Tampere University of Applied Sciences

The Influence of E-bikes on Carbon Emissions Related to Commuter Travel in Finland.

Donald Thompson

BACHELOR’S THESIS
April 2020

Degree Programme
Energy & Environmental Engineering

ABSTRACT

Tampereen ammattikorkeakoulu
Tampere University of Applied Sciences
DP in Energy and Environmental Engineering
Name of the Option

Donald Thompson:
The Influence of E-bikes on Carbon Emissions Related to Commuter Travel in Finland.

Bachelor's thesis 39 pages, appendices 4 pages
Month 2020

This thesis aims to understand if electrically assisted bicycles, also called E-bikes, have at present, or in the near future, an impact on carbon emissions due to commuting in Finland. As this method of transport becomes increasingly popular in Finland, no data exists on the habits and attitudes of this commuter segment. Information through an online survey and from existing data on carbon emissions and commuter travel was gathered. Analysis of commuter habits and trends as well as the carbon emissions was performed from this.

The survey asked questions on E-bike users background, commuting journeys and environmental awareness. The survey was available for one week and had 213 individual responses. Results showed E-bikes had significantly changed the respondents' commuter habits. Car journeys were mostly replaced, followed by cycling, walking and bus. Using existing carbon emission data, reduction of emissions through replaced car and bus journeys far exceed any increase from replaced cycling or walking. Responses to the survey also demonstrated further reductions in emissions would occur if trends continued and that limits to these reductions were based on cost, distance and infrastructure.

Based on the results, Finnish E-bike users followed trends elsewhere in non-cycling culture countries for usage, primarily car and bicycle replacement. Comments left by respondents indicate that decreased cost and increased battery life (or more charging points) would lower barriers for others to start E-bike commuting.

Key words: e-bike, pedelec, sustainable transport, carbon dioxide emissions, survey

CONTENTS

1 INTRODUCTION

Carbon neutrality is an objective for both Finland (by 2035) and the European Union (by 2050). As transport forms a significant part of these carbon emissions, alternatives to current travel patterns are being investigated. Bicycles which offer electrical pedal assistance (referred to in this paper as E-bikes) are one possibility; E-Bike sales have increase exponentially across Europe in the ten years between 2006 (98,000 units) and 2016 (over 1.6 million units) according to the Confederation of the European Bicycle Industry (CONEBI, 2017). This study will investigate E-bike usage in Finland to understand changing commuting habits through the use of this new technology and how it affects carbon emissions.

Figures have been sourced from VTT Technical Research Centre of Finland for carbon emissions, the Finnish national travel survey and an online survey through social media. This information has been combined to investigate if E-bikes are replacing other forms of transport, what impact this is having on carbon emissions and what it could mean for the future. The report has been broken down into sections including a review of current literature in the E-bike field, definition of terms and a description of the research and methods undertaken followed by the results and discussion and finally the conclusion.

1.1 Review of E-bike literature

Literature related to electrically powered bicycles is as young as the industry itself. Weinert, Ma and Cherry (2006) looked at E-bike emergence in China. Growth was a response to regulations limiting motorcycle use in cities, household income growth and transportation costs increasing. Production of E-bikes soared from 2million to 10 million in 5 years and is part of the personal transport boom underway in China. E-bikes can be seen as a primary means of transport, replacing public transport as a low-cost option compared with car ownership in distances under 20 kilometres. E-bikes in China also cover what could be called E-scooters, as well as more conventional electrical-assist bicycles, or pedelecs, as they can also be known. (Weinert et al, 2006)

Studies elsewhere in the world followed suit as E-bikes were exported globally and asked questions of ‘who uses E-bikes' and ‘what do they use them for’; Johnson and Rose (2013) conducted an online survey to understand Australian E-bike users. Respondents were predominantly older (41-60) working men with higher education and higher income bracket. The main reason for purchasing was to replace car journeys. The types of E-bikes covered in this study also included E-scooters, commercially bought E-bikes and normal pedal bicycles converted to be E-bikes which represented a significant portion of their respondents. (Johnson & Rose, 2013)

In America, findings from an E-bike user survey were similar to that of Australia with older (45+) working men with a higher education forming the majority, though no income bracket is mentioned. Replacement of car journeys was again the main reason stated for purchase. (MacArthur, Dill & Person, 2014)

Cairns et al. (2017) focuses on European studies, lists seventeen studies in Europe, of which thirteen offered E-bikes or subsidised E-bikes and gathered information based on those responses. Four studies were of active commuters and E-bike users. Of those four, only Engelmoer (2012) and Hiselius and Svenssona (2014) studies were in English. (Cairns et al. 2017)

Engelmoer (2012) quotes demographic studies from Hendriksen et al. (2008). While not providing split by age, gender, education or income, this Dutch study states that the bicycle was replaced most and then car followed by public transport. The age of the study is mentioned as a possible factor in the choice of modality. Environmental issues were also covered with a life cycle analysis of the E-bike. (Engelmoer 2012)

Kroesen and Harms (2018) provide a more up-to-date view of Dutch E-bike usage as part of the Dutch national travel survey; in 2016 over 12% of the population owned an E-bike. Age was still a factor with over 53% of E-bike population being 51 and over. More riders were female than male with 61%, with only the middle aged, full time employed category having more men than women. There was significant growth in younger groups in terms of usage though this is still mainly replacing bicycles. (Kroesen & Harms 2018)

Hiselius and Svenssona (2014) conducted an online survey in Sweden of E-bike customers to establish understanding of riding habits and buying decisions. Their study suggested that Swedish E-bike users were again predominantly men of an older age range (35-64), with car journeys being replaced most often followed by bicycles, public transport and finally walking. Calculations for carbon emission reduction are based on a yearly total per person of 327 kg CO2. This is then used to estimate the current CO2 reduction and possible position in 2030. However, few other studies look at the calculation of carbon emissions. (Hiselius & Svenssona 2014)

Haustein and Möller (2016) surveyed Danish E-bike users with an online survey. Weighting the responses, it was found that Danish E-bike users were more often women and in an older (50+) age bracket. Bicycle journey replacement was most common followed by car journey, bus and walking. Also provided is a segmentation by attitudes and mention one segment ‘enthusiastic e-bikers', who *“...probably made a major change to their every-day lives, such as using the e-bike to get to work instead of the car.”* This had a higher proportion of men of a slightly younger age than the average. (Haustein & Möller 2016)

2 DEFINITION OF RELEVANT TOPICS

2.1 Commuting definition

The need to define what commuting is comes in part from the historical vagaries of the English language and in part because, when writing the questions for the survey in Finnish, no direct translation of the word commute is available. Within the English language the word commute can have up to four possible meanings (Cambridge dictionary, 2020). The meaning for this study is that of 'to make a regular trip'. Again, from the Cambridge dictionary definition is "to make the same journey regularly from home to work". However, the expression can be considered to cover a wide variety of regular journeys, such as to a place of study, shopping, or possibly for medical needs. The important part is that the journey is undertaken frequently and usually in exactly the same route and method of transport.

2.2 E-Bike definition

Within the European Union, the legislation around what is an E-bike is clarified under Regulation No 168/2016; article 2, section H;

> pedal cycles with pedal assistance which are equipped with an auxiliary electric motor having a maximum continuous rated power of less than or equal to 250 W, where the output of the motor is cut off when the cyclist stops pedalling and is otherwise progressively reduced and finally cut off before the vehicle speed reaches 25 km/h.

In Finland this is set out in the Vehicles Act 1090/2002. There are differences in Finland from EU regulations that allow power up to 1000 Watts. Below in a reference diagram (Diagram 1) from the Finnish Transport Safety Agency (Traficom, 2019) showing the requirements for the E-bike, or electrically assisted bicycle as it is called in the diagram.

DIAGRAM 1. E-bike legal requirements (Traficom, 2019)

Electrically assisted bicycles and motorised bicycles operate in very similar ways with the main distinction between them being that a motorised bicycle has a throttle allowing speeds beyond 25 km/h. These motorised bicycles then fall, legally, into a class with scooters and other vehicles and are not included in this study.

.

2.3 Carbon dioxide emissions

Carbon dioxide emissions have been a measure of anthropogenic climate change for decades, with the now famous keeling curve (Named after Professor Keeling, who first monitored carbon dioxide emissions), showing the increase in carbon dioxide emissions over time. (Figure 1).

