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Acknowledgments

This master's thesis concludes our two-year master program in Urban and Regional Planning here at the University of Stavanger. During the last two years we have been introduced to a number of interesting topics, such as placemaking, spatial analysis and sustainable city regions.

The motivation for writing a thesis about Stavanger municipality’s approach to decarbonising the transportation sector occurred last semester, when we wrote a report on the new major transportation infrastructure project, the busway in Stavanger. This led us to question if and how an infrastructure project will impact the wider transportation system for the region, in particular its impact on the wider goal of tackling climate change.

We would like to first thank our supervisor Harald N. Røstvik for his guidance through this thesis. His comments and feedback have been helpful throughout this thesis.

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Abstract

The transportation sector is the second-largest contributor to greenhouse gas emissions by sector globally. In Stavanger, the transport sector is the primary contributor to greenhouse gas emissions. To decarbonise, the process of mitigation and reducing emissions, in 2010, the municipality adopted its own Climate and Environment Plan, which targeted a reduction of 20% by 2020 compared with 1991 emissions. In 2016, the Plan was effectively concluded, with the production of new targets from 2018. The targets were superseded, and no review of the document was undertaken following the conclusion of 2020. The current research seeks to address this.

The approach taken was to review the 2010 plan, identify the targets set and the policy approach taken. We then compared it with a similar plan, the Trondheim Energy and Climate Plan (2010 – 2020). Secondly, we investigated whether emission targets had been met and if there were other indicators to determine whether decarbonisation was being made relative to specific policies.

The significant findings of the research paper were that the 2010 plan adopted policies in line with the Avoid – Shift – Improve approach, which was also adopted within the Trondheim plan. Furthermore, the policies in the 2010 plan were primarily to encourage behaviours, through “carrot” policies, as opposed to restrictive policies or “stick”. When comparing with the Trondheim plan, it was evident that the Stavanger 2010 plan was less specific in terms of measures, targets identified and parties responsible for those measures.

In terms of the statistical data, we deduced that emission targets were not met, and they fell short of their goals. However, there was progress in terms of technological improvements, with a significant increase in low-emission cars. In the period 2009 - 2019, there was evidence of modal shift, with increasing passenger numbers on modes of public transport and a reduction in the use of cars. Before a reversal in 2020, the year of Covid-19, where public transport usage fell significantly and there was an increase in car usage. There was less evidence concerning reducing the need to travel. Further findings were that, despite the restrictive nature of the transport sector in 2020 as a result of Covid-19, the municipality still fell short of its emission targets.

Despite this, the targets for the new Climate and Environment Plan 2018-2030 are significantly higher, with a new goal of an 80% reduction in emissions. Based on historical data found over the course of the past ten years, they are likely to be significantly short of the target again. Further work is required to identify at a more detailed level where priorities need to be focussed for the municipality, but an overarching objective is that barriers need to be broken down to raise initiatives up the agenda.

CONTENTS

Abbreviations	
Automated vehicles	AVs
Stavanger Climate and Environment Plan 2010 – 2025	2010 plan
Stavanger Climate and Environment Plan 2018	2018 plan
Electric vehicles	EVs
Trondheim Energy and Climate Action Plan 2010 – 2020	Trondheim plan
Greenhouse gas emissions	GHG
Internal combustion engine vehicle	ICEV
National Travel Habits	NTH
Norwegian Environment Agency	NEA
Tonnes CO_2 equivalents	T/CO_2e

1. INTRODUCTION

1.0 Introduction

1.1 Context

In 2021, the United Nations' Intergovernmental Panel on Climate Change produced the Sixth Assessment Report on scientific findings related to global warming and climate change. The findings of the report are conclusive that human influence has warmed the climate at an unprecedented rate, which has led to widespread changes in the atmosphere, ocean, and biosphere across the globe (IPCC, 2021). Moreover, the rise in global temperatures has already led to extreme weather events and will continue to occur on a more regular basis; increased flooding, heat waves and droughts, forest fires, and hurricanes among others (Jackson, 2020).

In December 2015, an international treaty between 196 countries was signed, the Paris Agreement (United Nations for Climate Change, 2020). The treaty pledges to limit emissions to keep global warming to well below 2 degrees centigrade and an aim to limit a temperature increase to 1.5 degrees centigrade by 2100. However, current data from IPCC (2021), indicates that temperatures have already increased by approximately 1.2 degrees centigrade and estimates that the 1.5 degree and 2-degree targets will be exceeded during the 21st century unless significant reduction in GHGs occur over the coming decades.

According to Ritchie & Roser (2017), in 2016, the transportation sector accounted for 16.2% of all global greenhouse gas emissions (or 7.87 billion tonnes), and 11.9% of the total emissions resulted from road transportation. The International Energy Agency has forecast that between 2019 and 2070, global transport demand is expected to double, and car ownership rates are to grow by 60 percent. Alongside this, the IPCC has stated that without aggressive and sustained mitigation policies, transport emissions could increase at a faster rate between now and 2050 than any other sector (Foster, Dim, Vollmer, & Zhang, 2021).

Despite developments in vehicle technology, leading to more efficient and cleaner technology, the sheer increase in transportation volumes has overshadowed these efficiency improvements (Foster, Dim, Zhang, & Vollmer, 2021). This thesis reviews whether progress has been made to decarbonize the road traffic at a local level, specifically considering the municipality of Stavanger.

1.2 Research question and objectives

Norway is widely regarded as one of the leading nations in tackling climate change with progressive and aggressive climate policies. The largest cities and municipalities have adopted climate plans with ambitious goals. The most recent environmental plans show that Oslo municipality targets a 95% reduction in direct emissions by 2030 while Bergen is targeting to be fossil-free by 2030. In 2018, the Stavanger city council approved a new Climate and Environment plan that proposed an 80% reduction of the emissions in Stavanger (Stavanger Kommune, 2018b). The new target supersedes the previous target that was set out in the "Climate and Environment Plan 2010 – 2025" (hereafter "2010 plan"). The 2010 plan included measures to reduce direct emissions within the municipality, which targeted a 20% reduction in overall emission between 1991 and 2020. The 2010 plan is the main focus of this thesis.

With Norway being regarded as one of the leading nations in the fight against climate change, this thesis will seek to analyse whether, Stavanger, being one of the largest municipalities in the country, has been able to decarbonize the road transport sector in line with the targets set over the plan period, from 2010 to 2020.

Based on the information above we have formulated the following research and sub-questions as:

In 2010 Stavanger adopted a new Climate and Environmental plan for the period 2010 – 2025, setting out new climate targets for the plan period and within the transportation sector. This thesis will seek to address whether progress has been made in decarbonising the road transportation sector relative to the targets set within the plan. Based on the above, we have set out the following research questions:

1. What is decarbonization and what are the main methods to decarbonise the transportation sector within Stavanger municipality?

2. Since adoption of the 2010 Climate Plan, has progress been made in decarbonising the transportation sector and are they on track to meet their targets?

3. Based on the outcome of our analysis, can any recommendations be made to assist the municipality in achieving their new goal of an 80% reduction in emissions, within the road transportation sector?

1.3 Limitations and scope

This thesis only focuses on the progression in decarbonization within Stavanger municipality using publicly available statistics throughout 2010 – 2020, which relates to the plan period.

The data on emissions presented in this thesis is mainly coming from the Norwegian Environment Agency and Statistics Norway, and we have limited the emission to the municipal borders of Stavanger. Therefore, indirect emissions are not accounted for within the totals. For example, the central treatment plant is in Randaberg and the regional airport is located in Sola both which are outside of Stavanger municipality. Therefore, it is important to note that emissions in some sectors may not have gone down but rather been relocated to a nearby municipality.

In collaboration with our supervisor and the time scale available, the thesis is limited to only focusing on the direct emissions within road traffic. Direct emissions can be explained as " emissions that come from sources that are owned or controlled by the reporting entity, whilst indirect emissions are emissions that are a consequence of the activities of the reporting entity but occur at sources owned or controlled by another entity" (Ranganathan et al., 2004).

It shall also be noted that this thesis is concentrated around decarbonization within the transport sector in Stavanger municipality. The transport sector is often used as a common denominator for all forms of transport, but in this thesis, we are specifically reviewing land-based transport in accordance with the focus areas in the 2010 plan. Sea-based transport is not included in the assessment.

In addition, the thesis focuses on the latest available data up to the year 2020. However, it should be noted that in 2020 a global pandemic occurred, Covid-19, which caused governments to introduce restrictive measures on societies. Therefore, whilst we provide commentary on this year, it can be considered an anomaly. There is also limited to no available data for the year 2022, when restrictions placed on society began to be lifted. The thesis cannot provide any consideration as to whether there have been any lasting implications.

2. BACKGROUND

2.1 Emissions
2.2 Stavanger

2.0 Background

This chapter seeks to set the scene in respect of the wider issue of emissions within Norway as a whole and within the municipality of Stavanger. In addition, we provide some information on the municipality for context.

2.1 Emissions – National & Stavanger

Table 1 highlights total emissions across Norway in 2009, 2019 and 2020. It shows that emissions have fallen from approximately 52,7 million tonnes of CO_2 equivalent ('t/CO_2e) to 49,3 million t/CO_2e in 2020, a fall of approximately 6,5% over the period. While the oil & gas and manufacturing industries are the main emitters, the next largest emitter is the road traffic sector.

Million tonnes of CO_2 equivalent	2009	2019	2020
Oil & Gas	13 748	13 930	13 207
Manufacturing industries and mining	11 490	11 588	11 418
Energy supply	2 095	1 711	1 669
Heating in other industries and households	1 635	583	533
Road traffic	9 745	8 722	8 376
Aviation, navigation, fishing, motor equip. etc.	6 753	7 629	7 274
Agriculture	4 425	4 505	4 494
Other	2 780	2 418	2 312
Total	**52 672**	**51 086**	**49 283**

Table 1: Emissions to air – Norway (million t/CO_2e). Based on (Statistics Norway, 2021d).

In Table 2, we can see emissions to air in Stavanger. The data shows that between 2009 and 2019 total emissions fell by 27 000 t/CO_2e, a fall of approximately 5,5%. Before a significant fall of 44 000 t/CO_2e in 2020 from 2019, reflecting a reduction of approximately 9,6%. The largest emitter of greenhouse gases is the road traffic sector and despite seeing a significant fall between 2009 and 2020 it remains the sector with the most significant emissions.

Tonnes CO_2 equivalent	2009	2019	2020
Other vehicle combustion	23 525	74 896	65 546
Waste and sewage	1 269	1 208	1 283
Energy Supply	0	4 473	4 823
Industry, oil and gas	11 763	13 547	10 109
Agriculture	58 542	56 775	57 284
Aviation	1	2	3
Heating	51 179	28 318	27 868
Shipping	143 493	133 028	112 182
Road Traffic	193 620	144 062	133 687
Total	**483 392**	**456 309**	**412 786**

Table 2: Emissions to air – Stavanger (t/CO_2e). Based on (Miljødirektoratet, 2022).

2.2 Stavanger

Stavanger municipality is located on the southwest coast of Norway, within the county of Rogaland and, more specifically within the sub-area of Nord-Jæren. This area also includes the municipalities of Sandnes, Sola and Randaberg. The population in Nord-Jæren is mainly concentrated around the two urban areas of Stavanger city and Sandnes, another large settlement approximately 15km to the south of Stavanger city centre.

Stavanger municipality is located adjacent to Sandnes Municipality to the south, Sola municipality to the west, and Randaberg to the northwest. In 2020, the municipality extended further northwest as it was decided that Stavanger municipality would incorporate the island municipalities of Rennesøy and Finnøy.

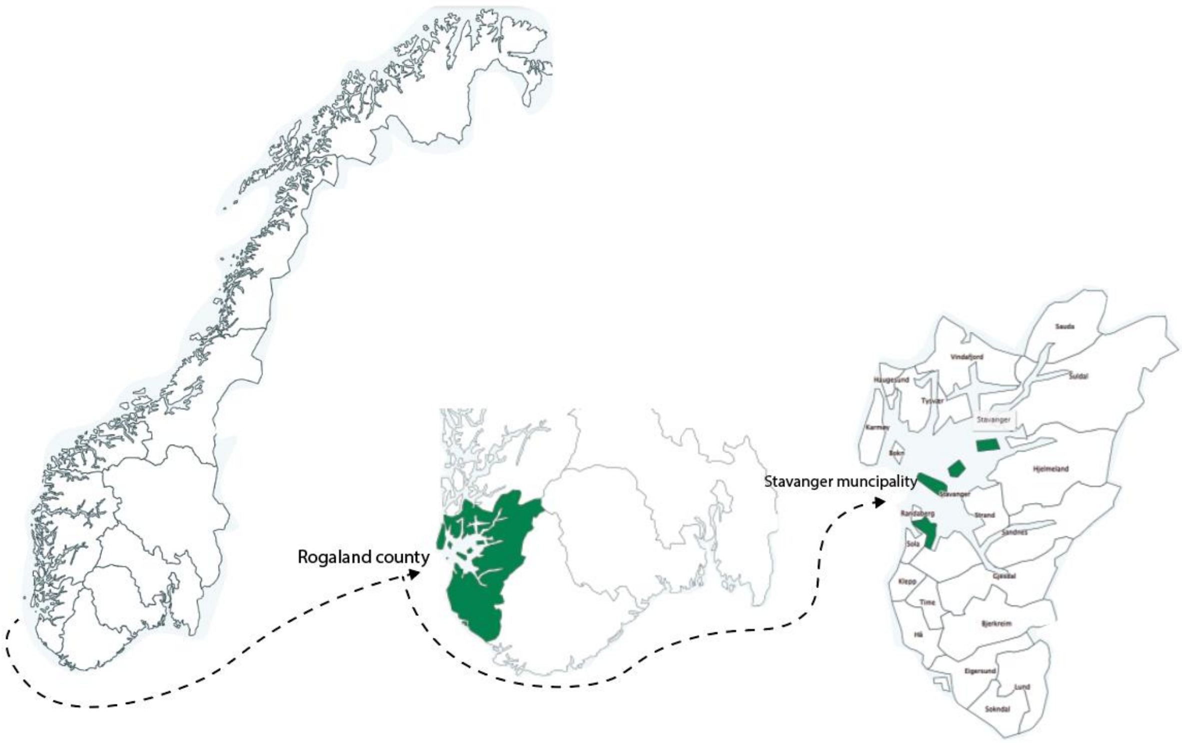

Figure 1: Location of Stavanger.

The region's population has grown dramatically, particularly following the oil boom starting in the late 1960s. Approximately 276 000 inhabitants live in Nord-Jæren today, of which the majority live in Stavanger. In 2010 around 130 000 people lived in Stavanger, compared to approximately 144 000 today, showcasing a 10% increase, and averaging just under 1% increase per annum.

The population resides predominantly in the south of the municipality, concentrated around the urban settlement of the city of Stavanger, which is the fourth largest city in Norway. The population is relatively evenly distributed in terms of residence across the city, as shown in Figure 2. In terms of key locations, there are several key employment hubs that have the highest concentration of employment, and this includes the city centre, Forus, Dusavik, Jåttåvågen, Mariero and the area surrounding the hospital, which is the location for the new hospital, currently under construction. Forus is the largest working area in Nord-Jæren, and is located at the municipal borders between Sola, Sandnes, and Stavanger.

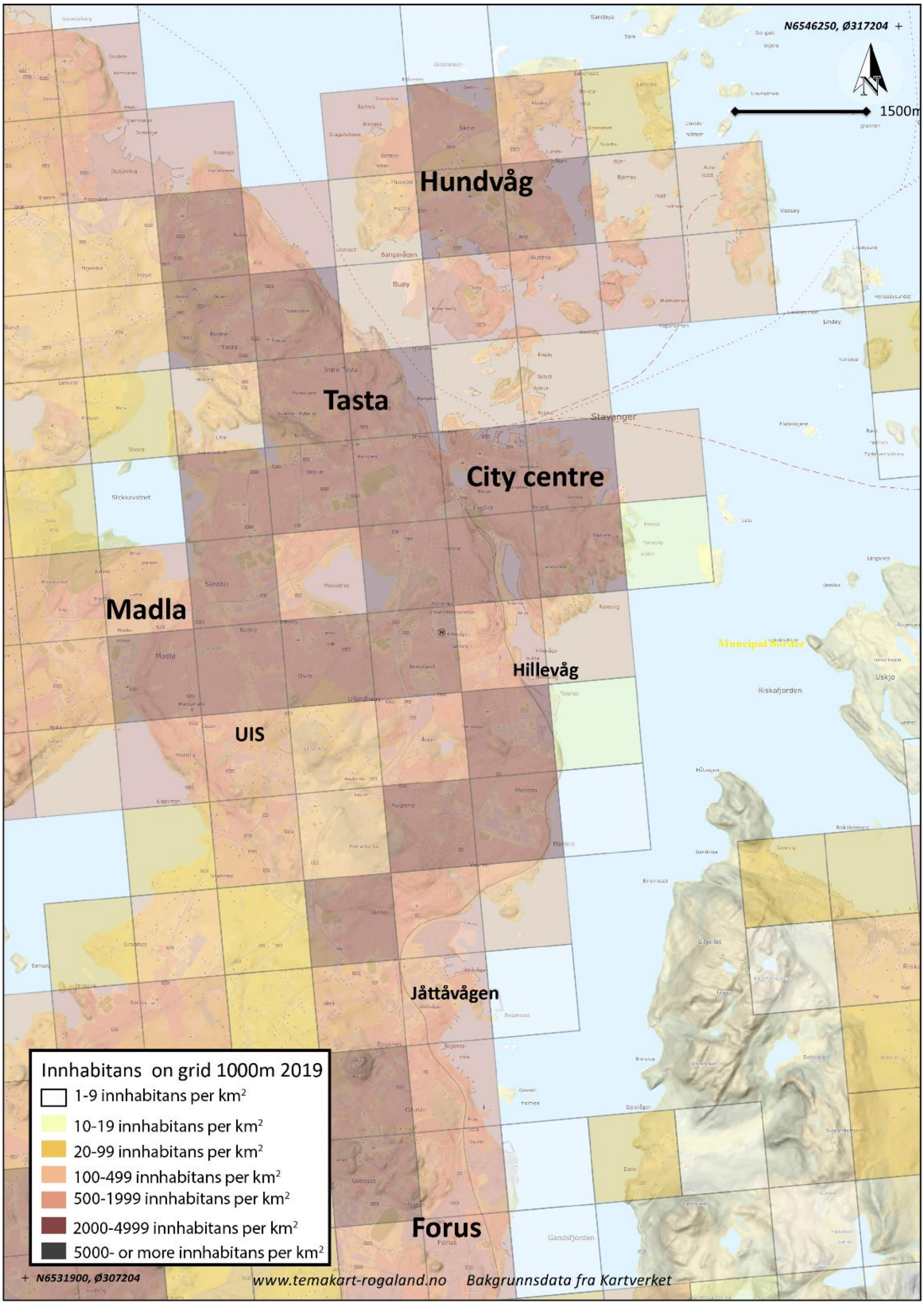

Figure 2: Population density in Stavanger. Based on ("Temakart-Rogaland", n.d.).

In Figure 3, key transportation routes within Stavanger are shown. This includes the busway, a major infrastructure project to provide better connectivity around the region that is under construction. Ryfast, a subsea tunnel system in Rogaland provides a connection toward Strand Kommune. Sørlandsbanen is the train system between Stavanger and Oslo. The Cycle Highway is another major infrastructure being delivered providing a high-standard cycle path between Stavanger, Forus and Sandnes.

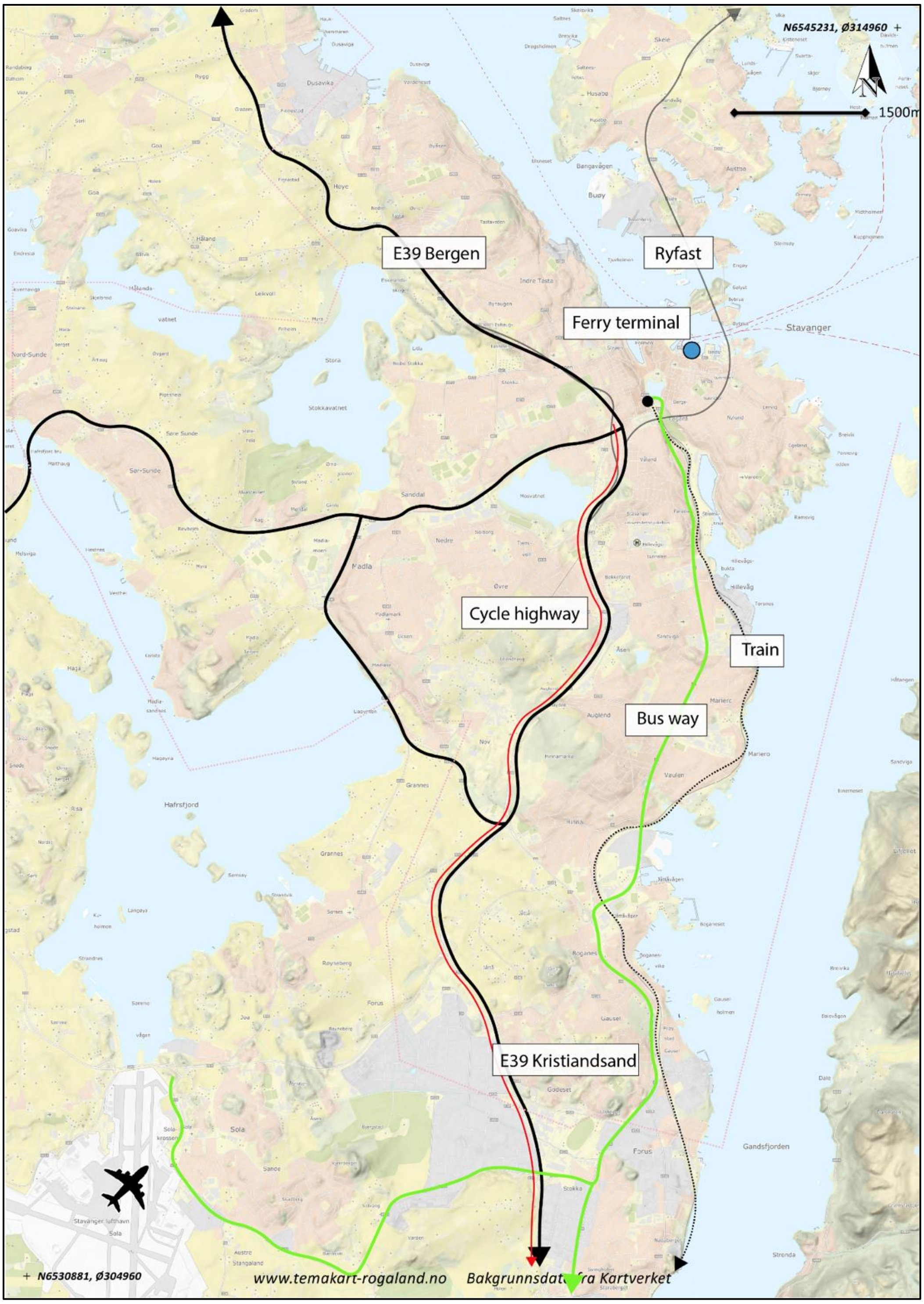

Figure 3: Major Transportation Routes – Stavanger.

3. LITERATURE REVIEW

3.0 Literature Review

3.1 Introduction

As set out in Chapter 1, this thesis seeks to address and evaluate how the municipality of Stavanger has sought to address the issue of emissions within the road transportation sector.

The literature review is used to explore research that has been undertaken, inclusive of providing oversight of main ideas and theories relating to emissions within the transportation sector. It also provides the thesis with a basis for understanding existing information within the field and allow us to provide context for our research and to explore whether there are any identified gaps.

While much research has been undertaken on the topic of climate change and greenhouse gas emissions, we begin the chapter with a brief overview of the issue and provide some background on how it is being tackled on a global basis. The literature review then explores greenhouse gas emissions within the transportation sector, specifically methods, strategies, and approaches to decarbonising the transport sector. Further to this, the literature explores how progress might be measured, inclusive of limitations to these measurement methodologies, and finally, we look at potential barriers to these measures. The literature review explores the above under the following headings:

1. The Issue of Climate Change and Greenhouse Gas Emissions
2. Emissions in the (Road) Transportation Sector
3. How to Decarbonise the Road Transport Sector
4. How do we measure progress?
5. What are the Main Barriers to Interventions?
6. Summary of the Literature Review

While the literature explores a range of themes on the topic of decarbonisation of the transport, the review has not set out to be a thorough approach to reviewing all approaches to interventions and methods of measurement. The literature review is sought to provide an overview of the topic, the potential measures that could be used, methods of measurement, and an overview of potential barriers that can be used further in our study.

Methodology

The process by which literature and data has been collected has taken place using a range of sources, primarily focussing on scientific research papers. We have used a systematic approach by using Oria, the online library service at the University of Stavanger, and using key terms as a process of collecting data.

3.2 The Issue of Climate Change and Greenhouse Gas Emissions

It is well documented that climate change is one of the largest threats of this century to the planet and its residents. The range of consequences includes increased erratic flooding, extreme fluctuations in temperature, high precipitation levels, an increasing number of unprecedented climate incidents, the emergence of new diseases, and prolonged dry spells and drought (Allam, Jones, & Thondoo, 2020). Furthermore, climate change is intimately entwined with the health and functioning of the biosphere, and the potential impacts as a result of the changing climate on a regional and global basis could be immeasurable (Malhi et al., 2020).

It is widely acknowledged that climate change has resulted from a rise in average global temperatures. At present, scientists estimate that global temperatures have increased by approximately 1.2 degrees Celsius since the 1900s and this will further increase without significant intervention (Leitzell, 2021).

3.2.1 The cause of climate change

Climate change is occurring with the rise in increased temperatures, which has been linked to anthropogenic activities. Science has shown that these anthropogenic activities have resulted in the increased release of global greenhouse gas emissions (GHGs), and thus the increase in global temperatures. GHGs take the form of carbon dioxide, the largest emitter, methane, nitrous oxide ad fluorinated gases (Olerud & Lahn, 2022).

These different gases have different heating effects and lifetime in the atmosphere and are therefore recalculated into CO_2 equivalents. This is the metric that has been adopted by the UN and is used in official GHG reporting. The use of this measure ensures that the greenhouse gases can be measured by an equivalent unit.

Data from Ritchie & Roser (2017) present how CO_2 emissions have developed over time, dating back to 1750. Carbon dioxide contributes to the largest proportion of greenhouse gas emissions. Table 3 shows that since industrialisation occurred CO_2 emissions from the burning of fossil fuels have increased significantly and in the period from 1950 to 2020, it has increased from 5 billion tonnes to more than 35 billion tonnes.

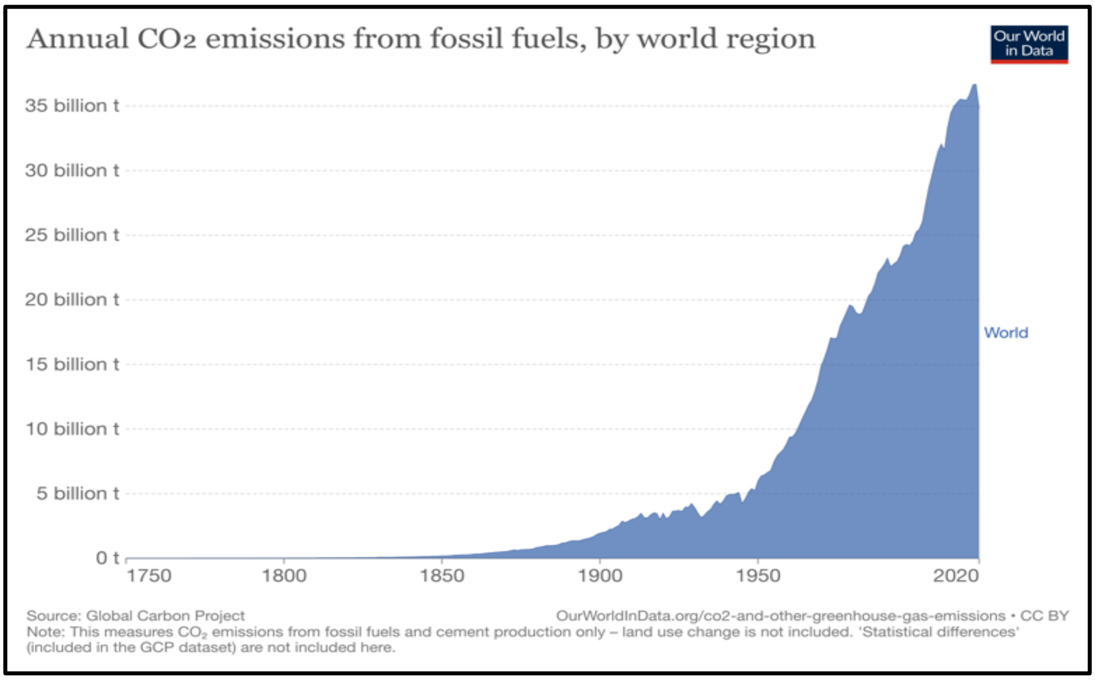

Table 3: Annual CO_2 emissions from fossil fuels, by world region (Ritchie & Roser, 2017).

3.2.2 Why are emissions on the rise?

We can see that global emissions continue to increase. However, it is equally important to understand where these emissions are coming from. United Nations (2017) states that cities and urban environments are directly responsible for over 75% of CO_2 emissions. As of today, approximately 54% of the world's current population of 7.6 billion people live in cities. With increasing urbanisation, estimates suggest that 68% of the world's population of 9.9 billion will live in cities by 2050. This suggests that emissions will continue to rise in urbanised environments.

Table 4 shows data based on GHG emissions on a sectoral basis over time across the globe. We can see that it is electricity and heating that is the main source of emissions, and that has increased significantly over the period from 1990 to 2018, the last recorded data set. The transportation sector is the second highest having grown from just over 4 billion t/CO_2e to just over 8 billion t/CO_2e. On a proportional basis transport emissions have risen from 14% to 16% of total emissions. G. Marsden & Rye (2010) state that the growing pattern of urbanisation is contributing to emissions rising, particularly in the transportation sector and the manufacturing sector.

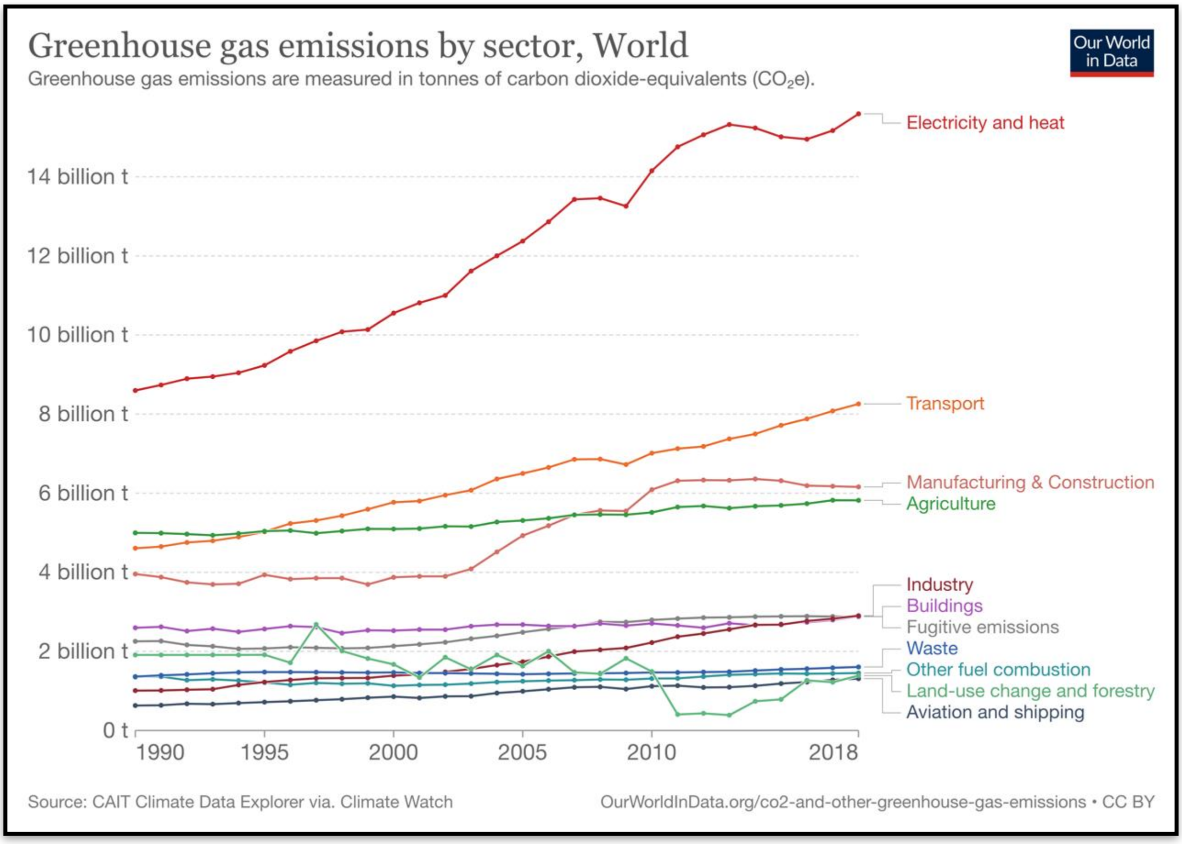

Table 4: Greenhouse gas emissions by sector, world. Retrieved from (Ritchie & Roser, 2017).

3.3 Emissions within the Road Transportation Sector

As stated above, on a global basis the transportation sector has been on an upward trajectory in terms of the overall emissions. According to statistics from Climate Watch (2020) the transportation sector is the second-largest emitter of greenhouse gases, behind the energy sector. It is recognised that reducing emissions within the sector is paramount to reducing the impact of climate change. Ding, Jin, Li, & Wang (2013) undertook a sectoral analysis and concluded that most of the emissions related to the transport sector derive from the use of fossil fuels in automobiles, reliance on the energy sector particularly during infrastructure development and partly from electricity to power transportation activities.

The transportation sector itself is complex with many different modes and forms of transportation ranging from road transportation, rail transportation, water modes of transportation and aviation. The data from 2016 provides a further breakdown of the transportation emissions. The road transportation sector accounts for the largest proportion of emissions, at 11.9% of total global emissions. 60% of these emissions are related to passenger travel (cars, buses and motorcycles) and 40% of the emissions relate to road freight (lorries and trucks) (Ritchie & Roser, 2017). The latest data also shows that in 2018 passenger vehicles emitted 3.62 gigaton CO_2e ($GtCO_2e$), up from 3.55 tCO_2e in 2015 and 2.53 GtCO2e in 2000. Whilst freight vehicles have followed a similar pattern, emissions in 2018 were 2.36 $GtCO_2e$, up from 2.29 $GtCO_2e$ in 2015 and 1.70 $GtCO_2e$ in 2000 (International Energy Agency, 2022).

Despite improvements being made in vehicle efficiency and emission intensity, these are being offset to a considerable extent by the greater overall volume of travel from both passenger and freight activity (Foster, Dim, Vollmer, et al., 2021; Thiel et al., 2016). There is a range of factors that can be linked to this rise in travel, but we can mainly distil factors into economic, social, and cultural drivers.

From an economic perspective, the main factor for the uptake in travel volume is that transportation costs have declined relative to the share of personal income. Particularly in non-OECD countries which have seen significant economic structural change, particularly through globalisation. Globalisation has led to more specialised and diversified work which has led to increased wages but also to longer commutes for people (McQuaid & Chen, 2012). In addition, the acquisition of motorized vehicles has proven to be increasingly common, especially among younger generations (Giuliano & Dargay, 2006). In determining the level of use of private cars against alternatives such as public transport, walking and cycling, the cost of fuel and transport modes, the development of mass-transit systems and non-motorized transportation infrastructure are primary factors (Hughes, Knittel, & Sperling, 2006). Globalisation has also led to easier access and transportation of goods around the globe, and this has led to significant increases in the volume and distances travelled (Henstra, Ruijgrok, & Tavasszy, 2007)

Population growth and demographic changes have also led to increasing demand for travel. Further societal factors in terms of the choice of travel can be driven by factors such as safety and security. In addition, the choice of travel mode can be influenced by age, with older generations tending to choose the private car over alternative modes (Fatima, Moridpour, De Gruyter, & Saghapour, 2020). Another societal factor is that owning a private car can be a symbolic function of status and a basis for sociability (Mokhtarian & Salomon, 2001).

