chargers will assist both tourists and nearby residents.

Furthermore, it is recommended that all chargers deployed are compliant for disabled drivers, potentially enforced through the conditions associated with financial incentives or support.

## Emerging Solutions for Commercial Vehicles

The final section tackles the thorny question of the Commercial Vehicle (CV) sector, which is immature in its development. The operators of these vehicles are much more sensitive to economics, technological risks and operational constraints, making policy formation much more complex.

Nonetheless, Battery Electric Truck (BET) uptake is expected to increase in the coming decade, with lighter vehicles leading. The economic case for electrification is strengthening and product choice is anticipated to grow.

For heavier CVs, a risk remains around the choice of electric over hydrogen and, if electric, whether charging is delivered by wired, wireless or catenary solutions (see table, below).

| | Plug-In conductive | Wireless Power Transfer | Overhead catenary |
|---|---|---|---|
| **Maturity** | Established technology | Under development for power transfer rates needed for CV applications | Established technology for tram and buses – under test for highway trucks |
| **Type** | Stationary | Stationary and Dynamic | Stationary and Dynamic |
| **Standards** | Regulation defined by 15118 (up to 300 kW) but being extended to 1 MW+ by CharIN work | Regulatory standards being formalised but 50 – 100 kW needed for public charging to be effective | |

From an infrastructure perspective, lighter BETs are expected to use the same private and public infrastructure as private vehicles. For heavier BETs, private commercial locations are expected to be the preferred location for charging, where space and the electricity network connection allows. Where this is not possible, it is recommended that a new network of public charging be developed, taking extensions of existing conductive (wired) charging, developments in wireless charging and innovations in catenary systems into account.

The most logical way to approach this puzzle is to start with return-to-depot operations but it is noted that this may not be the most equitable approach due to the structure of the market.

With this in-mind, a range of challenges to BET charging infrastructure are summarised and a series of corresponding recommendations are made to move the CV market forward:

- Low confidence in BET uptake – policies must be set to signal the market more strongly about the decarbonisation of CVs, including combined measures on OEMs, utilities and operators to build compelling reasons to switch;
- Uncertainty in charging technology – encourage research and development into emerging wireless and catenary solutions and define at a high level the potential role of each solution to give confidence into the market;
- High infrastructure costs – ensure finance is available and equitably distributed through grants and investment in CV charging infrastructure;
- Electricity network capacity constraints – ensure the evolving role of the electricity network includes alignment with the public charger rollout so that supply is reinforced at key locations;
- New hidden costs of public charging – consider promoting a parallel CV charging network, including for smaller vehicles that might otherwise be reliant on infrastructure for passenger cars; and
- Lack of infrastructure coordination – set strategic direction to incentivise the co-location of BET charging infrastructure with that for non-commercial vehicles, to make grid upgrades more cost-effective and enhance the business case with amenities.

It is recommended that these are added as a Commercial Vehicle-specific stream to the policy agenda noted before.

## Prognosis

Viewing these observations, conclusions and recommendations in the round, significant progress has been made in the ZEV Alliance jurisdictions, paving the way for other countries and municipalities to learn and follow. These policy recommendations should remove barriers and assist to provide equitable access to infrastructure for priority mainstream users who are reliant on public charging, to ensure a mature, flourishing, and equitable EV charging ecosystem.

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# 1 Introduction

## 1.1 The Project

*We, the participants in the International Zero-Emission Vehicle (ZEV) Alliance, recognise the essential need to reduce greenhouse gas emissions from the transport sector, in-line with international and national goals, to avoid the worst consequences of climate change.*

So begins the Press Release for the formation of the ZEV Alliance in December 2015 at the 21st Conference of the Parties meeting (COP21). In the last five years, the Alliance has grown to a group of 18 countries, jurisdictions and municipalities committed to a collaborative approach to expand the ZEV market and enhance governmental cooperation on relevant policies. The motivation for such a drive is clear at local, national and international levels.

Locally, Zero-Emission Vehicles (ZEVs) are generally cheaper to operate, quieter at slow speeds and more pleasant to drive. Nationally, their uptake will improve air quality, especially in congested zones, as well as creating new economic opportunities in a growing sector. And internationally, the mass rollout of ZEVs should help to slow the pace of global climate change and reduce oil dependency.

Yet despite this multi-scale potential to benefit societies around the world, the proliferation of ZEVs is by no means guaranteed.

Taking the not-insignificant challenges of revolutionising the auto manufacturing industry to one side, access to convenient, reliable, cost-effective charging is a key requirement to underpin the switch. However, charging is far from universally available, requires a change of re-fuelling mindset for almost all drivers and in some segments does not even have a positive business case.

By bringing together inputs from across the globe, this report seeks to highlight the remaining needs in the charging infrastructure ecosystem, with a particular focus on policies to smooth an electrified route to zero-emissions:

- Chapter 2 (page 12) reviews the current status of charging deployments, user segments, charging locations and typical technologies;
- Chapter 3 (page 16) outlines the gap between current and best-practice, and industry stakeholder's views of the barriers to success;
- Chapter 4 (page 21) evaluates the business case for public charging;
- Chapter 5 (page 27) explores the case for equitable charging; and
- Chapter 6 (page 27) examines emerging solutions for commercial vehicles.

A series of policy recommendations are proposed for the Alliance members to consider as routes to fulfil and extend their worthy commitment from 2015.

## 1.2 Scope

The issues and challenges which advice on international EV charging infrastructure could tackle are significant in their breadth and depth. To allow this specific piece of work to play its role in the wider tapestry of activities being carried out by the ICCT and ZEV Alliance, this report is scoped in the following ways:

### *1.2.1 Technology*

The move towards zero-emission transport can incorporate a range of technologies. This report is focused on electrification of vehicles, usually referenced as Electric Vehicles (EVs) or Battery Electric Vehicles (BEVs).

### *1.2.2 Industry*

Although much can be said about the vehicle side of the ZEV revolution, the primary focus of this report is on the EV charging infrastructure.

### *1.2.3 Geography*

This report is focused on global advice but with a particular focus on the geographies of the project team and ZEV Alliance members.

### *1.2.4 Users*

Although private charging infrastructure at homes and workplaces is a key facilitator of EV uptake, this report focuses on public charging infrastructure.

## 1.3 Navigation

Electric Vehicle infrastructure has different nomenclature across the globe.

The term ‘charger’ is used throughout this report to refer to Electric Vehicle Supply Equipment that can dispense a charge via one of more sockets. Typically, lower-powered chargers have two sockets to allow them to serve multiple vehicles, whereas higher-powered chargers have one socket.

To identify the different charger types, the following classification has been used:

*Table 1: Charger types*

| | Slow | Standard | Fast | Rapid | | Ultra-Rapid |
|---|---|---|---|---|---|---|
| **AC or DC** | AC | AC | AC | AC | DC | DC |
| **Power (kW)** | < 7 | 7 – 10 | 11 – 22 | 43 | 50 | 150+ |
| **Also known as** | Level 1 | Level 2 | | DC Fast Charge | | |

When referring to vehicle types, the US Class system has been used (see Appendix 5 on page 54 for more details).

Each chapter of the report covers a different aspect of the brief, along with appropriate commentary and recommendations. The appendices contain explanations of the methodologies and key assumptions for any calculations.

Key conclusions, recommendations or takeaways are highlighted like this.

! Important notes are highlighted like this.

*Case Studies are highlighted like this.*

# 2 Background and Motivation

## 2.1 Current Status

### *2.1.1 Global uptake of EVs accelerating*

The switch from Internal Combustion Engine (ICE) vehicles to Electric Vehicles (EVs) is increasing in pace across the world. Driven by policy announcements such as the phase-out of conventionally-fuelled vehicles between now and 2050, an expanding range of cars, vans and even commercial vehicles are giving drivers greater zero-emission transport options. As a result, EV uptake is expected to accelerate in the coming years, with Canada moving its target to 2035 and Austria joining the group at 2030 since Figure 1 was published.[i]

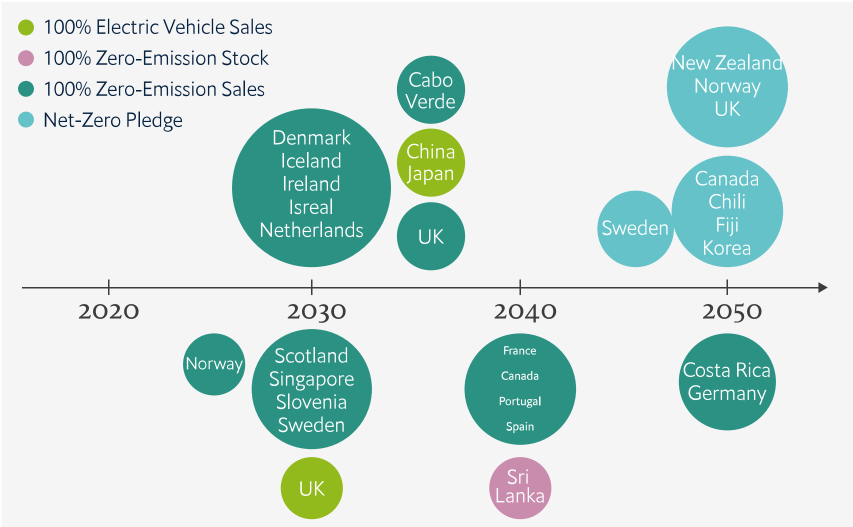



*Figure 1: International policy positions on zero-emission transport*

### *2.1.2 Global deployment of charging infrastructure expanding*

Correspondingly, the deployment of EV charging infrastructure is accelerating to meet this growing demand. Between 16 and 25 million public chargers are projected to be installed by 2030 from a baseline of around 1.3m public chargers at the end of 2020.

When examined in more detail, a varying picture emerges across the globe. Figure 3 shows that around 70% of all worldwide public chargers are installed in China, where each charger serves around five EVs (as indicated by the labels). Europe follows behind with 20% of the share and a slightly larger charger:EVs ratio. The rest of Asia has around 8% of the global total, primarily in Japan with a ratio of 1:5. North America is close behind with 6% but here there are 12 EVs for every public charger. Finally, South Africa has just 0.02% of the world's EVs.[ii]

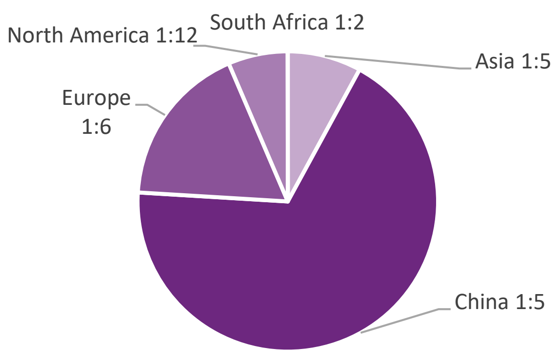



*Figure 3: 2021 locations of public chargers in 2021 and the ratio of EVs-to-chargers*

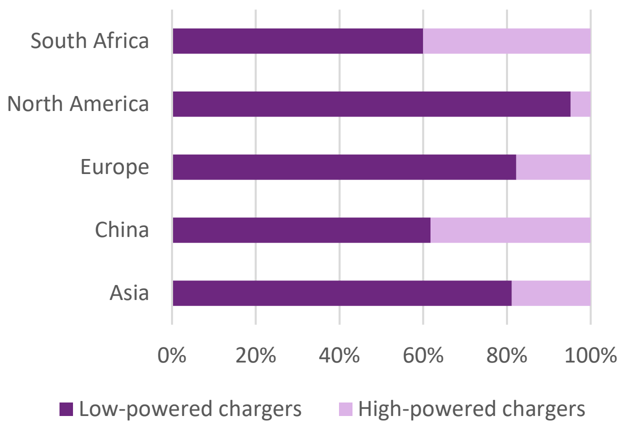



*Figure 3: Proportion of lower- and higher-powered chargers by location*

The charger:EVs ratio gives an indication of how infrastructure deployments are tracking EV uptake but should not be used as the basis for international benchmarking. Whilst a lower ratio may indicate a more widespread public charging network, the specific value will reflect many different local factors. For instance, the US tends to have a greater number of single-family homes with private residential charging, compared to Europe or China. This increases the ratio (because more vehicles can charge at home) and tends to reduce the proportion of chargers which are higher-powered (for the same reason). In the case of North America, just 5% of chargers are higher-powered (Figure 3).

In contrast, some 20% of the public chargers in Europe and Asia are more powerful, where there is a greater need for quick charging options for the many without the opportunity to charge at home. For example, Norway has at least two multi-standard public chargers every 50km on all main roads.

In the markets with high EV penetration, the low-hanging fruits of home charging, rapid charging and destination charging are already mostly solved from technology, customer and commercial perspectives. The supply chain for wired charging is maturing in more affluent markets (such as North America, Europe or China), with a wide range of reliable and compliant solutions across the spectrum of charging powers. This implies a positive outlook for those countries just entering the early adopter phase of uptake.

To extend the metaphor, the *mid-canopy* of hubs, workplace/fleet scenarios, rural situations and public residential needs are still at an early stage even in the most mature markets and are likely to need targeted policies to unlock. The hardest questions of tenant/leaseholder rights, disabled accessibility and ensuring equitable access to all types of EV charging are only just being tackled.

> Current EV charging infrastructure varies dramatically by continent but also according to local factors, which makes international comparisons difficult using simple ratios. Deployments are accelerating, supported by expanding supply chains and standards. Even the more advanced markets still need policy interventions to ensure equitable access to charging regardless of land tenure, disability or socio-economic status.

## 2.2 EV User Infrastructure Requirements

### *2.2.1 Priority user groups*

International stakeholder workshops held by the GSMP in Europe, India, South Africa, the USA and UK sought to understand the groups that will need the greatest policy support. An exercise was undertaken to categorise the most important current and future EV user groups (Table 2).

! These are presented in the order captured by each workshop and reflects regional terminology.

*Table 2: Top priority EV user groups identified by workshop*

| | Europe | India | South Africa | USA | UK |
|---|---|---|---|---|---|
| **Group 1** | Private & hired commuters | Two-wheelers | Private car owners | TNC drivers | Private on-street |
| **Group 2** | Home/errands | Three-wheelers | Government fleets | Private users in high-rise | Private off-street |
| **Group 3** | Taxi/ride-hailing | Four-wheelers | Micro-mobility logistics | Private users in family house | HGVs (en-route) |
| **Group 4** | Short distance logistics | HGVs and buses | Car sharing | Fleet drivers (en-route) | Company car drivers |
| **Group 5** | Commercial users | Agricultural vehicles | Utility vehicles (agriculture, mining) | Fleet drivers (depot-based) | Rural drivers |
| **Group 6** | Car sharing | [blank] | [blank] | Rural drivers | Taxi drivers |

The most common groups highlighted across all workshops were private users, commercial vehicle drivers and company car fleets. Niche fleets in agriculture and mining were common key groups for South Africa and India, and the latter added the two and three-wheeler parc, which presents its own unique charging needs. Taxi and ride hailing drivers were also recognised as important user groups in the UK, USA, and the Netherlands.

### 2.2.2 User segmentation

Through analysis of the workshop outputs, a clear division emerged between those who can charge privately (whether at residential or commercial premises) and those who cannot. In the former segment, drivers who have access to private off-street parking at home or a workplace will be less reliant on public infrastructure as they can charge at their convenience during downtime.

Those who cannot charge off-street can be sub-divided further:

*Table 3: Segmentation of those who cannot charge privately*

| Segment: | Typical Vehicle Types: | Needs: |
|---|---|---|
| Private vehicles | 2-wheelers, cars | May use removable batteries which can be swapped or publicly charging<br>Those parking on-street at home rely on public chargers |
| Fleets and Staff | Cars and LGVs | Require en-route charging to complete their operations |
| Rural | Cars, LGVs and specialised industrial vehicles | Face lower public charger provision, higher mileage and constraints in the electricity network |
| High mileage local | Taxis, LGVs, 2-wheelers and 3-wheelers | Need regular on-the-go charging for their operations |
| Long haul | HGVs | Need dedicated depot charging and/or reliable en-route charging for their journeys |

It is worth nothing that this is not an exhaustive segmentation and some users may be in multiple segments (e.g. fleets in rural locations).