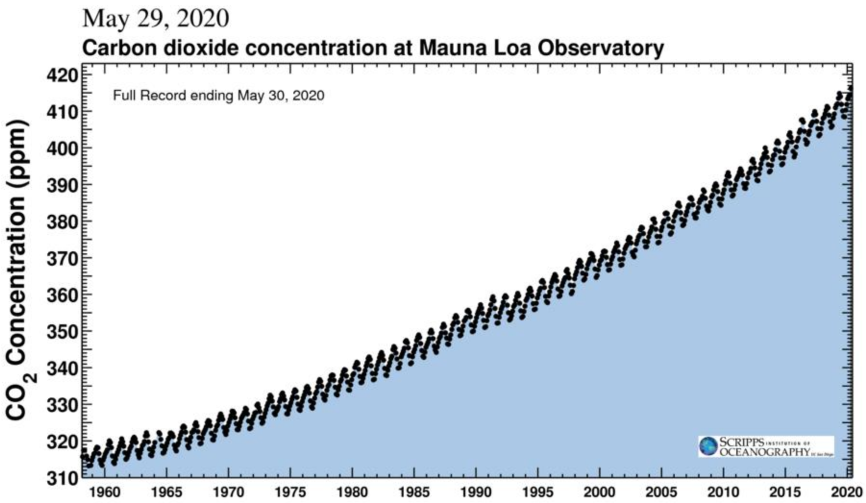

FIGURE1. Atmospheric carbon dioxide concentration (Scripps Institution of Oceanography, 2020)

Most human processes can cause carbon dioxide emissions, with heating and electricity generation for domestic, commercial and industrial uses being the largest portion. Transport emissions make a significant proportion with carbon dioxide from car emissions coming in over 500 million tonnes for the EU 28 in 2017 (Eurostat, 2020)

In Finland, the average carbon dioxide (equivalent) emissions per capita is 10.3 tonnes (Sitra, 2018). Of that total, around 30%, or 3 tonnes, comes from transport which is shown below in figure 2. The largest part, over 70%, relates to travel by passenger car. Carbon dioxide equivalent is discussed in greater detail in the next section.

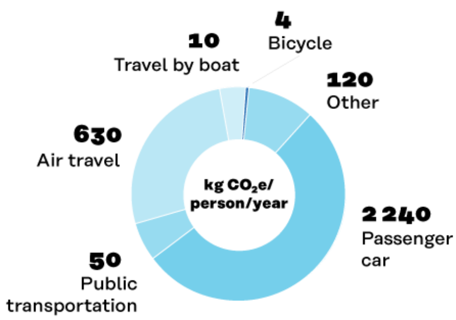

FIGURE 2. Carbon footprint of the average Finn (Sitra 2018)

2.4 Global Warming Potential (GWP) values

However, accounting for emissions has moved on from a simple count of the carbon emission to using carbon dioxide equivalent. The principle of global warming is that an increased amount of the sun's energy from radiation is trapped in the earth's atmosphere. The increase in the trapped energy is due to an increase in compounds in the atmosphere that radiate the energy back towards earth rather than allowing it to pass back into space.

The ability of the compound to radiate energy is defined in the Global Warming Potential (GWP) values and shown as carbon dioxide equivalent. These values are defined by the International Panel on Climate Change (IPCC) and the below table (Table 1) shows some of these values (IPCC, 2014). For example, one gram of methane is equivalent to 28 grams of carbon dioxide, over a 100-year period.

TABLE 1. Global warming potential values (IPCC AR5 Synthesis Report, 2014)

		GWP		GTP	
	Lifetime (yr)	Cumulative forcing over 20 years	Cumulative forcing over 100 years	Temperature change after 20 years	Temperature change after 100 years
CO_2	[b]	1	1	1	1
CH_4	12.4	84	28	67	4
N_2O	121.0	264	265	277	234
CF_4	50,000.0	4880	6630	5270	8040
HFC-152a	1.5	506	138	174	19

For the purposes of the study it is important to understand that while E-bikes and other electric vehicles may have an emission value of zero during their use, the emissions generated while charging the battery can be significant. In section 3.6, the value of 211 gCO2-eq/kWh is used for Finnish electricity. If this study was conducted in Poland then the value would be 980 gCO2-eq/kWh (Moro & Lonza, 2017). This is due to heavy coal dependency in Poland (80.9%) compared with Finland's (8.3%) (The World Bank, 2014).

2.5 Well to wheel and life cycle assessment methodologies

Several methodologies exist in environmental analysis: life cycle analysis and well to wheels. When choosing between these there are several factors. One is availability of data as Finnish emission statistics (VTT Technical Research Centre of Finland Ltd) are presented as well to wheel figures.

Choosing life cycle assessment would have given a view of areas such as pollutants produced during the other phases of the E-bike; production, maintenance and disposal. However, comparing the production, maintenance and disposal of a car, E-bike and bus, for example, would move away from the core question of how E-bikes are affecting commuter choices and from those choices, the emission values.

The final reason for limiting the scope to only the well to wheels rather than the whole life cycle assessment is that E-bikes are a replacement for other journey types rather than for the entire vehicle. There are well over 5 million vehicles in traffic use in Finland in 2019 and as the graph below (Figure 3) shows, there is not expectation for this to stop. People are purchasing E-bikes as well as owning cars. Note the graph in figure 3 has been modified to include axis titles.

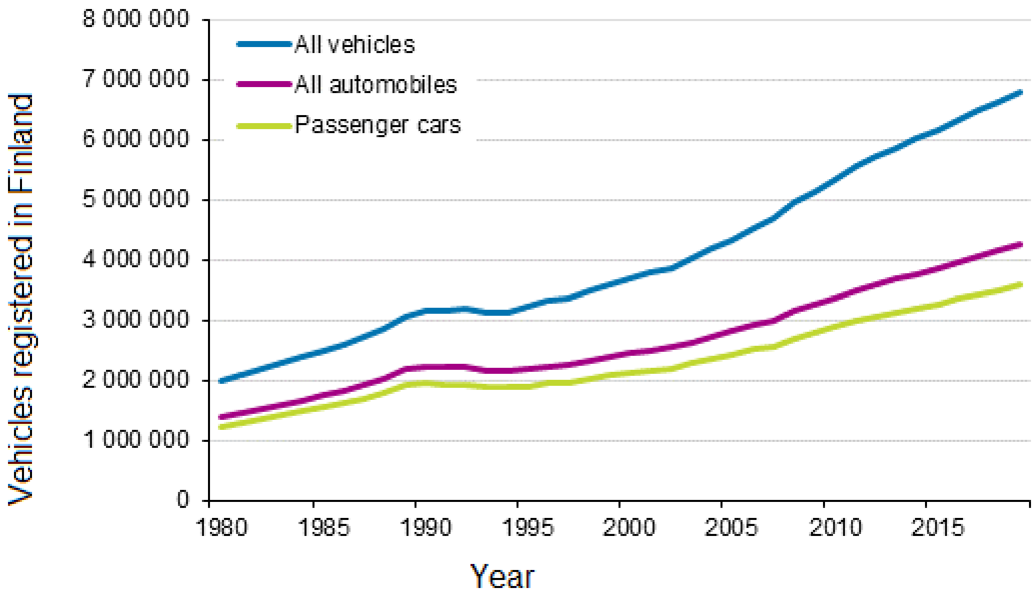

FIGURE 3. Vehicle stock in Finland, 1980 - 2019 (Statistics Finland 2020, modified)

2.6 Existing commuter habits in Finland

Emission figures, whether by vehicle type or estimated national level, provide one view of the emissions from commuter traffic. The next step is to add in the view of commuter habits. For example, commuting by car can cover a wide variety of distances and not all of those distances are suitable for replacement by E-bike. The national travel survey in Finland has been conducted over a number of decades and the 2016 edition (released in 2018) is used in this report. The follow graphs have been created from statistical information about the survey available at Traifcom webpage Henkilöliikennetutkimuksen 2016 tuloksia taulukoina (Traficom, 2019). The original survey was undertaken by WSP Group.

Some notes on the national travel survey; in the parts mentioned below all journeys relate to distances under 100km and from an age groups of 6 upwards. The population relates to people living and registered in Finland as of 2016. Some categories have been summarized for greater clarity and for ease of comparison with the E-Bike survey shown in the results section.

The average number of trips in Finland per person is 2.73 a day, with the average distance being 14.9km. Below (Figure 4) is a breakdown of transportation type for journeys under 100 km in distance. If we take car drivers and passengers together, this makes up the dominant part of all journeys followed by walking. All other journey types are less than 20%.

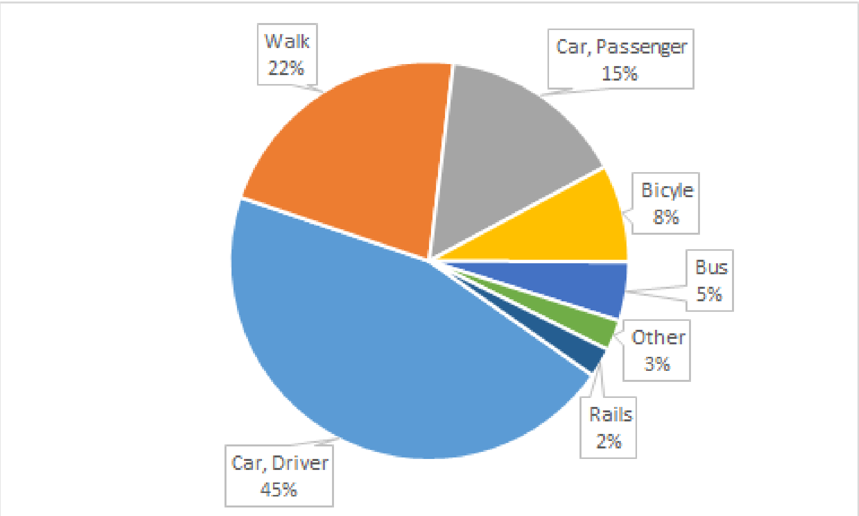

FIGURE 4. Transport mode in Finland for distances under 100 km.