The historic and continued development of urban structures is largely correlated to the development of road and transportation infrastructure. Land use planning is typically centred around travel times with the theory that higher mixed-use density can lead to reduced travel times and save on fuel. However, there is evidence to suggest that efficiencies in car travel can lead to an increase in use of the car in the longer term (Maat & Arentze, 2012; Small & Verhoef, 2007).

Emissions within the transportation sector continue to rise and there is a range of factors that contribute to this. Despite improvement in vehicle technology and efficiency, it is more than offset by the increased use of the car. According to Madslien & Hovi (2021), road traffic in Norway is expected to grow by 1,14% each year from 2018 to 2050. The Nordic region is a good example, whereby the countries have presented aggressive climate policies and are largely on track to meet the goals within the energy sector. However, according to Sovacool, Noel, Kester, & Zarazua de Rubens (2018) it is the transportation and mobility sector that remains the most challenging.

3.4 What is decarbonisation?

Whilst the aim of global economies is to achieve either carbon or climate neutrality, which is either net-zero carbon dioxide or net-zero greenhouse gas emissions. The process of mitigating and reducing carbon emissions is often referred to as "decarbonising" (IPCC, 2018). This is regarded as the most effective and reliable approach to neutrality.

The process of decarbonisation is not straightforward and requires differing strategies for relevant industries and sectors. Each sector and industry contribute to climate change and emissions in different manners. Therefor it is important that each sector needs to be looked at independently, where they require sector-specific interventions. This might include new technologies or infrastructure and as such it is important that the right strategy is implemented at the earliest opportunity to reduce inefficiencies and unnecessary costs (Allam et al., 2020).

3.4.1 Decarbonisation of the Transportation Sector

One of the most challenging environmental and social challenges is managing the mobility of people and goods, particularly with the importance of reducing overall emissions (Sovacool et al., 2018). Historically the key aim of the transportation sector has been to increase efficiency in terms of traveling by shortening journey times over greater distances with greater loads (passengers or freight). However, with the growing environmental concerns and further advancements in technology, this has widened to include alternative options for travel and more environmentally friendly ways.

Many studies have been carried out regarding approaches to decarbonising the transportation sector. This section considers several such studies detailing potential approaches to intervention, the results of the intervention and the overall effectiveness.

There are numerous approaches to decarbonising the transportation sector and moving towards more environmentally sustainable mobility. It is widely regarded (Banister, 2008; Bardal, Gjertsen, & Reinar, 2020; Xenias & Whitmarsh, 2013) that there are three primary approaches that can be considered, known as the ASI strategy:

1. **Avoid** / reduce the need to travel
2. Modal **Shift**
3. **Improving** vehicle technology

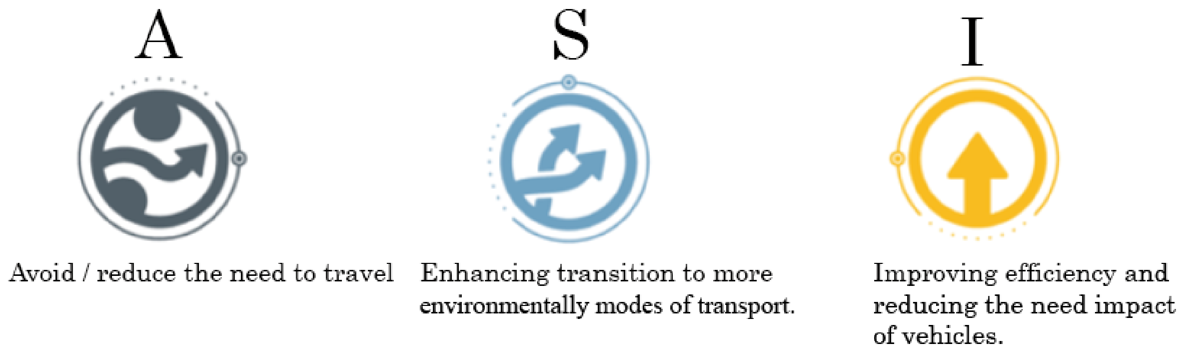

Figure 4: Avoid, Shift, and Improve strategy.

The further categorisation can be made in terms of the types of policies that can be looked at when consideration is made to the three categories above. Policies can be categorised in various ways, as set out in the Bardal et al. (Bardal et al., 2020) study. Kolbenstvedt & Ruud (2017) provide six categories of policy types:

1. Policies aimed at improving public infrastructure and provision.
2. Policies facilitating walking and cycling.
3. Policies that regulate the use of private cars.
4. Policies aimed at changing attitudes and behaviours.
5. Spatial planning strategies; and
6. Investment in roads and railways.

The types of transportation management policies can further be categorised with the metaphor devised by Meyer (1999) regarding transportation management of "carrot and stick". Strategies that entice desired travel behaviours can be termed as carrots to encourage behaviours. An example of this might be new bus infrastructure to encourage this as a mode of transport. Whilst stick methods seek to reduce a certain behaviour or are alternatively regarded as a deterrent, for example, additional tolls increases the cost of travel and therefore discourage the use of the car (Bardal et al., 2020; Piatkowski, Marshall, & Krizek, 2019).

3.4.2 Improving Technology

One of the main modes of decarbonizing the transportation sector has been through the advancements in technology. The transportation sector, particularly for long distances, has historically relied almost exclusively on the use of fossil fuels in internal combustion engine vehicles (ICEV). However, in recent years there has been a notable shift in technology to more environmentally friendly and lower intensity emission fuel sources.

One type of technological innovation is vehicle electrification. The technology is well advanced within the personal vehicle sector and is widely regarded as a key measure in the decarbonisation of the sector (Kodjak, 2021). Either as all-electric vehicles (EVs), such as battery electric vehicles or hybrid vehicles, which combine an internal combustion engine with an electric engine. As of 2018, global sales of electric vehicles have undergone exponential growth with approximately 1.2 million in the global vehicle stock, equating to around 1% (Langeland, 2018). Globally, China leads in terms of the number of EV sales whilst Norway lead on a per capita basis (Paoli & Gul, 2022).

It is widely regarded that EVs have the potential to significantly reduce air and noise pollution (Noel, Zarazua de Rubens, & Sovacool, 2018). Research has also shown that electric mobility can also provide additional benefits, such as enhancing the efficiency of distribution power networks when connected to the grid (Pirouzi, Aghaei, Niknam, Farahmand, & Korpås, 2018), a more stable grid network (Nunes & Brito, 2017) and they can act as decentralized modes of energy storage (Weiller & Neely, 2014).

When comparing EVs to ICEVs it is widely acknowledged that over the lifecycle of the vehicle – production phase, use phase and end-of-life phase the EVs generate lower emissions than the ICEV albeit they do result in higher emissions during the production phase (Ellingsen, Singh, & Strømman, 2016; Hawkins, Singh, Majeau-Bettez, & Strømman, 2012; Horne, 2020). A vital aspect of the difference in emissions within the use phase relates to the electricity mix, whether fossil fuels or renewables. Where there is a higher proportion of renewable energy, the difference in lifecycle emissions is greater, such as Europe generating a difference of 66-69% in emissions between EVs and ICEV, whereas India has a difference of 19-34%, as they use a much higher proportion of fossil fuels (Bieker, 2021). This is supported by Ellingsen et al. (2016) when looking at the use phase of EVs emissions were lower where there was a high proportion of renewable technology. However, it was in fact higher than ICEV when the mix of electricity was provided by coal. In a country such as Norway, emissions in the use phase are negligible where the mix of electricity comprises virtually 100% renewable energy (Statista, 2022).

It is also suggested by Andersson & Börjesson (2021) that to achieve climate neutrality across Europe in the transportation sector a combination of electrification and renewable fuels, inclusive of biofuels, is required. Rather than a focus on solely electrification of private vehicles given emissions associated with electricity across the wider European grid.

According to Paoli & Gul (2022) there are challenges to the transition, firstly with regard about policies. It is widely accepted that financial incentives and subsidies placed on EVs have been key to the increase in ownership of EVs, seen particularly in Norway, Sweden and the Netherlands which make them far more affordable. A second consideration relates to the expansion of the battery industry, the higher the production the greater strain on material supply (Andersson & Börjesson, 2021) and finally it is important that to maintain and promote sales the EV charging infrastructure must be expanded.

There are other emerging technologies at different stages in terms of their development and commercialisation such as electric road systems, other fuel types including hydrogen vehicles and the use of biofuels. The alternative fuel modes have varying barriers. For example, in hydrogen-fuelled vehicles, stakeholders remain deeply divided as there is the concern related to the technology, the on-board storage, safety, and the high cost of the fuel cells. Moreover, the technology is still very much in a test phase compared with EVs, which has a critical mass in the market plus supporting infrastructure (Langeland, 2018).

The transformation of the vehicular sector from ICEV towards non-fossil fuel technology has the potential to reduce emissions within the sector significantly. However, a couple of factors need to be considered. First, as there is no modal shift there is no reduction in vehicular traffic, in fact Wangsness, Proost, & Rødseth (2020) argue that in Norway the current policies favour electric vehicles and there could be increased congestion and a reduction in overall use of public transport. In Norway, in particular the increased use of electric vehicles has implications on the bus network as EVs are allowed to use bus lanes, which could further reduce demand for public transport.

Holtsmark & Skonhoft (2014) carried out a study related to policy interventions for e-vehicles, and found that there are a couple of disadvantages of promoting e-vehicles. First, from a financial perspective they found that the fiscal incentives can make the cost of using e-vehicles very low and often this might be at the expense of public transport or cycling. Another factor that they found was that given the low driving range of e-vehicles, many people acquired second cars which used fossil fuels for longer journeys.

Another aspect, particularly concerning electric vehicles is related to infrastructure and particularly availability in terms of both charging points and the impact on the grid and the overall power system. In Norway this is less of an issue as it is estimated that total annual electricity consumption will increase by approximately 3% if the government achieves the target of half of the vehicular fleet being electrified by 2030 (Skotland, 2016). It is currently estimated to account for approximately 1% of grid consumption (Baldursson, Fehr, & Lazarczyk, 2021).

In addition to EVs, there is a range of additional technologies related to travel that are also advancing but are at different stages of development. E-bikes or city bikes and scooters are current examples that are seeing significant market expansion. Berjisian & Bigazzi (2019) reviewed several studies and estimated that the average net reduction per e-bike was around 460 kg CO_2 per annum. The study considered lifecycle emissions (considering a 5-year lifecycle for a bike) and also the displacement of alternative modes of transport, including cars and walking (Philips, Anable, & Chatterton, 2022).

E-scooters are being called a solution to the "*last mile problem*" (Pojani & Sipe, 2018) in urban areas, on the basis that they do not have tailpipe emissions. A study by Hollingsworth, Copeland, & Johnson (2019) looked at lifecycle emissions of e-scooters and concluded that whilst they produce less emissions than a car, there are still relatively significant emissions associated with them over the course of their lifecycle. It does go on to state that this can improve with longer product lifetimes, reduced material burdens and reduced e-scooter collection and distribution.

The number of electric vans and buses is also increasing. Electric buses are a means that contribute to decreasing emissions, it has been demonstrated that they are around 80% more efficient than diesel buses and also improve noise pollution and air quality (Borén & Grauers, 2019). However, there are barriers to implementing electric buses related to the upfront investment costs, technology development and uncertainty related to operation and maintenance (Aldenius, Mullen, & Pettersson-Löfstedt, 2022). Similar issues surround the widespread implementation of electric vans, with upfront costs that need to be considered. The range, capacity and the operation and maintenance of the vehicles are issues that are particularly important for businesses' when considering alternatives.

The rapid development of automated vehicles (AVs) is another technology that is predicted to disrupt the transport sector in short order. It is anticipated that it will impact traffic and travel costs and offer a more sustainable method of travel with fewer road accidents (Wu, Cao, & Douma, 2021). However, the downside of the increased automation of the car fleet is that it has the potential to reduce demand for public transit and non-motorized transport (Bahamonde-Birke, Kickhöfer, Heinrichs, & Kuhnimhof, 2018).

As discussed, the introduction of new technology can reduce emissions. However, there is also the risk that new technologies that have emissions associated, are used over less emission producing modes of travel such as cycling and walking. An example might be people using an e-bike over a bicycle.

Policy Interventions

We have demonstrated that literature has shown that a technological shift can reduce emissions, particularly when moving from ICEV. However, the commercialisation of technology is at various stages, with EVs being far progressed whilst technology for heavy freight vehicles is at a relatively early stage of development. It is important to understand potential interventions that policymakers might be considered to encourage deployment into the market.

A study in the UK by Santos & Rembalski (2021) found that a particular limitation to ownership of electric vehicles was the high upfront purchase costs when compared with ICEVs.. Huang & Ge (2019) concluded that monetary policies such as reduced VAT on purchases, have been a key driver in the increased ownership of EVs. They also concluded that non-monetary policies, such as the right to use a bus lane, has limited influence on ownership.

Issues surrounding the positive and negative aspects are debated extensively, Aasness & Odeck (2015) conclude from literature reviewed that whilst Norwegian policy related to EVs might not be the most optimal from a social-economic perspective, it might be the most appropriate way to meet the challenge of climate change. In addition, policy relating to the promotion of EVs is primarily endorsed at a national level, there is minimal policy intervention that has happened at a local level.

Summary

We have demonstrated that technological intervention is one method of decarbonising the transportation sector. Technology is at various stages of integration into the marketplace, and it is primarily the electrification of the transportation network that is leading the way and providing a method of reducing emissions.

We have noted some of the downsides, one example being that EVs does not reduce traffic (seen as a primary driver for increasing emissions). There is also the potential hazard of people choosing electric vehicles over more environmentally friendly modes of transport and the potential to increase ownership of second cars with the second car tending to be fossil fuel-driven for longer distances.

We have also discussed a range of policy measures that might be considered. They generally fall under "carrot" policies, trying to incentivise people to use electric vehicles. This is particularly prevalent in Norway, and it is the economic benefits that have proven the most successful at transitioning people from ICEVs to EVs.

The final factor that we mention is that new technology must be available and competitive compared to alternative ICEVs. The battery technologies improving, allowing for longer journeys and longer lifetimes for the batteries. However, in certain sectors such as heavy freight there are limited alternatives at present.

3.4.3 Modal Shift

The second approach to decarbonising that has been considered by Bardal et al. (2020) is the transition from higher emitting modes of transport, such as cars, towards more "environmentally friendly" modes of transport, whether active travel in the form of walking and cycling, the use of public transport and even car sharing.

This method has a much broader scope for decarbonisation than a technological shift. It is widely regarded that there are two key approaches to modal shift. Firstly, by implementing policies that specifically seek to restrict the use of the car and thereby encourage alternative forms, or "stick" policies. The second approach is the use of policies to encourage more emission-reducing forms of transport through a range of "carrot" policies. We will consider them both and the effects demonstrated in studies.

"Stick" Policies – to reduce the use of cars

The first example of a "stick" policy to restrict the use of cars could be in the form of the introduction of toll roads, as exemplified around Stavanger and other Norwegian cities. Empirical data has shown that the introduction of road pricing schemes in major European cities has reduced traffic volumes. In London, traffic volumes reduce by between 14% and 21%, and gave a reduction of 16% in CO_2 emissions. In Stockholm, road traffic volumes were reduced by 18-20% and CO_2 emissions by 13% (Börjesson, Eliasson, Hugosson, & Brundell-Freij, 2012) and in Milan compared with the reference year of no pricing, traffic volumes reduced between 17-39% (Croci, 2016). The downside of this as a means of intervention is that road pricing is generally found to be unacceptable particularly to road users, whilst far more palatable to those that are non-road users (Jaensirisak, Wardman, & May, 2005).

Policies could also be in the form of restricting the use of roads, reducing car parking opportunities or through an increase in the cost of car parking. An example of this is in Oslo, where the municipality began prohibiting driving through parts of the city centre from 2016. They also reduced the number of available car parking spaces. These measures were introduced through the car-free "Liveability Programme" in 2016, as part of the city's goal to reduce carbon emissions. The results have shown that between 2016 and 2018, car traffic reduced by 11%, and by 19% between 2018 and 2019. Another survey showed that the number of pedestrians in a selection of streets had increased by 14% and people spending time in urban spaces had increased by 43% (Figg, 2021).

Other ways to potentially reduce car usage is through increased fuel prices, for example environmental taxes on fuel has been proven to be an effective method (Creutzig, 2014). In addition, the increased cost of car parking also has the potential to influence car use behaviour, in a study in Oslo this was shown to be the second most effective measure, behind low emission zones, both decreasing traffic and emissions (Sousa Santos et al., 2020).

"Carrot" Policies – to promote cycling, walking and public transport

The second approach to modal shift is through ranges of "carrot" measures, which promote more sustainable modes of transport whether walking, cycling, public transport, or car sharing as an alternative to using a private car.

Cycling and Walking

The first type of modal shift we consider are measures to increase the number of people walking and/or cycling. A variety of walking and/or cycling policies have been adopted to suppress the use of cars and promote active travel whether structural, infrastructural or behavioural interventions (Graham-Rowe, Skippon, Gardner, & Abraham, 2011).

The first possible approach is to invest in both walking and cycling infrastructure. In terms of investment this might be in a variety of forms, whether through investment in physical interventions or other forms. For example, physical interventions might take the form of new or upgraded cycle routes or pedestrian routes. We have reviewed several studies assessing this as a form of intervention to encourage modal shift and the results are mixed.

A study in the UK by Song, Preston, & Ogilvie (2017) considered a number of physical infrastructure interventions that encouraged modal shift to cycling and walking. They concluded that whilst infrastructure provision was not directly the cause of modal shift to more active modes of travel, it is one of the conditions required to encourage modal shift. They also state that full change in behaviour can take between one and two years, whilst shifting from use of a private car is more difficult as alternative modes are often perceived as less comfortable or less convenient and take more time to cover the same distance (Thøgersen & Møller, 2008).

A study in Oslo by Pritchard, Bucher, & Frøyen (2019) identified that after the construction of a contraflow bicycle land in Oslo, there was no significant increase in the modal share for bicycles. Whilst a study by Brand et al. (2014) found that although the introduction of new infrastructure did attract new walkers and cycling, there was no evidence that this translated into a sizeable decrease in CO_2 emissions from motorized travel across the study population (Brand, Goodman, & Ogilvie, 2014). However, whilst there may not be a significant modal shift, literature suggest that building accommodation for cyclists and extending the network of cycle paths and lanes typically results in an increased number of bicycle trips (Aasvik & Bjørnskau, 2021; Buehler & Dill, 2016).

Pucher et al. (2010) undertook an assessment of 14 international cities in relation to cycling packages and found that the cities that undertook a comprehensive package of cycling measures led to "large increases in the number of bicycle trips and share of people bicycling" (Pucher, Dill, & Handy, 2010). They concluded that the most important aspects for modal shift towards walking and cycling is increased safety, for example, where there are independent cycle lanes or car free zones.

Alternative initiatives that have been used are financial incentives aimed at encouraging cycling, such as the Cycle to Work scheme which was introduced in the UK in 1999 where employees of businesses that signed up to the scheme received financial benefits when purchasing a bicycle (Swift, Green, Hillage, & Nafilyan, 2016). A study by Martin, Suhrcke, & Ogilvie (2012) suggested that financial incentives particularly for active travel may be an underused but potentially promising method for encouraging more active modes of travel.

Public Transportation

The public transport network offers a good opportunity to provide a solid alternative to the use of the private car, particularly in the case of urban areas, where there tends to be the basis of a network whether that is a bus network, tram/urban railways, or the train. Studies have been carried out to look at the wider appeal of the public transport network and to establish what will encourage increased usage over the car.

It is widely regarded that the main incentive to encourage the use of public transport over the car is through improvement in quality. Quality can be defined and related to public transport considering the frequency of service, travel times between destinations, availability, cost, and reliability. Another important factor is to understand peoples motivation for using the private car in the first place (Redman, Friman, Gärling, & Hartig, 2013).

A study by Heinen, Harshfield, Panter, Mackett, & Ogilvie (2017) carried out in Cambridge, UK, relating to the expansion of public transport infrastructure did not find any evidence of significant modal shift albeit there was a partial modal shift (i.e. on some days people would use an alternative form of transport but not every day) as a result of the intervention. One of the limitations noted within the study was that the study only covered a short period and in the longer term there could be a greater overall change in the pattern of behaviour that might not be accounted for.

A reduction in public transportation costs is another approach to encouraging modal shift. A study by (Hess, 2017) showed that reduction in the cost of public transportation has the potential to significantly increase the number of users. A study that looked at several studies across Europe on the impact of ridership on public transport if the costs were provided at nil cost found that in Aubagne, France ridership doubled and in Hasslet, Belgium ridership increased by 900%. However, it was also found that is quite typical that ridership gains mainly occur at the expense of more sustainable forms, such as walking and cycling, rather than the use of the car.

Car Sharing

Another alternative form of transport is the expansion of car sharing. Positive aspects associated with this include reduced use of car and car ownership. However, there are potential negative aspects of car sharing, such as using a car instead of walking, cycling and public transport. It is noted that the shift to car sharing from private car ownership has a positive impact on emissions. A study by Amatuni et al. (2020) in three cities showed that participants that moved over to car sharing platforms reduced their annual mobility emissions by between 3-18% (Amatuni, Ottelin, Steubing, & Mogollón, 2020). Similar results were found in a study (Nijland & van Meerkerk, 2017) in the Netherlands, which showed that there was a reduction in car ownership of approximately 30%. People drove 15% to 20% less kilometres than prior to membership and overall emissions reduced by between 13% to 18%. However, a study in Germany of 80 cities that looked at car sharing and its impact on sustainable transport methods concluded that whilst car share members tended to use more environmentally friendly modes of transport, it was not sufficient to change mobility patterns and that a more effective strategy to reduce consumption would be needed to specifically reduce car ownership (Göddeke, Krauss, & Gnann, 2021).

Targeted Behaviour Programmes

Another way to encourage modal shift is through targeted behaviour change programmes or through mobility management programmes which are used as strategies "to change demand for particular modes of transport, most commonly the use of the car" (Tørnblad, Kallbekken, Korneliussen, & Mideksa, 2014). This might include a combination of information campaigns coupled with incentive or disincentive programmes, carrot and stick policies, without investment in physical infrastructure or transport services. Brög, Erl, Ker, Ryle, & Wall (2009) have undertaken a study to review voluntary behaviour change programmes (under the name IndiMark) across North America, Australia and Europe. They found that these programmes can inhibit behaviour change in motivated groups of people. Ogilvie, Egan, Hamilton, & Petticrew (2004) conducted a review of 22 studies concluding with similar findings as above.

On the other hand, a study carried out in Lillestrøm, Norway by Tørnblad et al. (2014) found that the effectiveness of targeted behaviour programs, which included increased information on public transport services and free transit passes, was minimal and did not provide a net modal shift. However, they do state that the program might work better in other locations as Lillestrøm itself had plentiful free car parking and, bad weather conditions. Even with several disincentives to use the car, people still chose to use this as a preferred mode of transport.

The emerging concept of Mobility-as-a-Service (MaaS) is another approach that enables people to use different types of mobility from a single platform, or application. Through a digital platform it allows people to plan routes and types of mobility whether that be public transport, cycling, walking, car share (or rental) or e-mobility options. The approach is a "one stop shop" for mobility, in the form of a subscription service. Studies have been carried out in Finland and Sweden, two pioneering countries in the promotion of MaaS, however, there is very limited data on the empirical effects of the impact of the scheme (Smith, Sochor, & Sarasini, 2018).

Summary

Modal shift as a method of decarbonising the transportation sector is a large topic area with numerous methods of trying to change behaviours. There are two key approaches to modal shift. Firstly, by restricting the use of the car (stick policies) and secondly, by encouraging the use of alternative means of more environmentally friendly transportation (carrot policies).

We have looked at several studies and from the information gathered it is evident that to push modal shift the most effective measures appear to be in the form of restriction of the car. However, this approach to modal shift is generally viewed less favourable by the general population. The effectiveness of encouraging the use of more environmentally friendly forms of transport is mixed, as is evident from the studies already mentioned. Nevertheless, it is noticeable that where there was a success in encouraging modal shift, it was in the form of "motivated" subgroups, i.e. where there is a willingness from the individual at the outset to consider a shift in travel habits.

3.4.4 Avoid / Reducing the need to travel

The final approach to promoting more sustainable modes of transport is to reduce the need to travel. This can be through urban planning strategies and through the use of Information and Communication Technologies (Bardal et al., 2020).

There are several planning theories related to the reduction of emissions. The theories primarily relate to the densification of urban areas. Where one increase the population and workplaces in an area in order to reduce the need to travel and therefore also reducing GHGs (Santos, Behrendt, & Teytelboym, 2010).

Among the various planning theories, “New Urbanism” promotes densification and diversity within built-up areas, promoting cycling and walking over the use of the car, which has led to terms such as the “15 minute city” (Overstreet, 2021). An alternative approach is “Transit Oriented Development”, which proposes that development is concentrated around transport hubs (Dittmar & Ohland, 2012), the hypothesis being that those living closer to public transport will use this means of travel more and people will also be located closer to work. A study carried out in Perth, Australia by Griffiths & Curtis (2017), showed that this type of approach can reduce car usage, albeit there is also a direct linkage with the availability of parking and the development of walking infrastructure.

Polycentric settlements are another approach where urban areas have secondary hubs around the city centre, effectively decentralizing land use. Theorists state that having secondary hubs would reduce the distances travelled to work and therefore reduce the use of the car. However, a study in the Netherlands by Schwanen, Dieleman, & Dijst (2003) indicates that commute times tended to be longer in polycentric settlements and commute times tended to increase with residential density.

The impact that land use measures can have is generally limited given the urban form that already exists (Aditjandra, 2013). There are many debates around the impact of land use specifically in relation to restricting the use of the car. One argument that has been made is that if urban sprawl is restricted then people might consider moving farther afield, for example, due to rising property prices. This might encourage people to move to settlements outside their working city and thereby having further negative effects on emissions.

Historically, the development of urban settlements has been centred around the development of roads and with priority toward car travel (Rydningen, Høynes, & Kolltveit, 2017). However, there are land use approaches that can seek to reduce the priority of the car on roads. This can be by way of re-allocating road space to alternative uses, such as public space or alternative means of transport such as cycle lanes as has been done in Copenhagen, albeit this can take considerable time (Carstensen, Olafsson, Bech, Poulsen, & Zhao, 2015). Alternatively, speed limits can provide an alternative method of promoting modal shift. This has two benefits, firstly, reducing car driving speed can increase safety for pedestrians and cyclists, and therefore promote these alternative means of transport. Second, it has the ability to reduce travel times between car travel and alternative means (Cleland et al., 2020; Pucher et al., 2010). Albeit the impact and evidence of modal shift as a result of speed reduction are minimal and inconclusive (Brown, Moodie, & Carter, 2017).

3.4.5 Policy summary

Decarbonisation of the transportation sector is a pressing issue in the fight against climate change. In this section, we have first defined what we mean by decarbonisation and then detailed the three main approaches to decarbonising the sector; technological innovation, modal shift and reducing the need to travel. Further, we have considered the types of policies that policymakers might consider to influence change and patterns of behaviour, principally whether it be via a method of encouraging behaviour, which is termed as “carrot policy” or policies that seek to reduce or restrict behaviours, termed in this thesis as “stick policies”.

In Figure 5 we set out a range of policies that might be considered, based on the three approaches:

Measure	Carrot or stick
Technological	
• Financial Incentives (i.e. tax breaks, reduced road pricing) • Non-financial incentives (access to bus lanes, investment in charging infrastructure) • Emission Standards	Carrot Stick
Model shift	
Reduce Car Use • Road Pricing Schemes • Reduced car parking / increased parking costs • Car-free areas • Increased costs (fuel, taxes)	Stick
Encourage Walking, Bicycling, Public Transport & Alternatives • Improved / increased physical infrastructure for bicycling and walking • Financial incentives for active travel (i.e. tax breaks) • Expansion / improvement in the quality of the public transport infrastructure • Public transport fares • Increased car sharing schemes • Mobility management	Carrot
Reduce the need to travel	
• Land use planning strategies (transit-oriented development) • Speed reduction measures / re-prioritisation of the road through land use planning • ICT	Stick Carrot

Figure 5: Carrot and Stick Policy measures. Based on literature.

The findings of this section of the literature review have intended to show the variety of measures that could be considered and the effectiveness of the measure types. We can conclude that these are mixed with some policies being demonstrated as being more effective in enabling change than others. It should also be noted that it is very difficult to generalise based on the outcomes of the studies analysed as the effectiveness very much depends on context, inclusive of geography, urban form, economic situation, demographics, policies already in place, the transportation infrastructure to name a few.

What we can see from the policy types that we have reviewed is that "stick" policies generally yield the most favourable results, however, it is in tandem with "carrot" policies that they work most effectively, according to Piatkowski et al. (2019).

Another important aspect is that generally policies are not considered in isolation and as noted above to enable change it is a package of policies that are proven to be most successful. As outlined by Nakamura & Hayashi (2013) "a package of measures should be designed not only for an existing urban land-use transport system, but also to develop its future system".

3.5 Can progress be measured?

In Section 3.4, we outlined a variety of policy measures that might be considered by policymakers when considering options related to decarbonising the transportation sector. Whilst the overall goal is to reduce GHG emissions from the sector, we need to consider whether and how one might measure progress and whether calculation of emissions is the only measurement that should be used.

3.5.1 Measuring Emissions

As we outlined in Section 3.2, GHG emissions take a variety of forms with the most common being CO_2. Another important clarification on GHGs is the difference between direct and indirect emissions. Direct emissions are those that are emitted directly from the source of the emissions, whilst indirect emissions are emissions that occur as a consequence of the activity, an example being emissions released as a result of using electricity (Ranganathan et al., 2004).

Numerous studies (Hertwich & Wood, 2018; Moran et al., 2018; Wiedmann et al., 2021) have demonstrated that indirect emissions can be significantly higher than direct emissions, this is particularly evident in larger and higher income cities. It is widely acknowledged that accounting for indirect emissions into GHG inventories is crucial to providing a holistic overview of emissions within the overall system. However, accounting for these emissions is difficult. In particular the reliability of results may vary (Chen et al., 2019; Wiedmann et al., 2021). It is important to recognise that when accounting for emissions, they primarily relate to direct emissions and that indirect emissions are often not accounted for.

As part of the United Nations Framework Convention on Climate Change (UNFCCC), (Bjøness, 2021) parties are required to develop and submit to the UNFCCC national inventories of GHG emissions and they are required to use the methodology for calculating emissions as set out by the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

In this thesis, the primary metric used is CO_2 equivalent which is the most common metric measure. A CO_2 equivalent is a unit of measurement used to be able to compare the heating effect of different GHGs on the atmosphere (IPCC, 2001).

How are Road Transportation emissions calculated in Norway?

In Norway, it is the Norwegian Environment Agency, Statistics Norway and Norwegian Institute of Bioeconomy that work together to calculate emissions. The general emission model is based on the following equation:

$$Emissions\ (E) = \ Activity\ level\ (A)\ *\ Emission\ Factor\ (EF)$$

For road traffic emissions our primary data source is the Norwegian Environment Agency. While this source is considered official for Norway, and the validity has been well-recognized, it is necessary to briefly understand how road traffic emissions are calculated. This is done using a model called NERVE (Weydahl, Grythe, Haug, & Høyem, 2018), built on four different datasets that covers most of the available information about road traffic in Norway. These datasets include:

- Road network, all public roads from the National Road Data Bank (NVDB)
- Traffic from the Regional Transport Model (RTM)
- Mileage statistics for Norwegian-registered vehicles from Statistics Norway

- Emission Factors from the Handbook of Emission Factors for Road Transport

The NERVE model calculates emissions that occurs within the municipal borders, regardless of whether the vehicle is registered within the boundary or not.

Another factor when considering emissions is that the numbers are based on direct emissions of fuel consumption. The emissions therefore do not account for indirect emissions, such as the production or disposal of the vehicle, which is where most emissions lie particularly for electric vehicles.

In relation to the NERVE model, there are limitations related to various aspects including scaling and counting methods (Weydahl et al., 2018). This means that there is an element of uncertainty in the data. However, there is consistency in using the model as the same model has been used for calculating emissions over an extended period.

3.5.2 Alternative measures of assessment

Whilst emissions are a key driver in relation to progress of decarbonisation it is also important to consider alternative measures to provide an overview of progress. This is particularly relevant where policies towards decarbonisation are specifically targeting behaviour change, which can subsequently impact GHG emissions. An example might be investment in bus infrastructure to encourage greater use. In this instance, one might consider reviewing whether this has increased passenger numbers for the bus.

As noted there are a wide range of indicators that can be used to understand relationships between factors (Toth-Szabo, Varhelyi, Koglin, & Angjelevska, 2011). When considering the most appropriate indicators, Nenseth, Christiansen, & Hald (2012) identify several factors to consider; is it policy relevant and is it composed of variables that policy can influence; secondly, is it comparable, over time or across cities; is it simple and straightforward, with limited numbers of variables. Finally, the indicator needs to be robust, measurable with accessible data and compatible with scientific demands for reliability and validity.

Examples of typical indicators to assess mobility might include the following:

- Transportation modality statistics
- Transit accessibility
- Vehicle miles travelled / average travel distances
- Vehicle occupancy
- Vehicle numbers (inc. by fuel type)
- Accessibility to car
- Car parking numbers
- Quality of service (public transport, bicycling, walking)
- Level of active travel infrastructure
- Number of users by transport mode

The fundamental factor relative to the information provided by the indicator is the quality of data that is available, which includes the quantum, where and how the information is sourced, and the level of detail provided. These all need to be assessed when considering the type of data (Nenseth et al., 2012).

3.6 Barriers to Decarbonising the Road Transport Sector

In Sections 3.4 and 3.5, we have discussed potential methods of intervention in the road transportation sector, following which we have subsequently discussed methods of measurements particularly when considering whether progress has been made. In this section, we consider what barriers exist in relation to the implementation of measures and approaches to decarbonisation.

A study by Bardal et al. (2020) across three cities in Norway identified six key barriers to the implementation of the policy: cultural, political, legal, organisational, financial and knowledge. Whilst there is relatively broad support for sustainable mobility on the political agenda, challenges occur at the point of design and implementation.

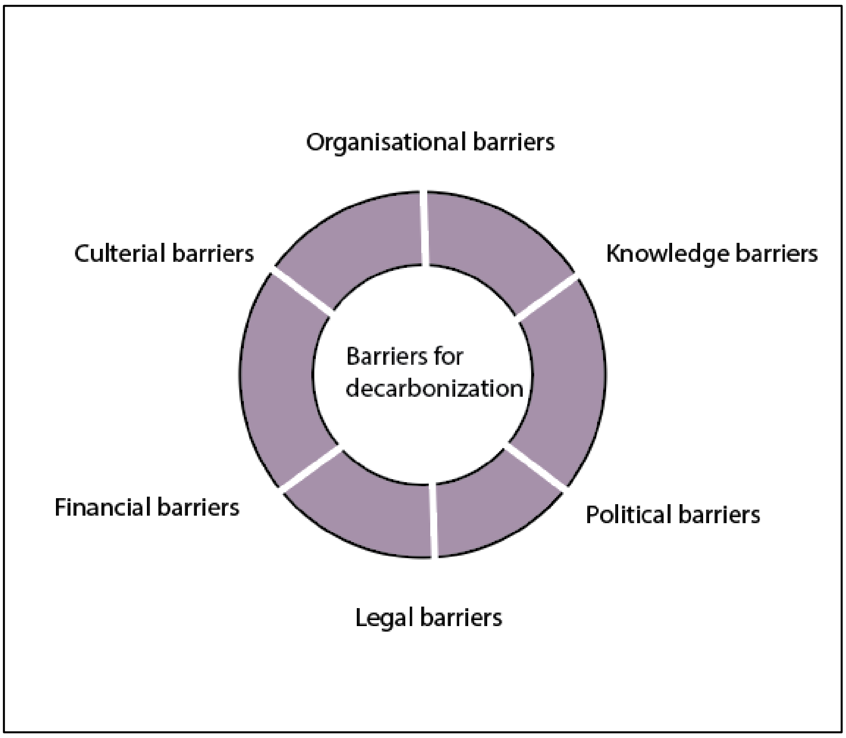

Figure 6: Barriers.