### 2.2.3 Common charging locations

The workshops also highlighted commonalities in how each segment is likely to prefer particular charging locations, according to their driving patterns and charging needs:

*Table 4: Common charging locations and the segments they serve*

| Location | Private | | Public | | | |
|---|---|---|---|---|---|---|
| | Residential | Commercial | Roadside | Destination | Hub | Travel Corridor |
| **Dwell Time** | Long | Short or long | Long | Short to medium | Short to medium | Short |
| **Payment** | Access free. Electricity paid | Access free. Electricity paid | Paid | Paid | Paid | Paid |
| **Segment** | Private vehicles | Fleets and staff | Private vehicles. High mileage local | Private vehicles. Rural Long haul | Fleets and staff. High mileage local | Fleets & staff. Rural. Long haul |

Infrastructure policies must differentiate between those who charge at private locations and those who need public charging, regardless of vehicle type.
Within the public charging group, policies will need to focus on the different common user groups and their typical charging locations to ensure proper support for electrification.

## 2.3 Charging Equipment Types and Use Cases

To serve these segments, both private and public chargers will need to be installed, operated and maintained. Charging equipment is normally divided into categories (or 'types') according to its power, reflecting how much electrical energy it can transfer in a given time period (Table 5). As a rule of thumb for vehicles achieving 3 miles per kWh, the power is equivalent to the number of miles of range added every 20 minutes of charging.

When the speed of charging, tariff levels, ease of installation, electricity grid impact and business case are examined, each charger type is seen to have different strengths and drawbacks. Therefore, different types will best-serve the locations identified above:

*Table 5: The locations best-served by different charger types*

| | Slow ϟ | Standard ϟ ϟ | Fast ϟ ϟ ϟ | Rapid ϟ ϟ ϟ ϟ | Ultra-Rapid ϟ ϟ ϟ ϟ ϟ |
|---|---|---|---|---|---|
| **Locations** | Private residential<br>Public roadside | Private residential<br>Private commercial<br>Public roadside | Private commercial<br>Public destination | Private commercial<br>Public destination<br>Public hub | Public hub<br>Public travel corridor |

By combining Table 4 and Table 5, an outline of an effective charging ecosystem emerges. For example, the *high mileage local* segment without access to private charging will typically use public roadside charging if their dwell times are long and public hub locations if their dwell times are shorter. In the former location, they would be expected to be served by a Slow or Standard charger; in the latter a Rapid or Ultra-Rapid charger would be more appropriate.

> Effective charging ecosystems match user segments with charging locations and charger types, primarily driven by the public/private charging divide and the relationship between dwell time and charger power.
> Policies to mature the market should support different charger types in different ways, as expanded in later sections.

## 2.4 Conclusions

The current deployment of charging infrastructure varies dramatically by continent and according to local factors. In the coming decade, EV uptake is expected to accelerate as they become a mainstream option for personal and commercial vehicles. Charger installations are also expected to accelerate, supported by expanding supply chains and standards. A range of policy interventions are needed to ensure equitable access to charging, regardless of land tenure, disability or socio-economic status, as well as sharing examples of best practice internationally for those points already well-addressed in more advanced markets. These are discussed in more detail in subsequent sections.

Users are divided between those who can charge privately and those who cannot. In the latter case, the stakeholder groups highlighted *private vehicles*, *fleets and staff*, *rural*, *high mileage local* and *long haul* segments as the priority segments. As a result, it is expected that the demand for Fast, Rapid and Ultra-Rapid chargers will increase significantly. In order to serve these segments well, plans for dedicated public hubs and public travel corridor locations to host these chargers for *fleets & staff*, *high mileage local* and *long haul* drivers will need to be accelerated.

Therefore, infrastructure policies must address those who will charge privately and those who cannot. Effective charging ecosystems will match user segments with charging locations and likely charging types. This means that policies are likely to need to support different charger types in different ways.

If achieved, this will deliver a significant and positive shift towards a more customer-orientated and diverse charging network, whatever the starting maturity of the market.

# 3 Building a Charging Ecosystem

## 3.1 Introduction

The prognosis for global EV uptake and charging infrastructure deployment is clear. Significant growth is anticipated, which will need a range of charger types to be deployed across different charging locations to meet the needs of each user segments.

To achieve this, a range of governmental structures and strategies will need to be in place. This section outlines the key best practice and reflects outside-in on the present situation. It then looks inside-out at stakeholders' views on the barriers that exist to meeting the ideal, along with potential policy solutions to overcome the barriers.

## 3.2 Targeting a Mature, Flourishing Charging System

### *3.2.1 Dedicated Government focus*

A mature charging system will take time to establish and will not flourish without specific and intentional action by public authorities of all shapes and sizes. A common feature of the jurisdictions in the ZEV Alliance is their dedicated government focus:

- Norway introduced the first EV policies in the early 1990s and has delivered a comprehensive legislative programme in the years since, coordinated by the Ministry of Transport;
- Transport Canada oversees a series of vehicle and infrastructure incentives programmes;
- The UK government has set up the Office for Zero Emission Vehicles to act as a nexus in government for the topic;
- In Germany, the Federal Ministry for Economic Affairs and Energy has the responsibility for driving the transition; and
- In the Netherlands, the Ministry of Economic Affairs and Climate owns the brief.

For these countries, the gap from present charging system to maturity is quite small. Although a ten- to fifty-fold increase in chargers may be needed to support the projected EV uptake, the governmental focus to achieve this is already present.

> Other jurisdictions, whether intending to be Alliance members or not, should consider a dedicated brief within their equivalent Transport Ministry or Energy Departments.

### *3.2.2 Infrastructure strategy*

A further commonality between the countries noted above is a published Electric Vehicle strategy.

Although high-level strategies have little tangible impact on drivers' day-to-day experiences in the short term, these national documents set the direction of travel and define the parameters within which the long-term consumer experience is established. Given the commitment of ZEV Alliance countries to the transition to EVs, it is unsurprising that there is also little or no gap at a national level between the ideal strategy and the status quo. If the published strategies are updated regularly to account for changing technologies and market conditions, this will continue to be a policy strength.

> *The German Programme for Electric Mobility,[iii] Canadian Zero Emission Vehicle Infrastructure Programme[iv] and Dutch National Charging Infrastructure Agenda[v] are excellent examples of National EV Infrastructure Strategies. They present the vision for the mobility systems of the future, outline the role that electric mobility has to play within this and articulate the role that public authorities can play to achieve this.*

Importantly, the policies shape co-investment strategies by the Automotive industry, the energy sector and EV charging infrastructure players. The latter group is particularly diverse ranging from companies dedicated to offering publicly accessible networks for users, through to hosts adding charging as a feature at their facilities to ensure ongoing customer visits where a lack of infrastructure would lead drivers to go elsewhere.

This multi-stakeholder aspect of the e-mobility ecosystem is a contributor to what, at the more granular scale, is much more mixed picture. Given this complexity and need to leverage market forces, the influence of place becomes important and the process of devolving responsibilities from a national to a federal, regional or local level can be at varying stages of maturity. Also, different political leadership and priorities can lead to local strategies sometimes exceeding or conflicting with the national direction.

Considerably more work can be done to harmonise the strategic layers and ensure clarity on the roles and responsibilities of different levels of government.

### 3.2.3 Infrastructure targets

Figure 1 showed just how many jurisdictions have vehicle-related goals but a mature, flourishing charging system will also have infrastructure targets. These act to both set a standard against which success is measured and create Key Performance Indicators (KPIs) which indicate progress towards the standard.

The best targets are contextual to avoid burdensome or inappropriate metrics. For much of the last decade, the charger-to-EVs ratio has dominated, as exemplified by the pre-2021 Alternative Fuels Infrastructure Directive (AFID) target of 1:10 for the whole EU. However, Section 1 noted that this measure is too simplistic to account for international socio-economic variations.

Therefore, new types of targets are emerging, for instance:

- The ratio of certain types of chargers to particular types of vehicles – e.g. fast chargers per Battery Electric Vehicle);
- The density of chargers compared to population density - e.g. chargers per square urban mile; or
- The distance between chargers on key routes – e.g. Rapid- or Ultra-Rapid chargers per Strategic Road Network mile.

*European non-governmental organisation Transport & Environment (T&E) has proposed a Supply Metric for EU Member States which takes into account national housing statistics, vehicle sales and average distance driven, then weights chargers according to their power to give a more contextual target.[vi] This target aims to dissuade public authorities from deploying a greater number of lower-powered chargers simply to achieve a charger:EV ratio target and recognise the role of different charger types in different situations.*

The gap between the current situation and the desired nuanced targets is significant. Very few jurisdictions have implemented these sorts of goals.

Targets should extend beyond the quantity of chargers to more locally adapted metrics. This will determine the acceptable standards and availability of the infrastructure, to ensure a charging system that is both fit and ready for the consumer.

### 3.2.4 Consumer representation

The most mature charging ecosystems will have good consumer representation. The Norwegian EV Association has been working for drivers for 25 years, representing their interests to government, industry and other organisations. By contrast, the UK only had Electric Vehicle Association (EVA) Scotland until the launch of EVA England in 2021.

These private member groups are critical to represent the voices and views of drivers to government, alongside the voices of the charger industry, vehicle manufacturers and vehicle sellers.

This is an area where many jurisdictions could do more to encourage formal advocacy and representation to grow.

## 3.3 Barriers and solutions

With these markers of a mature charging system clarified, it appears that the ZEV Alliance markets in particular have many of the right building blocks in-place. An inside-out process was conducted through the international stakeholder workshops to understand which barriers industry participants believe remain and the potential policy solutions which could address these.

One point to note across all solutions is that a big challenge for policy makers is to find the best way to police mandates or voluntary codes of practice.

> Sharing best practice working toward a uniform approach within a market is considered worthwhile, rather than the 'big stick' approach of rapid legislation.

### 3.3.1 Reliability of public chargers

All workshops highlighted that public chargers are often viewed as unreliable, due to long periods of downtime from faults, upgrades or poorly-maintained legacy hardware. Although range anxiety still exists for some drivers, the greater concern is now 'charging anxiety'. In the driver's mind, this can be exacerbated by a gap between the public perception and reality but there is undoubtably an issue. Poor reliability or poor perceived reliability can discourage those who would be dependent on public charging from adopting an EV.

***Potential Solutions***

- Mandate real-time broadcast of the location, type and availability of public chargers.
- Set minimum uptime requirements for individual public chargers for a guaranteed level of service.
- Apply minimum hardware and communications standards (especially in public procurement or where bundled with incentives) to avoid infrastructure becoming obsolete or inoperable.
- Encourage sharing of private residential chargers to reduce the burden on the public network.
- Encourage a 'right to charge' at workplaces to reduce the burden on the public network.

> Public charger reliability must be guaranteed visibly to users through technical and contractual means to build up confidence in the network.
> Increased private residential charging through sharing and giving access to private commercial chargers may lessen the demand on public networks.

### 3.3.2 Interoperability

Drivers' desires for reliable public charging are closely linked to their desire for interoperability. In more mature markets, a plethora of apps, RFID cards and accounts is often needed to traverse the country in an EV. This was recognised by stakeholders in the UK, USA and South Africa as an 'internal problem' but also constitutes an international issue in Europe where driving between countries is common.

Furthermore, understanding EV tariff structures can itself take some time for drivers who are used to a simple price-per-volume fossil fuel system. Pricing can be presented as a price-per-kWh, price-per-time or price-per charging session. This has the double disadvantage of making it hard to compare between chargers. In the extreme, some US States only permit electric utilities to sell electricity by the kWh, leading to different tariff structures from the same charger operator in different states.

***Potential Solutions***

- Require standardised communication protocols and open data from all chargers to facilitate the spread of e-Mobility Service Providers (e.g. Open Charge Point Protocol).
- Facilitate integrated payment solutions (e.g. combined parking and charging tariffs).
- Encourage network roaming availability at no cost to driver.
- Legislate for transparent and comparable pricing structures.

> Standardisation of protocols, payment, pricing structures and access will improve customers' experience, some of which may require legislative interventions.

### 3.3.3 Lack of coordinated policy

The workshops confirmed that the lack of coordinated international, national, regional and local policy and strategies to enable a reliable and interoperable public charging network is a clear issue for stakeholders. In Europe, regulations are not always applied in the same way across all countries – for instance the EV uptake projections for the next decade range from 1% to 40% across the member states.[vii] In the UK, it was mentioned that public authorities do not have the capacity or capability to enact a comprehensive public EV charging infrastructure strategy, whereas contributions from the Netherlands indicated that there can be over-regulation by municipal governments which can hinder progress. In the USA there is a particular issue with a lack of legislation in building regulations to enforce the installation of EV charging infrastructure in new developments.

***Potential Solutions***

- Create effective and coordinated multi-scale strategy to coordinate, guide and support local authorities to implement the required public infrastructure.
- Integrate charging requirements into building and planning legislation to ensure a minimum number of chargers is installed at new developments.
- Develop systems and support networks to share best-practice between local authorities, industry and central government to ensure guidance and regulations are feasible, proportionate and do not stifle innovation.

Coordination and best practice sharing between and across the different levels of government with clear national expectations will facilitate growth.

### 3.3.4 Electricity network constraints

Electricity network issues were recognised in USA, UK, and South Africa as significant barriers for infrastructure. Summer black- and brown-outs have regularly been a challenge for the electricity network in the USA in recent years, so there are doubts that the network is reliable enough to support an increasing number of EVs in the vehicle parc. The stability of the electricity supply was also considered a barrier in South Africa where there is a question of how an increased number of EVs can be introduced into a country already suffering an energy supply crisis. In the UK, stakeholders reported that the biggest issue for infrastructure deployment was the cost and length of time required for the upgrade of electricity network connection, especially for Rapid chargers.

***Potential Solutions***

- Publish detailed electricity network capacity data so public and private infrastructure planners can see where constraints are and plan charging locations accordingly.
- Support the integration of EV charging with battery storage and on-site renewable generation to take the pressure off the electricity network.
- Create EV-specialists or departments within electricity network operators to prioritise and fast-track EV charger connection requests.
- Ensure electricity providers have the legal authority and obligation to plan for and support growing EV charging needs.
- Promote managed charging through a variety of technology, behavioural, and economic incentive approaches, including requiring that all chargers are smart and connected.
- Focus public investment in EV charging on network upgrades

Significant work is needed to prevent network constraints being a barrier, through data sharing, innovative technologies, building expertise, mandating investment and funding.

### 3.3.5 Poor business case

Finally, all workshops noted that the business case for public charging infrastructure was a challenge. In India and South Africa, where EV penetration is currently low, this is exacerbated by the low density of EVs, which acts as a drag on the rate of deployment. Yet even in the US, UK and European markets which have greater EV penetration, Rapid and Ultra-Rapid charging still attract high installation and operation costs that make the business case hard to justify. Furthermore, in lower income areas, the need to keep public charging affordable for those who do not have access to private charging reduces the revenues for charging operators to invest in those areas.

***Potential Solutions***

- Targeted and more consistent funding and investment, particularly for low-income areas.

- Support governmental, municipality or council ownership and operations of charger networks or funding support for private operators where public intervention is necessary.
- Ensure policies and interventions target a *just transition* that provides a better quality of life and places society's interests at a similar level of profitability.
- Target grants at electricity network upgrades and not just charging hardware.

The business case for public charging may need direct financial intervention or public ownership to ensure a just transition.

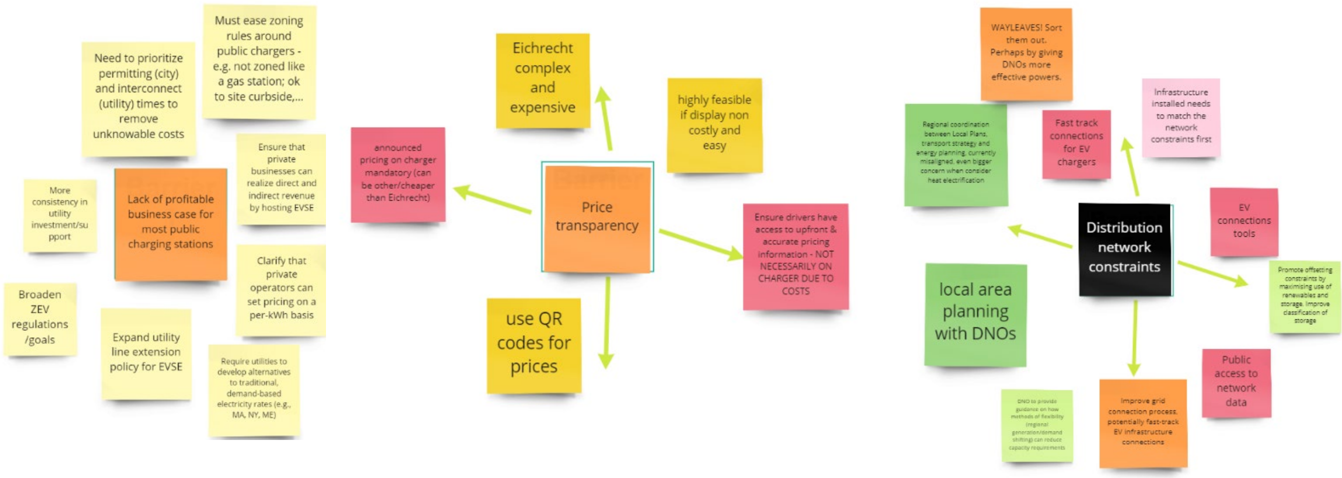



*Figure 4: Selected suggested verbatim policies from stakeholder workshops*

## 3.4 Conclusions

Mature and flourishing charging systems are more likely to exist with specific government focus, most likely through a dedicated Transport or Energy ministry brief. This will locate responsibility for the production and maintenance of an infrastructure strategy, as well provide a centre of gravity from which activity in the different levels of federal, regional and local government can be coordinated.

