Electric vehicle enabled buildings: evidence review of installation costs

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1. Executive summary

On behalf of the Scottish Government, ClimateXChange (CXC) commissioned this research to establish the difference in cost between installing electric vehicle (EV) charge points during initial construction or major renovation of a building as opposed to retrofitting at a later date. The research team consists of investigators from the Wood Group UK Ltd, the University of Strathclyde and Integrated Transport Planning Ltd. This report presents the background of the study along with the approach taken and the key findings from the research work.

The study took three independent approaches to investigate the research questions:

- Consultation – Developed through a series of workshops and one-to-one consultation with experts relevant to EV charge point installations
- Top-down approach - Developed using total cost of installation using Energy Saving Trust (EST) grant application data; and
- Bottom-up approach – Developed using market data for individual components of EV charge point installation.

There is very limited data available on the differences in costs of the installation of EV charge points in new buildings or those undergoing major renovation, as opposed to those being retrofitted. Neither the 'top-down' nor 'bottom-up' data analysis allowed us to quantify this factor. Further research is required when relevant data becomes available to be able to quantify those factors.

The consultation revealed that new developments do offer cost difference by offering some efficiencies in installing EV charge points when compared to buildings being retrofitted. These efficiencies are in relation to not incurring additional costs for extra civil works such as digging a trench or laying and ducting of the electrical cables which would already be covered as part of the construction of a new development. These efficiencies are quite site specific, and the scale of cost cannot be generalised, as such being difficult to quantify.

Installing EV chargers in new developments, as opposed to in those being renovated or retrofitted, is also more cost efficient in terms of the District Network Operator (DNO) upgrades. They are generally not required in respect to EV charge points as it is likely that increased capacity requirements have been considered as part of the new

development. The analysis suggests that DNO costs contribute significantly to the overall cost to install EV charge points. The bottom-up analysis, combined with information gathered from the various interviews and research regarding published DNO costs, suggests that individual installations in existing residential buildings with private driveways will not incur a DNO cost and that if the installation will require a major upgrade in capacity, DNO costs can increase in excess of £100k.

Geography is clearly a key factor influencing installation costs for EV charge points, with this largely being influenced by supply-chain issues such as availability of quality suppliers and technicians, labour and travel costs. This result in the costs being generally higher in the remote and island areas for all building types including new, undergoing major renovation, and retrofitted.

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2. Introduction

On behalf of the Scottish Government, ClimateXChange (CXC) commissioned this research to establish the difference in cost between the installation of electric vehicle (EV) charge points during initial construction or major renovation of a building as opposed to retrofitting at a later date. The research team consists of investigators from the Wood Group UK Ltd, the University of Strathclyde and Integrated Transport Planning Ltd. This report presents the background of the study along with the approach taken and the key findings from the research work.

2.1 Background of the study

In 2019, domestic transport (excluding international aviation and shipping) was the largest source of net greenhouse gas emissions in Scotland, with 25.1% of Scotland's greenhouse gas emissions.[1] The Scottish Government has pledged that Scotland will transition to a net-zero economy by 2045. In September 2018, Scottish Ministers announced ambitions to 'phase out the need' for sales of new petrol and diesel cars and light vans from 2032. This has been subsequently revised to 2030 in the Climate Change Plan Update published in December 2020.[2] As of December 2020 there were over 26,000 vehicles registered in Scotland as Ultra Low Emission Vehicles (ULEVs) with the majority being either a pure battery or plug in hybrid electric vehicle. Sales of battery, plug in hybrid vehicles and range extender vehicles represented 18.5% of new vehicle sales in December 2020.[3]

This research work aims at addressing several specific topics of cost impacts on EV charger installation at the point of construction. The brief of this research study is to examine the cost benefits of installation of EV charge points in new residential and non-residential buildings during construction or major renovation as opposed to retrofitting installation at a later date. The findings of this work will provide further evidence to Transport Scotland as they plan to propose legislative measures for a national requirement on the installation of EV charge points for new buildings.

2.2 Scope of work

The study sought to compare the cost of installation of EV charge points at construction or major renovation stages as opposed to retrofitting of residential and non-residential buildings. The study investigated the following costing scenarios:

- The costs of the installation of charge points and their associated infrastructure in the following scenarios
    - Car parks for new non-residential buildings in the initial stage of construction with more than 10 parking spaces
    - Car parks for non-residential buildings undergoing refurbishment, with more than 10 parking spaces
    - Car parks for existing non-residential buildings in buildings not undergoing refurbishment with more than 20 spaces
    - New residential development
    - Renovation of residential development

[1] Scottish Greenhouse Gas statistics: 1990- 2019- gov.scot (www.gov.scot)

[2] Securing a green recovery on a path to net zero: climate change plan 2018–2032 - update - gov.scot (www.gov.scot)

[3] Report on Public Electric Vehicle (EV) infrastructure in Scotland - Opportunities for Growth (transport.gov.scot)

- The difference in the above scenarios between different geographical contexts

Within the above scope, the study further includes the following two aspects:

1) Potential necessity for upgrading the upstream electrical infrastructure
2) Consideration of technology trends

The above research scope, however, was severely constrained by the availability of data. Therefore, the research team adopted several assumptions and modified the approach in consultation with CXC and Transport Scotland. The remainder of this report presents our approach to this study and any assumptions that the team had to make to address the data limitations.

2.3 Policy context

An existing consultation paper by the Scottish government[4] ”Building regulations- energy standards and associated topics- proposed changes: consultation” sets forth energy standards and proposed changes. Particularly pertinent for this report is part 7 of the consultation which describes the preferred policy options relating to the installation of EV charge points and enabling infrastructure to facilitate the future installation of EV charge points in the car parks of residential and non-residential buildings. The consultation document sets forth preferred options for the Scottish Government, forthcoming regulatory changes, and permissible exemptions to the rules. This consultation paper informs the costing landscape.

3. Research methods

The study took three independent approaches to investigate the research questions. The findings of these three approaches are then triangulated to reach conclusions. The approaches are:

- Consultation – Developed through a series of workshops and one-to-one consultation with experts relevant to EV charge point installation value chain for buildings, ranging from academics, local authorities, Electricity Distribution Network Operators (DNOs), charge point installers, property developers and building societies;
- Top-down approach - Developed using total cost of installation using Energy Saving Trust (EST) grant application data; and
- Bottom-up approach – Developed using market data for individual components of EV charge point installation.

Further details of these three approaches are given below.

3.1 Main research methods

3.1.1 Consultation

The purpose of the consultation was to collate feedback on perceived cost variations of EV charger installation at a building site. The research team engaged with multiple organisations, directly or indirectly associated with EV charge point installation. This analysis was conducted through a series of workshops as well as single and small group

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[4] Scottish Government, ‘Building regulations- energy standards and associated topics- proposed changes: consultation’, Part 7 – Electric Vehicle Charging Infrastructure - Building regulations - energy standards and associated topics - proposed changes: consultation - gov.scot (www.gov.scot)

interviews. Transcripts of the workshops and interviews have been collected throughout the process. Chatham House rules were followed throughout all the consultation. Appropriate GDPR rules were maintained when reporting the findings. The research team developed qualitative evidence of the key factors that commonly influence the cost of EV charger installation. The consultation also helped to identify the opportunities and constraints of EV charger installation at a new building site as opposed to retrofitting.

A summary of the workshops carried out is presented in Table 1.

Workshop	Attendees	Some key topics discussed
Workshop 1- Project Management Convening	Experts (EV Installers), Academics	• Key steps in installation process • Costs associated with each step • How are the costs affected by building age/ retrofit? • Implications of public/ private ownership or service
Workshop 2- Regional Built Environment Convening	Local authorities, Property Developers and Housing Association	• Grid variation depending on geographic location • Regional variations in installation costs and relevant factors
Workshop 3- Distribution System Convening	DNOs, Housing Association	• Costs incurred for connecting hard to reach charging stations • How is loading determined by DNOs? • Cost recovery procedure with DNOs

Table 1 Consultation workshops

The research team identified and invited a range of stakeholders to the workshops. Where experts were not able to attend a certain workshop, one-to-one consultations were arranged. Table 2 presents a summary of the number of organisations consulted throughout the process. Albeit initially planned, a fourth workshop related to technology was excluded due to lack of responses[5].

[5] Several car and battery manufacturers were contacted for the technology workshop. The research team did not receive any response from the invitees.

	EV Charger Installers	DNOs	Local Authorities	Property Developers	Technology Suppliers	Academics	Other Public Agencies
Workshop 1	1					1	
Workshop 2			7	2			
Workshop 3		2		1			
One-to-one meetings	3			1		1	2
Total	4	2	7	4	0	2	2

Table 2 Consultation Participation

3.1.2 'Top-down' Data Analysis

The Top-down approach used EST[6] data for EV charger installation grant application for both residential and non-residential buildings. The EST delivers a range of programmes aimed at decarbonising transport in the UK. In Scotland, this includes administering grants and loans available to both consumers and businesses wishing to install charging infrastructure. Funding is made available for residential and non-residential charge points via Transport Scotland.

There are a number of limitations to this data when applied to the primary questions of this report.

- The data was reported at the local authority level due to GDPR requirements, meaning that they could not be aggregated to the geographical context as defined within the study brief.
- There was no explicit reporting of on-street chargers, although these are presumably incorporated in the domestic/ residential data.
- The EST data was **not available for new buildings.** This is because no grant applications have been received for new buildings in Scotland up until the data was supplied to the research team. Further to that, the data **did not report whether or not the building was going through major renovation**.
- The installation costs of residential buildings were provided by the applicants to EST. Therefore, the accuracy of all data could not be verified by EST.
- The EST EV charge point installation costs cover materials and labour but **do not include the DNO cost.**
- The data **did not record the total number of car parking spaces** available at the building site for which the grant application was made. Therefore, the data

[6] The number of data points used in the analysis for the residential and non-residential developments were 14,398 and 594 respectively for the latest 5-year period i.e., 2017 to 2022.

could not be directly used to respond to the cost scenarios that included different scales of parking provisions.