Cultural Barriers

Cultural barriers may arise when there is a conflict with the norms and values of individuals and with those of society (Bardal et al., 2020). Cultural barriers seen across the cities were principally that there is a reliance on the private car and as a result the land use planning culture has been seen to prioritise the car despite policy stating that the primary objective was to prioritise walking, cycling and public transport. Modal shift requires behavioural change which can be difficult in societies that have always prioritized a particular mode of transport, principally the car (automobile dependence). It can be especially difficult where weather conditions are generally deemed worse, such as in Norway. As outlined in the study by Gärling & Axhausen (2003) behavioural change from using the private car is challenging as alternative forms of transport are typically perceived to be less comfortable or convenient and take longer time to cover the same distance.

Political Barriers

From a political perspective there are several key barriers to implementing measures. It is accepted that "stick" measures are generally seen as the most effective measures to create change in the mobility sector. However, for politicians that are elected for a four-year term it is difficult to implement these types of measures as citizens are generally opposed to increased taxation or tolls (restricting the use of the car). This is evidenced in Norway by the formation of a new political party that can be translated as "The People's Action to No More Road Tolls" (FNB), which gained support at the expense of traditional political parties in several major cities including Stavanger, where they have received 9,2% of the popular vote in local elections. The party has one single issue which is that road construction should be funded through taxes and that road tolls should be abolished (Boffey, 2019). Another political barrier identified is urban planning policies that promote urban sprawl. The further from the city centre, the greater the transportation needs and generally a greater reliance on private car. This suggests that there are conflicting objectives between spatial planning, economic growth, and climate policies, and therefore moving the focus towards environmental matters requires a paradigm shift.

There are a number of studies that have shown that whilst a shift towards more sustainable development is acknowledged within the local policy making process, economic growth was still the key driver (Hrelja, Hjerpe, & Storbjörk, 2015). A similar finding was also made when studying seven UK and German cities, where economic growth and job creation were prioritized over climate change policies. Policies were overwhelming "pro-growth" narratives, supporting supply side expansion and working against restrictive measures. Another example was found by Lambe, Murphy, & Bauman (2017) who found that retail lobby groups were a major factor in the failure to adopt policies that restrict cars.

Legal Barriers

In a study by Bardal et al. (2020) several legal barriers were noted, such as conflicting guidelines and technical standards for roads, pedestrians and cycling, and taxation on mobility incentives. Equally, Marsden & Groer (2016) found that across Germany and UK it is not clear where the legal obligation sits in relation to carbon reduction matters. This applies to the national, local and departmental level. It is difficult to qualify the consequences with respect to failing to meet such goals. This results in a lack of sufficient incentive for politicians, particularly at a local level, to tackle the issue.

Organisational Barriers

Organisational barriers relate to the conflicting views and interests from policymakers themselves. This was noted in a study undertaken by Sovacool et al., 2018 were conflicting governmental policies were identified as the major challenge to transport and climate policy, related to fossil fuel intensity.

Organisational issues are a key challenge. Conflicts in relation to the division of responsibility between various governmental bodies and the lack of communication between parties over common objectives are common examples of this. A good example in Norway was made by Bardal et al. (2020) referencing the Bergen Light Railway project, which is maintained and is the responsibility of the county administration of Vestland. However, the spatial planning decision related to the project are made at a municipal level with possible conflicts of interest. Across Norway it is the regional or county authority that is responsible for administering public transport, but it is directly impacted at a municipal level. As mentioned under "Political Barriers" typically climate policy can conflict with economic growth and cause division, with pro-growth policies dominating the political landscape.

In addition, Marsden & Groer (2016) have concluded that there is also a general lack of coordination between stakeholders about who is best placed to deliver climate policies.

Financial Barriers

An important aspect of mobility measures is how to fund these types of projects. Investment in infrastructure can be significant and also takes significant time to plan and build. In the study by Bardal et al. (2020) funding between cities differed, with larger cities, such as Bergen and Trondheim, receiving national funding towards the delivery of new infrastructure projects, through the Urban Growth Agreements programme. Smaller cities, such as Bodø had to rely primarily on local funding for infrastructure projects.

Whilst national goals are to improve sustainable solutions, it can be difficult to incentivise environmental options over projects, particularly at a local level, that support economic growth. One of the main challenges is the decoupling of economic growth and emissions (Loo & Banister, 2016). There are also very limited financial incentives for investing in the sustainable transport of goods.

Knowledge Barriers

From a knowledge perspective, there is a tendency for lack of communication between stakeholders, organisations, professionals, politicians and citizens regarding the measures and the effects of these. In Bardal et al. (2020), it was identified in all three cities mentioned above, that lack of knowledge transfer was a key barrier to implementation with the various actors working independently without communicating the effects of measures to other stakeholders.

From a technological perspective, there are a variety of barriers such as the implementation of existing solutions. Also, various technologies are at different stages of innovation. For example, the development of electric passenger vehicles is ahead of the commercialisation of electric heavy vehicles.

3.7 Literature Review Summary

This literature review has demonstrated that climate change is a major threat facing the planet and is primarily caused by rising emissions resulting from anthropogenic activities. Transportation is the second largest contributor to global emissions by sector, and it continues to grow. Despite improvements in vehicle efficiencies, the greater travel volume is causing an increase in emissions.

To reduce the impact of climate change a reduction in emissions is required, this process as discussed above, is defined as "decarbonisation". Within the transportation sector, we have detailed three approaches to achieve this: (1) technological innovation, by improving efficiency and reducing the impact of vehicles, (2) modal shift, shifting behaviours from private car use towards more environmentally friendly modes of transport: and (3) reducing the need for people to travel through land use and / or ICT.

We have discussed and detailed a range of policy types and interventions aimed at decarbonising via the mentioned approaches, distinguishing between "carrot" and "stick" policies. Whilst it is the "stick" policies that tend to have more significant impact, they are often met with greatest resistance from the public.

Further to the types of policies that can be adopted to promote change, we have also reviewed the types of indicators and measures that can be used to consider progress. This is because there are limitations to using emissions as a sole method of measurement. Firstly, there are limitations in terms of the data surrounding emission statistics, and secondly, it is not necessarily a specific measure for policy measures. Indicators to measure progress should be specific and relative to the policy. Finally, we have also considered some barriers to implementation of the mobility measures, which further allows us to understand why certain measures might not succeed.

There is a considerable amount of literature available related to the topic areas. This has provided us with a good base of knowledge and understanding of how decarbonisation of the transport sector can be approached. It has also allowed us to understand methods of measurement that can be used and to help identify the barriers that exist that we can consider when undertaking our assessment.

Taking the above into account provides this thesis with a good base of knowledge to help address our approach to assessing decarbonisation of the transportation sector within Stavanger, to help us to identify measures and policies that have been adopted, methods of measurement and what barriers might exist. In the next chapter, we discuss our approach to assessing the topic area.

4. METHODOLGY

4.0 Methodology

Before we set out our methodology, we first recap our key research questions and our thesis topic:

In 2010 Stavanger adopted a new Climate and Environmental plan for the period 2010 – 2025, setting out new climate targets for the plan period and within the transportation sector. This thesis will seek to address and evaluate whether progress has been made in decarbonising the road transportation sector relative to the targets made. Based on the above, we have set out the following research questions:

- *What is decarbonization and what are the main methods to decarbonise the transportation sector within Stavanger municipality?*
- *Since adoption of the 2010 Climate & Environment Plan, has progress been made in decarbonising the transportation sector and are they on track to meet their targets?*
- *Based on the outcome of our analysis, can any recommendations be made to assist the municipality in achieving their new goal of an 80% reduction in emissions, within the road transportation sector?*

Initially, the thesis was set to concentrate on a review of emissions within the transportation sector. However, following our literature review it was evident that emissions as a measure of decarbonisation in isolation can be misconstrued as it does not provide an understanding of the whole picture. As such, we have amended the wording to consider wider progress measures, and those that specifically relate to policy measures the municipality has adopted.

4.1 Research Design

Our research design adopts a "Descriptive research" approach, which focuses on the "what" rather than understanding the "why". As noted, we will be concerned with what the approach has been to decarbonise the road transportation sector and what has happened in the period from 2010, effectively exploring the opportunity to integrate both qualitative and quantitative methods of data collection.

The basis of the research design is to enable a holistic evaluation of our topic area. The study itself follows a multiple method approach combining both a document analysis and statistical analysis. Adopting this approach, we are able to triangulate the information for higher validity and it will involve the "collection of different but complementary data on the same phenomenon" (Edmonds & Kennedy, 2016).

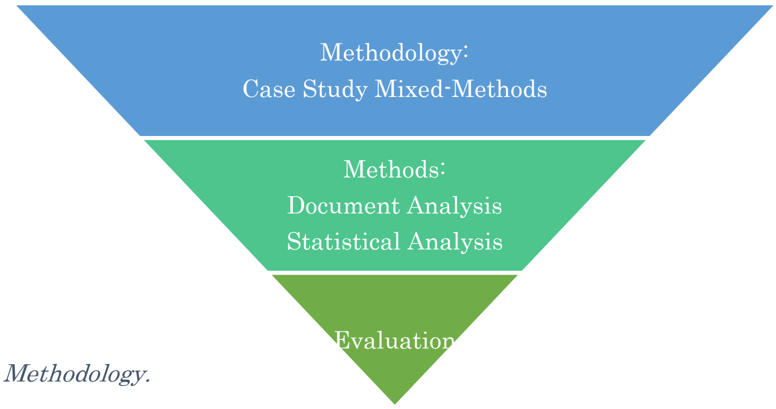

Figure 7: Methodology.

The Case Study-Mixed Methods is the approach that will be used within this design, whereby the mixed methods approach will be the basis for finding information pertaining to the parent case study (Guetterman & Fetters, 2018).

The case study in relation to this study is Stavanger Municipality. As noted by Simons (2009) "case studies provide an in-depth exploration from multiple perspectives of complexity and uniqueness of a project, policy, programme or system in a real-life context. It is research-based, inclusive of different methods and is evidence led. The primary purpose is to generate an in-depth understanding of a specific topic". Cresswell (2014) goes further and state that "cases are bound by time and activity and researchers collect detailed information using a variety of data collection procedures over a sustained period of time".

As noted in the research question, the thesis specifically looks at the case of Stavanger municipality and the research focuses on the time period from 2009, the year prior to the adoption of the 2010 plan and the earliest available data at the Norwegian Environment Agency for emissions.

The purpose of using a mixed-methods approach for data collection is first to help guide the quantitative research but also to yield complete understanding of the topic area (Guetterman & Fetters, 2018)

4.2 Data Collection

In terms of the types of data, we use publicly available sources such as governmental and leading authority documents and statistics within Norway.

In terms of qualitative data, the method of data collection for this element consists of undertaking a document analysis. A document analysis is a "systematic procedure for reviewing or evaluating documents", where information is gathered and interpreted in order to gain an understanding and develop empirical knowledge (Bowen, 2009).

The Climate and Environment Plan 2010-2025, forms the basis of our knowledge base and is used to help provide insight and answers to the first question. Our analysis help to identify the types and package of policies that the municipality of Stavanger seeks to adopt over the period in line with those identified in Section 3.4.

We will also consider the most up-to-date Climate and Environment Plan for Stavanger municipality, which was published in 2018. The use of document analysis will enable us to track change and development over the period and determine whether the policy progress aligns with national- and regional policy.

The second source of data collection is related to collecting statistical data relevant to indicators that help to identify and measure whether progress has been made in relation to decarbonising the transportation sector. The statistical data is collected from Statistics Norway, Norwegian Environment Agency, Norwegian Public Road Administration, and the Municipality of Stavanger.

4.3 Analysis

The analysis is based on a "sequential" approach to research, whereby the qualitative findings are used to undertake a quantitative analysis.

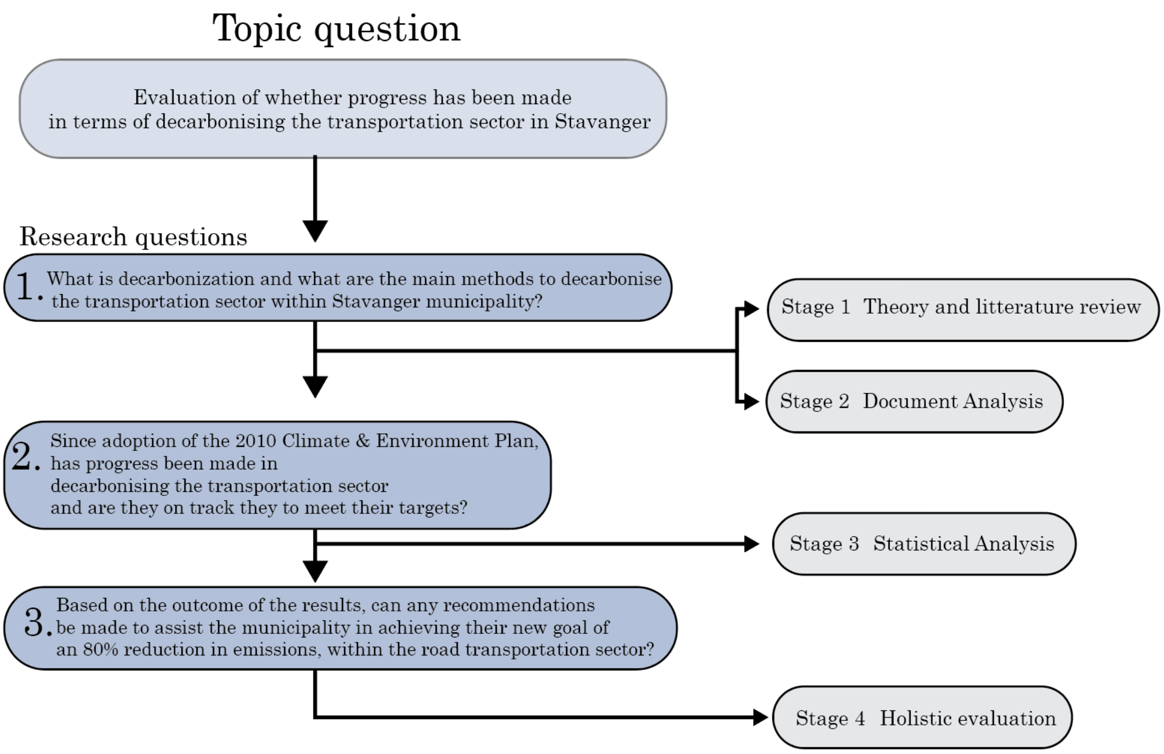

Figure 8: Structure of thesis.

4.3.1 Stage 2: Document Analysis

In our approach to qualitative analysis, we review national, regional, and municipal climate and transportation documents. In our document analysis we will consider transport related climate policies and targets. As noted by Bowen, (2009) it is used to provide background information and broad coverage of data and to help contextualise the research subject.

The first stage of our analysis is to review national documents relative to climate policy and transportation, principally climate plans and the National Transport Plan (NTP). Our approach to this element is to first understand how climate policy has evolved in Norway, specifically in relation to climate targets and secondly, at what point the National Transport Plans start referring to environmental matters, specifically related to emissions targets. The purpose is to understand and identify if and how this has impacted on climate policy within Stavanger. It contributes to widening our base of knowledge in relation to climate policy in Norway and how and

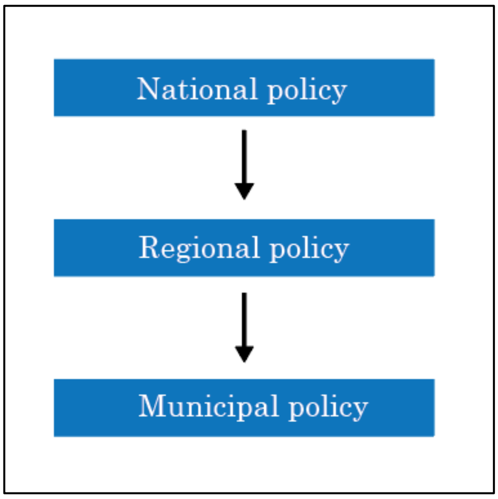

Figure 9: Policy.

when this has been integrated into the transportation sector at a national level.

In addition, at this stage, we also consider key regional documents from Rogaland County in relation to transportation and climate policy, specifically, at the beginning of the period in 2010.

The second stage of our qualitative analysis relates specifically to the 2010 plan, where we undertake a detailed review of the policies and associated targets specifically related to the transport sector.

Finally, we also compare the 2010 plan against a similar plan from another city in Norway. We have chosen to compare the plan with the Trondheim Climate and Energy Plan (2010-2020). Trondheim is the third largest city in Norway and provides a useful comparison. The Trondheim and Stavanger climate plans were also adopted over a similar timeframe starting in 2010 and for a period of 10 years. The comparison considers the key differences and similarities between the two plans, with principal consideration given to:

- Goals and targets for emission reduction and specific to the road transport sector.
- The types of policies that have been proposed within the plans.

4.3.2 Stage 3: Statistical Analysis of "Indicators" to measure progress

As set out above, we have collected quantitative data from three key data sets:

- Statistics Norway: providing a range of transportation statistics.
- Norwegian Environment Agency: providing detailed data on GHG emissions related to the municipalities.
- Norwegian Public Roads Administration: specifically related to the National Travel Habits Surveys that have been undertaken.

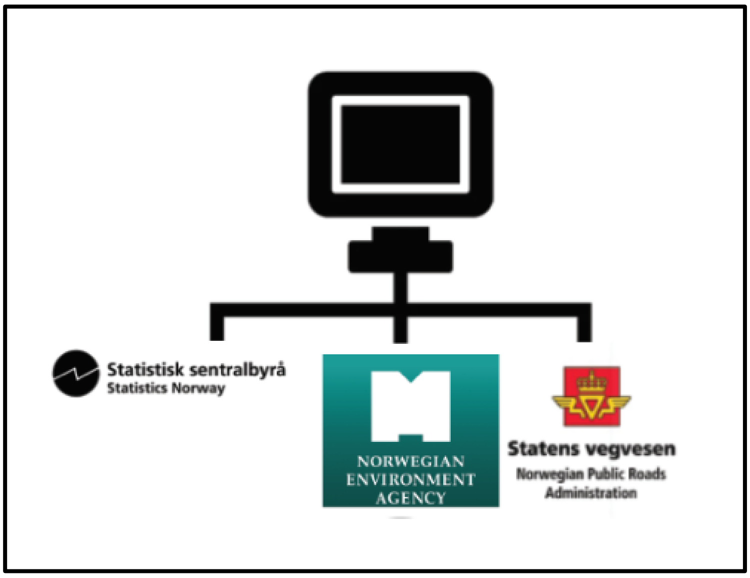

Figure 10: Data collection sources.

We have also collected data from secondary data sources where further detail was required, such as from Stavanger Municipality directly.

The purpose of the analysis is to identify "what" has happened and it is therefore a descriptive design or an "observational research method", rather than the focus of "why". This approach and the usage of secondary data sources allow the research to access large -scale data sets that have been provided principally by the above authorities. However, we cannot establish a cause and effect based on the data.

An important aspect which was considered when selecting data was to ensure that the data was available over the time-period from 2009 to 2020, or as near to the timeframe as possible. The rationale being that we are then able to draw inferences based on the trends in data and to allow for comparison over the time-period.

4.3.3 Stage 3a – Assessment of Emissions

When assessing emissions, we have used statistics provided by the Norwegian Environment Agency (NEA), which provides accounts based on those that have occurred within the municipal borders. This data differs marginally from emission statistics on a national basis, which can be found at Statistics Norway.

In addition, whilst NEA data contains the most up to date information, methodologies and borders have changed over the time period. All emission data and target numbers prior to 2009 adopt a different methodology. Whilst the 2010 plan was adopted in 2010, the data used in the plan pre-date this and therefore are subject to different methodologies for calculating emissions.

We also note that the municipal borders changed in 2020 when Finnøy and Rennesøy were included into Stavanger. All emission data from NEA, dating back to 2009 includes the extension of the municipal boundaries. Therefore, these amendments need to be factored in our assessment.

To alleviate this some targets in the plan have been recalculated to correspond with the latest data available. Therefore, our methodology when revising targets is then as follows:

1. Identify emission targets for the road transportation sector set within the 2010 plan.
2. Identify emission numbers for the municipality for the period 2009 – 2020, based on the most up to date information.
3. Re-base the target emissions based on the NEA emission data.
4. Compare the revised target with the emission accounts for the municipality based on the NEA figures over the period 2009-2020.

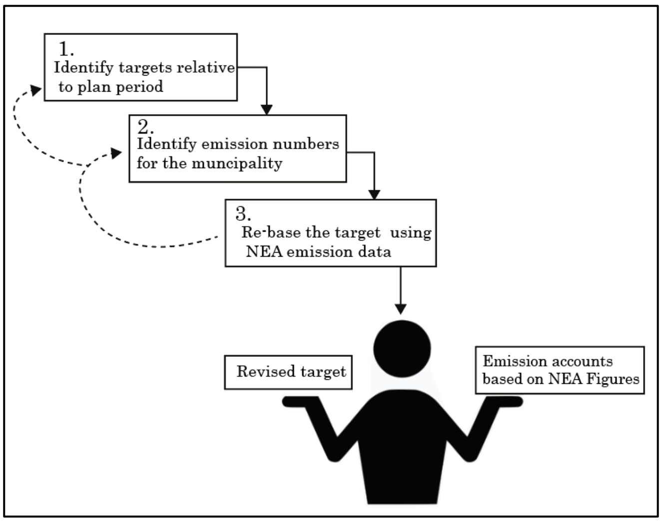

Figure 11: Process regarding emission targets

The methodology proposed is our approach to providing a comparison and to identify whether there has been progress against the targets made. As mentioned within the literature review, there are pitfalls as the methodology for collecting the data has changed. Therefore, whilst this is our interpretation of how emissions have progressed it is not a like-for-like because of the wider methodology changes.

4.3.4 Stage 3b: Assessment of Transport Related Indicators

As a secondary form of measurement we will consider a range of transport related indicators. For the indicators we will use data over the period 2009 to 2020.

In terms of our analysis, we are seeking to assess whether "progress" has been made in relation the decarbonisation to the transportation sector. As has been noted within the literature review, decarbonisation can be regarded as the mitigation and reduction of carbon emissions. Whilst data in relation to emissions can provide us with useful information and an overarching method of evaluation, this report considers the specific focus areas in more detail, where there is data available. To assess the focus areas, we will consider:

- What relevant indicators can be used to assess the policy areas addressed within the 2010 plan?
- How have the indicators changed over the period from 2009-2020?

It is also important to define progress in terms of decarbonisation. In this regard, we term "progress" as demonstrating progression in the use of technology, modal shift (a reduction in car use and increase in alternative forms of transport) and whether there has been a demonstrable reduction of the need to use cars, through densification.

4.3.5 Stage 4: Evaluation

The final element of the analysis is the integration of both the qualitative and quantitative data, which is a critical and defining feature of the mixed-methods approach (Guetterman and Fetters, 2018). In this section we seek to critically analyse whether Stavanger municipality has been successful in decarbonizing the transportation sector, based on the targets and policies set within the 2010 plan as we have set out in Stage 1.

We also seek to address whether there are any key measures or perspectives that can be taken forward in relation to the 2018 plan. As part of our evaluation, we also look to evaluate and understand what needs to be done to achieve the targets set of the 2018 plan in terms of what reduction in emissions is required.

Separately, we shall contact the municipality in respect of trying to find insight into the targets and objectives that had been set in the 2018 plan and whether there had been any recourse or further evaluation undertaken for the 2010 plan. The purpose of this exercise is to widen our understanding of policy making for the plans and whether the municipality believes that they are on track to achieve their objectives.

The approach to analysis is based on an inductive research basis, to see whether the patterns of data helps us to provide further thought as to whether there has been particular progress with certain policies that can be applied to future plans to decarbonising the transportation sector (Blackstone, 2012).

4.4 Limitations

The data is collected from a range of secondary sources. The first aspect to note is that whilst primary data are considered as a more authentic means of data that can be specific to the topic, there are downsides. It is both timely and costly to collect this data. Secondary data allows for a more representative sample of the general population of the municipality, whereas if data was collected from a primary perspective there would be only a very limited sample that we could collect for.

There are, however, limitations in relation to the use and collection of secondary data in that some of the information might not be specific to the research question. More importantly, is that we are using data collected and interpreted by third parties and are therefore relying on their methodology and collection methods.

Another important aspect to our research is that linked to our research questions our analysis is based on considering environmental outcomes and the research does not explore economic or social considerations. This is important, because as was noted in Section 3.6, it is often the case that economic growth is seen as a key barrier to decarbonising the transportation sector.

With respect of the data we have collected, there are limitations. In terms of the emissions data and specifically the road transport emissions data, the NEA have adopted the NERVE model. We have set out a selection of limitations in Section 3.5.1. We have also set out our methodology above for assessment of whether the municipality has achieved the targets set at the start of the plan period. The methodology for collecting data has changed over the time period and the NEA (Miljødirektoratet, 2022) state that it is difficult to compare on a like-for-like basis. As such our methodology does not provide a direct comparison and provides our own assessment based on the latest data.

For the indicators, we give limitations for each type of collected data in Appendix 1.

Our thesis is to be based on an assessment of Stavanger municipality and as such we have given limited regard to data from the surrounding area. This is important to note as there are two large conurbations within close proximity to Stavanger, in Sandnes and Sola which have areas of residential density. In addition, Forus the largest employment area within the region is partly located within all three municipalities. The area is also directly impacted by the neighbouring municipalities as there is significant cross-border travel, such as people living in one municipality and working in another. This thesis has not considered the wider region due to time constraints and there would be a significant amount of data that would need to be analysed, both from a policy perspective and the statistical data. This means that we have not looked at the wider region including Sola and Sandnes. However, there is one exception relating to bus transport data, which provides details of passenger numbers for the wider Nord-Jæren region collected from the County Council, which operates the local bus network.

A further factor is that the period we have sought to cover in our analysis is the period from 2009 – 2020. This includes the year 2020, which was the year that lockdowns took effect because of the pandemic. It should be noted that this year is an anomaly, as travel was heavily restricted due to measures placed on society by the government. Therefore, whilst we present data for this year, we focus our analysis on 2019 as it provides a representation of an uninterrupted year where travel was unrestricted.

5.0 NORWEGIAN CLIMATE AND TRANSPORTATION POLICY

5.0 The Evolution of Norwegian Climate / Transportation Policy

Norway is often considered to be a leading nation in terms of environmental and climate change policies. In 1989, it was the first country globally to set a stabilization target for CO_2 emissions (Hovden & Lindseth, 2004). The Norwegian Government is attempting to tackle climate change through a range of international, national, and domestic plans and policies.

In this thesis we consider how the municipal of Stavanger has sought to decarbonise the road transportation sector. To do so we need to first consider the wider backdrop against which the targets and approach to reducing emissions specifically are addressed at a national and regional level. In this chapter the roles and responsibilities of the various levels of government are considered, how climate policy and targets have evolved over time and then whether there are any key policy interventions that have been made at a state level to assist in the process of decarbonising the transportation sector. Finally, we consider whether there has been any specific policy at a regional level.

In Chapter 6 we consider more specifically how the municipal of Stavanger has approached the decarbonisation of the road transportation sector, with a specific review of the Climate and Environment Plan 2010 – 2025.

5.1 Government's Roles and Responsibilities

Climate change mitigation within Norway combines a top-down and bottom-up approach (Aall, 2012). Norway has effectively a three-tier system. The central government has overriding authority and supervises the two-tier system of local government, which comprises county authorities and municipal authorities. In relation to the topic, central government is responsible for the national road network as well as environmental and overarching planning issues. The county is responsible for regional development, county roads and public transport and regional environmental matters. Municipalities are responsible for local roads and all local matters related to planning and environment.

Central government has an important leadership in informing overarching targets and objectives related to a wide range of matters (Government - Norway, 2006). In terms of decarbonisation of the transportation sector, there are several key ministries. The Ministry of Climate ensures integrated climate and environmental policies including those related to climate targets. The Ministry of Finance is responsible for the national budget, which includes measures toward reducing emissions and relevant infrastructure projects. The Ministry of Local government and Regional Development is responsible for the Planning and Building Act and for providing central government planning guidelines relating to transport planning and land use. In addition to climate and energy planning which are to play a role in the decision-making process at a municipal level. The Ministry of Transport is responsible for all matters relating to the transportation sector which includes the preparation of the National Transport Plan. This sets out the financial framework for central government investments in the transport sector and taxation policy whilst also setting out methods by which to reduce GHG emissions, inclusive of overarching targets (UNFCCC, 2020).

The role of the county in supporting methods of decarbonisation is important as it is partly responsible for the public transport services. Within Stavanger, the county of Rogaland, via the company Kolumbus is the "mobility provider" for the region. They are responsible for managing and procuring the public transport fleet including buses, boats and city bikes (Kolumbus, 2019).

In relation to the planning system, the county is also responsible for spatial plans for the county which are intended to shape regional goals. Whilst the influence in determining specific planning decisions is limited, they have greater influence where the need for inter-municipal coordination is required (OECD, 2017).

The municipality is seen as a key actor in driving decarbonisation (Wang, Westskog, Selvig, Amundsen, & Mygland, 2016). Under the Planning and Building Act, it is the municipalities that are the main planning authorities, where they are responsible for local strategies and the more detailed land use strategies via zoning plans. In addition, they have the potential to influence emissions and energy reductions using other instruments to stimulate local actors.

Another example, is that local governments are free to lead their own policy initiatives in relation to reducing emissions, such as the Stavanger Climate and Environment Plan. (Westskog, Selvig, Aall, Amundsen, & Jensen, 2018). In relation to the transportation sector, there are a range of instruments and interventions that they can control in addition to land use regulations such as traffic prioritization and parking regulations.

5.2 Norwegian Climate Policy

For our research, we have reviewed white papers, associated with climate and environment. Table 5 summarizes key national policies that have been implemented since 1991.

5.2.1 Timeline of Key National Policies / Objectives

Year	Key Milestone	Type
1991	Norway introduces a CO_2 tax.	National policy measure
1994	Norway is the first nation globally to introduce a target on GHGs by seeking to stabilize emissions.	Emissions target
1996 /1997	Reduced road tax on e-vehicles and they are exempted from road tolls.	National policy measure
1999	Norway signs up to the Gothenburg Protocol - a commitment to reduce Nitrous Oxide emissions.	Emissions target
2002	Kyoto Protocol ratification - emissions must be no more than 1% higher in the period 2008-2012, compared with 1990 levels.	Emissions target
2004	Norway proposes that each sector will be responsible for environmental policies.	Emission targets
2006	Norwegian Climate Policy proposes three targets: • Carbon neutral by 2050; • Reduce emissions by 30% by 2020; • Norway will strengthen its Kyoto Protocol commitment to reduce emissions by 9% between 2008-12, compared with 1990 levels. National government introduced sector specific environmental targets. The transportation sector targets a reduction of between 2.5-4 million t/CO_2 equivalent by 2020.	Emission targets

2009	Norwegian NTP incorporates environmental targets into the plan.	Emission targets
2011	Introduction of the "zero-growth" objective in urban areas.	National policy measure
2014	Norway increases targets and commits to reducing emissions by 40% by 2030.	Emission target
2016	Paris Agreement comes into force, a global commitment to reduce emissions.	Emission target
2017	Norwegian Climate Change Act is adopted. Updated NTP (2018-29) is presented, detailing Urban Growth Agreements across the four main cities and targets for implementation of low emission vehicles: • By 2025 all passenger vehicles and light vans shall be zero emission or use biogas. • By 2030, all new heavy-duty vehicles, 75% of long-distance coaches, and 50% of new trucks shall be zero emission.	National policy measure Policy measure (implementation at a municipal level)
2020	Norway increases its emissions target under the Paris Agreement and the Climate Change Act to a commitment to reduce emissions to at least 50% and up to 55% by 2030, compared with 1990 levels, and a reduction in emissions of 90-95% by 2050.	National target

Table 5: National policy development over time.

Since 1991, it is evident from the documentation available that climate change has risen on the political agenda. The level of detail and information provided to the target levels has risen. If one considers the national emission goals, in 2002, the targets were to be no more than 1% higher compared with 1990, whereas in 2020 new targets are a 50-55% reduction by 2030. In addition, the responsibility that sectors have in contributing to targets has grown and thereby contributing towards policy and sector specific targets.

5.3 Development of state policy regarding electric vehicles

An important direct measure that the national government has played in the transportation sector relates to measures to promote EVs. As set out in Section 3.4.2, electrification of the road traffic modes is a key measure in decarbonising the transport sector and Norway has been a market leader, globally, on a per capita basis (Paoli & Gul, 2022). In this section, we outline the key incentives since 1990 regarding electric vehicles.

Several state-wide initiatives have been introduced which encourage the ownership of electric and hybrid cars. Conventional fossil-fuelled cars with ICE are heavily taxed in Norway with a carbon tax today of 55 EUR per t/CO_2 on fossil fuels, in addition there is a significant CO_2 component in registration tax (Norwegian Government, 2021), introduced in 2007.

Table 6 provides insight into incentives adopted in Norway for low-emission vehicles that have been developed since 1990 (Fridstrøm, 2021).

YEAR	INSTRUMENT	STATUS
1990	Abolishment of import taxes on EVs	Made permanent in 1996
1996	Road tax	Abolishment of road tax between 1996-2021. Reduced tax from 2021 and full tax from 2022.
1997	Road Tolls	Between 1997-2017, EVs were exempt from ferry fares, EVs pay at most 50% of the tolls compared to ICE cars. This has subsequently been increased, in 2022 they are subject to smaller discounts, subject to local conditions.
1997	Ferry Fares	Between 1997-2017 EVs are exempt from ferry fares. From 2018, EVs are charged at most 50% compared to ferry fares for ICE cars.
1999	Parking Fees	Free municipal parking for EVs. From 2018, Parking fees for EVs was introduced at a local level with an upper limit of 50%.
2000	Company Car Tax	From 2000 to 2018, company car tax was reduced by 50%, from 2018-2022 this was reduced to 40% and from 2022 it is at 20% reduction.
2001	Exempt from VAT on purchase	In place
2005	Access to Bus Lanes	From 2016, new rules allow municipalities to limit access to only include EVs that carry one or more passengers.
2015	Exemption from 25% VAT on vehicle leasing	In place

Table 6: Incentives related to low-emission vehicles. Based on (Fridstrøm, 2021).

5.4 The Regional Perspective

The regional policy is adopted by Rogaland city county. This policy lays the foundation that the current municipalities are obliged to follow. The regional policy shall maintain national interest in decisions, goals, and guidelines from the Storting and the government.

The county is responsible for environmental management and climate measures for the region. This includes the creation of regional plans which coordinate national and local policies and translate national goals into regional and local ones. In addition, the county is responsible for the county roads.

The mobility provider for the region is Kolumbus, which is owned and managed by Rogaland County Council. In 2019, Kolumbus was responsible for 450 buses, 10 speedboats and 3 ferries and provided for approximately 85 000 daily trips across the region (Kolumbus, 2019).

In 2007 Rogaland County decided that a comprehensive and overall energy and climate plan should be created to clarify the state's, county municipality's and municipalities' goals and tools. In 2010 the county council adopted a regional climate plan 2010 – 2020, which includes the regional climate policy. The main objective in this plan was that Rogaland should reduce its energy consumption by 20% by 2020 and reduce its GHGs between 600 000 to 700 000 CO_2e tonnes, when large-scale industry is excluded (Rogaland fylkeskommune, 2010).

The land and transport sector was identified as the sector with the largest emissions, with a target reduction of 550 000 t/CO_2e. The identified areas of action with target reduction levels are shown in Figure 12.

Area of action	Estimated reduction	
Improved vehicle technology	230 000	t/CO2e
Optimization of land, sea and air transport	60 000	t/CO2e
Concentrated area development	66 000	t/CO2e
Environmentally friendly transport	30 000	t/CO2e
Electrification of transport to a large extent	100 000	t/CO2e
Road pricing and further restricitive parking	64 000	t/CO2e
	Total: 550 000	

Figure 12: Rogaland Fylkeskommune Road Transport Emission Targets - Area of action. Based on (Rogaland fylkeskommune, 2010).