Of those same trips, split by destination type there is no one dominant destination. Shopping accounts for nearly 20% followed by 6 different destinations that make up 69% spread between 15% for work at one end and 9% for errands at the other. Three other destinations split the last 12% of journeys.

Looking at number of trips split by transportation type and age category (Figure 5); again car driver is dominant in all categories except for children (6-17 years) and elderly women.

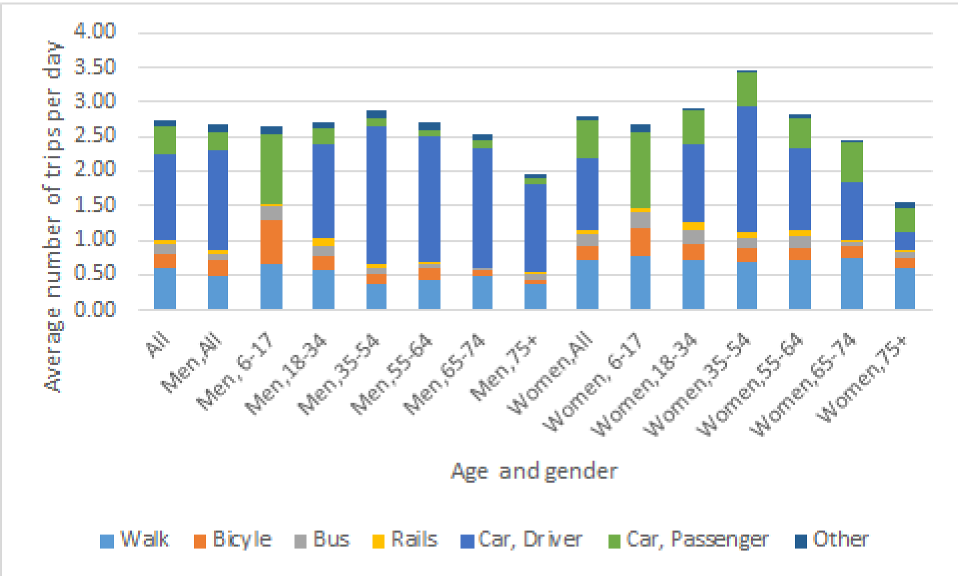

FIGURE 5. Transport modes by age and gender, showing averaged daily trips.

Looking at distances for journeys by vehicle type, we can see that for walking distances under 1 kilometre are dominant, and any journeys over 5km are rare (cumulative total for journeys over 5km is only 4.6%). Cycling offers a wider spread, but distance also drops rapidly with journeys 7-10km equating to only 4.7% of the total and any over 10km being 4.4%. This is displayed in Figure 6.

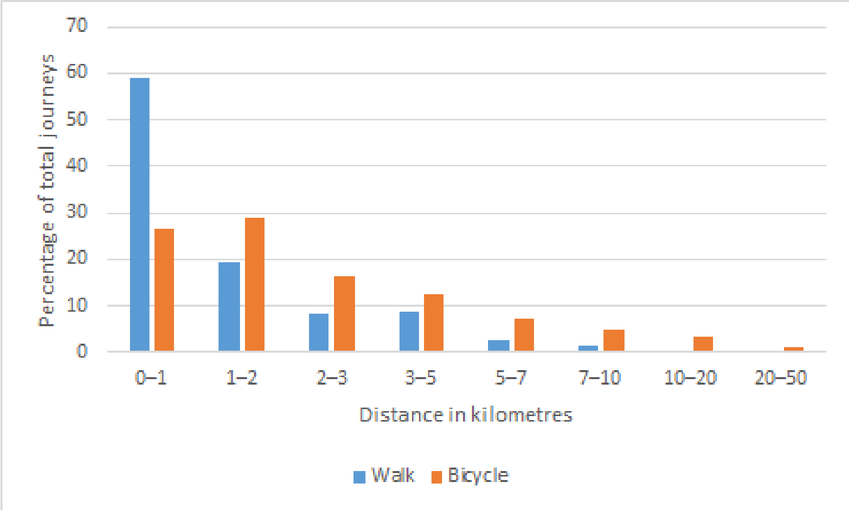

FIGURE 6. Distance by walking or bicycle

Bus and rail, with rail transport including trains, trams and metro/underground, are almost the opposite of walking and cycling (Figure 7). Short journeys, up to 3km, represent less than 10% for each category. Buses have a small peak at 3-5km but otherwise both bus and rails follow a trend upwards to peak at 10-20km, representing almost 20% of bus and 25% of rail journeys.

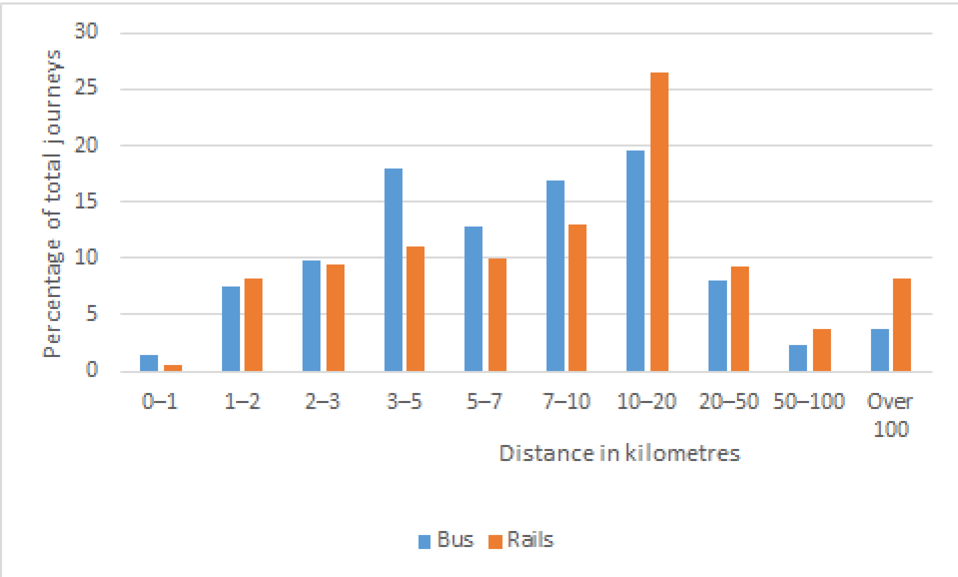

FIGURE 7. Distance by bus or rail transport

Car journeys show the greatest equality over all distances below 50km (Figure 8). Peaks again at 3-5km, like bus transport, and again 10-20km, reflecting both bus and rails.

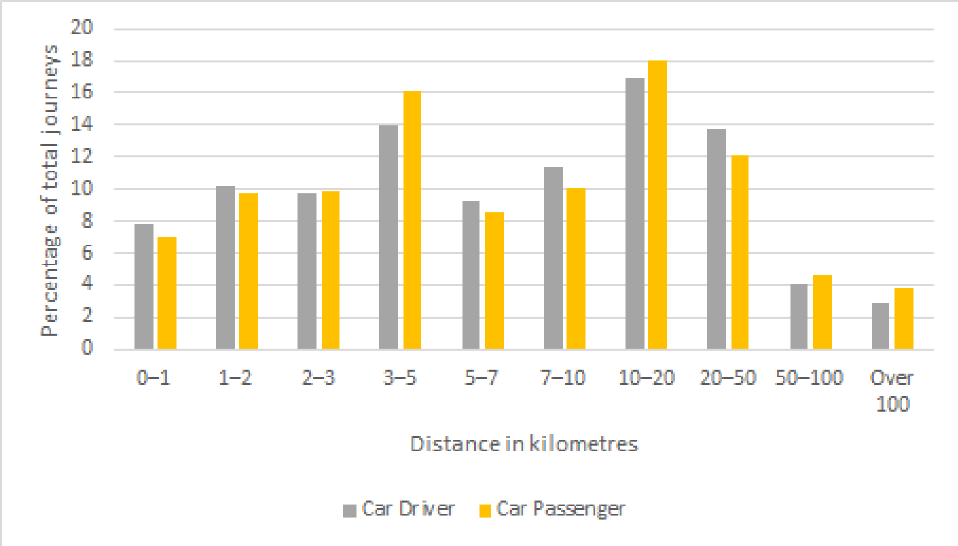

Figure 9. Distance by car and car passenger

Looking at all transport types as a value of 100% per journey distance (Figure 10), the dominance of the car at all journeys except less than 2km is clear.

