Stopford Energy & Environment

Keele UNIVERSITY

Benefits of Electric Vehicles

for

Able Electric

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Author: Christopher Betteridge
Chris.Betteridge@stopford.co.uk
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Stopford Energy & Environment,
the trading name of Stopford Projects Ltd

VAT Registration Number: 388 107 726
Company Registration Number: 1630328

Enquiries:
Stopford Energy & Environment
Custom House
Merseyton Road
Ellesmere Port
Cheshire
CH65 3AD
United Kingdom

tel: +44 (0)151 357 7740
fax: +44 (0)151 345 8087
enquiries@stopford.co.uk

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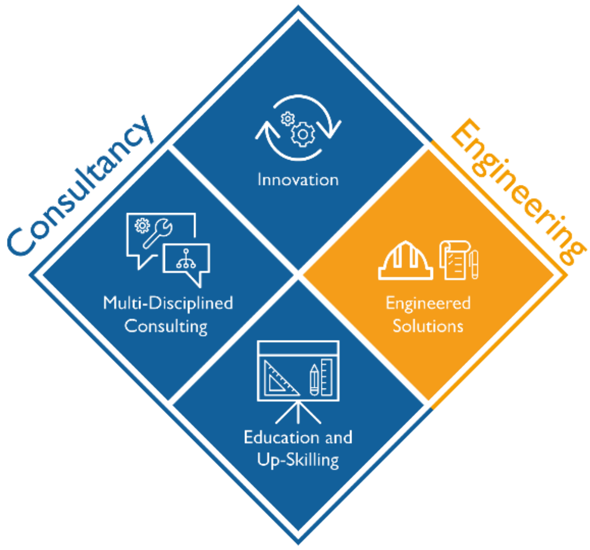

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Issue	Reviewed by (date)	Approved by (date)	Comments
A1	DS (26/10/20)	BMJH (27/10/20)	

1 Scope of Work

Able Electric is based in Tamworth, Staffordshire, and specialises in electrical services. More recently, its services have been expanded to include electric vehicle charging infrastructure.

To support their business, Able Electric is seeking expert consultancy to highlight the climate and wider benefits associated with the installation of electric car charging infrastructure and the carbon impact of electric vehicles, when compared with conventional (petrol and diesel) alternatives.

The report output will allow Able Electric to understand more about the wider benefits of electric vehicles, which will aim to support the adoption of low carbon infrastructure across their supply chain.

2 Introduction to Climate Change

Climate change, or global warming, is the name given to long-term changes to temperature on and around the Earth's surface, which causes long-term shifts to weather patterns.

Most climate scientists concur that the main cause of the current global warming trend is the anthropogenic emission of greenhouse gasses, resulting in the expansion of the "greenhouse effect" (a process whereby warming is caused by the atmosphere trapping heat radiating from Earth toward space).

Gases that contribute to the greenhouse effect include:

- Water vapour – this is the most abundant greenhouse gas in the earth's atmosphere.
- Carbon dioxide (CO_2) – this is a minor but very important component of the atmosphere. Carbon dioxide is released through natural processes such as respiration, volcanic eruptions and through human activities such as deforestation, land use change, and the burning of fossil fuels. Human activity has increased atmospheric carbon dioxide concentrations by more than a third since the Industrial Revolution, as such making the single biggest impact on climate change.
- Methane – this is hydrocarbon gas produced from both natural sources and human activities. Sources include the decomposition of wastes in landfills, agriculture (especially rice cultivation) and cattle farming. On a molecule-for-molecule basis, methane is circa 25 times more potent as a greenhouse gas compared to that of carbon dioxide, however it is also much less abundant in the atmosphere.

- Nitrous oxide – this is another potent greenhouse gas (298 times that of carbon dioxide) generated through soil cultivation (e.g. fertiliser application), fossil fuel combustion, nitric acid production, and biomass burning.
- Chlorofluorocarbons (CFCs) – these are synthetic compounds entirely of industrial origin used in a number of applications, but now largely regulated in production and release to the atmosphere by international agreement for their ability to contribute to destruction of the ozone layer.

Over the last century the burning of fossil fuels like coal and oil has increased the concentration of atmospheric carbon dioxide, whilst other activities, albeit to a lesser extent, such as agricultural and industrial practices, have also served to increase concentrations of other greenhouse gases.

As such, the impacts of climate change are widespread, with likely consequences being:

- An increase in the average temperature of Earth.
- Warmer conditions are likely to result in greater evaporation and precipitation events, with some regions becoming wetter, whilst others becoming dryer.
- Ocean warming which in turn will partially melt glaciers and sea ice, increasing sea levels. The increase in temperature will also serve to expand ocean water as it warms, resulting in further sea level rise.
- Some crops and plants may respond positively to elevated atmospheric carbon dioxide concentrations, however changing climate patterns may also impact upon the best areas in which to grow crops as well as the composition of native plant communities.

As a result, there is now an international effort required to combat climate change and to accelerate and intensify the actions and investments needed for a sustainable low carbon future.

Central to this is the Paris Agreement, negotiated at COP21, which has set an ambitious goal to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5°C.

Since coming into force on 4th November 2016, over 185 countries have now ratified the agreement (of the 197 parties to the agreement), which brings all nations, for the first time, into a common cause to undertake ambitious efforts to combat climate change.