Following the adoption of the plan in 2010 an action program was adopted in 2014 which specified specific measures that the county must carry on its own. This provides greater clarity and detail and responsibility for the respective areas. However, there is no information to state whether an assessment of the targets was made following the conclusion of the period in 2020.

6. STAVANGER'S APPROACH

6.1 Climate and Enviromental Plan 2010 - 2025
6.2 Land use and transportation sector
6.3 Comparison with Trondheim

6.0 Stavanger Municipality's Approach to Decarbonisation

Over the course of 20 years, Stavanger municipality has published several reports regarding emissions and the environment. The first climate plan for Stavanger was adopted in 2002. Since then, two main climate plans have been published, one in 2010 and one in 2018. In line with the increasing attention to climate change nationally, the plans have also become more comprehensive. In this section, we address the local policy in Stavanger as set out in the Climate and Environment Plan 2010 - 2025 and 2018 - 2030.

These plans are meant to be valid for longer time periods and were proposed by different administrations. In 2014 the local government decided that the climate plan should be re-evaluated every four years to see if measures are on track to reach their targets (Ueland, 2014). In addition, the municipality was instructed to create statistics on the discrepancy between each goal and the expected development. This should also suggest what is needed to achieve the goal.

Figure 13 shows a timeline of the main Rogaland and Stavanger climate plans and relevant updates.

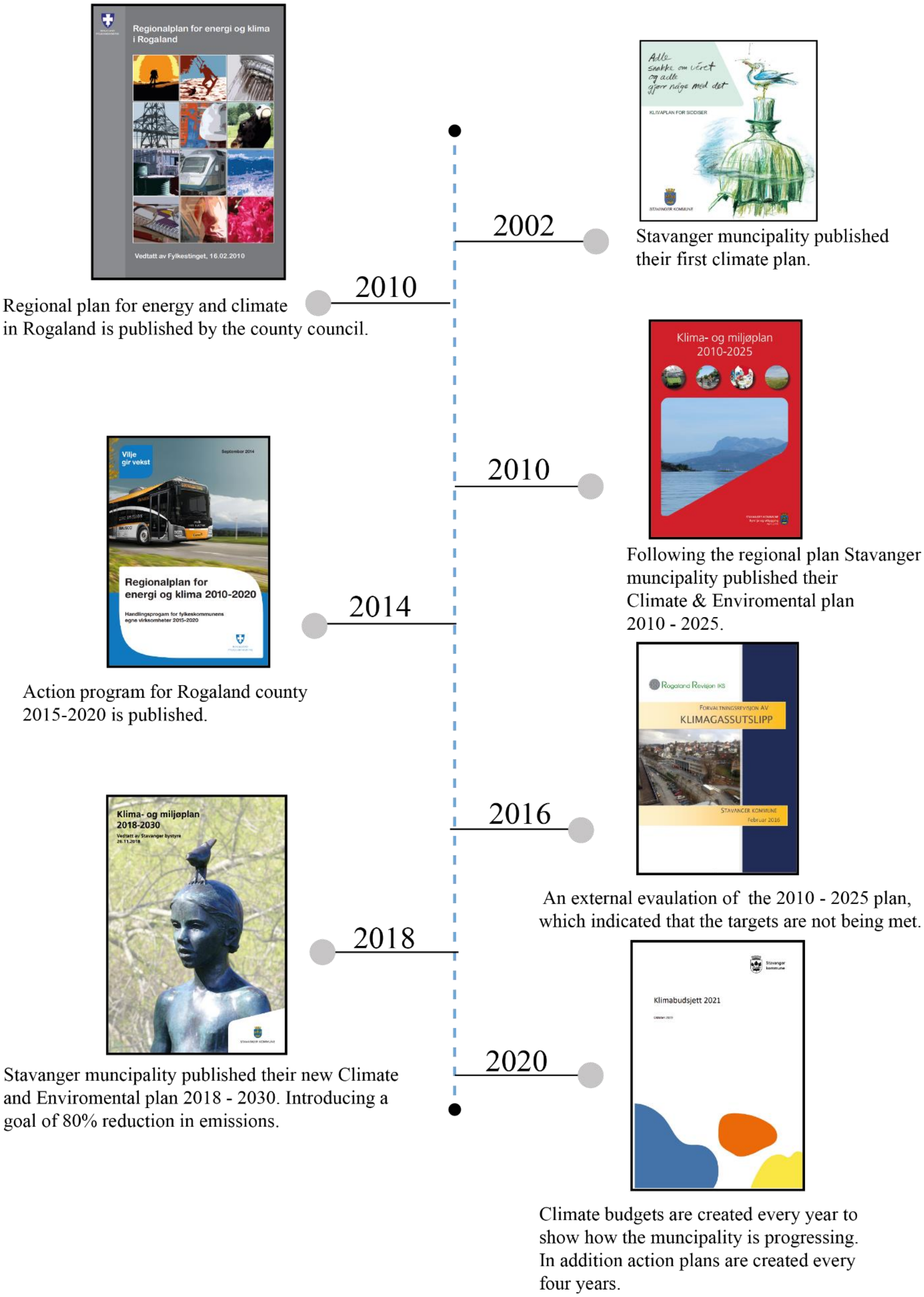

Figure 13: Timeline of Stavanger and Rogaland Climate Plans and supporting documents.

6.1 Climate and Environment Plan 2010 - 2025

Stavanger Climate and Environmental plan 2010 – 2025 was the municipality's public climate and environmental policy until 2018. The sectoral plan is part of the municipality's policy to contribute towards meeting the national targets, as agreed in 2008 (Stavanger Kommune, 2010). The Urban Environment and Development section within the municipality was responsible for the creation of the plan. The plan was voted on in the city council June 14, 2010, before full adoption.

The plan has a goal of reducing emissions with 85 000 tonnes CO_2e by 2020 compared to 1991. This equates to an overall reduction in emissions of 20%, and a reduction of 30% compared with 2009 emission levels. The plan identifies the following targets for the sectors:

- 35 000 tonnes – stationary energy use
- 5 000 tonnes from the processing industry and agricultural sector
- 45 000 tonnes from the transportation sector (40 000 tonnes from road traffic)

It should be noted that these figures relate to direct emissions that emanate within the municipality. As such, there is no accountability in relation to any indirect emissions, for example, related to emissions from Sola airport. It should also be noted that as part of the target and goal section of the plan document, there is recognition from the municipality that there is a need to reduce indirect GHGs in the period from 2009 to 2025, albeit the targets relate to the year 2020.

In 2014 the city council approved that the municipality should produce an analysis of the discrepancy between the target of 20% reduction and the expected development. An evaluation report of the 2010 plan was published in 2016 to provide a status update on the progress made so far (Stavanger kommune, 2016).

6.2 Transportation Sector in the 2010 Plan

The Climate and Environment Plan 2010 - 2025 provides specific targets for transportation listed under "Land use and transportation". Within this chapter the plan identifies four focus areas, which this thesis focuses on. The plan recognises that the transportation sector is the greatest source of direct CO_2 emissions and as such there is recognition that there is a need to target a reduction in emissions of 45 000 tonnes.

FOCUS AREA	ASSUMED T/CO_2E REDUCTION	TARGET
1. **Improved Vehicle Technology**	20 000	Reduce emissions per km driven
2. **Concentrated Land Development**	15 000	Reduce number of km per trip
3. **More Environmentally Friendly Transport**	5 000	Reduce emissions per km driven
4. **Transport Efficiency Improvement**	5 000	Reduce number of km driven by car
TOTAL	**45 000**	

Table 7: Emission targets from the Climate & Environmental plan 2010 – 2025. Based on (Stavanger Kommune, 2010).

We now seek to provide an analysis of the various policy methods that are discussed within the four focus areas. This includes an analysis of the types of policies, potential interventions that are discussed and the role of the municipality in influencing the relative policy.

Land use and transportation is divided into four focus areas based on the regional polices for transportation. These are summarized in Table 7. The municipality acknowledges that there are uncertainties related to the assumed CO_2 reductions and predicts that improvements in vehicle technology will contribute most towards reductions. As set out in the literature review, we highlighted three main interventions for decarbonising the transport sector: (1) reducing the need to travel, (2) improvements in technology, and (3) enhancing transition to more environmentally sustainable modes of transport. We can see that the four focus areas are directly linked to the interventions for decarbonising the road traffic sector.

Whilst the 2010 plan summarizes the municipality's climate policy for the respective period, there are limitations to what the municipality has jurisdiction over. Within transportation the municipality has impact on area and transport planning, parking, charging infrastructure and facilitating environmentally friendly travels (Miljødirektoratet, 2021a).

We note that the municipality has taken the approach of adopting a wide range of measures and policies to impact all aspects of the transportation sector that are recognised in the literature as important in terms of decarbonising the transportation sector.

6.2.1 Focus Area 1 – Improved Vehicle Technology

The first focus area concentrates on incorporating technological development as a means of decarbonising the road transportation sector (Stavanger Kommune, 2010). Several approaches to encouraging and influencing the transition to lower emitting vehicular choices have been considered by the municipality. These include:

- Contributing information on the importance car technology has for emissions.
- Choosing low-emission / emission-free technology for its own vehicle fleet.
- Work to influence central authorities on regulations in favour of eco-friendly technology (inclusive of cheaper parking and reduced toll rates).
- Develop 250 re-charging stations.

The municipality has estimated that these measures have a potential of reducing emissions by 20 000 CO_2e. Through technological innovation, as per Table 7, they have identified that this can contribute to a reduction in emissions per driven km.

As described in the literature review, given the historical reliance on fossil fuelled vehicles within the transportation sector, a transition to new technologies has the potential to bring about several benefits including a reduction in air emissions, noise pollution and provide greater grid stability among other things.

The approaches that have been identified by the municipality are mainly "carrot" measures to favour eco-friendly technology. Whilst there are identified measures that the municipality can seek to influence, they have limited tangible measures except for incorporating low emission vehicles into their own fleet and influencing the development of infrastructure to support the promotion of low-emission vehicles. The policy relies on measures at a central level, particularly in relation to financial incentives and the availability of technology outside the municipality's control. This is acknowledged in the plan.

The policy and the targets are heavily reliant on the financial measures introduced at a national level. As identified by Huan and Ge (2019), it is the financial incentives that can drive the most significant change in the transition. There are also potential downsides with promoting low-emission vehicles as identified in the literature review. One of these is that ownership of e-vehicles can potentially discourage the use of alternative modes of environmentally friendly travel such as walking, cycling or public transport.

As stated above, one potential limitation to the policy approach is a reliance on the availability of technology in the market that can compete with fossil fuelled cars, in terms of price, range, available infrastructure etc. Another potential limitation to the policy is the emphasis on cars while there is limited focus on alternative technologies for other modes of transport such as buses.

6.2.2 Focus Area 2 – Concentrated Land Development

The second focus area identified within the 2010 plan is to reduce emissions through the concentration of land development. There are several means by which the municipality proposes to do so:

- Stavanger will prioritise development along public transportation axes and in existing urban areas, providing a range of housing and workplaces, with a reduced need to travel. This can be done through the municipality's role as planning decision maker but also in their capacity as landowner.
- By facilitating self-contained neighbourhoods with reduced transportation needs, through strict localisation requirements. One of the principles being that housing areas shall be within bicycling/walking distance of a major employment area and also be close to public transport facilities with high frequency to other working locations. In addition, developments should be equipped with a range of facilities such as shops, nurseries, schools etc.
- By prioritising safe and simple public transportation and with parking lots at traffic hubs.

As noted in Chapter 5, the municipality recognises that they have relatively high degree of control over development, to stimulate a reduced need to travel. The municipality recognises, however, within their policy that cooperation with neighbouring municipalities is necessary for a well function public transportation.

The municipality identified concentrated land development as the area that can contribute to the second largest reduction in emissions over the time period, identifying a reduction of 15 000 tonnes between 2009 and 2020 and a target to reduce number of km per trip. The approach seeks to reduce the need to travel, with the aim of locating inhabitants in closer proximity to work and other destinations and where they can connect into the wider transport network. As noted within the literature review, land use measures can be difficult to measure given the length of time that development takes and it is also influenced and often curtailed by the urban form that already exists (Aditjandra, 2013).

The concept of densification is that dense land use gives on average shorter travel distances between different functions in the urban structure compared to scattered land use. This makes it possible and attractive for more people to walk or cycle in dense cities, rather than use cars.

Whilst it is recognised widely in literature that concentrated land development can bring about change in the transportation system, it is a long-term strategy, and it brings about a multitude of challenges. This includes challenges from an economic, social, environmental, and planning perspective which might include negative feedback from stakeholders, reliance on land acquisition/availability and having the land to be able to deliver a development that implements the requirements from the 2010 plan. In addition, once developed there is the impact of transit-induced gentrification, which limits accessibility to the development as a result of inflated prices on the land and housing, which again might lead to people moving further afield and increasing their travel distances (Derakhti & Baeten, 2020).

6.2.3 Focus Area 3 – More Environmentally Friendly Transport

The third focus area within the 2010 plan is to reduce emissions through enabling an increase in the use of environmentally friendly means of transport, by encouraging modal shift. The plan states that they shall do this by:

- Working towards providing a more robust public transport system with improved regularity. This includes giving priority to buses and to start on an urban railroad project.
- To enforce a more restrictive parking policy and to encourage the use of public transport, walking and bicycling.
- To facilitate safe bicycle parking at public transport hubs.
- To improve bicycle paths and networks, particularly in the urban areas to make it a more attractive proposition. This will include reducing the number of conflicts on the existing network, and to build new routes to ensure reduced distances and times to reach the main working areas and public transport hubs.

The municipality has targeted a reduction of 5 000 t/CO_2e and to reduce emissions per km driven, as per Focus area 1.

The policy focuses on providing a range of “carrot and stick” measures. “Carrot” methods to encourage cycling by increasing cycle parking and improve bike networks and to provide better public transport offer. The plan suggests to adopting a restriction on car parking, a “stick” type policy, used to discourage using the car.

While the municipality plays a key role in the transportation network, being a landowner and responsible for land use planning, it is the Rogaland County Council that are the “mobility operator” and are responsible for the management and operation of the public transport system across the region inclusive of Stavanger. Another important aspect is that it also requires cooperation with neighbouring municipalities.

Modal shift is widely regarded as a key method of decarbonising the transportation sector and whilst “carrot” type policies have seen mixed results, it is the restrictive “stick” methods that generally give better outcomes, albeit these are generally less politically palatable. We can see from the approach that the municipality has taken that there is a tendency towards promoting more environmentally friendly methods of transport and less on restrictive methods.

6.2.4 Focus Area 4 – Transport Efficiency Improvement

The final focus area that the 2010 plan seeks to help reduce emissions by is through transport efficiency improvement. The plan identifies several approaches for how this can be achieved:

- To collaborate with other parties in the region to ensure the necessary standard of service for citizens and companies. This includes parking, car and bicycle schemes, tax policies and information. The aim of this is to champion efficiencies within the transportation in urban areas and logistic sectors. There is reference to several examples such as how kindergarten places are allocated and to introduce car sharing schemes in the city centre and in urban districts such as Jåttåvågen and Urban Sjøfront.
- The municipality will test out an Intelligent Transport System (ITS), using information and communication technology (ICT) as a method of contributing to an improved transport system, improved traffic flow and reduced environmental impact from road haulage. This will also contribute to traffic control and give priority to buses and public transport.
- A key aspect of the policy is a commitment to an urban railway system alongside offering a public transport network with high frequency.
- Consider establishing a central distribution point to reduce freight traffic within the town centre.
- In addition, the focus area specifically references restricting car parking, through reduced parking of private cars during working hours and by introducing parking fees in shopping malls and business areas.

Focus area 4 can be identified as a combination of promoting technologies whilst also encouraging modal shift. The interventions that have been suggested under the policy includes targeted behaviour programs, the promotion of car sharing schemes, restricting car parking, and using technology in the form of ICT as a method to reduce emissions. In addition, this policy also considers commercial vehicles (lorries and vans) which have otherwise been overlooked in the plan. They have identified the need for a central distribution point for Stavanger to provide a more efficient logistics service within the area.

This focus area seeks to adopt primarily "carrot" type policies with the introduction of measures aimed at bringing about change. Although there are restrictive "stick" measures such as limiting car parking. Parking restrictions is a key policy which Stavanger municipality has jurisdiction over. As planning authority, the municipality can "place restrictions on parking capacity through regulations in municipal sub-plans and zoning plans. Establish regulatory provisions on the upper and lower limits for parking coverage in accordance with the Planning and Building Act" (Miljødirektoratet, 2021b). The municipality can also reduce the parking capacity and increase parking prices where they have ownership.

The plan indicates that the methods proposed could bring about a reduction of approximately 5 000 CO_2e tonnes. The specific target indicator for the focus area, as referenced above, is to reduce the number of driven km specifically by car i.e., primarily through means of modal shift.

6.3 Comparison with Trondheim

In 2010, Trondheim adopted their Energy and Climate Action Plan (Trondheim Kommune, 2010), the same year that Stavanger adopted their 2010 plan. The purpose of this section of the thesis is to provide a comparison of the documents to understand and be able to compare how two similar size cities have sought to approach the goals of reducing emissions within the municipality. More specifically how policies and targets compare in relation to the road transportation sector. The rationale for using Trondheim as a point of comparison to Stavanger, is firstly that the settlements are of comparable size being the third (Trondheim) and fourth (Stavanger) largest cities in Norway, with populations of approximately 200 000 and 140 000 respectively (Statistics Norway, 2021a). In addition, the plans were adopted in the same year, both in 2010, with environmental targets over a ten-year period.

For Trondheim, it should be noted that in 2008 the city adopted an Environmental and Transportation Package which has been incorporated into the Energy and Climate Action Plan. In Table 8, we set out some of the key aspects of the plan documents.

	Stavanger Municipality	Trondheim Municipality
Plan	Climate and Environment Plan 2010-2025	Energy and Climate Action Plan 2010-2020
Overall targets within the Plan	Reduce emissions by 85 000 t/CO_2e compared with 1991 by 2020. 20% reduction compared with 1991 and 30% compared with 2009.	25% reduction between 1991 – 2020. 70-90% reduction between 1991 - 2050. Emissions shall not exceed 372 000 tonnes CO_2e by 2020.
Road transportation targets (per annum)	45 000 t/CO_2e (equating to a 14% reduction of total emissions). Period: 2010 to 2020.	47 000 t/CO_2e (equating to a 20% reduction). Period: 2008 – 2018
Main measures & identified reduction potential	1. Improved Vehicle Technology (20 000 t/CO_2e). 2. Concentrated Land Development (15 000 t/CO_2e). 3. More Environmentally Friendly Transport (5 000 t/CO_2e). 4. Transport Efficiency Improvement (5 000 t/CO_2e).	1. Area (Densification and Localization of Housing and Employment) & Parking Policy (12 000 t/CO_2e). 2. Restrictive Private Car Measures (18 000 t/CO_2e). 3. Public Transport Improvement (3 000 t/CO_2e). 4. Strengthening Walking and Cycling (6 000 t/CO_2e). 5. Local Environmental Car Investment & Mobility Planning (18 000 t/CO_2e).

Table 8: Comparison between Stavanger and Trondheim. Based on (Stavanger Kommune, 2010; Trondheim Kommune, 2010)

There are some similarities in terms of the approach when comparing the plans. Both plans have emission reduction targets as a percentage of the current emissions, with Stavanger targeting a 20% reduction compared to 1991 and Trondheim a 25% reduction, albeit the Stavanger targets are evidently slightly less ambitious.

In addition, when we look at the strategies to decarbonisation within the transportation sector both municipalities adopt comparable approaches. They both consider a range of measures that seek to bring about change, incorporating the use of new technology, promoting modal shift towards more environmentally friendly forms of transport, and adopting policies that seek to reduce the need to travel i.e., through densification.

Whilst there are some notable similarities, there are also several differences between the plan documents. First, when we look at the targets that have been set within the road transportation sector, the Trondheim plan recognises the importance of national led policies as a means of reducing emissions. In fact, there is recognition that national policies relating to taxation of combustion engine cars along with financial incentives promoting low-emission vehicles could contribute towards a reduction of 46 000 t/CO_2e, or 46% of emission reductions from the sector. The 2010 Stavanger plan does not mention the contribution of national policies, albeit there is reference that national policy and external market factors will provide for a large proportion of the 20 000 t/CO_2e reduction.

Another key difference between the policy documents relates to the granularity and detail of the approaches towards reducing emissions. Whereas Stavanger provides reference to possible measures and policies that they will seek to introduce within their plan, Trondheim municipality provide greater detail in terms of the policy measures that they seek to propose and, they give sub-targets for the measures. As an example, while the Stavanger policy on concentrated land development (or densification) only mentions that this shall be achieved along public transport axes, the Trondheim plan goes further and states that 80% of all new homes shall be developed within the existing city limits and 60% of all new jobs shall be located within the "Kollektivbuen", a central area within Trondheim.

To encourage use of public transport the 2010 Stavanger plan identifies the need to develop the transport system with increased regularity. The Trondheim plan identifies several ways to improve the public transport system by prioritizing a more consistent and regular bus service, introducing priority signals for buses, reducing the price of buses and replacing diesel buses with electric, hybrid or biofuel buses. For each measure there is also an estimate of the impact it will have on reducing car usage. For example, an increased service with new routes and better service is estimated to produce a 0,7% reduction in car use across the municipality.

Another difference between the two approaches is the use of "stick" measures. Whilst the 2010 Stavanger plan has reference to a more restrictive parking policy, the Trondheim plan in addition proposes to introduce more toll roads as a means of restricting car use. Car parking restrictions are further detailed by having maximum car parking standards for new developments, stating that no more spaces will be introduced in the city centre, car parking prices should be increased, replacing street parking etc.

To summarise, both plans set out to achieve the goal of reducing emissions within the transport sector. There are similarities in terms of the range of measures that have been adopted. There are also differences in both the level of ambition in terms of target emission reductions and the specificity in terms of how the municipalities will go about reducing emissions and how the different stakeholders will be involved. The Trondheim plan identifies the government's role and public stakeholders that are responsible. For example, signal priority for buses requires involvement from Planning Department and the Norwegian Public Roads Administration. There is no reference of this within the 2010 Stavanger plan.

7. HAS PROGRESS BEEN MADE?

7.0 Has Stavanger made progress in decarbonizing the road transportation sector since 2010?

7.1 Introduction

In 2010, the municipality of Stavanger adopted a new Climate and Environment Plan for the period 2010-2025. As addressed in Chapter 4 the use of this policy document is a tool for the municipality to address decarbonisation across several sectors, inclusive of road transportation. In this chapter, we seek to assess "what" has happened over the time period from 2010 - 2020 and whether progress has been made in respect to the decarbonisation of the transportation sector in the municipality.

Using a range of indicators based on statistical data collected we seek to describe what has occurred over the time period of 2010 - 2020 (the latest available data). This data is set against the four focus areas identified within the transportation sector of the Climate and Environment Plan. It should also be noted that whilst the plan is for the period up to 2025, the targets are set for the period up to 2020.

To remind the reader, the four focus areas for decarbonisation are as follows:

FOCUS AREA	T/CO_2E REDUCTION	TARGET
Improved Vehicle Technology	20 000	Reduce emissions per km driven
Concentrated Land Development	15 000	Reduce number of km per trip
Environmentally Friendly Transport	5 000	Reduce emissions per km driven
Transport Efficiency Improvement	5 000	Reduce number of km by car
TOTAL	**45 000**	

Table 9: Emission targets from the Climate & Environmental plan 2010 – 2025. Based on (Stavanger Kommune, 2010).

As per our review in Chapter 6, whilst it is useful to note the target reductions for each of the focus areas it is very difficult to assess the impact on emissions for each specific area. Consequently, and, following our literature review, we look at a range of indicators that make up a useful alternative measure of emissions when considering whether progress has been made over the time period. The choice of measurements is considered relative to the focus areas and the methods of intervention identified under each area.

Our analysis considers whether progress has been made in the process of decarbonisation. As referred to in Chapter 4, "progress" has been identified as demonstrating a progression in the use of technology, modal shift (a reduction in car use and increase in alternative forms of transport) and whether there has been a demonstrable reduction in the need to use a car through densification.

Covid-19

As mentioned in Section 4.4, travel habits in 2020 have been impacted by the global pandemic. By the end of March 2020, the World Health Organisation (WHO) declared it a pandemic (De Vos, 2020). The spread of the disease resulted in unprecedented measures to restrict travel and activity participation through a range of social distancing measures to reduce and slow down the spread of the virus. The International Transport Forum,

(2020) stated that “the virus has transformed the positive aspect of public transport – the ability to move large numbers of people rapidly, efficiently and affordably – into a liability”. The impact on the use of public transport across Norway can be seen in Figure 14, highlighting the significant drop in passenger numbers for the year 2020, where passenger numbers fell by almost 30% across the country (Statistics Norway, 2022a).

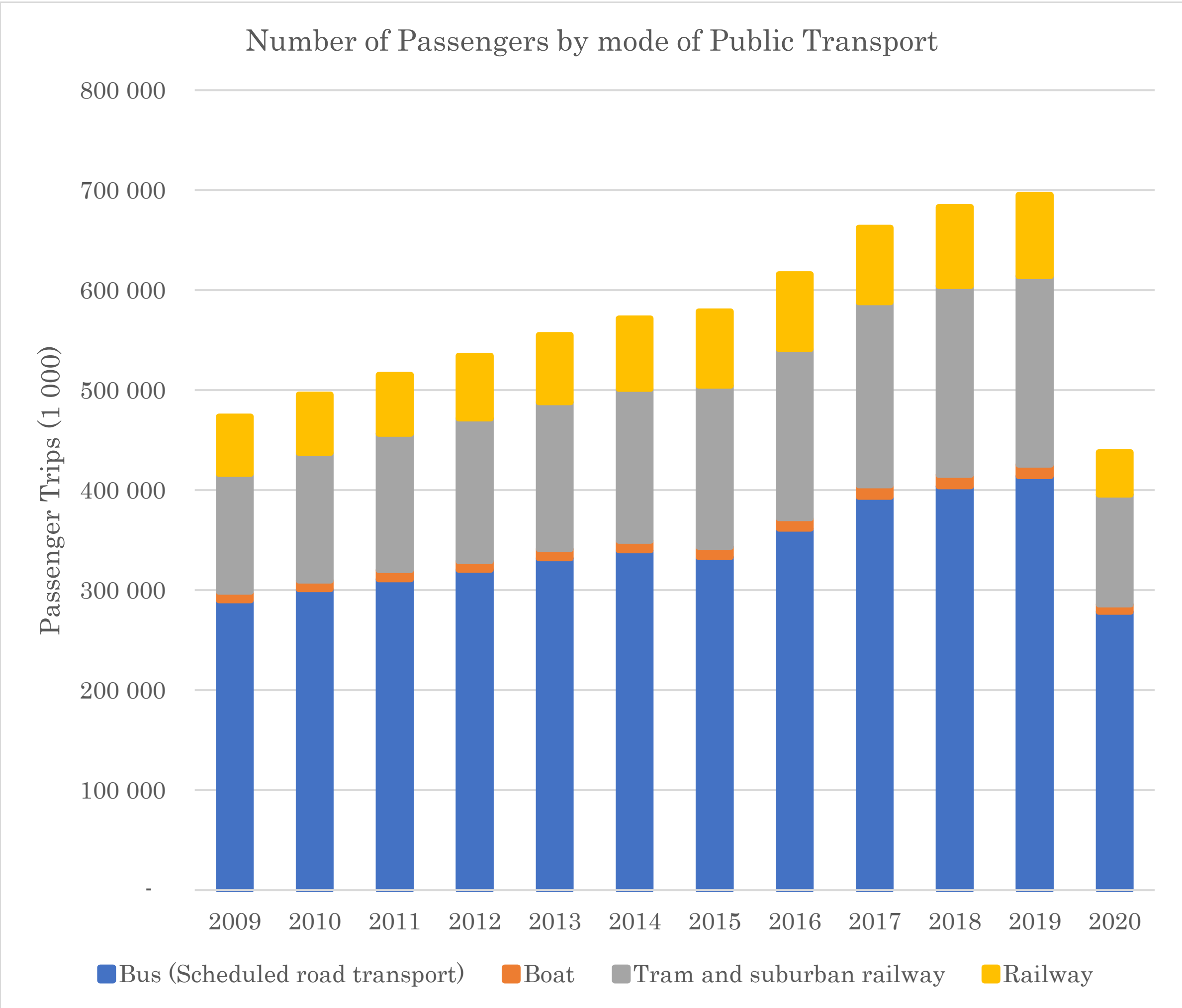

Figure 14: Public transport in Norway 2009 – 2020. Based on (Statistics Norway, 2022a).

7.2 Road Transport Emissions Analysis

As per the methodology chapter, the thesis undertakes an assessment of how the municipality has progressed in reducing their emissions. Because the methodology for calculating emissions has been amended since the Climate and Environmental plan 2010 - 2025 was adopted and the boundaries of the municipality has changed, we need to undertake a rebasing exercise using the latest and most up-to-date emission data available via the NEA.

Finnøy and Rennesøy were incorporated into the Stavanger municipality in 2020. Thus they were not part of Stavanger when the 2010 plan was adopted. However, the NEA data for Stavanger exclusively incorporates Finnøy and Rennesøy into the emission data from 2009. The only data we have found concerning road traffic emissions in Finnøy and Rennesøy is that in 2017, Finnøy road traffic emissions accounted for under 7% and Rennesøy approximately 12% (Stavanger Kommune, 2017). We are also not aware of any targets specifically set by the two former municipalities at the time. Therefore, our assessment includes both the former municipalities in our analysis.

The rebasing of the targets set in 2009, in relation to the Climate and Environment Plan 2010 - 2025 includes:

- Adjust the data, following the latest methodology for calculating emissions from the NEA.
- Finnøy and Rennsøy were incorporated into the municipality in 2020, but data from the NEA dating back to 2009 now includes them in Stavanger municipality.

As a consequence of these changes, we are not able to state whether emissions have reduced in accordance with the targets that were set at the time of adoption.

7.2.1 2010 Plan – Existing Targets

At the time of adoption, the 2010 plan based its reduction targets on the following:

- Total emissions in 2007 was: 286 000. This equates to 2.3 t/CO_2e per inhabitant.
- Land use and transportation contributed to 67% of the total emissions.

The targets for the 2010 plan were as follows:

- 30% reduction from 2010 (based on 2007 figures) to 2020, equating to a total of 85 000 t/CO_2e.
- Inclusive of population growth (as of 2009), the total reduction in emissions will need to increase to 120 000 t/CO_2e, if emissions per inhabitant are to remain the same as in the 2010 plan.
- 40 000 tonnes CO_2e (of the 85 000 t/CO_2e) are to be reduced from the road transportation sector. This equates to 14% of the total emissions in the municipality.

7.2.2 Rebasing the 2010 Plan Targets

As set out in the methodology, we have rebased the targets using the latest emission data.

1. Latest Data from Statistics Norway and Norwegian Environment Agency for 2009

- Population of Stavanger municipality: 128 288.
- Total emissions: 483 392 t/CO_2e. This equates to 3,77 t/CO_2e per inhabitant.
- Road transport emissions: 193 620 t/CO_2e. This equates to 1,51 t/CO_2e per inhabitant.

As already stated, these numbers are based on how emissions are calculated today and also include Finnøy and Rennesøy.

2. Rebasing of targets

To rebase the reduction targets in accordance with the NEA data we set the new amount for total emissions and road transportation as follows:

$$Total\ Emissions\text{: } 30\% \ * 483\ 393\ \mathrm{tCO_2e} = \ 145\ 017\ \mathrm{tCO_2e}$$

$$Road\ Transport\ Emission\text{: } 14\% * 483\ 393\ \mathrm{tCO_2e} = \ 67\ 675\ \mathrm{tCO_2e}$$

For the avoidance of doubt, 30% is the total reduction target from the 2010 plan, compared to 2009 levels. In addition, the 14% is the 40 000 t/CO_2e (road traffic) as a percentage of the total emissions figure provided within the 2010 plan, at the time of adoption (285 000 t/CO_2e). This gives the numbers shown in Table 10.

Alternatively, one could also have calculated the reduction for road transport as being the same fraction of the total reduction as in the 2010 plan. This would give a reduction of

$$\frac{40\ 000\ \mathrm{tCO_2e}}{85\ 000\ \mathrm{tCO_2e}} * 145\ 017\ \mathrm{tCO_2e} = \ 68\ 243\ \mathrm{tCO_2e}$$

This is only 1% higher than the number in Table 10 and thus we stick with this.

	Reduction (t/CO_2e)	Target Total (t/CO_2e)
Total	145 017	338 375
Road Transport	67 675	125 945

Table 10: Revised target.

7.2.3 Comparison from 2009 – 2020 (Total)

To assess whether the municipality has achieved their targets based on the revised numbers, we have undertaken a comparison between 2009 (the earliest available data and prior to the adoption of the 2010 plan) and 2019. As set out above, the year 2020 is an anomaly due to Covid-19 and therefore not a true projection of travel given the restrictions placed on the transport network.

We have, however, included, 2020 for the purpose of identifying the impact that the pandemic had on emissions and the road transport network. The numbers are shown in Table 11.

Road Transportation

Road Traffic	2009	2019	2020
Actual emissions (t/CO_2e)	193 620	144 062	133 687
Target emissions (t/CO_2e)		125 945	125 945
Target reduction t/CO_2e (% of 2009 RT emissions)		**67 675 (35,0%)**	**67 675 (35,0%)**
Actual reduction t/CO_2e (% of 2009 figures)		**49 558 (25,5%)**	**59 933 (31,0%)**
Difference between actual and target (t/CO_2e)		18 117	7 742

Table 11: Road traffic emission targets.

Relative to the targets, actual emissions in 2019 within the road transportation sector fell by approximately 50 000 t/CO_2e compared to the 2009 figures. This gives a reduction of

25,5% over the ten-year period, and an annual average reduction of approximately 5 000 t/CO_2e. This is below the target goal of 67 675 t/CO_2e target reduction (35%).

The impact of Covid-19 can be seen as emissions within the sector fell by slightly over 10 000 t/CO_2e from 2019 to 2020. This reduction is almost double the annual average of the previous 10 years. Despite this further reduction the road transportation emission target was still not met.

Table 12 shows the total emissions for Stavanger municipality using the adjusted numbers.

Total Emissions

Overall Emissions	2009	2019	2020
Actual emissions (t/CO_2e)	483 392	456 309	412 786
Target emissions (t/CO_2e)		338 375	338 375
Target reduction t/CO_2e (% of 2009 emissions)		**145 017 (30%)**	**145 017 (30%)**
Actual reduction t/CO_2e (% of 2009 targets)		**27 083 (5,6%)**	**70 606 (14,6%)**

Table 12: Overall emission targets.

As can be seen in Table 12, between 2009 and 2019, the overall emissions fell by approximately 27 000 t/CO_2e or 5,6%. As road transport emissions fell by more than the total emission reduction this means that there was a total emissions increase, when excluding the road transportation sector. It shows that the municipality was significantly behind the target in 2019.

The impact of Covid-19 did cause a further fall in the emissions with an overall reduction of just below 71 000 t/CO_2e between 2009 and 2020. Thus, even including 2020, the overall emission reduction was below half of the target rate.

Comparison on a per inhabitant basis

We also compare the data based on a per inhabitant basis to understand how emissions have changed in proportion to the population size. Considering the targets on a per inhabitant basis, and adopting the same methodology we get the following numbers:

- Road transport target = 125 945 t/CO_2e.
- Inhabitants (2009) = 128 288.
- Target emissions for road transport per inhabitant = **0.98 t/CO_2e**.
- Target reduction per inhabitant = 0.53 t/CO_2e

Road Traffic	2009	2019	2020
Emissions (t/CO2e)	193 620	144 062	133 687
Population	128 288	142 034	143 574
Emissions per inhabitant (t/CO2e)	1,51	1,01	0,93
Actual Reduction (t/CO2e)		0,50	0,58

Table 13: Comparison per inhabitant.

As shown in Table 13, based on the methodology above, we see that from 2009 to 2019 emissions reduced by 0,50 t/CO_2e per inhabitant falling just short of the target on a per inhabitant basis. However, in 2020, further demonstrating the impact of Covid, road traffic emissions reduced to 0,93 t/CO_2e per inhabitant, a fall of 0,58 t/CO_2e per inhabitant. These figures would demonstrate that on a per inhabitant the target emission has been reached if 2020 was included. However, the emission targets are not set on this basis and are primarily considered on a total emissions account.

