The transition to Electric Vehicle charging points… what is the impact?

With Project Partner Cenex

By

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This report presents original work undertaken by the author. The work has been conducted in accordance with the University of Nottingham's Code of Research Conduct and Research Ethics and in accordance with the School of Geography's risk assessment procedures.

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The University of Nottingham

Preface

I would like to thank my supervisor Joseph Hewitt for his support throughout this project. I would also like to thank the whole of the school of Geography and especially the Environmental Leadership and Management MSc team who have offered guidance whenever required throughout an abnormal academic year.

Abstract

This study undertakes a Life Cycle Analysis (LCA) to examine the environmental impact of Electric Vehicle Charging points. The charging point is broken down into its constituent parts and each component is assessed using LCACalculator to arrive at a CO2 value. These values are combined to arrive at an overall impact of 253kg CO2 for a single charging point during its lifetime. The life cycle analysis is composed of four main elements: Manufacture, Transport, Use and Disposal. Manufacturing accounted for 218kg (86.2%) of the total emissions, whilst transport was the second biggest contributor at 32.6kg (12.89%). 94.79% (30.9kg) of the transport's emissions are due to air freight from China. Relocating manufacturing closer to the consumer would enable the environmental impact to be significantly reduced. Furthermore, innovations in electronic componentry, to transition away from precious metal use will offer significant environmental benefits.

Contents

Aims and Objectives

The aim of this study is to calculate the environmental impact of electric vehicle charging points. The transition to electric vehicles is ongoing, but there has been little research on the manufacturing practices that create the components used to make up a charging point. This study aims to fill this literature gap to offer a comprehensive understanding of the environmental cost in relation to the transition to electric vehicle use.

This study has two objectives, firstly: to quantify the environmental impact of specific components that make up the hardware for charging points. Secondly: to understand the context of this calculation and its impact for the future of charging points and wide scale electric vehicle usage.

Background/context

Cenex

Cenex was established as the UK's first Centre of Excellence for Low Carbon and Fuel Cell technologies in 2005. Today, Cenex focuses on low emission transport and associated energy infrastructure and operates as an independent, not-for-profit research technology organisation (RTO) and consultancy, specialising in project delivery, innovation support and market development.

Electric Vehicle (EV) Charging points refers to the hardware of the units used for an individual to charge an EV car. Figure 1 below shows a breakdown of the hardware used in an AC domestic charger. This figure has been provided by Cenex and offers key insights of which this study is based.

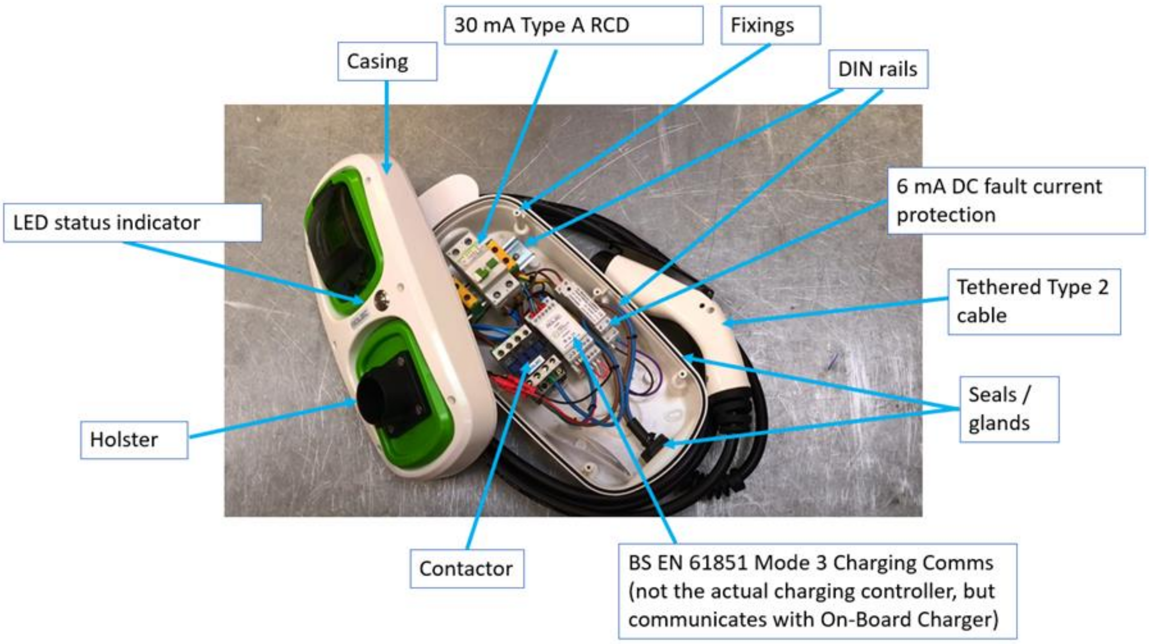

Figure 1

Social context

Electric Vehicles have been widely recognised as being a key technology in reducing future emissions and consumption within the transport sector (Helmers and Marx 2012). The UK is set to end the sale of petrol and diesel cars by 2030, highlighting the intention of the motor sector to decrease its environmental impact. Currently, battery electric vehicles (BEV) offer the only alternative to internal combustion engine vehicles (ICEV). Hydrogen offers the potential to be another clean alternative to Petrol and Diesel, particularly in the transport sector, however the technology is still in its development phase (Kotze et al 2021). The current global CO2 concentration is at 416ppm, up from 310ppm in 1950 (W. Steffen et al 2007), mainly due to the expansion in fossil fuel use. Hence, it is of critical importance that the transition to renewable means is efficient and unidirectional.

'Electric Vehicle' is a label applied to many different vehicles that use varying amount of electricity for power. There are four main types of electric vehicles: PHEVs (Plug-in hybrid electric vehicles), HEVs (Hybrid electric vehicles), BEVs, (battery electric vehicles) and E-REVs (extended range electric vehicles). As much as it is important to differentiate between the different 'Electric' Vehicles, it is also important to highlight the differences between the batteries used, such as Lithium-ion, nickel-metal hydride, lead-acid, and ultracapacitors (energysage.com). Each of these stores of power vary in their ability to generate certain outputs, memory effect, depth of discharge, number of charges per cycle, weight, amongst many other variables (Tagliaferri et al 2016). The type of battery used is integral to this study since it determines the specific construction of an electric vehicle charging point, specifically in terms of hardware required, and level of power it is required to generate.

Environmental Context

Whilst the transition to Electric Vehicles will no doubt present many challenges, it is important to understand and quantify the benefits of such a change. There is an abundance of literature that looks at the decreased environmental impact of Electric Vehicle usage (Helmers and Marx (2012), Chen et al (2021), Notter et al 2010, Hawkins et al 2013), with much attention being paid to the origins and usage of the battery (Costa et al 2021, Zackrisson et al 2010). Even though these studies do consider the broader context of Electric Vehicle usage, such as the infrastructure for charging and where the power being delivered, they do not consider the physical infrastructure into the assessments.

The use of biogenic carbon content fuels such as soy biofuel or cellulosic ethanol, rather than currently used petrol or diesel is proposed as an alternative in the pursuit of lowering the environmental impact of the transport sector. However, liquid biofuel production has many disadvantages, most notably the intense production methods over large amounts of land (Pulyaeva et al 2020). Therefore, as Zackrisson et al (2010) notes, the transition to wide scale use of Electric Vehicles offers the greatest potential savings of GHG emissions throughout the vehicle sector, being able to reduce GHG emissions by 90%, whilst hybrid Electric Vehicles and plug in hybrid EVs only offer 25% and 65% savings respectively.

Environmental Impact Assessments (EIA) originated from legislation that was introduced in the USA over fifty years ago, followed by a European Community Directive in 1985 that increased uptake within EU member states (Glasson and Thrievel 2019). Glasson and Thrievel highlight the range of definitions of EIAs, ranging from Munn (1979) defining it as 'the need to identify and predict the impact on the environment and on man's health and well-being of legislative proposals, policies, programmes, projects, and operational procedures, and to interpret and communicate information about the impacts' (pg.7) to the UNECE (1991) definition of 'an assessment of the impact of a planned activity on the environment' (pg.5). The EU Directive focuses on certain types of developments, specifically in terms of gaining planning permission for a certain build. This Directive applies specifically to projects, but the process of undertaking an EIA is much the same no matter on the size of the plot, whether that be a new factory or much smaller scale EV charging infrastructure.

An EIA for a project is required to undertake 5 steps (gov.uk 2017):

1. Screening – to determine if a project falls within regulations and requires an assessment.
2. Scoping – assess the extent of issues to be considered in the assessment.

3. Preparing an Environmental Statement – if an EIA is required, the applicant should provide and submit a statement to include information about the likely effects of the development
4. Making a Planning Application and Consultation – statement must be publicised alongside planning application, with public being able to voice their thoughts.
5. Decision Making – combination of the environmental statement and planning, along with public comments to be used in the final decision-making process.

The rigorous process undertaken by an EIA is pertinent to this study since the process undertaken provides a framework for this study. Electric Vehicle charging points would not be deemed as a large-scale project, nor will they have significant environmental impacts to the immediate surroundings where they are installed. However, the effects of the production process for the raw materials used in the charging point along with the local infrastructure will be the focal point of this study.

This study diverges from the Environmental Impact Assessment projects that have been undertaken but looks at the specific impact of the life cycle of a single entity, an EV charging point. Kaval (2011) undertakes a systematic review of the existing methodologies for measuring and valuing environmental impacts, producing figure 2 below showing the percentage of studies reporting the use of a specific tool. As displayed in the figure, Life Cycle Assessments (LCAs) and Ecological Footprints are the most widely used tools.