Practical measures are required in order to enact and achieve the goals laid out in the Paris Agreement. One such method is by reducing carbon emissions from transport - the transport sector produced 7.0 $GtCO_2eq$ of direct GHG emissions (including non-CO_2 gases) in 2010 and hence was responsible for approximately 23 % of total energy-related CO_2 emissions (6.7 $GtCO_2$). Reducing the reliance on fossil fuels is the best way to achieve this, and hence electric vehicles are increasingly coming to the fore in many developed nations around the world.

3 Carbon Footprinting

Carbon footprinting is one such approach that organisations can take in order to start quantifying the impact of their activities on the environment, from a carbon perspective, with a view to identifying areas and setting targets for improvement.

A carbon footprint can be defined as the total mass of greenhouse gas (GHG) emissions caused either directly and indirectly by an individual, organisation, event or product, and is expressed as a carbon dioxide equivalent (CO_2e). A carbon footprint accounts for all six Kyoto GHG. The term CO_2e is used for describing the impact of all different greenhouse gases in a common unit. Therefore, for any quantity and type of greenhouse gas, CO_2e signifies the amount of CO_2 which would have the equivalent global warming impact.

Whilst there are many different approaches that can be taken in order to derive the carbon footprint of an organisation, the Greenhouse Gas Protocol (https://ghgprotocol.org/), a methodology created by the World Resources Institute and the World Business Council for Sustainable Development, is a standardised method that enables consistency in how organisations account and report emissions.

3.1 Organisational Carbon Footprint

An organisational carbon footprint measures the mass of GHG emissions associated with activities across the organisation. Such GHG emissions typically include energy use, transportation and waste management. As such, quantifying GHG emissions enables an organisation to benchmark its contribution to global emissions, as well as to identify areas for improvement and set targets. Therefore, once the carbon footprint of an organisation has been calculated, this can be used for both internal and external reporting, as well as to enable the tracking of GHG emission reductions against targets.

By adopting the carbon footprinting methodology outlined in the Greenhouse Gas Protocol, GHG emissions for consideration are categorised into three groups or 'scopes':

Scope 1 – These relate to all **direct emissions** from the activities within an organisation's control, which typically include the combustion of fossil fuels, emissions from company vehicles, as well as losses of refrigerants.

Scope 2 – These relate to all **indirect emissions** from electricity, heat or steam purchased and used by the organisation. Whilst the emissions are not generated directly by the organisation, by virtue of using energy, the organisation is therefore indirectly responsible for any associated GHG emissions.

Scope 3 – These relate to all **other indirect emissions** associated with the activities of an organisation, that are outside of the organisation's control. Typically, these will include GHG emissions from business travel, water consumption, waste disposal and materials procurement.

Therefore, in line with the principles of the GHG Protocol, in order for an organisation to calculate its carbon footprint, all Scope 1 and Scope 2 emissions must be included. With respect to Scope 3 emissions, inclusion of these can be tailored to meet the requirements of your organisations or the availability of data to enable such emissions to be calculated. However, it would be generally recommended to include employee business travel (including commute) and emissions associated with the disposal of waste to landfill within an organisational carbon footprint.

3.2 Calculation of an Organisational Carbon Footprint

The first critical step to enable the calculation of an organisational carbon footprint is to determine which method the organisation will adopt (e.g. The Greenhouse Gas Protocol) to ensure consistency in approach. The second key step is to determine the boundaries in which the organisation's carbon footprint will be captured (e.g. whether to include subsidiaries, joint ventures or leased assets if appropriate). The third step is to determine which Scope 3 emission sources to include (operational boundaries) within a carbon footprint assessment, mindful of both the application of the resultant data and the availability of accurate data to complete the exercise. The fourth step is to then start collecting data reflective of the emission sources within the organisation's determined boundaries (e.g. for energy use, the number of kWh used can be taken from meter readings or bill, whilst vehicle emissions data can be calculated using fuel consumption or distance travelled). The final stage is then to identify carbon emission factors (in tonnes of CO_2e) for each identified emission source and calculate the carbon footprint for each source by multiplying the activity data with the emission factor.

3.3 Example Carbon Footprint Calculation

As Able Electric has a specific interest in calculating the mass of GHG emissions that could be avoided through organisations adopting electric vehicles instead of petrol or diesel vehicles, the quantification of carbon emissions associated with business travel will be used as an example of carbon footprint calculation.

To enable the accurate calculation of the carbon footprint associated with business driving, it is critical to find out the activity data for each client, which in this case will comprise of the number of miles that each client travels, the fuel source of the vehicle (petrol or diesel), the size of car/engine (e.g. small, medium or large) and the frequency of the journey. Therefore, for the purpose of this example, the resultant activity data assumes that the employee in question travelled a total of 36 miles to and from work per journey, in a car with a 2.0L petrol engine, 220 times per year.

Based upon this activity data, an emission factor detailing the mass of CO_2e emitted per unit of distance for a specific car and fuel type can then be identified. Whilst there are numerous sources of emission factors available on the internet (please note that values for the same activity may differ between sources depending on the methods employed to calculate an emission factor), an excellent database for UK specific values can be found at:

https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2019

Therefore, in this case, using the stated employee activity data, the respective emission factor for this activity would be 0.45536 kg CO_2e per mile travelled, as presented in Table 1.

Table 1. Department of Business, Energy and Industrial Strategy; Greenhouse gas reporting: conversion factors 2019 (Passenger Vehicles).

