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# Roadmap for decarbonisation of fleet vehicle at NHS Greater Glasgow & Clyde board, Scotland, United Kingdom

Sonam Dagay

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| **Supervisor I**<br>Dr Craig Thomson | **Supervisor II**<br>Mr Paul Carroll | |

**Title**

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**Degree:** Master in Urban Climate & Sustainability

**Abstract** Road transport plays a vital role in the socio-economic development by moving goods, services and people. However, being highly dependent on fossil fuels it has significant impact on global climate change and human health. There have been minimal emission reductions in the transport sector in UK and Scotland. It is now the highest emitter of GHG and a major source of air pollution. The UK and Scottish governments have set legally binding targets of achieving net zero emissions. While committing to phase out conventional fuel vehicles by 2030. Through a case study research strategy and using mixed method approach, the study aims to design a roadmap for decarbonisation of fleet vehicles at the NHS Greater Glasgow and Clyde board. Firstly, an extensive literature review was conducted to understand the background of policies, impacts of transport on GHG emission and air pollution and explore evolution of electric vehicle technology. Then a review of deployment of EVs in Norway and China was conducted to understand best practices, success factors, challenges and effectiveness of electric vehicles in decarbonisation of transport. Thirdly, using secondary data and interviews a SWOT analysis was conducted to identify and analyse the key factors and challenges affecting the decarbonisation of transport. Next backcasting was performed through combination of qualitative desk research and a quantitative analysis to assess the implications of achieving “net zero emission” fleet for two target years (2025 & 2045). Lastly, informed by the literature review, SWOT and outcomes of the backcasting exercise, key interventions were identified and it is presented in the form of a roadmap for achieving “net zero fleet” by 2045 at NHSGGC. The research reveals highly favourable policies and incentives for decarbonisation of transport, high potential of EVs in reducing emissions in UK and Scottish context. Uncertainty in funding, practical capability of EVs, adequacy of charging points and under utilisation of existing fleet vehicles were found to be key challenges in achieving a “net zero fleet” by 2025. It is recommended to undertake mass adoption of EVs with caution to avoid disappointments from technological failure since most of the EV models are yet to be tested and tried. Comprehensive review of the fleet and investigation of the EVs would reduce the risk of technological disappointment and sustainability impacts of mass adoption of EVs.

**Keywords**

fleet vehicle, net zero fleet, roadmap

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| **Originality statement.** I hereby declare that this Master’s dissertation is my own original work, does not contain other people’s work without this being stated, cited and referenced, has not been submitted elsewhere in fulfilment of the requirements of this or any other award. | **Signature** |

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## ABBREVIATIONS

| | | |
|---|---|---|
| 1. | EV | Electric Vehicle |
| 2. | PHEV | Plug-in Hybrid Electric Vehicle |
| 3. | HEV | Hybrid Electric Vehicle |
| 4. | ICEV | Internal Combustion Engine Vehicle |
| 5. | CO2eq | Carbondioxide equivalent |
| 6. | PM | Particulate matter |
| 7. | NOx | Nitrogen oxides |

# CHAPTER 1: INTRODUCTION

## 1.1 Rationale

According to the 5th assessment report of the IPCC, there is continued increase in global anthropogenic emission of greenhouse gases mainly due to growth in population and economic activities. Combustion of fossil fuel is the key driver in the increase of GHG emissions. Amongst the various sectors responsible for the rising emissions, transport sector has a significant contribution accounting for 11% of the 10 $GtCO_2eq$ increase in global GHG emissions between 2000 and 2010. Owing to the increased emissions, the average global temperature has risen by 0.85°C between 1880 and 2012. It is projected to increase by 3.7°C to 4.8°C compared to pre-industrial levels by the end of the century if additional measures to reduce emissions are not implemented. This would have adverse impacts on both human and natural systems. Further delay in mitigation efforts is expected to significantly increase the difficulty of transitioning to low longer-term emissions levels and limit the range of options available for preventing dangerous consequences of climate change (IPCC, 2014).

There have been significant achievements in reductions of the net GHG emissions in UK and Scotland. In UK the emissions decreased by 44% between 1990 and 2019. The highest emission reductions have been achieved in the energy supply (66%) and waste management (71%) compared to 5% reduction from the transport. Similarly for Scotland, the emissions decreased by 43.8% between 1990 and 2018. The highest reductions were from energy supply (71.8%) and 70.8% from land use, land use change and forestry (LULUCF). Only 11.3% reductions were achieved in the transport sector. As such, transport is currently the highest emitter in the UK and also in Scotland. In 2019, emissions from transport accounted for 27% of the total emissions in UK with majority of the emissions from combustion of fossil fuel in road transport. In 2018, transport emissions accounted for 36% of the total Scottish emissions of which 68% were from road transport (BEIS 2021, Scottish Government, 2020). In addition to being the highest contributor to the GHG emissions, road transport is also a major source of air pollution in UK and Scotland. Particulate matter pollution in UK causes about 29000 deaths annually and coupled with nitrogen dioxide pollution, approximately 40,000 persons die each year from exposure to poor air quality (Royal College of Physicians, 2016). Globally 7 million people die each year from air pollution and combustion of fossil fuel is one of the main contributors to air pollution (WHO, 2020).

Towards achieving emission reduction from transport and improving the air quality to reduce impacts on human health, numerous policy and legislative interventions have been adopted and implemented in UK and Scotland. Legislation to prevent pollution and improve air quality has been enacted as far back as 1956. Specifically with regard to controlling emissions from vehicles, euro emission standards have been implemented since 1992. Most ambitious legislation for emission reduction was the adoption of the *Climate Change Act 2008* and *Climate Change (Scotland) Act 2009* to set legally binding emission reduction targets. In response to global climate emergency in 2019, the emission reduction targets have been further raised to achieve "net zero emissions" by 2050 and 2045 respectively. In order to fulfil the new targets, transport is identified as the most important sector for decarbonisation. The UK and Scottish governments have already made announcements to phase out the conventional fuel vehicles by 2030 and 2032. To complement the announcements, detailed plans such as "Decarbonising Transport A Better, Greener Britain, 2021" and "Transitioning to zero emission cars and vans: 2035 delivery plan, 2021" has been approved for implementation. A key highlight of the recent announcements and the plans is to achieve zero emissions from fleet vehicles owned by the government and public sector organizations latest by 2030.

In view of the urgency to reduce emissions and achieve zero emission from fleet vehicles, the study through a case study approach aims to design a roadmap for ensuring a smoother transition towards ultimately achieving a "net zero emission" from the fleet vehicles at NHS Greater Glasgow and Clyde board, Scotland, UK.

## 1.2 Research questions

The underlying research questions have been used to inform the aim of the research.

1. Are electric vehicles the best available technology for achieving a net zero fleet?
2. What are the actions needed to be taken to achieve a "net zero emission" fleet at NHSGGC?

### 1.3 Aims an objectives

**Aim:** The aim of the study is to design a roadmap for decarbonisation of fleet vehicle at the NHS Greater Glasgow and Clyde Board towards achieving a “net zero” fleet by 2045.

**Objectives:**

1. To understand the background policies and legislation, fleet composition, baseline emissions and existing infrastructure
2. To understand the role of electric vehicles in decarbonisation of transport
3. To identify and analyse the key factors influencing decarbonisation of transport
4. To assess the implications of achieving net zero fleet by 2025 and 2045
5. To design a roadmap to achieve a net zero fleet at NHSGGC by 2045

### 1.4 Structure of the report

The report is divided into six chapters as outlined below.

Chapter 1 of the report begins with an introduction to the rationale, the underlying research question and the aims and objectives of the study.

Chapter 2 presents the review of the literature on impacts of road transport on climate change and sustainability, overview of the electric vehicle technology and background policy context with regard to decarbonisation of the transport.

Chapter 3 covers detail description of the key research elements beginning with the research philosophy. It presents a comprehensive description of the analytical methods and approaches adopted for achieving the objectives of the study.

Chapter 4 includes the results and discussions on the SWOT, review of the role of EVs in decarbonisation of transport

Chapter 5 presents the roadmap for decarbonisation of the fleet vehicles at NHSGGC with detailed description of the interventions necessary to achieve a net zero fleet by 2045

Chapter 6 provides the conclusion, the limitations of the study and recommendations for future work.

# CHAPTER 2: LITERATURE REVIEW

## 2.1 Road transport and climate change

Currently 95% of the energy market related to road transport is dominated by gasoline and diesel and there has been nominal progress in reducing emissions since the increase in number of vehicles on road compensates the reductions achieved per unit of vehicle (EASAC, 2019). In 2010, the transport sector released 7.0 GtCO2eq of direct GHG emissions amounting for approximately 23 % of total energy-related CO2 emissions globally. Global emissions from transport are projected to reach approximately 12 Gt $CO_2$ equivalent per year by 2050 if more robust and reciprocally supportive policies to decouple transport emissions from growth in GDP are not adopted (IPCC, 2014).

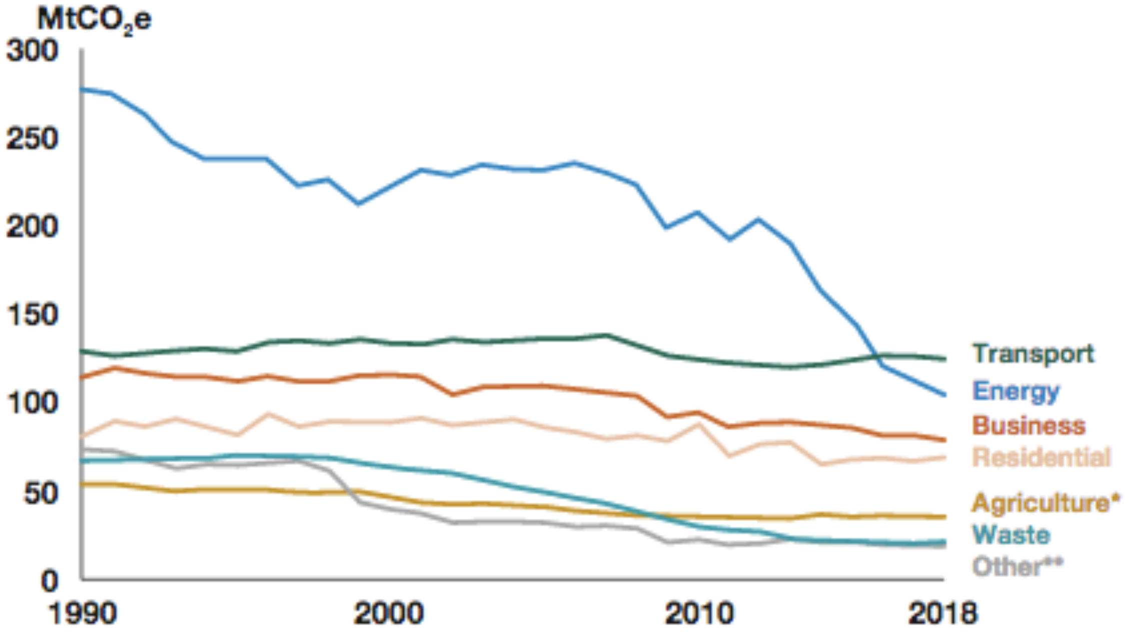


**Figure 1 GHG Emissions in UK (Source: UK Government, 2020)**

As shown in figure 1, emissions from transport in UK have remained static over the years with minimal reduction compared to the other sectors. It is now the highest emitter accounting for 28% of total emissions in 2019. Similarly, in Scotland as well, only 4.9% emission reductions have been achieved in the transport sector between 1990 and 2018 (Scottish Government, 2020).