The following assumptions were made in processing of the EST data:

- The geographical context of the cost scenario of the study brief were defined into the followings three categories. The local authorities were grouped based on the Scottish Government Urban Rural Classification 2016.[7] (Figure 1)
    - Urban
    - Rural
    - Remote islands.
- For residential buildings, the total installation cost is unitised per single charge point.
- For non-residential buildings, the total installation cost is unitised per post which can have up to 3 sockets (typically 2 sockets).
- Due to the inherent issue of the EST data for residential buildings[8], we limited the selection criteria to cost data that ranged between £300 and £5000. The lower range represents the likely contributions from the applicant, therefore any costs below £300 would not represent the full cost of installation. The upper range was set to £5000 as above this it appeared extraordinarily high for residential installation based on the experience of the research team and there were no clear explanations for such high costs. Any data within that range assumed to represent 100% of the cost of installation.
- The EST contribution value for the non-residential installations represented 50% of the total cost of the installation. Therefore, the cost data of non-residential buildings were doubled to account for the full costs.
- OZEV regulatory consultation document "Consultation Response: EV Charge points in Residential and Non-residential Buildings, Department for Transport, November 2021" was used to develop a proxy measure of the total number of car parking spaces.

[7] Scottish Government Urban Rural Classification 2016 (2. Overview - Scottish Government Urban Rural Classification 2016 - gov.scot (www.gov.scot)

[8] The residential applications are made to EST by individuals. EST does not have direct control over how the cost data are provided by the applicants. As a result, the residential data provided by EST may contain a combination of full costs of installation and only the EST contribution.

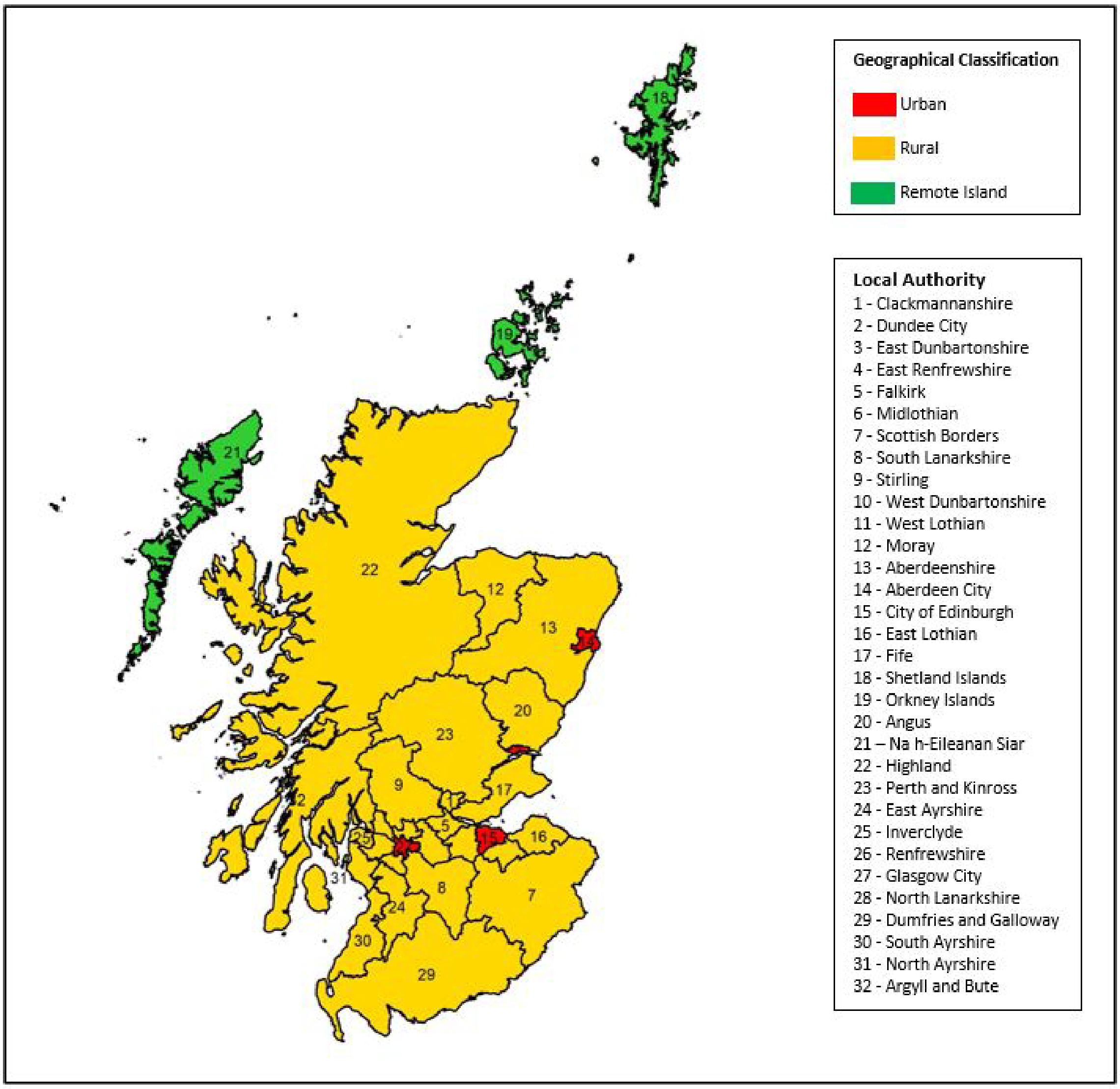

Figure 1 Geographical classification. Source: Scottish Government Urban Rural Classification, adapted to show remote islands.

3.1.3 'Bottom-up' Data Analysis

The Bottom-up approach used market data to build up cost of installation of EV chargers. Each of the facility types are decomposed into necessary components for costing including materials and installation. The component costs are sourced from business-to-business commerce sites.[9]

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[9] https://www.replenishh.com/Shop
https://www.spenergynetworks.co.uk/userfiles/file/Electric_Vehicle_Handbook.pdf
https://www.legislation.gov.uk/ssi/2014/142/made
https://energysavingtrust.org.uk/wp-content/uploads/2020/10/EST0013-Local-Authority-Guidance-Document-Incorporating-chargepoints-into-local-planning-policies-WEB.pdf
https://pod-point.com/guides/business/ev-charging-business-models
https://www.argyll-bute.gov.uk/fees/21/network
https://www.wiltshire.gov.uk/highways-works-cost (Scottish figures could not be identified)
https://www.electrical2go.co.uk/project-ev-dc-60kw-ev-charger-2-gun-rfid.html?gclid=Cj0KCQiA95aRBhCsARIsAC2xvfxwin7Y2P4UuryZWAlg49GnUWwNaVMLwTR1HPzR9xWPEervvel9ycAaAsNLEALw_wcB
https://afdc.energy.gov/fuels/electricity_infrastructure_maintenance_and_operation.html

The potential EV charge point installation costs developed as part of the 'bottom-up' method include:

- Materials (charger, switchgear & distribution, cabling & ducting, fault detection, earthing and ground works, tarmac/ asphalt, paint, and signage)
- Installation (labour, traffic management, DNO)

The costs relating to efficiency savings when installing EV charge points in new buildings or ongoing major renovation, as opposed to retrofitting, are not quantified due to lack of quantitative data. Further research is required when such data becomes available.

The costs were developed for residential developments with private driveways and residential/ non-residential properties with shared car parks using fast (7kW) output charge points.

A summary of the 'bottom-up' EV charge points installation costs' development is shown in Table 3.

	Cost categories (per each charger)	Fast (7kw) - Residential-private driveway			Fast (7kw) - Residential/non-residential-shared car park		
		Cost - Lower Range	**Cost - Upper Range**	**Unit**	**Cost - Lower Range**	**Cost - Upper Range**	**Unit**
Materials	Charger	£500	£700	Per charger	£1,000	£4,000	Per charger
	Switchgear & Distribution	£100	£200	Per charger	£0	£0	N/A
	Cabling and ducting	£10	£50	Per charger	£250	£750	N/A
	Fault Detection	£100	£300	Per charger	£0	£0	N/A
	Earthing and Ground Works	£300	£400	Per charger	£0	£0	N/A
	Tarmac/asphalt	£0	£0	N/A	£120	£140	Per charger
	Paint and road signage	£0	£0	N/A	£85	£100	Per charger
	Signage indicating chargers	£0	£0	N/A	£150	£180	Per charger
Installation	Labour to install charger	£250	£300	Per charger	£500	£1,000	Per charger
	Labour to install ducting	£0	£0	N/A	£1,000	£2,000	Per charger
	Traffic Management	£0	£0	N/A	£0	£13,000	Per development
	DNO	£0	£3,000	Per charger	£0	£100,000	Per development

Table 3 Bottom-up installation cost development summary

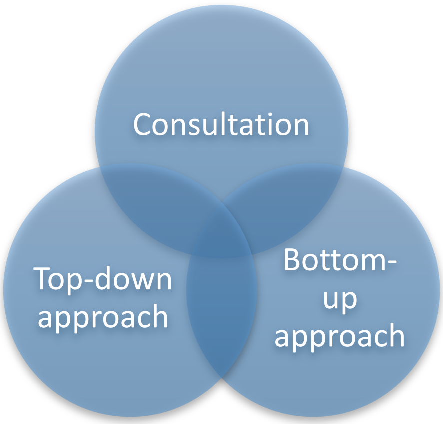
3.2 Triangulation

The three research methods (stakeholder consultation, top-down and bottom-up) are used in tandem in the research. None of the approaches addressed the research questions in their entirety. Therefore, a triangulation process was needed to derive appropriate conclusions.