			Diesel				Petrol			
Activity	Type	Unit	kg CO_2e	kg CO_2	kg CH_4	kg N_2O	kg CO_2e	kg CO_2	kg CH_4	kg N_2O
Cars (by size)	Small car	km	0.14208	0.14024	0.000004	0.00184	0.15371	0.15301	0.00032	0.00038
		miles	0.22868	0.2257	0.00001	0.00297	0.24736	0.24624	0.00051	0.00061
	Medium car	km	0.17061	0.16877	0.000004	0.00184	0.19228	0.19158	0.00032	0.00038
		miles	0.27459	0.27161	0.00001	0.00297	0.30945	0.30833	0.00051	0.00061
	Large car	km	0.20947	0.20763	0.000004	0.00184	0.28295	0.28225	0.00032	0.00038
		miles	0.33713	0.33415	0.00001	0.00297	0.45536	0.45424	0.00051	0.00061
	Average car	km	0.17336	0.17152	0.000004	0.00184	0.18084	0.18014	0.00032	0.00038
		miles	0.27901	0.27603	0.00001	0.00297	0.29103	0.28991	0.00051	0.00061

Therefore, by multiplying this emission factor by the number of miles travelled per journey, and then by the number of journeys made each year, the annual carbon footprint associated with that employee commuting to work can be calculated:

*36 (miles per journey) * 0.45536 (emission factor kg CO2e) = 16.39 kg CO_2e (mass of carbon dioxide equivalent GHGs emitted per journey)*

then

*16.39 kg CO_2e (mass of carbon dioxide equivalent GHGs emitted per journey) * 220 (number of journeys per year) = 3,606 kg CO_2e/annum (mass carbon dioxide equivalent GHGs emitted per year).*

Therefore, in this example the carbon footprint of the employee's described commute can be estimated to be **3.61 tonnes CO_2e/annum**.

By switching to an electric vehicle, a different emission factor can be applied. For the purposes of this example, it is assumed that the employee in question makes exactly the same journeys using a battery powered electric vehicle instead.

Therefore, in this case, using the stated employee activity data, the respective emission factor for this activity would be 0.10764 kg CO_2e per mile travelled, as presented in Table 2.

Table 2. Department of Business, Energy and Industrial Strategy; Greenhouse gas reporting: conversion factors 2019 (Electric Vehicles).

			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle			
Activity	Type	Unit	kg CO_2e	kg CO_2	kg CH_4	kg N_2O	kg CO_2e	kg CO_2	kg CH_4	kg N_2O
Cars (by size)	Small car	km	0.04066	0.04034	0.00010	0.00022	0.04567	0.04531	0.00012	0.00024
		miles	0.06545	0.06493	0.00017	0.00035	0.07350	0.07292	0.00019	0.00039
	Medium car	km	0.03607	0.03579	0.00009	0.00019	0.05317	0.05275	0.00014	0.00028
		miles	0.05807	0.05761	0.00015	0.00031	0.08557	0.08489	0.00022	0.00046
	Large car	km	0.04458	0.04423	0.00011	0.00024	0.06688	0.06635	0.00017	0.00036
		miles	0.07173	0.07117	0.00018	0.00038	0.10764	0.10679	0.00027	0.00058
	Average car	km	0.04107	0.04075	0.00010	0.00022	0.05549	0.05505	0.00014	0.00030
		miles	0.06610	0.06558	0.00017	0.00035	0.08931	0.08860	0.00023	0.00048

It is important to note that the emission factor is greater than 0. This is to take into account the associated carbon cost of charging an electric vehicle. Carbon emissions associated with electricity supply arise from the generation of electricity, i.e. the nature of the UK's energy mix. As a proportion of the UK's electricity is supplied by fossil fuel burning (coal and gas), as well as "clean" nuclear and renewables, a carbon cost is incurred. This is accounted for in the BEIS calculation methodology for greenhouse gas reporting.

3.3.1.1 Worked Example – Carbon Savings

Therefore, by multiplying this emission factor by the number of miles travelled per journey, and then by the number of journeys made each year, the annual carbon footprint associated with that employee commuting to work can be calculated:

*36 (miles per journey) * 0.10764 (emission factor kg CO2e) = 3.88 kg CO_2e (mass of carbon dioxide equivalent GHGs emitted per journey)*

then

*3.88 kg CO_2e (mass of carbon dioxide equivalent GHGs emitted per journey) * 220 (number of journeys per year) = 852.51 kg CO_2e/annum (mass carbon dioxide equivalent GHGs emitted per year).*

Therefore, in this example the carbon footprint of the employee's described commute can be estimated to be **0.85 tonnes CO_2e/annum**. **This represents a saving of 2.76 tonnes CO2e/annum over the use of the equivalent petrol vehicle.**

A similar approach can then be used to aggregate emissions data for each employee to enable an organisational carbon footprint for driving to work to be estimated.

3.4 Carbon Footprinting Calculator

To support Able Electric's ambition to demonstrate the virtues of the uptake of electric vehicles to organisations, from a carbon and cost perspective, a carbon and cost footprinting calculator has been developed. The carbon and cost calculator will enable Able Electric to assimilate data relating to distance travelled, car size and fuel type for organisations. Furthermore, to enable the carbon emissions associated with travelling to work to be contextualised, the calculator also presents a carbon equivalence to other well-known energy consuming or carbon saving activities. The calculator also allows for a year on year cumulative carbon footprint and cost savings to be calculated too. An example of the calculator and the output data is presented in Figure 1.