## 2.2 Road transport and sustainability

Despite the high dependency on fossil fuels, transport is an essential element of social and economic development by way of moving goods and people to fulfil essential requirements such as transporting food and travel for work. Amongst the different modes of transport systems, road transport forms a necessary component for the existence of all other modes of transport (IRU, 2021). A well-developed transport system generates economic and social benefits by increasing international trade and is a key component of globalisation (Nistor & Popa, 2014). For instance, enhanced accessibility due to investment in transport is expected to create a food market worth a trillion US Dollar in the African region by 2030 (World Bank Group, 2021).

However, besides the economic and societal benefits, transport has significant contribution to air pollution posing risks to environment, human health and mortality (Batterman et al. 2020). Particularly in urban areas, transport is identified as one of the primary sources of air pollution. Unusually reduced level of nitrogen oxide pollution in Scottish cities during the months when nationwide lockdown was enforced to contain spread of COVID-19 (Scottish Government, 2020) is indicative of the contribution of road transport to air pollution in urban areas. Since road transport emissions mostly occur closer to workplace and residential areas in the cities, it is comparatively more harmful than other sources of pollution (EEA, 2020). More importantly, air pollutants such as particulate matter (PM) and nitrogen oxides emitted by road transport are amongst the pollutants with strongest evidence of impacts on human health (WHO, 2021). As such, PM and Nitrogen dioxide are considered as the main pollutants in UK and is estimated to have caused approximately 29000 and 23500 deaths respectively in 2008 (COMEAP, 2009). Still around 35% of nitrogen dioxide and 12 % of PM pollution in UK were from road transport in 2019 (UK Government, 2021). Likewise in Scotland also, transport is identified as the major contributor to air pollution. Transport accounted for 60% of NOx, 18% of PM10 and 24% of PM 2.5 in 2017 (Scottish Government, 2019).

### 2.3 Policy context for decarbonisation and air pollution

Taking a leadership role in the fight against climate change, UK became the first country in the world to set legally binding targets for reducing GHG emissions through the enactment of the *Climate Change Act 2008*. In the following year Scottish parliament also adopted the *Climate Change (Scotland) Act 2009.* These have been successful in establishing requisite institutional arrangements and consensus on concerted climate action in the country. Above all, the Acts have been successful in creating a consensus amongst all political parties on the need for climate action (Averchenkova et al. 2021) and thus ensuring high political will and commitment for addressing the climate challenge. The success of the Acts and continued political commitments are apparent from the increase in the ambitions to achieve "net zero emissions" by 2050 and 2045 respectively in UK and Scotland. The Acts were amended in 2019 in response to the global climate emergency.

Transport is recognized as a major contributor to air pollution and GHG emissions and as such numerous strategies and policies have been adopted to reduce emissions from the transport. Controlling vehicular emissions began in 1992 with the adoption of the Euro standards, which were made stricter in a progressive manner. In order to further reduce emissions from vehicles, the government introduced a variety of financial incentives. In 2011, the government introduced "plug-in vehicle grant scheme (PIVG scheme)" in order to promote the uptake of vehicles that were either devoid of tailpipe emissions or emitted less than 50g CO2/km. Based on the type and size of the vehicles, grant amounts ranging from £1500 to £16000 are provided to compensate the higher cost of purchasing (UK Government, 2020). In addition to the grant for purchasing, ULEVs benefit from discounted vehicle excise duty, zero emission vehicles costing less than 40,000 are exempt from the tax. Electricity consumed at home for charging electric vehicles are also levied only 5% VAT while other fuels have a VAT of 20%. ULEVs are further promoted through providing provision of grant for installation of EV chargers at home (UK Government, 2021).

In addition to the incentives, there are additional measures being implemented to accelerate decarbonization of transport. Low Emission Zones (LEZ*)* restricting access to conventional vehicles with high emissions are increasingly being introduced in cities across UK with plans to further increase the numbers. The political commitment and urgency to decarbonise the transport has been further enhanced through the announcements of the UK and Scottish governments to ban the sale of conventional fuel vehicles by 2030. At the same time the governments have made announcements to decarbonise the government and public sector fleet vehicles by 2027 and 2025 (UK Government, 2020; Scottish Government, 2020). This highlights the government's commitment to decarbonisation and to take a leadership role in the transition. In support of the highly ambitious commitments and announcements, the government approved comprehensive plans with detailed plan of actions and specific commitments for different modes of transport. Plan for and further going to the details of vehicle type.

## 2.4 Health care systems and climate change

Healthcare system is a huge emitting sector owing to its high socio-economic importance and scale (Arup & HCWC, 2019, NHS, 2015). In 2019, the global carbon emission from the health care activities was 2.2 GtCO2, which is equivalent to 4.4% of net global carbon emissions. (Arup & HCW, 2019). As shown in the figure 3, the emissions from the health care systems are segregated broadly into 03 scopes.

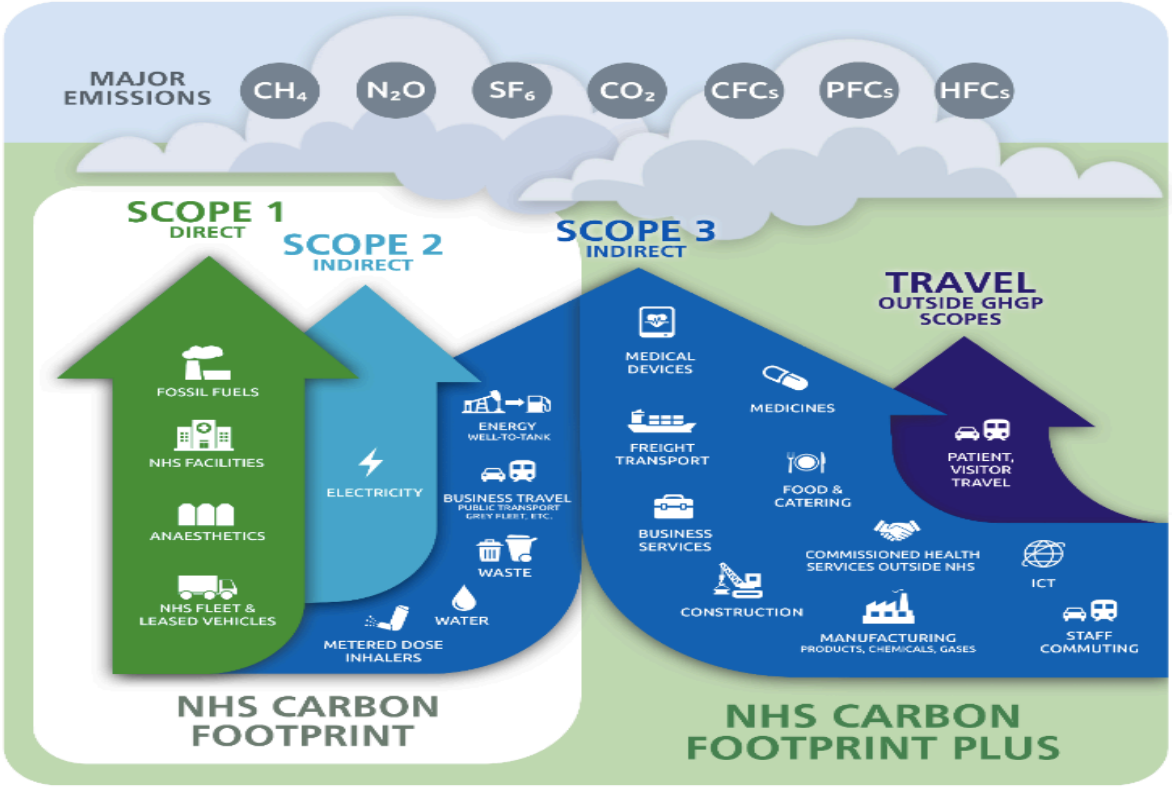


**Figure 2 Scopes of GHG emissions from healthcare systems in the context of NHS (Source: NHS, 2020)**

Scope 1 includes those emissions that the health care facility has direct control such as combustion of fossil fuels on site for energy generation including for fleet vehicles. Scope 2 pertains to the emissions related to generation/operation of electricity procured by the healthcare facilities. Scope 3 covers the indirect emissions resulting from the whole supply chain of manufacturing and transporting medical supplies and services. It also includes emissions from waste disposal and staffs commutes. Scopes 1, 2 and 3 accounted for 17%, 12% and 71% respectively of the total global emissions from health care, predominantly from use of fossil fuels in 2019 (Salas et al, 2020, HCWC & Arup, 2019).

### 2.5 Transport at the NHS

The National Health Service (NHS) of the UK is the largest employer in Great Britain and account for annual carbon emissions of approximately 20 million tons, equivalent to 5.4 % of the national total (Arup& HCWC, 2019). Out of around 9.5 billion miles of road travels related to NHS in England, it is estimated that 4% is covered by the fleet and for business travels. Considering the total distance covered, estimated 18% of the NHS emissions from transport (BRE, 2019) seems reasonable. Conforming a similar challenge of emissions from transport, the Sustainable Development Strategy of NHS Scotland 2009 identifies carbon reduction from fleet vehicles as a key priority area for NHS boards. All the health boards are required under the strategy to monitor and reduce emissions from the fleet by 80% compared to 1990 levels (Health Facilities Scotland, 2009). In the wake of the current urgency for decarbonisation of the transport, NHS Scotland committed to achieve net zero emissions from NHS owned vehicles by 2025 (NHS Scotland, 2020).