The consultation process is used to select and interpret the data for the 'top-down' analysis.

The 'top-down' analysis is used to describe a range of different costs using the EST data.

A range of costing scenarios are created by means of the 'bottom-up' method. The resultant triangulated costing is then used in the reporting methodology, which is described in the following section.



3.3 Costing scenario reporting

Hypothetical Case Studies (See Appendix A) are used as a method for reporting various costing scenarios of the study brief. Case Studies are necessitated by the complexity of the costing environment.

Six Case Studies are used in this report to compactly represent the multiple interacting factors such as the building type, lifecycle, and geographical context. The Case Studies are presented in Section 4. A mix of real-world details, derived from local authority planning data bases and desk-based research, and plausible, but synthetic data from the methods are used to populate the cases. Each Case Study involves the following components:

- There is a relevant and real-world planned development, with relevant local-authority and location.
- The development details, including building cost and status are then discussed.
- The preferred options for the Scottish Government in terms of EV ready buildings are then outlined.
- The estimated EV infrastructure installation costs are included.
- A statement about whether the building would qualify for an exemption is provided.
- Each case study concludes with a discussion of likely variations by region or urban context.

Case Studies are constructed out of separate causal or costing factors. Each factor is presented independently. The evidence regarding each factor is drawn from the triangulation procedures.

One further point to note is that we have liaised with each Local Authority to develop the Case Studies and note that these are hypothetical examples of potentially how the proposed Scottish Government options would work in the real world.

4. Landscape for costing

This section presents the costing landscape for residential and non-residential buildings when new or undergoing major renovation, as opposed to being retrofitted, taking into consideration three factors:

1) Variability by geographic context
2) Potential necessity for upgrading the upstream electrical infrastructure
3) Consideration of technology trends

4.1 New, renovated and retrofitted buildings

There is very limited data available on the differences in costs of the installation of EV charge points in new buildings or those undergoing major renovation, as opposed to those being retrofitted. Neither the ‘top-down’ nor ‘bottom-up’ data analysis allowed us to quantify this factor. Further research is required when such data becomes available in order to be able to quantify these factors. The outcomes of the consultation and workshops strongly indicated that the difference between new, renovated, and existing buildings (when it comes to this being an influencing factor on EV charge point material and installation costs) are not significant when compared to other influencing factors such as the cost of the equipment itself, variation in labour costs and DNO costs.

The consultation revealed that new developments do offer some cost difference by offering some efficiencies in installing EV charge points when compared to buildings being retrofitted. These efficiencies are in relation to not incurring additional costs for **extra civil works such as digging a trench or laying and ducting of the electrical cables** which would already be covered as part of the construction of a new development. These efficiencies are quite site specific, and the scale of cost cannot be generalised. It is also important to note that for new residential and non-residential developments **DNO upgrades (and ultimately costs) are generally not required in respect to EV charge points as it is likely that increased capacity requirements have been considered as part of the development. This can potentially result in a significant cost saving when installing EV charge points in new developments, as opposed to when retrofitting.**

All things being equal (such as hardware and software of the charger itself, DNO upgrade) for all building types, a new development or building going through major renovation can offer the following cost efficiencies compared to retrofitting EV chargers at an existing building site:

- Additional cost for civil works (digging additional trenches, resurfacing) for retrofitting of an existing building.
- Laying and ducting of electrical cables for retrofitting at an existing building, where this cost can be absorbed in the building design stage for a new building or a building going through major renovation.
- Additional costs for civil works for installation of a wall box for domestic installation at an existing building.
- Upgrading cost of safety features (such as fire hydrants) at an existing building.
- Additional cost of upgrading internal wiring system connecting to the EV chargers of an existing building.
- Gained efficiency where the EV charge point installation takes place in a new development related to the economies of scale when bulk buying, likely not available to a retrofit.

- Non-monetised benefits such as the avoidance of disruption and inconvenience caused to the public or building occupants from works involved (disruption to electricity supply, property access issues, parking disruption, noise, and road closures).
- By providing EV charge points in new and renovated buildings, it is less likely that the public will bear financial and logistical cost of the installation and it will in turn increase the perception of access to charging, potentially removing a barrier to EV adoption, increasing EV uptake, and resulting in reduced emissions.

The consultation revealed clear differences between the cost of EV charge point installations in residential and non-residential buildings for all building types including new, undergoing major renovation, and retrofitted. Multiple respondents described the suitability of lower versus higher voltage chargers in residential and non-residential buildings. Since residents can await charging in their homes over an extended period of time, lower voltage and therefore less costly chargers are more suitable for residences.

Residential buildings will realistically require installation of a 7kW or 11kW wall-box or “totem” charger, whereas non-residential buildings might install anything from a 7kW fast charger to 50kW rapid charger. The “bottom up” analysis identified that this difference in charger unit cost based on type can greatly influence the overall installation cost due to the unit itself, the material required and increased labour cost. DNO upgrades (and ultimately costs) are generally not required in respect to EV charge points for new developments? as it is likely that increased capacity requirements have been considered as part of the development. This can potentially result in a significant cost saving when installing EV charge points in new developments, as opposed to when retrofitting.

The ‘top-down’ data analysis revealed clear differences in the costing of residential and non-residential buildings. Non-residential installations entail higher costs, as well as a higher variability in the incidence of costs. The data did not provide a distinction between new, undergoing major renovation, and retrofitted buildings.

4.1.1 Key Findings

No quantitative data was found to establish the difference in the costs of the EV charge point installations for new developments and those undergoing major renovation, as opposed to those being retrofitted. The consultation revealed that new developments and buildings going through major renovation do offer efficiencies in installing the EV charge points when compared to an existing building, which are mostly related to the requirements for additional civil and electrical works and potentially the economies of scale when bulk buying of equipment and labour when done at scale rather versus individual retrofit.

Non-residential installation costs are greater than in residential buildings and the range of costs is much larger, the key differentiator being the type of the EV charge point to be installed which is driven by the voltage required, as well as the type of a car park (private/ shared).

4.2 Geography

The consultation highlighted several factors that may influence the cost variation by geographic location. This analysis assumed all things that have been discussed in Section 3.1 are being equal for all locations and costing scenarios and investigated the specific impact of geography in the installation costs. The installers tend to be based in urban areas. As a result, the labour costs are higher for remote islands and rural areas. The availability of skilled contractors and installers is limited in general and may be particularly scarce in remote islands and rural areas. Nonetheless developers use local contractors wherever possible. Competition for scarce skills and labour adds to the overall cost of installation in the remote regions compared to the urban area. On the other hand, there is also intense competition to install charge points in affluent areas where there is the potential for higher utilisation. Private EV charge point network operators develop complex charge point installation strategies based on the characteristics of local communities, including their affluence, their EV adoption, and their travel propensity. This may result in competition to develop more extensive, and higher performing networks in specific areas.

For residential installations, the general patterns are for more affordable installations to be made in the central belt of Scotland, and more expensive in more remote areas both north and south of these more densely populated and central municipalities. Costs are notably higher in the Orkney Islands and the Shetland Islands.

For non-residential installations, the cost incidence is somewhat different. Costs are higher in the south and in the east of Scotland. Costs for the islands (where there is evidence) are much higher than those for the rest of Scotland.

The range in installation costs by geography obtained from the 'top-down' data analysis is presented in Table 4. The costs are presented per charge point and there is no differentiation between new buildings, those undergoing major renovation or retrofitted due to lack of data. The costs include material and labour but no DNO costs.

Geography	Residential	Non-Residential
Urban	£579 - £1,035	£2,044 - £11,569
Rural	£570 - £1,030	£1,273 - £7,255
Remote island	£777 - £1,307	£1,653 - £26,584

Table 4 Range in installation costs by geography (EST data) per charge point

Costs of EV charge point installation in residential buildings are within a similar range, with urban and rural costs being similar, and island costs being slightly elevated. This is likely to result from the labour and material costs being slightly higher for island communities. The base material costs would largely remain the same.

There is a much greater variation in non-residential costs across the geographies. This would likely result from a greater variety in the types of non-residential developments. A similar pattern can be seen for remote islands, where cost variability is significantly higher than that of urban and rural areas.

The bottom-up data analysis showed that labour costs for installation are a meaningful component of the overall installation costs. The triangulation between the study methods suggests that labour costs, and particularly travel time, play an important factor which results in higher costs for remote and island areas.

4.2.1 Key Findings

Geography is clearly a key factor in influencing installation costs for EV charge points, with this largely being influenced by supply-chain issues such as availability of quality suppliers and technicians, labour and travel costs which result in the costs being generally higher in the remote and island areas, regardless of the building being new, undergoing major renovation or being retrofitted.

4.3 Electricity network upgrades

The available data to support examining the potential necessity for upgrading the upstream electrical infrastructure was difficult to derive from the "bottom up" and "top down" data analysis as neither specifically identify DNO costs. The "bottom-up" approach is only able to identify costs based on available information from the SP Energy Networks 'Connecting Electric Vehicles' paper[10]. The time, costs and impact on the network depend heavily on what needs to be connected and existing network constraints, such as distance to cables or available capacity. An approximate cost of an upgrade for the EV charge point installation for residential houses or small offices would be between £300- £3,000. For a small business, this would increase to £5,000- £100,000 and £100k+ for larger commercial premises. There is no distinction made in the information provided between new buildings, those undergoing major renovation and those being retrofitted.

These figures will also be linked to issues surrounding land purchase, engineering works, engineering difficulties, and the presence of obstructing civil works such as motorways, canals, bridges, and railways. The capacity of the electricity grid can vary considerably by substation, and the balance of costs experienced in upgrading can vary depending on the urban context of the substation.