Targets on infrastructure deployment will be needed to act as a standard against which success and progress can be measured. The best will be adaptable to local settings as they determine the standards and availability of chargers that will be needed to ensure a good customer experience. Supplemented by a strong customer voice, this will complete the feedback loop to the governmental departments.

In the case of the ZEV Alliance jurisdictions, many of these building blocks are in-place. A range of additional solutions have been suggested to overcome existing barriers highlighted by the international workshops. These seek to deliver a reliable, interoperable, coordinated, unconstrained and profitable charging network that supports those who are reliant on public charging. Where sharing of private residential chargers or access to private commercial charging is possible, this may reduce the number of public chargers needed by spreading the load. Some of these suggestions will require direct financial or legislative intervention.

# 4 Improving the Business Case for Public Charging

## 4.1 Introduction

The robustness and profitability of the business case for public charging has already been noted as a key barrier in the global deployment of charging infrastructure. Even if governments are able to construct and apply policies to overcome the other issues identified in the previous chapter, if there is no acceptable business case, then the much-needed private investment and innovation will be lacking.

This chapter examines the range of possible ownership and operational models available to public authorities, the case for public charging and the sensitivities of the business model to key input parameters.

## 4.2 Ownership Models

Four common public charger ownership models are used in mature markets. In each model, elements of the capital cost, operating cost and revenue are shared differently between the landowner and charger provider.

### *4.2.1 Ownership Models Options*

A summary of the typical proportions of cost incurred and revenue retained by the landowner (usually the national or local government) in different ownerships models is shown in Table 6.

*Table 6: Illustrative example of proportion of costs incurred and revenue retained by landowner across ownership models*

| | Hardware | Ground-works | Back-office | Electric | Mainten-ance | Income |
|---|---|---|---|---|---|---|
| **Own and Operate** | 100% | 100% | 100% | 100% | 100% | 100% |
| **External Operator** | 100% | 100% | 0% | 100% | 100% | 90% |
| **Lease** | 0% | 0% | 0% | 0% | 0% | 20% |
| **Concession** | 0% | 100% | 0% | 0% | 0% | 30% |

When making decisions on charger ownership models, it is important to also consider the non-financial implications of each model. Whilst the most obvious distinctions between each ownership model are in how costs and revenue are shared, there is also a variable share in the contractual control over how the chargers are operated. In most cases, the greater the investment made by an external supplier(s), the greater the control of the supplier(s). In turn, this means that the landowner will have less control over the quality and type of service(s) provided to EV users on their site which, in a worst-case scenario, could create a negative perception of the landowner that they cannot easily address.

Regardless of the ownership model pursued, contractual terms should be sought that ensure both financial and reputational risk are fairly distributed and that the level of service to EV users is maintained to the satisfaction of the landowner.

### *4.2.2 Ownership Model Analysis*

The ownership models have been qualitatively compared regarding their suitability for specific EV charging infrastructure applications and for elements of financial and operational considerations that should be made when planning an EV infrastructure network.

The definition of the criteria is shown in Table 7:

*Table 7: Definition for criteria used to score different ownership models for their suitability.*

| Group | Criteria | Definition |
|---|---|---|
| Charging Infrastructure Use Cases | Roadside | Suitability to implement and operate Standard chargers in residential locations. |
| | Destination | Suitability to implement and operate Fast or Rapid chargers in destinations such as retail, leisure and tourist attractions. |
| | Travel Corridor | Suitability to implement and operate Rapid or Ultra-Rapid in travel corridor locations such as on the strategic road network and/or motorway services. |
| | Hub | Suitability to implement and operate clusters of Rapid or Ultra-Rapid chargers. |
| Network Finance and Operation Considerations | Revenue | Potential to generate ongoing revenue for the public authority and/or landowner. |
| | Risk | Short-to-medium-term financial risk to public authority and/or landowner. |
| | Service | Ability for public authority and/or landowner to control the level of service provided to EV users. This takes into account factors such as network interoperability, ad-hoc payment, open data and equipment reliability |
| | Resource | The amount of internal resource required to implement and operate EV charging infrastructure under the given ownership model. |

***Own and Operate***

The “Own and Operate” model represents the most involved level of intervention for the landowner. All costs are covered, and all revenue is retained by the landowner. The landowner prepares the site, including groundworks and electrical connection, procures the EV charging equipment, funds the installation of the equipment and purchases a back-office system to manage the charger. All revenue is hence retained by the landowner. By comparison with other ownerships models, Own and Operate offers the greatest revenue opportunity but also the greatest risk to the landowner. In this model, the landowner has control over all aspects of how the charger is operated.

Own and Operate is particularly appropriate for public roadside charging. This is because the short-term commercial business case for investing is often unattractive and therefore can be difficult to procure private suppliers who are prepared to accept the associated financial risks.

***External Operator***

The “External Operator” model is identical to the Own and Operate model in all regards except that the operation of the charger is procured through an external supplier. The supplier then provides the back-office system at no direct cost, in return for a share of net revenue gathered by the charger. This ownership model removes some of the operating expense associated with the charger, therefore reducing the risk whilst retaining most of the revenue gathered by the charger. The capital investment is still entirely provided by the landowner and, in all regards except for network compatibility, the landowner retains control of how the charger is operated.

The involvement of a contracted third-party operator to share a degree of the financial risk and take on most of the operational activities reduces risk and resource requirements to the landowner. The local authority will lose some control over the level of service provided, as an external operator would want an additional amount of operational control in exchange for their investment. Like Own and Operate, it is well-suited to public roadside charging.

***Lease***

The “Lease” ownership model represents the lowest level of investment from the landowner. In this model, all capital and operating costs are covered by an external supplier, with a share of revenue retained by the landowner in return for making their land available. This model involves the least exposure to financial risk but also the least opportunity for revenue generation.

The Lease model is not without other risk or challenges, however. The success of this model relies on sourcing an external supplier with the appetite to accept the financial risk, which will be dependent on the type of site being offered and the revenue generating potential that it presents. In less ideal sites, external suppliers may seek additional contractual assurances to mitigate long-term risks, such as having autonomy over usage tariffs, a longer lease period, 24-hour access and/or favourable contract termination conditions. Another key risk to the landowner is that, as the external supplier has ownership of the electrical connection point, the landowner may incur additional costs associated with asset transfer of the connection point at the end of the contract period.

The attractiveness of a lease proposition to a commercial investor relies solely on the anticipated charger usage. As a result, the Lease model will typically only be appropriate in locations with the high vehicle traffic and high-powered equipment to take advantage of it. With high commercial interest in public hub or public destination locations, the benefits of the lease model to a public authority are reduced risk and ongoing resource requirements. These benefits come in exchange for lower revenue generation potential and little or no control on level of service provided beyond what is already offered by a supplier.

***Concession***

The “Concession” model is similar to the Lease model but much of the risk to the landowner is mitigated in exchange for a lower share of revenue. The key difference between the Concession and Lease models is that the landowner provides the capital investment to establish an electrical connection point for an external supplier to install and operate a charger. The benefit of this model is that, as the landowner retains ownership of the connection point, there is no lasting obligation to the external supplier, beyond the terms of their concession. This increases their control.

By sharing the risk and revenue more evenly than in the Lease model, a Concession model can be considered as the middle-ground between public intervention and private enterprise. This approach is particularly appropriate for higher powered infrastructure where meeting the cost of establishing an electrical connection point can be key to unlocking private investment – most likely to be the case in travel corridor charging applications.

***Results***

Scores from one to five – representing least to most ideal – and a red-amber-green scheme have been given against the eight criteria for each ownership model, summarised in Table 8.

*Table 8: Summary comparison of EV infrastructure ownership models, their relative strengths and weaknesses and their appropriateness for different types of infrastructure installations.*

| Ownership Model | Charging Infrastructure Types | | | | Network Finance and Operation | | | |
|---|---|---|---|---|---|---|---|---|
| | Residential | Destination | Travel corridor | Hub | Revenue | Risk | Service | Resource |
| Own & Operate | 5 | 3 | 3 | 2 | 5 | 1 | 5 | 1 |
| External Operator | 4 | 3 | 3 | 2 | 4 | 2 | 4 | 3 |
| Lease | 1 | 4 | 2 | 5 | 1 | 5 | 1 | 5 |
| Concession | 1 | 3 | 5 | 3 | 3 | 3 | 3 | 3 |

! Note that a score of 1 means ‘least ideal’. For revenue, 1 means the lowest income but for risk, 1 means the highest risk. A score of 5 means ‘most ideal’ (e.g. highest income and lowest risk).

From a national or local government perspective, the Own and Operate model is best-suited to public residential charging locations, although the External Operator model is a strong second.
In contrast, public hubs are best-operated under a Leasing Model and the Concession approach most closely fits public travel corridor locations.

## 4.3 Public Charging Business Case

### *4.3.1 Outline Business Case*

An outline business case for different charger types was constructed using input data from the Netherlands, UK and USA. All public charger installations involve similar stakeholders whose costs and revenues come from similar sources:

*Table 9: Common charger cost and revenue sources*

| Capital Costs: | Operating Costs: | Revenue Sources: |
|---|---|---|
| Hardware | Electricity | |
| Groundworks | Maintenance and servicing | Customer tariffs |
| Installation | Repair | Leasing fees |
| Communications infrastructure | Communications channels | |

These costs and revenues were used to construct a comparison of the 10-year Net Present Value (NPV) in a hypothetical installation of 10 Standard, Fast, Rapid and Ultra-Rapid chargers (see Appendix 4 on page 51 for details of the key assumptions and inputs).

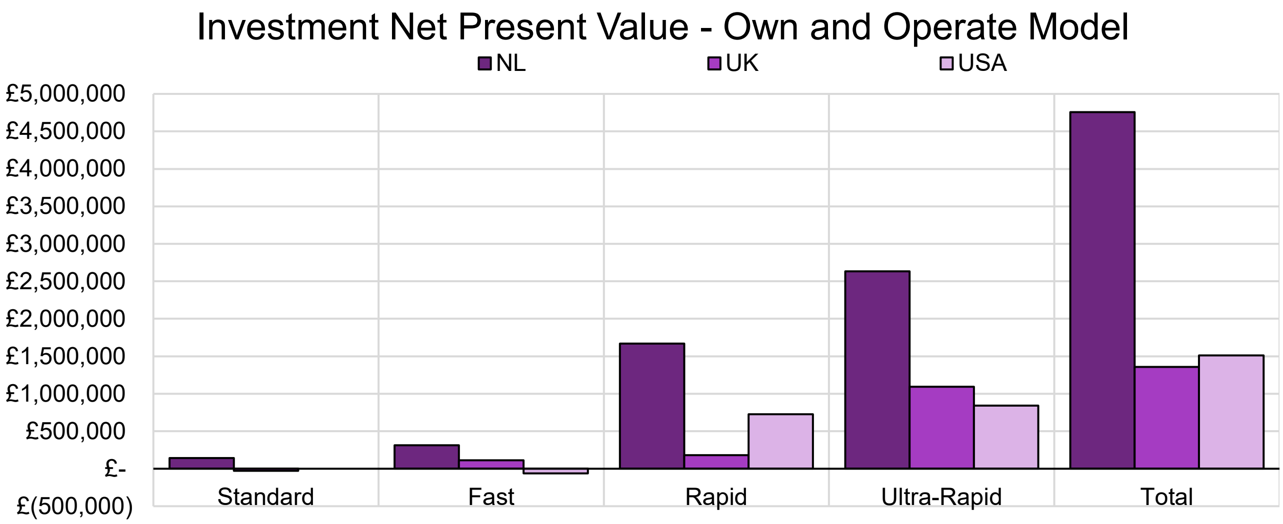



*Figure 5: NPV for the Own and Operate Model*

Figure 5 shows that the investment value of chargers in all countries increases with the charging power. Standard and Fast chargers have a generally low or slightly negative NPV, whilst Rapid and Ultra-Rapid chargers have a significant NPV.

Chargers in the Netherlands are financially more viable than their UK or USA counterparts because the tariffs charged are higher across all EVSE categories.

In the UK, Rapid and Ultra-Rapid chargers deliver a positive NPV, whereas Standard is judged to be slightly loss-making. This is because the more powerful chargers deliver more charging sessions per time period and command a higher tariff.

The results are similar in the USA in that the positive NPV for investment in more powerful chargers outweighs that for slower EVSE to give an overall positive NPV. However, there is a smaller step change between DC Level 1 (equivalent to Rapid) and DC Level 2 (equivalent to Ultra-Rapid) than in the UK. This is because the inputs received for public charging in the USA are on a per-time basis, rather than per-kWh as in the Netherlands or UK. This means that charging at a higher power is better value for money for the consumer as it will take less time to charge and so will pay less for using the charger. However, this also reduces the value of the EVSE for the operator as they recoup less profit compared to per kWh tariffs.

In all three cases, the NPV increases with the power of the charger.

When the effect of the chosen ownership model is included, the NPV values available to the landowner are, of course, lower when Lease or Concession models are applied. This underlines how much the ownership model impacts the financials when involvement in the charging arena is considered by public authorities. For example, attempting to let a Concession contract for Standard chargers in the Netherlands is likely to attract any private tender responses as the meagre total NPV must be split between landowner and contractor.

The NPV available must be viewed from the perspective of both the landowner and contractor to ensure that the chosen model is suited to the charger type.

### *4.3.2 Sensitivity Analysis*

The outputs of any modelling are only as good as its inputs and therefore the specific values presented above are indicative rather than specific. Detailed business modelling should be undertaken before any significant investments are made on this basis.

However, by re-running the model, a sensitivity analysis has been completed to allow these results to be transposed across national boundaries where the specific inputs may differ from those captured for the Netherlands, UK and US.

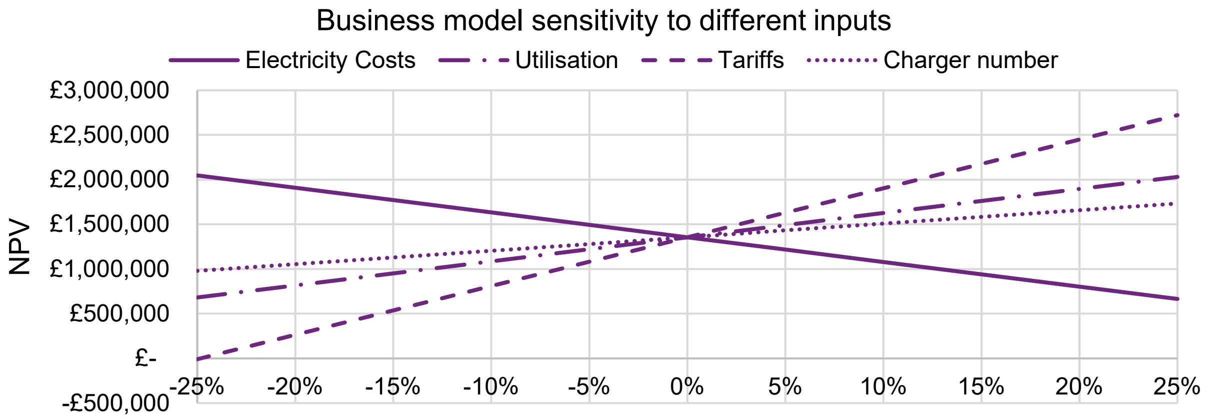



*Figure 6: Business model sensitivity to different input parameters*

Figure 6 shows the impact that increase or decreasing the electricity costs, utilisation, tariffs and charger numbers by up to 25% has on the NPV of the same hypothetical installation in the UK using the Own and Operate model.