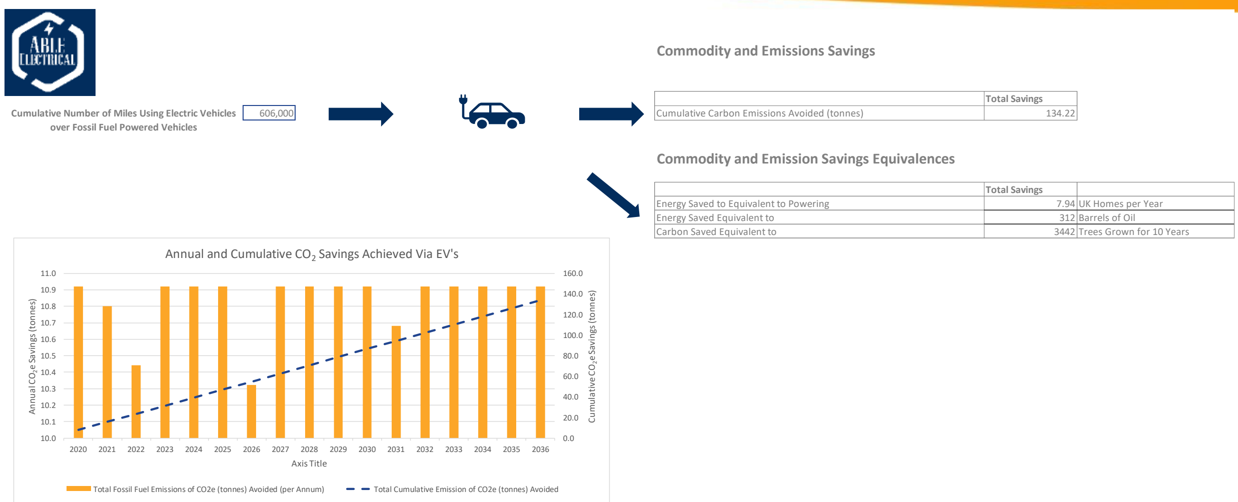

Figure 1. Schematic of Able Electric's carbon saving calculator.

Therefore, using a hypothetical data set to generate mileage data for 2020, and the outputs from this study, Table 3 presents the estimated energy and carbon savings that can be offset by using an electric vehicles over fossil fuel (petrol) powered small car, driving a distance of 1000 miles.

Table 3. Total estimated energy and carbon savings achievable through replacing fossil fuel powered (small petrol car) with electric, over a distance of 1000 miles.

Activity	Quantum	Units
Carbon Emissions Avoided	1.7	tonnes CO_2e
Energy Saved to Equivalent to Powering	0.1	UK Homes per Year
Energy Saved Equivalent to	4	Barrels of Oil
Carbon Saved Equivalent to	44	Trees Grown for 10 Years

The output of this calculator could be used by Able Electric to highlight estimated emission and operational cost savings to clients, associated with a transition to electric vehicles. This will aim to support the uptake of Able Electric's charging infrastructure technology.

4 Electric Vehicle Benefits - Business

4.1 Green Credentials

Marketing a company's green credentials serves to raises awareness of the company's commitment to the environment. Through the effective communication of the measures that an organisation has undertaken to manage and reduce its operational impact on the environment, the reputation of the company can be readily enhanced across supply chains and consumers alike. This in turn may enable the business to access new supply chains and capitalise on the growing demand environmentally responsible products and services.

The term "green credentials" refers to the evidence and achievements that demonstrate that a company is committed to minimising its impact on the environment. As such there are several standards, certifications and awards that companies can seek to obtain in order to effectively demonstrate the environmental performance of its operations to clients and stakeholders alike. As well as serving as a tool to demonstrate a company's commitment to the environment, such accreditations and certifications can be used across corporate and publicity material to enhance the company brand.

Electric vehicles are an effective way for organisations to promote their commitment to the environment across their supply chain, whilst making significant operational savings.

4.2 Financial Incentives – Operational Savings

Costs for commercial installations, can vary considerably depending on what is required, the main categories to consider are hardware & installation cost (which may include additional supply cables, electrical cabinets, distribution boards, metering etc. when compared to a domestic property), upgrading the site supply (incl. costs with the DNO), groundworks for digging cable trenches, and the cost of marking / allocating parking bays. A typical EV charging point unit itself costs around £800 - £1,000 to the consumer.

It is also important to understand existing capacity and upgrade requirements if needed. In some extreme cases a whole new transformer is required.

There are a number of EV charging products that are now looking to integrate with solar PV or other onsite renewables / battery storage – one example is Zappi. Zappi can essentially monitor for any excess solar going to Grid and instead divert it to vehicles, configurable so that the consumer is supplied with the required charge when needed (i.e. will charge from Grid if no solar available).

A number of financial incentives are available to assist with the installation of charging points.

The Workplace Charging Scheme (WCS) is a grant that businesses can use to reduce the cost of installing electric vehicle chargepoints for their staff by up to £14,000.

- Any voucher applications submitted on or after 1st April 2020 will receive a rate of £350, for up to 40 sockets.
- The WCS is available to any business, charity or public authority, with some conditions.
- The grant is provided by the government Office for Low Emissions Vehicles.

The WCS is available to any business, charity or public authority, with some conditions including the following:

- You must have sufficient off-street parking.
- While you do not need to currently have electric vehicles as part of your fleet, you will need to express an existing or future need for the business.
- You must have the charging station installed by an OLEV-approved workplace charging station installer like Pod Point.

The WCS is a voucher based system.