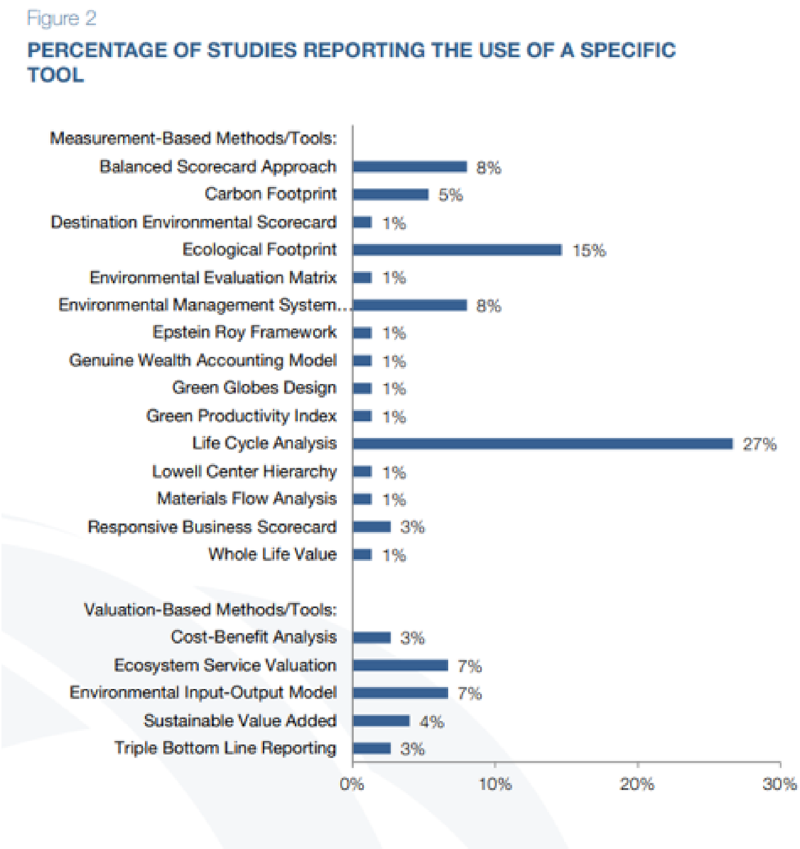

Figure 2

The Ecological Footprint measures the area of ecologically productive land and sea required to support human resource demands and a Life Cycle Assessment compares all social and environmental damages related to a product or service. An Environmental LCA is defined by the ISO (International Organisation for Standardisation) as the environmental interventions and potential impacts throughout a product's life, from raw material acquisition through production, use and disposal. An LCA is undertaken by 'compiling an inventory of relevant inputs and outputs of a system (inventory analysis), evaluating the potential impacts of those inputs and outputs (impacts assessment), and interpreting the results (interpretation) in relation to the objectives of the study' (Clift et al 2000 pg. 280). For this study, an LCA is the most appropriate method.

Political context

Electric Vehicle Charging points are composed predominantly of electronic hardware. In recent decades, there has been rapid growth in the production of electronic hardware and devices to fuel the global consumption of tech devices. However, this increase in production has caused greater demand for the toxic chemicals that are used in electronics production processes. Tu and Lee (2010) highlight the costs associated with the global demand for electronic hardware. Tu and Lee argue that policies to regulate production span across the globe and are largely dictated by the political agendas and their desire for environmental regulation and policies. It is clear that politics has a significant impact on environmental decision making, so it is predominantly the responsibility of the producer of the EV charging points to source the components from a territory that has an active environmental agenda, and to do what they can to minimise the environmental impact.

Local scale environmental issues often come under the banner of corporate social responsibility (CSR), with some countries enforcing specific regulations to promote environmentally friendly practices. However, if the regulations are low or categorised as best practice then there may be little incentive to use environmentally friendly materials and undertake novel production methods with low environmental impact. In contrast, some governments promote the tech industry so are not willing to implement measures that could limit the growth of the sector. Cenci et al (2021) draw on Arshad et al's (2017) five principles to achieve green IoT (internet of things) and reduce the carbon footprint: 'i) reduce network size using nodes and routing optimization, ii) collect only the data that is required for a particular situation (Selective Sensing), iii) use passive or active sensors according to the types of tasks required in the network, iv) have policies that aim to reduce energy consumption, and v) use intelligent trade-offs concerning cost, processing or communication to save energy' (pg.4). Point iv is extremely pertinent to the political considerations that dictate how electrical componentry can be manufactured. Point v is an ongoing consideration during a life cycle assessment. Saving energy will deliver a more positive overview of the product system being studied, so, trying to increase efficiency, use recycled materials and increase the duration a product can be used are all key considerations for electrical componentry.

Being able to reduce the energy that goes into a product or process is often a difficult task, however, with strong political backing this task can become much easier. In 2020, the EU created a list of 30 critical raw materials (CRMs) (European Commission 2020). Critical Raw Materials are those with limited availability, due to the environmental footprint of their supply as well as the geopolitical pressure for some ores and elements (Cenci et al 2021). CRMs are just one critical component that show how political relationships can dictate the composition and quantity of hardware that is produced, such as precious metals used in electrical componentry.

The quantification of environmental impacts.

The ability to accurately quantify the environmental impact of any product or system has had much interest among society in recent times. An 'Environmental Impact' involves anything that has a negative impact on any constituent part of the global environment. The world is currently amidst a global climate crisis (Perkins et al 2021), highlighting the need to understand which parts of society are having the greatest impact on the global environment. The Kyoto Protocol, Rio Declaration and Agenda 21 all attempted to address the global climate crisis in the 1990s, however these attempts have not had the levels of success they hoped to achieve. There has long been, and will likely continue to be, a conflict of interests between economic development and environmental sustainability.

To move towards a more sustainable future, it is vital that a quantification of current processes and practices can be made. Quantifying the current environmental impact is the first step towards lowering it. Suditu (2012) highlights the movement towards widespread digitization of environmental impact assessments, away from the previous methodologies that are 'influenced by the experience of evaluators' (pg.841). However, there has been some resistance to this movement, as Toro et al (2013) highlights the importance of qualitative EIA methodology. Toro et al assess the environmental impact of oil exploration in Colombia, highlighting that the intricacies of social, economic, and environmental factors require quantitative and qualitative assessments to be applied. Toro et al conclude that 'enhanced objectivity reduces the risk of the manipulation of data by the evaluator and assures that major impacts will not be unfairly eliminated' (pg.18).

For this study, the Environmental Impact Assessment is undertaken using solely secondary quantitative data. This is because it is not within the scope of this study to travel to the origin countries and assess the parts used to make the Electric Vehicle charging point.

Scope of emissions

Emissions calculations and preventative measures fall under three categories:

- Scope 1 emissions: Under direct control of a particular organisation
- Scope 2 emissions: From the organisations purchase of electricity, heat, and steam
- Scope 3 emissions: Upstream and downstream indirect emissions in the organisations value chain.

Thus far, organisations have focussed on reducing Scope 1 emissions and attempts to reduce scope three emissions have been largely ignored, even though this makes up most emissions from an organisation. Scope 1 and Scope 3 emissions will be the focus of this study. Even though this investigation is not undertaken in relation to a specific company, it will be gathering data about specific components that make up the final product of an Electric Vehicle charging point. Therefore, the data acquisition for this study will be from secondary data sets.

Scope of this project

From the outset of this study, it has been hard to define exactly how far into the supply chain it would be possible to navigate.

The aim was to go as far as possible down the chain to gain as much information as possible about a component since this will mean that the final calculations are as accurate as possible of the full impacts of production. However, navigating beyond a few suppliers proved an impossible task and time was not infinite so alternative strategies had to be engaged, which came in the form of Life Cycle Assessment software and online platforms. Figure 3 below is a simple diagram depicting what sits in and out of the scope of this project.