! Note that this sensitivity analysis does not include any corner cases where for instance the tariff drops below the wholesale electricity cost.

Electricity Costs have an inverse impact, as would be expected since it is a cost. A 10% increase in the underlying cost of the energy produces just over a 20% deterioration in the NPV. This is due to the interaction of the wholesale electricity cost with the tariff to impact the operating cashflow and so the effect scales linearly.

A variation in the number of charging sessions per time period (utilisation) has almost the exact opposite effect. A 10% increase in the number of sessions improves the NPV by just under 20%. This is because of how utilisation is the key factor in revenue.

The impact of a variation in the number of chargers on-site is considerably less than might be thought. Here a 10% increase drives just a 6% jump in NPV. This implies that increasing the number of chargers may deliver modest improvements in the long-term value of a charging location. However, if this principle is pushed too far, then the law of diminishing returns applies as charger numbers is mutually-dependent on utilisation.

Finally, tariffs have a strong positive impact with a 10% increase producing a nearly 40% improvement in the NPV. This is partly due to how the discount rate handles the improvement in the cashflow but also shows what a strong lever tariffs are.

Tariffs have the strongest impact on NPV, followed by electricity costs and charging sessions. Changing the number of chargers on-site has the lowest impact on the investment value of the charging location.

### *4.3.3 The Case for Public Intervention*

The results above show that governments and subnational jurisdictions may have an opportunity to invest in revenue-generating charging infrastructure (subject to national costs and tariff norms). It is not essential for them to intervene but this may be an opportunity to capture revenue which would otherwise be delivered to the private sector.

For others, the opposite may be true. They may feel that the profitable Rapid and Ultra-Rapid chargers will be attractive for private investment but beyond providing a public point of contact, the market can be left to deliver. Their attention is drawn by the loss-making options where the case for public intervention is stronger. Without facilitation or perhaps active involvement, these chargers are less attractive to charger operators and therefore the public sector must step in to ensure equitable access to charging. This theme is developed further in Chapter 5 (page 27) but either way, the exact nature of that intervention and the division of costs and revenues will depend on the ownership model which is selected.

For others still, there may be a case for intervention in both. If considered from a “whole installation” perspective, the overall NPV for investing in infrastructure is still positive for countries like the UK where Standard chargers are loss-making. In this approach, the revenue from the higher-powered chargers is used to offset the losses of the strategic lower-powered chargers.

The positive NPV for higher-powered chargers may lead governments that wish to be more actively involved in charging to conclude to invest to capture that revenue, to invest in lower-powered chargers to ensure equitable access or to maintain a balanced portfolio across both.

## 4.4 Conclusions

The business case for chargers is essential to get right if the much-needed private investment is to be obtained. Where public intervention is desired, a range of models can be used to distribute the financial, reputational and operational delivery risks. Public authorities wishing to involve themselves actively should seek contractual terms which balance risks and opportunities with their chosen contractor.

Four such models have been analysed, concluding that the Own and Operate model is best-suited to public residential charging locations. In contrast, public hubs are best-operated under a Leasing Model and the Concession approach most closely fits public travel corridor locations.

An outline business case was constructed for the Netherlands, UK and US. In all cases, the NPV increases with the power of the charger, although the value available to the landowner will be diminished under certain ownership models.

A sensitivity analysis revealed that tariffs have the strongest impact on NPV, followed by electricity costs and the number of charging sessions. Changing the number of chargers on-site had the lowest impact.

Taken together, governments wishing to intervene in the charging arena may have an opportunity to capture revenue, invest in lower-powered chargers to ensure equitable access or maintain a balanced portfolio across both. Although intervention is not required or desirable in all jurisdictions, this forms the case for public intervention.

# 5 Providing Equitable Access to Charging

Identifying the barriers preventing the deployment of public charging and understanding the key business case levers lays a solid foundation for building robust policy solutions. However, these policy solutions must be sensitive to ensure appropriate levels of access to the available charging solutions. The terms ‘equality’ and ‘equity’ are often used interchangeably in policy discussions but are, in fact, distinct.


*Figure 7: Visualising equality and equity*

Equality generally refers to treating people similarly. For example, a programme to give away a standard-size free bicycle to every resident might promote equality. However, this assumes everyone starts from the same place and needs the same help.

By contrast, an equity-focused approach aims to ensure people receive what they need to be successful and recognizes the need to overcome the impact of their current situation and history. For example, it might recognize that some people need adaptive bikes, whereas others may need shorter or taller bikes (Figure 7).[viii]

> Making equity the focus is likely to be more challenging in the short run than simply focusing on equality but will yield stronger and more resilient outcomes in the long-term.

This chapter looks at general approaches to achieve equitable access to charging, defined as universal access to the necessary infrastructure to support the use of an EV. It identifies specific populations with higher barriers to access and presents potential strategies to overcome these.

! The term “historically underserved” is used to enable insights to be translated globally.

## 5.1 Rationale for equitable EV charging access

Expanding access to electric mobility has significant social and environmental benefits.[ix] EV charging does not by itself benefit historically underserved communities but as mentioned, it is a critically important barrier that must be overcome for the potential benefits to be realised.

As noted in Chapter 4, the viability of business models depends on the utilisation of the chargers, so the market naturally tends to deploy higher-powered charging into areas with heavier EV adoption. These tend to be wealthier neighbourhoods. Where there is no public intervention, this has led to significant inequities in public charger access. For example, the ICCT found that Californian cities where EVs account for 10% or more of the market tend to be the wealthiest, such as Palo Alto, Los Altos or Saratoga in Silicon Valley.[x]

Without public intervention and investment, these less affluent neighbourhoods have the potential to be further excluded as nations move towards and all-electric fleet. As one recent report pointed out, these are long term capital investments: “Because investments in charging infrastructure will shape communities’ transportation options for decades to come, it is important for these investments to be thoughtfully sited”.[xi]

Government agencies, electric utilities, and cities are the main institutions driving e-mobility investments and programs across the world. All of these organizations tend to be slow moving and risk averse, so traditional cost/benefit analysis may point to investing most heavily in programs that will increase e-mobility at the lowest marginal cost. There should be a tight and coordinated approach that ensures charging is not a barrier to accessing clean mobility.

> An equitable approach is essential to deploy e-mobility investments to leverage more balanced opportunities for potential EV users.

## 5.2 Providing equitable access

Providing equitable access requires intentional actions, and the focus must be on people and communities, not technology and companies. A targeted approach specifically focused on the most marginalized groups to meet universal goals can promote racial justice and accelerate growth in electric mobility simultaneously. If EVs can work for people with the greatest barriers, EVs can work for everyone else too. This process is easiest to follow at a community level, but a similar approach can also work at a state or national scale to ensure that historically underserved communities are partners in designing interventions to improve equitable charging access.

> *A good example of this practice would be the Transportation Electrification Infrastructure Need Assessment conducted by the State of Oregon where listening sessions of key stakeholder groups were assembled and the outcomes incorporated into the final report and recommendations.*[xii]

### *5.2.1 Community-Based Needs Assessment*

This process should start with a community-based needs assessment, ideally led by trusted organizations grounded in the community. However, these organisations currently tend to have little information about the availability, cost and other characteristics of new technology. Therefore, partnerships should be formed with mobility experts who can identify the nature of the community's needs and challenges, housing stock composition, public facility locations and points of interest. Together with trusted community partners and leaders, this can anchor and promote and equity-based strategy.

### *5.2.2 Engage the Community in the Development Process*

Community engagement is key to ensure all voices are heard, information widely shared and practical solutions identified. Engaging in the community's native language and meeting them where they live and work with a participative approach will improve access to the process. Application of best practices in equitable outreach, such as providing childcare and compensating participants for their time will further improve results.

### *5.2.3 Measure and Analyse the Results*

As the process proceeds, the application of mobility equity indicators will allow progress to be appropriately measured. Figure 8 outlines a range of possible metrics to increase access to mobility, reduce air pollution and enhance economic opportunity[xiii]. As the infrastructure deployment plan gets developed and implemented, partners should measure and evaluate equity outcomes in a clear and transparent way, and solicit ongoing community feedback to improve outcomes.

**Goal #1**
Increase Access to Mobility

1. Affordability
2. Accessibility
3. Efficiency
4. Reliability
5. Safety

**Goal #2**
Reduce Air Pollution

6. Clean Air and Positive Health Benefits
7. Reduction in Greenhouse Gases
8. Reduction in Vehicle Miles Traveled

**Goal #3**
Enhance Economic Opportunity

9. Connectivity to Places of Employment, Education, Services, & Recreation
10. Fair Labor Practices
11. Transportation-Related Employment Opportunities
12. Inclusive Local Business & Economic Activity

*Figure 8: Example of 12 mobility equity indicators*

Properly-funded community-based efforts will facilitate a clear needs assessment, appropriate engagement and measurable results in those communities most likely to lag in EV adoption.

## 5.3 Policy Recommendations

National governments and subnational jurisdictions have a range of tools at their disposal to increase equitable access to charging. Whilst the leading markets are just starting to deploy these, early lessons and best practice are emerging on which approaches are most productive in different settings.

### *5.3.1 Urban Locations*

***Private Residential Charging***

The impact of access to private residential chargers, especially in single-family homes, has already been noted as a key feature of early adopters. However, as EV adoption accelerates, more EV drivers will live in residences here charging access is not as simple or cheap, such as Multi-Unit Dwellings (MUDs), high-rise apartments or flats. This is especially critical because historically underserved populations more often live in these homes and they are much less likely to have both dedicated parking spaces and access to power.

In the United States, the “Right-to-Charge” legislation has removed barriers to accessing home charging. For instance, this addresses Homeowner Associations (HOAs) who control common elements such as the parking structure through which power cables will pass. Despite the success of Right-to-Charge laws, other barriers still remain. While owners cannot now be prevented from installing a charger in their deeded spots, the owner assumes all costs. Limited panel space, building electrical upgrades and trenching can all increase expenses to a point where this may be unaffordable. In Colorado and California, Right-to-Charge laws also include provisions allowing renters to install charging stations. Renters are a group that face an especially hard time accessing home charging due to unbalanced power dynamics with landlords or management companies, and renters tend to have fewer resources to fund a charger installation than home-owners.

One long-term solution that begins to address charging access in MUDs is EV-readiness requirements. Building (and energy) codes can require various levels of EV readiness (e.g. the European Performance of Buildings Directive or “EV-ready” indicators in the Southwest US).[xiv] In the US, building codes usually only apply to new construction or major renovations and are critical to ensuring future buildings and parking lots are built for EV charging. In contrast, some US “EV-readiness” requirements exempt affordable housing altogether. While that can reduce the risk of gentrification and rent increases, underserved people living in affordable housing face more barriers to accessible charging and adopting EVs.

There are many barriers to providing equitable access to home charging for low-income, historically underserved communities, especially renters as a subset of those communities. Intentional policies that integrate the community into planning processes will help ensure equitable access to charging. These communities’ needs should be assessed regionally in order to identify best practices for specific groups. The electric utilities, local governments, and NGOs may need to step in to assist EV charging access for historically underserved groups.

Some promising approaches to increase equitable access to home charging include:

- Focusing incentive programmes on lower-income drivers, reducing information barriers as well as costs;
- Programmes that proactively fund the installation of charging at existing MUDs with lower rents, provide hands-on technical assistance to building managers, ensure affordable charging rates, and are paired with community engagement and outreach efforts;
- EV readiness requirements that apply to all housing, including affordable units or public/social housing;
- Programs that provide financing to reduce the upfront cost of charging infrastructure; and

- Subsidized or low-cost Rapid charging nearby MUDs, often utility or municipally owned.

Financial support and programmes targeting the infrastructure at private residential locations are important to deliver equitable EV-readiness, whether installed at the time of construction or retro-fitted.

***Public Hubs***

As noted in Chapter 2, Fast or Rapid chargers at hubs have an important role for public urban charging, which can be leveraged to promote more equitable charging access. They can provide a reasonable alternative for drivers who live in MUDs or high-rise environments. At least one study in the USA has documented that hubs deployed in areas with an above-median number of MUD residents lead to high percentages of MUD residents choosing it as their primary charging mode.[xv] These residents are more likely to state a preference for charging close to their home, even if they have access to home charging. This suggests that it is advisable to target Hubs near these residents to satisfy the short-term charging needs.

Besides these residents, public Fast or Rapid chargers also serve ride-hailing services and the gig economy where private vehicles are leveraged for shared trips and delivery services. This brings a great benefit since the emissions benefits of electrifying a vehicle in a Transportation Network Company (TNC) fleet, such as Uber or Lyft, are nearly three times greater than that from electrifying a privately-owned vehicle in California.[xvi] Furthermore, a large share of TNC trips begin or end in disadvantaged communities and a high percentage of gig economy drivers come from historically underserved communities. Strategically placing hubs in historically underserved areas not only helps the uptake of EVs by the community, but also allow TNC drivers to electrify their vehicles and drive cleaner vehicles in such neighbourhoods.

Furthermore, the *high mileage local* segment like TNCs require heavy use of hub infrastructure. Even with far less than 10% of the fleet electrified, TNCs often make up 30-40% of all charging sessions at existing Direct Current Fast Charge (DCFC) hubs in American cities today. Because of this heavy use, TNC drivers can serve as “anchor tenants” that create a more viable business model for placing DCFC in historically underserved communities, as well.

However, this also highlights some of the challenges with DCFC hubs as an equitability strategy. Fast charging tends to be expensive, often far more expensive than the equivalent ICE refuelling, and some authorities make it difficult to zone and permit such infrastructure. Unless there is careful planning, hubs in historically underserved communities may eventually benefit mostly wealthy residents from outside the community.[xvii]

Governments can promote equitable charging access through urban fast charging hubs by:

- Making it easier to permit and locate public hubs, ideally in highly visible urban locations;
- Ensuring there are affordable charging plans available for the drivers who are most dependent on these hubs, such as TNC drivers, taxis, and those without home charging;
- Siting public hubs in close collaboration with communities and as part of a broader engagement strategy that ensures local residents and community based organizations will benefit; and
- Co-locating the hubs with battery swapping and charging stations for two- or three-wheelers.

*Portland General Electric Company (PGE) offers a range of affordable payment plans for EV fleets or operators who use their charging station. Users may choose between a point-of-sale option, pre-pay or a monthly subscription. If the user is also a PGE customer, they can bundle the monthly subscription with their business energy bill for a simple single-point of contact service.*[xviii]

Locating hubs in urban locations as part of a broader community support programme with affordable charging plans will support those reliant on public charging.

### *5.3.2 Rural Locations*

In many rural settings in Western Europe and North America, EVs are more likely to be four-wheelers, with the majority world tending towards two- and three-wheelers. There will be considerable variety in the needs of the former group, depending on the driving distances, as rural Denmark is not the same as rural Canada. Nonetheless, due to generally longer driving distances, rural drivers are even more concerned about range and so the provision of charging infrastructure is critical.

Until recently, the relatively short vehicle ranges have made it difficult to promote equitable access but as improved models are being released into the market, ensuring charging access will be a key focus for rural settings.

***Installation Process Streamlining***

Rural EV drivers are more likely to have single-family homes or townhouse units with garages. However, it is still important to ensure access to charging through the streamlining of the installation and permitting process. In the USA, the preference for larger vehicles and a higher likelihood of longer daily driving distances in the rural areas means that Slow chargers are usually insufficient for the individual's needs. Higher-powered Standard or Fast chargers are required but often have longer installation lead times. Streamlining the process by standardised checklists, electronic permit systems and mandating a maximum response time will accelerate the deployment overall.[xix]

In the UK and Europe, historic rural villages and towns often have homes without off street parking and heritage considerations can become a barrier to the installation of public roadside chargers.

*The Belper Clusters is part of the UK's Derwent Valley World Heritage Site due to its role in the early Industrial Revolution. Development is therefore highly constrained in order to protect the area. Following a feasibility study, a residents' group is looking to develop an innovative charger which is concealed within a dry-stone wall, allowing the historic Industrial Revolution character of the streets to be maintained without delaying the new Transport Revolution.*[xx]

Innovation in charger form-factors and installation processes will be needed to meet the particular needs of rural communities.