As seen from the literature review above, there are urgent needs and increasing obligations to transition to a cleaner fleet of vehicles. Specifically for health boards in Scotland, there are calls from all levels of governance to replace the fleet. Accordingly, having a clear roadmap or strategy is necessary to ensure a smoother transition. Roadmaps help in strategic decision making through assessment of the existing situation and by helping in identifying the opportunities, challenges and risks associated with achieving the desired objectives (Phaal, Farrukh and Probert, 2004; Siebelink et al. 2021)

### 2.6 Foresighting

Foresight is a process of creating alternative future visions and analyzing the consequences in a systematic and participatory manner with the aim of ensuring informed decision-making. A key assumption in foresighting is that future is affected by present decisions and actions (Andersen and Andersen, 2017). Foresighting as a planning tool is mainly applied for facilitating choice of technology, creating multiple future scenarios of development, inspiring change and above all in improving decision making. As such it has been used by numerous governments and corporation for decades to shape futures that are more desirable and advantageous (Wehrmeyer, Clayton and Lum, 2014). Today it is a tool widely used for sustainable development planning. As shown in Figure 4 there are 03 main approaches to foresighting.

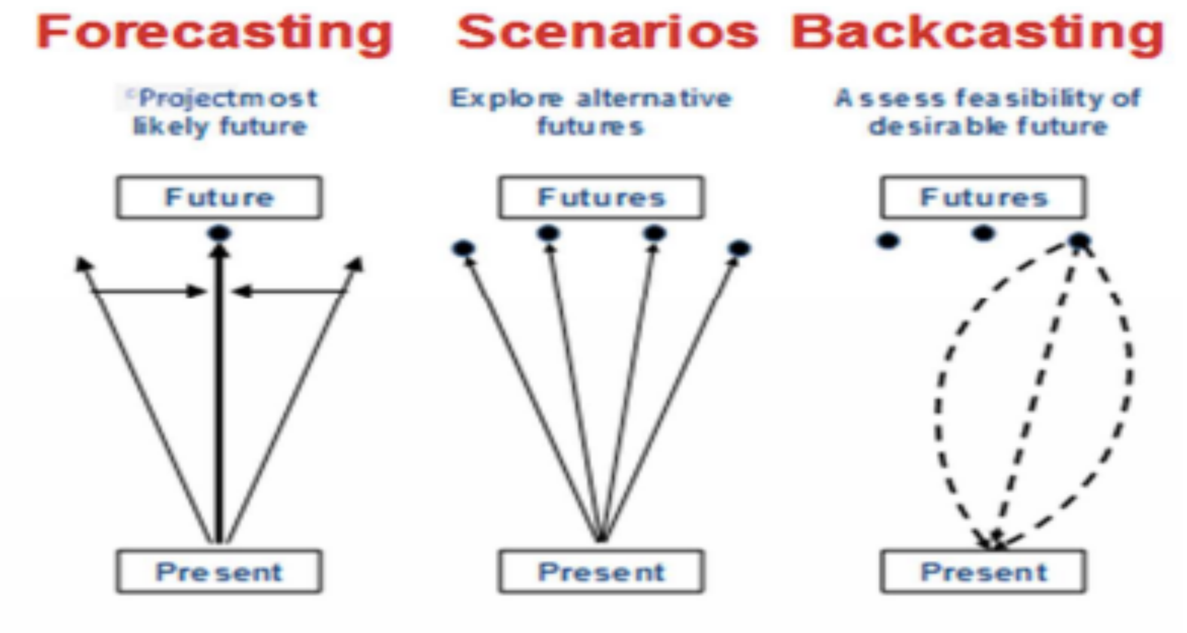


**Figure 3 Foresighting approaches (Source: Robinson 2011 cited in van Bers, Bakkes and Hordijik, 2017)**

Forecasting involves projection of the most likely future based on the historical data and considers future to be an extension of the past (van Bers, Bakkes and Hordijk, 2017). In contrast to forecasting, backcasting involves looking back from a desired future and developing strategies and action plans towards achieving that future. While forecasting is more predictive and show the likely future, backcasting suggest the implications of policy objectives and determine the feasibility of the goals (Zimmermann & Gracht, 2012; Bibri, 2018). Since a objective of the study pertains to assessing the implication of decarbonisation for two target years, backcasting is explored in more detail in section 3.8.4.

## 2.7 Electric vehicles

Electric Vehicles are categorised into three distinct types. (1) Hybrid Electric Vehicles (HEVs) which are run on one or more electric motors that use energy stored in a battery in addition to a traditional internal combustion engine vehicle (ICEV). There is no option for plugged in charging and the battery is charged by the ICE and through regenerative braking. (2) Plug-in Hybrid Electric Vehicles (PHEVs) can be charged by plugging in to a charger as well as via regenerative braking and by the ICE. PHEVs can be either run solely on electricity or fossil fuel. (3) Battery Electric vehicles (BEVs) are exclusively driven by electric motors powered by energy stored in batteries larger than HEVs and PHEVs. Plugging in to a charger and regenerative braking charges batteries in BEVs (DOE, 2017).

### 2.7.1 Emissions

BEVs do not generate tailpipe emissions referred to as “tank to wheel (TtW)” emissions or emissions from combustion of fuel on board. PHEVs emit zero tailpipe emissions when driven in all-electric mode and produce tailpipe emissions when using the ICE engine (DOE, 2020). Nonetheless, compared to the conventional ICE vehicle PHEVs generate 30% to 60% lesser emissions per mile and are highly more fuel efficient than an ICE vehicle even if they are heavier (MPCA, 2007; Tseng et al, 2015). Besides tailpipe emissions, all vehicle types generate “well-to-wheel” emissions. These include emissions generated from fuel production, processing, distribution, and use. In case of electric drive vehicles it is the emissions produced from extraction, processing, and distribution of the primary energy sources used for electricity generation (DOE, 2020). Therefore, emission reduction benefits of the electric drive vehicles would be greater if decarbonisation of electricity generation systems takes place in parallel with EV deployment (IEA, 2019, (WHO, 2016).

### 2.7.2 Investment cost

Although the initial cost of EVs is higher than ICE vehicles, the cost of maintenance and fuelling are lower. While conventional vehicles are most cost-efficient over short distance, EV possesses the potential to become most cost-efficient over long distance (Wu et al. 2015). Improvements in the battery technology are expected to lower the price of electric drive vehicles and fiscal incentives and tax regulations also help to offset the cost (IEA, 2019). Substantial cost reductions have been achieved with advancement in battery chemistry and with increased production capacities. It is expected to drop further with additional technological developments such as redesigning vehicle-manufacturing platforms that capitalize on compact electric motors and fewer moving parts than ICE and use of big data to avoid over sizing of batteries (IEA, 2021).

### 2.7.3 Range anxiety

Storage of energy in batteries is bulkier and more expensive compared to metal sheet fuel tanks, indicating shorter driving ranges for initial EVs (Pearre et al, 2011). Therefore, shorter driving range of electric vehicles compared to ICEVs has been one of the main challenges in promoting mass uptake of EVs. Nonetheless, with advancement in EV battery technology, the driving range of the EVS has been increasing over the years. The average driving range of EVs has increased from 211 km in 2015 to 338 km in 2020 (IEA, 2021)

### 2.7.4 Refuelling time

In terms of refuelling, it takes between 30 minutes and 12 hours to charge an EV from empty to full charge depending on the battery size and speed of the charging point. Using rapid/fast chargers can provide between 60-200 miles driving range within 20-30 minutes (Pod point, 2020).

### 2.7.5 Life cycle impacts of EVs and ICEVs

Life Cycle Assessment (LCA) is an internationally certified (ISO: 14040:2006) environmental assessment tool for assessing the environmental aspects and potential impacts throughout the life cycle of a product. Analyses of impacts begin from acquisition of raw materials, product use and finally disposal (cradle to grave) of the waste product (Klöpffer, 2014). While assessment of the vehicles based on the fuel consumption is important to ascertain the impacts on air pollution and GHG emissions, LCA helps in understanding sustainability impacts of vehicles in much more detail. As such numerous studies have been conducted to compare the net impacts of EVs in comparison to ICEVs. Due to zero tailpipe emissions during use phase, EVs have been found to generate higher emission reduction and improved air quality benefits. The emission benefits of the EVs increased with higher share of renewable energy sources in the electricity grid (Burchart-Korol *et al.*, 2018; Nimesh *et al.*, 2021). On the hindsight EVs had higher human toxicity, eutrophication of fresh water, acidification, depletion of metal and emission of particulate matter. These are primarily due to energy intensive process for manufacturing and production of the batteries, electric motor and powertrain, and from increased mining activities to extract raw material such as cobalt and Lithium (Hawkins *et al.*, 2013; Bicer and Dincer, 2018; Burchart-Korol *et al.*, 2018). Considering the higher sustainability impacts, EVs are not the best options for decarbonisation. However, Mckinsey & Co. 2009 cited in Hawkins et al. 2013 argue that despite of having millions of point source of emissions (ICEVs), EVs aggregate emissions to fewer sources like the manufacturing units, power plants and mines. This in turn reduces the quantity of air pollutants reaching to millions residing mostly in cities. Additionally, benefits from EVs are expected to serve as an inspiration for decarbonisation of the electricity grid (Hawkins *et al.*, 2013) thus achieving greater emission reductions.

### 2.8 Research gaps/knowledge gap

At the global level, there are calls for more robust policies and plans to reduce dependency of the transport sector on fossil fuel to limit global temperature rise and prevent catastrophic consequences of climate change. Responding to the global climate emergency, there is increasing political commitment to reduce GHG emissions. Moreover, there is call for urgent actions towards meeting the legally binding target to achieve "net zero emissions". Transport is recognized as the most important sector for decarbonisation in both UK and Scotland in order to meet the legal targets and prevent harmful affects of air pollution. Most importantly, the recent announcement from the governments requires urgent and immediate action, especially from public sector organisations to decarbonize their fleet vehicles. Within the NHS Scotland, transport is acknowledged as an important source of emission and has committed to achieve net zero emissions from the NHS owned fleet by 2025. However, at the level of individual health boards, there is lack of clear plans and strategies for decarbonisation of the fleet vehicles. Therefore, this study aims to design a roadmap to enable smooth transition towards a achieving a net zero fleet at NHSGGC.