- First you complete an online application.
- If successful you will be emailed a voucher code which you can then present to your OLEV-approved installer which your installer will then use to claim the grant after the installation is complete.
- The voucher code is valid for 120 days from the date of issue.

4.2.1 Vans

The EV van market has seen significant growth over the past few years, with an increasing number of vehicle manufacturers developing hybrid and fully electric models. This has enhanced the viability of a low carbon vehicle transition for the those in the commercial sector. The following vehicles have CO_2 emissions of less than 75g/km and can travel at least 16km (10 miles) without any emissions at all:

- BD Auto eTraffic
- BD Auto eDucato (3.5 tonnes)
- Citroen Berlingo
- Ford Transit Custom PHEV
- Mercedes-Benz eVito
- Mitsubishi Outlander Commercial

- Nissan e-NV200 (cargo van)
- Peugeot ePartner
- Renault Kangoo ZE
- Renault Master ZE
- LDV EV80 van
- LDV EV80 chassis cab

You can get a discount on the price of brand new low-emission vehicles through a grant the government gives to vehicle dealerships and manufacturers.

You do not need to do anything if you want to buy one of these vehicles - the dealer will include the value of the grant in the vehicle's price. The plug in vehicle grant will pay for 20% of the purchase price for these vehicles, up to a maximum of £8,000.

4.2.2 Large Vans and Trucks

These vehicles have CO_2 emissions of at least 50% less than the equivalent conventional Euro VI vehicle that can carry the same capacity. They can travel at least 16km (10 miles) without any emissions at all:

- BD Auto eDucato (4.25 tonnes)
- FUSO eCanter
- Paneltex Z75

For the first 200 orders the plug-in grant will pay for 20% of the purchase price for these vehicles, up to a maximum of £20,000. The grant will then pay for 20% of the purchase price for these vehicles, up to a maximum of £8,000. Further information is available at: https://www.gov.uk/plug-in-car-van-grants

4.3 Energy Management of the Grid

4.3.1 Time-of-Use Electricity Costs

Utilities are moving toward Advanced Metering Infrastructure (AMI) that will allow for "time-of- use" electricity rates on a wide scale. AMI would enable utilities to charge much higher rates at peak usage, say summer afternoons, versus low rates at 2:00 A.M.

This capability provides an enormous economic driving force for both the utility and the consumer. The consumer pays a very large penalty to use electricity at peak rates, making non-peak electrical usage attractive.

Non-peak rates typically occur at night, while the consumer sleeps. Thus, charging an EV at night provides both convenience and low electricity rates. For these reasons, conventional wisdom opines that the vast majority of future EV charging will happen at night. This, also, is where Level I and II charging infrastructure will be most prevalent.

Consumers will no doubt need to charge their vehicles during the daytime, which will drive the requirement for public charging infrastructure at all charging levels.

In addition to time-of-use rates, utilities and/or charging service providers will likely bill based on the power level of electricity provided. For example, a slow charge at 120V, 15A would undoubtedly cost less per kWh than a DC fast charge at 125kW.

Already, however, promoters have begun to develop business models that would minimize the impact of electricity costs. Placing advertising on the charger, or billing for the parking slot are examples of schemes that would offset infrastructure and electricity costs.

4.3.2 Grid Impacts and Synergies

4.3.2.1 Grid Impacts

AMI also provides a powerful market tool for utilities to control the grid. One potential scheme, as mentioned above, would be for a utility to bill based on how loaded the grid might be at a given time. In addition to influencing consumer behaviour through pricing, the utility could be given control of individual chargers (Level II and III) such that no charging could occur if the utility anticipated a brown-out condition.

One pervasive fear is that fast charging could negatively impact the grid. However, extensive modelling has shown minimal real impact to the grid. Figure 2 depicts the hierarchy for a generic electricity network in the US. Figure 3 depicts six 250kW fast chargers—possibly a replacement for a petrol station in the future.

If all six fast chargers operated simultaneously at full output, they would require about 1.5MW DC, or about 33A at the local 26kV AC line. The capacity for this line is typically 600-900A. Thus, in the event of such an occurrence, only a small portion, maybe 5%, of the local line capacity would be used.

In addition to not threatening the grid, charging schemes that include battery storage between the grid and the charger bank, could provide a buffer and further reduce the potential for adverse grid impacts. Indeed, utility control coupled with a high peak use rate structure ensures that fast charging will have minimal grid impacts.