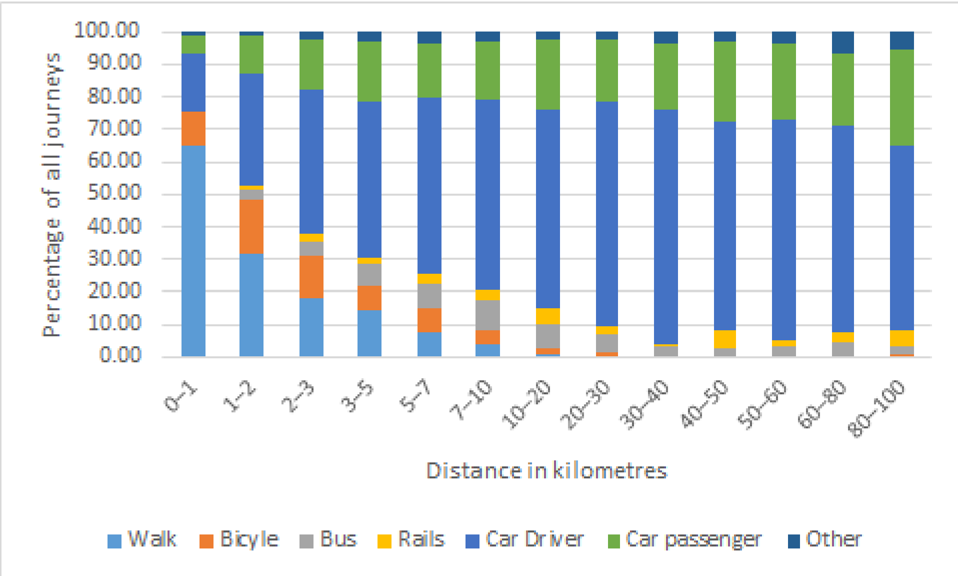

Figure 10. Total journeys by transport mode.

Passenger occupancy (Figure 11) for cars is one consideration when investigating what journeys can be replaced by E-bikes. Below is a summary of key journey types and occupancy rates.

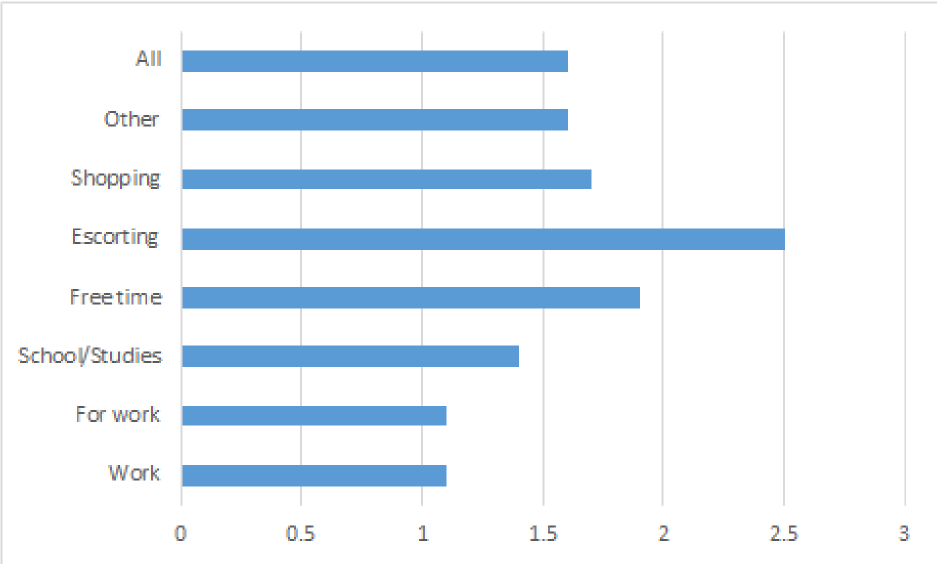

FIGURE 11. Car journey occupancy rates

3 RESEARCH DESIGN

3.1 Research questions

The aim of this research is to understand how E-bikes usage is affecting Finland's commuting carbon emissions. It has been shown that, where an E-bikes is available to use, a significant number of car journeys are replaced; a literature review lists 6 separate studies within Europe over a 7 year period showing between 16% and 76% of car journeys being replace by E-bikes during the studies (Cairns et al. 2017). However, there are no studies on E-bike usage in Finland.

With a reduction in the number of journeys by car, and public transport, then a corresponding reduction in carbon emissions was to be expected. In Sweden it was calculated that 327kg of carbon dioxide emissions were reduced a year for every person who changed transport mode to an E-bike (Hiselius & Svenssona 2014).

To gather the information needed to understand E-bike contribution to carbon emission change, a survey of E-bike users commuting habits was necessary. Depending on what mode of transport was replaced there would be a change in carbon emissions. The following questions were asked to understand the change in carbon emissions due to E-bike commuting in Finland:

1. How have E-bikes affected established commuter journeys in Finland?
    a. How has this changed carbon dioxide equivalent?
2. How would continued E-bike uptake effect carbon dioxide equivalent for commuting?
    a. What limits to E-bike commuting?

3.2 Objectives

To answer these questions, it was necessary to gain a deeper understanding of E-bike usage in Finland. Primary data on the topic was gathered through an online survey of E-bike users.

Vehicle carbon emissions, from VTT Technical Research Centre of Finland Ltd were used to calculate the change in carbon dioxide equivalent emissions from the survey data.

Existing statistical information was retrieved on commuting habits in Finland, (based on the national travel survey) to calculate upper and lower values for E-bike commuter use and carbon dioxide equivalent change.

3.3 Method

To answer the research questions primary data was collected. This was a mixed method, primarily quantitative as the questions asked related to facts, often numerical, rather than opinions or attitudes. However, in order to add some greater depth to answers received a qualitative section was included.

Based on the information gathered from the survey an estimation of the change in carbon dioxide emission equivalent will be calculated, based on well to wheels formula. Additionally, based on the trends shown from the survey, projections will be made to show possible future outcomes to carbon dioxide equivalent emissions.

3.4 Methodology/Survey questions

When considering how to answer the question of E-bike influence on carbon dioxide equivalent emissions on Finland, we have to consider how we get from the question to the answer; data on commuting habits in Finland is readily available in the Finnish national travel survey (Henkilöliikennetutkimus 2016). However, this data does not go into the granularity of E-Bike usage. Using figures from the Confederation of the European Bicycle Industry (CONEBI), E-bike sales from 2011 to 2017, suggest there are seventy-one thousand E-bikes in use in Finland by the end of 2017 (Table 2). Note that the figure for 2014 is an estimate, based on sales in 2013 and 2015, as no sales figure was reported for that year. (CONEBI, 2011, 2012, 2013, 2014, 2015, 2016, 2017)

TABLE 2. E-bike sales in Finland

Year	2010	2011	2012	2013	2014	2015	2016	2017
E-bike sales	N/A	3000	3000	5000	10000	15000	15000	20000

As there was no primary data available around E-bike usage in Finland then the survey is one way of obtaining that information. Facebook is a social media platform that is prevalent in Finland; Yle, Finland's national news broadcaster, quotes a figure from the Federation of Finnish Enterprises that *"...some 2.5 million Facebook users in Finland, a country with a population of roughly 5.5 million."* (Yle, 2018). Further detail of Finns Facebook usage is provided by Statistics Finland with a survey where, on average, 55% of respondents used Facebook. That figure hides the fact that for certain age groups this percentage moves closer to 100%, see graph below (Figure 12), and others show only a small proportion of users, both in the very young and old categories. (Statistics Finland, 2017)

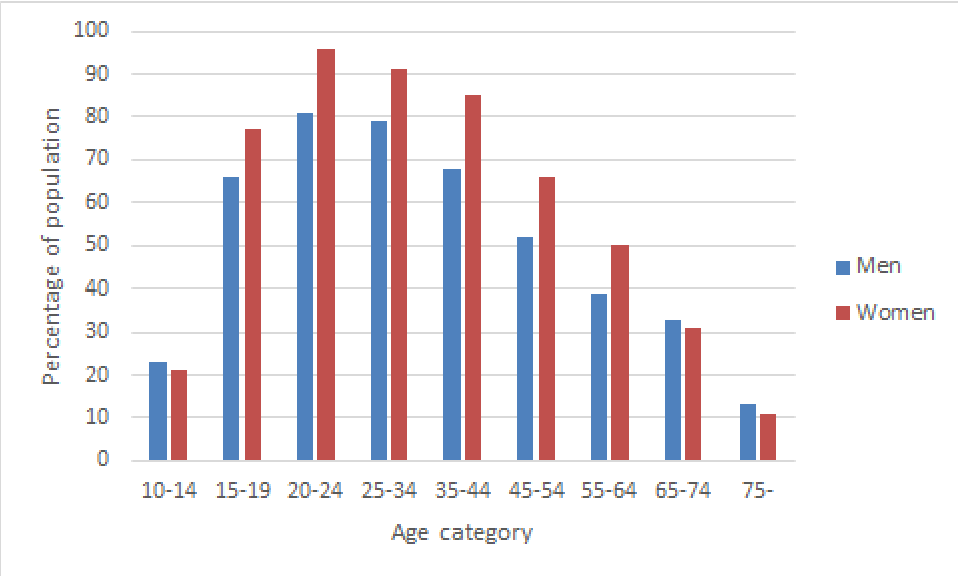

FIGURE 12. Percentage of population using Facebook

With such a large number of users Facebook should allow a representative sample of the population once weighted for any bias. Three Facebook groups were chosen, listed below, with the number of people who are members of the groups (Table 3). The survey was available for 7 days, between the 8th and 15th of March 2020.