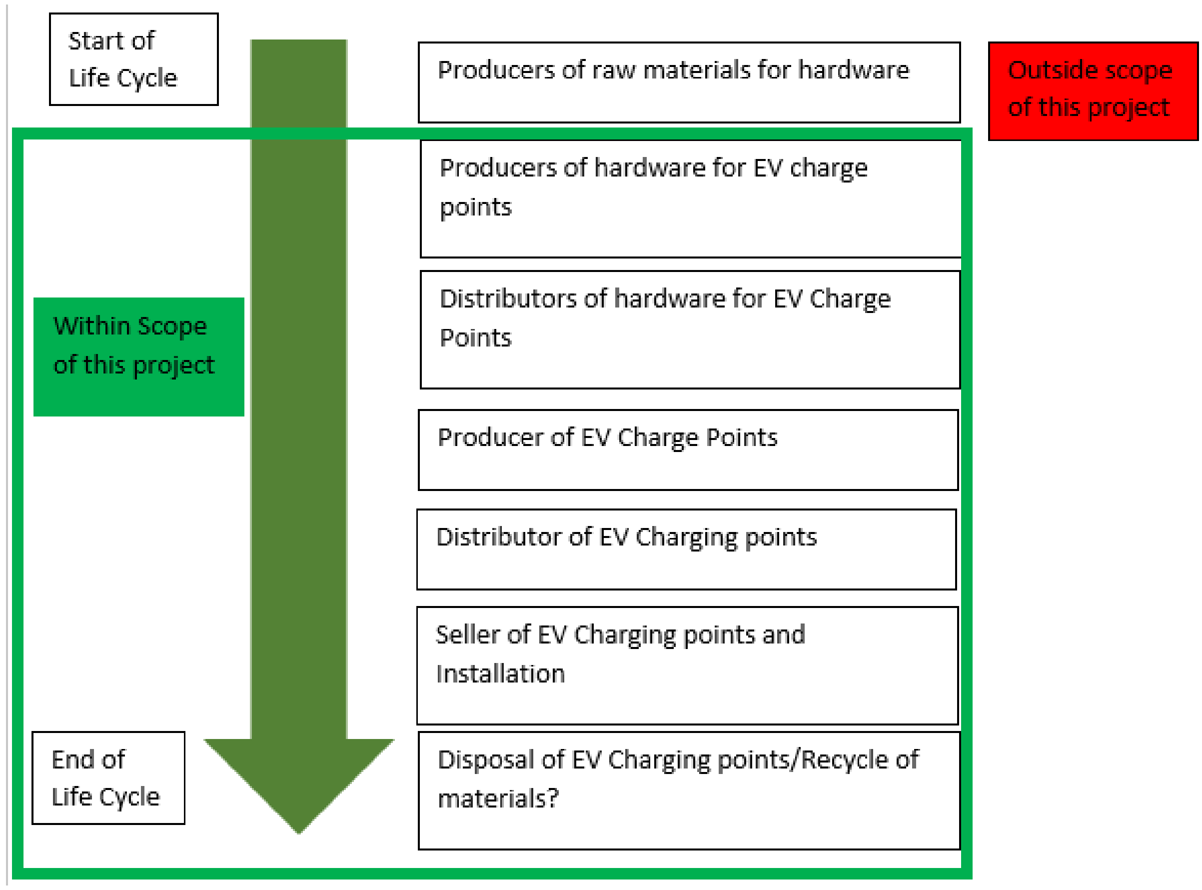

Figure 3 – Project Scope

Value of this study to environmental leadership and management

Being able to manage emissions of any company or sector is only possible if they can be calculated accurately. Any organisation that can accurately measure all inputs and outputs will be able to reduce financial and environmental excess costs wherever they may occur. A company that understands their exposure to the risks of climate change and can demonstrate leadership towards strengthening their green credentials will reap various benefits, in a society and marketplace that is extremely environmentally conscious (defra.gov.uk 2009).

Being a leader in the environmental sector is not about shouting about what needs to be done, the most powerful leaders actively carve new paths to which they can demonstrate that the institution is committed to the underlying principles (Gallagher 2012). As much as an Environmental Leader would like to report that everything is green and having no environmental impact, the reality is that many sectors, including the transport sector, are a long way from net zero emissions. A leader in this sector must be able to set an example and keep people informed. Setting an example can be as simple as publishing honest emissions reports, to keep people informed.

Understanding the environmental impact of Electric Vehicle charging points will take a step forward in the quantification of the transition to wide scale Electric Vehicle usage and offer a clearer picture to consumers of the full environmental impact of widescale EV usage.

Methodology: Life Cycle Assessment

The key methodology used in this study will be the quantification of greenhouse gas emissions to determine the overall environmental impact of an EV charging point. The method of collecting this data is a Life Cycle Analysis (LCA), for the reasons presented above.

An LCA follows four steps:

1. Scope and Goal Definition – ensures consistency.

Step one involves making it clear as to why the LCA is being carried out, and what exactly is going to be informed by the results (Clift et al 2000). Clift et al acknowledge that LCA's are often carried out based on comparisons between two alternatives. For this project, the intentions are to quantify the environmental impact of an EV charging point, and in a future project could be compared to an LCA of the infrastructure used for petrol and diesel fuelling. The benefit of such comparison would be to enable the quantification of the transition to EV charging points. The scope of this study has been defined previously in a diagram. The scope of this project does not hold any geographical limits. The considerations of project scope were constantly reviewed as the project developed and a definitive scope was found to be where the original parts were made.

2. Inventory analysis of extractions and emissions – look at all associated inputs and outputs.

Input and output (or emission) flows are referred to by the ISO as elemental flows. An inventory table can be created to show all the possible environmental impacts. These inputs are then traced back to their raw material extraction phase, however the scope of this study will finish where the hardware is produced. Inventory analysis goes beyond just the production process of the materials, it must include any transport logistics between various phases of the supply chain. In many sectors, transport is a key contributor of the environmental impact (Clift and Wright 2000). The inventory analysis for this project is somewhat simplified by a single metric of CO_2 being produced. This simplifies the inventory analysis but limits the true impact of the production process to be identified. This limitation is further assessed in the discussion section.

3. Impact assessment – what is most important? How to present results? Broken down or single metric?

Once the inventory analysis has been completed, the final output will be a table with lots of statistics showing how the process arrived at the final CO_2 value. Even though this is useful, it is important to understand what this means in terms of the actual impacts on the environment. A table of impact categories is a common method used to understand the environmental impact. Figure 4 below shows a list suggested by the SETAC-Europe working group on LCIA (Udo de Haes 1996). Allocating the inventory data to an impact category, along with a quantification of the impact is a common method used. Finally, the impacts are weighted based on their magnitude on the environmental system, and there is a valuation placed on the impact. The valuation is often undertaken as a cost-benefit analysis. This valuation is a highly contested issue (Clift et al 2000) since it requires an assessment of social, political, and ethical values. For this project, the goal is to be able to look at the carbon footprint of a charging point, and this will be done through the evaluation of CO2e (Carbon Dioxide Equivalent). CO2e is a standard unit for measuring carbon footprints and is suitable as some emissions are more harmful than others. Therefore, by converting all emissions to CO2e, the figures are comparable and give a more accurate representation of their harmfulness (Cenex 2019).

Input related categories

1. Abiotic resources (deposits, funds, flows)
2. Biotic resources (funds)
3. Land

Output related categories

4. Global warming
5. Depletion of stratospheric ozone
6. Human toxicological impacts
7. Ecotoxicological impacts
8. Photo-oxidant formation
9. Acidification
10. Eutrophication (incl. BOD and heat)
11. Odour
12. Noise
13. Radiation
14. Casualties

Pro memoria: Flows not followed to the system boundary

Input related

Output related

Figure 4

4. Interpretation of results – check conclusions are well substantiated.

The final step of an LCA is to interpret the results. The findings from the impact assessment are coupled with that of the inventory analysis to make final conclusions that address the goals of the study.

Product Environmental Footprint (PEF)

Product Environmental Footprint (PEF) refers to the impact any single product has on the environment. PEF is a methodology that builds on existing life cycle assessment methodologies. PEFs aim to enable easier comparability between products due to a clear presentation of the methodologies used to create the product (Finkbeiner 2014). PEF is of significant relevance, since this project is looking at the life cycle of an Electric Vehicle Charging point (a product). The PEF concept was proposed alongside the Organisation Environmental Footprint (OEF) which looks at the impact a single organisation has on the environment. These two methods were published by the EU Commission in 2013 (EU 2013) as part of the publication 'Building the single market for green products'. These methods aim to assist in the implementation of Life Cycle Assessments in European Environmental Policy. Finkbeiner (2014) insists that PEF and OEF cause more harm than good when being integrated with Environmental Policy. The PEF process utilises the LCA methodology to understand the full impact of any product. Therefore, this project is conducting a PEF assessment by conducting an LCA.

Methodology (Continued) Undertaking of LCA:

Life cycle assessment methodology has become increasingly digitised in recent times. There is a growing number of materials and products which have undertaken a life cycle assessment, with the information slowly becoming available to the public. Collecting primary data for this study was considered in the proposal of this project, however from the outset of data collection it soon became clear that this was not possible and so alternative means of data collection were required.

Babu (2006) presents that there are many organisations and software platforms that have developed databases specifically to undertake LCAs. These databases contain most of the basic data needed to conduct a Life Cycle Assessment. These platforms provide many benefits such as ease of access to an abundance of data, however they often lack transparency about the methods used to create this data. Transparency is a key concept when it comes to LCAs. The International Standard Organisation (ISO) defines two objectives of life cycle interpretation, with transparency of results being at its core (EN ISO 1998):

1. Analyse results, reach conclusions, explain limitations, and provide recommendations based on the findings of the preceding phases of the LCA, and to report the results of the life cycle interpretation in a transparent manner.
2. Provide a readily understandable, complete, and consistent presentation of the results of an LCA study, in accordance with the goal and scope of the study.

This project intended to undertake primary data collection. This would involve navigating the supply chain of each component of the Electrical Vehicle charging point from final component right back to raw material phase. Initially this method seemed plausible and desirable, however once additional research was undertaken looking into just one of the components, it soon became clear that this was not going to be possible. This was due to several reasons, largely since there was insufficient information about where each part was sourced from. This did not hinder the scope of the project, rather it just meant that many assumptions had to be made regarding many factors, of which will be outlined later in this section.

Upon understanding that primary data acquisition was no longer possible for this study, a search began to find secondary data sources which would provide the necessary information to undertake the life cycle analysis. To use any data acquired, a platform to display, manipulate and utilise the data was required. The LCA platforms are only as good as the data that is inputted, so finding comprehensive datasets was the first objective. Figure five below shows the platforms encountered and whether they were applicable to this project.