7.2.4 Road Transport Emissions by Vehicle Type

Emissions from the road transportation sector comprise direct emissions from the various vehicular types. All data relates to emissions that have occurred within the municipal borders. Figure 15 shows the emissions from the various vehicle types.

In the period 2009 to 2019, we can see that emissions for all vehicle types have seen a reduction in emissions. Cars saw the greatest reduction both on an overall basis, falling over the period by 37 054 t/CO_2e and 22% on a proportional basis. In the year 2020, there was a further reduction in car emissions by about 10 000 t/CO_2e, again demonstrating the impact of Covid-19. On a proportional basis, in 2009 cars accounted for approximately 68,1% of road transport emissions which was reduced to approximately 65,8% by 2019.

On a proportional basis, vans saw the greatest reduction in emissions between 2009 and 2019, seeing a fall of approximately 33% overall. Over the same period, emissions from busses fell by 22% and lorries by around 4%.

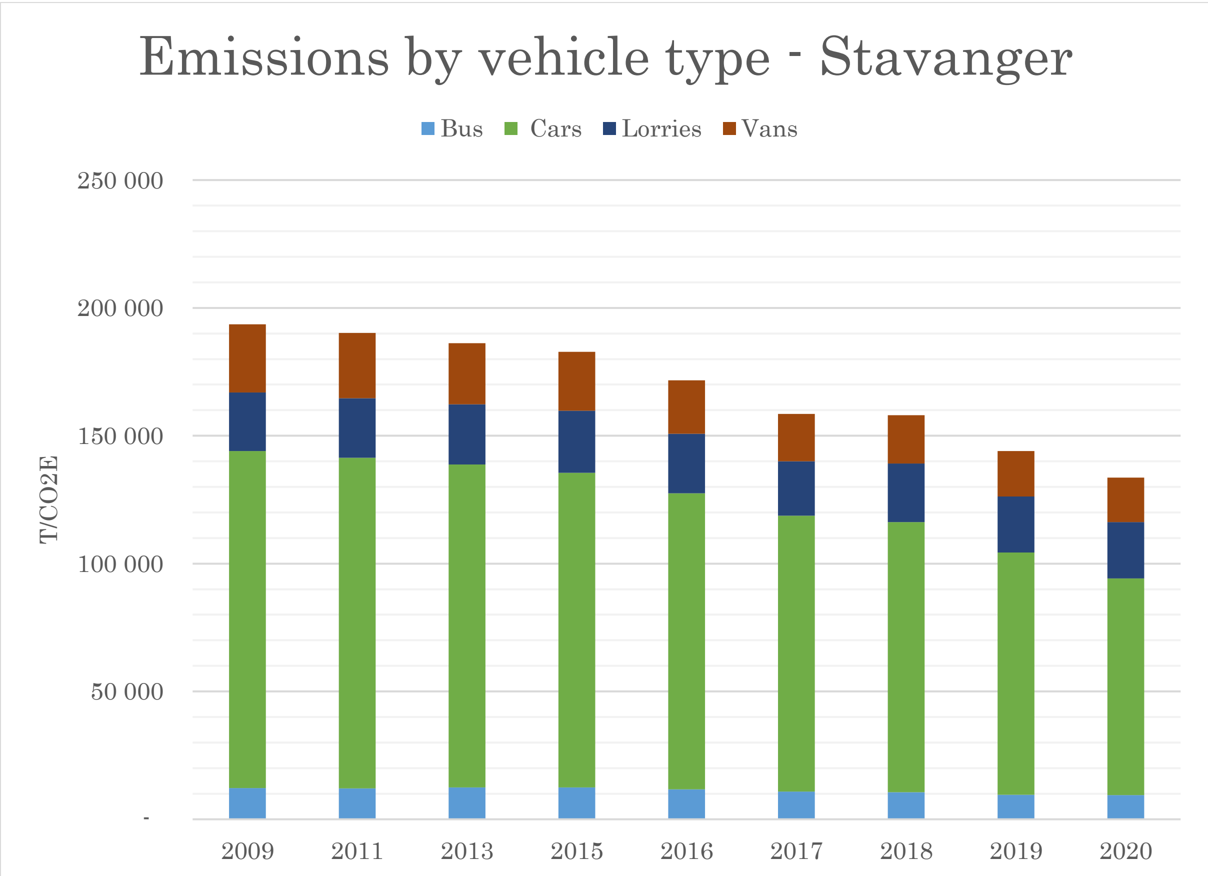

Figure 15: Emissions by vehicle type - Stavanger. Based on (Miljødirektoratet, 2022).

Next, we consider a range of indicators based on the focus areas to establish whether "progress" has been made to decarbonising the road transport sector. Details of the policies for the focus areas can be found in Section 6.2.

7.3 Focus Area 1: Technological Development - Indicators

Technological development was identified by the municipality as the area that can contribute to the largest reduction in emissions over the time period, identifying a reduction of 20,000 tonnes between 2009 and 2020. An additional target was to reduce emissions per driven km. It should be noted that reductions in emissions following this focus area is primarily driven by global development, in combination with national incentives, something which is acknowledged in the plan.

In this section we have considered a range of indicators to assess how the municipality is progressing in its transition towards lower emission technology.

Emissions per driven km

Based on statistics available from Statistics Norway and the Norwegian Environment Agency, we show in Table 14 that the emission intensity for all vehicular (inclusive of lorries, vans, cars and buses) traffic has reduced between 2009 and 2019 by about 27g/CO_2e per km driven. For cars (only), a similar pattern can be seen in Table 15 with emission intensity reducing from about 200g/CO_2e to approximately 170g/CO_2e per km driven and with a further fall in 2020.

Year	Road traffic volume – all registered vehicles (Million km)	Road transport emissions (Stavanger registered vehicles) t/CO_2e	Kg/CO_2e per km
2009	926,3	218 925	0,236
2019	792,4	166 214	0,209
2020	843,4	154 885	0,184

Table 14: Road transport emissions for all Stavanger registered vehicles. Based on (Miljødirektoratet, 2022; Statistics Norway, 2022e)

Year	Road Traffic Volume - Cars (Million km)	Road Transport Emissions (Stavanger registered cars) t/CO_2e	Kg/CO_2e per km
2009	725,8	144 732	0,199
2019	635,3	107 721	0,169
2020	670,8	96 260	0,144

Table 15: Road traffic emissions for cars registered in Stavanger. Based on (Miljødirektoratet, 2022; Statistics Norway, 2022e)

Car Registrations

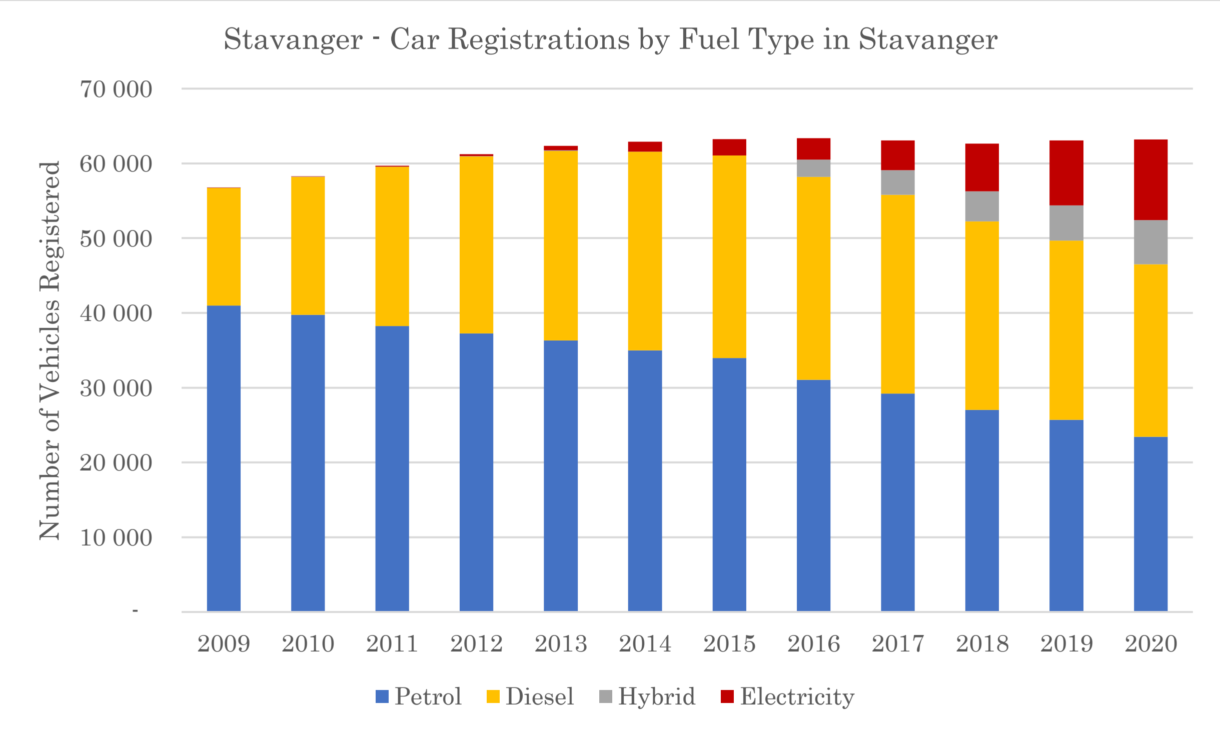

Figure 16: Private car registrations. Based on (Statistics Norway, 2022b).

Another indicator demonstrating how technology is developing amongst the car fleet in Stavanger can be demonstrated through a review of the registered cars. As shown in Figure 16, over the course of 10 years the fuel mode of car registrations in Stavanger has changed drastically. In 2009 the car fleet consisted primarily of petrol (40 997) and diesel (15 737) fuelled cars with just 50 electric cars and four hybrid cars registered within the municipality.

By 2019, the vehicular fleet had increased by a total of 6 286 cars. However, the composition of the fleet had changed considerably. Petrol cars had reduced by 25 702, a reduction of about 15 000, diesel cars had increased by approximately 8 000, and electric and hybrid cars now comprised a total of 13 412, or 21% of the total car fleet, compared with less than 0,1% in 2009. Despite the Covid-19 pandemic, in 2020 this trend increased further whereby electric and hybrid cars totalled 10 758 and 5 905 respectively or approximately 26,4% of the total registered cars.

Other Vehicles – Buses, Vans, and Lorries

Whilst there has been a significant change in the number of registered electric cars, there has been slower progress for buses, vans, and lorries. In terms of the registered lorries, (Statistics Norway, 2022b) only one electric lorry was recorded in 2019, whilst the majority of the lorry fleet are diesel. In terms of vans, there has been some progress with five electric vans in 2009, compared to 256 in 2020. Most of the registered van fleet, however, runs on diesel albeit the number of petrol fuelled vans has fallen from 1 259 to 412.

In 2009 there were 417 buses registered in Stavanger. In 2020 this number had increased to 750. In addition, whilst most of these buses run on diesel, there are now 16 that run on electricity. We are aware that Kolumbus, the Rogaland mobility provider, currently has 5 electric buses in operation within Stavanger (Kolumbus, 2019).

Re-charging Stations

As set out in the 2010 plan, Stavanger municipality aimed in 2010 to establish 250 charging stations. There are no official statistics on the increase of charging stations in Stavanger over the last 10 years. However, Andersen, (2010) stated that prior to 2010 Stavanger had 22 charging points, with 49 new charging stations scheduled to be set up during the summer of 2010. The difference between a charging point and a station is that a station consists of several single charging points. According to the Norwegian Electric Car Association Stavanger had 160 publicly available charging points in 2018 and 368 in 2019 (Støen, 2019). As of March 2022, there are 519 charging points in Stavanger. As it varies how many charging points each charging station has, we cannot say exactly if 250 charging stations have been established in Stavanger in the last 10 years, as was the goal of 2010. Still, the number of charging points has gone from 22 to 519 in the last 10 years (Bøe, 2022). It is also important to emphasize that these are available public charging points, and that private charging stations and points are not included.

Stavanger municipality along with several other municipalities in Rogaland has created a strategy for establishing charging infrastructure in the region. This sets demands for minimal number of charging points at city centres, malls as well as demands for charging points in zooning plans for new housing areas (Rogaland, 2017). In addition, Stavanger parking which is a municipal enterprise has established 139 charging points within their parking houses over the period and 28 charging points along public streets (Stavanger Parkering, 2022).

Stavanger Municipality Vehicle Fleet

As stated in the Climate and Environmental Plan 2010 - 2025 the city will lead the way by choosing the best possible technology for its own vehicles. Figure 17 shows the proportion of their vehicle fleet that runs on electricity for the time period 2017 to 2020. During this time the percentage has increased from just below 19% to 48% in 2020.

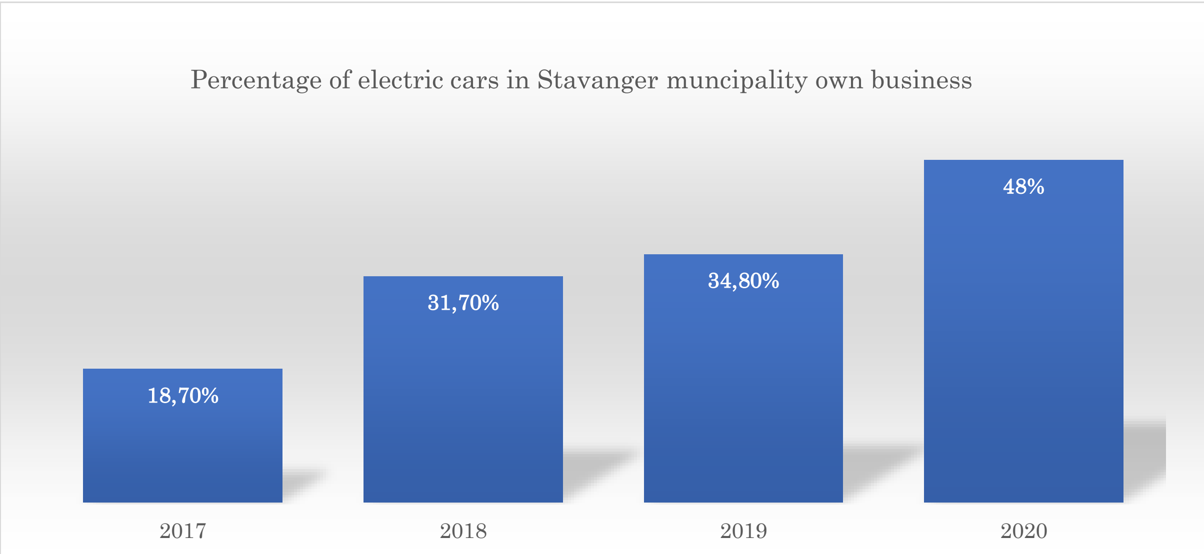

Figure 17: Percentage of electric cars in Stavanger municipality own business. Based on (Stavanger Kommune, 2020).

7.4 Focus Area 2: Concentrated Land Development

The municipality identified concentrated land development as a focus area that can contribute to the second largest reduction in emissions from 2010 to 2020, identifying a reduction of 15,000 tonnes between 2009 and 2020 and a target to reduce the number of km per trip.

The municipality has within its 2010 plan and also as its function as the planning authority sought to concentrate on densification to reduce the need to travel through transit-oriented development.

To assess and measure whether progress has been made, we consider a range of indicators. However, it should be noted, as referenced in the methodology chapter, that we have not used geographic information systems (GIS) as a tool for assessment, due to the complexity and time-intensive nature of these. The use of GIS would be particularly relevant for this focus area. However, we have considered a range of other indicators.

Number of km per trip

The 2010 plan targeted a reduction in the number of km travelled per trip. The National Travel Habits Survey (NTS) provides details on several aspects that can give insight on this. As part of the survey respondents provide details of average daily trip lengths. In the 2013/14 survey (Hjorthol, Engebretsen, & Uteng, 2014) respondents from Stavanger reported an average trip lengths of 9,5km (20 minutes), while in 2019 (Grue, Landa-Mata, & Flotve, 2021) the same question gave an average daily trip of 11,6km (21 minutes).

Average Road Traffic Volumes – Private Cars

Statistics Norway has data giving the average traffic volumes by vehicle type registered within the municipality. This includes details of the average traffic volumes conducted by private cars over the period 2009 to 2020.

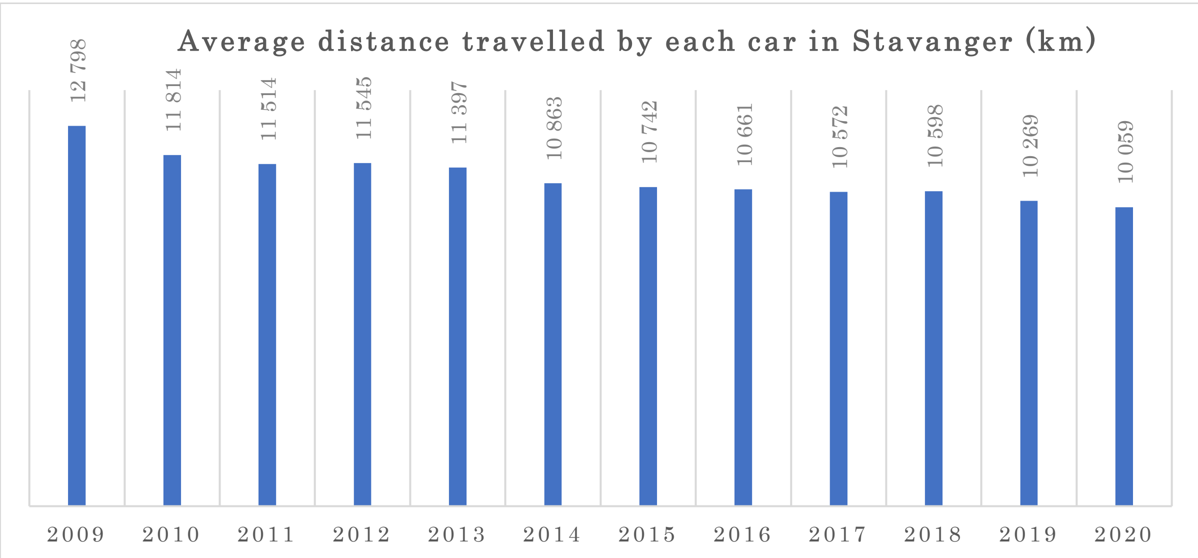

Figure 18: Average road traffic volumes by car. Based on (Statistics Norway, 2022e).

The data in Figure 18 shows that on average, cars registered within the municipality of Stavanger travelled less per year in 2019, compared to 2009. The average passenger car travelled approximately 12,800 km per annum in 2009 and this has reduced to 10,269 in 2019. This data is supported by that the total volume travelled by cars registered in Stavanger, has reduced from 758,8 million km to 635,3 million km. Whilst the data does not provide details on average km per trip, the information implies a reduction in car travel. It should also be noted that this data relates to vehicle kilometres travelled for those cars that are registered within the municipality, this does not capture information related to vehicles travelling within the municipality that are registered outside of the municipality.

Population Densities

As part of the Statistics Norway database, we can analyse several aspects relative to population densities, particularly relative to building stock which is important when considering whether there has been progress in terms of people living more densely, as per the proposed policy.

	2013	2014	2015	2016	2017	2018	2019	2020
Area of urban settlements (km²)	42,36	43,43	43,62	43,85	43,95	44,11	44,12	44,13
Number of residents in urban areas	129 728	131 769	133 302	134 420	134 642	135 190	136 138	137 663
Average number of residents per km²	3 063	3 034	3 056	3 065	3 064	3 065	3 086	3 119

Table 16: Population density 2013 – 2020. Based on (Statistics Norway, 2021a).

It is important to first point out that we have excluded data available prior to 2013 as a different methodology was in place for measurement of the boundaries of urban settlements, defined in Appendix 1. However, as shown in Table 16 we can see that after 2013 there have been two key changes. Firstly, the area of urban settlement grew, year-on-year. This implies that there was an extension of the development area involving development on greenfield, or previously unbuilt areas. The second aspect is that despite the marginal increase in the settlement boundaries, there was an overall increase in average population densities across the municipality, equating to just under 2% increase in density over the period 2013 - 2020, although with a 1% increase from 2019 to 2020.

Strategic Development and Densities

The indicators above demonstrates that average population densities have increased, there has been an increase in the number of households without a car and the average road traffic volumes for cars registered within the municipality has fallen. We also need to consider how the municipality has grown from a development perspective in terms of the number of dwellings registered and if Stavanger is seeking to focus on developments in specific areas.

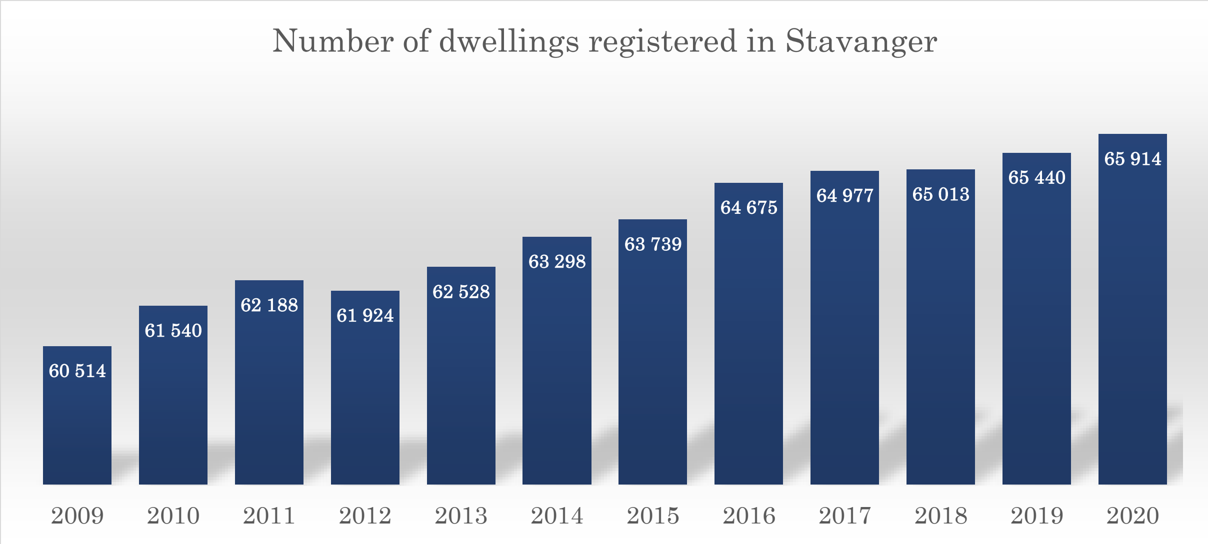

Figure 19: Dwellings registered in Stavanger. Based on (Statistics Norway, 2022c).

In Figure 19 data collected from Statistics Norway show that between 2009 and 2020 the number of dwellings increased by 5 400 homes, a 9% increase over the period. This also demonstrates an average increase of 450 homes per annum. Whilst this does not give an indication of the concentration, it does show growth in housing, albeit lower than the population growth at 13,62%.

The municipality of Stavanger as both the planning authority and a major landowner can influence the number of new developments and their location. There are several large strategic developments close to strategic hubs that are proposed to deliver high-density development in line with policy. This includes Hinna Park and Jåttåvågen, which are to deliver 1 500 homes and 6 000 new jobs (Stavanger Utvikling, 2021). The first phase of these has already been developed and was planned specifically within the 2010 plan. A second strategic area is Paradis, which has been identified for up to 10 000 new jobs and 1 000 new homes. Several phases of the development have been delivered, the first being area B2 for 210 apartments, which was approved in January 2016 and completed in 2021 (Bane NOR, 2022). Another key strategic site is Madla-Revheim which in 2022 is still in the relatively early phase of development and planned to contain 4 000 new homes alongside commercial and social facilities.

One strategic development area that has seen a significant increase in construction activity over the period is the Urban Sjøfront in Storhaug. The area has shown an increase in population between 2006 and 2021 of over 5 000 people, an increase of 42.5% in population size (Christensen, 2021).

Cars per household

Another aspect that we have considered from the NTH survey, is the number of cars registered per household within Stavanger as shown in Table 17.

Cars per household	2013/14	2019	2020
0	12%	16%	15%
1	55%	52%	51%
2	28%	27%	28%
3+	5%	5%	6%

Table 17: Cars per household in Stavanger. Based on (Grue et al., 2021; Hjorthol et al., 2014; Opedal, Skar, Røsand, Dischler, & Brauteset, 2020).

It follows that there is a greater proportion of the population in 2019 compared to 2013/2014 that does not have access to a car, this would suggesting a greater reliance on alternative, more environmentally friendly forms of transport.

7.5 Focus Area 3: Environmentally Friendly Travel

The third focus area within the 2010 plan is to reduce emissions through enabling an increase in the use of environmentally friendly means of transport. As set out in Section 6.2.3 this focus area suggests a range of measures such as restricting parking and initiatives to promote public transport, cycling and walking. The municipality has targeted a reduction of 5,000 tonnes CO_2e and to reduce emissions per km driven, as per Focus area 1.

Based on the data available it can be shown that in line with the target, the average emission per driven km has reduced. Albeit it is difficult to state to what extent a move to more sustainable transport modes has contributed to this.

Mode of Transport

The NTH surveys asked participants to provide details on their most common mode of transportation for daily travels. As shown in Table 18, the respondents' modes of transport remains relatively consistent over the four years of the survey. The most significant findings are that the number of people driving a car fell from 49% in 2013/2014 to 46% in 2019. There was also a marginal increase in the use of public transport from 10% to 11% in the same time period.

Larger changes can be seen in 2020, which can largely be attributed to Covid-19. Principally car driving increased as a proportion of daily travels to 50% and public transport fell 4% between 2019 and 2020.

Transport Mode (daily travels)	2013/ 2014	2018	2019	2020
Walking	24%	23%	24%	25%
Cycling	8%	9%	9%	8%
Car driver	49%	47%	46%	50%
Car passenger	8%	9%	9%	9%
Public Transport	10%	11%	11%	7%
MC / other	1%	1%	1%	1%

Table 18: Transport modes from the National Travel Habits Survey. Based on (Epinion, 2018; Grue et al., 2021; Hjorthol et al., 2014; Opedal et al., 2020).

The NTH survey also has data in relation to public transport in the form of bus and railway as well as additional data related to cycling.

Bus

The 2010 plan identified the delivery of an urban railroad project as a major contributor for public transport in Nord-Jæren. At the time the 2010 plan was adopted this was planned as an urban railroad. However, in 2012 the county council decided to proceed with a new and improved bus service, known as the busway project. The project is to introduce a new bus-only road along existing highways to provide a faster and improved service within the Nord-Jæren region. In September 2013, the first section of the busway at Hillevåg was opened. As of 2022, just six of the twenty five sections have been constructed (Rogaland fylkeskommune, 2022).

Figure 20 provides details in relation to passenger trips and vehicle kilometres conducted by bus. Vehicle kilometres refers to the total distance the buses have travelled and not only trips when carrying passengers. The data shows that between 2009 and 2019, passenger trips increased from 14.014 million to 22.309 million, before falling to 16.079 million in 2020.

In terms of vehicle kilometres travelled, the data shows that the overall distance travelled has remained relatively stable, particularly between 2017 and 2020 where the total distance driven has remained between 12 and 15 million km. The number for 2016 is significantly below the other years. We do not know why this is the case.

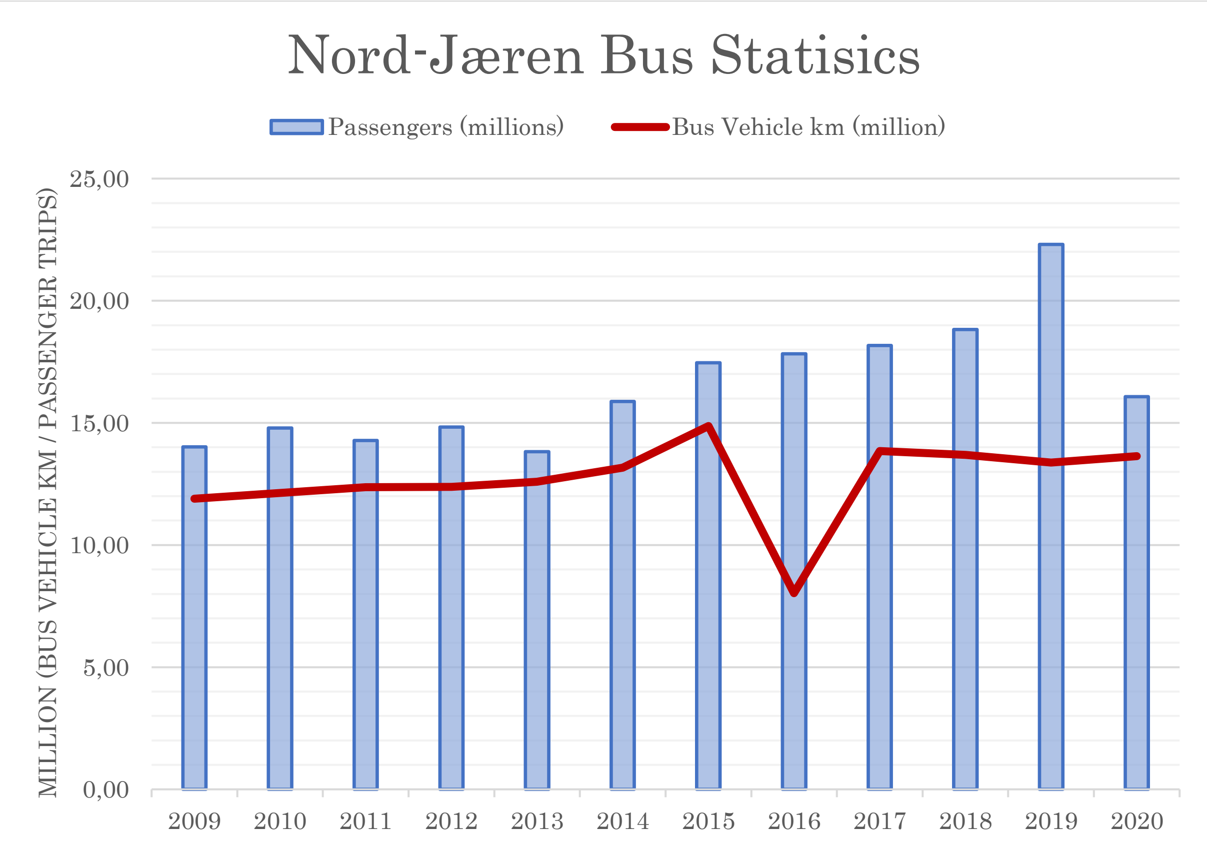

Figure 20: Bus statistics. Based on (Statistics Norway, 2021b).

Figure 21 shows that the length of the average bus ride has decreased. The average distance increased from 10,5km to 11,2km between 2009 and 2013, before falling significantly and in 2019 the average passenger trip was just over 5,5km, a reduction of approximately 47%.

Figure 21 also shows the utilisation of capacity, or the average proportion of the bus that is filled. We can infer that the higher the number the better, wasting less capacity. As can be seen, utilisation remained relatively stable from 2009 to 2014 at between 30% and 32%. In 2016 we saw utilisation increase significantly, which is linked to the unusual low bus vehicle km in 2016, identified as an unexplained potential anomaly. Utilisation then fell significantly to 24% and then fluctuating at modest levels of 19% and 23% in 2018 and 2019 before falling significantly in 2020.

From the data we can deduct that whilst passenger numbers increased and the distance travelled in total by the buses has increased, the utilisation has fallen. This could imply that passengers are using buses for shorter trip distances, hence the far lower utilisation rates.

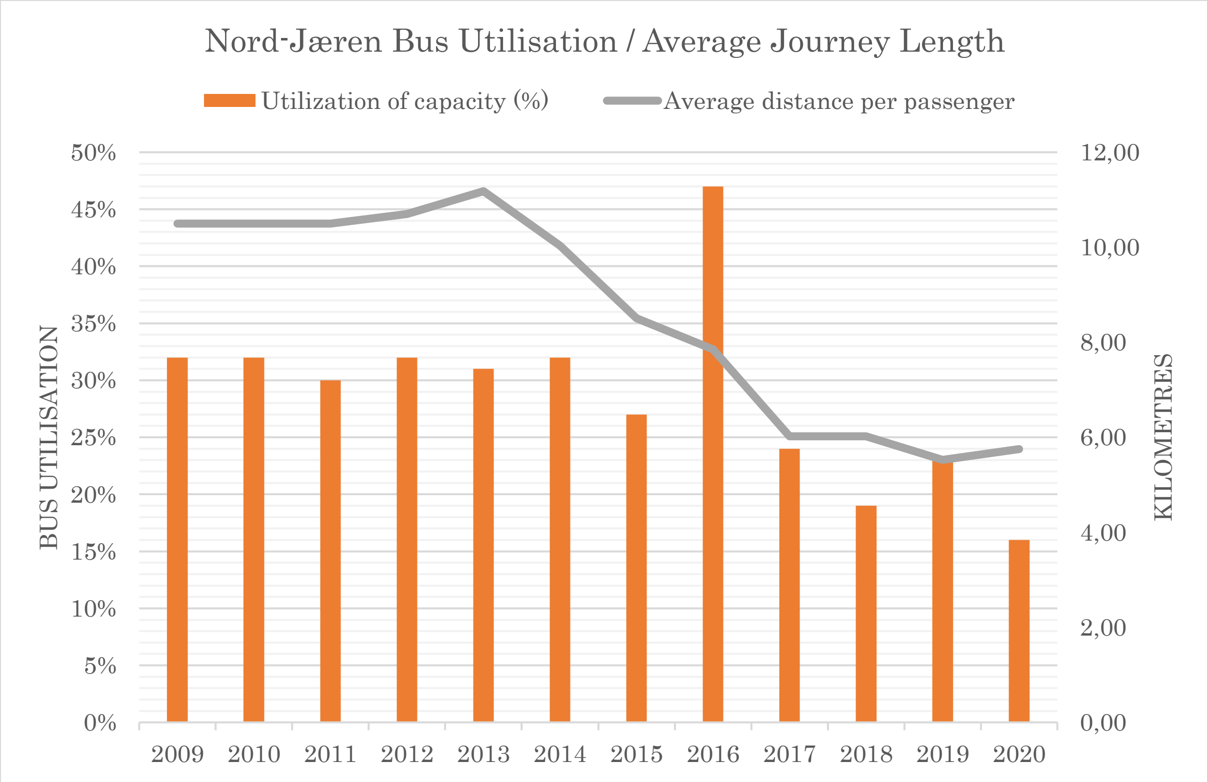

Figure 21: Passenger travels and utilization of capacity. Based on (Statistics Norway, 2021b).

Bus transportation across the region is managed and operated by Kolombus, a company owned by Rogaland County Council. As it is managed at a regional level, we can only collect data related to the Nord-Jæren region of Rogaland, inclusive of Stavanger, Sandnes, Sola and Randaberg. There is no available data exclusively related to Stavanger.

Railway

In addition to the bus usage, it is important to recognise the railway network as a key element of public transport infrastructure within the region. Whilst the Climate and Environment Plan does not recognise this element specifically, there are several trains stops from Stavanger towards Sandnes, including Paradis, Mariero, Jåttåvågen and Gausel.

As shown in Figure 22 between 2012 and 2019, the number of passengers on local trains within the Stavanger region increased from just below 3,3 million to just over 5,0 million, an increase of 53%. Between 2019 and 2020, passenger numbers fell to similar levels as for 2012.

Figure 22 also gives data relating to the total amount of passenger kilometres. This shows a similar pattern of increasing kilometres travelled between 2009 and 2019, before a significant fall in 2020, further demonstrating the impact of Covid-19 on the transportation network. We can conclude based on the data that, similar to bus journeys, the average distance per train ride has fallen from just over 20 km in 2012 to just under 18 km in 2019.

Figure 22: Train Statistics in the Stavanger area. Based on (Statistics Norway, 2021c).

Cycling

As set out in Section 6.2.3 there are several specific policies related to encouraging the use of bicycles. This includes making bicycle parking available close to transport hubs and more significantly to improve bicycle paths and networks. In particular to introduce new routes to reduce distances and travel time between key areas such as working areas (Stavanger Kommune, 2010).