TABLE 3: Number of users in Facebook groups

Group name	Number of members
SÄHKÖPYÖRÄT (sähköavusteiset, 250W, 25km/t, tieliikennekelpoiset)	2747
Sähköpyörät - ostetaan / myydään	4517
Sähköpyörät	5854
Total members in all groups	13118

However, members can belong to one or more groups. Members can join or leave at any point. Posting the survey to the group does not automatically mean it is seen by all members, Facebook provides visibility of posts to users based on its own algorithms. For example, a ‘popular’ post may be shown to more of the members for a longer period of time than one that is less popular.

3.5 Survey questions

The survey questions are available in appendix 1. To summarise the survey asked questions about;

- Gender, age, occupation and if the respondent had a physical impairment.
- How long the respondent had owned an E-bike. How far, how often and where they rode the E-bike.
- In addition, how they previously commuted or commuted when not riding their E-bike.
- A section on environmental awareness

These four sections only allowed the respondent to select particular answers, or numerical values, in order to provide quantitative answers. For some questions the categories that could be selected by the respondent reflected that of the answers of the national travel survey.

Finally two open-ended questions to allow the respondent to provide more feedback (qualitative feedback). In addition, some of the quantitative questions allowed the respondent to leave an alternative text reply or give qualitative feedback if they felt that the pre-selected options did not reflect their own needs.

3.6 Survey weighting

In order to address bias within the survey based on age and gender, a weighting of the results is necessary. This is based on population statistics provided by WSP Finland Oy, who produced the Finnish national travel survey. The survey responses presented in the results, section 5.1, will not be weighted, but for further analysis such as comparing with the Finnish national survey results, it is necessary.

TABLE 4. Population weighting for age and gender

	Population	Proportion
All	5098368	1.00
men.All	2503330	0.49
men. 6-17	356718	0.07
men.18-34	596109	0.12
men.35-54	697454	0.14
men.55-64	365657	0.07
men.65-74	312109	0.06
men.75+	175283	0.03
women.All	2595038	0.51
women. 6-17	343065	0.07
women.18-34	562098	0.11
women.35-54	678720	0.13
women.55-64	373929	0.07
women.65-74	353265	0.07
women.75+	283962	0.06

3.7 Emissions by vehicle type

Having considered the survey process for gathering primary data on E-bike users in Finland, the next step is to calculate the emission values. The combination of these two data sets will provide a picture of the commuter emission change through E-bike use in Finland.

Carbonneutralfinland (2017) provide figures for the total emission generation for the whole of Finland. Based on data gathered at a municipality level there is an average of 25% of emissions from road transport. Table 5 shows a breakdown of this 25%, or over 9,6 million tonnes of carbon dioxide equivalent. From that over 61% is emissions from cars, representing over 5,9 million tonnes of carbon dioxide equivalent. Please note that this information is available in Excel format only from the Finnish version of the webpage 'Kuntien ja alueiden kasvihuonekaasupäästöt' and not the English translation 'Municipalities' and regions' greenhouse gas emissions.' (Carbonneutralfinland, 2017)

TABLE 5. Carbon dioxide equivalent emissions by vehicle type (2017)

Vehicle type	Emissions ktCO_2-eq	As a percetage
Car	5,938.54	61.73
Truck	2,492.22	25.91
Bus	353.59	3.68
Motorbike	86.73	0.90
Moped car	7.87	0.08
Moped	24.95	0.26
Van	716.64	7.45
Total	9,620.54	100.00

Trucks and vans are not included in this study. This is because while they can be used for commuting, typically their role is related to other tasks such as transporting goods over long distance, moving heavy loads, or a combination of the two. Looking at the replacement of small, urban loads by E-Cargo bikes would be a separate study in itself.

E-bike carbon emission values come solely from the source of the electricity used for charging. The carbon intensity of electricity generation is a measure that can be used to estimating the carbon emission cost of electric vehicles. Carbon intensity for low voltage consumption in Finland is 211 gCO_2-eq/kWh, based on 2013 figures (Moro and Lonza 2017). The next step is to calculate the efficiency of the E-bike. How far can it travel on one battery charge? The efficiency of the motor, as with all vehicles, varies hugely.

An Italian study of an E-bike gave values between 45 and 85km ridden on one battery charge. The motor used in the report is listed as 48 Volts (*V*) and 10 Ampere hour (*Ah*). (Abagnale et al. 2015). This calculates to 480 Watt hour *(Wh)*, using the formula (1) below.

$$Wh = V * Ah$$

In order to calculate the value of grams of carbon dioxide equivalent per kilometre, the Watthour (*Wh*) value is divided by the number of kilometres (*Km*) ridden until the battery was discharged, and then multiplied by the grams of carbon dioxide generated during electricity production (Formula 2). This is measured in carbon dioxide per Watthour *(CO_2/Wh)*.

$$(Wh / Km) * CO_2 / Wh = CO_2 / Km \qquad (2)$$

Below is a table (Table 6) showing carbon dioxide emissions for an E-bike in a comparative manner to emissions from automotive vehicles. The Watt hour value calculated earlier is converted into kilo Watt hour value to match that of the electricity generation. This is then multiplied by the distance ridden before battery failure, and then multiplied by the carbon dioxide equivalent emissions mentioned earlier. Finally, the emission value per kilometre cycled with an E-bike is calculated. The mode column represents the level of electrical pedal assistance the user receives and the distance column the kilometres ridden before battery failure (Abagnale et al. 2015).

TABLE 6. Carbon dioxide equivalent emission values for an E-bike

Mode	Distance (km)	kilowatt hour (kWh)	kWh/km	gCO_2eq/kWh	$gCO_2eq/kWh/km$
Speed	45	0.48	0.0107	211	2.2507
Power	55	0.48	0.0087	211	1.8415
Standard	70	0.48	0.0069	211	1.4469
Eco	85	0.48	0.0056	211	1.1915

In order to compare different transport types then the expected emission figures are needed. For all vehicles, the carbon emissions, or carbon emission equivalent, is an estimated value. It is possible to get an exact value, say through emissions testing on a car. However, even these values are a representation of the vehicle under certain conditions. All forms of transport have many possible factors which can change, in turn affecting the performance and emissions of the transport; road surface, elevation change, tyre pressure, load of the vehicle and environmental conditions are but a few of those. As such estimated values of kilograms or grams of emission (or equivalent) per kilometre is typically used.

Figures below (Table 7) are taken from the Lipasto traffic emissions database maintained by Teknologian tutkimuskeskus VTT Oy. Figures are from 2016

TABLE 7. Carbon dioxide equivalent per person by road transport

Vehicle type	grams of CO_2-eq	number of occupants	grams of CO_2-eq per person
Car	152	1.7	89
Bus, urban	949	18	53
Bus, long distance	574	14	41
Bus, average	762	16	47
Motorbike	112	N/A	107
Moped	68	N/A	62
Moped car	128	N/A	124

The VTT figures follow European standard EN 16258, also known as SFS-EN 16258:2012 in Finland. These cover a 'Well-to-Wheels' assessment of the emissions but not a whole life-cycle of the vehicle producing the emissions.

Passenger cars in Finland emit on average grams of 152 gCO_2-eq/km with an average occupancy of 1.7. This leads to an average of 89 gCO_2-eq/km per person. Electric cars are list below due to calculation values.

Table 8 covers information for rail and electrical transports. Bus carbon emission figures for Finland in 2016 averaged at 949 gCO_2-eq/km for urban buses (with an average of 18 passengers) and 574 gCO_2-eq/km (average 14 passengers) for long distance coaches. Taking these figures together would give an average of 47 gCO_2-eq/km per passenger (occupancy rate of 16 passengers). Electric buses which have begun to operate in Finland are listed below due to the calculation values. Also included in the survey are trains, trams and the metro. For the values below, the electricity consumption is based on 'per passenger kilometre' and the average per person is on a gCO_2-eq/km per passenger basis.

TABLE 8. Carbon dioxide equivalent per person by rail and electrical transport

Vehicle type	Electricity consumption (kWh/km/per person)	gCO_2eq/kWh	$gCO_2eq/kWh/km/per person$
Train	0.085	211	17.94
Tram	0.240	211	50.64
Metro	0.180	211	37.98
Electric bus	0.078	211	16.46
electric car	0.100	211	21.10

For motorcycles, mopeds and moped cars no per passenger figure is available. On that basis it is assumed that the occupancy is one. To provide a representation of the comparative emission production, the graph below (Figure 13) presents all forms of transport in this section together with their carbon dioxide equivalent emission value per kilometre per person.