Tool Name	Characteristics	Cost	Applicable?
Ecochain	Company Wide footprints	Free	
openLCA	technical	Some databases not free	
Mobius	create product environmental footprints	Subscription	
SimaPro	complex & many add ons. For consultants.	Subscription	
GaBi	complex & many add ons. For consultants.	Subscription	
oneclicklca	Solely for construction industry	Subscription	

Figure 5

As shown in figure 5 only one platform was worth testing for this project. Whilst the main reason for not using the others was cost, OpenLCA still requires some databases to be purchased. OpenLCA was downloaded for free, and the navigation of the platform was reasonably self-explanatory. There are also many tutorial videos online which were utilised to establish a new product system so that data can be inputted to the Life Cycle Assessment. Multiple datasets were downloaded and combined to offer the widest scope of products, in the hope that the items that made up the charging point would be present. An array of datasets were downloaded and tested within the OpenLCA software to see whether they had the required items to complete the life cycle assessment. Whilst some of the databases had a few of the individual components or raw materials used, such as an LED Indicator or plastic casing, none had all the constituent parts, specifically the electrical componentry. This limitation of the databases made the use of any LCA software package redundant, so another means of conducting the LCA was required.

The alternative to downloading software and databases is by using online platforms that enable the same goal to be achieved but without the need to download a range of datasets. The benefits of the online tools are that they are much quicker to use since they do not require the time to set up and they are simpler to navigate. Lots of the software platforms listed above are designed to be used by trained professionals so they come equipped with lots of add-ons and technical functionality. For this project, the desired output from the Life Cycle Assessment is the CO2e (CO2 equivalent) emissions from the production, use and disposal of the Electric Vehicle Charging point. This metric is a basic function from the downloadable platforms but a standard output from the online tools. An additional benefit of the online tools is that due to them being web based they have quicker access to a more extensive database. The downloadable platforms only have access to the databases you download for it, and whilst these may be very detailed on a specific sector, if they do not cover your desired area (in this case electronic items) then the platform's functionality is completely redundant. Online platforms tended to have a more extensive product lists within the electronics sector and for this reason have been utilised for the methodology and to ultimately inform the results section of this project.

This project aims to assess the environmental impact of Electric Vehicle Charging points. As highlighted in the environmental context section, a Life cycle assessment is the most widely used tool to quantify an environmental impact and is the most applicable tool for this study. The ability to break down the EV charging point into its constituent parts makes it appropriate for this method. Essentially, a Life Cycle Assessment of each component is undertaken to arrive at the final output which is a product of all the life cycle assessments combined.

The best tool to conduct the Life Cycle Assessment

After much assessment of the options online, it was decided that 'LCACalculator' was the best option to determine the environmental impact of the Electric Vehicle Charging Point. The LCA Calculator is a quick and intuitive way for engineers to understand, analyse and compare environmental impact of products and particular design decisions (lcacalculator.com 2021). Even though this project is not undertaken by an engineer, the principles and goals are the same: break down a product into its constituent parts and quantify their environmental impact. The LCA Calculator was the easiest online platform to navigate and produced the most detailed results.

LCA Calculator

LCA Calculator consists of four main sections: Manufacture, Transport, Product Use and Disposal. These sections represent the phases that the components of an Electric Vehicle Charging point go through in their life cycle. Crucially, the output from this tool was in CO2 emissions which enabled ease of analysis and was complementary to current literature looking at environmental impacts.

All materials for the charging point are assumed to have originated in China, following a four-phase transport process:

1. **Raw materials from China to the producers of hardware.**

Transported via international air freight over 6780km. This assumes a direct flight from China to central Europe (which is 6780km). This distance will vary based on where the destination in Europe is, however, it will likely average out to the distance of 6780km over all the constituent parts.

2. **Distribution of Electric Vehicle hardware to the producers of charging points.**

This is assumed to travel 1770km via a 36-tonne lorry. 1770km is the distance from central Europe to central United Kingdom. A 36-tonne lorry is the approximate weight for a multi-axle articulated lorry, of which 44 tonnes is the maximum weight it can bear (oxfordshire.gov.uk 2021), so 36 tonnes is an average load.

3. **Charging point production to final installation company**

At this stage, the constituent parts of the charging point have now been utilised to build the charging point. The assumption of this part of the travel process is that the Electric Vehicle charging point travels 200km in a 7.5-16 tonne lorry. 200km is the approximate distance from the centre of the UK that will span over most of the country. This is under the assumption that the charging points are distributed from a centrally based hub, such as in the Midlands. The weight of 7.5-16tonne is the maximum gross weight of a 2-axle rigid lorry (oxfordshire.gov.uk 2021).

4. **Installation company to consumer installation**

The final stage of the transport process is the movement from the Electric Vehicle charging point retailer/installation company to the consumer. This journey is going to be shorter than any of the distribution movements, so is assumed to be 100km in a van that weighs less than 3.5 tonnes. A vehicle with a maximum gross weight of less than 3.5 tonnes and with 2 axles is identified as a light goods vehicle (Department for transport 2003). Therefore, if the installation company use a standard car that would also fall into this category.

Populating the LCACalculator

This section will go through the eleven components of the Electric Vehicle Charging point and details what information has been inputted into the LCA Calculator platform for the impact assessment to be undertaken, to ultimately arrive at the overall CO2 value.

As previously alluded to, the biggest challenge this project faced was the acquisition of data surrounding the production and transport of the constituent parts that make up the Electric Vehicle charging point. There were five main assumptions made about the five aspects below and these are detailed in the following section. Assumptions made on:

- weight of materials
- origin of materials,
- mode of transport,
- method of production
- percentage of product recycled in disposal phase

LED Status Indicator

The LED (Light Emitting Diode) status indicator was the easiest component to define within the tool. An approximate weight of 100 grams was inputted, used at a power rating of 1 watt for an hour per day. A typical 4-watt LED bulb can achieve a light output comparable to a 50-watt halogen bulb (thelightbulb.co.uk 2021), therefore due to the light on the charging point being much smaller, it was assumed to be only 1 watt in power. The use of one hour per day is due to a car being disconnected and plugged in every day and the light will remain on for half an hour post disconnection and connection. The LED light will be disposed of via a WEEE (waste electrical and electronic equipment), with 70% of it being recycled. Greentechsolutionsgroup.com (2017) state that 95% of an LED is recyclable, however this involves complex procedures to strip the light into its constituent parts. Therefore, this project assumes 70% is recycled due to the average process not being fully completed but being optimistic that most of the correct steps are taken to fully recycle as many parts as possible.

Holster

The holster is where the piece of hardware that is plugged in to the car is held when not being used for charging. This is assumed to be made from PVC (polyvinyl chloride), is rigid, and weighs 300 grams. It is assumed that this item was made by Injection moulding. Injection moulding is commonly used for domestic appliances (Llado and Sanchez 2008) and involves the melting of thermoplastic compounds which are then injected into a moulding machine. Injection moulding is a quick process often used for large scale production, such as of this charging point. Globally, only a very small amount of PVC is recycled (Shadat-Shojai and Gholam-Reza 2011), therefore as highlighted by Shadat-Shojai and Gholam-Reza, this process assumes only 5% of PVC is recycled.

Plastic Casing

The plastic casing is simply used to protect all the electrical equipment from the weather and as a means of mounting all the componentry together. Like the holster, it composes of rigid PVC, made by injection moulding with a total mass of 100 grams. 5% of this product is assumed to be recycled, the same percentage as the holster.

Contactor

An electrical contactor is used to switch an electrical circuit on and off. Based off the diagram provided by Cenex, it was not possible to identify exactly what model of contactor this was. The LCA Calculator does not have specific models or brands of electronic equipment, therefore a generic 'contactor' was selected. Based on the size of the diagram and approximate weight of the contactor, it was inputted as weighing 150 grams. The contactor is assumed to be disposed of via a WEEE treatment facility at a percentage of 12.5%, as per the US EPA report in 2015 that looked at the management of electronic waste in the United States. LCACalculator uses a slider to select the percentage of part that is recycled. This slider only moves in 5% increments, therefore the 12.5% is rounded up to 15%.

BS EN 61851 Mode 3 Charging Communications Device

This piece of hardware is specific to Electric Vehicles and is used for digital communication between a DC (direct current) Electric Vehicle charging station and an electric vehicle of DC charging. This is a very specific piece of hardware, which is not listed within the database of LCACalculator. As a means of compromise, there was an item listed as 'integrated circuitry', of which was the best alternative, with an assumed weight of 200 grams. This device is recycled at a WEEE treatment facility at a recycled percentage of 15%, due to the same reasons as the contactor.

Seals/Glands

The seals/gland sit in a ridge on the casing and act as a means of keeping any water or moisture away from the electrical components. This component is assumed to be made of silicone rubber at a weight of 200 grams. There are two seals so an overall weight of 400 grams. Silicone is difficult to recycle via traditional methods. Once silicone has been reacted or moulded it cannot be melted down and reused, and due to the chemical inertness and high thermal stabilities, recycling via traditional means is not an option (Petrus et al 2021).

The Dow Corning Corporation patented a method of recycling silicone with a two-step recycling process that achieved a 49% polymer conversion at the first phase, then an 88% at the second phase, creating an overall recycling rate of 43% via this process (Petrus et al 2021). Therefore, the silicone in this item is assumed to be recycled at a rate of 45% due to this being the closest 5% increment.