Furthermore, if upgrade costs are required, these costs may be borne by multiple parties, with any subsequent installation or electricity user on that substation sharing costs for the initial upgrade with those initially making the request for upgrade. Nonetheless not all EV charge point installations will require upgrades. Despite this it is increasingly likely that an upgrade is required when installations are more extensive, thereby necessitating a higher incremental load on the network.

Further analysis heavily relied on interviews with charge point operators and DNO representatives, though the latter were reluctant to share detailed costs. The result of the research and conversations highlighted the following:

- For new residential and non-residential developments, DNO upgrades (and ultimately costs) are generally not required in respect to EV charge points as it is likely that increased capacity requirements have been considered as part of the development.
- For existing residential buildings with private driveways where a charge point is being installed there are unlikely to be any upstream upgrades as it is assumed the local capacity can absorb an increase in demand.
- For residential and non-residential buildings undergoing a major renovation (and existing buildings being retrofitted with communal/ shared parking), the required upgrade on upstream electrical infrastructure is determined by the number of charge points installed. The size of the upgrade and associated costs relate to the number and type of charger installed, with an example upgrade of up to 1Mega Voltage Ampere (MVA) costing anything up to £100k.
- One charge point installer noted that where expensive costs are quoted for 7kW EV charge points, the installer will normally change their plans to install the EV

[10] SP Energy Networks (2022), " Electric Vehicle Handbook," Accessed online 20 March 2022: https://www.spenergynetworks.co.uk/userfiles/file/Electric_Vehicle_Handbook.pdf

charge point in a nearby local area where there is sufficient capacity and thus no additional cost.

Based on the ‘bottom-up’ data analysis, the analysed DNO scenarios ranged from no additional cost, where the installation would have no impact on the network, all the way through to £100k[11]+ costs, where extensive work is required to support the additional draw created by chargers on the network.

Triangulation between methods indicates that upgrade costs occur with moderate frequency, and with little generality across various frequencies. Upgrade costs may be quite substantial, but property developers and many private EV charge point network operators are likely to either relocate connections, or to forego new EV charge point installations requiring much beyond £5,000 in value.

4.3.1 Key Findings

The analysis suggests that DNO costs contribute significantly to the overall cost to install EV charge points, however, due to limits in the provided EST data, the proportion this contributes is difficult to ascertain. DNO costs are likely to be mainly required for existing buildings and those undergoing major renovation, as the increased capacity requirements would most likely be considered as part of a new development.

The bottom-up analysis, combined with information gathered from the various interviews and research regarding published DNO costs suggests that individual installations will incur no DNO cost and that if the installation will require a major upgrade in capacity, DNO costs can increase in excess of £100k per development.

4.4 Technology trends

The consultation addressed multiple aspects of technological change and the implications of these changes on costing. The topic of technological change is especially salient for automotive companies, original equipment manufacturers, installers, private EV charge point network operators and property developers. A number of technology providers such as vehicle and battery manufacturers were approached for consultation. Unfortunately, the research team did not receive any responses from the companies approached. The team therefore carried out desktop research on several emerging technologies that are being piloted but not commercially available in the market. The findings of the desktop research were further supported by expert opinions received at the stakeholder consultations. The relevant case studies are included in Appendix B. The available technologies which will have a major impact on costing are already available in the marketplace and are unlikely to be displaced in the short-term or medium term.

The analysis highlighted that in relation to the focus of this study, the technologies of interest are primarily 7kW and 50kW chargers. Ultra-rapid 100kW+ chargers were excluded as an area of focus due to these primarily being deployed in motorway service areas to enable charging on longer distance journeys. In terms of technology trends, these chargers will continue to play a role going forward but not likely in short to medium term.

Regarding battery and EV technologies, both are expected to continue evolving, with larger, longer- range batteries becoming the norm. This advancement will likely mean that vehicles will not need to charge as regularly but that they will tend to charge for

[11] SP Energy Networks (2022), " Electric Vehicle Handbook," Accessed online 20 March 2022: https://www.spenergynetworks.co.uk/userfiles/file/Electric_Vehicle_Handbook.pdf

longer. It is not expected that this will impact on the demand for EV infrastructure (e.g. this demand will continue to grow), only on how long a vehicle stays at a location charging, which, in turn may require regulations or changes to local parking stay times to prevent charger hogging.

A high-level analysis of battery and EV technology was completed in conjunction with the above analysis. A key finding is that although batteries will continue to become more efficient and hold greater capacities which, in turn, translates into longer ranges, there will still be a high demand for charging at residential and non-residential locations. This means that there will still be a requirement for the installation of suitable infrastructure. This is due to the fact that regardless of the technology in the vehicle, they will still need to charge somewhere, and this will continue to be where vehicles spend most time stationary (at home and in office / shopping/ leisure facility car parks). The charging segment which will be the most impacted will be rapid and ultra-rapid chargers, as greater battery efficiency and longer ranges will likely result in not needing to charge vehicles enroute. This is the market segment these chargers are specifically designed for, though enroute charging is not the focus of this study.

One advancement that will have an impact will be the emergence of Vehicle-to-Grid (V2G) technologies in new EVs. This technology enables EV batteries to be used as part of the electricity grid to even out demand. For example, electric car owners could charge their vehicle at off-peak rates overnight and sell energy back to the grid during the day when not in use. This will not, however, reduce the need for charging EVs at any of the building types, including new, undergoing major renovation and those being retrofitted.

4.4.1 Key Findings

The advancements in battery and EV technologies have been considered though they will have little impact on residential/ non-residential charging in short to medium term. Vehicle to grid technologies have the potential for further development and adoption. It, however, needs further studies to assess technical viability of introducing at a building site.

5. Scenarios for costing

Six scenarios for costing are described below. The six cases involve: New residential building (urban), residential building undergoing upgrades, new non-residential building, non-residential building undergoing upgrade, existing non-residential building, and new residential building (remote). Materials include the charger, cabling, ducting, tarmac, paint, and signage. Installation includes labour.

Table 5 provides a simplified summary of the scenario case studies.

Building Type	Location	LA	Details	Bottom-up EV cost analysis – By Charger		EST data analysis – By Charger	Permissable exemption from the rules?
New Residential Building	Water Row, Govan, Glasgow	Glasgow City Council	92 Dwellings 25 Car Parking spaces £26.5m development At planning stage	Materials Installation DNO Total	£1,330 £275 £0 £1,605	Classed as urban £579 - £1,035	No - no expected additional DNO costs to connect to the grid.
Residential Buildings Undergoing Major Renovation	Niddrie Road Tenement	Glasgow City Council	8 Dwellings 4 Car Parking spaces £704k development Completed	Materials Installation DNO Total	£2,888 £750 £2,500 £6,138	Classed as urban £579 - £1,035	No, as the cost to install recharging and ducting would not exceed 7% of the development cost

Building Type	Location	LA	Details	Bottom-up EV cost analysis – By Charger		EST data analysis – By Charger	Permissable exemption from the rules?
New Non-Residential Buildings	Plot 3 and 4 Lammermoor Avenue Abbotsford Business Park Falkirk	Falkirk Council	16 commercial units 63 Car Parking spaces £5.2m development At planning stage	Materials	£2,888	Classed as urban £2,044 - £11,569	No, there is no criteria relating to exemption
				Installation	£750		
				DNO	£0		
				Total	£3,638		
Non-Residential Buildings Undergoing Major Renovation	Residential Care Home, Dingwall	The Highland Council	1 commercial unit 45 Car Parking spaces £400k development Complete	Materials	£2,888	Classed as urban £2,044 - £11,569	No, as the cost of installing recharging and ducting infrastructure does not exceed 7% of the budget
				Installation	£750		
				DNO	£2,500		
				Total	£6,138		
Existing Non-Residential Buildings	Morrisons Peterhead	Aberdeenshire Council	1 commercial unit	Materials	£2,888	Classed as urban £2,044 - £11,569	No, as no exemptions have been stated for this building type.
				Installation	£750		
				DNO	£2,500		

Building Type	Location	LA	Details	Bottom-up EV cost analysis – By Charger		EST data analysis – By Charger	Permissable exemption from the rules?
			380 Car Parking spaces Active site	Total	£6,138		
New Residential Buildings	King Harald Street, Lerwick	Shetland Islands Council	27 dwellings 27 Car Parking spaces £5.6m development Completed site	Materials	£1,330	Classed as remote island £777- £1,307	No, as no exemptions have been stated for this building type.
				Installation	£275		
				DNO	£0		
				Total	£1,605		

Table 5 Case Study Development Summary

5.1.1 Key Findings

The scenarios bring to life each building type, geographical variation and the likely associated costs of installation based on the “top-down” EST data analysis and “bottom up” data analysis, drawing on the analysis completed in the previous steps. What is clear, as has already been stated, is that building type does not influence installation cost. It is rather the specific type of technology and context of installation. Wall-box installations are suited to residential (both new and renovated) properties with a driveway whereas “totem” chargers are suited to residential (new and renovated) and non-residential (new, renovated, and existing) buildings where parking is shared between multiple people. Where we can draw out regional differences based on EST data analysis it is clear that the likely difference in cost by scenario is determined by geographical variance, categorised into three types: urban, rural, and remote island. Our overall analysis therefore suggests that the building type only matters in so much as the technology that will be deployed as a result of it and that the geographic location only differs based on whether the building is urban, rural or island. In all hypothetical scenarios the proposed exemptions would not apply.

6. Conclusions

The study sought to investigate the cost impact of installing EV charge points at a new development or going through major refurbishment compared to an existing building needing retrofitting.