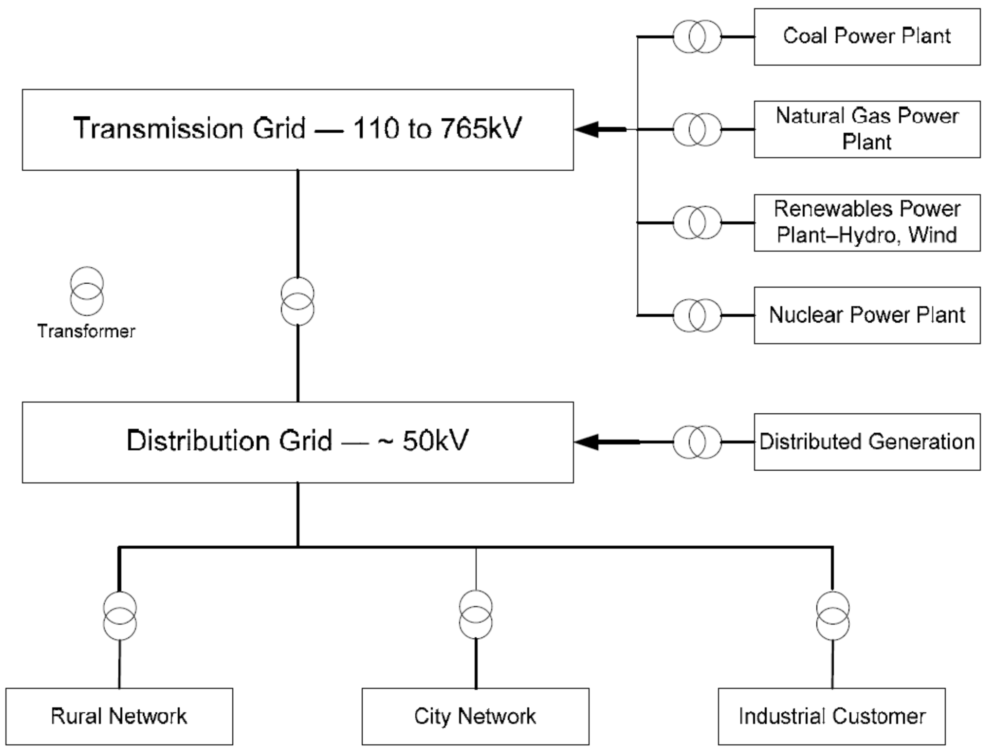

Figure 2. Generic electricity network (US).

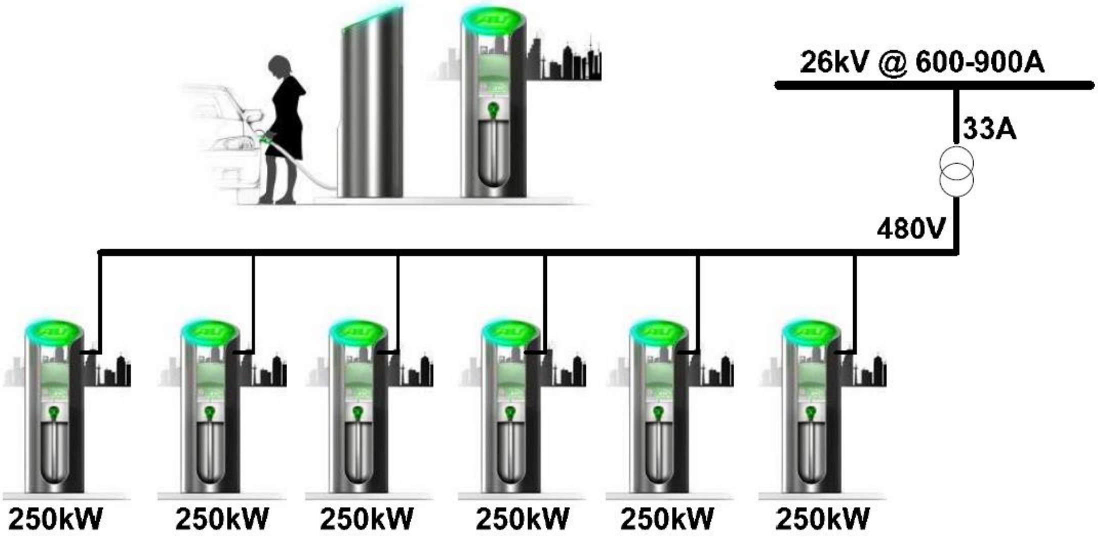

Figure 3. Six 250kW EV fast chargers on a 26kV low voltage neighbourhood line.

Utilities have well founded worries relative to system-wide grid impacts from the millions of future EVs charging their batteries—even at night. Indeed, most regional US grids have ample night-time surplus capacity that would allow the addition of EVs for the foreseeable future without the addition of generation or grid capacity. Long term, the favourable night-time time-of-use economics could change to close the gap between daytime use and the low use valley at night. However, there are questions over whether this would be enough to modify behaviour, especially when the convenience of night-time charging is considered.

4.3.2.2 Grid Synergies

Enabling utility control to protect and enhance grid operations, along with consumer control to operate their vehicles would appear to be an ideal synergy.

Movements toward smart grids and communications at every level are progressing rapidly. Rather than a detriment, EVs could enhance the grid and provide stability. Bi-directional methods, called vehicle-to-grid (V2G), vehicle-to-home (V2H), and others would enable EVs to act as a massive energy storage device for the grid. A simpler, uni-directional method would allow grid ancillary services such as grid regulation through mere on-off charger control by the utility or grid operator, through an aggregator.

For potential future V2G infrastructure, all levels of EV chargers, including on-board chargers, will need to be capable of bi-directional power flow. One method of on-board charging is the integrated recharge method that uses the traction inverter together with the motor’s inductance, which obviates the need for a separate on-board charger. This method is bi-directional by design and was originally developed by AC Propulsion.

4.3.2.3 Renewables

Over the next decade, as wind and other renewables become a more important contributor to the electricity power generation mix, the question of grid impacts must be addressed. In the current grid configuration, wind energy may be limited to 20% of the total power generation mix. A new mechanism that allows a much greater penetration of wind energy and other renewables to contribute to the grid would be valuable.

Wind, solar, hydro, geothermal and other renewables provide an opportunity to work in synergy with the grid through the use of energy storage such as EVs. Wind, in particular, while considered a non-dispatchable, intermittent power source, could overcome these disadvantages via EVs. Several US utilities are conducting demonstrations on the MW scale using large batteries as buffers between wind farms and the grid, which show the potential benefit of using EVs to provide grid services. This, also does not require bi-directional power flow.