Tethered type 2 cable

A tethered cable is one which is always attached to a charge point, unlike a free cable that can be unplugged and plugged into a socket. A type 2 cable is the European standard plug type used by every new Electric Vehicle (drivingelectric.com 2020). This type of cable features a seven-pin connection and allows for slower AC charging (up to 43kW), rather than DC rapid charging. Within the LCACalculator, there was not a specific ‘Type 2 tethered cable’, but the closest alternative was standard electronic cabling at a weight of two kilograms. The two-kilogram weight is based off a 15metre cable weighing 4.5 kilograms, and the average length is about 7 metres so two kilograms is the assumed weight (based off EV Cables TP003(15m)). This cable is made from inner wires surrounded by a layer of PVC as a protective layer against electrical current. The process of separating the two parts of this product so that the cable and PVC can be recycled is complex and energy intensive, therefore it is assumed that the item is recycled at a rate of 5% since it is likely a few devices will be sent to specialist facilities and recycled however it is likely that the vast majority will not. 5% is the lowest percentage above zero that can be selected within the LCACalculator.

6 mA DC fault current protection

A fault current protection device protects against the potentially dangerous effects of overcurrent’s (Keller 2010). This specific piece of electronic equipment was not within the database of LCACalculator, therefore a compromise had to be made. For this item, a general resistor was selected with a weight of 200 grams. An electrical resistor limits the flow of current through a system, so in many ways does a similar job to a fault protection device, therefore it has been assumed they require similar hardware as well. This device is recycled at a WEEE treatment facility at a recycled percentage of 15%, due to the same reasons as the contactor.

DIN Rails

DIN Rails are long metal strips that act as a core part of a global industry standard of rail mounting. DIN rails are mostly used for attaching electrical and industrial control products (Uk.rs-online.com 2021). There are two rails made from steel, with an assumed weight of 300 grams each, so a total of 600 grams of steel. Steel is 100% recyclable, with scrap metal having the potential to be converted to the same grade steel depending on the metallurgy and processing of the required products (Broadbent 2016). Globally, there is a growing demand for steel, the World Steel association forecast demand to grow by 5.8% in 2021, and a further 2.7% in 2022 (Worldsteel 2021). The increase in demand will promote recycling practice since this is a more environmentally friendly method of sourcing steel, and is cheaper than mining for iron ore, the most important input to produce steel, which has seen increasing prices in recent times (Pathak 2021). Sansom and Avery (2014) state that ‘steel has increased its combined reuse and recycling rate to 96% (up from 93%) with, on average, 91% recycled and 5% reused’ (pg.89). Therefore, the Steel used in the Electric Vehicle Charging point is assumed to be recycled at a rate of 90%, due to this being the nearest 5% increment.

Fixings

As shown in figure one, the fixings are small plastic cylinders that enable a screw to go through to mount to the wall. These are made of rigid PVC, produced by injection moulding at an assumed weight of 8 grams per fixing. There are six fixings so an overall weight of 48 grams. Due to the fixing being made of PVC like the Holster, they are assumed to be recycled at a rate of 5% for the same reasons.

30 mA Type A RCD

RCD stands for residual current device. An RCD is designed to prevent an individual from getting a fatal electric shock should they touch something live, such as a bare wire. Residual Current Devices also offer some protection against electrical fires, enabling protection against hazards that ordinary fuses and circuit breakers cannot provide (electricalsafetyfirst.org.uk 2021). Much like the mode 3 charging communications device, this product is very specific and does not exist within the LCACalculator database. Again, as a means of compromise, ‘integrated circuitry’ was selected at an assumed weight of 100. This device is recycled at a rate of 15%, due to the same reasons as the contactor.

Results

There are various tables and figures presented below displaying the results of the life Cycle Assessment. The main figure is a total of 253kg of CO2 produced during the lifetime of the Electric Vehicle Charging point.

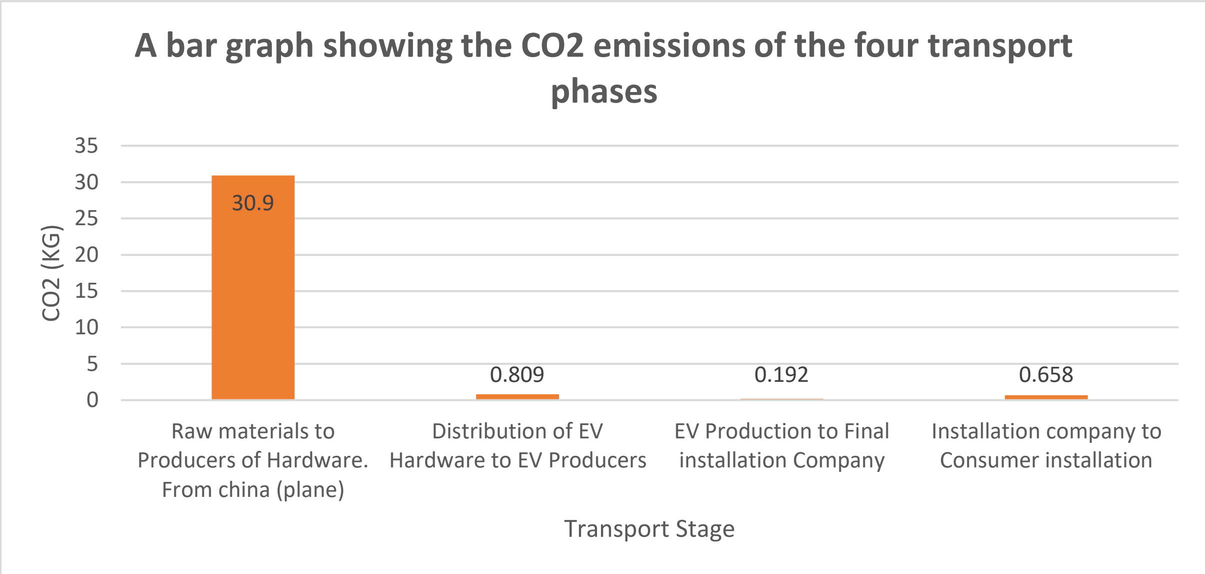

Figure 6

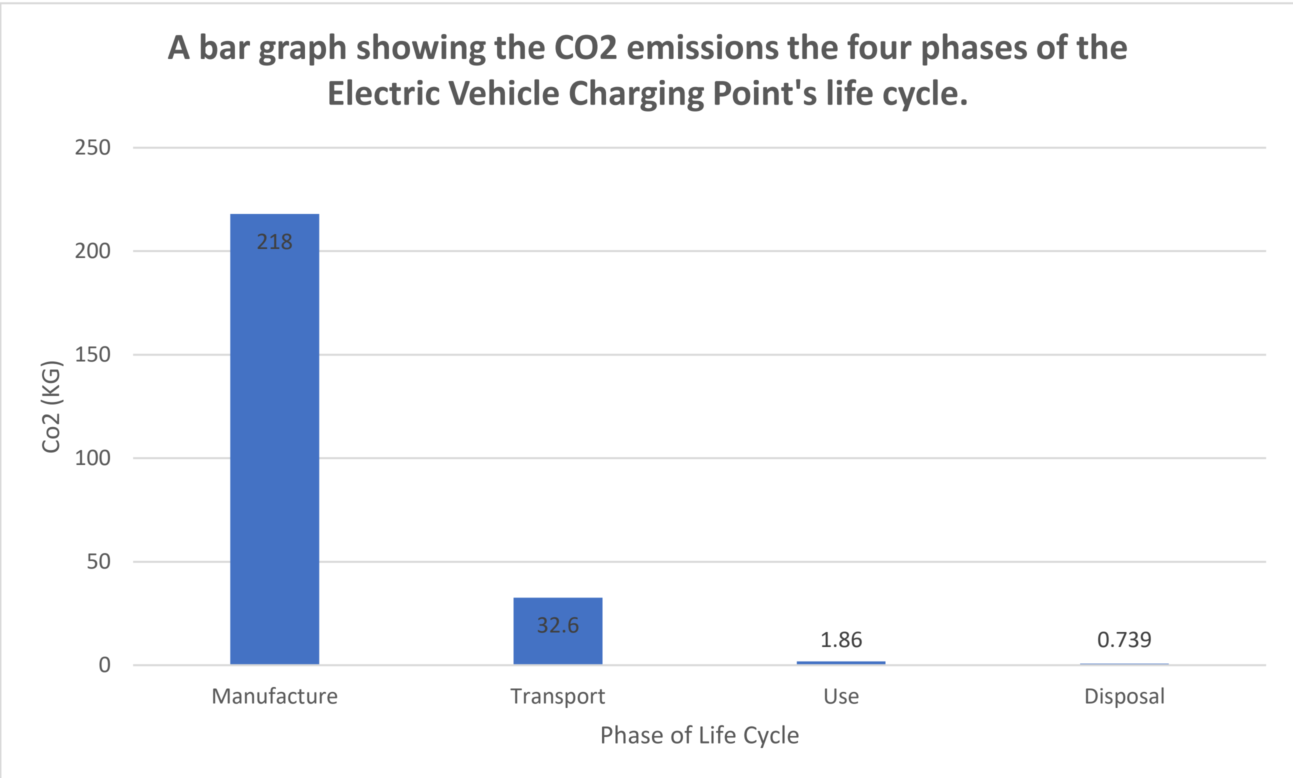

Figure 7

A Pie chart showing the composition of the total CO2 emissions in kilograms from each phase of the life cycle