No quantitative data was found to establish the difference in the costs of the EV charge point installations for new developments and those undergoing major renovation, as opposed to those being retrofitted. The consultation revealed that new developments and buildings going through major renovation do offer efficiencies in installing the EV charge points when compared to an existing building, which are mostly related to the requirements for additional civil and electrical works and potentially the economies of scale when bulk buying of equipment and labour when done at scale versus individual retrofit. Further research is required when such data becomes available to be able to accurately quantify those efficiencies.

Installing EV chargers in new developments as opposed to in those being renovated or retrofitted is also more cost efficient in terms of the DNO upgrades as they are generally not required in respect to EV charge points as it is likely that increased capacity requirements have been considered as part of the new development. The analysis suggests that DNO costs contribute significantly to the overall cost to install EV charge points. The bottom-up analysis, combined with information gathered from the various interviews and research regarding published DNO costs suggests that individual installations will incur no DNO cost and that if the installation will require a major upgrade in capacity, DNO costs can increase in excess of £100k.

Non-residential installations costs are greater than residential buildings and the range of costs is much larger, the key differentiator being the type of the EV charge point to be installed which is driven by the voltage required, as well as the type of a car park (private/ shared), regardless of the building being new, undergoing major renovation or being retrofitted.

All things being equal (such as hardware and software of the charger itself, DNO upgrade) for all building types, geography is clearly a key factor in influencing installation costs for EV charge points, with this largely being influenced by supply-chain issues such as availability of quality suppliers and technicians, labour and travel costs which result in the costs being generally higher in the remote and island areas for all building types.

The advancements in battery and EV technologies have been considered though they will have little impact on residential/ non-residential charging in short to medium term. Vehicle to grid technologies have the potential for further development and adoption. It, however, needs further studies to assess technical viability of introducing at a development.

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Appendix A: Scenario Case Studies

1. New Residential building

Glasgow City Council

Hypothetical Case Study: New Residential Building

Real World Planned Development: Water Row, Govan, Glasgow

Development Details

Glasgow City Council have received a planning application for the erection of a mixed residential and commercial development (Class 1, 2, 3, 4, 7, 8, 10 and 11) with associated access, parking, open space, and public realm works.

If EV infrastructure was considered as part of the site a number of 7kw totem chargers would be installed.

No of dwellings	92	No of Car parking spaces	25	Development Cost	£26.5m*	Status	At Planning Stage

* The overall plan, approved in January 2019 was for £57m which includes 200 homes and 3500sqm of commercial space. For the purpose of this case study the Govan development is assumed to comprise half of the total development cost.

Where possible, we have spoken to the local authority regarding this case study, though these are purely hypothetical and should not be used as actual proposed plans.

Scottish Government preferred options

All dwellings with a parking space to have at least one EV charge point socket with minimum 7kW output power rating.

Exemption to requirement to install EV charge point if additional cost of electricity grid connection exceeds £2000.

If exemption applies ducting infrastructure to be installed in each car parking space.

Estimated EV Infrastructure Installation Costs

By Charger installed (7kw totem)

Category	Average Cost
Materials	£1,330
Installation	£275
DNO	£0
Total	£1,605

By Development (14 chargers)

Category	Estimated Cost
Materials	£17,290
Installation	£3,575
DNO	£0
Total	£20,865

By Development – Ducting only

Category	Estimated Cost
Materials	£6,500
Installation	£19,500
DNO	£0
Total	£26,000

*This is to install the chargers in situ only and does not include ducting.

All Figures above are estimates based on the example development and are potential costs derived from the bottom-up approach of market analysis. We assume 13x 7kw totem chargers with 2 sockets each (at least 1 per parking space). Figures exclude planning, traffic management and maintenance of infrastructure. DNO costs are excluded as we assume there would be network capacity as part of the new development. Average ducting costs have been estimated but may vary based on the development size. It is assumed that all parking is residential. The total cost of the development where 13 chargers are installed would be a combination of ‘By Development (13 chargers)’ and ‘By Development – Ducting Only’.

Would Exemption Apply: No, as there are no expected additional DNO costs to connect to the grid.

Regional Variations based on Geography if this development was built in different locations

Note that this development would be classed as an urban development.

Geography	Urban	Rural	Remote Island
Total Installation Costs by charger	£579 - £1,035	£570 - £1,030	£777 - £1,307
Total Installation Costs by development (13-chargers)	£7,527 - £13,455	£7,420 - £13,390	£10,101 - £16,991
Exemption?	No - no expected additional DNO costs to connect to the grid.	No - no expected additional DNO costs to connect to the grid.	No - no expected additional DNO costs to connect to the grid.

The regional variation figures above are derived from a top-down approach of data processing provided by the Energy Savings Trust (EST). Although the EST data was available for existing residential buildings, for comparison purpose, it was caveated to use for new residential buildings. EST data does not include 'Ducting only' as an option. EST data ranges are different from the data used in the 'bottom-up' approach and as such the estimated cost will not always fall within the EST data range.

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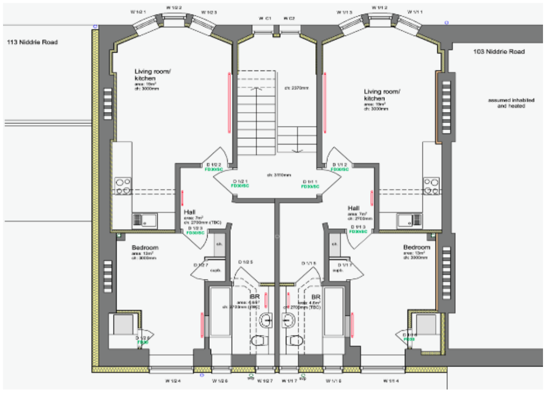
2. Residential Buildings Undergoing Major Renovation

Glasgow City Council

Hypothetical Case Study: Residential Buildings Undergoing Major Renovation

Real World Planned Development: 107 Niddrie Road Tenement



Development Details

The Niddrie Road project received funding from the Scottish Government as part of its Climate Emergency Collaboration Challenge to renovate a tenement building, The four storey 8 flat building, owned by Southside Housing Association, was empty and in a poor state of repair. A 'hypothetical car park' with 4 parking spaces is assumed to be included within the development as part of the refurbishment.

No of dwellings	8	No of Car parking spaces	4	Development Cost	£704k	Status	Completed

Where possible, we have spoken to the local authority regarding this case study, though these are purely hypothetical and should not be used as actual proposed plans.

Scottish Government preferred options

For buildings with more than 10 car parking spaces, ducting to be installed in each residential car parking space to support the future installation of an EV charge point.

EV charge points sockets to be installed, with minimum 7kW output power rating, in as many residential car parking spaces as the electrical capacity of the building post-renovation allows. Exemption applies if the cost of installing recharging and ducting infrastructure exceed 7% of total major renovation cost.

Estimated EV Infrastructure Installation Costs

By Charger installed (7kw totem)

Category	Average Cost
Materials	£2,888
Installation	£750
DNO	£2,500
Total	£6,138

By Development (14 chargers)

Category	Estimated Cost
Materials	£5,776
Installation	£1,500
DNO	£5,000
Total	£12,276

By Development – Ducting only

Category	Estimated Cost
Materials	£1,000
Installation	£3,000
DNO	£1,650
Total	£5,650

*This is to install the chargers in situ only and does not include ducting.

All Figures above are estimates based on the example development and are potential costs derived from the bottom-up approach of market analysis. We assume 2 7kw on-street chargers (total of 4 sockets) are required based on 1 socket per parking space. Figures exclude planning, traffic management and maintenance of infrastructure. DNO costs are based on interviews with charging infrastructure companies and available public information. The figure above is the average figure and quotes from the DNO will differ to this. For ducting only a hypothetical DNO cost has been included to cover negotiations relating to where to connect the ducting to. The total cost of the development where 2 chargers are installed would be a combination of 'By Development (2 chargers)' and 'By Development – Ducting Only'.

Would Exemption Apply: No, as the cost to install recharging and ducting would not exceed 7% of the development cost

Regional Variations based on Geography if this development was built in different locations

Note that this development would be classed as an urban development.

Geography	Urban	Rural	Remote Island
Total Installation Costs by charger	£579 - £1,035	£570 - £1,030	£777 - £1,307
Total Installation Costs by development (2 chargers)	£1,158 - £2,070	£1,140 - £2,060	£1,554 - £2,614
Exemption?	No, as the cost to install recharging and ducting would not exceed 7% of the development cost		

The regional variation figures above are derived from a top-down approach of data processing provided by the Energy Savings Trust (EST). EST data does not include 'Ducting only' as an option.

Data Sources

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3. New Non-Residential Buildings

Falkirk Council

Case Study: New Non-Residential Buildings

Real World Planned Development: Plot 3 and 4 Lammermoor Avenue Abbotsford Business Park Falkirk


Development Details

The proposed development is for the creation of 16 commercial units on plot 3 and 4 of the Abbotsford Business Park in Falkirk. The planned development already includes provision for 4 7kw charging totems, each with 2 sockets, cabling ducts and connections to the DNO. For the purpose of this case study, it was assumed that no EV chargers are available at the moment.

No of commercial units	16	No of Car parking spaces	63	Development Cost	£5.2m*	Status	At Planning Stage

* Based on development figures for the original business park, built in 2016 which was for 4 units (£1.3m. £325k per unit). This base figure has been adapted based on the number of planned units.

Where possible, we have spoken to the local authority regarding this case study, though these are purely hypothetical and should not be used as actual proposed plans.

Scottish Government preferred options

For buildings with more than 10 non-residential car parking spaces, 1 in every 2 non-residential parking spaces to have ducting installed and 1 in every 10 non-residential parking spaces to provide an EV charge point socket with minimum 7kW output power rating.