# CHAPTER 3: METHODOLOGY

### 3.1 Introduction

This chapter presents an outline of the methodology that has been adopted for the study. Presentation of the essential elements of research for achieving the aims and objectives of the study follows the “research onion” diagram from Saunders et al. (2012) shown in figure 3. The ‘onion’ is unwrapped in a sequential manner starting from the outer layer and going towards the center.

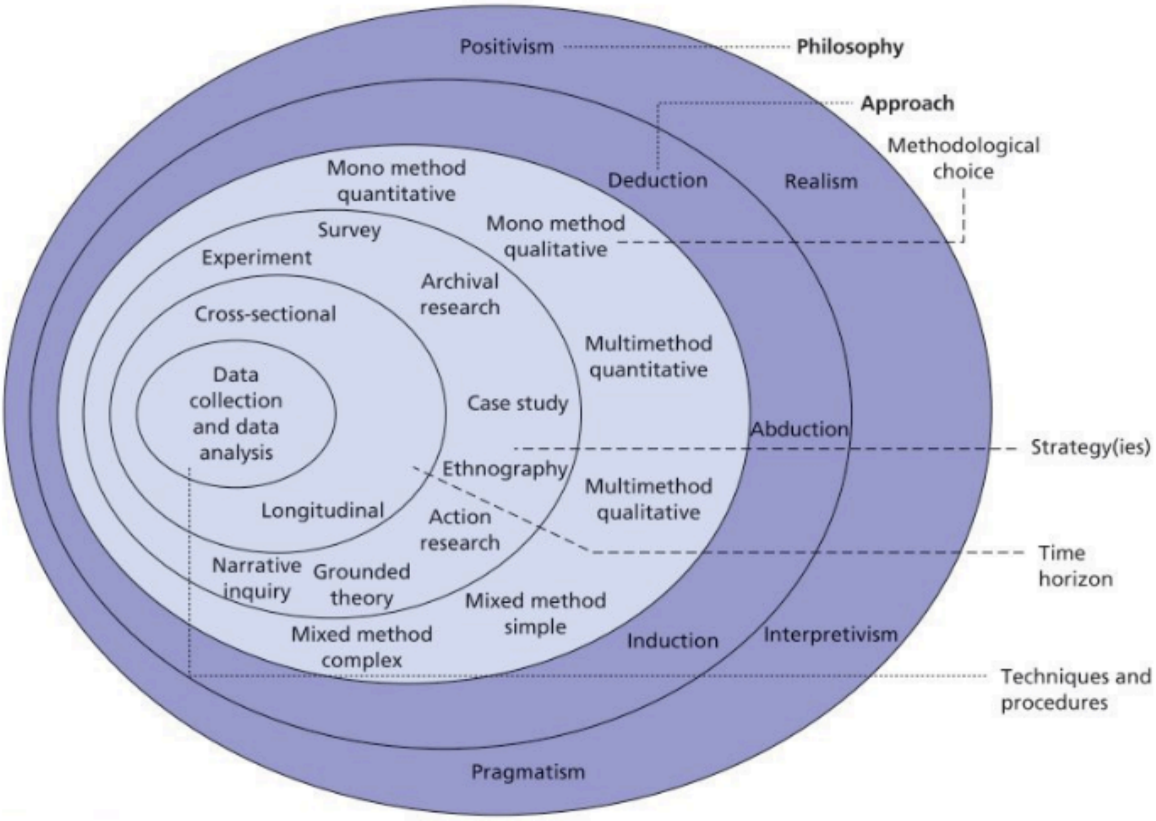


**Figure 4 Research Onion diagram (Source: Saunders et al. 2012)**

### 3.2 Research Philosophy

According to Saunders et al. (2017) *"research philosophy refers to a system of beliefs and assumptions about the development of knowledge".* Research philosophy forms the basis of choice of all the essential elements of research and helps in designing a well-organised research project (Saunders et al. 2017).

The research philosophy that best describes the study is pragmatism. Pragmatism emphasises on the problem and strives to provide solutions that are realistic and well informed. Guided by the research problems and questions, pragmatist researchers use variety of methods (Saunders et al. 2015). Pragmatist researchers hold the belief that reality and the world undergo constant change because of human actions and that reality can be changed only through action. 'Mixed method' is the most common methodical approach in pragmatism (Kaushik and Walsh, 2019). In the quest to resolve the problem of increasing emissions from road transport, the current study strives to get a deeper understanding of factors affecting decarbonisation of the sector and provide practical solutions towards achieving a net zero fleet. The focus of the study is to design a roadmap that would enable transition from highly polluting vehicles to zero emission vehicles.

## 3.3 Research approach

There are three research approaches namely deductive, inductive and abductive. In a deductive approach, the researcher develops a theory based on literature review and goes on to test the theory. Researcher, using an inductive approach begins with gathering of data to investigate a phenomenon and the result in most cases is generation of a theoretical framework. Using abductive approach, the research begins with data collection to investigate a phenomenon, identify themes and describing patterns in order to modify theories that are already in existence or to develop a new theory. The researcher then goes on to test the new theory by gathering additional data (Saunders et al. 2015). Using an inductive approach, the current study begins with collection of data to understand the challenges and implications of decarbonisation of the transport and aims to develop a roadmap for achieving "net zero emission" fleet.

### 3.4 Methodological choice

Guided by the pragmatist research philosophy, the study used mixed-method. Fully integrated mixed method involves using both methods at all stages of the research while partially integrated mixed-method at only one or particular stages of the research (Natasai et al. 2010 cited in Saunders et al. 2015). Quantitative and qualitative methodologies were used for data collection and analysis and for interpretation stages and therefore it is a partially integrated mixed-method research.

**Qualitative method:** Qualitative method was used to conduct literature review to understand the overarching policies and to evaluate electric vehicles as the technological choice for decarbonisation of the fleet vehicles. Qualitative SWOT analysis and interviews were conducted to identify the key factors influencing decarbonistion of the fleet. Qualitative analysis was also used for analyzing the implications of the scenarios created for decarbonisation of the fleet vehicles.

**Quantitative method:** Quantitative analysis was performed for estimating the carbon emissions and related impacts from the existing fleet. An arithmetic quantitative analysis was also conducted for backcasting to assess the implications of achieving a net zero fleet. Quantitative data was also used for analyzing the scenarios in the backcasting exercise.

### 3.5 Research strategy

A case study is defined as *"an in-depth inquiry into a topic or phenomenon within its real-life setting"* (Yin, 2014 cited in Saunders et. Al 2015). Often using mixed methods the strategy helps in answering the 'what' "why' and 'how' questions (Saunders et. al 2015). Through a case study strategy and using mixed method, the study explores the factors affecting decarbonisation and implications of decarbonisation of transport in the context of achieving "net zero emission" fleet vehicles at NHSGGC. It then provides solutions as to how a 'net zero emission" fleet can be achieved at the NHSGGC.

### 3.5.1 Introduction to the case study

The study focuses on designing a roadmap for decarbonisation of the fleet vehicles at NHS Greater Glasgow and Clyde (NHSGGC) board (hereafter referred to as the "board"). NHSGGC was chosen in particular because it is the largest health board in the UK and therefore could serve as a reference for all other health boards to initiate decarbonisation. Established in 1974, the board has about 38,000 employees providing healthcare services to approximately 1.15 million persons through around 6000 beds. Annually, it attends to around 7.5 million general practice (GP) services and dispenses approximately 24 million prescriptions (NHSGGC, 2020). The board operates a fleet of 421 vehicles, 79 % of which are ICEVS and 21% are EVs. Majority of the fleet vehicles comprises of vans (224) followed by passenger cars (135), heavy goods vehicles and buses (59) and vehicles for agricultural purposes (03).

## 3.6 Data collection

***Primary data collection***: Primary was gathered through in-depth interviews to get a deeper understanding of the key challenges in terms of decarbonisation of the fleet vehicles at NHS health boards. The interviews (02) lasting over 30 minutes each were conducted through use of digital platform "Microsoft teams".

***Secondary data collection:*** Secondary data were gathered from a range of sources such as academic journals, published annual reports, government publications and other relevant resources available in the public domain. Especially, information and data for technological evaluation were sourced from the relevant websites published for public dissemination. The data and sources for the analyses are presented and discussed in detail under relevant sections.

### 3.7 Data Analysis

As mentioned earlier, the data analysis for the study was conducted using a mix of qualitative and quantitative analysis. The purpose and details of the analysis conducted for the study are presented in the following sub-sections under specific headings.

#### 3.7.1 Baseline emission from existing fleet at NHSGGC

The analysis of the baseline emission and fleet composition was conducted to provide basis for quantitative analysis in section 3.8.3 analysis and development of scenarios. The data used for the analysis and sources are presented in the tables below.

**Table 1 Fleet vehicles by fuel type and average annual driving mileage (Source: NHSGGC)**

| Fuel Type | No. of cars | Source |
|---|---|---|
| Petrol | 124 | NHSGGC |
| Diesel | 207 | |
| Electric | 90 | |
| Average Mileage | 7448.9 KM | Own calculation based on data from NHSGGC |

**Table 2 Average carbon emission factors of cars in UK (Source: RAC Foundation, 2021)**

| Type of car by fuel | Average Emission (gCO2/KM) |
|---|---|
| Petrol | 149 |
| Diesel | 165.5 |

**Table 3 Average annual emission of NOx, PM 2.5 and average annual health impact cost of cars based on fuel type (Source: Brand & Hunt, 2018)**

| **Type of car** | **Nox (Kg/car/Yr** | **PM2.5 (Kg/car/yr)** | **Health impact cost/car/yr (£ )** | **Source** |
|---|---|---|---|---|
| Petrol | 1.09 | 0.13 | 258 | (Brand and Hunt, 2018) |
| Diesel | 10.56 | 0.45 | 37 | |
| BEV | 0 | 0.12 | 13 | |
| ICE Average | 5.825 | 0.29 | 147.5 | Authors calculation |

### ❖ Estimation of carbon emission

According to IPCC (2006), the emissions from vehicles can be estimated using two approaches (1) using the distance travelled by the vehicle and (2) quantity of fuel sold/consumed. For this study, the emissions from the existing fleet were estimated using the distance travelled. The emissions were estimated using the basic equation:

"Emission = Emission factor X Activity Data".
(Activity Data: Quantity of fuel consumed/distance travelled).