4.4 Market Opportunities

4.4.1 Current Behavioural Evidence

Initial evidence (Amsterdam Roundtable Foundation and McKinsey & Company, 2014) shows that most of the early adopters of BEVs and PHEVs have the opportunity to charge at home, and this is their primary charging location. In Norway, for example, 95% of BEV and PHEV owners have charging access at their homes (either personal or shared within apartment complexes). For those who own a garage, home charging an electric car can be done using either a household plug or a relatively cheap residential charger (“wall box”).

Secondary to charging at home, this first group of EV drivers charges at work. Research by the Norwegian Vehicle Association (November 2013) indicates that almost 60% of the country’s BEV and PHEV drivers have access to charging stations at their places of work. Public charging stations (at either retail locations or fast-charging stations) are the third most popular charging locations after home and office. When asked about their use of public charging stations during the last month, 11% of BEV and PHEV Norwegian owners said they used public charging on a daily basis, 28% – on a weekly basis, and 35% – less frequently than that, 26% reported not using public charging at all in the last month.

Since fast-charging stations have been introduced fairly recently, only very preliminary conclusions can be drawn about their use. From the Norwegian survey, 62% of respondents indicated they did not use fast chargers at all in the last month, compared to 9% that used fast chargers at least once a week. It should be noted, however, that the current number of fast-charging stations in Norway is still quite limited (67 as of June 2013) and the three most popular fast-charging stations in Norway (located centrally and offering free electricity) have had 10,000 charging sessions in one year, averaging approximately 9 charging sessions per day for each of the three chargers.

4.4.2 Future Trends

In the future, charging behaviour – and in particular the use of public charging infrastructure, both slow and fast – is likely to change, influenced by multiple factors (below and in Figure 4):

- Need for public charging stations for EV drivers without access to garages. The need for public charging stations will increase if consumers who do not have access to a garage or other private or semiprivate residential parking – a large share of people living in cities – also adopt EVs. For instance, in Germany almost two-thirds of all households have a garage or parking space. Looking at the urban metropolis of London, however, two-thirds of homes have neither a garage nor off-street parking.

- Battery size. Conversely, the need for public slow-charging stations would decrease if the average battery size and range of BEVs increases. With less frequent charging required, drivers who rely solely on public stations will use them less, and those with access to stations at home and work may stop using public stations altogether.

- Use of the car. When it comes to slow- vs. fast-charging stations, the potentially changing role of the BEV may shift the ratio required. Experience from Norway shows that currently BEVs are often purchased as a second car for households and used primarily for daily commuting purposes. If the adoption of BEVs grows and more people want to use their BEV for long-distance trips (between cities or even countries), the demand for fast-charging stations will increase.

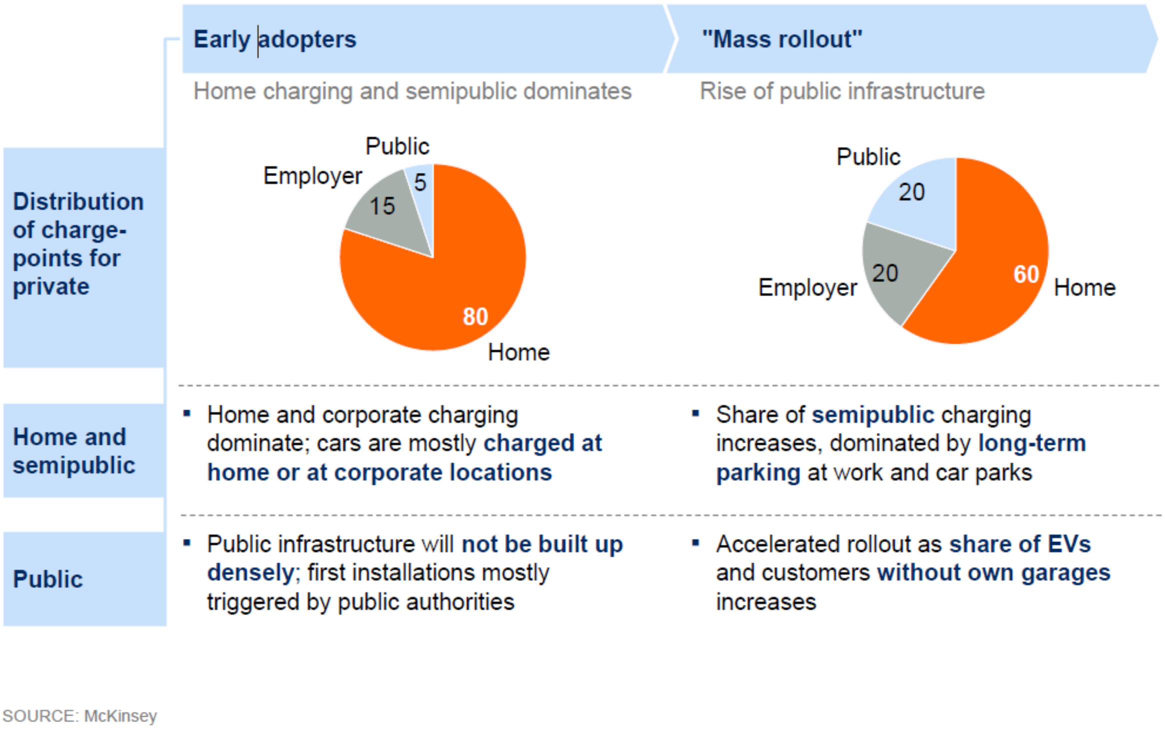

Figure 4. Implications for charging infrastructure: basic belief from interviews and pilot results: In the first years, home charging will dominate.