Estimated EV Infrastructure Installation Costs

By Charger installed (7kw totem)

Category	Average Cost
Materials	£2,888
Installation	£750
DNO	£0
Total	£3,638

By Development (14 chargers)

Category	Estimated Cost
Materials	£11,552
Installation	£3,000
DNO	£0
Total	£14,552

By Development – Ducting only

Category	Estimated Cost
Materials	£2,000
Installation	£6,000
DNO	£0
Total	£8,000

*This is to install the chargers in situ only and does not include ducting.

All Figures above are estimates based on the example development and are potential costs derived from the bottom-up approach of market analysis. Based on the Scottish Government's preferred option we assume 4 7kw charging totems, each with two sockets. The planned development already meets this requirement though additional ducting would be required based on the site diagrams to align with the preferred option. A combination of 'By development – 4 chargers' and 'By Development – Ducting only' would be required to ascertain the full cost. Figures exclude planning, traffic management and maintenance of infrastructure. DNO costs are excluded as we assume there would be network capacity as part of the new development. Average ducting costs have been estimated but may vary based on the development size. The total cost of the development where 4 chargers are installed would be a combination of 'By Development (4 chargers)' and 'By Development – Ducting Only'.

Would Exemption Apply: No, there is no criteria relating to exemption

Regional Variations based on Geography if this development was built in different locations

Note that this development would be classed as an urban development.

Geography	Urban	Rural	Remote Island
Total Installation Costs by charger	£2,044 - £11,569	£1,273 - £7,255	£1,653 - £26,584
Total Installation Costs by development (4 chargers)	£8,176 - £46,276	£5,092 - £29,020	£6,612 - £106,336
Exemption?	No, there is no criteria relating to exemption		

The regional variation figures above are derived from a top-down approach of data processing provided by the Energy Savings Trust (EST). Although the EST data was available for existing non-residential buildings, for comparison purpose, it has been adapted to use for new non-residential buildings. EST data does not include ‘Ducting only’ as an option.

Data Sources

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https://www.scottishconstructionnow.com/articles/construction-commences-at-falkirk-business-park

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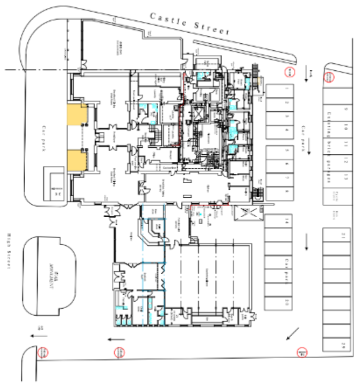
https://energysavingtrust.org.uk

4. Non-Residential Buildings Undergoing Major Renovation

The Highland Council

Hypothetical Case Study: Non-Residential Buildings Undergoing Major Renovation

Real World Development: Residential Care Home, Dingwall



Development Details

Change of use from Hotel to Residential Institution (Residential Care) with some internal renovations including the installation of a lift

No of commercial units	1	No of Car parking spaces	45*	Development Cost	£400k**	Status	Complete

* Estimated based on available information

** Based on a high-level estimation of the development

Where possible, we have spoken to the local authority regarding this case study, though these are purely hypothetical and should not be used as actual proposed plans.

Scottish Government preferred options

For buildings with more than 10 non-residential car parking spaces, 1 in every 2 non-residential parking spaces to have ducting installed and 1 in every 10 non-residential parking spaces to provide an EV charge point socket with minimum 7kW output power rating.

Exemption applies if the cost of installing recharging and ducting infrastructure exceeds 7% of total major renovation cost.

Estimated EV Infrastructure Installation Costs

By Charger installed (7kw totem)

Category	Average Cost
Materials	£2,888
Installation	£750
DNO	£2,500
Total	£6,138

By Development (14 chargers)

Category	Estimated Cost
Materials	£14,440
Installation	£3,750
DNO	£12,500
Total	£30,690

By Development – Ducting only

Category	Estimated Cost
Materials	£2,500
Installation	£7,500
DNO	£1,650
Total	£11,650

* This is to install the chargers in situ only and does not include ducting.

All Figures above are estimates based on the example development and are derived from the bottom-up approach of market analysis. Based on the Scottish Government's preferred option we assume 5 7kw charging totems, each with two sockets. Figures exclude planning, traffic management and maintenance of infrastructure. Average ducting costs have been estimated but may vary based on the development size. DNO costs are based on interviews with charging infrastructure companies and available public information. The figure above is the average figure and quotes from the DNO will differ to this. For ducting only, a hypothetical DNO cost has been included to cover negotiations relating to where to connect the ducting to. The total cost of the development where 5 chargers are installed would be a combination of 'By Development (5 chargers)' and 'By Development – Ducting Only'.

To align with the Scottish Government's preferred options, it is likely that the total cost would be a blend of 'By Development – 5 Chargers' and 'By Development – Ducting Only'

Would Exemption Apply: No, as the cost of installing recharging and ducting infrastructure does not exceed 7% of the budget.

Regional Variations based on Geography if this development was built in different locations

Note that this development would be classed as an urban development.

Geography	Urban	Rural	Remote Island
Total Installation Costs by charger	£2,044 - £11,569	£1,273 - £7,255	£1,653 - £26,584
Total Installation Costs by development (5 chargers)	£10,220 - £57,845	£6,365 - £36,275	£8,265 - £132,920
Exemption?	No, as the cost of installing recharging and ducting infrastructure does not exceed 7% of the budget		

The regional variation figures above are derived from a top-down approach of data processing provided by the Energy Savings Trust (EST). EST data does not include 'Ducting only' as an option.

Data Sources

https://wam.highland.gov.uk/wam/applicationDetails.do?activeTab=documents&keyVal=QPP7X0IHHKI00

https://wam.highland.gov.uk/wam/files/88C6457EFD017DADE6BC89CB0769CE4B/pdf/21_01130_FUL-SITE_LAYOUT_AND_PARKING_PLAN-2458195.pdf

https://www.replenishh.com/Shop

https://www.spenergynetworks.co.uk/userfiles/file/Electric_Vehicle_Handbook.pdf

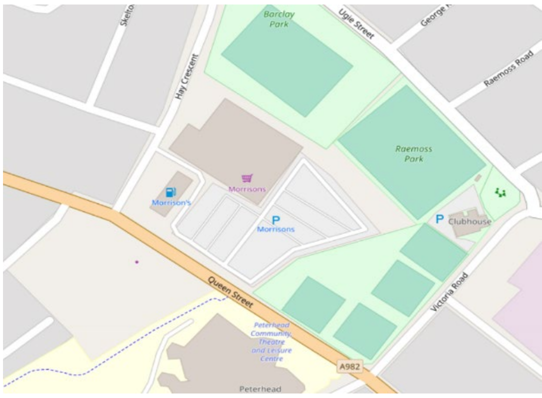
https://energysavingtrust.org.uk

5. Existing Non-Residential Buildings

Aberdeenshire Council

Hypothetical Case Study: Existing Non-Residential Buildings

Real World Development: Morrisons Peterhead



Development Details

Supermarket site with no current EV charging infrastructure.

No of commercial units	1	No of Car parking spaces	380	Development Cost	N/A	Status	Active site

Where possible, we have spoken to the local authority regarding this case study, though these are purely hypothetical and should not be used as actual proposed plans.

Scottish Government preferred options

By 1 January 2025, for buildings with more than 20 non-residential car parking spaces, 1 in every 2 non-residential parking space to have ducting installed and 1 in every 10 non-residential parking space to provide an EV charge point socket with minimum 7kW output power rating.

Estimated EV Infrastructure Installation Costs

By Charger installed (7kw totem)

Category	Average Cost
Materials	£2,888
Installation	£750
DNO	£2,500
Total	£6,138

By Development (14 chargers)

Category	Estimated Cost
Materials	£109,744
Installation	£28,500
DNO	£95,000
Total	£233,244

By Development – Ducting only

Category	Estimated Cost
Materials	£19,000
Installation	£57,000
DNO	£1,650
Total	£77,650

* This is to install the chargers in situ only and does not include ducting.

All Figures above are estimates and are potential costs derived from the bottom-up approach of market analysis. Based on the Scottish Government's preferred option we assume 38 7kw charging totems, each with one socket. Figures exclude planning, traffic management and maintenance of infrastructure. DNO costs by development are based on guidance from SP Energy Networks. Developments with connections greater than 1 MVA can cost over £100k but we have simplified the cost based on a per charger cost. This development would require a maximum power capacity of 2.66 MVA so it is likely the quoted DNO cost will be higher. DNO costs are based on interviews with charging infrastructure companies and available public information, DNO costs for this stay the same as this is to cover determining where the ducting connects to. To align with the Scottish Government's preferred options it is likely that the total cost would be a combination of 'By Development – 38 Chargers' and 'By Development – Ducting Only'.

Would Exemption Apply: No, as no exemptions have been stated for this building type.

Regional Variations based on Geography if this development was built in different locations

Note that this development would be classed as an urban development.

Geography	Urban	Rural	Remote Island
Total Installation Costs by charger	£2,044 - £11,569	£1,273 - £7,255	£1,653 - £26,584
Total Installation Costs by development (38 chargers)	£77,672 - £439,622	£48,374 - £275,690	£62,814 - £1,010,192
Exemption?	No, as no exemptions have been stated for this building type.		

The regional variation figures above are derived from a top-down approach of data processing provided by the Energy Savings Trust (EST).