Using the above formula, carbon emissions for the vehicles were calculated by multiplying the annual average driving mileage (Table 2) with the corresponding emission factors for the fuel type (Table 3) and the number of cars.

### ❖ Estimation of NOx, PM 2.5 & Health impact cost

The estimate of the NOx and PM 2.5 emissions and health impact cost of the fleet, the total number of cars were multiplied by the average annual units (Table 3) and added to obtain the total for the fleet.

### 3.7.2 Understanding the role of electric vehicle in decarbonisation of transport

In order to understand the role of EVs in the decarbonisation of the transport sector (objective 3), a review of the experiences of deployment of EVs in Norway and China was conducted. Norway and China were chosen since the two countries are the leaders in the electrification of the transport in the world today. While Norway has been leading in terms of the share of EV sales, China has the biggest EV market and highest number of EVs on road in the world. The review focussed on understanding the effectiveness, best practices and challenges of mass deployment EVs in the respective countries. It was conducted primarily through review of case study reports and other relevant reports and journal articles. All the reports were sourced using search engines "Google" and "Google scholar".

For Norway, two case study reports were reviewed. The first one was from a non-governmental organization titled "Norway Transport the progressive electrification of land and maritime transport" by Simonet, 2019 and the second was from European Commission titled "Case Study Report: The Norwegian EV initiative (Norway)" by Kristensen, Thomassen and Jakobsen, 2018. In addition, one full report and two summary reports from Norwegian Centre for Transport Research and a peer reviewed journal article were reviewed. In the case of China a case study report from European Commission titled "Case Study report: New Energy Vehicles (China)" by Pelkonen, 2018 and another report from Harvard University titled "The Role of Electric Vehicles in Decarbonizing China's Transportation Sector" by Qiao & Lee, 2019 were reviewed. In addition the review also included relevant reports from International Energy Agency, Massachusetts institute of Technology and peer reviewed journal articles.

In addition to the case study report for Norway and China, case study reports from initiatives undertaken by local authorities and organisations in UK were also reviewed. This was conducted to learn lessons and best practices and challenges in replacing fleet vehicles with EVs. The case study reports were all obtained from the website of Energy Saving Trust and available from https://energysavingtrust.org.uk/listing/case-studies/?servicetype%5B%5D=1800. A synopsis of the cases reviewed is provided in appendix 1.

### 3.7.3 SWOT Analysis

SWOT analysis is a strategic planning tool used for assessing the internal (strengths and weaknesses) and external (opportunities and threats) factors for strategic planning (Weihrich, 1982). For environmental planning and management it helps in identifying the advantages of the organization in execution of the plan and barriers to successful implementation including external threats and opportunities (Nikolaou and Evangelinos, 2010). SWOT analysis has been widely used across various sectors such as environmental management, healthcare, education, tourism (Nikolaou and Evangelinos, 2010; Reihanian *et al.*, 2012; Aslan, Çınar and Özen, 2014; AlMarwani, 2020).

#### ❖ Approach

In this study a SWOT analysis was conducted to fulfil objective 4 to identify the key factors that influence the decarbonisation of the transport. The outcome from the analysis was used to inform the conduct of the backcasting (section 3.8.4) and for identifying relevant measures in the roadmap (chapter 5). The author using secondary data conducted the SWOT analysis independently. The conduct of the analysis is outlined below.

#### ❖ Review of literature

In order to identify the factors influencing the decarbonisation of transport, an extensive literature review was conducted. Literature search was conducted using popular search engine “google’ and “google scholar”. Google was mostly used for searching non-academic reports, legislation, policies and locating relevant websites. Google scholar was used for finding resources from published academic journals, articles and research papers. Review of government reports, policies, plans and legislation (refer chapter 2) provided insight into the legal mandates and political commitments for decarbonisation of the transport. Understanding the popular political stance and legal framework was important since these have implications on the funding, development of infrastructure, energy supply etc. Political decisions also influence investments (government and private) such as in vehicle technology. The academic papers, journals, articles, websites etc. provided deeper knowledge on the impacts and benefits of decarbonisation including the challenges (refer section 2.3 -2.5).

- **Developing the matrix**

In this step, the key messages from the review were put in the SWOT matrix. ‘Strength’ consists of the factors that favour decarbonisation of the transport. These include the existing developments and commitments that form the basis and provide guidance on “how” to achieve decarbonisation of the transport. ‘Weaknesses’ include the challenges that are likely to impede the efforts to decarbonise. ‘Opportunities’ are the positive factors with beneficial impacts on decarbonisation and the beneficial outcomes resulting from decarbonisation of the transport. ‘Threats’ are the negative factors that hinder decarbonisation as well as the negative impacts that are likely to result from decarbonisation of the transport. The threats in this analysis mostly pertain to impacts from EVs. Detailed discussion of the matrix is provided in section 4.2.

### 3.7.4 Backcasting

According to Dreborg (1996), backcasting is useful in making decisions for sustainable development when: (i) problems are complex and affect various sectors and levels of society; (ii) problems require major change; (iii) problems arise from dominant trends; (iv) problems are greatly influenced by externalities; and (v) the time horizon allows for cautious choice. As such the method is a best fit for the study since it deals with an urgent issue of urban sustainability, increasing emissions from transport. While carbon emissions impact global climate change, air pollution affects all sections of the society and there is a need for a major transition from fossil fuel based to zero emission vehicles. Decarbonisation of the transport is also a complex issue influenced by various factors such as global market, politics, technology and funding which are external and beyond the control of the organization.

Numerous future studies in the recent years have underscored the effectiveness of using backcasting in assisting policy formulation and guiding actions for transition to sustainable development. Musse et al. (2018), used the backcasting approach to investigate and propose planning for sustainable low income housing in a Brazilian City. It has been used for developing policy roadmap to align development in agricultural sector with 2030 Sustainable Development Goals (Kanter et al. 2016). Zimmermann, Darkow & Gracht,

(2012) in their study illustrates a 2030 vision for electric mobility in Germany and presents a discussion on the factors for realizing the vision using participatory backcasting approach. Backcasting approach has also been used for incorporating sustainability principles in electricity generation industry (Anderson, 2001). Similarly, with the aim to develop a roadmap for decarbonisation, backcasting approach was adopted for the study to assess the implications of achieving net zero fleet by 2025 and 2045 (objective 5). According to Zimmermann & Gracht (2012), backcasting can be performed either through desk research or workshops. In this study it was done through desk research since it was difficult for conducting workshops and focus group discussions owing to the pandemic. For the backcasting, a mix of quantitative and qualitative analysis was used. The phases of analyses for the backcasting exercise are discussed below.

### ❖ Phase I: Quantitative analysis

A basic arithmetic analysis was conducted for backcasting the implications of achieving a net zero fleet. The arithmetic analysis was done with support of a friend who is a mathematician and currently pursuing his PhD at the University of St. Andrews, Scotland. This was adopted since detailed quantitative projections and forecasting could not be performed due to data constraints. This analysis focussed on determining the desired annual rate of increase in the share of EVs, average number of EVs added and ICEVs replaced annually. These parameters were then used to estimate the investments required and potential emissions reduction that could be achieved compared to the baseline. Overall, the analysis was highly helpful in generating quantitative parameters and figures for analysing the desired scenarios. The details of the analysis are outlined on the following page.

**Table 4 Arithmetic calculation for determination of the desired increase in share of EVs**

| | A | B | C | D | E | F | G | H | I |
|---|---|---|---|---|---|---|---|---|---|
| 1 | **Desired increase in share of EV** | **Year** | **Total fleet** | **% Share of ICE** | **% Share EV** | **EV Cars** | **No. of EV added** | **ICE Cars** | **No. of ICE replaced** |
| 2 | 20 | 2021 | 421 | 79 | 21 | 88 | | 333 | |
| 3 | 20 | 2022 | 425 | 59 | 41 | 174 | 86 | 251 | -82 |
| 4 | 20 | 2023 | 429 | 39 | 61 | 262 | 88 | 167 | -83 |
| 5 | 20 | 2024 | 434 | 19 | 81 | 351 | 89 | 82 | -85 |
| 6 | 20 | 2025 | 438 | -1 | 101 | 442 | 91 | -4 | -87 |

### ❖ Calculations

Data source: The figures in row 2 of columns C, D, E and H are the data obtained from NHSGGC. The steps followed for the analysis are detailed below in sequential steps.

### Step 1. Calculating the increase in total number of fleet vehicles

The first step was to calculate the number total fleet vehicles taking an annual increase rate of 1% p.a. The rate of increase in the fleet total has been deduced from the average increase in number of vehicles in Great Britain. The number of licensed vehicles in Great Britain increased by 1.3% between 2018-2019 and by 0.8% between 2020-2021 (UK Government 2020). The expert was also of the opinion that the 1% increase was a fair assumption. Through this step, the total number of vehicles for the consecutive years is obtained.

### Step 2. Determining the desired rate of uptake of EVs

The current share of ICEV (79%) and EVs (21%) are used as the baseline. For the consecutive years, the desired rate of increase in share of EVs (Column A) is added to the Column E. For the share of ICEVs in the consecutive years, Column E is subtracted from 100%. This is then replicated for all the consecutive years using Microsoft Excel until share of EVs is equal to or more than 100%.

**Step 3. Calculating the average number of EVs to be added and ICEV replaced annually**

The number of EVs for each year is calculated by multiplying column A (total fleet vehicles) with column E (% share of EVs). This is replicated for all the consecutive years using Microsoft excel. The difference in number of EVs between one year and the following years is the number of EVs added in that year. For instance, the number of EVs added in 2022 is the difference between number of EVs in 2021 (existing) and 2022 (calculated).

Similarly for change in ICEV, column C with multiplied by column D to obtain the number of ICEV in that year. The number of ICEV in the present year is subtracted from the number in the preceding year to obtain the number of ICEVs replaced in that year.

**Step 4. Estimating the annual emissions, required investment for purchasing EV**

The average of Column G (No. of EVs added) and column I (No. of ICEV) is obtained by using the "average" function in Microsoft excel. This number is then multiplied with the units provided in Tables 1, 2 & 3 to estimate the emissions of NOx, PM 2.5, carbon and health impact costs.