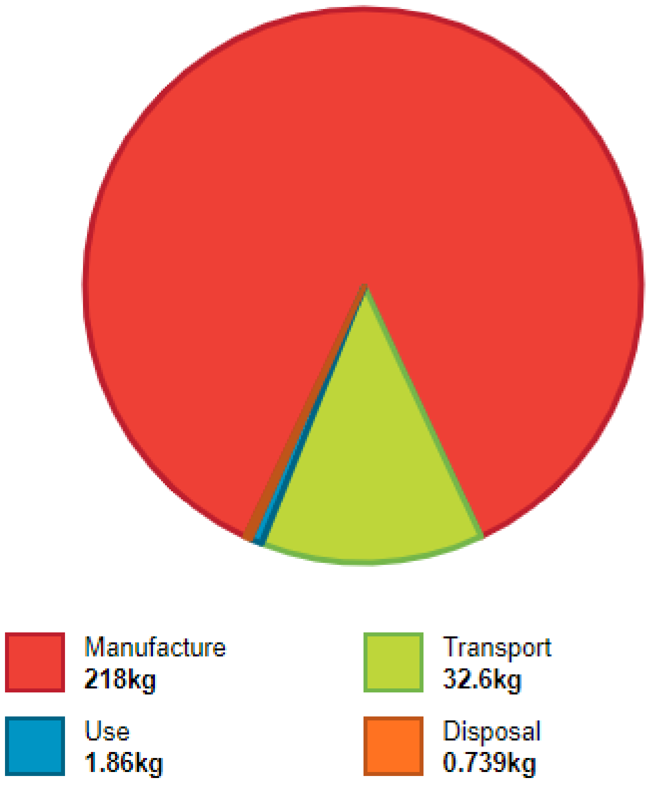

Figure 8

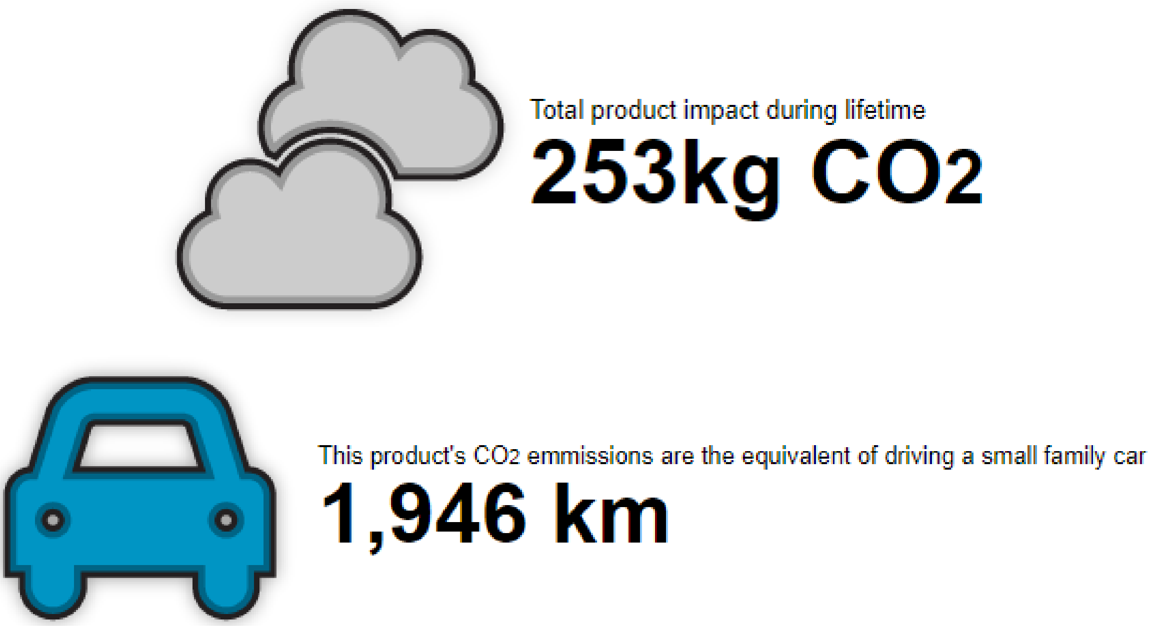

Figure 9 – Graphical display of total CO2 emissions produced from the Life Cycle Analysis of Electric Vehicle Charging point

Figure 10 - breakdown of results from the LCACalculator.

Part name	Part total CO2 (kg)	Material name	Material CO2 (kg)	Disposal method	Disposal CO2 (kg)	Process name	Process CO2 (kg)
30 mA Type A RCD	32.8	Integrated circuitry	30.1	15% recycled, 85% landfilled	0.0249	Soldering, Mounting Through-hole	2.59
Fixings	1.68	PVC, rigid	1.02	5% recycled, 95% landfilled	0.00608	Injection Moulding	0.66
DIN Rails	1.06	Steel, carbon steel	1.06	95% recycled, 5% landfilled	0.000096		
6 mA DC fault current protection	16.4	resistor, general	11.2	15% recycled, 85% landfilled	0.0498	Soldering, Mounting Through-hole	5.19
Tethered type 2 cable	70.6	cable	18.2	5% recycled, 95% landfilled	0.557	Soldering, Mounting Through-hole	51.9
Seals/Glands	0.111	Silicone rubber	0.111	45% recycled, 55% landfilled	0.000293		
BS EN 61851 Mode 3 Chargng Comms	65.5	Integrated circuitry	60.3	15% recycled, 85% landfilled	0.0498	Soldering, Mounting Through-hole	5.19
Contactor	4.97	connector, computer peripheral	1.04	15% recycled, 85% landfilled	0.0374	Soldering, Mounting Through-hole	3.89
Plastic Casing	0.351	PVC, rigid	0.212	5% recycled, 95% landfilled	0.00127	Injection Moulding	0.137
Holster	1.05	PVC, rigid	0.636	5% recycled, 95% landfilled	0.0038	Injection Moulding	0.412
LED Status Indicator	23	LED, light emitting diode	23	70% recycled, 30% landfilled	0.00879		

Discussion

The main figure to take away from the results is an impact of 253KG CO2 during the lifetime of the Electric Vehicle charging point, this section will assess the implications of this figure, but also delve into the specific impacts that the Electric Vehicle Charging point may have due to the nature of the components it uses.

Electrical componentry

Of all the components used in the Electric Vehicle Charging point, the BS EN 61581 Mode 3 Charging Communications device, or as selected within the LCACalculator 'integrated circuitry' produced the greatest amount of CO2 emissions at 65.5kg of CO2. Cenci et al (2021) state that Electrical and Electronic Equipment (EEE) is 'both part of the environmental cure and the environmental disease' (pg.1). This is due to the disposal of the equipment having detrimental impacts on the environment, but the equipment offers the potential to assist reducing the need for energy and natural resources. The terms 'Eco-friendly Electronics' or 'Green Electronics' grew out of a 21st century movement towards greater regulation of this sector particularly in the interest of environmental protection. For Arushanyan et al (2014), the use phase is often the most impacting phase of the life cycle of Electrical Equipment due to the need for energy. For this Electric Vehicle charging point, the only component that requires energy at its end use is the LED light, which is only used for a short duration each day. There is a huge amount of energy that passes through the charging point to the vehicle, however this is not considered in the life cycle of the charging point since it merely passes through the hardware.

Lead is the most abundant heavy metal in Earth's crust, with key characteristics such as abundance of supply, resistance to corrosion, high conductivity, low melting point and high malleability that make it an important material for electronic products (Ciocci and Pecht 2006). Lead is toxic, with threats to the environment being caused by the Lead Oxides from the solder which can become soluble and leach into and contaminate ground water. There has been a movement towards lead-free electronics, however, there is yet to be a perfect substitute. E-Waste contains more than 1000 different substances, many of which are toxic such as Lead, Mercury, Arsenic, Cadmium, Selenium, Hexavalent chromium, and flame retardants that create dioxins emissions upon being burned (Widmer at al 2014). E-waste also contains many precious metals, such as gold. Recycling E-Waste has the potential to be an attractive business venture should it be cost effective to extract the precious metals. However, this attraction is a double-edged sword for the environment. On one hand, it promotes recycling of the metals and avoids them being burnt or put into landfill. On the other hand, the demand for the precious metals will see the items cover thousands more air miles to get to a facility where the extraction can take place. These distances come at a further cost to the environment due to carbon emissions from the transportation process.

Today, promoting a completely circular economy is the path to go down, especially for products that require little external energy input. However, for materials such as precious metals used in circuit boards, the energy required to re-extract the substance is on a par with the environmental cost of just disposing of it in the first place. This brings into question the use of such materials in the first place: with technology evolving so quickly there are bound to be movements towards zero precious metal usage in electrical componentry. In 2009, Nissan announced they had reduced the amount of precious metals used in their catalyst from 1.3g to 0.65 grams (Nissan 2009). This development came alongside a 75% reduction in NOx and non-methane hydrocarbons (NMHC) emitted. This development by Nissan sets a precedent for all sectors to strive for less use of precious metals. Even though this example is from the automotive sector and not electrical componentry, it shows the trajectory of society towards less precious metal use, which ultimately results in less of an environmental impact of Electric vehicle Charging points.

Fang et al (2021) look at ways in which technology will be evolving in the future. It is highlighted that future electronics will have functional features such as: ability to selfheal, stimuli responsive, artificial intelligence, health monitoring and even disease diagnoses. These features are only in their infant stages, however given that the world has been made aware of the importance of spotting disease before it can be spread, this kind of advancement will be of huge benefit to the whole of society. An advancement that is of greater relevance to this study is one in which Fang et al (2021) focus on in their review: Biodegradable Electronics. Fang et al assess the ability to use multiscale wood cellulose for the fabrication of biodegradable electronics. The review concludes that wood cellulose is an appealing green material to use in electronics, however, it is currently only used on a smaller scale so requires further research to be used for industrial applications. Wood cellulose offers a green alternative for the fabrication of biodegradable electronics and is certainly something that could be utilised in electric vehicle charging points to reduce their environmental impact. The impact would be reduced primarily due to a reduction in manufacturing emissions, but also due to less impact at its end-of-life phase. This study has revealed that manufacturing accounts for 86% of the total emissions, so using materials that are less polluting to produce, whilst also being degradable if it does end up in land fill, helps reduce the environmental impact at all phases in the lifecycle.