Data Sources

https://en.parkopedia.co.uk/parking/carpark/morrisons/ab42/peterhead/?arriving=202203152000&leaving=202203152200

https://www.replenishh.com/Shop

https://www.spenergynetworks.co.uk/userfiles/file/Electric_Vehicle_Handbook.pdf

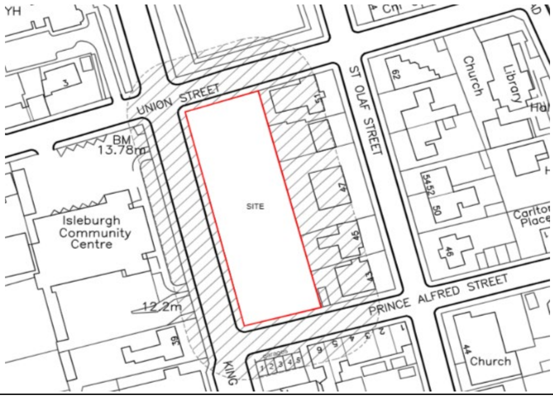
https://energysavingtrust.org.uk

6. New Residential Buildings (Remote)

Shetland Islands Council

Hypothetical Case Study: New Residential Building

Real World Development: King Harald Street, Lerwick



Development Details

Existing buildings demolished and replaced with three new two-three storey buildings containing in 27 one-bedroom flats. Note that the original plans did not include car parking so this hypothetical case study assumes each flat would have an associated car park and that this would be included in the development cost below.

No of dwellings	27	No of Car parking spaces	27	Development Cost	£5.6m*	Status	Completed site

According to Hjaltland Housing Association the total investment for this development and another development of 24 dwellings in Tingwall was £10.4million. An average per dwelling cost was developed across both developments and then multiplied by the number of dwellings at this site (£204k x 27).

Where possible, we have spoken to the local authority regarding this case study, though these are purely hypothetical and should not be used as actual proposed plans.

Scottish Government preferred options

All dwellings with a parking space to have at least one EV charge point socket with minimum 7kW output power rating.

Exemption to requirement to install EV charge point if additional cost of electricity grid connection exceeds £2000.

If exemption applies ducting infrastructure to be installed in each car parking space.

Estimated EV Infrastructure Installation Costs

By Charger installed (7kw totem)

Category	Average Cost
Materials	£1,330
Installation	£275
DNO	£0
Total	£1,605

By Development (14 chargers)

Category	Estimated Cost
Materials	£18,620
Installation	£3,850
DNO	£0
Total	£22,470

By Development – Ducting only

Category	Estimated Cost
Materials	£7,000
Installation	£21,000
DNO	N/A
Total	£28,000

* This is to install the chargers in situ only and does not include ducting.

All Figures above are estimates based on the example development and are potential costs derived from the bottom-up approach of market analysis. We assume 14x 7kw totem chargers with 2 sockets each (at least 1 per parking space). Figures exclude planning, traffic management and maintenance of infrastructure. DNO costs are excluded as we assume there would be network capacity as part of the new development. Average ducting costs have been estimated but may vary based on the development size. Ducting only costs can be higher than installing the charge points if the location of the charge points is unknown and it is necessary to future proof the site. The actual cost will be a blend of 'by development (14 chargers)' and 'by development – ducting only'.

Would Exemption Apply: No. While there might be a £2,000 cost exemption, it is not triggered in this case.

Regional Variations based on Geography if this development was built in different locations

Note that this development would be classed as a remote island development.

Geography	Urban	Rural	Remote Island
Total Installation Costs by charger	£579 - £1,035	£570 - £1,030	£777 - £1,307
Total Installation Costs by development (14 - chargers)	£8,106 – £14,490	£7,980 - £14,420	£10,878 - £18,298
Exemption?	No - no expected additional DNO costs to connect to the grid.	No - no expected additional DNO costs to connect to the grid.	No - no expected additional DNO costs to connect to the grid.

The regional variation figures above are derived from a top-down approach of data processing provided by the Energy Savings Trust (EST). Although the EST data was available for existing residential buildings, for comparison purpose, it was caveated to use for new residential buildings. EST data does not include 'Ducting only' as an option. EST data ranges are different from the data used in the 'bottom-up' approach and as such the estimated cost will not always fall within the EST data range.

Data Sources

https://pa.shetland.gov.uk/online-applications/caseDetails.do?caseType=Application&keyVal=OI2BNLOAGWT00

https://www.hjaltland.org.uk/properties/schemes/lerwick/king-harald-street

https://www.replenishh.com/Shop

https://www.spenergynetworks.co.uk/userfiles/file/Electric_Vehicle_Handbook.pdf

https://energysavingtrust.org.uk

Appendix B: Technology Case Studies

Name of the technology:	Hydrogen Fuel
Likely impact on EV Charging cost:	Low as mainly suitable for commercial use/ refuelling stations. The cost between electricity and hydrogen is likely to be comparable for practical fleet operations so is not expected to have a significant impact on the cost.
Owner or developer:	Demonstrator Project Example:
Location:	Dundee
General description of the system: Vehicle which is powered by fuel cell which utilises hydrogen and oxygen[12] in a fuel cell stack to create electricity to power the car's motors. The advantages of using hydrogen fuel are it allows faster recharge than battery EVs with hydrogen car refuel in 3 minutes while 7 minutes for bus[13].	
Current state of development: There are many demonstrator projects of Hydrogen Fuel buses across Europe that have been or are going to be undertaken[14]. This includes in Dundee through The Hydrogen Accelerator (funded by Transport Scotland partnered with University of St Andrews and University of Strathclyde and Aberdeen)[15]. The European Zero Emission bus conference (2021)[16] identifies the need to make this form of power to be affordable particularly through developing retrofitting of vehicles. A report, *Scottish Hydrogen Assessment,* from the Scottish Government 2020[17] highlights the potential of this technology for heavy fleet road vehicles in Scotland and in both rural, island and urban locations.	
Potential date for commercialisation:	Hydrogen infrastructure for vehicles is in existence but not wide-spread – for example UK has fewer than 10 currently in existence[13]

[12] Office of Energy efficiency and Renewable Energy (undated) *Hydrogen Fuel Basics,* [online], Available at: https://www.energy.gov/eere/fuelcells/hydrogen-fuel-basics [Accessed 21/02/2022]

[13] ukh2 mobility (2019) *Refuelling stations,* [online] Available at: http://www.ukh2mobility.co.uk/stations/#hydrogen_infrastructure [Accessed 21/02/2022]

[14] Fuel Cell Electric Buses, (undated). *Bus Locations.* [online] Available at: https://www.fuelcellbuses.eu/category/demos-europe [Accessed:10/02/2022]

[15] Hydrogen Accelerator (undated). Dundee Hydrogen Bus Deployment Project [online] Available at: https://h2-accelerator.org/projects/dundee/ [Accessed 10/02/2022]

[16] European Zero Emission Bus Conference (2021) *European Zero Emission Bus Conference: Summary,* [online] Available at: https://www.fuelcellbuses.eu/public-transport-hydrogen/european-zero-emission-bus-conference-summary [Accessed 10/02/2022]

[17] Scottish Government, (2020). *Scottish Hydrogen Assessment.* [online] https://www.gov.scot/publications/scottish-hydrogen-assessment-report/documents/ [Accessed 10/02/2022]

Commercial costs:	Not available
Suitability:	Most suitable for commercial – refuelling stations
Any installation prerequisites:	Infrastructure for hydrogen refuelling etc – storage, compressors, pre-cooling system, dispenser13

Name of the technology:	High Power/Fast Chargers
Likely impact on EV Charging cost:	Low in short to medium term. Long term impact mainly in commercial setting with en route charging. Fast EV charging is cheaper than the slower options, so it is likely to reduce the cost of EV charging.
Owner or developer:	Fast Charging Example: Tesla Supercharge Stations
Location:	Widespread – including Scotland18

General description of the system:

Fast charging decreases charging times for EVs compared with normal chargers. Zhang et al (2019) compare a residential 7kW normal charger taking over 9 hours to go from 15% charge to full charge on a Tesla Model S while a fast charger (120kW) takes only 32 minutes to complete this charge, which means a reduced charge time which is highlighted as a key issue. Lui et al (2019)[19] define extreme fast charging as a 15-minute recharging time but highlights battery technology as a barrier to implementation, due to a balance between fast charging and performance/safety.

Current state of development:

The UK government in 2020[20] stated an aim to have a minimum of 6 high powered (150-350 kilowatt) capable chargers at motorway service areas by 2023 providing 120-145 miles of range within 15 minutes charging. Additionally, they aimed to have 6,000 high powered charge points for major roads/motorways by 2035. This shows intent for adoption of this technology in the near future.

High power chargers are a technology already in use. There are over 3,000 Tesla Supercharger Stations in Europe & Middle East including in Scotland[18] and are able to deliver peak charge rates of up to 250kW (V3) or 150kW (V2)[21] and focused in locations on key routes – as opposed to destination charging which are located at key destinations[22] where charging times are less likely to be constrained.