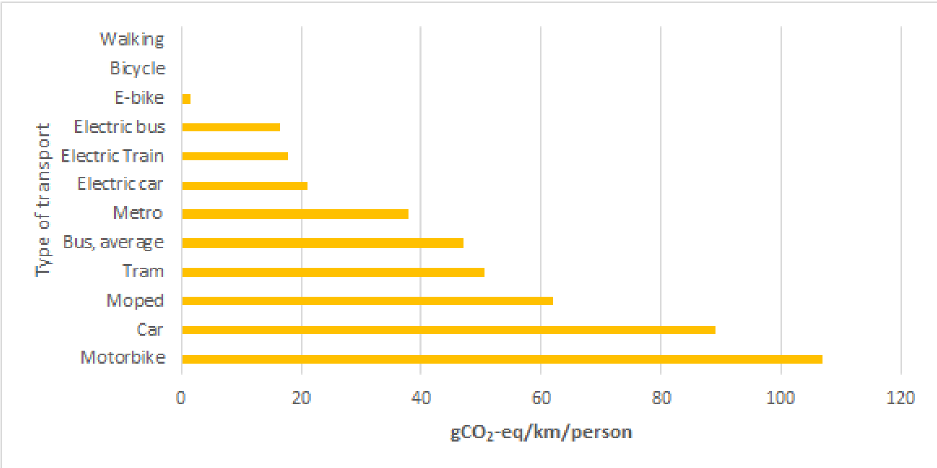

FIGURE 13. Carbon dioxide equivalent emissions by transport type

4 RESULTS & DISCUSSION

Results are split into four sections representing the four research question. The original survey responses in Finnish are available in appendix 2.

4.1 Changes in established commuter journeys

When respondents were asked 'How did you previously commute before an E-bike?' only 2 out of 213 replied there had been no change in their commuting choices. This in itself is a strong indication of the change E-bikes have had on the survey group. The frequency of use is also a good marker of change to previous commuter habits; nearly 1 in 4 respondents rode more than 5 times a week and 81% rode 3 or more times a week.

Looking at which commuter segments have been affected the most (after weighting), men in the 18-34 and 35-54 age categories, who drove cars, made up 38.5% of the population. Of that group, 92.7% were employed, and 72.7% rode their E-bike to work. Based on the population usage of Facebook and having weighted the survey to compare with the national travel survey, there is lack of respondents in the female categories except for 35-54 age range. This gender bias has been seen various studies covering Australia, American and Sweden, (Johnson & Rose 2013, Hiselius & Svenssona 2014, MacArthur et al 2014). Table 9 shows the weighting of survey results against the population used in the national travel survey.

TABLE 9. Weighting of survey by age and gender

	Population	Proportion	Survey	Proportion	Response weighting
All	5098368	1.00	213	1.00	1.00
men.All	2503330	0.49	175	0.82	0.60
men. 6-17	356718	0.07	3	0.01	4.97
men.18-34	596109	0.12	31	0.15	0.80
men.35-54	697454	0.14	93	0.44	0.31
men.55-64	365657	0.07	30	0.14	0.51
men.65-74	312109	0.06	16	0.08	0.81
men.75+	175283	0.03	2	0.01	3.66
women.All	2595038	0.51	36	0.17	3.01
women. 6-17	343065	0.07	1	0.00	14.33
women.18-34	562098	0.11	7	0.03	3.35
women.35-54	678720	0.13	22	0.10	1.29
women.55-64	373929	0.07	6	0.03	2.60
women.65-74	353265	0.07	1	0.00	14.76
women.75+	283962	0.06	0	-	-

Regardless of age or gender, cars and bicycles were replaced significantly more than any other previous commuting method. 57% of respondents replaced car journeys, with 20% replacing cycling with E-bikes. Based on the E-bike sales figures there are at least 71,000 E-bikes in Finland, replacing over 40,000 car users and 14,000 bicycle users. The national travel survey reported modal split as; car driver 45%, walking 22%, car passenger 15% and bicycle 8%. Based on those figure bicycle commuting has been affected to the greatest extent due to its smaller size, but car commuting replacement is the greater by volume. This information is summarised in table 10, below.

TABLE 10. Estimated replaced modes of transport.

Travel type	Percent	Breakdown
Car driver	57%	40,667
Bicycle	20%	14,000
Bus passenger	7%	5,000
Walking	5%	3,333
Multiple modes mentiond	3%	2,000
Did not previously travel	2%	1,333
car passenger	1%	1,000
Train or metro	1%	1,000
Motorbike/Moped	1%	1,000
Tram	1%	667
E-bike has not replaced previous modes	1%	667
Mountain bike	0%	333

The car replacement over bicycle replacement was seen again in Australia, American and Sweden, (Johnson & Rose 2013, Hiselius & Svenssona 2014, MacArthur et al 2014). But not in Denmark and the Netherlands (Hendriksen et al 2008, Haustein & Möller, 2016).

One last interpretation is that in Denmark there was a segment of E-bike users nicknamed ‘enthusiastic E-bikers' who match the category of male and replacing car with an E-bike (Haustein & Möller 2016)

4.2 Calculation of the emission change

Change in carbon emissions, in the form of a reduction, is greatest due to car use. The change from bus to E-bike was also a reduction. For cycling and walking to E-bike, this had a far smaller impact but was an increase. An average of total distance travelled per week, per respondent was calculated based on:

Average of the total number of journeys. Where respondents said they travelled more than 5 times a week, a value of 7 was used and where respondents said they travelled less than once a month a value of 0.5 was used. One response was excluded due to having a blank value for number of journeys.

Average journey length was calculated using all journeys, excluding the previously mentioned blank value. For each journey length category, the average was used, for example 3-5km category, 4km was used.

With the average distance covered in a week at 35km, with the average number of trips at 4.29 and average distance of 8.16km. Emission value was calculated and then projected to a per person per year value, dependent on the transportation method. Car driver, bicycle, bus and walking, which made up 89% of respondents, are shown below (Table 11)

TABLE 11. Yearly carbon dioxide equivalent emissions

Travel type	gCO_2-eq/km/person	Yearly Distance	Yearly CO_2-eq kg
Car driver	89.00	1820	161.98
Bicycle	-	1820	-
Bus passenger	47.00	1820	85.54
Walking	-	1820	-
E-bike	1.45	1820	2.64

Based on the average carbon emissions for a Finn (section 2.3) this would result in around a 5% decrease in emissions for a car driver, 3% for bus passenger and a negligible increase for walking and cycling (less than 0.1% of the yearly total).

Using the table in 4.1 of total E-bike users, a total of 7015 tonnes of carbon dioxide equivalent would be saved from car and bus use and 50 tonnes would be generated from bicycles and walking replaced by E-bike.

4.3 Future changes

Respondents to the survey gave values for how long they had been riding an E-bike for, from less than 1 year to more than 5 years. Charted below (Figure 14) are those responses in a cumulative graph over time, representing the replacement of previous modes of transport with E-bikes.

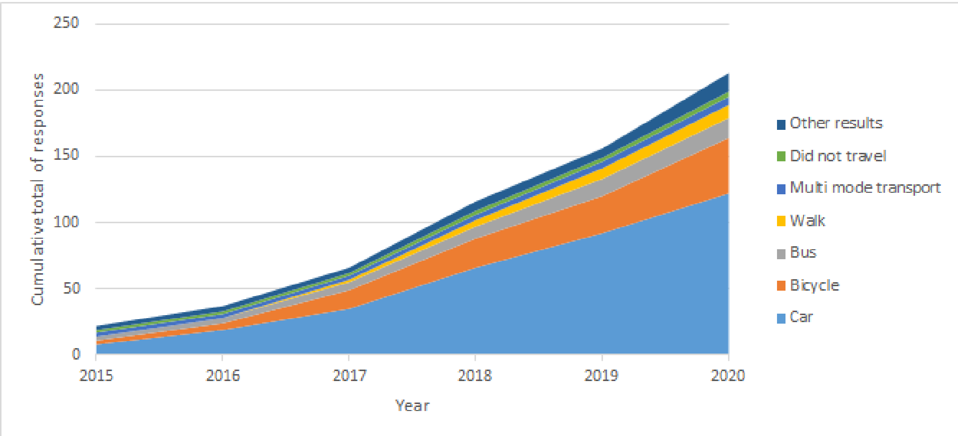

FIGURE 14. Transport mode replaced over time

This matches with the earlier graph taken from sales of E-bikes in Europe and seems to confirm a steady increase in the availability of E-bikes for commuting. Car, and secondly bicycles, have seen an increasing share of journeys replaced. As car replacement is greater than all other forms of transport together, it also includes the greatest reduction in carbon emissions.