Whilst there are no specific targets, the 2010 plan identifies the "bicycle highway" that runs from Stavanger to Sandnes via Forus, as a key project. In 2010 it was in the planning stages of development (Stavanger Kommune, 2010). The project has been split into sections with some having opened following the start of construction in 2014 (Bymiljøpakken, 2022) (Statens Vegvesen, 2021).

As shown in Table 18, bicycles as a mode of travel increased by 1% between 2013/2014 and 2019, before a fall in 2020. This can be supplemented and considered alongside a bicycle survey conducted by Stavanger municipality (Table 19, Section 7.5) to gather information about people's bicycle usage and the perception of the bicycle infrastructure. A review of the survey between 2013 and 2021 shows that there is an increase in people using the bicycle both in the winter and in the summer. From 2013 to 2019 the percentage of the respondents that biked in the summer increased by 5% and for the winter by 11%.

One of the key findings, however, is that there has been a significant increase in the use of e-bikes. By 2021, nearly 25% of the respondents owned an electric bicycle.

Year:	2013	2015	2017	2019	2021
Number of respondents:	802	800	800	800	800
E-bike ownership	N/A	6%	9%	17%	24%
Cycling in winter	13%	19%	22%	24%	23%
Cycling in summer	30%	33%	34%	35%	35%

Table 19: Statistics from Stavanger municipality cycle survey 2013 – 2021. Based on (Stavanger Kommune, 2022b).

Figure 23 shows the total numbers of km adapted for cycling during 2015 to 2021. It shows that over the last six years, this has increased by approximately 22%. A large proportion of this increase is due to the "bicycle highway" being developed between Stavanger and Sandnes.

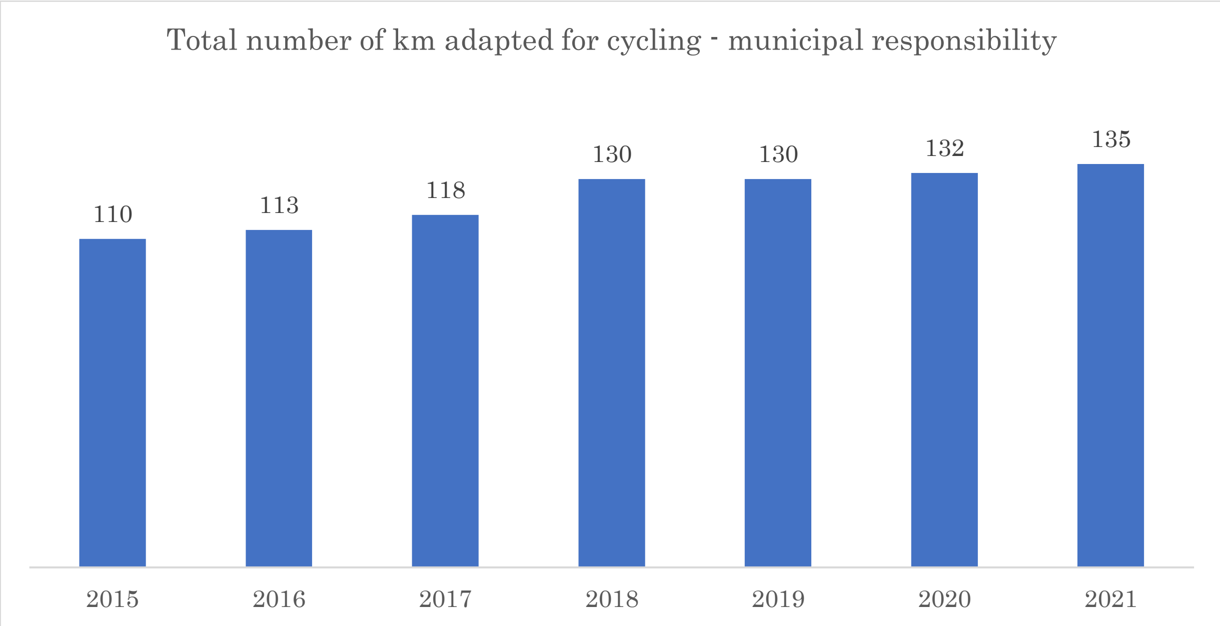

Figure 23: Kilometres adapted for cycling in Stavanger. Based on (Statistics Norway, 2022d).

One of the priorities in the 2010 plan was to deliver bicycle parking at public transport hubs. There is limited data available specifically related to this topic. However, we are aware that since 2016, the municipality has delivered over 1 000 bicycle parking spaces in key locations such as schools and local hubs (Stavanger Kommune, 2022a).

Another important development regarding bicycles are the city bikes that have been available in Stavanger since 2014. In 2014 there were approximately 200 city bikes. This number has increased to 750 in 2020. Over this period electric city bikes have also been introduced for longer more comfortable journeys (Bymiljøpakken, 2022).

7.6 Focus Area 4: Transport Efficiency Improvement

The final focus area where the Climate and Environment Plan 2010 - 2025 seeks to reduce emissions is through transport efficiency improvement. As set out in Section 6.2.4, a wide range of measures are proposed including the use of ICT, restrictions on car parking, the development of a logistics distribution centre and the urban railway system (now the "busway" project).

The plan states a goal of reducing emissions by 5 000 CO_2e tonnes and also has a target to reduce the number of km driven by car.

Reduce number of km driven by cars

The first aspect to note when considering the number of km driven by cars is that the target is not specific about the total or average km driven. As seen in figures 24 and 25, the total and average distance travelled by cars registered in Stavanger has fallen between 2009 and 2019. Total volumes have fallen by approximately 12,5% and average traffic volume by 20%. It should be noted that while the population has grown, so too has car ownership.

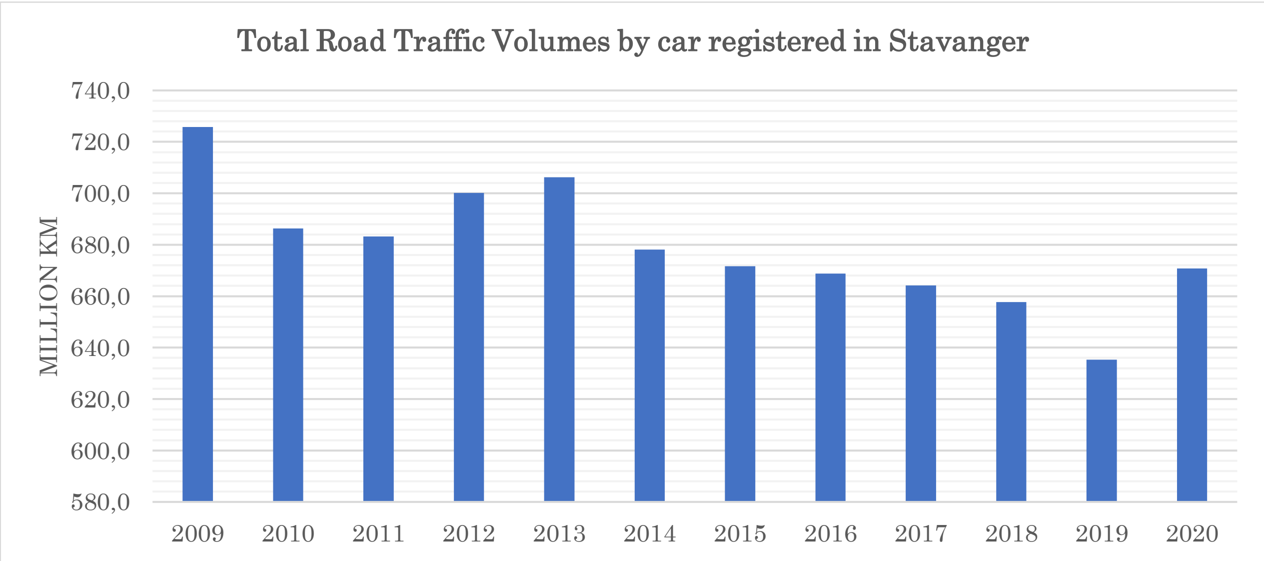

Figure 24: Total road traffic volumes by car in Stavanger. Based on (Statistics Norway, 2022e).

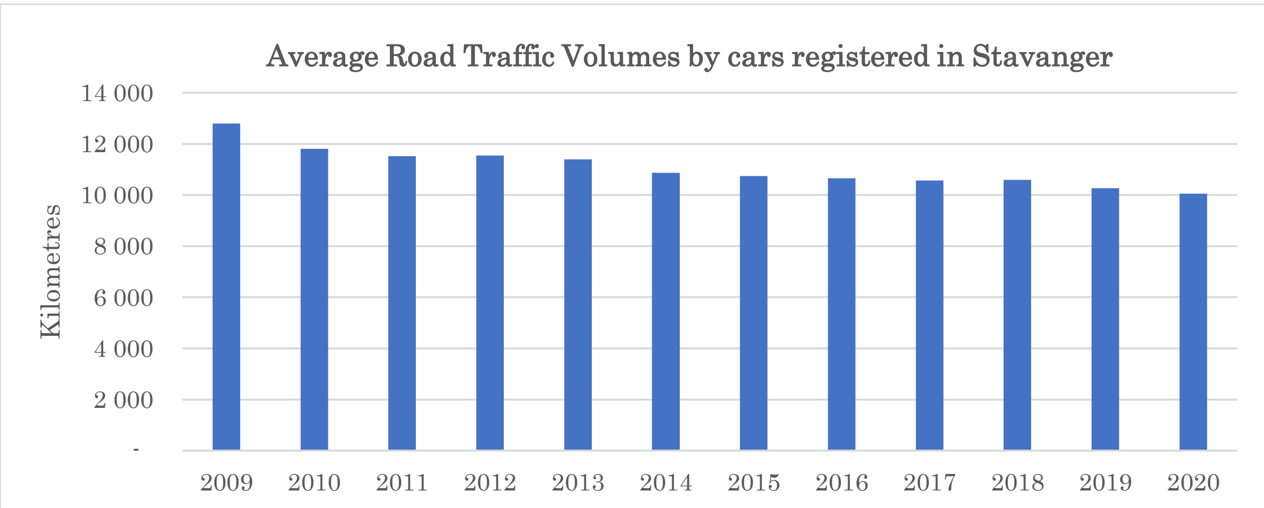

Figure 25: Average distance travelled by cars registered in Stavanger. Based on (Statistics Norway, 2022e).

Car Parking

As part of the NTH survey, participants were asked specifically about access to car parking at work – whether there was parking and if parking was available if it was free (Figure 26). Compared with 2013/2014, the availability of car parking at work in 2019 was slightly more restrictive, with the proportion of participants with free car parking having been reduced, whilst those without access to car parking also slightly increasing.

It should, however, be noted that in the Travel Survey for 2019, Bergen and Trondheim, cities of relatively comparable size, had more restrictive car parking availability with 25% and 26% of participants from Bergen and Trondheim respectively having no access to car parking at work. This should be compared to 15% in Stavanger.

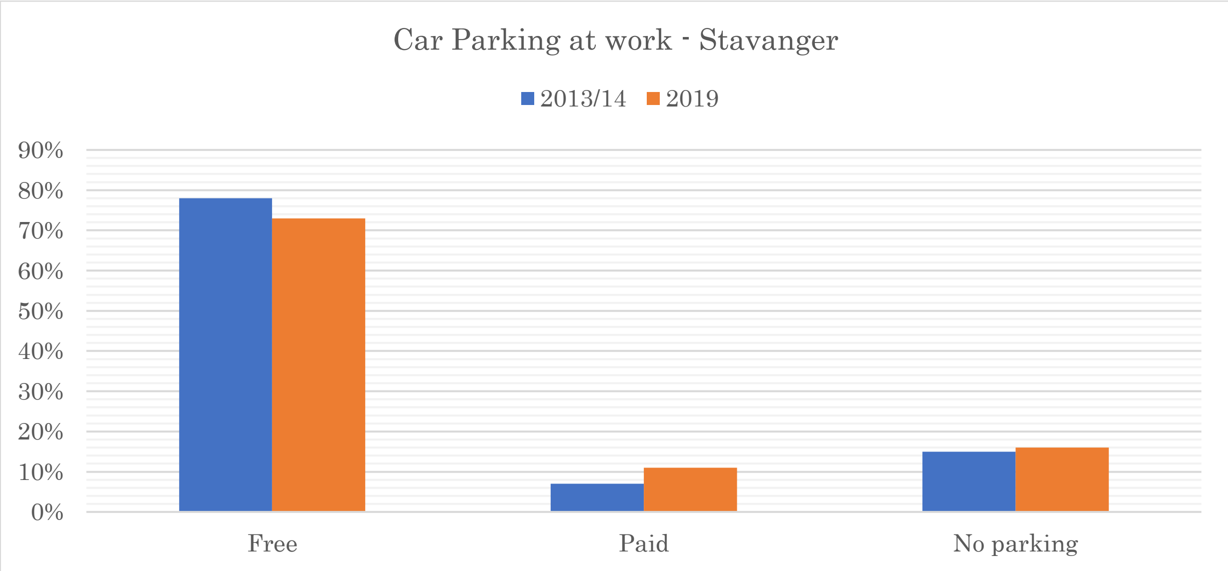

Figure 26: Car Parking availability at workplaces across Stavanger – 2014 and 2019. Based on (Grue et al., 2021; Hjorthol et al., 2014).

Participants were also asked whether they had access to car parking near to their place of residence. The study showed that in 2013/2014 91% of participants had access to their own car parking space. This increased to 94% in 2018 and 95% in 2019. This suggests a negative movement with greater access to car parking despite policy suggesting it would become more restrictive.

Stavanger has around 3 070 public parking spaces in 10 parking garages (Stavanger Parkering, 2022). There are additional parking places around Stavanger for example in streets, but the municipality does not have statistics on this. There is limited information available on how many parking spaces the municipality had in 2010.

In Table 20, there is further support to show that parking policy has changed. The table shows parking policy for the Stavanger municipal plans of 2014 - 2029 and 2019 - 2034. It shows that the parking requirements have been reduced, for example in Zone 1 (Central Stavanger) the policy for housing was 1 space per unit and has now reduced to 1 space for every two units.

2014 - 2029				
Category	Basis per parking space	Zone 1	Zone 2	Zone 3
Housing	Housing unit	1	1	2
Guest parking for housing	Housing unit	1	1	1
Commercial buildings	100m^2	Min. 0,5 - Maks 0,9	Min. 0,9 - Maks 1,2	Min. 1
2019 - 2034				
Category	Basis per parking space	Zone 1	Zone 2	Zone 3
Housing	Housing unit	0,5	Min. 0,5 - maks 0,8	1
Guest parking for housing	Housing unit	0,2	0,2	0,2
Commercial buildings	100m^2	Min 0.3 - 0,5	Min. 0,3 - maks 0,9	Min. 0,2 - Maks 0,5

Table 20: Stavanger Municipal Parking Guidelines. Based on (Stavanger Kommune, 2015) and (Stavanger Kommune, 2019).

Targeted Behaviour Programmes

Another aspect of the policy is to effectively encourage behaviour and to provide more information related to services. This is typically introduced via technology or ICT. There are several developments that have occurred over the ten-year period that we have knowledge of, albeit data related to these programs is restricted.

The first is the introduction of the Kolumbus software application (“app”) system. It consists of three apps: “Travel planner”, “Ticket” and “Real time”. Whilst data is limited, we are aware that in 2019, 82% of all tickets were purchased using the Ticket app. This increased to 92% in 2020 (Kolumbus, 2020). However, Covid-19 might have been partly responsible for this increase.

Hjem-Jobb-Hjem is a separate scheme for mobility planning in companies that can be a model for several municipalities. The purpose is to reduce car traffic in the urban areas of Nord-Jæren by offering products and services that include cycling, walking and public transport (Mellberg, 2021). Hjem-Jobb-Hjem was established in 2015 and currently has an agreement with 631 companies, with over 70 000 employees. Members are offered discounted tickets for public transport in Nord-Jæren.

The 2010 plan suggests to promote car sharing schemes as a means of reducing car ownership and usage. Car sharing schemes exist across Norway and in 2018 there were 11 such services or platforms that provide access to more than 200 000 reported members (Nenseth & Julsrud, 2019). Nabobil is one such scheme that operates in Stavanger. There is limited data for the period 2010-2020 in terms of number of vehicles and users. However, in 2021, following the conclusion of the plan period we are aware that Kolumbus has launched their first cars for car-sharing in Stavanger (Henriksen, 2022).

8. DISCUSSION

8.0 Discussion

Rising global greenhouse gas emissions are one of the major dangers facing the world today. If we are to stop the rise in global temperatures it is vital that we decarbonise rapidly. This thesis has sought to look at this at a municipal level in relation to one of the largest emitting sectors, the road transportation sector. Specifically, we have sought to answer the following research questions:

1. *What is decarbonisation and what are the main methods to decarbonise the transportation sector within Stavanger municipality?*

2. *Since adoption of the Climate & Environment Plan 2010 - 2025, has progress been made in decarbonising the transportation sector and are they on track to meet their targets?*

3. *Based on the outcome of our analysis, can any recommendations be made to assist the municipality in achieving their new goal of an 80% reduction in emissions, within the road transportation sector?*

8.1 Decarbonisation in the Transportation sector

Decarbonisation of the transportation is a very complex matter. However, it can be outlined as "*the process of mitigating and reducing carbon emissions"* (IPCC, 2018). In relation to the transportation sector specifically, it is widely agreed that there are three key methods that seek to tackle the issue of decarbonisation within the transportation sector, known as the ASI approach (Banister, 2008; Bardal et al., 2020; Xenias & Whitmarsh, 2013):

- **Avoid** / Reduce the need to travel.
- Modal **Shift.**
- **Improving** vehicle technology.

Decarbonisation of the transportation sector requires the collaboration of a range of stakeholders spanning across the whole society, involving individuals as well as both the private and public sectors. It involves issues such as regulations, planning, the development of technology as well as funding. The public sector primarily acts as facilitators for the process, specifically by intervention via policy as issued by government bodies. It is this approach we have sought to review, specifically looking at it from a local perspective for Stavanger municipality.

As we have seen in Section 6.2, Stavanger has adopted wide-ranging policies identified under four key focus areas as means of decarbonising the transportation sector. The four focus areas correspond with the ASI approach and identifies policies related to different aspects of the transportation sector.

However, when we compared the 2010 plan with the approach of Trondheim it was evident that whilst there were similarities, the Stavanger policy position was less specific in terms of the measures proposed and the targets were less ambitious. In addition, the Trondheim plan provided more detail in relation to responsibilities for measures and identified funding requirements as well, which the Stavanger plan did not. This demonstrates that there is not a "one size fits all" approach to decarbonisation.

Whilst the onus is on the municipality to set goals and policy approach to decarbonisation, there are also other governmental stakeholders that have significant influence on how effective these policies are. One key example is the transition to new technology and low-emission vehicles. This is influenced by policy set at a national level i.e., taxation and financial incentives matters. More importantly for technology is the availability of it. This is impacted by external markets, research and development factors. The influence of the municipality to encourage the transition is therefore somewhat limited with measures such as providing information to inhabitants, promoting infrastructure and seeking to change its own fleet of vehicles.

Another example is that of the public transportation network. Whilst the municipality can influence the development of public transport projects such as the busway through the municipalities planning powers, the actual management and operation of the public transport fleet is run at a regional level, in this case by Rogaland County Council, through Kolumbus. Both are examples of potential organisational barriers as identified in Section 3.6.

We have established that whilst looking at emissions as a measurement of decarbonisation is a good starting point, there are limitations. The methodology used, NERVE, only assess direct emissions, with indirect emissions such as the production of vehicles being attributed to other sectors. In addition, the model does not account for non-exhaust emissions, which are believed to have a more significant impact on air quality (Liu et al., 2021).

As a secondary source of measurement and to provide a more specific measurement of policies, we have used indicators to assess whether there has been progress in decarbonising the transportation sector. In terms of technology, this would include an increase in low-emission vehicles. For modal shift, this would include a reduction in the use of the car and an increase in the use of "environmentally friendly" modes of transport such as, public transport, cycling and walking. For reducing the need to travel, this relates to whether there was an increase in densification and a demonstrable reduction in car use.

8.2 Key Findings

The second research question for this thesis sought to address whether progress has been made to decarbonise the transport sector relative to the targets set out by Stavanger municipality in 2010. The 2010 plan set a target to reduce overall emissions by 30 % compared to numbers from 2009. This is equivalent to a 20 % reduction compared to numbers from 1991, amounting to 85 000 tonnes CO_2e in total. For road transportation sector specifically, there was a target of 40 000 tonnes CO_2 reduction from 2009.

Based on the available data, we have estimated that between 2009 and 2019, the municipality reduced emissions by 49 558 t/CO_2e, from 193 620 t/CO_2e to 133 687 t/CO_2e. However, based on the rebased target, which accounted for changes in methodology and boundary changes, they were unable to achieve the target reduction in road transport emissions of 67 675 t/CO_2e, as set out in Section 7.2.2.

Based on our assessment despite progress in decarbonising the sector, the municipality has not reached its target as given by the revised numbers. However, to review how progress has been made, we can look at it based on:

1. Technology (Improve).
2. Modal Shift.

3. Avoid / Reduce the need to travel.

8.2.1 Improving Technology:

Technological innovation and development is recognised as a key approach to decarbonising the transportation sector. Stavanger has identified this approach as the main means of decarbonising the transportation under Focus area 1. The means and measures by which the municipality can approach this is limited and the main reductions will be through national policy. Comparing with Trondheim, that have specifically referenced the impact that national policy can have on emissions, Stavanger has just acknowledged that this will influence emission reductions.

From the indicators we can see that between 2009 and 2019, there has been a technological shift, with increases in the ownership of low-emission vehicles, specifically electric cars whilst the number of petrol cars have reduced significantly. In Figure 16 (Section 7.3), there is a notable increase in the number of electric cars from 2013, at which point it had not exceeded 1%. After 2013, the number of electric and hybrid car registrations in Stavanger average year-on-year growth was approximately 70%. As of 2020, the number of electric and hybrid cars now represents over a quarter of the total car fleet. It is expected that this number will continue to grow considering the national incentives and the targets set out in the National Transport Plan 2018-2029. From 2025, the Plan has set a target of only zero emission new vans and cars being sold and no new ICE cars or vans being sold.

Although there are many factors that affect the shift towards electric cars, we note, that the incentives for electric vehicles were in place prior to the plan period (Table 6, Section 5.3), and that exemption from VAT on purchase was adopted in 2001. However, it was not until 2013 when there started to be a significant increase in sales in Norway, as seen in Figure 27. This corresponds with the trend in vehicle registrations in Stavanger (Figure 16, Section 7.3). The correlation between national new car sales and local registrations demonstrates that the uptake in electric and hybrid cars relates to the national policy set.

It can also be deduced that the technology was either not available or as competitive, on a price, quality, or comfort basis, compared to ICEV prior to 2012/2013. An example of this shift is Tesla cars, which were introduced in Norway in 2013. In 2015 it was the 5th most

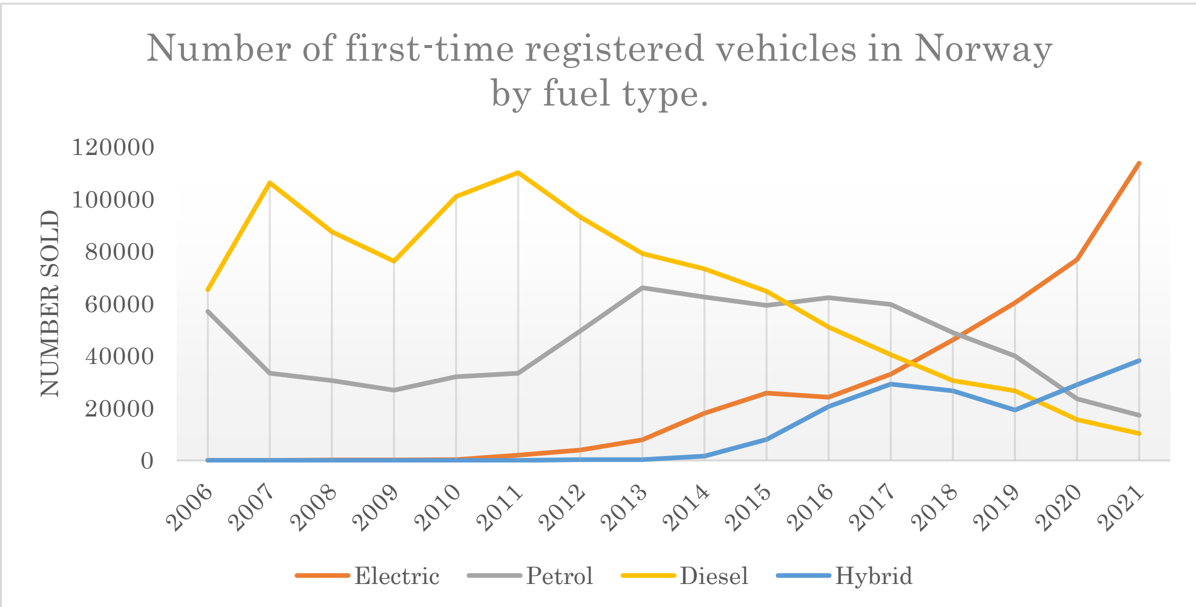

Figure 27: First-time registered vehicles in Norway by fuel type. Based on (Statens Vegvesen, 2022).

sold car brand in Norway, and the most sold in 2021 (Jarslett, 2022). Car batteries have also come a long way over the period. In 2011 the range of an electric vehicle was around 250 kilometres (Valle, 2016), while in 2022 tests done by NAF and Motor showed a driving range up to 600 kilometres in Nordic climate (NAF, 2022).

To conclude, the contribution that the municipality has had is limited, however, they have contributed to the development of a publicly available charging infrastructure, which has increased from 22 to 519 charging points (Bøe, 2022).

However, the major factors contributing to the transition to electric cars since 2014 has most likely been a response to the availability of technology and because of financial incentives that has been set at a national level. Whilst policy is directed towards encouraging technological development, there are limited methods of intervention that the municipality can control, apart from the composition of their own car fleet and encouraging the development of infrastructure. At a regional level, Kolumbus, being the main mobility provider across Stavanger and the wider region have the potential to deliver a greater technological shift with the electrification of the modes of public transport. The municipality is limited to contributing towards the development of publicly available charging infrastructure, which nevertheless requires third party developers and operators.

Whilst there is plenty of statistical data relating to passenger cars and it is evident that progress has been made, technology is generally lacking behind for other vehicle types, particularly for lorries. There is, however, some progress that has been made for heavier vehicles and in particular for buses.

For buses, emissions fell by approximately 22% in the period 2009 - 2019 (Figure 15, Section 7.2). In addition, we are aware that annual vehicle km of buses over the period has marginally increased, a 12,4% increase (Figure 20, Section 7.5). This would suggest that there has also been a shift towards more efficient fuel forms across the bus fleet.

For vans, emissions fell by approximately 33% between 2009 and 2019. This is a similar proportional reduction as for cars. It is likely that the primary factor is that road traffic volumes for vans fell by 41% over the period. However, there has also been a slight transition in fuel types, with 256 electric vans registered in 2020, compared to just 5 in 2009. This, however, still represents only 3% of the total number of vans registered. But the increase shows that there is a greater selection of electric and lower emission van types available on the market.

8.2.2 Modal Shift:

In the 2010 plan modal shift is primarily identified under Focus area 3 (more environmentally transport) but also relates to Focus area 4 (transport efficiency improvement). The concept consists of decarbonising the transport sector through transition from transport modes that generate greater emissions i.e., reducing the use of the car, to more “environmentally friendly transport” or lower emission modes such as public transport, cycling and walking or car sharing.

The policy position within the 2010 plan was to primarily encourage the use of environmentally friendly transport by investing in infrastructure, specifically an urban railroad or tram system. There is also reference to potential measures for restricting car use in relation to car parking.

From the indicators that we have analysed between 2009 and 2019 there was a demonstrable increase in passenger numbers for public transport services, both for the bus service and the railway service in the area. Over the period, bus passenger trips increased by approximately 60% and rail passenger numbers increased by approximately 52%. This correlates with the fact the car traffic volumes reduced by approximately 12,5% over the same time period. In addition, over the same period population also increased by around 12%. From this we can deduct that there has been a significant shift towards public transport over the period. However, 2020 saw the impact of Covid-19 on travel as road traffic volumes for cars increased, whilst passenger numbers for both bus and rail services significantly decreased, with a reduction in passenger numbers of 28% and 33% respectively.

Whilst there is a policy to improve the public transport service, the municipality has influence primarily through its planning power over land use. In the 2010 plan the policy position for public transport was centred around the delivery of an urban railroad project, which became the busway project, a section which is shown in Figure 28. This is still under development and is not scheduled to complete for some time yet. The operational side of the bus service is run by Rogaland County Council.

Figure 28: Photo of the busway at Hillevåg (Tønnessen, 2020).

Rogaland are responsible for delivering the bus service including the fleet itself and the necessary ICT infrastructure such as apps and web services. The introduction of the app might have influenced the increase in passenger numbers between 2009 and 2019.

There is no specific policy within the 2010 plan related to the rail service. The railway service, however, did increase over the period and is governed at a national level. It is therefore difficult to quantify the level of contribution that the municipality has had in relation to the increase in uptake,

From a cycling perspective, several initiatives have been introduced inclusive of the new cycle highway project that is being delivered between Stavanger and Sandnes, along the E39, shown in Figure 29. Indicators show that since 2015, the earliest available data, the total length of cycle paths across the municipality has increased, which corresponds with the construction of the new cycle highway. Based on the survey data that has been collected, the NTH suggests that the proportion of the population that use bicycles for daily travels has remained fairly stable at 8-9% between 2014 and 2020, whilst the Stavanger survey (Stavanger Kommune, 2022b) suggests there has been an increase between 2013 and 2019 from 30% to 35% and from 13% to 23% for summer and winter cyclists respectively.

Figure 29: A completed section of the cycle highway between Stavanger and Sandnes (Refvem, 2020).

Finally, it is important to recognise the shift towards increasing the number of people walking. However, there is very limited data in this regard. The only data we are aware of is the NTH survey which shows that between 2014 and 2019 the proportion of the population that walked for transport remained at around 24%. This increased to 25% in 2020 something which could be associated with the Covid-19 pandemic.

We have already highlighted the reduction in the volume of car traffic over the period. Specific policies that the municipality was looking to adjust were mainly concerning car parking. The data on this is relatively limited but from the NTH survey it follows that between 2014 and 2019 there has been a slight increase in those without car parking at work and also in those who have to pay for parking at work. However, this is somewhat offset by the fact that there was a slight increase in those with access to car parking at their place of residence.

It also follows from the NTH, that of those surveyed, there was an increase in participants that did not have access to a car. This supports the concept of modal shift. However, when we consider the number of cars registered in the municipality, this number has increased by approximately 11% between 2009 and 2019, which corresponds to the population growth. This would infer that there has not necessarily been a decrease in ownership on a proportional basis.

From the indicators considered we can deduce that progress has been made in terms of modal shift, with more passengers using public transport and less people using cars. There is however, limited and less reliable data related to walking and cycling modes of transportation, which are the most environmentally friendly with zero direct emissions.

A key assumption in the evaluation is that travelling by bus produces less emissions than travelling by cars. However, data from Engedal (2019) suggests that due to the makeup of the bus fleet in Norway in 2018 there is a larger emission per km travelled by the bus than by car. This is largely influenced by the uptake in electric cars across Norway, which does not provide any direct emissions.

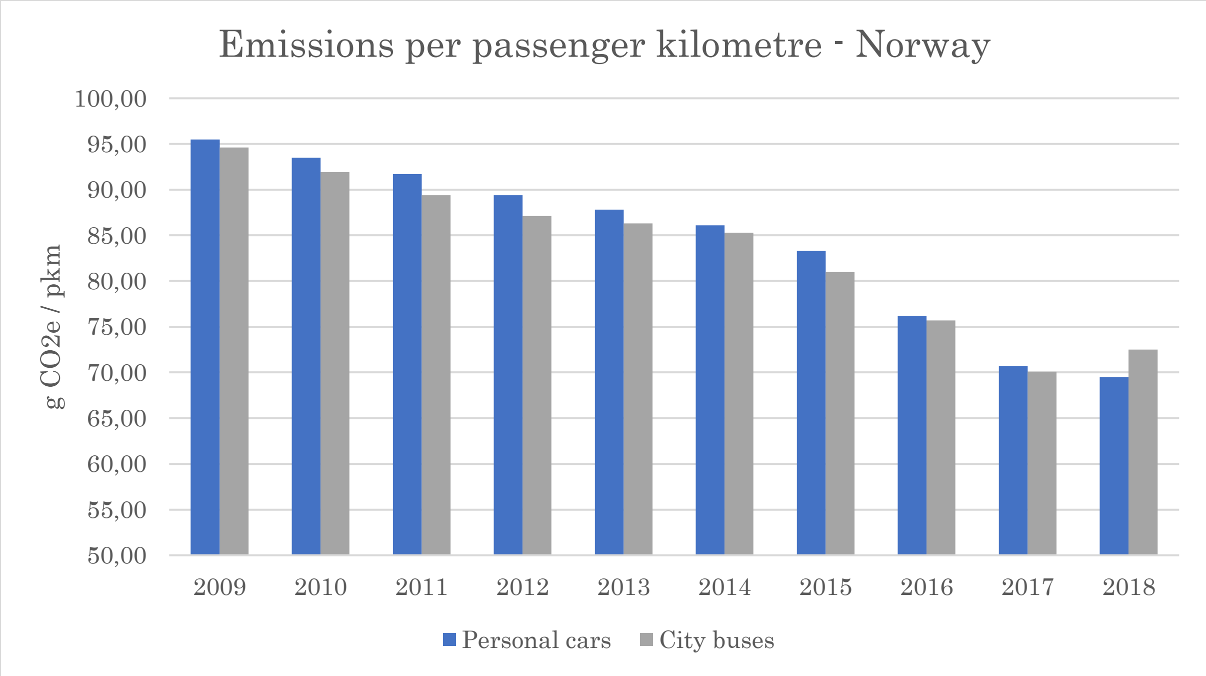

Figure 30: Emissions per passenger kilometre – Norway. Based on (Engedal, 2019).

Figure 30 shows the trend in emissions per passenger kilometre for cars and city buses across Norway. As can be seen, 2018 was the first year when emissions per passenger kilometre was higher for traveling by bus than by car. Whilst we do not have specific data related to Nord-Jæren and the municipality of Stavanger specifically, the conclusions that we can draw from this is that to ensure that buses are a lower emitting mode of transport compared to cars, the bus fleet needs to reduce its emissions. Specifically, a transition to more electric buses, currently accounting for just 5 of the Kolumbus fleet in 2019 (Rogaland fylkeskommune, 2019). We also note that Stavanger has seen a significant reduction in bus utilization (32% in 2009 to 23% in 2019) which would lead to a higher emission intensity for buses.

8.2.3 Reducing the need to travel

The 2010 plan identified reduction in the need to travel as one of the focus areas, under "Concentrated Land Development". The plan sought to promote a transit oriented development concentrated along public transport routes. As both the planning authority and a major landowner, the municipality can have considerable influence over this. However, it is complex to assess the effect through indicators.

In order to comprehensively understand whether densification as a means of reducing the need to travel has been successful a range of factors would need to considered. This would among other items, include understanding where people travel to and from and access to transport networks. Given time constraints we have not been able to comprehensively review this.

Another factor that needs to be considered when assessing the impact of densification is that strategic developments take a significant amount of time. An example being Jåttåvågen, where planning for the project began in 2000. By 2022, the first phase has been completed but the next phases are estimated to span over the next ten to twenty years (Lundhagem, 2019. Therefore, demonstrating the effectiveness of densification can be difficult.

Nevertheless, the indicators that we have considered suggests that there has been an increase in population densities across the municipality and in line with the targets set within the 2010 plan. As an example, average traffic volumes of cars have reduced whilst the number of households have also increased. However, according to the NTH survey, average journey times and distances have increased over the period. Thus, it is hard to estimate the impact of more concentrated land development.