5 Electric Vehicle Charging Points – UK Status

5.1 Current Charging Infrastructure

Poor provision of charging infrastructure in the UK is one of the greatest barriers to growth of the domestic EV market, and the challenge raised most frequently by critics. The existing charging network is lacking both in size and geographic coverage, with the fastest ('rapid') charge points being particularly scarce. Analyses by the Energy Saving Trust and HSBC indicate that there are substantial disparities in the provision of public charge points across the country, with wide regional variations in both the average distance to a public charge point, and the ratio of public charge points to people.

However, the UK's EV charging network is improving, through the increased rate of installation of charging points, through companies such as Able Electric. According to Zap-Map, there are over 12,800 connectors at over 4,470 public charging point locations across the UK, with their number growing consistently each month. An increasing proportion of these are rapid or fast chargers. The West Midlands has 772 connectors as of June 2017, 6.3 per cent of the UK's total charge points. Of these connections, 206 are publicly funded, representing 27,549 people per public charge point. The average distance to public charging points is shown in Figure 5.

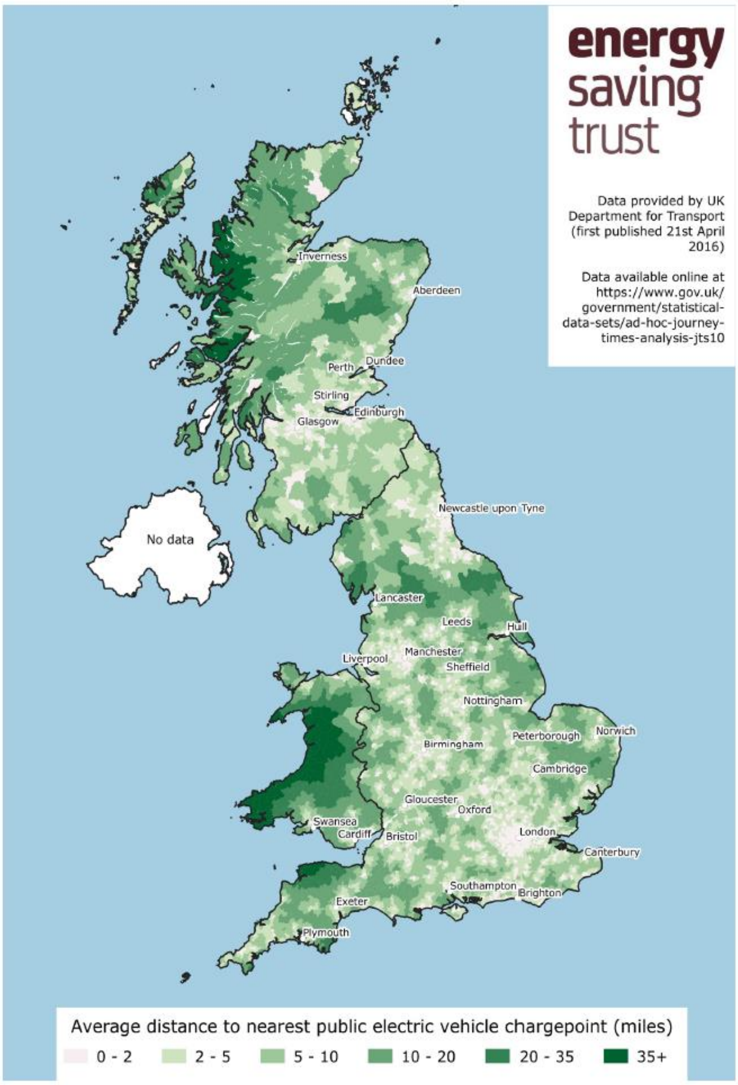

Figure 5. Average distance to nearest public electric vehicle charging point. Image provided by the energy saving trust.

By installing charging points, Able Electric are removing a key barrier to growth of Electric Vehicles in the UK and helping the country in its obligations to a 2050 net zero carbon target.

6 Conclusion

This report has provided an overview of the carbon savings and wider benefits which can be achieved through the installation of electric car charging points and the subsequent uptake of electric vehicles. A separate carbon footprinting calculator was developed for Able Electric, allowing the user to input the fossil fuel (petrol/diesel) mileage avoided and subsequently used by a battery electric vehicle. The calculator identifies the potential emission and operational costs savings associated with the ultra-low carbon vehicle transition. It is anticipated that this can be used by a client to simulate a phased introduction of electric vehicles into a fleet.

Financial incentives for electric vehicles are also presented. Furthermore, the report also discusses indirect benefits of electric vehicles, such as increased grid synergy, battery storage and grid balancing. The report concludes with an appraisal of potential future trends.

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8 T&Cs

Terms and conditions are as per the 'Smart Energy Network Demonstrator (SEND) Supply Chain Development Project Proposal and Beneficiary Agreement' form, signed by authorised people on behalf of Keele University, Stopford Energy & Environment and the Beneficiary prior to undertaking the project.

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Stopford Projects Ltd
Custom House
Merseyton Road
Ellesmere Port
Cheshire
CH65 3AD
United Kingdom

+44 (0) 151 357 7740
+44 (0)151 345 8087