Sales figures for E-bikes, both at a Finnish and European level, show a continued growth. Taking the sales table from 3.4 and projected the sales beyond the existing 2017 with three different options: no growth, continued growth and high growth. The figures below are representative of 2030 and displayed in table 12.

No growth scenario; if E-bikes no further sale of E-bikes then no further change in carbon emissions due to E-bikes.

Continued growth scenario; at present sales of E-bikes in Finland have increased at an average of 2855 units a year, based on the average yearly sales between 2011 and 2017

High growth scenario; if sales are twice that of the continued growth scenario, or 5710 units a year.

TABLE 12. Future E-bike ownership scenarios.

Travel type	Percent	no growth	low growth	high growth
Car driver	57%	6,587.19	10,030.62	13,474.04
Bicycle	20%	-	-	-
Bus passenger	7%	427.70	651.28	874.86
Walking	5%	-	-	-

By 2030, the low growth scenario shows nearly 62,000 cars being replaced at just over 10,000 tonnes of carbon dioxide equivalent are replaced, and for high growth scenario just over 83,000 cars are replaced reducing emissions by over 13,000 tonnes a year.

4.4 Limitations to growth

- Journey length

Journeys below 20 kilometres, and in particular those between 10 and 20 are a key area of E-bikes overlapping with buses and cars. Both buses and cars have a peak at 10-20km journey range shown in the national travel survey, shown in section 2.6. Total car journeys (Figure 15) and bus journeys (Figure 16) are summarised below, compared with the values from the national travel survey. Note that the values for the 10-15 and 15-20 in the E-bike survey have been combined, and the values marked as 20+ on the E-bike survey are contained in the 20-50 category.

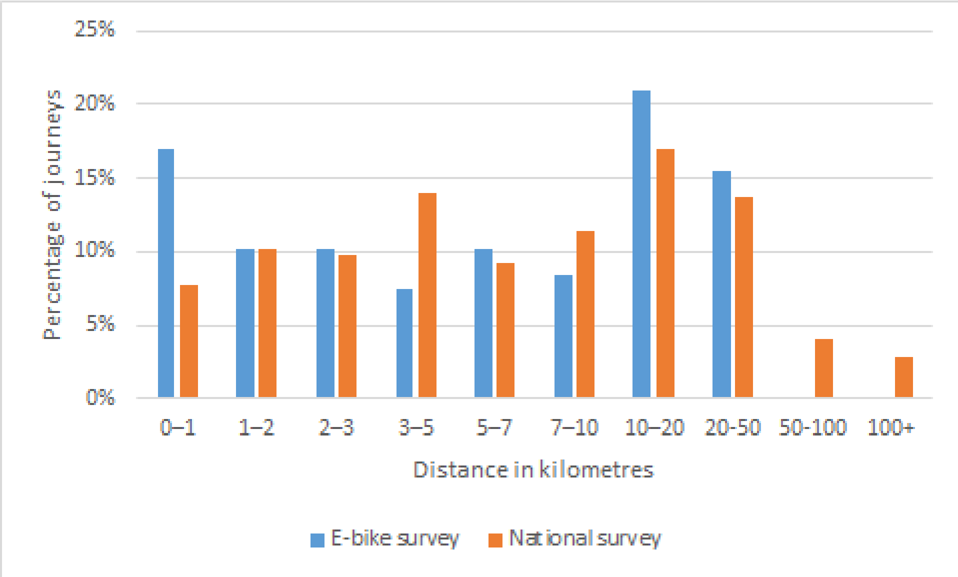

FIGURE 15. Car journey distances by survey type

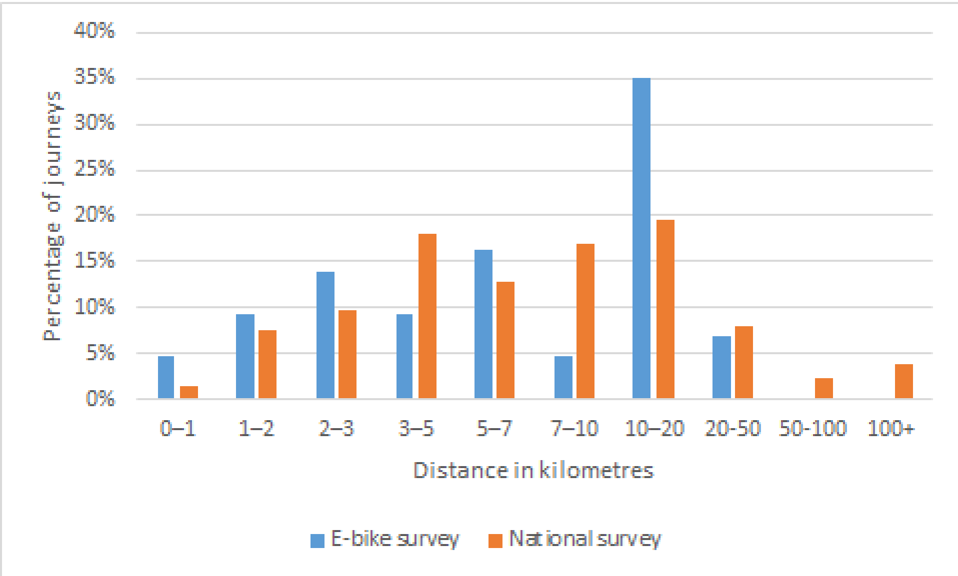

FIGURE 16. Bus journeys distances by survey type

For cars, around 80% of all journeys were under 20km. For buses this value was 86%. In terms of journey distance, E-bikes are well placed to replace car and bus journeys. For journeys over 20km then the ability to replace automotive transport is limited.

- Occupancy

Limits to journey replacement are also based on the number of occupants of the car. Average occupancy used in the national travel survey is 1.7. However, this ranges from 1.1 for commuting to work by car to over 3.1 for escorting.

- E-bikes

Respondents were able to leave qualitative feedback in the form of free text fields for two questions. Price of E-bikes received 12 (5.6%) separate replies and battery life in 3 (1.4%).

- Future of E-bikes

At present the emission values for cars and buses from combustion engines are sufficiently high that an E-bike replacement will always result in a reduction. It is possible that, as electrical cars and buses become common, the E-bike will no longer be as competitive in reducing emissions. At this point the life cycle assessment of the different electric vehicles will become necessary.

5 CONCLUSIONS

E-bikes are part of a bigger change in transport for the 21st century. Electrical cars, buses and E-bikes are starting a move away from the combustion engine in transport. The Finnish E-bike experience appears to mirror that of a number of other countries; a larger number of older working men who drive make up the majority (Johnson & Rose 2013, Hiselius & Svenssona 2014, MacArthur et al 2014). While this difference is mentioned in several studies, no study has yet focused on why, or conversely why other categories do not make use of E-bikes to the same degree. As mentioned in 4.1, it is possible that the ‘enthuisastic E-biker' matches with the particular profile of the majority of Finnish E-bike users (Haustein & Möller, 2016).

If the trend can be realised across a larger part of the commuting population then the reduction in carbon emissions would be significant. Clearly E-bikes would not replace all commuter options, but replacing short car journeys is the key area, in particular for journeys with a single occupant over a distance less than 20km.

Recommendations; as mentioned in the beginning, a decision to offer subsidies for purchasing E-bikes was not offered at a governmental level. Cost was viewed by respondents as one of the barriers to purchasing an E-bike. An alternative to subsidizing purchases would be to have offer E-bike pick-up points at locations near transport centres and encourage an integration of bus, train an E-bike, with public transport for longer journeys and E-bikes for smaller end journeys. Additionally, charging points at secure bicycle parking facilities would help encourage longer journeys as one worry, battery life, would be further addressed.

As this study has targeted a survey population with a positive bias towards E-bikes, further studies should investigate other demographics groups to understand what other barriers there are to adopting E-biking as a method to assist with emission reduction. Finally, looking to the future when electric transport is the norm, comparing the different modes of electric transport through a life cycle assessment would be necessary.

REFERENCES

Abagnale, C. Cardone, M. Iodice, P., Strano, S. Terzo,M. Vorraro, G. 2015. Power requirements and environmental impact of a pedelec. A case study based on real-life applications. Environmental Impact Assessment Review 53 (2015) 1–7.