The urban growth agreement (Bymiljøpakken) is a regional agreement between different stakeholders in Nord-Jæren and the government of Norway. The overall goal of the agreement is to achieve zero growth in passenger transport by car and good accessibility for all road users, especially those who travel by public transport, cycle or walk – and also for business transport. The urban growth agreement is not mentioned in the 2010 plan, firstly because it was not implemented until 2016, and it's based on the regional area of Nord-Jæren. Nevertheless, the agreement represents the carrot and stick approach, where the government contributes with funding if the local authorities ensures that future development of housing and jobs takes place in a way that strengthens public transport and reduces the need for transport. Indicators that have been outlined in Section 8.1.2 indicates that there has been a strengthening of the use of public transport and less reliance on using cars, as demonstrated by a reduction in traffic volume.

8.2.4 Summary of Progress

Based on the discussion so far, we can deduct that "progress" has been made in terms of decarbonisation following the various approaches. In relation to technological progress this has been widely a result of technology being available for cars, and importantly state-wide financial incentives. Less progress has been made for other vehicle types.

For modal shift, again, between 2009 and 2019, there was an increase in passenger numbers for public transport whilst car traffic volumes reduced. It is more difficult to conclude whether there has been demonstrable increase in cycling and walking, despite a noticeable increase in investment, not least the cycle highway.

For reducing the need to travel, indicators would suggest that there has been a marginal increase in densification and as per modal shift evidence, less reliance on the car. We cannot, state conclusively whether densification was a contributing factor in this.

Despite these factors, the municipality did not achieve their emission targets set within the 2010 plan, based on our calculations. This is true even in the year of 2020, when the transportation sector was significantly restricted.

8.3 The Impact of Covid-19

As briefly mentioned above, due to the Covid-19 pandemic, the year 2020 provided some anomalies related to the data. It originated from China around the turn of the year 2019/2020. It quickly spread to the entire world, and in March 2020 the World Health Organisation declared it as a pandemic. By the end of 2021 more than five million people had died from the virus (Tjernshaugen, Hiis, Bernt, Braut, & Bahus, 2022). On 12 March 2020 the Norwegian government imposed a wide-ranging set of measures to limit the spread of infection in Norway. Measures were implemented at both a national and municipal level and included requirements to avoid using public transport, social distancing and employees were required to work from home, particularly at the start of the period. It was not until February 2022 that the government removed most of the Covid-19 measures.

Between 2019 and 2020, there were several telling statistics demonstrating the impact of these measures. Road traffic emissions reduced by 7,2%. In addition, as we have set out in Section 8.1.2, there was a significant reduction in passengers on public transport, with a 28% and 33% reduction in passengers using the bus and rail service respectively. At the same time, car traffic volumes increased. This suggests that those that were able to travel, adopted a modal shift from public transport towards the car, as demonstrated by the increase in car traffic volumes in 2020, shown in Figure 31. The fall in bus passenger numbers is shown in Figure 32.

There was a significant impact on the transport system and as we have stated, this year is an anomaly given the restrictions in place on society. Therefore, the statistics for 2020/2021 are mainly not a result of applied policy related to the 2010 plan, but because of national policies relating to measures implemented to stem transmission of Covid-19.

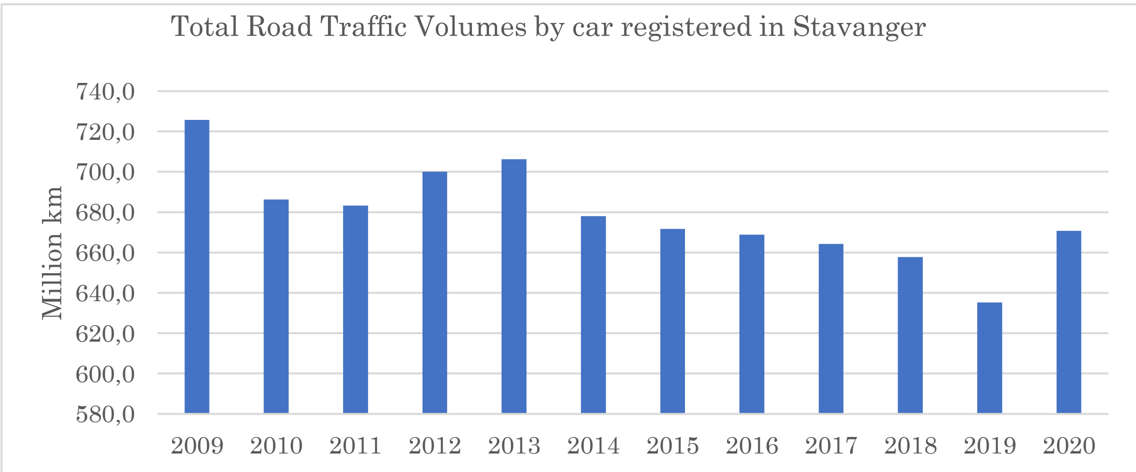

Figure 31: Total road traffic volumes by car registered in Stavanger. Based on (Statistics Norway, 2022e).

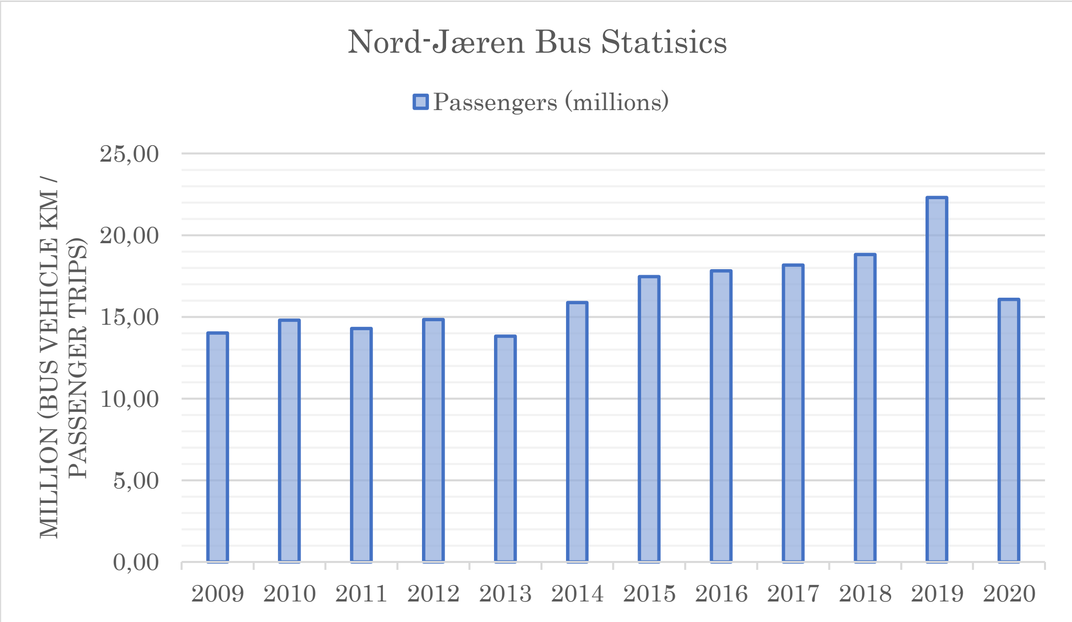

Figure 32: Annual bus passengers - Stavanger. Based on (Statistics Norway, 2021b).

8.4 How do the numbers compare with Trondheim?

In Section 6.3, we compare the Trondheim Climate and Energy Plan (2010 – 2020) with the Stavanger Climate and Environment Plan (2010-2025) in terms of the municipalities approach to decarbonising the transportation sector. Whilst there were similarities in their approach in terms of adopting a number of similar measures and policies. However, the noticeable differences were that Trondheim had a more ambitious plan at the time for emission reduction targets and they provided greater detail in the specificity of their approach, the responsible bodies for the policy and in terms of funding/cost of the project.

Based on the details of the two approaches it is useful to compare them specifically related to their targets for reducing emissions now that the plan periods have concluded.

	Stavanger Municipality	Trondheim Municipality
Overall targets	85 000 CO_2e reduction in emissions by 2020. 20% reduction compared to1991 and 30% compared to 2009.	25% reduction between 1991 and 2020. 70-90% reduction between 1991 and 2050.
Road transportation targets (per annum) Plan Period	45 000 t/CO_2e (14% of total emissions) Plan Period: 2010-2020	47 000 t/CO_2e (20% reduction) Plan Period: 2008-2018
Revised road transportation targets (based on the methodology)	67 675 t/CO_2e	38 423 t/CO_2e

Table 21: Stavanger and Trondheim targets. Based on (Stavanger Kommune 2010) and (Trondheim Kommune 2010).

Based on the methodology as outlined in Section 7.2, we have sought to revise the road transportation target for Trondheim to compare with the latest figures for emissions as per the NEA (Table 21). The Trondheim plan targeted a 20% reduction from their 2008 road transportation figures, which at this time totalled 235 000 t/CO_2e. The NEA figures, however, show road transport emissions for Trondheim in 2009 at approximately 192 000 t/CO_2e.

For the adjusted target we have assumed a target of 20% of the NEA road transport emission figure (192 000 t/CO_2e). This means the total target reduction reduces from an original target of 47 000 t/CO_2e to an updated target of 38 423 t/CO_2e.

Comparison	Trondheim	Stavanger
2009 Rt emissions (t/CO_2e)	193 620	192 117
2019 Rt emissions (t/CO_2e)	152 939	144 062
Target reduction (t/CO2e)	38 500	67 675
Actual reduction compared to '09 (t/CO_2e)	39 178	49 558
% Change	-20,4%	-25,6%
Emissions per inhabitant (t/CO_2e) - 2019	0,75	1,01

Table 22: Stavanger and Trondheim road transport emissions.

As shown in Table 22, between 2009 and 2019 the total volume of road transport emissions fell to a greater extent in Stavanger by approximately 50 000 t/CO_2e compared with Trondheim at 40 000 t/CO_2e. If, however, we compare them relative to the revised targets, based on our methodology Trondheim has achieved its overall goal while Stavanger has not. On a proportional basis (per inhabitant) Trondheim is performing significantly better in relation to reducing emissions.

With the revisions of the methodology for assessing emissions and because of boundary changes to the municipalities that have occurred in the period 2009-2020, we cannot state whether the policy approach and measures have been successful in relation to their targets. However, Stavanger has generated a greater reduction in total emissions. On the other hand, if we consider emissions on a proportional basis then Trondheim is outperforming Stavanger. The information demonstrates that both Trondheim and Stavanger have made progress over the plan period in relation to decarbonising the road transport sector.

The result of this comparison further raises the question of the impact of local policy on decarbonisation within the road transport sector, given that Trondheim was more detailed in terms of their goals. In addition, it further supports the difficulty of comparing the 2009 plan targets based on the revised emission data as collected by the Norwegian Environment Agency, given that despite more ambitious targets in 2009 the revised targets for Stavanger increased, whilst Trondheim targets decreased.

8.5 The Climate and Environment Plan 2018 - 2030

The Climate and Environmental Plan 2018 – 2030 was adopted by the city council of Stavanger in November of 2018. The plan targets an 80% reduction of all GHG emissions across the municipality by the end of 2030 compared to emission levels of 2015 and to be a fossil-free municipality by 2040 (Stavanger Kommune, 2018b).

Like the 2010 plan, the 2018 plan seeks to target specific sectors where transport remains the largest emitting sector in the municipality. The targets for the transportation sector correlate with the overarching plans, aiming to reduce the transport sector emissions by 80% by 2030 and 100% by 2040. Whilst the focus of the policy relates to road transportation methods, it also covers sea transportation (Stavanger Kommune, 2018b).

In addition to these primary objectives there is a range of secondary objectives which includes that 70% of people transport to be conducted either by foot, on bike or by public transport. The plan also calls for shortening average journey lengths and proposes new emission reduction targets for heavy and light vehicles among others. A range of specific measures are set out that the municipality will adopt with the aim of achieving their goal. This includes measures towards increasing and improving the public transport system, measures aimed at restricting the use of the car with new tolls and more restrictive parking measures, plus reference to a charging infrastructure strategy for the wider region. Also discussed are measures related to ensuring the municipality's fleet of vehicles are emission free by 2025 and several measures related to encouraging cycling within the city including the new cycle route between Stavanger and Stavanger, and the Hjem-Jobb-Hjem scheme that has been mentioned earlier.

One of the key changes between the 2010 plan and the 2018 plan is the introduction of the Action Plan, which identifies specific measures that provides additional layers and detail to the measures and targets proposed within the overarching plan. The action plan also covers just a four-year period i.e., 2018-2022 and will be updated in May 2022. The specific measures in the action plan identifies the responsible stakeholder within the municipality, external stakeholders, potential funding options and timescale to implement the measures over the four year period. As an example, Table 23 identifies measures to increase walking.

Measures for increasing walking						
ID	**Measures**	**Respon-sibility Stavanger Munici-pality**	**External stake-holders**	**Funding**	**2018-2019**	**2020-2022**
T13	Implement the shortcut project in all districts to survey, update and establish new shortcuts to important everyday destinations, e.g. kindergartens, schools, shops, bus stops and other important places in the local community.	Urban and Community Planning BMU	Nord-Jæren coope-ration	HØP Urban Environ ment Package Nord-Jæren		
T14	Ensure the identified shortcuts are well maintained	BMU				
T15	Initiate and support walking campaigns such as Beintøft (walk to school competition)	BMU	Eco-Agents	HØP		

Table 23: Section from Stavanger municipality action plan. Retrieved from (Stavanger Kommune, 2018a).

In addition to the action plan, the municipality has also committed to produce a climate budget on an annual basis as an initiative to monitor performance of the updated climate and Environment Plan 2018 - 2030. The purpose of the climate budget is to identify how they are performing in terms of reducing emissions and to identify what measures should be prioritised with the aim of decarbonisation.

When comparing the new document with the 2010 plan, there are numerous differences. There are two key aspects that we can state. First, the target levels have significantly increased (despite the municipality, based on our analysis, not reaching their goals for the 2010 plan). The target increases, fall in line with how the ambition on a national basis also has increased, as outlined in Section 5.2.1. The second aspect of the 2018 plan and supporting documents is that it provides a much greater level of detail in terms of the measures identified, through the production of the action plan, identifying sub-measures, parties responsible for delivering as well as funding and timescales. Alongside the Climate Budget, which the municipality will publish on an annual basis, it provides a much greater level of accountability to move towards reaching their goals.

In accordance with the Plan and Building Law of 2008 the Climate and Environment plan for 2018 – 2030 was out for consultation in May / June 2018. The initial plan proposed a target reduction of 50% by 2030 relative to 2015 emission levels. However, at the Stavanger City Council meeting when the plan was discussed, the Labor Party (AP), the Socialist People's Party (SV) and the MDG proposed to increase the target levels from 50% reduction to 80%. This got support from KRF, the Liberal Party (V) and the Conservative Party (H). There are no available documents on whether the politicians had a professional basis for how to achieve 80% reduction in emission. When asked about how they will achieve this goal, that time major Christine Sagen Helgø (H) stated "Electric buses are coming in full force. In a few years, all new cars will be zero-emission cars. If we look at other cities we can compare ourselves with, they have similar and even higher ambitions" (Aasland, 2018). It should also be noted that no additional measures were proposed to support the increase in targets. Thus it can be concluded that the increase in target levels was a political decision.

8.6 Projections to 2030

To assess how the municipality is progressing with the new targets we have used some of the data over the past period to project whether the municipality is on track with their targets. We have looked at the annual emission reduction averages for three periods over the period 2009-2020, for both road transport emissions and total emissions. The first being the 10-year average between 2009 and 2019, the period prior to Covid and the main scenario considered in this thesis. The second is the period 2015 to 2020, the rationale being that the 2018 Plan uses 2015 emission figures as the baseline for the targets to 2030 and we have actual data available up to 2020. Finally, we have also looked at the rate of reduction from 2019 to 2020, the year of the global pandemic, which showed a higher reduction rate. The average rates are shown in Table 24 and further data can be found in Appendix 2.

Annual Rate	Road Transport	Total Emissions
10-year average (2009 – 2019)	2,56 %	0,56 %
5-year average (2015-2020)	5,37 %	2,04 %
2020 (Covid-19 impacted year)	7,20 %	9,54 %

Table 24: Average annual reduction rate in emissions.

For this analysis, we have considered both road transportation emissions and total emissions for Stavanger. It should also be noted that we have adopted a compounded annual rate when projecting the figures into the future. The rationale for reviewing the data based on an annualised rate as opposed to a straight-line basis, is that it is likely to be more difficult to reduce emissions, as they decrease.

Road Transportation Emission Projections

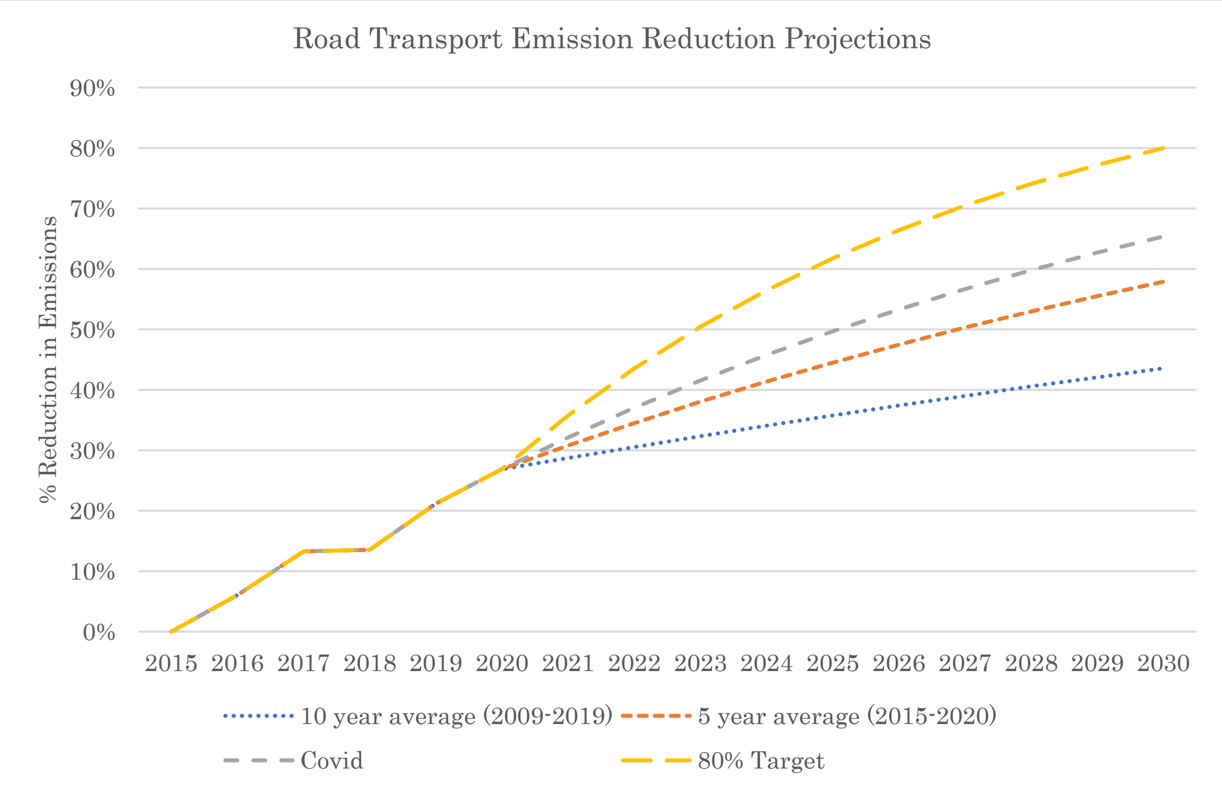

Figure 33: Road transportation emission projections.

In Figure 33, we can see that no scenario for road transport emissions achieve the 80% reduction, based on historic rates. Based on the historical trends for road transportation, there is a potential to achieve between 44% (based on the ten-year average) and a 65% reduction (based on the Covid year numbers). However, as already noted 2020 was an unusual year with many restrictions in place. We note that if Stavanger had sought to adopt the original 50% goal, then this is achievable based on the 5-year average but not the 10-year one. If Stavanger was able to achieve an annual reduction in emissions in line with the average over the period 2015-2020 (inclusive of Covid), then they could potentially achieve a 58% reduction in emissions.

We have calculated that based on the 2015 numbers, to achieve an 80% reduction in emissions, from 2020 through to the end of 2030, Stavanger will need to achieve an annual compounded rate of 12,16% per annum or an average emission reduction of 9 710 t/CO_2e per year, which reflects an average 7,26% reduction relative to the 2020-year emissions.

Total Emissions Projections

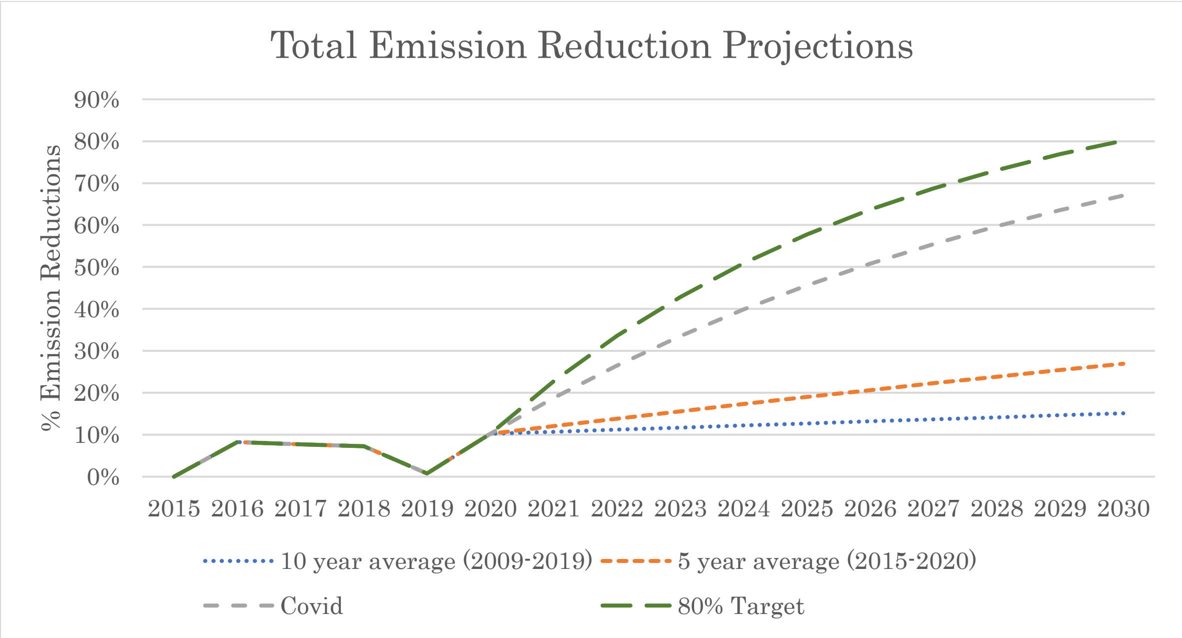

Figure 34: Total emissions projections.

For total emissions, Figure 34, we can also see that in all the historical average scenarios, total emission reductions will not meet the 80% target reduction in emissions compared with 2015 levels. Based on the compounded five-year average rate the municipality will only achieve a reduction of approximately 27%, considerably short of the 80% target. In 2020 the overall emissions fell by 9,54%. If we take this as the annual rate reduction the overall reductions by 2030 will reach 67%.

To achieve an 80% reduction based on an annualised rate, the municipality will need to achieve an average annualised rate of 14,00%.

8.6.1 Comparison with the municipality's projections

As part of the climate budget, Stavanger municipality have also produced their own projections and presented them in the document "Faggrunnlag till klimabudsjett 2022-2025 – Method, calculations and projection towards 2030" (Stavanger Kommune, 2021). This document was produced October 2021.

As part of the document the municipality presents three scenarios, moving towards 2030, where they seek to predict emissions based on measures that have been. The three scenarios are as follows:

- **Scenario 0** – "Activity change" – emissions develop only as result of estimated change and not related to specific measures. Examples provided are population growth and traffic growth. One such assumption is that traffic will grow by 15.4% over the time period.
- **Scenario 1** – "Reference Path" – emissions based on current adopted policy. This includes local measures proposed within the Stavanger Climate & Environmental Action Plan and also the National Transport Plan targets for phasing in low emission vehicles i.e., all passenger cars sold from 2025 and city buses will be emission free and

by 2030, the same will apply to vans, 75% of all long-distance buses and 50% of heavy trucks.

- **Scenario 2 –** "Ambitious Scenario" – this includes some more ambitious targets, relative to the shipping and fishing sectors. As noted previously, the shipping and maritime sector is the second largest emitter in Stavanger. It should be noted that there are no new road transport related reductions in this scenario.

It should also be noted that as we have noted previously, the base number for the Stavanger projections are slightly different to the base numbers that we have collected from NEA. The first difference is that Stavanger have excluded agriculture from their calculations and secondly, there are differences in reference to "Other vehicle combustion / annen mobil forbrenning". This accounts for some differences between the results, but nonetheless, they do provide a good source of comparison.

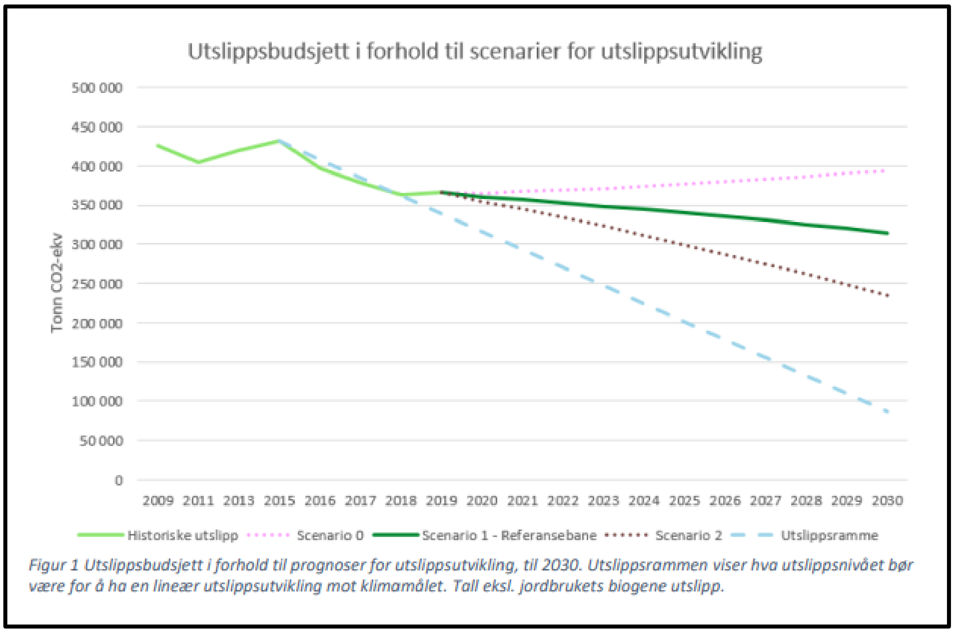

Figure 35: Emission budget in relation to scenarios for emission development. Retrieved from (Stavanger Kommune, 2021)

Figure 35 presents the projections based on the presented scenarios. It shows that based on Scenario 0, emissions will reduce by 9% between 2015 and 2030, Scenario 1 (Reference Path) could achieve a 27% reduction in emissions between 2015 and 2030 and Scenario 2 (optimistic scenario) suggests that a 45% reduction between 2015 and 2030 could be achieved. This is clearly significantly below the 80% goal and even their most optimistic scenario is below the pre-consultation target for 2030 of 50%.

In addition, based on our review of the historical numbers (inclusive of agriculture), the 10-year average that we have projected based on annualized growth (%) shows a reduction of 15,1% and the 5-year average of 26,9%, which broadly accords with the reference path scenario.

We can see that based on all the projection data, in no scenario presented does the municipality achieve the goal of 80% reduction in emissions.

8.7 Contact with the Municipality

To further our understanding of the decision making of the Climate and Environment Plan 2018-2030, we attempted to contact the municipality, specifically Jane Aalhus, the Environmental Protection Leader. We first sent an email on 24 January 2022, with no response.

This was followed up with an email on 29 April 2022, this time we sent our questions to the wider environmental team within the municipality. On the same day we received a response from Gabriele Brennhaugen, an advisor within the Climate and Environment section of the municipality.

The questions asked (translated from Norwegian to English) were as follows:

1. *The Climate Plan for Stavanger Municipality states that emissions within transport shall be reduced by 80%, while the climate plan that was out for consultation in May / June 2019 states a reduction of 50%. We therefore wondered if it was the municipality that proposed 80% following a professional basis or if this was a political decision in the city council?*

2. *After reviewing the "Professional basis for the climate budget 2022 - 2025", we see that in the emissions budget in relation to scenarios for emission development, the scenarios are given a 45% and 27% reduction. We therefore wonder whether it is expected that the transport and shipping sectors will be the largest emissions sectors by 2030? Or will there be other sectors that will require drastic measures?*

3. *Are previous climate plans such as the climate plan for 2010 - 2025 in Stavanger being revised and evaluated to examine whether the climate plan's goals were achieved?*

4. *If the target of 80% is not reached, or if forecasts show that the target cannot be achieved, will the target of 80% then be reduced to a lower, more achievable number?*

The following is a summary of the response that we got from the municipality, with full response being set out in Appendix 3 (in Norwegian).

In response to setting the goal, the administration initially took the decision of a 50% target as this was slightly above the goals that had been set at a national level, which was a 40% reduction. However, as we have noted in Section 8.5, the goal to go to 80% was a political one. It should also be noted that they have referred to goals set across other major cities that will have played a factor in selecting their emission targets; Oslo – 95% reduction compared with 1990, Bergen to be "fossil-free" by 2030 and Trondheim targeting an 80% reduction compared with 1990 levels.

In terms of the 2010 plan, they state that they did a review in 2015/2016, after this time the focus was on the new plan and some key recommendations were made, which primarily relates to the production of the action plan and the monitoring/follow up process.

When asked about their goals for 2030, there is no consideration of reducing their goals despite their forecasts and that the goal is *"ambitious" as "it shows where we want to go and creates commitment to move in this direction".*

In terms of measures the municipality references the phasing out of "fossil cars" at a national level as a key policy and incentive schemes in maritime transport as key methods of helping to reduce emissions. The municipality also references the Climate Budget as an important development to help in terms of governance and to be able to identify whether stricter measures are required.

8.8 Does Policy Work?

Following our dialogue with the municipality and when reviewing the findings of our thesis, the question arose as to whether policy works and contributes to decarbonisation.

Firstly, we need to consider the plan as a whole. The intention of the 2010 plan was to reduce emissions by 30% by 2020, with a wider plan period until 2025. However, as we are aware a review of the plan was undertaken in 2016, which concluded that they were significantly behind the target reduction. Following this, the 2010 plan was effectively disbanded and made way for the new 2018 plan. One of the barriers recognised in Section 3.6 is that there is no recourse if plans are not met or even whether there is a need to assess the plans. As outlined here following a review in 2016, the 2010 plan was effectively abandoned. The 2018 plan is now in place and whilst there is an annual review process to assess whether they are on track, the question remains as to whether the plan will be disbanded in the future like the 2010 plan?

In addition, it is important to consider the impact of local policy on decarbonisation. We have demonstrated that larger inroads into emission reductions are mainly influenced by external factors, case and point being technological shift is largely reliant on external stakeholders, being vehicle manufacturers and state-led financial policy. The penetration of local based policy is relatively limited, whilst it can influence its own organisation and assets that it controls.

Another aspect to consider is if the municipality is solely responsible for not reaching its targets. When the targets they set are not met, do we then "point fingers" at the municipality as its their own fault? Or is the municipality's role primarily as a facilitator in emission reduction and should we therefore be looking elsewhere for responsibility for the targets? The municipality's measures are regulated by the law such as the Planning and Building Act, meaning that there are only certain aspects they can influence, and they are reliant on third party stakeholders to implement means. On the other hand, if the plan did not exist, would we see the same progress that has been identified throughout this thesis?

In Section 3.6, we also highlighted a range of barriers that exist such as cultural, knowledge, financial, organisational, legal, and political. Whilst the thesis is not focused on the barriers that exists, for policy to work more effectively at the municipal level these need to be broken down further. A case in point being the economic growth vs environmental matters. For decarbonisation to occur at a faster rate, then environmental matters need to be prioritised. However, this comes at a cost.

8.9 Recommendations for the 80 % target

In Section 8.6 we have demonstrated that the 80% goal is very ambitious and it will require a significant increase in annual emission reductions to reach within both the road transportation sector and for total emissions. We estimate that road transportation emissions will need to reduce annually by 12,16% to achieve the goal that has been targeted. This is broadly in line with the municipality's own projections, insomuch as they are significantly behind the emission reduction targets.

When comparing the 2018 plan with the 2010 plan, it has gone significantly beyond its predecessor providing more detailed targeted measures, action plans, and emissions account. The list of means and measures proposed within the plan includes detailed approaches to increasing use of public transport, cycling, walking, restriction of cars through car-free zones and car sharing schemes, reduced impact of commercial transport (Stavanger Kommune, 2018a). The municipality knows that it needs to go beyond this to get close to the 80% target.

Our findings have demonstrated that the two most direct approaches to climate change is through technological improvement and modal shift, reducing the use of the car and transitioning to more "environmentally friendly" modes of transport. The measures outlined in the plan need to be prioritised and they need to be pushed. Based on our findings a utopian approach to decarbonisation is likely to be required, whereby environmental matters are prioritised over and above social and economic matters.

In this thesis we have consequently focused on "What has happened" rather than "Why has it happened". We cannot state a clear cause and effect from the 2010 plan and actual progress. Through statistical and documental research our aim has been to clarify how the municipality has progressed with their targets within the transportation sector. We haven't considered measures in isolation and therefore cannot provide specific recommendations that will aid in Stavanger municipality future work with the Climate and Environment plan 2018 - 2030.

8.10 Future research

This thesis has tried to detail the approach to decarbonisation within road transportation in Stavanger for the period 2010-2020 and how it has fared. Over the course of writing the thesis, we have identified several limitations both in terms of data and understanding the effectiveness of targets. Time has also been a contributing factor for decisions and approaches in the thesis.

The shift towards more sustainable transport is seen as a key factor to reduce emissions. However, there is limited research on the impact on travel trends of large-scale infrastructure projects and how that effects people shift towards sustainable transport. Further research that would assist this thesis specifically, is to what extent the busway contributes to shift people towards taking the bus. At the time of writing the thesis, the project is less than halfway complete. It is well praised by the county and politicians, and it is expected that it will help to reduce travel time around Nord-Jæren. However, there is little research if the busway will contribute to reducing emissions and change travel habits. This might cause for further research during and post-completion of the project.

Throughout writing this thesis substantial time has gone into data collection and finding relevant statistics. Stavanger municipality gets their emission data from the Norwegian Environment Agency. However, if we compare data from NEA and from the municipality in many cases, there are differences in what is being accounted for, making it challenging to provide easy comparison. Whilst methodologies are being refined and there is greater standardisation, perhaps a consistent methodology should be used.

Concentrated land use development is seen as a key focus area within the 2010 plan. It's difficult to calculate the effectiveness in a 10-year period, given the length of time that development takes. Therefore, further research would be useful when looking at how land-use development contributes to decarbonisation over a longer period or looking at specific developments in isolation and their impact on travel habits.

The Covid–19 pandemic is presented as an anomaly in this thesis mainly, because we are looking at progress over a 10-year period in relation to local policy in 2010, and during the pandemic national restrictive measures where implemented. Despite this, the pandemic brought new ways of working and teaching from home and showed peoples willingness to adapt. In addition, it showed how very restrictive measures impacted emissions, both at a national and at a municipal level, with limited data beyond. Further research on how the pandemic changed our traveling habits could be useful, and if any trends affect transportation on a more permanent basis.

9. CONCLUSION

9.0 Conclusion

The transportation sector is one of the leading contributors to rising global GHGs and the challenge globally is to decarbonise the sector, reducing or mitigating these rising emissions. Norway is often regarded as one of the leading countries in the fight against climate change. This research aims to identify how, at a municipal level, Stavanger, approaches decarbonisation within the transportation sector following the adoption of the Climate and Environment Plan in 2010, and whether it was successful in the targets set within the plan.

The research was based on a two-step approach following the literature review. Firstly, an assessment of the 2010 plan to identify the targets adopted and the policy identified, whilst also providing a comparison with the Trondheim plan. Secondly, we undertook a statistical analysis to provide a comparison between 2009 data and 2019/2020 data to assess whether progress has been made and targets achieved.