***Travel Corridors and Hubs for Rural Communities***

Another key component of the rural charging network is the provision of infrastructure along the strategic road network. It is vital for long distance trips to have reliable access to Rapid or Ultra-Rapid chargers to ensure that drivers are not left stranded. This implies deploying at travel corridor locations at least every 50 miles with redundancy to ensure reliability and minimise wait times.

*A 2021 report on the application of the EU's Alternative Fuels Infrastructure Directive (AFID) has reasserted the target of Rapid or Ultra-Rapid chargers placed every 60km along the Trans-European Transport Network (TEN-T), noting that this is still not achieved in parts of Southern and Eastern Europe.*[xxi]

Local governments could consider providing funding at key locations, especially given the stronger business case for these types of chargers, as highlighted in Chapter 4. Publicly-funded stations could be deployed with pricing ceilings to ensure affordability. In the US, this would need to be supported by new utility rate structures designed for EV charging to ensure price transparency and avoid undermining the business case with a price-per-kWh tariff.

Equally, India is planning charging hubs on the key road network but this will also require development of localised energy generation and storage due to many countries across the world not having a national grid system.

While travel corridor charging often focuses on the needs of urban drivers between cities, an equity-centred approach should engage the community to understand the needs and travel patterns of local residents to ensure that hubs are located where they can conveniently serve local drivers. For example, rather that placing charging at a freeway rest area, it is generally better to place it in a nearby community, if it can still be quickly accessed by those driving through. Incidentally, this can also help ensure that local businesses benefit from driver spending during their charging breaks as charging stops are likely to be around 30 minutes or more.

Co-location of amenities with rural EV charging will both bolster the business case and provide economic opportunities to the local community beyond payment for the charge.

***Point Of Interest and Destination Charging***

For more equitable EV charging access in rural areas, setting up charging stations at facilities and locations that the rural residents and travellers frequent provides another key pillar in the EV charging deployment. Points of interest as public libraries, city halls, hospitals, grocery stores and shopping malls are all strong locations for Fast or Rapid deployments, depending on the average dwell time of the visitors. In addition, local tourist locations should also provide destination charging for travellers or local residents to top up so drivers can visit these locations with confidence. As noted above for rural locations, EV charging at tourist locations can become an attractive amenity that boosts the local economy as well as attracts more EV drivers who would be hesitant to travel there without EV charging.

### *5.3.3 Ensuring Universal Accessibility*

People with disabilities face an array of challenges to accessing mobility and electric vehicle charging is certainly no exception. In the United States, the Americans with Disabilities Act (ADA) is a federal civil rights law that prohibits discrimination in public places against individuals with disabilities. Anyone installing public charging is required to follow special design guidelines to ensure all persons may access and use public facilities. Although the ADA does not provide specific design standards for charging station-equipped parking spots, several industry studies and PEV planning guides do.[xxii] [xxiii]

*In the UK, the charity Motability published research into the regulatory, market, infrastructure and technical barriers for some drivers to charge EVs. It found that around 50% of all drivers or passengers with physical impairments will not have reliable parking and charging at home, and therefore will be reliant on public charging infrastructure. Amongst the 50% of physically impaired drivers and passengers without reliable home charging access, 14% have inadequate or no parking, 20% will rely on on-street charging, and the remaining 16% are tenants/renters with off-street parking but potential unable to obtain charging through the landlord or building managers.*

*Despite this, there is currently no published information on the accessibility of chargers and no universal design standards for their location and installation, which is a particular challenge for those with physical impairments to use the heavy cable and connectors, and navigate around the charging stations. It highlighted that the charger guns and heavy cables of Rapid or Ultra-Rapid chargers are particularly difficult to operate.*[xxiv]

When designing accessible charging stations, consider ease of use, and safety for drivers, including those using mobility-assistive equipment, those with low vision and others. Key considerations include ensuring adequate space for exiting and entering the vehicle, unobstructed access to the EVSE, free movement around the EVSE and connection point on the vehicle, as well as clear paths and close proximity to any building entrances.

Special consideration should be given in all charger deployments to accessibility for disabled users, potentially through conditions tied to financial incentives or support.

## 5.4 Conclusions

Delivering equitable access to EV charging is important to ensure the social and environmental benefits of electric mobility are available to all. Without public intervention, chargers will tend to be deployed in more affluent areas where EV ownership is higher. Whilst making equity the focus of EV charging policy is likely to be more challenging in the short-run, it will yield better opportunities and outcomes in the long-term.

### Policies for a mature, flourishing, equitable EV charging ecosystem

An equitable angle in policy-formation must be built upon an assessment of the community's needs and early engagement with them to develop solutions. A suite of mobility equity indicators has been suggested to measure the results. Both of these may require funding community efforts to ensure that historically underserved communities are not left out.

In urban locations, private residential and public hubs are key to equitable success. Policies need to target the lack of infrastructure at private residential locations through finance, information, EV-readiness programmes and other incentives. Where private residential charging is still simply not possible, public hubs are the best way to deliver equitable access. Strategic placement and alignment with community support programmes will best-serve those that still cannot charge at home, as well as users from the high mileage local segment.

In rural locations, the installation process for homes and travel corridors between urban zones requires focus. In the latter case, co-location of EV chargers with amenities will boost the business case and provide economic activity for the immediate community. Similarly, deployment of charging at points of interest and destinations can assist both tourists and nearby residents to avoid a lack of infrastructure being to the detriment of the local economy.

Finally, ensuring that all users can access and use charging stations is an especially important consideration for both location and design. Where chargers are deployed as part of a broader programme, accessibility should be included as an assessment criterion for funding applications.

# 6 Emerging Solutions for Commercial Vehicles

## 6.1 Introduction

Decarbonising the Commercial Vehicle (CV) sector presents businesses and governments with a challenge equal to the hurdles faced by passenger vehicle electrification, especially since this sector is earlier in its development. Although CVs represent only a small proportion of the global vehicle parc, emissions from these vehicles account for a significant part of Greenhouse Gases (GHGs), air pollutants and noise. Therefore, there are strong benefits associated with the decarbonisation and cleaning of these vehicles.

Furthermore, the CV sector is by definition *commercial*, which means vehicles are primarily performing economic activity for financial gain. For these operations, the transition from ICE vehicles must be economically attractive or, if driven by regulation, non-prohibitive in terms of Capital Expenditure (capex), Operational Expenditure (opex) and whole-life costs. This means that policies must be carefully crafted to facilitate the transition, rather than hinder particular parts of the market.

As will be shown, the high capex for current EV models and associated EV charging infrastructure creates a high initial cost barrier for a conservative risk averse sector. Whereas progress has been seen to be made in other sectors through nudge economics, the commercial vehicle sector requires much more of a concerted push. Financial incentives alone may not be enough to accelerate progress for a sector that sees new technology and any associated changes to working patterns as a threat to operational continuity.

The growing possibility to use hydrogen to fuel CVs means Governments will want to avoid having to choose between technologies which are often seen as competing. This report leaves the task of judging the relative merits of hydrogen and electric to individual governments and focuses on Battery Electric Trucks (BETs) and their associated charging infrastructure.

BET charging shares many features with passenger cars and 2-wheelers. However, CVs have a wide range of operational duty cycles, high Gross Vehicle Weights (GVW) and varying vehicle ownership models. Therefore, only some types of chargers are appropriate for CV charging.

! Note that the United States CV classification has been used as reference throughout this section, splitting all CVs into eight classes based upon their GVW: light (classes 1-2), medium (3-4) and heavy vehicles (class 5-8). See Appendix 3 on page 54 for more details.

CV sector policy-formation will be more challenging in terms of utilising nudge economics to achieve impact when compared with other sectors due to the more conservative nature of the commercial vehicle sector which is risk averse when it comes to new investments, technology risk and operational considerations.

## 6.2 Transitioning to Battery Electric Trucks

Figure 9 shows the roadmap for BETs operational maturity and commercial readiness.[xxv]

Class 1 and 2 vehicles represent the low-hanging fruit for CV market development. In the first half of the decade, it is expected that these will increase relatively quickly from a low baseline in all geographies. This includes Class 1 car-derived vans, popular in Europe, as well as pick trucks popular in ASEAN and North America. Product choice will grow and range is expected to lengthen to 150 – 200 miles, subject to payload, driving style and weather conditions.

High capex costs are a barrier to uptake but the economic case is already quite strong when viewed by Total Cost of Ownership (TCO). Purchase cost parity with equivalent ICE vehicles is expected to be reached by the mid-2020s in Western economies.

In some Asian countries, such as India, Indonesia, Vietnam and Thailand, the use of three-wheelers is very popular as a viable option for last-mile deliveries. The electrification of these Class 2 vehicles poses similar challenges to four-wheelers but the reduced size offers a more affordable alternative. Product choice is also expected to grow here with the possibility of battery swapping, which removes the need to have locally-accessible charging infrastructure.

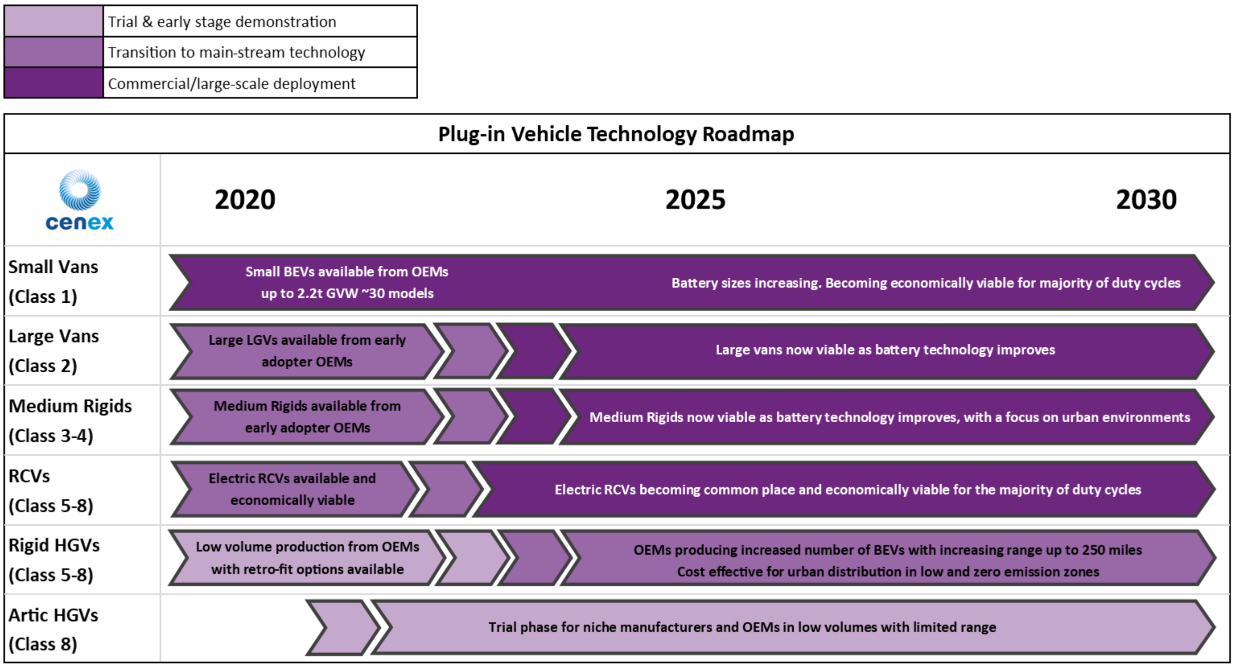



*Figure 9: Roadmap for heavier vehicle electrification*

At present, the development of Class 3 and 4 BETs is still at an early stage. Only a few models are available in the market and most manufacturers are currently testing prototypes under different real-world duty cycles. They are generally rigid (non-articulated) vehicles with dimensions facilitating the inclusion of a battery within the chassis. By relying on opportunity charging during frequent stops in urban areas to top-up during their shifts, the requirement for longer range is reduced, so batteries can be smaller and payload is less impacted. Correspondingly, most vehicles currently available in the market have relatively modest mile ranges. These vehicles are increasingly penetrating low- or zero-emission zones where their economic case in comparison to diesel alternatives is improving.

*School buses are an interesting case study in this Class. They are candidates for electrification because they run on short, fixed routes with ample time for recharging – all factors which help minimise the operational disruption when it comes to a switch to battery power. The policy push to cut exhaust emissions from school buses to protect children's health effects has been a policy driver for more than two decades and the zero tailpipe emissions from battery power effectively resolves this issue[xxvi].*

*However, they can be two to three times more expensive than their diesel equivalents and are unsuitable for longer routes or school trips so uptake is anticipated to be slow. Three school districts in Massachusetts used grant funding to pilot Type C electric school buses which travelled 14,000 miles over 279 days, reducing carbon emissions by around 50%.*

In the long-term, it is expected that the combination of increased battery energy density and lower costs will facilitate lower-cost Class 3 and 4 BETs and options for range-extended variants. As the electric-only range reaches 300 miles, a rapid growth in model availability is expected and cost parity is expected with diesel equivalents by 2030.

Class 5 to 8 vehicles are the segment where decarbonisation of the fleet poses the greatest challenges. These vehicles operate for long hours, which translates to high energy demand. The Mining, Agriculture and Utility vehicle segment highlighted in South Africa and India is included here, along with logistics, freight and refuse collection. More information can be found in the recent ZEV Alliance report on Zero-Emission Freight.[xxvii]

Over the last decade, technological improvements have resulted in BETs becoming a technically viable solution for heavier CVs. This is driving growing interest in the *long haul* segment, where Tesla announced its Semi model in 2017 for delivery in late 2021 with an advertised range of 500 miles. Opportunities are also opening-up for low-mileage fleets such as Refuse Collection Vehicles

(RCVs) in urban areas and port drayage – the majority of OEMs either have a first product in trial or low-volume production.

Given these challenges, in the second half of the decade, policy measures driving towards net zero targets are expected to extend regulation deep into the CV sector. For example, the UK Government's recently launched Transport Decarbonisation Strategy will consult on a target of 2040 for the ending of the sale of all non-zero emission class 5 to 8 vehicles.[xxviii] In the run up to 2040, CV developers are expected to bring forward a wider choice of vehicles, driven by customer Environmental Social and Corporate Governance (ESG) needs, emissions regulations and local Environmental Zones in cities.

> BET uptake is expected to increase in the coming decade, with lighter vehicles leading. The economic case across all Classes is strengthening and product choice is expected to grow.
> Strong policy intervention will be needed if the uptake of heavier BETs is to be accelerated.

## 6.3 Charging Battery Electric Trucks

### *6.3.1 Charging Options*

***Class 1 and 2***

The use of Class 1 or 2 vehicles tends to be divided between those concentrated in urban areas and higher-mileage operations on the strategic road network or in rural regions. For urban operations, BETs are usually able to complete their activities on a single charge, which is provided overnight by Standard and Fast chargers at private commercial or private residential sites. As with the *private vehicle* sector, these charging locations are more convenient and cost-effective in comparison to public options.

> *Leeds City Council (LCC) in the UK is transitioning towards a zero-emission van fleet for property maintenance, highway maintenance, greening, parks and waste management. LCC has deployed more than 80 Nissan eNV200 vans with a further 12 on order. The use of EVs has been so successful that LCC now views them as the default option, with diesel vehicles to be provided only where it can be shown that an EV is not suitable.*
>
> *The greatest challenge identified is the impact of a large fleet of EVs on the grid if these are to be charged at a depot, as it would be cost-prohibitive to upgrade the local grid. To circumvent these capacity limitations, it undertook an innovative trial in which drivers took vans home and plugged them in to a domestic charger with costs paid by the council. Based on the success of this trial, LCC is now poised to roll this out across the fleet.*[xxix]

Class 1 and 2 vehicles reliant on public charging can share almost all infrastructure with passenger cars. In contrast to chargers at private locations, there will be a preference for Rapid or Ultra-Rapid options where battery sizes are large or dwell times are limited. As highlighted in Table 4 (page 14), these are likely to include public destination, public hub and public travel corridor locations.

> Class 1 and 2 vehicles are expected to use the same private and public infrastructure as private vehicles.

***Class 3 and above***

For the heavier vehicles, the option may still exist to charge at private commercial depots, especially if there is adequate space for vehicle parking and charger infrastructure, and the electricity network connection has sufficient capacity. Within the bounds of these caveats, this remains preferable from a logistics, downtime and operating cost perspective, although it may mean that the business must incur additional capital costs for installation.