Manufacturing processes

As previously mentioned, the manufacturing process produces 86% of the overall emissions for the Electric Vehicle charging point. Whilst it is rather expected that the production of the charging point would present the greatest impact, it is surprising that when compared to the emissions from the transport process, it is almost seven times more polluting. This study assumed all products are produced in China and transported to their final location in the UK. This section will evaluate why the emissions from production is so high and suggest ways in which the manufacturing process could reduce its environmental impact.

China has seen rapid economic development since the late 1970s, in the early 2000s the Chinese central government promoted a model of export-led industrialization which resulted in rapid economic growth (Zhu and Lan 2016). In 2015 China implemented the 'Made in China 2025' (MIC 2025) policy to transition to a more self-reliant economy with less dependence on the West (Agarwala and Chaudhary 2021). The movement of China towards self-dependence will have an impact on global supply chain patterns, which when coupled with an ever changing political, economic, and physical climate will impact where and how items are sourced. Due to all items of this Electric Vehicle Charging point being sourced from China it is important to understand how these changes will impact this specific product.

Manufacturing costs in China began to decline because of increased supply of labour and a workforce with growing aspirations. This attracted many multinational corporations to outsource their production to China and it has increasingly been referred to as the 'World's factory'. The 'Made in China 2025' initiative would challenge current monopolies, particularly those surrounding Multi-National Corporations (Agarwala and Chaudhary 2021). The Made in China 2025 initiative would further promote increases in efficiency in manufacturing throughout China. Greater efficiencies would mean less pollution from manufacturing, reducing the environmental impact of the production process. The Made in China 2025 initiative aims to reduce CO2 emissions intensity by 40% in 2025 compared to 2015 levels. A focus of the scheme is on green development which will promote innovations across all sectors to produce goods which carry a lower environmental burden to previous versions.

Made in China 2025 has a focus on the establishment of innovation centres which specifically focus on the promotion of developments in the electronics sector (Li 2018). Since a high percentage of the environmental burden of the Electric Vehicle Charging point stems from the manufacturing phase, and more specifically the electrical components, the future looks promising for a reduction in the environmental impact should manufacturing stay in China.

Transport

Made in China 2025 is largely a positive initiative for the field of electrical componentry; however, this does not take away from the fact that the geographical distance between the UK and China will forever exist. Transport for the composition of the electric vehicle charging points totals 32.6kg of CO_2, 12.9% of total emissions.

Utilising the tools within the LCACalculator, it is possible to adjust the origins of the components. If the items are made in Europe, the overall CO_2 impact from Transport reduces from 32.6kg to 1.6kg, taking the total CO_2 impact from 253kg to 222kg, a 12.25% decrease. Minimising the distance a product has to travel is the goal of any organisation. Less distance means lower costs incurred through travel, and less environmental impact due to the pollution associated with travel.

According to the European Commission (EC 2021), transport accounts for almost a quarter of Europe’s Greenhouse Gas Emissions and is the main cause of air pollution in cities. The IPCC report in 2014 (Sims et al 2014) assessed the greenhouse gas emissions from the transport sector and in 2010 road transport accounted for 72% of emission whilst aviation accounted for only 10.6%. Although road and air aviation should not be directly compared, since they are used for different applications over different distances, and both are needed for certain reasons. Considering that road transportation accounts for the majority of total greenhouse gas emissions, it is worthwhile targeting innovation and investment at this sector. Reducing the emissions from transport would significantly reduce the overall environmental impact of the electric vehicle charging point

Transitioning to universal electric vehicle use will decrease the impact from greenhouse gas emitting vehicles. Electric lorries would be the single most significant improvement that could be made to the transport sector. There is a slow emergence of electric trucks, however the issue of range is the biggest barrier to their roll out. One full tank of fuel in a lorry will enable approximately 900miles of travel, whereas electric trucks are currently only able to travel approximately 125miles on a full charge. The only viable green alternative to electric batteries is hydrogen. Hydrogen provides benefits through its ability to be recharged faster and provides a longer range but poses issues surrounding cost of storage and inefficiencies of transfer into vehicles. These two issues do not make it the best alternative to petrol and diesel, instead it is only being seriously considered at a larger scale such as for shipping vessels (Monios and Bergqvist 2019).

Should the Electric Vehicle charging point be able to be transported via solely electric means, whilst being produced in Europe, this would reduce the environmental impact of the product by a further 1.66kg, to a total of 215.34kg of CO_2.

Improvements to manufacturing process

Even with improvements to the transport process, and with production being shifted closer to the final point of sale, manufacturing remains to be the most significant environmental impact. Wood cellulose has been presented as one technological improvement to decrease the environmental impact of the electrical componentry and this section will look beyond just the components in to how the environmental impact of the manufacturing process could be reduced.

The LCACalculator tool is used to quantify the environmental impact but it does not specifically state what the impacts are from the individual componentry used, rather just an overall CO2 figure. Whilst this is useful and sufficient information for this study, to gain a full understanding of the spatially and temporally distributed impacts from the charging point, more specific impacts are required. However, there are currently no tools that enable analysis to this level. The LCA Software packages such as 'OpenLCA' which was used in the early phases of this study, also offered only a CO2 output. This is a key avenue of improvement for these platforms. It has long been acknowledged that climate change impacts are unevenly distributed over the globe (Tol et al 2004), so knowing where resources are best targeted to mitigate the impacts of certain items is the second most important thing on any environmentally conscious companies' environmental agenda. First on the list is reducing the use of impacting materials or substances in the first place. These difficulties will likely remain until there is sufficient knowledge and transparency through entire supply chains.

Navigating a supply chain is extremely difficult. Prior to discovering platforms that could assist in CO2 emissions approximations, it was assumed that this study would require a navigation of supply chains from retailer through to raw materials producer. Even though LCA platforms are only as good as the data inputted into them, the structure they offer to a study such as this is far more consistent and accurate than a manual navigation of the supply chain. Looking ahead, availability and transparency of environmental credentials for companies will become increasingly important. Fowler et al (2006) highlight how a Life Cycle Assessment can be utilised to substantiate the environmental credentials of a product or system. Therefore, it is likely that society will see wider applications of Life Cycle Assessments from a range of sectors. For the Life Cycle Assessments to be easily digestible by consumers there should be a uniform platform used, with open access databases that are constantly being updated. Guinee et al (2011) projected that there would be frameworks created that pose questions at different level of products, sectors, and economies, which address these aspects to the full scope of sustainability. In recent times, rather than doing product life cycle assessments, the life cycle assessments have become increasingly focussed on different components rather than entire products. Porzio and Scown (2021) assess the considerations of a life cycle assessment for batteries and battery materials. Their study draws on many previous studies into the environmental impact of batteries. Porzio and Scown (2021) highlight the complexity of LCAs for batteries since they ‘pose a particular challenge for LCAs as it has historically been applied. Batteries are simply storing energy for later use, and how batteries are cycled will impact their longevity and the value of the service they provide in ways that are not straightforward to predict’ (pg.3). Furthermore, it is noted how the assumptions made about how the battery is used over the course of its lifetime will vary between studies, making comparisons between studies difficult. This limitation is also experienced in this study, with many assumptions being made. Studies loaded with assumptions increase the possibility of inaccuracy and decrease the ability to compare between studies. Since there is so many varying compositions of electric vehicle charging points, a consistent life cycle assessment of all models will be the best approach to understand which model is best to use, and what avenues should be explored to lower the environmental impact.

LCA Process

A Life Cycle Assessment was the best option for the assessment of the environmental impact of the Electric Vehicle charging point, however this tool does not come without limitations. Life Cycle Assessments are often undertaken with different definitions of system boundaries. Porzio and Scown (2021) highlight that Life Cycle Assessments are sometimes referred to as 'cradle to grave' or 'cradle to gate', where gate refers to the factory gate, whilst grave could be referring to the recycling, reuse, or final disposal of the product in question. Fate and transport modelling aims to estimate the contaminant concentration at a single location at a single point in time. For a Life Cycle Assessment to be perfectly accurate a fate and transport model must be constructed to show how every emission interacts with soil, air, and water. Studies, such as this one looking at Electric Vehicle charging points, rely on averages on a local to global scale which are likely to be one or more orders of magnitude different from the actual values (Porzio and Scown 2021).

Life Cycle Assessments are not always the best tool to be used for assessing the environmental impact of a product. Once the environmental impact has been quantified (such as CO2 emissions in this case), then what next? All that the LCA does is offer a framework to quantify the impact but offers no framework for action to be taken against the issues presented. However, LCAs do enable the most impactful aspects to be identified, so resources can be targeted to the most important areas. Gutowski (2018) offers a critique of LCAs, suggesting that the biggest issue occurs when LCA outcomes are scaled up and used to represent large boundary results. Gutowski's assertions relate to LCAs in an engineering setting, but the suggestions carry to the LCA conducted in this study. For example, the final environmental impact quantification of 253kg of CO2 emissions is for one electric vehicle charging point, so it would be reasonable to assume that two charging points would result in 506kg CO2 and three would be 759kg CO2. However, as Gutowski notes, scaling up from a single LCA would offer greater complexity, since there would be economies of scale for more charging points due to parts travelling together. In the future, LCAs could be undertaken with a degree of understanding on how increasing the scale of production change the overall impact. Furthermore, Gutowski frames the problem of scale by referring to 'missing people' within the LCA framework. It is suggested that the LCA tool should be integrated with other methodologies to enable a more holistic understanding of the full impact that the LCA is having on the environment and humans. These other methodologies would be impact assessment methodologies that cover a full spectrum of impacts that the life cycle of the product could have. In terms of how this would be applied to the Electric Vehicle Charging point, it would require knowledge of exactly where the goods and materials are produced.