Cambridge University Press. 2020. Meaning of commute in English. Released on n.d. Updated on n.d. Read on 01.05.2020.
https://dictionary.cambridge.org/dictionary/english/commute

Cairns, S. Behrendt, F. Raffo, D. Beaumont, C. Kiefer, C. 2017. Electrically-assisted bikes: Potential impacts on travel behaviour. Transportation Research Part A: Policy and Practice Volume 103, September 2017, Pages 327-342

CarbonneutralFinland. 2017. Kuntien ja alueiden kasvihuonekaasupäästöt Released 10.02.2020 Updated 23.04.2020 Read on. 10.04.2020 https://hiilineutraalisuomi.fi/fi-FI/Paastot_ja_indikaattorit/

Confederation of the European Bicycle Industry (CONEBI). 2017. European bicycle market. Read on 18.02.2020 http://www.conebi.eu/facts-and-figures/

Engelmoer, W. 2012. The E-bike: opportunities for commuter traffic. The potentials of using electric bicycles and –scooters in commuting traffic in relation to energy use, local emissions and the accessibility of a compact Dutch city. Master's thesis

Engelmoer, W. 2012, quoting Hendriksen, I., Engbers, L., Schrijver, J., van Gijlswijk, R., Weltevreden, J. and Wilting, J., 2008. Elektrisch fietsen. Marktonderzoek en verkenning toekomstmogelijkheden [E-bikes. Market Research and Explorationof Future Possibilities]. TNO Kwaliteit van Leven, Leiden.

Eurostat emission figures. 2020. Greenhouse gas emissions by source sector (source: EEA). Released on. n.d. Updated on 24.02.2020. Read on. 05.03.2020. https://appsso.eurostat.ec.europa.eu/nui/show.do?query=BOOKMARK_DS-089165_QID_-10EF3997_UID_-3F171EB0&layout=AIRPOL,L,X,0;SRC_CRF,L,Y,0;UNIT,L,Z,0;TIME,C,Z,1;GEO,L,Z,2;INDICATORS,C,Z,3;&zSelection=DS-089165GEO,EU28;DS-089165TIME,2017;DS-089165INDICATORS,OBS_FLAG;DS-089165UNIT,THS_T;&rankName1=UNIT_1_2_-1_2&rankName2=INDICATORS_1_2_-1_2&rankName3=TIME_1_0_1_0&rankName4=GEO_1_2_1_0&rankName5=AIRPOL_1_2_0_0&rankName6=SRC-CRF_1_2_0_1&rStp=&cStp=&rDCh=&cDCh=&rDM=true&cDM=true&footnes=false&empty=false&wai=false&time_mode=NONE&time_most_recent=false&lang=EN&cfo=%23%23%23%2C%23%23%23.%23%23%23

Haustein, S., & Møller, M. 2016. Age and attitude: Changes in cycling patterns of different e-bike user segments. International Journal of Sustainable Transportation, 10(9), 836-846. https://doi.org/10.1080/15568318.2016.1162881

IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp https://www.ipcc.ch/site/assets/uploads/2018/05/SYR_AR5_FINAL_full_wcover.pdf

Johnson, M. & Rose, G.. (2013). Electric bikes - cycling in the New World City: An investigation of Australian electric bicycle owners and the decision making process for purchase. Australasian Transport Research Forum, ATRF 2013 - Proceedings. https://api.semanticscholar.org/CorpusID:106930265

Kroesen, M. Harms, L. 2018. User characteristics and trip patterns of e-bike use in the Netherlands. Results from the Dutch National Travel Survey and the Mobility Panel Netherlands. Ministry of Infrastructure and Watermanagement https://www.kimnet.nl/publicaties/presentaties/2018/04/10/user-characteristics-and-trip-patterns-of-e-bike-use-in-the-netherlands

LIPASTO unit emissions database. 2017 Releaased on n.d. updated 07.07.2017. Read on 15.04.2020 http://lipasto.vtt.fi/yksikkopaastot/indexe.htm

MacArthur, J., Dill, J. and Person, M. 2014. Electric Bikes in North America: Results of an Online Survey. Transportation Research Record, 2468(1), pp. 123–130. https://doi.org/10.3141/2468-14

Moro, A. Lonza, L. 2018. Electricity carbon intensity in European Member States: Impacts on GHG emissions of electric vehicles. Transportation Research Part D: Transport and Environment Volume 64, October 2018, Pages 5-14. https://doi.org/10.1016/j.trd.2017.07.012

REGULATION (EU) No 168/2013 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL. 2013. on the approval and market surveillance of two- or three-wheel vehicles and quadricycles. Read on 17.02.2020 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32013R0168&from=EN

Scripps Institution of Oceanography. 2020. The Keeling Curve. Released on n.d Updated 30.05.2020 Read on 30.05.2020 https://scripps.ucsd.edu/programs/keelingcurve/

SFS 5989. 2012. Lähde- ja tekstiviitteitä koskevat ohjeet. Helsinki: Suomen Standardoimisliitto SFS. Read on 3.4.2017. Requires access right. https://online.sfs.fi/fi/index.html.stx

Statistics Finland. 2017. Using social media service, those aged 10 or over (2017) % by Year, Sex, Background variable, Data and Response. Read on 03.03.2020 https://pxnet2.stat.fi:443/PXWeb/sq/67cc95f6-33b7-4774-a47b-30c546ec8dee

Statistics Finland. 2020. Vehicle stock grew in 2019. Released 28.02.2020. Updated on n.d. Read on 01.04.2020.
https://www.stat.fi/til/mkan/2019/mkan_2019_2020-02-28_tie_001_en.html

Sitra. 2018. Carbon emissions average Finn. Released on 12.03.2018. Updated on n.d. Read on 01.02.2020 https://www.sitra.fi/en/articles/carbon-footprint-average-finn/

The World Bank. 2020. Electricity production from coal sources (% of total). Released on n.d. updated on n.d. Read on 28.03.2020 https://data.worldbank.org/indicator/EG.ELC.COAL.ZS?end=2015&locations=FI-PL&start=1960&view=chart

Traficom. 2019. Electric personal transportation devices. The Finnish Transport and Communications Agency. Read on 03.02.2020 https://www.traficom.fi/en/transport/road/electric-personal-transportation-devices

Traficom. 2019 Henkilöliikennetutkimuksen 2016 tuloksia taulukoina. The Finnish Transport and Communications Agency. Accessed on 13.04.2020 https://www.traficom.fi/fi/tilastot-ja-julkaisut/julkaisut/henkiloliikennetutkimuksen-2016-tuloksia-taulukoina

Vehicles Act (1090/2002; amendments up to 402/2005 included). 2005. Ministry of Transport and Communications of Finland. Read on 15.02.2020 https://www.finlex.fi/fi/laki/kaannokset/2002/en20021090_20050402.pdf#L2

Weinert, J., Ma, C. & Cherry, C. The transition to electric bikes in China: history and key reasons for rapid growth. Transportation 34, 301–318 (2007)

Winslott-Hiselius, L. Svensson, Å. 2014. Could the increased use of e-bikes (pedelecs) in Sweden contribute to a more sustainable transport system?. The 9th International Conference "Environmental Engineering 2014". Vilnius http://lup.lub.lu.se/record/5305011

Yle. 2018. 300,000 in Finland quit Facebook this year, expert tells paper. Released on 29.08.2018. Updated on 29.08.2018. Read on 06.03.2020. https://yle.fi/uutiset/osasto/news/300000_in_finland_quit_facebook_this_year_expert_tells_paper/10375826

APPENDICES

Appendix 1. Survey questions (in English)

Questions:

1. Gender

Female

Male

Prefer not to say

Other

2. Age /

Under 18

3. Occupation /

Student

Employed (including self-employed)

Retired, pensioner

Home carer (disabled, elderly, etc)

Home carer (parent)

Unemployed

Other

Prefer not to say

4. How long have you used an E-bike?

Less than a year

1

2

3

4

5 or more years

5. Where do you commute on your E-bike?

To School/University/Educational establishment

To Work

To Shops

To Leisure/Free-time activities

Work related travel

Other

I do not commute on my E-bike

6. How did you previously commute before an E-bike?

Car, driver

Car, passenger

Bus

Train/Metro

Bicycle

Walk

Tram

Other

7. How often do you travel by E-bike? In days per week

1

2

3

4

5

More than 5 days a week

Only a few times a month or less

8. How far do you ride your E-bike? (In kilometers)

To school

To work

Shopping

Leisure/Free-time activities

Work related travel

Other

9. Which seasons do you ride your E-bike in?

Spring (Mar-May)

Summer (Jun-Aug)

Autumn (Sep-Nov)

Winter (Dec-Feb)

10. If you are not commuting due to season (question 8), how do you travel?

Car, driver

Car, passenger

Bus

Train/Metro

Bicycle

Walk

Tram

Other

11.I recharge my e-bike with electricity from renewable/sustainable sources

Yes

No

Mixed

Don't know

12. Environmental awareness (on a scale of 1-5, with 1 as completely disagree and 5 completely agree)

My commuting choice affects the environment

I can choose my commuting method

I chose my commuting method to help the environment

The infrastructure in my area is sufficient to support E-bike commuting

I make purchases based on how sustainable/environmental they are.

I make changes in my life to help the environment/be more sustainable.

My E-bike commute is better for the environment than my previous commuting method.

I bought an E-bike because I am interested in new technology

13. What would help you start to commute by E-bike? If you would still not choose to commute by E-bike, why?

14. Any additional points

15. Do you consider yourself phyiscally impaired in any way?

Yes

No

Prefer not to say

Appendix 2. Survey results

Microsoft Excel
Worksheet