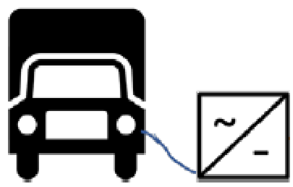
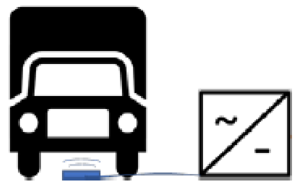
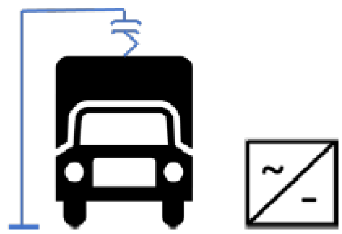
*The Battery Electric Truck Trial (BETT) is a one-year UK Government-funded project. Leyland Trucks will supply twenty 19 tonne DAF electric trucks which have been engineered to meet key customer requirements including a range over 100 miles and the ability to be Ultra-Rapid charged. This means the vehicles can turn-around quickly between shifts and maintain a payload of up to 11.7 tonnes. The vehicles will be used for hospital laundry operations and by public authorities for deliveries to schools. Where operations are return-to-base, a Fast charger will be used but Ultra-Rapid chargers will be able to supply 90 kW from two outlets or up to 180 kW with a single vehicle charging. The project will report its results in 2022.*[xxx]

Vehicles of Class 3 and above are expected to prefer charging at private commercial locations where space and electricity network capacity allows.

Where private charging cannot support the operational duty cycles of the vehicles, public charging will become necessary as the heavier vehicles cannot make use of existing public infrastructure. At present, this looks likely to use conductive (wired) technologies (as in the case study below) but alternative technologies are being examined too (Table 10).

*Portland General Electric and Daimler Trucks North America recently announced that a charging station for electric trucks will be built in the city of Portland, Oregon. Located near Daimler's headquarters, the facility will be equipped with Rapid chargers specifically designed to cater the needs of BETs. Although it will start from 150-200 kW, it will gradually increase to powers of 1 MW to test the new CharIN MCS standard. The facility will allow to test the impact that electric trucks power needs have on the grid, as well as complementary technologies such as vehicle-to-grid.*

*Table 10: Current and future CV charging options*

| Plug-In conductive | Wireless Power Transfer | Overhead catenary |
|---|---|---|
|  |  |  |
| Established technology | Under development for power transfer rates needed for CV applications | Established technology for tram and buses – under test for highway trucks |
| Stationary | Stationary and Dynamic | Stationary and Dynamic |
| Regulation defined by 15118 but being extended to 1 MW+ by CharIN work[xxxi] | Regulatory standards being formalised | |
| Private Commercial: 22-150 kW | Limited to lower power transfer currently. 50 – 100 KW needed for opportunistic charging on public network | |
| Public Destination: 150-300 kW | | |
| Public Hub/Transit: 150-300 kW | | |

A new network of public charging locations will need to be developed for heavy BETs.

Wireless Power Transfer (WPT) is an established technology for mobile phones and can be applied both statically or dynamically to vehicles as they pass over matts or coils in the road.

*The largest trial of WPT on a public road has been conducted in January 2021 in Gotland, by Israeli company ElectReon in partnership with the Swedish Road Administration. The trial was carried out over a 200-metre road segment. The vehicle being charged was a 40-tonne Class 8 truck driving at speeds up to 60 km/h. The test revealed a stable transfer at a rate of 70 kW from the road to the truck's battery and showed that wintry conditions on the road did not affect performance.*[xxxii]

Overhead catenary charging is the backbone of rail electrification and is being explored as a solution for the electrification of road-freight. Catenary charging has been trialled for city bus operation for static charging at buses stops, as well as for dynamic charging of moving trucks.

*The first section of e-highway in Germany was opened in 2019 along a 5-kilometre of the A5 autobahn near Darmstadt, in the state of Hesse. This is one of the most heavily polluted in Germany, carrying 135,000 vehicles daily, including 14,000 trucks. The project, led by Hessen Mobil, is funded by the Federal Ministry for the Environment. In 2021, it was announced that a further 7 km section would be equipped with catenary, expanding the existing length to a total of 12 km. Electric trucks have been provided by manufacturer Scania, with the infrastructure developed by Siemens.*

Wireless and catenary technologies are less mature and less common than conductive options, but offer alternatives for both static and dynamic applications.

### *6.3.2 Charging Challenges*

Looking at the global prognosis for the sector and the charging options, six key barriers have been identified for Commercial Vehicles.

***Low Confidence in BET Uptake***

As noted in Figure 9 (page 35), there is expectation that market uptake of BETs of all classes will increase in the coming decade. The international workshops conducted for this report highlighted that fleet operators recognise the need to move to BETs to help meet net-zero targets. However, there is limited motivation among a majority of fleet operators to be first movers. With few vehicles available and a great deal of uncertainty, upfront costs remain too high for many fleet operators to justify making the transition.

This risk carries over to the business case for EV charging investments, especially in public locations where utilisation will be low for many years. Confidence to invest in public chargers for BET is therefore quite low. It is expected that the first markets for charger operators will be high-profile fleets where greater assurances can be translated into contractual commitments.

***Uncertainty in BET Charging Technologies***

Even if the case for investment in charging technologies can be made, the question remains about which technology to use. Assuming that a commitment to electric has been made, the natural choice might appear to be conductive charging, which is technically more mature and understandable to business owners who see public roadside chargers on a daily basis. Alternatives which take up less space such as wireless chargers or which are being put forward for strategic rollouts such as catenary systems may give competition to the status quo, leaving CV owners wondering whether they are ‘backing the wrong horse’. These risks are likely to depress appetite for rollout at private commercial locations too.

***High Infrastructure Costs***

Deployment costs come from more than simply the charging hardware. A typical installation will also include surveys and design work, electricity network permission applications, groundworks, installation and commissioning, back-office management, servicing and maintenance. This causes high up-front costs or high ongoing costs where these are procured via a turnkey service, neither of which is easily affordable to most businesses.

This challenge can be exacerbated by mixed ownership of assets. For instance, the landowner leasing a site may not be the operator, creating additional risks for those seeking to electrify. Furthermore, each business must account for the additional effort which comes when fleet operations, facility oversight and utility management must collaborate to ensure efficient charging.

***Electricity Network Capacity Constraints***

When many vehicles are charged at the same location, the power requirements can exceed the local grid supply capabilities. In private commercial locations where overnight charging is possible, smart or load-managed charging can be used to keep power transfer within the site constraints or reduce the cost of upgrading the supply. However, this may not allow all vehicles to be at the optimal state-of-charge for the next days' operations.

Where higher powered Rapid or Ultra-Rapid charging is desired, the cost to enable the installation is a key challenge and poses a significant financial disincentive. A greater capacity may be needed on-site, which requires chargeable work by the electricity network company to upgrade the line back to the substation. In the case of megawatt-scale charging, the network may need to be reinforced further upstream, causing even greater costs of potentially hundreds of thousands to millions of dollars to the end-user before they have been able to complete their first charging session. When charging or depot operations are on leased land, there is an added complication about who pays. For public travel corridor or public hub charging locations that rely on high-powered charging, this is a key challenge to their business case.

***New Hidden Costs***

For those reliant on public charging locations, without the right number, types and powers of chargers, it is possible that the demand from others will lead to queueing. All petrol and diesel drivers are accustomed to waiting in-line from time to time, but even on the highest power chargers, the longer charging time could extend this. Coupled with under-provision of public chargers, this may add unnecessary costs or downtime to the vehicle owner.

However, the opposite issue of over-provision is not better. As noted in section 4 (page 21), the business case is sensitive to utilisation of the charger. If too much infrastructure is deployed, then the price of charges may rise to compensate.

***Lack of Infrastructure Coordination***

Finally, there is a challenge around the coordination of infrastructure deployments. Currently, infrastructure for BET is sporadic, inconsistent or invisible. Charger operators are naturally cherry-picking sites where current demand is high but as noted in section 5 (page 27), this does not always correspond to where future demand will be or infrastructure is most needed for equitable access.

Furthermore, lessons will need to be learnt from the passenger car sector to ensure that BET charging does not suffer from a morass of charger networks, apps, ID cards and systems.

Infrastructure is currently being installed at private commercial locations but this is not always visible to the relevant authorities as they shape their response to the challenges of the CV sector.

> Charging of CVs is currently hampered by low confidence in vehicle uptake, uncertainty in the charging technology options, high costs of infrastructure and grid connection, new hidden costs and a lack of coordination of infrastructure.

## 6.4 Policy recommendations for Commercial Vehicles

### *6.4.1 Approaches*

Two possible models are available to Governments looking to support the deployment of BET charging infrastructure.

***Impact-Focused Model***

*Transport and Environment* (T&E) have developed a model which emphasises policy support to accelerate market uptake in those operations best-suited to transition to BETs (Figure 10).[xxxiii]

In this case in the European Union, return-to-depot applications are taken first, followed by charging at urban nodes and finally looking at infrastructure for long haul operations. The approach is entirely logical in terms of achieving market penetration and may represent the least-cost route to electrification of the relevant vehicle Classes. However, it does not address the challenge of electricity network capacity constraints raised in the previous section.

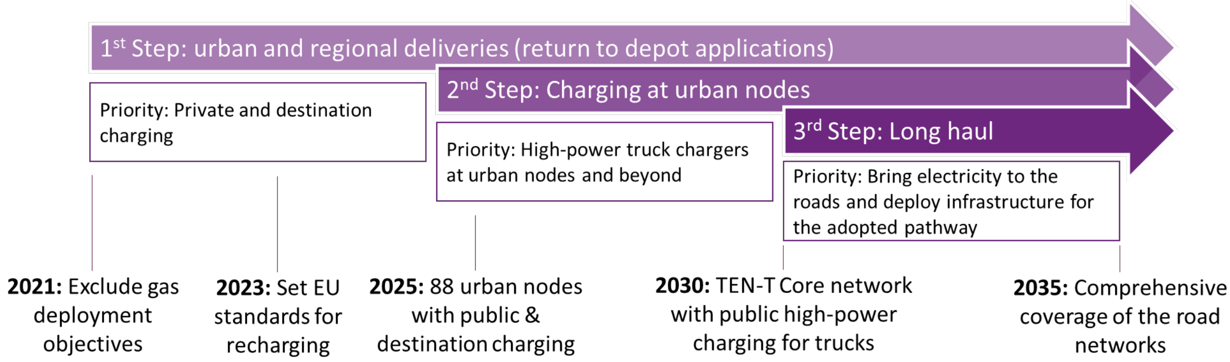



*Figure 10: T&E Impact-focused model*

Furthermore, investment in this type of charging requires a high degree of confidence that the truck OEMs and fleet operators will prefer electrification as opposed to alternatives like hydrogen fuel cell trucks.  The sheer scale of investment required to support this type of truck operation on strategic highway networks makes it a high-risk approach for early investors.

### *Equitable Model*

The second model is one which focuses on an equitable deployment as the primary consideration. In the case of CVs, there are two challenges to note.  The first is who pays for the cost of the infrastructure and the second is equity for truck operators within a highly competitive market.

| Customer segments | | Fleet size | Market share[1)] |
|---|---|---|---|
| Segment | Definition | | |
| Owner-driver | > Truck driver owns truck<br>> Works as subcontractor and/or covers market niche | 1 | ~15-25% |
| Small/mid-sized fleet operator | > Works as subcontractor and/or covers market niche<br>> Lower professionalization due to lack of economies of scale | 2-20 | ~35-40% |
| Municipalities | > Fleets operated by public authorities<br>> Transport not a core function | up to 100 | ~5-10% |
| Special vehicle fleet operator | > Focus on specific transport needs<br>> High professionalization in their segment | 1-5 | <5% |
| Large fleet operator | > Large logistics providers or large corporate fleets<br>> Highly professionalized, e.g. some with own repair shops | >100 | ~25-35% |

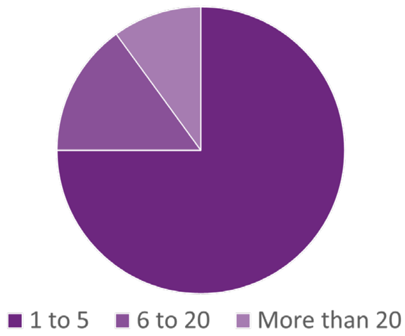



*Figure 11a (left): European fleet market composition; b (right): Indian fleet truck ownership*

Figure 11a focuses on the composition of the fleet market in Europe from the fleet operator perspective.[xxxiv]  What can be seen within the segmentation is that an appreciable percentage of the CV fleet operator market is serviced by very small fleet operators including owner-drivers.  In India (Figure 11b), the situation is even more stark with 75% of CVs held by fleets of not more than 6 vehicles.[xxxv]

Owner-drivers and small fleet operators run on very low margins and don't have the financial reserves necessary to make major business investments.  They are typically also individuals who are historically underserved.  Under the T&E model, the market can transition via larger fleet operators being first movers at their depots and then passing the BETs into the second-hand market for smaller operators.  However, the case would be more equitable if investment was made in public charging open equally to both smaller and larger fleet operators, alongside incentives and loans for small operators to go electric.

Least-cost quickest-transition pathways are may not be the most equitable routes to support the market uptake of BET.

### 6.4.2 Recommendations

***Set Policies to Increase Confidence in the Uptake of BET***

The current policy approach of identifying the future need for BET has been accepted by the main CV manufacturers, as evidenced by the ACEA commitment to zero emissions by 2040.[xxxvi]

The EU has introduced $CO_2$ emissions standards for heavy vehicles for the first time, with manufacturers being set individual fleet-wide average $CO_2$ targets based on a 15% reduction in 2025 compared to their 2019/20 baseline. Most of this target is expected to be met through the electrification of Class 3 and 4 vehicles for local delivery services.

However, it will take time for the vehicles to be available and the higher capex will be a continuing barrier. The OEMs are resistant to policy efforts to push for earlier gains and note that conservative fleet operators are under no obligation to buy BETs until fleet purchase requirements, $CO_2$ mandates or bans come into effect.[xxxvii] Furthermore, they can temporarily circumvent an impending ban by bringing forward replacement cycle sales to buy diesel before the deadline and then hold on to diesels within their fleets for longer timeframes.

Given these considerations, single measures such as regulating only the OEM or applying only a ban to impact operators, are not enough in themselves to establish a complementary framework of policy measures. Combined measures are needed to encourage co-investment by all parties including electric utilities and help EV charge point operators build compelling business cases for private sector investment.

For this reason, measures including the introduction of Environmental Zones or Zero-Emission Zones can assist in shaping the case for change by impacting the business case for switching. One possible policy approach to partly mitigate market distortions may lie in city investments in consolidation centres on the edges of these zones, where fleet operators can decant their cargoes into smaller EVs for city centre delivery.

*A recent example of the successful implementation of a low-carbon consolidation centre in Europe is the construction of a distribution terminal in central Oslo, Norway, by logistics company DB Schenker. Parcels collected at the Oslo City Hub are delivered to their final destination using electric motorised vehicles and e-bikes, which has reduced the company's emissions from city-wide distributions by 80%.*

***Encourage Standardisation of Charging Infrastructure***

Several innovative technologies such as wireless power transfer and overhead catenary are considered as potential viable options for a large scale implementation of BET charging infrastructure. It is essential that standardisation of both the technology and deployment scenarios for these solutions is pursued to reduce the risks perceived by investors. Otherwise, wider development, industrial maturity and market implementation may be slowed.

Whilst there is still uncertainty over the real-world performance of these technologies, policy flexibility can be maintained by supporting research, development and deployment on a technology-neutral basis to ensure that cost effective solutions can emerge. Likewise, a neutral role can be maintained by governments on the potential role of each solution in the future, beyond high-level definition of the key applications foreseen. For instance, overhead catenary seems best-fitted to *long haul* segments on predictable routes.

Such a declaration by policy makers would reduce perceived risks and reinforce the position of investors to further promote development in these areas. Effective engagement of key stakeholders by policymakers can ensure that the individual research projects generate compatible products which may enable a quicker market development of any solutions identified.

***Ensure Finance is Available and Equitable***

The CV sector is highly competitive, which keeps down logistics costs on foodstuffs, materials and other road transported goods. The transition to Net Zero will represent a fundamental disruption to the economics of logistics. Many current players are likely to exit because of the investment costs associated with moving to the new paradigm.

Policy approaches to assist BET uptake and charging infrastructure need to take into account the risks of market distortion and find ways to respect the needs of smaller operators. Grants or other fiscal incentives must be made available whilst investing in public charging infrastructure will help this sector circumvent this challenge.