**Step 5. Estimating the annual reduction in emissions and cost of health impacts**

*Reduction in NOx*: The annual reduction in NOx is obtained by multiplying the average number of ICEVs replaced with the unit emissions per year per car and the average annual mileage provided in Table 1. This provides a negative integer since this is the emission avoided by replacing ICEVs. This is then compared with the baseline emissions presented in table 5 to estimate annual reductions.

*Reduction in PM 2.5:* This is obtained by adding the emissions from the number of EVs added with the emissions avoided (negative integer) by replacing the ICEVs. This is compared with the baseline emissions in Table 5.

*Reduction in health impact cost*: The annual reduction in cost of health impacts is obtained by adding the cost of health impacts of the average number of EVs added with the avoided health impacts cost (negative integer) by replacing the ICEVs. It is then compared with the baseline health impact cost in Table 5.

*Reduction in carbon:* This is obtained by multiplying the number of ICEV replaced with the average mileage and unit emissions provided in Table 1 & 2. It is then compared with baseline emissions in table 5.

- **Phase II: Scenario building**

The study adapted backcasting method proposed by Robinson (1990) as shown in figure 3 for the scenario building. This method was chosen because the steps provided a coherent and logical framework for thought processing. Especially for novice researchers, the steps are simple to follow and understand. It is also highly suited for the study since it provides sequential steps leading to identification of interventions towards achieving the desired goals.

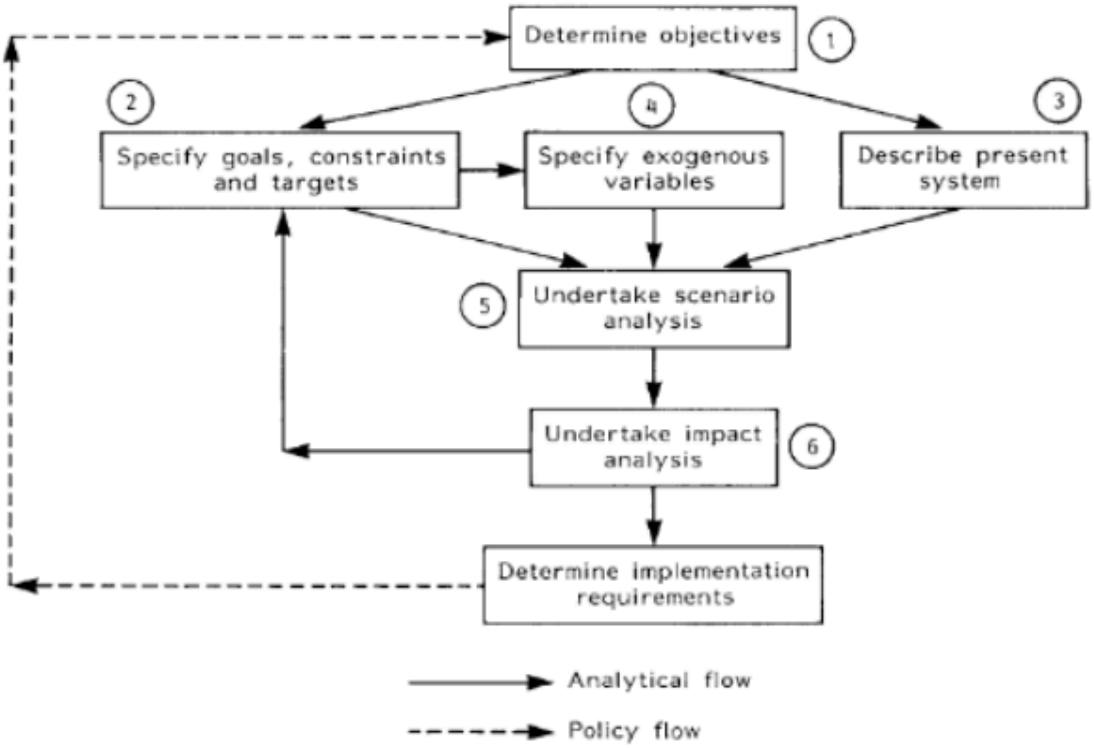


**Figure 5 Outline of backcasting method adapted from (Source:** Robinson, 1990)

Figure 5 is the graphical representation of the steps that have been followed for the backcasting exercise. The detailed description of the steps are provided in a sequential manner on the following page.

### Step 1: Determining the objectives

Two normative scenarios for achieving a net zero fleet by 2025 and 2045 were analysed for the purpose of the study. The business as usual (BAU) scenario assumes a continuous future developmental pathway without any major changes compared to the past. Since the present is unsustainable and characterised by technological advancements, it is claimed that BAU is not an option (Vergragt and Quist, 2011). Therefore, considering the unsustainability of fossil fuels and need for decarbonisation, BAU is not considered in the study.

### Step 2: Specifying goals and target

Two desirable futures of achieving net zero fleet by 2025 and 2045 were considered. Firstly, 2025 was considered based on the announcement of the Scottish Government to achieve net zero fleet across all public sector organizations by 2025. Also, NHS Scotland made an announcement to achieve net zero emission from the corporate owned fleet by 2025. Secondly, the Climate Change (Emission Reduction Targets) (Scotland) 2019 has set legally binding commitment to achieve net zero emissions by 2045. NHS Scotland also committed to become a net zero emission organization by 2045. Thus the target years have been chosen to align with political commitment and legislative requirement.

### Step 3: Describing present situation

This step pertains to the description of the existing situation. A review of political commitment, legislation, vehicle technology and related infrastructure was conducted. This was to understand the baseline of external factor that influences decarbonisation of transport in UK and Scotland.  Review of the fleet composition and emissions from the current fleet was undertaken to understand the baseline of the share of zero emission vehicle and baseline emissions. The above were conducted to set the baseline to develop the analysis of implications and feasibility of achieving a net zero fleet.

### Step 5. Specifying variables

The key variables considered are the rate of increase in the total number of fleet vehicles; desired rate of uptake of EVs; average number of EVs added and average number of ICEVs replaced for the quantitative analysis. For the qualitative analysis the key variables considered were technological availability and maturity, adequacy of infrastructure and energy and availability of funds.

### Step 6. Scenario and impact analysis

Traditionally, in backcasting method the scenario and impact analysis is either based on quantitative or qualitative analysis. However, for this study a mix of quantitative and qualitative analyses was used to assess the scenarios and the related impacts. Combination of two analyses methods made the scenarios more realistic given that the exercise was conducted independently through desk research and in the absence of brainstorming workshops. The results from the quantitative analysis helped in assessing the environmental and economic implications in the scenarios. The qualitative analysis based on the outcomes of the SWOT analysis and additional literature search enhanced understanding of the implications and feasibility of the scenarios.

### Step 7. Determining implementation requirements (roadmap)

Based on the scenario and impact analysis, implementation requirements are presented as a roadmap in chapter 5.

# CHAPTER 4: RESULTS AND DISCUSSIONS

## 4.1 Role of electric vehicles in decarbonisation of transport

According to literature (section 2.6), the “cradle to grave” life cycle impacts on environment and human health of EVs are higher compared to ICEVs. However, considering the zero tailpipe emissions in use phase, it is today the preferred technology for decarbonisation of the road transport. Norway is well recognized as a front-runner in terms of electrification of transport. In 2020, electric vehicles accounted for 75% of the new cars sold in Norway (IEA, 2020), making it the first country where sale of EVs surpassed ICEVs (Kelsty, 2021). The increase in the number and high share of EVs has been largely due to introduction of policy incentives beginning as early as 1990 and government investment in developing an extensive network of charging points. Availability of charging points has been found to be a key factor in boosting sales of EVs in Norway (Mersky et al. 2016). Other incentives such as exemptions from tax and road tolls, free parking, cheap electricity, and allowing EVs to drive on public transport bus lanes (Kristensen, Thomassen and Jakobsen, 2018) have resulted in higher cost savings from operation and eliminated the difference in the upfront price of the EVs and ICEVs (Figenbaum, 2018). Above all, despite increase in demand for road transport (Farstad, 2018), the increase in number of EVs has resulted in substantial decline in GHG emissions from road transport by 8.8% between 2012 and 2017 (Simonet, 2019). Although the consumption of electricity by the road transport in Norway increased from 33 GWh in 2012 to 335 GWh in 2018 (Enerdata, 2019 cited in Simonet, 2019), it has not resulted in increased emission from electricity generation. This is because 96% of the electricity is generated from hydropower and the increase in total electricity generation between 2010 and 2017 far exceeded the increase in electricity consumed by the road transport (Simonet, 2019). Norwegian experience clearly demonstrates the high potential of EVs to achieve carbon reduction.

While Norway had the highest share of EV in new vehicle sales in 2020, China recorded 1.2 million new EV registrations taking the total number to 4.5 million EVs, the highest in the world. In order to enable the goals for accelerated uptake of EVs, China has installed around 810,000 EV charging points that are accessible publicly (IEA, 2020). Similar to the case of Norway, the increase in the number of EVs and charging infrastructure are driven by regulatory measures, subsidies and incentives introduced by the Chinese government (Qiao and Lee, 2019). Driving factors for increase in EVs include tax exemptions, subsidies for manufacturing as well as the buyers, unrestricted access for EVs unlike ICEVs that are restricted on certain days based on licence plate, free parking, investment in charging infrastructure and increased procurement by the government (Columbia University, 2021). The policy mandate for companies to ensure that 10% of the vehicles produced or imported are EVs with the goal to reach 40% of all vehicle sales to be EVs by 2030 is expected to even further China's success with EV uptake. As the largest car market in the world, this mandate is also expected to have huge implications on cost reduction for EVs worldwide (Stauffer, 2021). Globally the EVs achieved a net carbon emission saving of 40 Mt $CO_2$ eq and 77% were from EVs in China. However, this does not represent the emission reduction advantage of the EVs compared to ICEV due to high carbon intensity of electricity generation in China (IEA, 2019).