Knowing exactly where the materials are sourced from and being able to trace this until the final product phase allows a full impact assessment throughout the life of the material. More spatially focussed assessments will enable a more granular understanding of the impacts that the product is having, such as if there is local scale pollution into rivers.

Use of and limitations of CO_2 as a metric

Guinee et al (2011) highlight how studies that only focus on CO_2 as the focal point of impact are limited to global warming. However, other impacts that a product or system is having on the environment can be significantly more important, such as: biodiversity impacts, acidification, eutrophication, and water stress. One should not infer from this that CO_2 is a bad indicator for general assertions.

It has long been reported that CO_2 emissions are a significant contributor to global warming and climate change, which creates significant impacts on the environment and ultimately humans over the globe. CO_2 emissions trap heat in the Earth's atmosphere, forming a layer in the earth's atmosphere and causing heat to be stored, resulting in increased temperatures. The impacts of global changes are unevenly spatially distributed (Harrington et al 2018). This distribution makes targeting the remedial efforts in response to a specific product extremely difficult.

Monetization of environmental impacts

An alternative and emerging strategy for companies or countries to incur the cost they are having on the environment is through the monetization of environmental impacts (Arendt et al 2020). In economic terms, the environment is categorised as a non-excludable (not possible to exclude people from the use or consumption of it) and rivalrous (interference in the use of a good that is being used by another user) good. Monetization efforts are largely used in the context of cost-benefit-analysis (CBA). The cost benefit analysis is currently carried out on a retrospective basis, however in the future it is hoped that this can be executed in the planning phase of any new products. The cost benefit analysis is heavily integrated with the Life Cycle Assessment to understand the full viability of any production process. Monetization of impacts can facilitate two processes: emission permits or payments for ecosystem services. An emissions permit enables the production of a certain type of emissions, which can be traded, offering incentives to reduce emissions and sell permits. Payments for ecosystem services (PES) is the benefits that humans receive from the natural functioning of healthy ecosystems (Jeffers et al 2015). Payments for ecosystem services works by financial transactions being made to landowners or farmers who agree to take action to manage their land in a way that is of ecological benefit. Quantifying the overall cost of pollution is always going to be a contested topic, and one which will produce a range of results.

Hassan et al (2021) attempt to assess the cost of fossil fuels to society. Fossil fuels are the dominant energy source in society, whilst petroleum, coal and natural gas make up around a quarter of global energy requirements. Besides from contributing to global warming as previously mentioned, the gases can cause fatal lung and cardiovascular diseases. Hassan et al look specifically at the impact of air pollution on humans and agriculture specifically. Hassan et al find that natural gas is found to be the most environmentally friendly energy source. Furthermore, Hassan et al note that 'The results of this study unequivocally show that the early adaptation of cleaner energies, such as wind, solar, and hydrogen, will be extremely beneficial to society, economically viable, and environment-friendly' pg.21209. Being able to control which energy source is used is almost impossible for small companies, such as those producing electric vehicle charging points. However, lobbying and putting pressure on those who do have the authority and control to change the methods of energy production should be a key priority for a company at any level. Transitioning to a renewable and clean energy system is a critical step to reduce not just the environmental impact of electric vehicle charging points, but for the whole of society to live in a healthier and more sustainable world.

Social Life Cycle Assessment (S-LCA)

Understanding an approximate value of the impact that any single product or system has on the environment is extremely valuable. Being able to disincentivise against pollution through financial burdens is a powerful tool in a society largely fuelled by a burning desire for profit. Many scholars have asserted that life cycle assessments are too focussed on economic and environmental factors but fail to consider the social intricacies at play (Jorgensen et al 2008). A key issue to consider when undertaking any social assessment is scale. Norris (2006) suggests how social impacts could be assessed from a more macroeconomic scale, but this will give very broad results of social patterns on a country wide scale. Globalisation has seen a change in cultural norms and a blend of social patterns which means that in 2021 doing country wide social assessments is unlikely to be executed accurately due to spatial inconsistency. For the impact of a product or system to be fully understood, since the early 2000's there has been an emergence of Social Life Cycle Assessments (S-LCA).

Martin-Gamboa et al (2021) undertake a life cycle assessment of Biomass to Electricity systems, focussing on six social indicators: child labour, forced labour, gender wage gap, women in the sectoral labour force, health expenditure, and contribution to economic development. These indicators are by no means exhaustive, but they focus on what is specific to the product system. Due to recent advancements in technology, and shifts to more renewable energy sources, Martin-Gamboa et al highlight how it is essential to fill the literature gap in social life cycle studies to ensure that the burden of sustainability is not just being shifted along, and that technological advancements strengthen a product systems alignment with the sustainable development goals (SDGs). Using Social life cycle assessments is a crucial tool to complement a standard life cycle assessment to ensure not only that the current product system is not having detrimental environmental impacts, but that when advancements and improvements are made to decrease the environmental impact, this does not come at the cost of social welfare.

Conclusions

This project fulfils the aims of calculating the environmental impact of Electrical Vehicle charging points, of which the key figure is 252kg CO2.

The first objective was to quantify the environmental impact of specific components that make up the hardware of the charging point. This objective was achieved by undertaking a Life Cycle Assessment of the constituent parts of the charging point. Not only did this study arrive at the final figure, but it highlighted how the manufacturing aspect of the Life Cycle Assessment offers the greatest scope for improvements in reducing the overall environmental impact. Based on the assumption that all the products were made in China, there could also be significant environmental benefits from bringing production closer to the point of sale, however this is understandably on a seesaw with economic considerations. Finally, the quantification of the various components, highlighted how the electronic componentry posed the greatest threat through not only the manufacturing process, but the disposal phase. For example, Lead is used widely in the electronics industry, with Lead-Oxides from the solder having the potential to become soluble and contaminate ground water. However, the industry is moving in the right direction, as highlighted by Fang et al (2021) who assess the ability to use biodegradable wood cellulose as a green alternative to use in electronics, which would result in significant reductions in the environmental impact of electrical components. The emissions produced by air cargo from China was the most impacting phase of the transport process. Production in China is mainly for economic reasons, due to lower costs of production. China is implementing a 'Made in China 2025' policy which seeks to promote innovations, especially in the electronics sector which could offer significant benefits in reducing the overall environmental impact of Electric Vehicle Charging point.

The second objective seeks to understand the context of the calculations and understand, and, if possible, forecast, what is the future of electric vehicle charging points. One significant limitation of this study is that it has only looked at one specific model of charging point. The scope of this study has not enabled other Electric Vehicle charging points to be studied, however, it is reasonable to assume that most are composed of similar components, and it is merely the outer casing and different tolerances of current that differentiate them. It poses the question as to whether it is acceptable for the widescale use of electric vehicle charging points in their current state or should Electric Vehicle manufacturers seek to decrease their impact. Whilst this study has shown that the charging point has a significant environmental impact, is this a necessary evil for widescale electric vehicle usage? Electric Vehicle manufacturers invest heavily in ensuring that the vehicles have minimal environmental impact whilst in use, but it is widely suggested that ‘Electric Vehicles are only as clean as their power supply’ (pg.1) (Deb 2016). Perhaps car manufactures should be directing their resources towards ensuring that the energy supply to recipients of the cars is as renewable as possible.

In practice, this could consist of manufacturers carrying out due diligence to ascertain energy sources in certain geographic locations and making sure that it is within their specified threshold of renewable energy. From this perspective, the EV charging point plays a small part in the overall picture of widescale EV usage since it merely delivers the energy to the vehicle. However, in pursuit of a greener society it is a key component of Electric Vehicle infrastructure that should not be ignored.

With the UK set to ban the sale of petrol and diesel cars in 2030, there will be an urgent requirement for a significant increase in the Electric Vehicle charging network that must be able to serve a far larger percentage of the population than it currently does. This means increased production of charging points. Therefore, now, and in the coming years, are critical times to invest in reducing the environmental impact of the hardware through ideas mentioned in this study, but also through means that are as a result of future research. Furthermore, it is likely that once the infrastructure is put in place, it will remain for a long time, until being disposed of. Under the assumption that once a charging point is installed at a residential premises or for public charging means, it will not be fully replaced, then best efforts must be made for the initial installation to have as low an environmental impact as possible.

Future research

Future research in this literature gap would involve an environmental assessment of alternative electric vehicle charging points. This would enable a means of comparison that could validate the findings of this study. Comparisons with other electric vehicle charging points would enable feedback to the producers and offer them a ranking of where they rank in comparison to other producers. This ranking system could then be made publicly available, which would incentivise producers to strive for an environmental impact that is as low as possible. Competition drives innovation, so by increasing transparency on the true cost to the environment will enable consumers to make their own decisions about which charging point to install, which would likely be in the best interests of the environment. A Life Cycle Aassessment would be a good way to progress and evaluate this, creating a final CO2 value as a simple comparison across products. CO2 comparison is not the perfect tool to compare, as this study has presented, but it does offer a simple metric that is easily presented to consumers.

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