The 2010 plan firstly identified that they were targeting a 20% reduction in overall emissions, relative to their 1991 emission figures and the road transport sector was identified as the sector with the highest targets. The findings of our literature review identified three key approaches to tackling decarbonisation within the sector; (1) Avoid / Reduce the need to travel; (2) Modal Shift and (3) Improving Technology by way of their policy approach. The approach that Stavanger adopt within the 2010 plan identifies four key focus area, which follow the three key approaches taken. We did also undertake a comparison with Trondheim's approach, and it was apparent that whilst it also followed this broad approach, the 2010 plan (Stavanger) was less detailed in specifying measures, responsibility, targets and how measures would be funded.

From our statistical analysis we can conclude that Stavanger did not achieve their emission targets from the 2010 plan by 2019 or 2020, based on the updated data. There are limitations to assessing solely emissions in relation to decarbonisation as firstly, the data refers to direct emissions from the sector and there is no account for indirect emissions. Secondly, emissions do not provide for a specific assessment of the impact of policy. As such, we have also used a range of indicators in our assessment of policy.

In terms of technology, there has been progress across the municipality, significantly in personal cars, with electric and hybrid cars accounting for over a quarter of the registered vehicle fleet in 2019 compared with under 1% in 2009. Other vehicle types, such as buses, vans and lorries are further behind in terms of lower emission vehicle numbers, principally as a result of less competitive technology available for these vehicle types. Further to this, our findings were that technology was heavily influenced by elements outside the control of the municipality, principally private sector parties in the development of technology and national policy, in the form of financial incentives.

From the indicators, there was evidence of modal shift between 2009 and 2019, there was a reduction in the volume of travel by cars and a significant increase in passenger numbers for both rail and bus. Statistics related to cycling and walking were limited and as such difficult to conclusively state whether there had been an uptake in these modes.

The final approach was to reduce the need to travel. Whilst the policy approach was to densify along and around public transport axis, data was inconclusive as to whether this approach over the ten-year period had an impact on the transportation sector. However, we also found that given the timescale and based on our approach to data it would be challenging to establish a link.

Overall, there were signs of progress in decarbonising but not to the extent that was targeted as they fell short of the emission targets. In addition, the municipality's role is predominantly as a facilitator with direct measures that they can contribute to largely being limited. Therefore, should the onus also be on outside stakeholders to contribute to the goals to a greater extent?

The statistics also show that Covid-19 did have a meaningful impact on the transportation sector. In the year 2020, when nationwide restrictions were placed on society, emissions fell at a significant rate from the previous year and there was a significant reduction in passenger numbers on public transport. The impact of policy on 2020 was therefore very limited and it will be interesting to see what the data tells us over the coming years and whether Covid-19 has had any long-term effects on the transportation sector.

Another key finding that has come out of this thesis relates to the plan itself. Whilst the municipality set targets relating to the period of 2010 through to 2025, we found that the municipality carried out a review of the plan in 2016 which found that they were falling short of the targets that had been set. After this review, the plan was then disregarded, and they started to prepare a new Climate and Environmental plan for the period 2018-2030. There was no review in 2020 to assess whether the targets had been met and therefore no accountability for the municipality. Will the same happen for the 2018 Climate and Environment Plan?

The municipality has set out the new 2018 plan, with more ambitious targets setting a goal of reducing emissions by 80% by 2030. Based on our projections, significant work and changes in the transportation sector are required. Over the period there have been changes particularly from a technological perspective and modal shift (towards public transport), change is required at a faster and greater rate than has occurred over the previous period. In our opinion, to get closer to these ambitious targets, barriers need to be broken down and environmental matters need to be prioritised and decoupled from economic factors.

Finally, it is worth stating that decarbonisation of the transportation sector is vital in the global attempt to reduce the impact of climate change. We have found that even in a widely regarded, leading nation in tackling climate change, Norway, targets are still not being met. If goals and targets are to be met in line with the Paris Agreement, then environmental matters need to be prioritised.

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Figure 22: Train statistics in Stavanger area. Based on Statistics Norway. (2021c). 10484: Passenger transport by rail, by rail line 2012—2020 [Statistics]. Retrieved 13 May 2022, from https://www.ssb.no/statbank/table/10484/tableViewLayout1/

Figure 23: Kilometres adapted for cycling in Stavanger. Based on Statistics Norway. (2022d). 11816: Selected key figures for transport (M) 2015 - 2021 [Statistics]. Retrieved 13 May 2022, from https://www.ssb.no/statbank/table/11816/

Figure 24: Total Road traffic volumes by cars registered in Stavanger. Based on Statistics Norway. (2022e). *12579: Road traffic volumes, by home municipality of vehicle owner (M) 2005 - 2021* [Statistics]. https://www.ssb.no/en/statbank/table/12579/

Figure 25: Average distance travelled by cars registered in Stavanger. Based on Statistics Norway. (2022e). *12579: Road traffic volumes, by home municipality of vehicle owner (M) 2005 - 2021* [Statistics]. Retrieved 13 May 2022, from https://www.ssb.no/en/statbank/table/12579/

Figure 26: Car Parking availability at workplaces across Stavanger – 2014 and 2019. Based on:

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Figure 27: First-time registered vehicles in Norway by fuel type. Based on Statens Vegvesen. (2022). Oppdatert status på nullutslippskjøretøy. Retrieved 23 May 2022, from Statens vegvesen website: https://www.vegvesen.no/fag/fokusomrader/miljovennlig-transport/nullutslippsmalene/

Figure 28: Photo of the busway at Hillevåg. Retrived from Tønnessen, E. (2020). *Bilder og presentasjoner Bussveien—Rogaland fylkeskommune*. Rogaland Fylkeskommune. https://www.rogfk.no/vare-tjenester/vei-og-kollektivtransport/bussveien/bilder/

Figure 29: A completed section of the cycle highway between Stavanger and Sandnes. Retrived from Refvem, F. (2020). *Sykkelstamveien må spare, men det skal fortsatt bygges for nær 1,4 milliarder*. Stavanger Aftenblad. https://www.aftenbladet.no/lokalt/i/EpbPLj/sykkelstamveien-maa-spare-men-det-skal-fortsatt-bygges-for-naer-14-milliarder

Figure 30: Emissions per passenger kilometre – Norway. Based on Engedal, M. (2019). *Elbiler reduserer utslipp per personkilometer*. Ssb.No. https://www.ssb.no/transport-og-reiseliv/artikler-og-publikasjoner/elbiler-reduserer-utslipp-per-personkilometer

Figure 31: Total road traffic volumes by car registered in Stavanger. Based on Statistics Norway. (2022e). *12579: Road traffic volumes, by home municipality of vehicle owner (M) 2005 - 2021* [Statistics]. https://www.ssb.no/en/statbank/table/12579/

Figure 32: Annual bus passengers - Stavanger. Based on Statistics Norway. (2021b). 06672: Public transport by bus. City area routes 2005 - 2020 [Statistics]. Retrieved 13 May 2022, from https://www.ssb.no/en/statbank/table/06672/

Figure 33: Road transportation emission projections.

Figure 34: Total emissions projections.

Figure 35: Emission budget in relation to scenarios for emission development. Retrieved from Stavanger Kommune. (2021). *Faggrunnlag til klimabudsjett 2022-2025. Metode, beringer og fremskivning mot 2030*. https://www.stavanger.kommune.no/siteassets/renovasjon-klima-og-miljo/miljo-og-klima/klimabudsjett/faggrunnlag-klimabudsjett-stavanger-2022-.pdf

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Table 15: Road traffic emissions for cars registered in Stavanger. Based on:
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Table 19: Statistics from Stavanger muncipality cycle survey 2013 – 2021. Based on Stavanger Kommune. (2022b). *Sykkelundersøkelse og statistikk | Stavanger kommune*. https://www.stavanger.kommune.no/vei-og-trafikk/stavanger-pa-sykkel/sykkelstatistikk/

Table 20: Stavanger Municipal Parking Guidelines. Based on:
Stavanger Kommune. (2015). *Kommuneplan for Stavanger 2014—2029* (p. 134). https://www.stavanger.kommune.no/siteassets/samfunnsutvikling/planer/kommuneplan/kommuneplan-2014-29-lavopploselig.pdf
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Table 21: Stavanger and Trondheim targets. Based on
Stavanger Kommune. (2010). *Klima- og miljøplan 2010—2025*. https://www.stavanger.kommune.no/siteassets/samfunnsutvikling/planer/temaplaner/klima-og-miljoplan-for-stavanger-2010-2025.pdf
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Table 22: Stavanger and Trondheim road transport emissions.

Table 23: Section from Stavanger municipality action plan. Retrieved from Stavanger Kommune. (2018). *Climate and Environmental Plan 2018-2030 Action Plan 2018-2022* (p. 40). https://www.stavanger.kommune.no/siteassets/renovasjon-klima-og-miljo/miljo-og-klima/climate-and-environmental-action-plan--stavanger-2018-2022---final-version.pdf

Table 24: Annual rate of road transport and overall emissions.

Appendix

Appendix 1 – Statistics

Appendix 2 – Projections

Appendix 3 – Email correspondence with Stavanger kommune

APPENDIX 1
Statistics

Data: Population
Area: Stavanger Municipality
Source: Statistics Norway. (2021e). 06913: Population 1 January and population changes during the calendar year (M) 1951 - 2022 [Statistics]. https://www.ssb.no/en/statbank/table/06913/

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Population	128 288	130 709	133 142	134 849	136 825	138 567	140 043	140 721	140 856	141 186	142 034	143 574	144 147
Year-on-year change		1,89 %	1,86 %	1,28 %	1,47 %	1,27 %	1,07 %	0,48 %	0,10 %	0,23 %	0,60 %	1,08 %	0,40 %

Information:

- Population relates to the population at the beginning of the quarter. For the purpose of the data we have used Q4 population figures for each year
- Population figures for Stavanger are inclusive of Finnøy and Rennesøy

Limitations:

- Margin of error is low within th data related to coding, revision and processing errors - regarded as insignificant
- Survey undertaken for a census in 1990 concluded that registered residence was incorrect for 5,5% of the population - there can be difficulties in calculating certain aspects of the population. Students are an example, where they might be registered elsewhere also those that move abroad can pose some error where they have not reported the move.
- Does also not account for population that are residing in Norway illegally and therefore not registered.

Data: Greenhouse Gas Emissions in Stavanger
Area: Stavanger Municipality
Source: Miljødirektoratet. (2022). Utslipp av klimagasser i Norges kommuner og fylker—Miljødirektoratet. Miljødirektoratet/Norwegian Environment Agency. https://www.miljodirektoratet.no/tjenester/klimagassutslipp-kommuner/

t/CO2e	2009	2011	2013	2015	2016	2017	2018	2019	2020
Other vehicle combustion	23 525	33 222	38 901	26 771	22 207	23 726	31 516	74 896	65 546
Waste and sewage	1 269	1 310	1 169	1 248	1 270	1 283	1 192	1 208	1 283
Energy Supply	0	0	104	77	217	7 801	6 622	4 473	4 823
Industry, oil and gas	11 763	12 057	10 891	9 299	10 251	15 442	14 388	13 547	10 109
Agriculture	58 542	56 271	55 955	57 195	57 543	56 334	55 198	56 775	57 284
Aviation	1	0	0	1	1	3	1	2	3
Heating	51 179	42 286	42 694	38 825	32 602	33 709	32 030	28 318	27 868
Shipping	143 493	143 493	143 493	143 493	125 982	127 573	127 437	133 028	112 182
Road Traffic	193 620	190 255	186 244	182 763	171 704	158 510	157 999	144 062	133 687
TOTAL	483 392	478 893	479 453	459 672	421 777	424 380	426 382	456 309	412 786

Information:

- Measured on CO2 equivalent tonnes
- Data relates to emissions that have occurred within the municipalities boundaries - i.e. this means emissions direct from exhaust of a diesel car will relate to those that occur within the municipal boundary
- Data collected on a bi-annual basis prior to 2015 and no sufficient data prior to 2009
- Data covers only Scope 1 (direct) emissions.

Limitations:

- Measured in CO2 equivalents
- Indirect emissions that occur will fall under a different category. For example, production of car falls under 'Industry, oil and gas'
- The emission accounts use data sources that show the development at the local level to the greatest possible extent. The data sources, and also the total amount of greenhouse gas emissions, can therefore vary from the national emission accounts. albeit the methodology is the same
- No direct comparable data prior to 2009 as it is based on differing methodologies for the collection of data
- Indirect emissions are not accounted for.
- Differences between municipal accounts and the national accounts. The methodology for calculating emissions are predominantly the same with some differences. For municipality calculations:
  > Emissions from offshore oil and gas are not included
  > Emissions from road traffic uses a different methodology
  > Municipalities do not include hydrocarbon emissions in calculations

Data: Road Transport Emissions by Vehicle Type - Stavanger
Area: Stavanger Municipality
Source: Miljødirektoratet. (2022). Utslipp av klimagasser i Norges kommuner og fylker—Miljødirektoratet. Miljødirektoratet/Norwegian Environment Agency. https://www.miljodirektoratet.no/tjenester/klimagassutslipp-kommuner/

t/CO2e	2009	2011	2013	2015	2016	2017	2018	2019	2020
Bus	12 200	12 036	12 406	12 511	11 755	10 814	10 607	9 530	9 511
Personbiler	131 877	129 388	126 386	122 998	115 688	107 882	105 642	94 823	84 693
Lorries	22 859	23 209	23 550	24 296	23 349	21 323	22 850	21 917	21 992
Vans	26 685	25 622	23 903	22 958	20 913	18 490	18 901	17 792	17 491
TOTAL	193 620	190 255	186 244	182 763	171 704	158 510	157 999	144 062	133 687

Information:

- Calculated on an annual basis
- Method for calculating emissions differs from national emission inventory
- Calculated using the 'NERVE' model - which calculates emissions depending on type of vehicle, fuel type,driving situation and environment

Limitations:

- Biofuel emissions uses a national average rather than local differences in the blend
- Some changes are captured more slowly. For example, this applies to changes in the road network or driving patterns which are captured in the Regional Transport Model and are captured every four years

Data: Domestic Passenger Travels
Area: Norway
Soruce: Statistics Norway. (2021f). *03982: Domestic passenger transport, by mode of transport 1965—2020* [Statistics]. https://www.ssb.no/en/statbank/table/03982/tableViewLayout1/

Passengers (million)	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Railway transport etc.	175	183	195	201	211	219	233	245	255	266	272	153
Scheduled bus transport	346	314	322	332	340	344	356	369	396	404	434	290
Taxis	55	53	55	54	54	52	51	46	48	49	50	35
Rental cars etc.	78	83	93	103	110	117	126	133	147	164	178	195
Private cars	4188	4194	4267	4316	4368	4506	4588	4605	4693	4707	4720	4384
Motorcycles, mopeds	157	161	165	168	171	174	177	178	178	173	170	169
TOTAL	4999	4988	5097	5174	5254	5412	5531	5576	5717	5763	5824	5226

Information:

- Domestic travel refers to transport from one place to another within Norway
- Passengers - refers to individual journeys

Limitations:

- Uses a number of databases to collect statistic for the various modes of transport, it is therefore reliant on these databases.
- Database also states that there is an element of uncertainty related to the model assumptions. No specific detail on these.

Data:	Bus Transport Statistics	
Area:	Nord-Jæren	
Source:	Statistics Norway. (2021b). *06672: Public transport by bus. City area routes 2005 - 2020* [Statistics]. https://www.ssb.no/en/statbank/table/06672/	

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Passengers (1 000)	14 014	14 796	14 286	14 836	13 821	15 872	17 461	17 825	18 167	18 820	22 309	16 079
Vehicle kilometres (1 000 km)	11 895	12 134	12 373	12 377	12 588	13 166	14 871	8 030	13 842	13 687	13 382	13 640
Passenger Km (1 000)	147 148	155 359	149 999	158 749	154 525	159 215	148 488	139 923	109 363	113 299	123 255	92 456
Ave. Distance per passenger	10,50	10,50	10,50	10,70	11,18	10,03	8,50	7,85	6,02	6,02	5,52	5,75
Ave. Passenger km per inhabitar	671	695	671	685	654	663	599	561	436	448	482	352
Utilisation of Capacity	32 %	32 %	30 %	32 %	31 %	32 %	27 %	47 %	24 %	19 %	23 %	16 %

Information:

- Vehicle Km: Total distance driven in km (inclusive of position run and other out of journey routes without passengers)

- Passenger Km: An inter modal statistic. Number of passengers * travelled distance

- Ave. Distance per Passenger: Passenger km / Passengers (own calculation)

- Utilisation capacity: Passenger km / Seat km (measure of capacity found by multiplying no. of seats * distance the seats are offered)

Limitations:

Data related to public transport relates to the Nord-Jæren region. The data relates to Stavanger, Sandnes, Sola and Randaberg. As Rogaland Kommune manages the bus transport across the region.

According to SSB, the data is collected via questionnaires to key stakeholders. There can be an element of inaccuracy in collecting this data. A non-response accounts for approximately 2%

Passenger km is also established using estimates by the relevant establishments, and often based on averages.

Data: Train Statistics
Area: Stavanger & Norway
Source: Statistics Norway. (2021c). *10484: Passenger transport by rail, by rail line 2012—2020* [Statistics]. https://www.ssb.no/statbank/table/10484/tableViewLayout1/

Stavanger	2012	2013	2014	2015	2016	2017	2018	2019	2020
Passengers	3 291 741	3 455 045	3 687 356	3 622 309	3 713 267	3 586 017	4 322 029	5 024 461	3 323 953
Passenger kms	66 715 398	70 025 162	73 358 166	72 553 905	72 433 499	69 029 369	80 291 828	89 928 275	54 693 772
Ave. Distance per passenger	20,3	20,3	19,9	20,0	19,5	19,2	18,6	17,9	16,5

Norway - all Routes	2012	2013	2014	2015	2016	2017	2018	2019	2020
Passengers	62 689 207	67 250 555	70 340 655	73 836 237	74 295 092	73 560 977	77 732 015	80 402 213	42 599 038
Passenger kms	3 108 954 418	3 259 864 133	3 439 782 823	3 555 033 832	3 695 387 322	3 584 485 060	3 721 894 539	3 715 089 785	1 803 943 240
Ave. Distance per passenger	49,6	48,5	48,9	48,1	49,7	48,7	47,9	46,2	42,3

<u>Information:</u>

- Passenger - individual trips
- Passenger kms - Passengers * km per trip travelled
- Data collected at a national level

<u>Limitations:</u>

- Margin of error within the statistics and reliance on questionnaire data provided by all rail operators

- No available data prior to 2012

Data: Road Traffic Volumes - Total & Average
Area: Stavanger
Source: Statistics Norway. (2022e). 12579: Road traffic volumes, by home municipality of vehicle owner (M) 2005 - 2021 [Statistics]. https://www.ssb.no/en/statbank/table/12579/

Total Road Traffic Volumes (million km)	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
All passenger cars	725,8	686,3	683,2	700,1	706,2	678,1	671,7	668,8	664,2	657,7	635,3	670,8
All buses	8,4	6,7	8,6	9,7	10,3	12,4	16,9	17,5	15,4	24,9	31,7	34,4
All vans and small lorries	158,0	145,0	138,0	133,1	122,3	115,1	109,7	103,1	98,5	94,1	93,2	103,3
All heavy lorries and road tractors	34,2	31,0	31,1	31,0	31,2	31,1	29,8	28,8	29,7	33,1	32,3	34,9
All vehicles	926,3	869,1	860,9	873,9	869,9	836,7	828,1	818,2	807,8	809,8	792,4	843,4

Average Road Traffic Volumes (km)	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
All passenger cars	12 798	11 814	11 514	11 545	11 397	10 863	10 742	10 661	10 572	10 598	10 269	10 059
All buses	21 883	18 964	23 855	27 629	28 660	31 577	41 414	40 177	35 803	40 277	40 169	43 624
All vans and small lorries	16 189	14 932	14 494	14 352	13 815	13 260	13 142	12 967	12 775	12 493	12 381	12 103
All heavy lorries and road tractors	39 785	35 645	36 816	34 851	34 683	36 153	35 564	35 096	35 143	38 406	36 141	35 327
All vehicles	13 680	12 590	12 288	12 282	12 070	11 564	11 481	11 374	11 249	11 394	11 150	10 953

Information:

- Bus - registered to carry more than 16 people
- Vans and small lorries - with a carrying capacity of between 1 and 3.5 tonnes
- Vehicle-km - kilometres driven
- Calculated at a municipal level
- Statistics covers vehicles registered in Norway and the data is based on data collected from register administered by the Norwegian Public Roads Administration
- Data is based on odometer readings (accounting for c. 75% of vehicles), estimated for the remaining 25%
- Revised model for collecting data was deveoped in 2018 - allowing to provide more detailed information relative to fuel types within each vehicle type. Limited deviations with respect of the overall results
- In 2020, odometer readings were only used for the second half of the year.

Limitations:

- Measurement errors can occur i.e. wrong scale between mile and kilometres
- Processing errors - an example being that approximately 2% of odometer readings are deleted. Processing errors are not believed to introduce systematic errors within the result
- Sampling errors can occur where estimates are based on a sample of the population and not a census of the entire population
- There are some discrepancies between 2019 and 2020 as a result of a change in technology and new content for the vehicle register.

Data: Registered Vehicles by type of transport and type of fuel
Area: Stavanger
Source: Statistics Norway. (2022b). 07849: Registered vehicles, by type of transport and type of fuel (M) 2008—2021 [Statistics]. https://www.ssb.no/statbank/table/07849/tableViewLayout1/

Cars	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Petrol	40 997	39 763	38 262	37 270	36 305	34 974	33 952	31 050	29 200	27 037	25 702	23 445
Diesel	15 735	18 453	21 290	23 681	25 363	26 598	27 104	27 150	26 579	25 210	23 958	23 085
Electricity	50	51	128	272	619	1 299	2 175	2 839	3 973	6 391	8 707	10 758
Other Fuel (Hybrid)	4	8	9	17	72	24	18	2 325	3 335	4 008	4 705	5 905
TOTAL	56 786	58 275	59 689	61 240	62 359	62 895	63 249	63 364	63 087	62 646	63 072	63 193

Buses	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Petrol	21	20	11	8	6	7	6	5	3	2	2	2
Diesel	395	353	379	360	367	384	396	390	341	480	637	641
Electricity	0	0	0	0	0	0	2	2	5	10	14	16
Other Fuel	0	1	1	1	2	1	1	1	11	89	91	91
TOTAL	416	374	391	369	375	392	405	398	360	581	744	750

Vans	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Petrol	1259	1127	990	935	826	740	655	585	512	467	444	412
Diesel	7729	7873	7909	7882	7658	7707	7550	7314	7181	7024	7035	7294
Gas	31	70	92	102	105	102	77	76	73	71	72	68
Electricity	5	5	5	4	6	18	38	43	65	125	192	256
TOTAL	9 024	9 075	8 996	8 923	8 595	8 567	8 320	8 018	7 831	7 687	7 743	8 030

Lorries	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Petrol	98	92	84	75	63	54	40	28	23	21	18	14
Diesel	1416	1363	1293	1292	1286	1206	1137	1114	1106	1092	1109	1153
Gas	3	6	6	6	9	11	13	13	12	11	11	19
Electricity	0	0	0	0	0	0	0	0	0	0	1	1
TOTAL	1 517	1 461	1 383	1 373	1 358	1 271	1 190	1 155	1 141	1 124	1 139	1 187

Information:

- Other fuel - relates to hybrid vehicles

Limitations:

- Distribution of vehicles refers to where the car is registered, this does not necessarily correspond to where the car is in use. A particular example of this relates to leased vehicles which will state that the location of registration relates to the leasing company.

Data: Cycling adapted routes - Stavanger
Area: Stavanger
Source: Statistics Norway. (2022d). *11816: Selected key figures for transport (M) 2015 - 2021* [Statistics]. https://www.ssb.no/statbank/table/11816/

	2015	2016	2017	2018	2019	2020	2021
Number of kms adapted for cycling which is a municipal responsibility (km)	110	113	118	130	130	132	135
Number of km designed for cycling per 10 000 inhabitants (km)	8,3	8,5	8,9	9,7	9,6	9,2	9,3
Proportion of km adapted for cycling in per cent of all municipal roads (per ce	18,5	19,1	19,9	21,7	22	18,5	18,9
Number of kms arranged for cycling last year (km)	15	5	5	5	5	2	5

Information:

- Number of kms adapted for cycling which is a municipal responsibility (km)
Includes cycle paths, combined pedestrian and cycle paths, own cycling fields and measures in streets with a speed limit of 30 km / h or 40 km / h in a cycle network. Pavements along the municipal road is not included.

Limitations:

- Processing errors can occur
- Partial non-response occurs

Data: Population Densities of Urban Settlements
Area: Stavanger
Soruce: Statistics Norway. (2021a). 04861: Area and population of urban settlements (M) 2000 - 2021 [Statistics]. https://www.ssb.no/en/statbank/table/04861/

	2009	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Area of urban settlements (km²)	45,95	46,48	46,53	42,36	43,43	43,62	43,85	43,95	44,11	44,12	44,13
Number of residents	121 162	125 571	127 113	129 728	131 769	133 302	134 420	134 642	135 190	136 138	137 663
Average number of residents per km²	2 637	2 702	2 732	3 063	3 034	3 056	3 065	3 064	3 065	3 086	3 119

Information:

- Population is different from population of municipality as this data refers to the population that lives within a settlement boundary
- Urban settlement - cluster of buildings is registered as an urban settlement if it is inhabited by at least 200 people. Distance between buildings should not exceed 50 metres but can be increased to 200m where the area includes other uses.
- Boundary of urban settlement is independent o administrative boundaries and change over time depending on construction activity and change of population.

Limitations:

- Data is collated by merging two registers. If data is not identical witin the registers then it will not be counted.
- Method for collecting delimitation was changed in 2013 across the country. The area of urban settlements declined and number of inhabitants increased as a result. Therefore data, prior to this year cannot be regarded as comparable to data after 2013.

Data:	National Travel Survey Statistics
Area:	Stavanger
Source:	Hjorthol, R., Engebretsen, Ø., & Uteng, T. P. (2014). Den nasjonale reisevaneundersøkelsen 2013/14: Nøkkelrapport. Transportøkonomisk institutt. https://www.vegvesen.no/globalassets/fag/fokusomrader/nasjonal-transportplan-ntp/reisevaner/2014/toi-rapport-1383-2014-rvu-2013-nokkelrapport.pdf Epinion. (2019). NASJONAL REISEVANEUNDERSØKELSE 2018. https://www.vegvesen.no/globalassets/fag/fokusomrader/nasjonal-transportplan-ntp/reisevaner/nokkelrapport-rvu-2018-vedlegg-002.pdf Opedal, J., Skar, H., Røsand, P., Dischler, R., & Brauteset, O. (2021). Nasjonal reisevaneundersøkelse (RVU) Nøkkeltallsrapport 2020. Opinion. https://www.vegvesen.no/globalassets/fag/fokusomrader/nasjonal-transportplan-ntp/reisevaner/2020/nokkeltallsrapport-2020-versjon-per-23.12.21.pdf Grue, B., Landa-Mata, I., & Flotve, B. (2021). Den nasjonale reisevaneundersøkelsen 2018/19 (p. 198). Transportøkonomisk institutt. https://www.toi.no/getfile.php?mmfileid=71405

	2014	2018	2019	2020
Participants - Total	61 366	55000-150000*	90 000	38 448
Participants - Stavanger	1 547	900-3000	3 819	2 018

* 2018 NTS asked different number of people each question

Mode of Transport - Daily Jour	2014	2018	2019	2020
Walking	24 %	23 %	24 %	25 %
Cycling	8 %	9 %	9 %	8 %
Car driver	49 %	47 %	46 %	50 %
Car passenger	8 %	9 %	9 %	9 %
Public Transport	10 %	11 %	11 %	7 %
MC / other	1 %	1 %	1 %	1 %

Public Transport- Daily Journe	2014	2018	2019	2020
Bus	77 %	70 %	74 %	N/A
Train	5 %	13 %	13 %	N/A
Flying	5 %	4 %	5 %	N/A
Taxi	7 %	7 %	5 %	N/A
Boat	6 %	6 %	4 %	N/A

Cars per household	2013/14	2018	2019	2020
0 cars	12 %	13 %	16 %	15 %
1 cars	55 %	53 %	52 %	51 %
2 cars	28 %	29 %	27 %	28 %
3+ cars	5 %	5 %	5 %	6 %

Access to bicycles	2013/14	2018	2019	2020
Yes	80 %	N/A	74 %	74 %

Car Parking at work	2013/14	2018	2019	2020
Free	78 %	N/A	73 %	N/A
Paid	7 %	N/A	11 %	N/A
No parking	15 %	N/A	15 %	N/A

<u>Limitations:</u>

- There are variations in terms of the questions asked between the different surveys
- 2018 Survey was carried out over a three year period from 2016-2018 and the number of participants relative to the questions asked varies within this survey

APPENDIX 2
Projections

Data	Emission Projections to 2030
Area	Stavanger Municipality
Source	Self-calculated based on Miljødirektorate data for emissions

Per annum basis	Road Transportation Emissions	Total Emissions
10 year average rate	2,56 %	0,56 %
5-year average rate	5,37 %	2,04 %
Covid (2019-2020)	7,20 %	9,54 %
Required Rate (80%)	12,16 %	14,00 %

Target Emissions Total	**36 553**	**91 934**

ROAD TRANSPORT EMISSIONS	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
10 year average (2009-2019)	182 763	171 704	158 510	157 999	144 062	133 687	130 265	126 931	123 682	120 516	117 432	114 426	111 497	108 643	105 863	**103 153**
5 year average (2015-2020)	182 763	171 704	158 510	157 999	144 062	133 687	126 507	119 713	113 284	107 200	101 443	95 995	90 840	85 961	81 345	**76 976**
Covid	182 763	171 704	158 510	157 999	144 062	133 687	124 060	115 125	106 835	99 141	92 001	85 376	79 228	73 522	68 227	**63 314**
80% Target	182 763	171 704	158 510	157 999	144 062	133 687	117 437	103 163	90 623	79 608	69 932	61 432	53 965	47 405	41 643	**36 581**

TOTAL EMISSIONS	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
10 year average (2009-2019)	459 672	421 777	424 380	426 382	456 309	412 786	410 473	408 173	405 886	403 612	401 351	399 103	396 867	394 643	392 432	**390 234**
5 year average (2015-2020)	459 672	421 777	424 380	426 382	456 309	412 786	404 365	396 116	388 035	380 119	372 365	364 769	357 328	350 038	342 898	**335 903**
Covid	459 672	421 777	424 380	426 382	456 309	412 786	373 413	337 796	305 576	276 430	250 063	226 212	204 635	185 117	167 460	**151 487**
80% Target	459 672	421 777	424 380	426 382	456 309	412 786	354 996	305 296	262 555	225 797	194 185	167 000	143 620	123 513	106 221	**91 350**

APPENDIX 3
Email correspondence

VS: Spørsmål vedrørende en masteroppgave

Gabriele Brennhaugen <gabr@stavanger.kommune.no>

Fri 29/04/2022 10:22

To: torkelm@hotmail.com <torkelm@hotmail.com>;261850@uis.no <261850@uis.no>;ben.dzicz@hotmail.com <ben.dzicz@hotmail.com>

Cc: Jane Nilsen Aalhus <jane.nilsen.aalhus@stavanger.kommune.no>;Imme Dirks Eskeland <imme.dirks.eskeland@stavanger.kommune.no>

Hei Torkel og Ben,

Takk for henvendelsen deres!

Nedenfor ser dere svar på spørsmålene, og enda mer informasjon finner dere om dere går inn i de politiske sakene vi refererer til.

Lykke til med masteroppgaven!

Med vennlig hilsen
Gabriele Brennhaugen
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Stavanger kommune

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Emne: Spørsmål vedrørende en masteroppgave

Hei Jane, Gabriele og Imme.

Vi er to master studenter som studerer byplanlegging ved Universitet i Stavanger. I forbindelse med masteroppgaven vår som handler om utslipp innen transportsektoren i Stavanger Kommune, lurte vi på om dere kunne svare på noen spørsmål.

1. **I Klimaplanen for Stavanger Kommune står det at utslipp innen transport skal reduseres med 80 %, mens i klimaplanen som var ute på høring i mai/juni 2019 står det en reduksjon på 50 %. Vi lurte derfor på om det var kommunen som foreslå 80 % med et faglig grunnlag eller om dette var en politisk avgjørelse i bystyret?**

Målet for utslippsreduksjon i Stavanger ble diskutert i flere politiske møter under planarbeidet i 2017/2018. Det nasjonale målet var den gang 40 % kutt innen 2030, men flere større byer hadde vedtatt mer ambisiøse mål: Oslo 95 % fra 1990-nivå, Bergen skulle være «fossilfri by» innen 2030, og Trondheim skulle kutte 80 % innen 2030, fra 1990-nivå.

Ut fra de politiske føringene som ble gitt, valgte administrasjonen å gå litt ut over det nasjonale målet på 40 prosent, og foreslo 50 %. Dette gjaldt for øvrig ikke bare for transportsektoren, men for alle utslippene innenfor den daværende kommunegrensen.

Vedtaket om å sette mål om 80 % reduksjon kom ved siste politiske behandling, i Stavanger bystyre den 26.11.2018. Per A. Thorbjørnsen (V) foreslo på vegne av sju parti (Ap, V, MDG, KrF, SV, Sp, Rødt) å sette mål om 80 % kutt, og det ble flertall for dette, med stemmene til disse partiene samt 4 fra Høyre. Dere kan lese saksdokumenter og protokoller på denne siden: Politiske møter - Møter - Stavanger bystyre (26.11.2018) (360online.com)

2. **Etter å ha gjennomgått «Faggrunnlaget til klimabudsjett 2022 – 2025» ser vi at i utslippsbudsjettet i forhold til scenarier for utslippsutvikling er scenariene gitt 45 % og 27 % reduksjon. Vi lurer derfor på om det er forventet at transportsektoren og sjøfart vil være de største utslipp sektorene ved 2030? Eller vil det være andre sektorer som vil kreve drastiske tiltak?**

Veitrafikk og sjøfartssektorene vil fortsatt være de største utslippssektorene i fremtidsscenariet (selv om sektorene har kuttet betydelig). Andre bidrag til utslipp omfatter naturgassbruk i sektor «oppvarming», og annen mobil forbrenning, selv om disse er mindre. Som beskrevet i budsjettet er ikke biogene jordbruksutslipp omfattet av fremskrivingen.

3. **Blir tidligere klimaplaner som for eksempel klimaplanen for 2010 – 2025 i Stavanger revidert og evaluert for å undersøke om klimaplanens mål ble oppnådd?**

   Dersom målet om 80 % ikke blir nådd, eller at prognoser viser at målet ikke lar seg oppnå. Vil målet om 80 % da kunne reduseres til et lavere, mer oppnåelig tall?

Vi gjorde en grundig intern evaluering av klimaplanen for 2010-2025 i 2015/2016, før vi startet arbeidet med den nye planen. Omtrent samtidig gjorde Rogaland Revisjon en analyse av oppfølgingen av planen. Det kan dere lese mer om her: Politiske møter - Møter - Stavanger Bystyre (09.05.2016) (360online.com). Anbefalinger om å lage konkrete handlingsplaner og plassering av ansvar for oppfølgingen tok vi med oss inn i den nye planen, og har så langt veldig positiv erfaring med dét.

Når det gjelder målet, er det ingen tanker om å redusere ambisjonene. Tvert imot har dette målet satt en tydelig retning, og både administrasjonen og politikerne jobber for å nå så store kutt som mulig. Mange tiltak er også knyttet til nasjonale føringer – som f.eks. utfasing av nye «fossilbiler» innen 2025, eller incentivordninger for å redusere utslipp innen sjøtransport, slik det blir gjort for veitransport.

Vi har også fått flere nye verktøy for å følge utviklingen nøye – ikke minst Klimabudsjettet, som viser reduksjonspotensialet med de vedtatte tiltakene, og gapet opp mot målet. Det gir bedre muligheter for politisk styring og til å sette inn nye eller strengere tiltak der hvor det trengs.

Et ambisiøst mål vil derfor være viktig selv om man kanskje ikke klarer å oppfylle det akkurat «på tida». Det viser hvor vi vil hen, og skaper engasjement for å bevege oss i denne retningen.

Vennlig hilsen Torkel og Ben