Conforming to the literature, the experiences from mass deployment of EVs in Norway and China makes it evident that EVs can achieve significant emission reductions in a scenario of electricity generated from renewable sources. However, equally important is to ensure generation of adequate electricity to meet increased consumption by EVs. Guaranteeing higher economic benefits and ease of commute and convenience through provisions of monetary and other incentives such as preferential privileges are of utmost important in making EVs a preferred choice over ICEVs. Installing extensive network of chargers and providing accessibility remain at the core of mass adoption of EVs. Subsidies and specific policy mandates for manufacturers, the supply side, has greater impact on increasing market share of the EVs since it results in more choice of vehicles and ultimately reduces the cost. The existing policy scenario of UK and Scotland (refer section 2.3) has undeniably set the necessary policy environment for mass uptake of EVs. Although the number and current market share of EVs in UK and Scotland are comparatively low, the increasing share of EVs in the most recent years is a clear indication of the positive effects of the policy interventions. UK and Scotland also have the advantage of increasing share of renewable energy in the energy mix. Especially for Scotland, the energy scenario is highly favourable for uptake of EVs. Through improvements in energy efficiency, the consumption of energy in the country decreased by 13.1% in 2018 compared to baseline of 2005-2007. At the same time, the country is a net exporter of electricity, recording an increase in net exports by 21% between 2019 and 2020. Above all the share of renewable energy has the highest share in the energy generation mix accounting for 97.4% in 2020. To complement the surplus electricity generation and high share of renewable sources, there is 14 Giga Watt planned projects (Scottish Government, 2021). Therefore, taking all these into account EVs can achieve significantly towards reduction of emissions from road transport in Scotland. Based on current trends, it can be expected not to have any detrimental impacts on energy security and increased carbon emission from electricity generation.

### Lessons and best practices in reducing emission and cost from fleet vehicles

The case studies of initiatives aimed at reducing emissions and preventing air pollution from vehicles clearly demonstrate the favourable policies and tremendous role EVs play in the decarbonisation of road transport in the context of UK and Scotland. While the amount and quantity of cost savings and emission reduction depend on the number and type of vehicles and mileage, it is certain that EVs are well suited and generate highly beneficial results. In terms of replacing the fleet vehicles with EVs, analysis or review of the current fleet is an important first step to identify the vehicles that have electric variants well suited for the purpose. In all the cases, it is evident that well-planned and adequate charging facilities are a key to successful and efficient deployment of the vehicles. In addition to the public charging points, installation of chargers at homes of the officers driving the vehicle has also been found to be highly efficient in case of space constraints at the site or depot. Solar photovoltaic have been found to be an efficient source of power for charging the EVs. Therefore, in addition to being a sustainable solution to increased electricity demand, generating electricity on site from solar energy would also lessen the burden on the national grid.

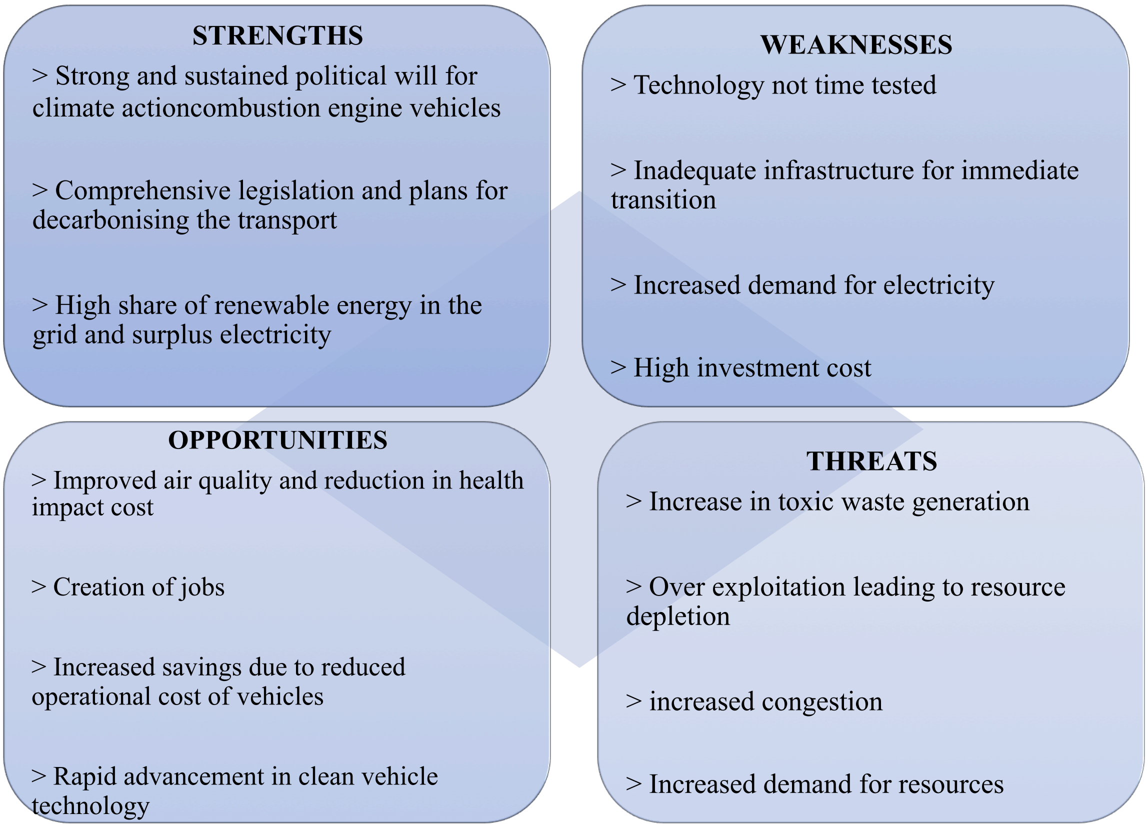
### 4.2 Baseline emissions and health impact cost from the existing fleet

The annual estimates of air pollutants, carbon emissions and health impact costs from the existing fleet.

**Table 5 Summary of baseline emissions from the existing fleet vehicles**

| Fuel Type | No. of cars | CO2 (tons) | NOx (Kg) | PM 2.5 (kg) | Health impact cost |
|---|---|---|---|---|---|
| Diesel | 207 | 255 | 2186 | 93 | 53406 |
| Petrol | 124 | 138 | 135 | 16 | 4588 |
| Electric | 90 | 0 | 0 | 11 | 1170 |
| **Total** | **421** | **393** | **2321** | **120** | **59164** |

### 4.3 SWOT Analysis for decarbonisation of transport



**STRENGTHS**

- > Strong and sustained political will for climate actioncombustion engine vehicles
- > Comprehensive legislation and plans for decarbonising the transport
- > High share of renewable energy in the grid and surplus electricity

**WEAKNESSES**

- > Technology not time tested
- > Inadequate infrastructure for immediate transition
- > Increased demand for electricity
- > High investment cost

**OPPORTUNITIES**

- > Improved air quality and reduction in health impact cost
- > Creation of jobs
- > Increased savings due to reduced operational cost of vehicles
- > Rapid advancement in clean vehicle technology

**THREATS**

- > Increase in toxic waste generation
- > Over exploitation leading to resource depletion
- > increased congestion
- > Increased demand for resources

**Figure 6 SWOT Analysis for decarbonisation of fleet**

**Strengths:** The biggest strength in decarbonisation of fleet vehicles is the sustained political commitments for climate action coupled with surplus generation of electricity from renewable sources. As seen from section 4.1, these are the key to a successful adoption and effective emission reductions using EVs. In a classic case of "carrot and stick" coming together, the announcements imposing increased obligations to decarbonise transport has been accompanied with commitments for investment for advancing vehicle technology, providing fiscal incentives, installation of charging points. Materialization of the commitment as promised would have greatly smoothen the transition to a clean fleet. Rapid advancement in vehicle technology also presents multiple options to choose models best fit for purpose. The number of EV models available globally increased from 55 in 2015 to 235 in 2020. Average driving range per single charge increased from 211 Km in 2015 to 338 Km in 2020 (IEA, 2021).

**Weaknesses:** Despite the detailed plans and commitments, for the public sector organizations like NHS, high investment cost of EVs still remains a challenge. NHSGGC in particular already reported a huge deficit in funding in the 2019-2020 financial year due to increase spending (NHSGGC, 2020), which does not include investments in new fleet. From the interviews it was revealed that additional funding for fleet replacement remains uncertain. Lack of trained technicians to provide after sale services for EV is another concern since this would result in longer vehicle downtime incase of a mechanical failure or accident (Prez, 2021). This is highly likely to cause disruption in the delivery of efficient services. The

**Opportunities:** Improved air quality, reduced cost of health impacts pollution and increased savings would be the greatest opportunities from decarbonisation of the fleet vehicles. In UK, between 2020 and 2050, decarbonisation of the transport is expected to create 72000 jobs, reduce around 1800 metric tons of carbon. In the same time it is expected to save health cost from pollution by around 9 billion (UK Government, 2021). In terms of savings, driving an annual mileage of 7600 miles, compared to ICEV, EVs have the potential to save approximately £ 1000 (Yurday, 2021). Northumbria Healthcare estimated around 80% reduction in the vehicle running cost from deployment of EVs (Northumbria Healthcare, 2015).

**Threats:** As seen from literature review, mass adoption of EV would increase demand for resources and generation of toxic waste. Dumping of used batteries at the landfills will release heavy metals and improper handling during recycling would release toxic fumes

(Morse, 2021). These would pose serious threats to human health and environment. There will be increased demand for Lithium, Copper, Nickel and Cobalt to meet the increasing demand for EVs. It is estimated that 80% of the demand for Lithium in 2030 would be for production of EV batteries (Parajuly, Ternald and Kuehr, 2020). UK's plan to decarbonize transport through deployment of EVs is projected to increase the number of car ownership to about 43.5 million by 2050. This is estimated to increase the traffic by 11% leading to more congestion on the road (Frost et al. 2021).

## 4.4 Scenarios

### 4.4.1 Net-zero fleet by 2025

Achieving net zero fleet by 2025 would require addition of an average of 71 EVs annually to replace 67 ICEVs. Compared to the current levels, annual NOx emissions could be reduced by around 20%, PM2.5 by 10%, $CO_2$ by 20% and health impact cost by around 18%. An annual investment of around £3.11 million will be required to completely replace the fleet by 2025. However, achieving the target seems unlikely because of the huge funding required for replacement of the fleet and installation of additional charging infrastructure to support the increase in EVs. Despite the rapid increase in number of charging stations across Scotland, it is uncertain if these would adequately cover the routes most frequented by the NHS vehicle in the next 4 years. A greater concern is inability to meet the charging requirement in a scenario of all public sectors fleets converting to electric vehicles around the same time and triggering mass adoption by the general population. A key concern with immediate replacement of the fleet is the capability of the EVs for specialized services of the NHS. NHS deploy vehicles that carry heavy specialized medical equipment, therefore one key concern is if EVs would be able to deliver the specified driving mileage and payloads. Certain vans at the NHS are also equipped with tail lifts and there aren't many electric vans with the feature. Additionally, there are highly limited or no electric models of HGVs and buses (4.5% of the current fleet) currently available in the EV market. Most of the existing fleet vehicles would also not have achieved optimal use by 2025. This would result in unnecessary retirement of the vehicles in use today.