***Coordinate Electricity Network Investment with Transport Need***

For the public policy maker, the option to use grant funding to incentivise grid upgrades on private land is problematic and can give rise to questions of state aid. Where chargers cannot be deployed on public land, if these costs can be built into plans for electricity network capacity increases, there is the option to socialise them through electricity tariffs. Grid upgrades can be amortised over long time periods of 30 years or more to keep tariff costs low and since there is a risk of market failure (e.g. no investment case for charging provision), there is a case for Government intervention.

All countries need to recognise that their electricity network has not been developed to supply transport energy needs, so the transition to BET will require a transitioning role for the electricity network including the need to reinforce the supply at key locations on the strategic road network.

This is best facilitated by coordinated regional planning between local government, logistics companies and the energy sector. Potential models whereby the Government owns the connection and takes a contribution to repay these investments represent one approach by which to apportion the grid investment costs between the end-user and the wider stakeholder community.

***Consider Creation of a Commercial Vehicle Charging Network***

Whilst the sharing of infrastructure between private vehicles and BET may be possible with Class 1 or 2 vehicles, the inevitable hidden costs of additional downtime may be too much. Some specialised users, including emergency responders, may need a parallel network of infrastructure reserved for their exclusive use in order to guarantee availability. This approach could mirror how radio frequency spectrum management resolves similar issues with dedicated channels for communication uses.

The creation of a second tier of charging infrastructure dedicated to the needs of commercial vehicles is worth considering. This network would have higher-powered chargers which publish their status to the relevant fleet managers and are able to be booked in advance. By ensuring this data is open-sourced, commercial vehicles will be able to intelligently schedule their jobs around their need to charge, thus reducing hidden costs and unnecessary downtime.

***Co-locate Charging Infrastructure for Multiple Vehicle Types***

Public travel corridor and public hub charging locations for passenger cars are already showing that there will be a business case for infrastructure at popular locations with high vehicle movements (as confirmed in Section 4 on page 21). The market could rollout the infrastructure needed for BETs but the notable challenges of network connection capacity and first mover disincentives already mentioned may mean this is unlikely without policy support.

Charging more than one vehicle type at a single location is already an established feature at many local municipality depots where vans, buses and RCVs are based. Co-locating infrastructure can reduce installation and maintenance costs, and provides a single visible hub for charging all vehicle types. It can also make upgrading the electricity grid more cost effective, by focusing investment on a small number of locations, rather than decentralising upgrade requirements across the network.

For heavier vehicles, the main caveat is compatibility with other vehicle types due to their height and width requirements. Whilst large bays spaced to accommodate Class 6 to 8 vehicles could be made accessible to Classes 1 to 4, as more BETs are introduced, it is expected that these bays will be upgraded to 1 MW+ Ultra-Rapid chargers and be dedicated to those vehicles.

Increasing confidence in BET uptake, standardising BET charging infrastructure, ensuring access to equitable finance, coordinating electricity network investments, creating BET charging network and co-locating this with other infrastructure are recommended to support the electrification of Commercial Vehicles.

## 6.5 Conclusions

Decarbonising the commercial vehicle sector will be more challenging due to greater sensitivity to economic factors, technology risks and operational considerations. However, BET uptake is expected to increase in the coming decade, with lighter vehicles leading. The economic case for electrification is strengthening and product choice is expected to grow in the coming years. However, stronger policy interventions are needed if the uptake of heavier BETs is to be accelerated.

From an infrastructure perspective, lighter BETs are expected to use the same private and public infrastructure as private vehicles. For heavier BETs, private commercial locations are expected to prefer charging locations where space and the electricity network connection allows. Where this is not possible, a new network of public charging locations will need to be developed taking developments on wireless and catenary charging into account.

A range of challenges to achieve this deployment have been highlighted including low confidence in BET uptake, uncertainty in the technical solution, high costs of infrastructures and grid connection, new hidden costs and a lack of coordination in infrastructure.

Although starting with return-to-depot operations first may be the most logical way to navigate these challenges, this may not be the most equitable approach due to the structure of the market. Therefore, with this in-mind, a series of recommendations have been made to address the challenges raised above.

# 7 Abbreviations

| Abbreviation: | Explanation: |
|---|---|
| | |
| AC | Alternating Current |
| ADA | Americans with Disability Act |
| AFID | Alternative Fuel Infrastructure Directive |
| ASEAN | Association of South East Asian Nations |
| BET | Battery Electric Truck |
| CAPEX | Capital Expenditure |
| CEO | Civil Enforcement Officer |
| CV | Commercial Vehicle |
| DC | Direct Current |
| DCFC | Direct Current Fast Charger |
| DNO | Distribution Network Operator |
| ESG | Environmental, Social and Corporate Governance |
| EU | European Union |
| EUR | Euros |
| EV | Electric Vehicle |
| EVA | Electric Vehicle Association |
| EVSE | Electric Vehicle Supply Equipment |
| GBP | Great British Pounds |
| GSMP | Global Sustainable Mobility Partnership |
| GVW | Gross Vehicle Weight |
| ICCT | International Council on Clean Transport |
| ICE | Internal Combustion Engine |
| KW | Kilowatt |
| LCC | Leeds City Council |
| MCS | MegaWatt Charging System |
| MUD | Multi-Unit-Dwelling |
| MW | Mega Watt |
| NL | Netherlands |
| NPV | Net Present Value |
| OEM | Original Equipment Manufacturer |
| OPEX | Operational Expenditure |
| PEV | Plug-in Electric Vehicle |
| PGE | Portland General Electric company |
| PICCHU | Planned Investment in Car Charging Utilities |
| PV | Solar Photovoltaic Electricity Generation |
| RFID | Radio-Frequency Identification |
| TCO | Total Cost of Ownership |
| TEN-T | Trans-European Transport Network |
| TNC | Transport and Network Company |
| UK | United Kingdom |
| UN | United Nations |
| US | United States |

| Abbreviation: | Explanation: |
|---|---|
| USA | United States of America |
| USD | US Dollars |
| WP | Work Package |
| WPT | Wireless Power Transfer |
| ZEV | Zero Emission Vehicles |

# 8 Appendix 1: Background

## 8.1 About the International Zero-Emission Vehicle Alliance

The International ZEV Alliance is a collaboration of 18 governments, founded in late 2015 to accelerate the global transition to zero-emission vehicles. The member governments are five countries (Canada, Germany, Netherlands, Norway, United Kingdom) and 13 subnational jurisdictions (Baden-Württemberg, British Columbia, California, Connecticut, Maryland, Massachusetts, New Jersey, New York, Oregon, Québec, Rhode Island, Vermont, Washington).

The collaboration includes the sharing of data, best practices, and lessons learned and involves coordinating on action plans to help the group collectively achieve its ZEV deployment goals.

The International Council for Clean Transportation (ICCT) serves as the secretariat to the Alliance.

## 8.2 Introduction to the Global Sustainable Mobility Partnership

The GSMP is a global alliance of independent, not-for-profit organisations with extensive, practical and real-world experience in implementing low and zero emission mobility.

The mission of GSMP is to drive zero emission mobility solutions for all. The partnership works with regions, countries and cities in a consulting capacity to share best practices and lessons learned on mobility decarbonization strategies and programs.

The members participating in this project are summarised briefly in the sections below.

### *8.2.1 Cenex UK*

Cenex was established in 2005 as the UK's Centre of Excellence for Low Carbon and Fuel Cell technologies.

Today, Cenex operates as an independent, not-for-profit consultancy specialising in the delivery of projects, supporting innovation and market development, focused on low carbon vehicles and associated energy infrastructure. We highly value our independence as it allows us to provide impartial advice and helps us build trust with our customers.

Cenex UK was the project lead for this report.

### *8.2.2 Cenex NL*

Stichting Cenex Nederland (Cenex NL) is an independent not-for-profit Consultancy and Research Technology Organisation part of the Cenex group of not for profit organisations. It specialises in zero-emission vehicle and energy infrastructure, smart mobility and related circular economy applications with a mission to support customers and partners in stimulating the energy transition and achieve the UN Sustainable Development Goals.

Cenex NL has an active portfolio of research projects on transport and energy as works collaboratively with Cenex on techno-market and policy research.

### *8.2.3 Forth*

Forth is a publicly supported non-profit organization based in Portland, Oregon, advancing electric, smart and shared mobility through innovation, demonstration, advocacy and engagement. It specialises in four key areas; demonstrating smart transportation, accelerating market adoption, strengthening the industry network and advancing transport policy.

Forth believes that electric and smart transportation can change our lives and our communities for the better. This can only be achieved by making these technologies available to traditionally underserved communities. To accomplish this goal, Forth has a strategic focus on promoting diversity, equity, and inclusion within all aspects of its work

### *8.2.4 TERI*

TERI is an independent organization based in India, with capabilities in research, policy, consultancy and implementation. It has been acting as an agent of change in the energy, environment, climate change and sustainability space. Over the last 40 years, the organization has worked with different stakeholders including the Indian government to create policies and provide various recommendations. It has also worked at the grassroots, developing energy efficiency solutions for India's small and medium businesses. Moreover, TERI's work in the transport sector aims at low-carbon modes of transport that are sustainable and inclusive in nature. It has pioneered policy research in this sector with expertise in issues related to energy efficiency and emissions modelling. Core areas of focus include electric vehicles, railways and urban transport. It has also developed a roadmap for the electrification of urban freight in India with an aim to increase the overall penetration of electric vehicles (EVs). The research and solutions developed by TERI have had a transformative impact on industry as well as communities. It has also fostered international collaboration on sustainability action by creating a number of platforms and forums.

### *8.2.5 uYilo*

The uYilo Electric Mobility Programme was established in 2013 focused on enabling, facilitating and mobilising electric mobility in South Africa. As a multi-stakeholder programme, uYilo has various activities that include government lobbying, industry engagement, pilot projects, capacity development, enterprise development and thought leadership. uYilo is a representative and consulting stakeholder to multiple electric mobility sector related forums, committees and working groups both locally in South Africa and internationally.

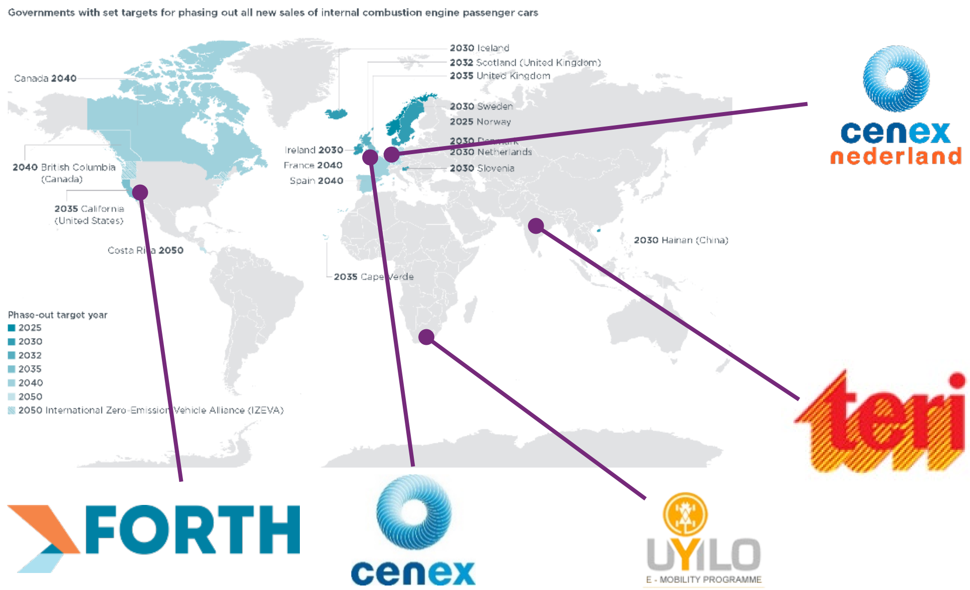
The programme's supporting technology facilities, expertise and activities extend across battery energy storage technologies, electric mobility systems and smart-grid ecosystems for EV-Grid inter-operability.

For EV charging infrastructure, the smart grid facility is Africa's largest and most technology advanced EV charging hub spanning across solar PV generation, storage with second-life EV batteries (multi-manufacturer), AC and DC charging stations, Vehicle-to-Grid for ancillary grid services, and an autonomous energy management system providing resilient charging infrastructure for electric vehicles aligned to international smart grid protocols.

The name 'uYilo' is derived from the local Xhosa language which means "to create", along the motive of the programme's activities of creating this new, eMobility industry in South Africa.

### *8.2.6 Project Team Locations*

*Figure 12: GSMP project team locations*



# 9 Appendix 2: Methodology

The project was broken down into five work packages, each contributing part of the evidence to build up a coherent picture to support the infrastructure policy recommendations. The work packages and their relationships are shown below:

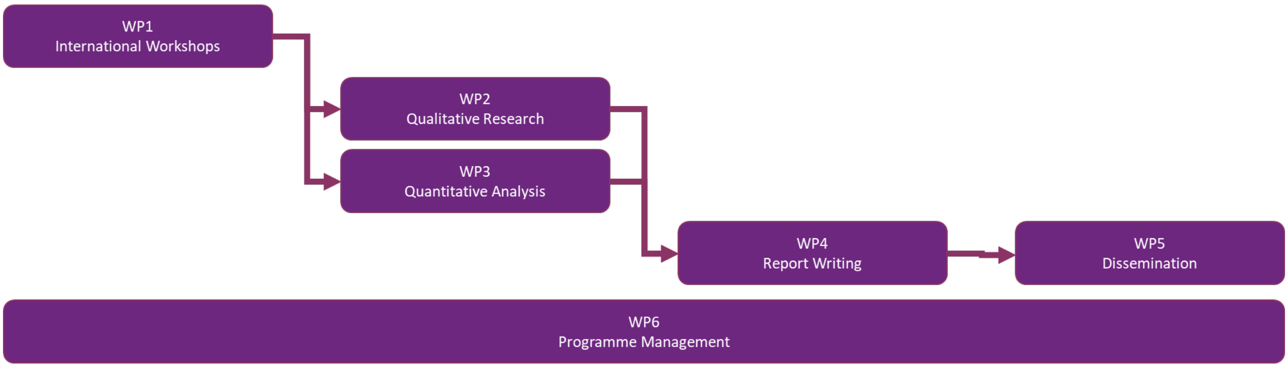



*Figure 13: Project work package linkages and sequencing*

The definitions of each work package and their contribution to this report are shown in Table 11:

*Table 11: Work package definitions and contributions*

| WP | Title | Purpose | Specific Contribution to this Report |
|---|---|---|---|
| 1 | International Workshops | Capture EV charging industry views on current and future charging behaviours, barriers and potential policies | Chapter 2<br>Chapter 3 |
| 2 | Qualitative Research | Desk-based research to draw together an evidence base on equitable charging and commercial vehicles | Chapter 3<br>Chapter 6 |
| 3 | Quantitative Analysis | Modelling to evaluate the business case for different types of charging and varied ownership models | Chapter 5 |
| 4 | Report Writing | Draw the evidence, recommendations and conclusions together into a coherent and publishable report | All sections |
| 5 | Dissemination | Publicise the results and recommendations to the ZEV Alliance and wider international community | N/A |

The workshop methodology is summarised in Appendix 3 (page 49).

# 10 Appendix 3: International Stakeholder Workshops

## 10.1 Aim

The aim of the workshops was to gather views from industry on the key challenges and opportunities presented by the transition to zero-emission vehicles. Workshops were run by GSMP partners in the USA (Forth), Europe (Cenex NL), South Africa (uYilo), India (TERI) and the UK (Cenex) with each workshop being set within the political, industrial and socioeconomic context of their country or region.