[18] Tesla, (2022) *On the Road,* [online] Available at: https://www.tesla.com/en_GB/supercharger [Accessed 11/02/2022]

[19] Liu, Y., Zhu, Y. and Cui, Y. (2019) Challenges and opportunities towards fast-charging battery materials - Abstract, *Nature Energy*, 4, pp. 540-550

[20] UK Government (2020) *Policy Paper Government vision for the rapid chargepoint network in England,* [online] Available at: https://www.gov.uk/government/publications/government-vision-for-the-rapid-chargepoint-network-in-england/government-vision-for-the-rapid-chargepoint-network-in-england [Accessed 11/02/2022]

[21] Tesla, (2022) *Support Supercharging,* [online] Available at: https://www.tesla.com/en_GB/support/supercharging#v3 [Accessed 11/02/2022]

[22] Tesla, (2022). *Upon Arrival,* [online] Available at: https://www.tesla.com/en_GB/destination-charging [Accessed 11/02/2022]

Potential date for commercialisation:	High Powered Chargers being introduced and intent to increase installation over next 10 years, in UK, shown.
Commercial costs:	Cost to user of current supercharging £0.28 per kW hour[18]
Suitability:	Most suitable for commercial – due to kW level
Any installation prerequisites:	Availability of delivery of charging power e.g. Tesla 250kW – requires dedicated transformers and utility connections[23], space constraints, optimal location point

[23] Tesla (2022) *Home Charging Installation*, [online] Available at: https://www.tesla.com/en_GB/support/home-charging-installation/faq [Accessed 21/02/2022]

Name of the technology:	Solar Powered Charging
Likely impact on EV Charging cost:	Potential impact longer term in residential and non-residential settings as it would reduce the cost of electricity and as a result reduce the cost of EV charging.
Owner or developer:	No commercial/public example located (home charging to be integrated into to home/business solar system product example myenergi - Zappi24)
Location:	Widespread
General description of the system: EV charging can be powered by solar power through infrastructure including a photovoltaic panel, which can reduce the environmental impact of EV charging as compared with fossil fuel powered charging (Khan et al, 2017)[25]. EV charging points with solar power can also include various other connections for example Prem et al (2019)[26] outline a system with grid integration and battery back up to operate effectively, they outline solar powered daytime charging, battery charging when solar is not available and grid provided charge when the battery no longer has sufficient charge. Similarly, Chellaswamy et al. (2018)[27] outline an EV charging system using both solar and wind power and also smart charging grid connection allowing power to be transferred to the grid if in excess.	
Current state of development: Solar photovoltaic power is considered within the Scottish Energy Strategy as a part of providing Scotland's energy requirements to meet its low carbon aims[28]. Research and investigation of different methods of utilising this system. Deshmukha and Pearce (2021)[29] explore the potential for EV charging stations with solar photovoltaic power canopies over parking areas for retail establishments, providing retailers with more attractive facilities and potential to provide free charging to users. Zhou et al (2021) outline a different form of this	

[24] Myenergi (2022) *zappi,* [online]. Available at: https://myenergi.com/product/zappi/#product-overview [Accessed 21/02/2022]

[25] Khan, S., Ahmad, A., Ahmad, F., Shemami, M. S., Alam, M. S. and Khateeb, S. (2018) A Comprehensive Review on Solar Powered Electric Vehicle Charging System - Abstract, *Smart Science,* 6 (1), pp. 54-57

[26] Prem, P., Sivaraman, P., Raj, J. S. S. S., Sathik, M. J. and Almakhles, D. (2020) Fast charging converter and control algorithm for solar PV battery and electrical grid integrated electric vehicle charging station, Automatika, 61 (4), pp. 614-625

[27] Chellaswamy, C. Nagaraju, V. and Muthammal, R. (2018) Solar and Wind Energy Based Charging Station for Electric Vehicles, *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering,* 7 (1)

[28] Scottish Government, (2017). *Scottish Energy Strategy: The future of energy in Scotland*, [online] Available at: https://www.gov.scot/publications/scottish-energy-strategy-future-energy-scotland-9781788515276/documents/ [Accessed: 11/02/2022]

[29] Deshmukh, S. S. and Pearce, J. M. (2021) Electric vehicle charging potential from retail parking lot solar photovoltaic awnings - Abstract, *Renewable Energy,* 169 pp. 608-617

technology with reviewing a combination of solar photovoltaic pavement and wireless EV charging.	
Potential date for commercialisation:	Solar technology widespread – not currently widely adopted for EV charging points commercially – studies exploring potential of adoption – are current charge points manufactured to integrate with homes and businesses with solar/wind power generation e.g. zappi
Commercial costs (if available)	Single home point zappi charger available from £695 for unit with additional installation costs[24]
Suitability:	Potential for commercial and residential
Any installation prerequisites:	Dependent on grid or non-grid connection; suitable grid connection if required along with connected infrastructure e.g. battery back-up smart system[26], area constraints for sufficient solar panels (and associated infrastructure) and in sufficient solar conditions for operation.

Name of the technology:	Bi-directional or Return to Grid Energy
Likely impact on EV Charging cost:	Low in short to medium term. High in long term both in residential and commercial settings, as it will allow to recover some of the energy costs. Potential to reduce the cost of EV charging.
Owner or developer:	Kaluza, Ovo Energy, Nisan Motor Company, Cenex, Indra Renewable Technology with funding from Office for Low Emission Vehicles and Department for Business Energy and Industrial Strategy30
Location:	UK

General description of the system:

Connections can be grid-vehicle only or also, vehicle to grid. Bi-directional charging allows EV batteries to store energy during low demand times and be a source during peak hours Thakre et al., (2020)[31]. Having bi-directional charging, instead of uni-directional charging helps to reduce peak network demand with Crozier et al. (2020)[32] outlining potential reductions of 40% in peak demand with vehicle to grid connections and smart charging but increased cost of installation.

Prem et al (2019)[26] outline a system with grid integration and battery back-up to operate effectively, for example they outline solar powered daytime charging where excess energy is transferred to the grid, battery charging when solar is not available and grid provided charge when the battery no longer has sufficient charge. Thakre et al., (2020)[31] also, highlight the range of infrastructure, and associated costs, for the vehicle to grid connection including: the EV itself, Electric Vehicle Supply Unit (multi-locations), grid control indicators and smart meters, home energy management gateway, software, and driver communication devices. Garruto et al (2020)[33] also discuss the theoretical use of this technology, not just at residential areas or other areas where EVs are positioned over night for instance, in a railway station car park with solar energy production.

Current state of development:

Systems that operate with grid-battery connections exist. An example is the Kaluza[30] programme was vehicle-to-grid connection from 2018 with bi-directional energy flow dependent on price levels (particularly related to renewable energy availability) and local grid needs – 330 V2G devices were installed and used with a Nissan Leaf vehicle and an app. Energy from vehicle to grid was sold within the trial at 30p per kWh.

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[30] Maher-McWilliams, C. (2021) *Case study (UK): Electric vehicle-to-grid (V2G) charging,* [online]. Available at: https://www.ofgem.gov.uk/publications/case-study-uk-electric-vehicle-grid-v2g-charging [Accessed: 21/02/2022]

[31] Thakre, M. P., Mahadik, Y.V. and Yeolo, D. S. (2021) Potential Effect of a Vehicle to Grid On The Electricity System, *IOP Conference Series: Materials Science and Engineering,* 1084

[32] Crozier, C. Morstyn, T., Deakin, M. and McCulloch, M. (2020) The case for Bi-directional charging of electric vehicles in low voltage distribution networks - Abstract, *applied energy,* 259,

[33] Garruto, R., Longo, M. Yaici, W. and Foiadelli, F. (2020) Connecting Parking Facilities to the Electric Grid: A Vehicle-to-Grid Feasibility Study in a Railways Station's Car Park

Potential date for commercialisation:	Existing technology – not yet widely adopted in EV charging UK but expected to increase with decreasing installation costs[30]
Commercial costs (if available)	At end of the Kaluza trail[30] V2G installation costing outlined at £3,700 more than smart charge one direction point – with anticipated future reduction in cost and example of technology costing £1000 cost with pay-back period lower than 5-years given pay back opportunities
Suitability:	Both commercial and residential
Any installation prerequisites:	Grid connection – with additional potential requirements of smart system.

Name of the technology:	Battery Swapping
Likely impact on EV Charging cost:	Low. Not likely to impact on the cost of EV charging.
Owner or developer:	Charge-up
Location:	India
General description of the system: Battery swapping is the exchange of a charged battery for a depleted battery. Batteries are charged and exchanged at a battery swapping station through various methods (Ahmad et al., 2020)[34] autonomously or manually. Ahmad et al. (2020) outline various benefits and considerations of this system of EV charging benefits include fast and efficient charge receival for the driver, conserving batter life as compared with fast chargers, grid connection efficiency and cost effectiveness for vehicle owners. The challenges outlined include requiring interchangeable batteries between vehicle manufacturers, batter design, high infrastructure requirement for the swapping stations, battery degradation and financial/ownership challengers. Ahmad at al. (2020), also, identify the suitability of this method for public transport particularly due to its short delay times and known battery demands due to scheduling they also note that this form of charging will provide set locations for charging, this would therefore have impacts on business cases for where this system of charging is suitable. Mahoor et al (2017)[35] identify the need for optimal locations for these stations to give the benefits of increased travel distance range.	
Current state of development: There are examples of battery swapping in various different forms one example is the battery swapping service charge-up in India who offer battery swapping for E-rickshaws outlining benefits of a two-minute swapping time with 200km range per day as opposed to a 10-hours charge and 80km per day[36].	
Potential date for commercialisation:	Limited numbers of services currently in operation, more widespread in some countries than others.
Commercial costs:	Upfront cost to user reduced – Sarker et al (2015) in Ahmad et al. (2020)[34] outline a leasing scheme

[34] Ahmad, F., Alam, M. S., Alsaidan, I. S. and Shariff, S. M. (2020) Battery swapping station for electric vehicles: opportunities and challengers, *IET smart grind,* 3 (3), pp. 280-286
[35] Mahoor, M., Hossenini, Z. S., Khodaei, A. and Kushner, D. (2017) Electric Vehicle Battery Swapping Station, *CIGRE US National Committee 2017 Grid of the Future Symposium.*

[36] Charge-up (2020) *charge-up,* [online] Available at: https://echargeup.com/ [Accessed: 14/02/2022]

	to replace the $12,000-$14,000 cost of replacement 24kWh battery in 2012 Replacement of cost for upgrading a home charger point to be faster which is outlined as costing $849 for 3.3kW (7-hour charge for 24kW battery) charger as opposed to 1-6kW charger (15-hour charge) in 2013 Sarker et al (2015) in Ahmad et al. (2020)[34].
Suitability:	Commercial
Any installation prerequisites:	Compatible battery technology; suitable information system setup for driver-battery swapping infrastructure communication; space and cost restrictions (charging and discharged batteries etc) [34]

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