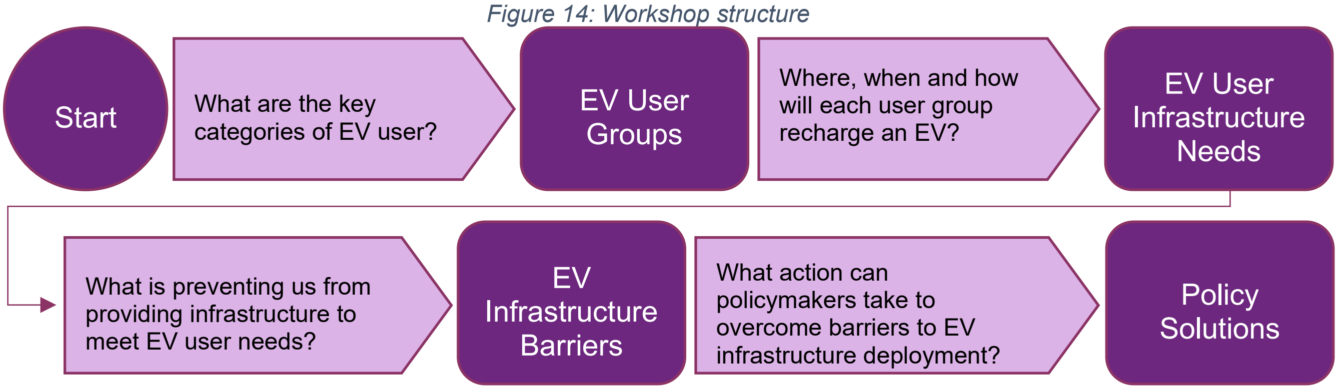
The key research questions discussed and answered in the workshops were:

- How are EV users currently charging their vehicles, and how will this change in the future?
- To what extent is industry currently able to meet EV user infrastructure requirements?
- What are the barriers preventing industry from meeting present and future EV charging demand?
- What action and intervention is required from policymakers to remove barriers and enable industry to meet future EV charging demand?

## 10.2 Method

The workshops took a semi-structured approach, allowing participants to freely express their views within the context of some pre-determined themes. This ensured the output from each of the workshop sessions was a true reflection of the attitudes of industry but could still be compared and contrasted with the other results to highlight geographical variations. Figure 14 shows the structure of the workshops with the discussion points and key outcomes.

*Figure 14: Workshop structure*




The workshops took place virtually using a video conferencing platform and an online whiteboard provided by Miro. The whiteboards ensured all attendees could easily contribute to the session. Some example outputs from the workshops are shown in Figure 15.

The attendees of the workshops included representatives from across the EV charging infrastructure industry, particularly those who are responsible for the strategic development of their respective organisation.

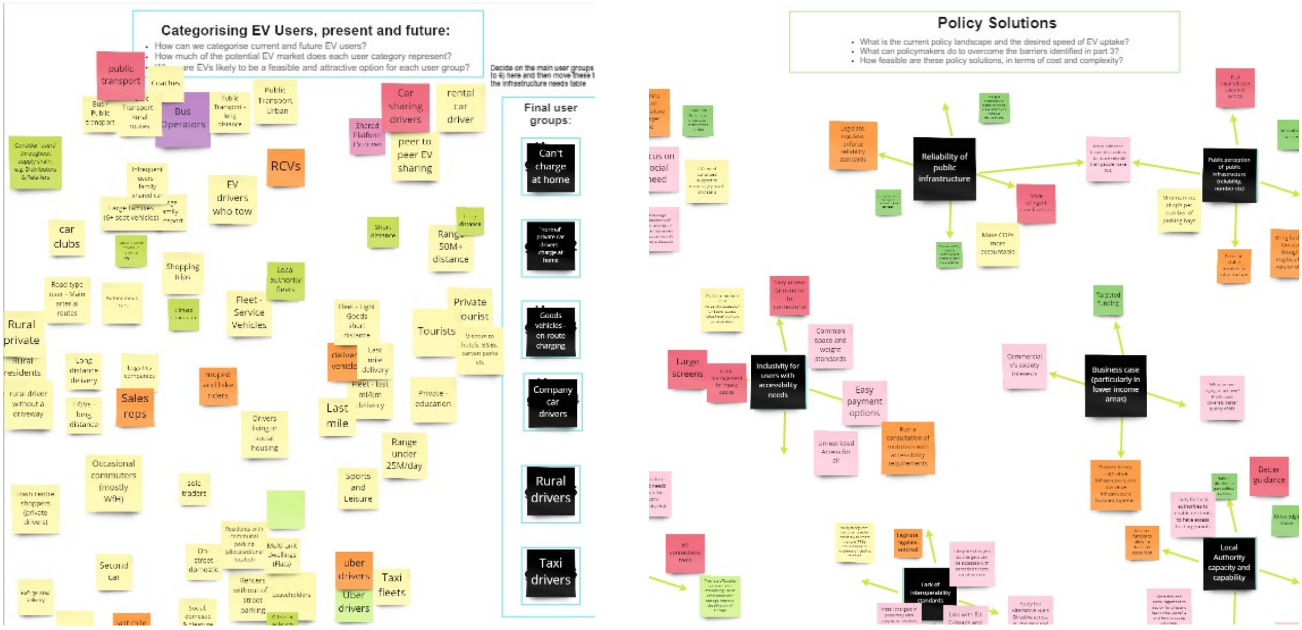



*Figure 15: Example whiteboard outputs from the UK workshop*

# 11 Appendix 4: Business Case modelling assumptions

## 11.1 Quantitative Modelling

Cenex has used its Planning Investment in Car CHarging Utilities (PICCHU) model as the basis of the quantitative analysis in Chapter 4 (page 21). This appendix outlines the key assumptions and inputs which stand behind the results.

The model explores the business case for investing in Electric Vehicle Supply Equipment (EVSE), accounting for the different specifications of EVSE available on the market. The strength of the EVSE business case is assessed by the Net Present Value (NPV) result, a metric commonly used to inform investment decisions.

! Note that the inflation and discount rates used in the NPV calculation have been assumed to be constant across all countries.

The impact that different ownership models have on the NPV of EVSE is considered across two key stakeholder groups:

- The "Landowner": The freeholder of the land upon which EVSE is installed.
- The "Contractor": An external organisation that funds one or more elements of the EVSE installation and/or operation for a fee or share of the EVSE revenue.

! Note that all calculations have been completed using the Own and Operate model (see Section 4.2 on page 21 for more details). This gives the clearest view of the range of capital costs, operating costs and potential revenues.

## 11.2 Assumptions

### 11.2.1 EVSE Specification

The model has been run with a hypothetical EVSE installation that includes equal quantities of 7 kW (Standard), 22 kW (Fast), 50 kW (Rapid) and 150 kW (Ultra-Rapid) EVSE. The hypothetical installation includes ten units of each charger type.

Whilst this configuration is arguably unlikely to be employed in a real-world setting, it provides an ideal basis upon which to compare the impact of different EVSE ownership models.

The assumed specification of each type of EVSE is shown in Table 12.

*Table 12: Summary of EVSE assumptions used as inputs into business model.*

| EVSE Type | Max Power (kW per connector) | EVSE Units Modelled | Charge Efficiency | Simultaneous connectors | Equipment Lifespan (years) |
|---|---|---|---|---|---|
| **Standard** | 7 | 10 | 90% | 2 | 12 |
| **Fast** | 22 | 10 | 90% | 2 | 10 |
| **Rapid** | 50 | 10 | 85% | 1 | 8 |
| **Ultra-Rapid** | 150 | 10 | 85% | 1 | 8 |

### 11.2.2 EVSE Utilisation

The frequency and duration of EVSE use is an important factor in determining the business case for EVSE investment. The maximum utilisation could be considered as the sales capacity for the EVSE, dependent on the output power of the EVSE and the availability of the infrastructure for use. In this case it has been assumed that all modelled EVSE is available on a 24/7 basis.

*A summary of assumptions regarding the maximum utilisation for each charger is shown in*

Table 13.

*Table 13: Summary of assumptions on the maximum utilisation of EVSE.*

| EVSE Type | Availability (hours per day) | Average charging duration (hours) | Max Daily Uses | Availability (days per week) | Max Uses Per Year |
|---|---|---|---|---|---|
| **Standard** | 24 | 7.5 | 6.4 | 7 | 2330 |
| **Fast** | 24 | 2 | 24 | 7 | 8736 |
| **Rapid** | 24 | 0.75 | 32 | 7 | 11648 |
| **Ultra-Rapid** | 24 | 0.5 | 48 | 7 | 17472 |

! Note that the maximum utilisation of Standard and Fast EVSE takes into account that two users can connect simultaneously.

### 11.2.3 Costs and Tariffs

Whilst the previous assumptions have been kept constant across all countries modelled, the costs of infrastructure and electricity network connection capital costs as well as electricity wholesale prices and typical charging tariffs have been specified for each country. Those costs that are standard across all countries are shown in Table 14. The capital and operating costs are based on an average of three UK confidential industry quotes.

*Table 14: Summary of capital and operating cost assumptions used within the business model across all countries modelled.*

| Item Costs (per EVSE unit) | Standard | Fast | Rapid | Ultra-Rapid |
|---|---|---|---|---|
| **Installation** | £3,600 | £3,600 | £3,000 | £3,000 |
| **Warranty** | £1,300 | £1,300 | £3,500 | £3,500 |
| **Backoffice** | £500 | £500 | £250 | £250 |
| **4G Connection** | £150 | £150 | £150 | £150 |
| **Maintenance** | £100 | £100 | £100 | £100 |
| ***Total Operating Cost (per year)*** | ***£750*** | ***£750*** | ***£500*** | ***£500*** |

Electricity distribution network connection costs ("DNO Costs") have been divided into installer and DNO works:

- Installer works cover all works and equipment up to the main point of connection. These costs are based on the average of three quotes for 5m of cabling and 2.5m$^2$ of ducting per EVSE unit. This is a conservative estimate and in many cases the distance to the main point of connection could be much greater which would impact the business case.
- DNO works cover works and equipment beyond the main point of connection, which may include upstream network reinforcement (e.g. at the distribution substation, primary substation, bulk supply point and/or grid supply point). This cost is spread across each EVSE unit, based on the proportion of the total power demand that the unit adds. For example, one Ultra-Rapid (150 kW) EVSE unit requires three-times more power than one Rapid (50 kW) EVSE unit, and therefore the DNO DNO costs attributed to it are three-times greater.

A consumption-based usage tariff, charged in pence per kilowatt hour (p/kWh) has been applied across all types of EVSE considered in this report. Usage tariffs vary between different types of EVSE, mirroring current EVSE industry practices, and the values have been set to reflect those that are typically charged by EVSE operators in real-world settings in each country.

### 11.2.4 Capital and Operating Cost Assumptions

***UK***

This hardware costs shown in Table 15 are based on the average of three quotes. The exception is Ultra-Rapid EVSE for which no quotes were available at time of writing, and therefore capital equipment costs have been assumed as approximately 2.5 times that of Rapid EVSE. The charging tariffs are based on public charging market research.

*Table 15: EVSE hardware capital costs and usage tariffs for each charger type (UK)*

| | Standard | Fast | Rapid | Ultra-Rapid |
|---|---|---|---|---|
| **Equipment cost (per EVSE unit)** | £1,900 | £2,100 | £20,000 | £50,000 |
| **Charging tariffs** | 25p/kWh | 28p/kWh | 30p/kWh | 45p/kWh |

The DNO installation costs are assumed to be £150,000 across the entire hypothetical EVSE installation, based on the 2.6 MW of power that it would require. A wholesale electricity cost of 15p per kilowatt hour (kWh) has been assumed.

***USA***

Public charging infrastructure in the USA can be considered in three categories of AC Level 2 (<19.2 kW), DC Level 1 (35 – 48 kW) and DC Level 2 (up to 400 kW), approximately equivalent to the fast, rapid and ultra-rapid categories used in this report. Due to there being no specific equivalent for standard charging, the number of AC Level 2 chargers was doubled to compensate. The charging tariffs and equipment costs have come from market research and then converted from USD to GBP.

*Table 16: EVSE hardware capital costs and usage tariffs for each charger type (USA)*

| | AC Level 2 | DC Level 1 | DC Level 2 |
|---|---|---|---|
| **Equipment costs (per EVSE unit)** | £2,500 | £18,000 | £45,000 |
| **Charging tariffs** | 9p/kWh | 27p/kWh | 17p/kWh |

***Netherlands***

Table 7 shows the assumed hardware costs and charging tariffs for each charger type in the Netherlands, found through market research and converted from EUR to GBP.

*Table 17: EVSE hardware capital costs and usage tariffs for each charger type (Netherlands)*

| | Standard | Fast | Rapid | Ultra-Rapid |
|---|---|---|---|---|
| **Equipment cost (per EVSE unit)** | £3,000 | £3,000 | £19,000 | £25,500 |
| **Charging tariffs** | 30p/kWh | 30p/kWh | 59p/kWh | 59p/kWh |

# 12 Appendix 5: US Commercial Vehicle Classification

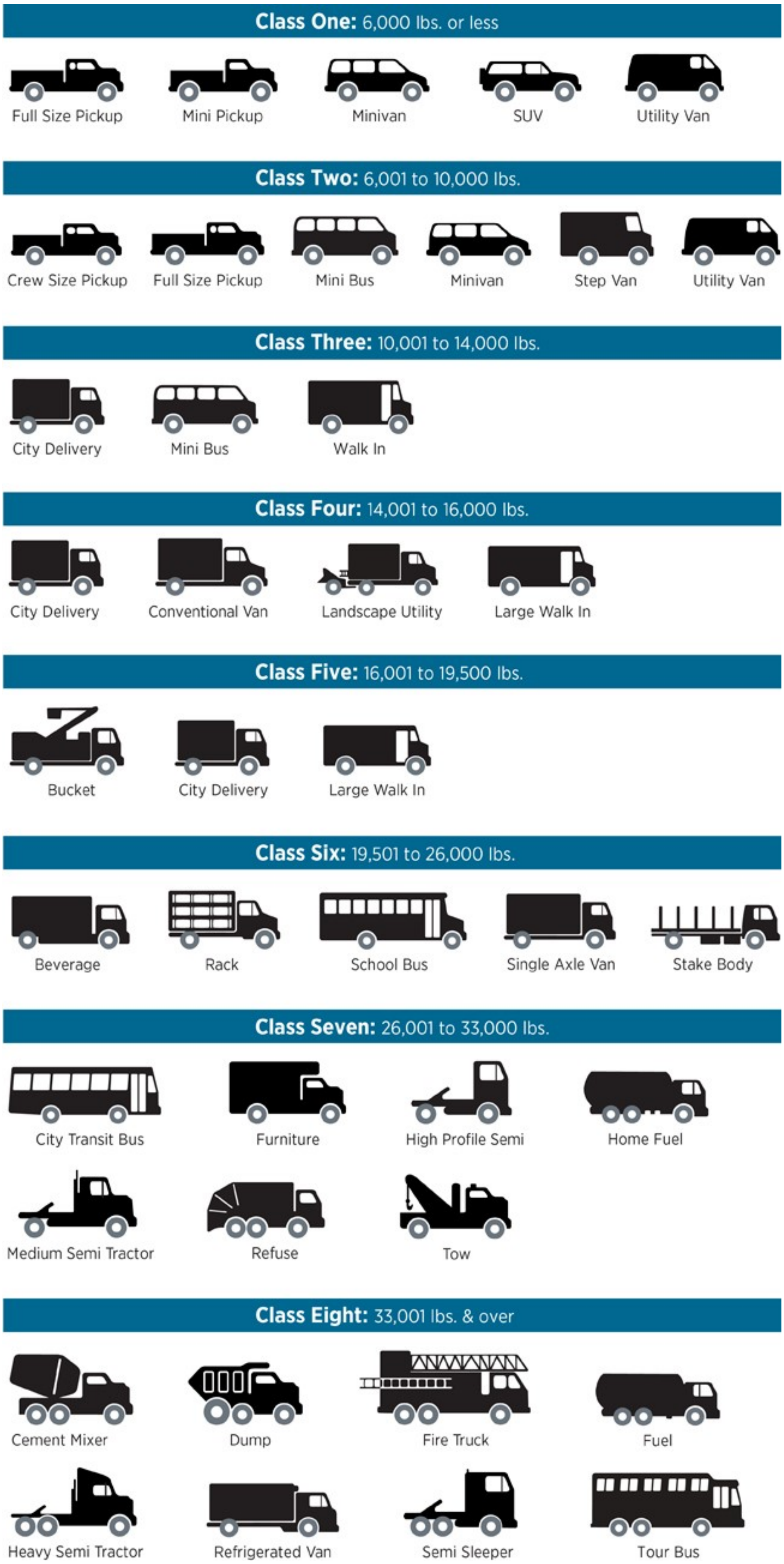



*Figure 16: US commercial vehicle classification*

[i] Cenex UK research

[ii] Source: IEA

[iii] Electromobility in Germany, 2021. https://www.bmwi.de/Redaktion/DE/Dossier/elektromobilitaet.html

[iv] Zero Emission Infrastructure Program, 2021. https://www.nrcan.gc.ca/energy-efficiency/transportation-alternative-fuels/zero-emission-vehicle-infrastructure-program/21876

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