### 4.4.2 Net-zero fleet by 2045

Achieving net zero fleet by 2045 would require addition of an average of 18 EVs annually to replace 13 ICEV. Compared to the current levels, annual NOx emissions could be reduced by around 4%, PM2.5 by 2%, $CO_2$ by 4% and health impact cost by around 3%. An annual investment of around £0.79 million will be required to completely replace the fleet by 2045. The UK government has made additional financial commitments for uptake of electric vehicles. The funds are likely to be made available in order to meet the legal commitment to achieve net zero economy by 2045. Therefore, it can be expected to have adequate funding and charging infrastructure to support replacement of the increase in EVs. Going by the decarbonisation plans and rapid advancement in vehicle technologies, HGVs run on electric and FCV are also likely to be made available in the next 10-15 years at the latest.  More importantly, most of the vehicles would have reached the optimal use phase. This scenario seems more likely to be achieved provided there is adequate funding made available. Most importantly, a majority of the EV models would have already been tried and tested. This would be the key to avoid any uncertainties with models deployed for the fleet.

# CHAPTER 5: ROADMAP FOR ACHIEVING “NET ZERO” FLEET BY 2045

## 5.1 Introduction

This chapter presents the roadmap with key interventions required to achieve a net zero fleet by 2045. The interventions identified in the roadmap are expected to ensure a smooth transition and ensure maximum sustainability benefits without compromising the delivery of health services.

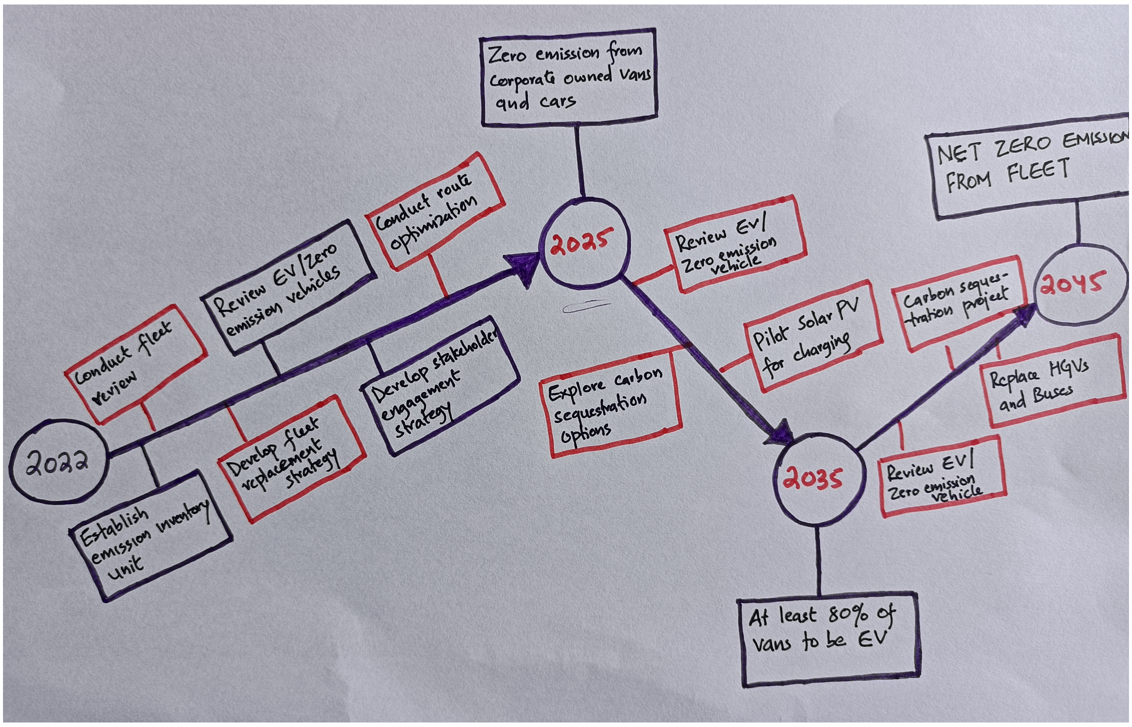


Figure 7 Timeline for implementation of the roadmap

## 5.2 Key interventions for achieving a net zero fleet

### 5.2.1 Establish emissions inventory unit and maintain inventory of emissions

Emission inventories serve as an important tool in identifying the opportunities for reducing emissions and implementation of related policies. It also helps in monitoring the emissions towards fulfilling the commitments and ensuring compliance (D’Avignon et al. 2010) Other benefits of an inventory include identification of the most significant emission sources, generation of historical trends in emissions, establishing basis for decision making including goal setting (Strategic Energy Innovations, 2009). Therefore establishing an inventory management unit and maintaining an inventory of emissions would enable the board to monitor carbon emissions from the fleet vehicles for future decision making including for fleet reviews.

### 5.2.2 Devise financing strategy

Uncertainty in funding for phasing out ICEVs with EVs is one of the main concern and challenge facing the board today. A financing strategy will be useful tool in identification of funding sources, exploring fund generation sources to support transitioning to "net zero" fleet.

### 5.2.3 Develop fleet management/replacement strategy

Fleet management strategy is defined as *"a strategic document that demonstrates how a fleet aligns to an organisation's overarching objective, strategy and plans"* (O'Dea, 2020). The strategy is useful in ensuring optimal use of the fleet vehicles while ensuring cost effectiveness, safety and reliability and prevent excessive fuel consumptions (Spireon, 2021; Stazzone, 2021). Review of the fleet must be a core component of the strategy. Fleet review would assist in estimating emissions from the fleet, determining the vehicles that can be replaced with EV, calculate savings on cost and carbon emissions, increase efficiency through route optimisation and assist in developing strategies to reduce mileage (Energy Saving Trust, 2019). As for the replacement of the fleet, it is recommended to target replacement of diesel vehicles (vans) first. This is mainly because the health impact costs of diesel vehicles are substantially higher than petrol vehicles. Also, emissions of NOx and PM 2.5 from diesel vehicles are around 10 times and 3 times higher than petrol vehicles ((Brand and Hunt, 2018). Therefore, phasing out of the diesel vehicles would result in achieving higher benefits in terms of air quality and emissions. There are ranges of electric vans that are currently available in the market. Table 6 presents the best 10 electric vans in the UK in 2020.

**Table 6 Top 10 best models of electric vans in UK 2020**

| **Model** | **Driving range** | **Payload** | **Min. charging time** |
|---|---|---|---|
| Nissan e-NV200 | 124 miles WLTP | 705 kg | 40-60 mins |
| Mercedes eVito | 93 miles | 900 kg | 6 hours |
| Mercedes eSprinter | 75 miles | 700 kg | upto 80% in 30 mins |
| Vaukhall Vivaro-e | 200 miles | 1226 kg | upto 80% in 30 mins |
| Peugeot e-Expert | 143-211 miles | 1001-1226 kg | upto 80% in 45 mins |
| Citroen e-Dispatch | 170 miles | 1000-1002 kg | 30 mins |
| Toyota Proace Electric | 142 miles | 1200 kg | Upto 80% in 32 mins |
| Renault Master ZE 2020 | 124 miles | 1490-1740 kg | 6 hours |
| Renault Zoe van | 245 miles | 387 kg | 80 % in 70 mins |

Source: Hubbard, 2021

### 5.2.4 Conduct route optimization

Increase in efficiency of vehicles through route optimisation reduces total fleet mileage and consumption of fuel by 20%. Route optimisation also has the capability to increase the efficiency of a unit of vehicle and increase the efficiency of the fleet. There are also route optimisation software that can analyse and identify routes and vehicles that can be most suitably replaced with EV models (The Algorithm People, 2021). As such, use of route optimisation would have multiple benefits especially in the transition to a net zero emission fleet. Firstly, it would help identify vehicles that can be replaced with available EVs and reduce the risk of disappointment. Secondly, increased efficiency of vehicles and integrated fleet management systems using route optimisation would translate into reduction of the fleet size as well as reducing emissions from the vehicles that cannot be readily replaced. It thus presents an opportunity to lessen the investment burden by reducing the fleet size.

### 5.2.5 Evaluation of zero emission vehicles

There has been a boom in the electric vehicle technology in less than a decade. However, considering the pace of the technological development, the sustainability benefits and risks need to be assessed cautiously. Most of the EV models are fairly new and their efficiency and reliability are not time tested. Additionally, the whole life cycle impact of vehicles (refer section 2.6) needs to be taken into consideration to minimise impacts on the environment and human.  Therefore, the selection of the vehicles should not only be based on the upfront price of the vehicles. It is necessary to conduct a detailed evaluation of the EVs currently available to ascertain the model best suited with minimal impacts. For instance, manufacturers using highest share of recycled materials should be prioritised. As other vehicle technologies like FCVs mature, its necessary to make comparative assessments between the technologies. It is recommended to conduct periodic evaluation of the EVs and other zero emission vehicles that may be made available over time.

### 5.2.6 Strengthen collaboration with stakeholder organizations

Multiple stakeholders are involved in the transition to a zero emission transport system. Therefore it is important to strengthen collaboration with all relevant stakeholders to garner support and keep abreast with the latest developments. The developments could be in terms of technology, logistics, political, technical assistance etc. For instance, through collaboration with organizations involved in installation of charging facilities, the board can identify the routes that can be serviced by an EV. By collaborating with manufacturers, EVs customised EVs can be developed to meet the requirements of the board. Especially since the technology is fast evolving, collaboration with all stakeholders would be vital in achieving a net zero fleet.

### 5.2.7 Explore options for carbon sequestration

Achieving a “net zero emission” fleet would require investment in enhancing the carbon sink or in Carbon Capture and storage technologies to sequester unavoidable emissions. Even with complete replacement of fleet with EVs, carbon sequestration would be relevant because of the embedded carbon in the vehicle as well as the high emissions from the manufacturing and production of EVs. Moreover, investment in greening the space with trees and vegetation as a means of carbon sequestration would have multiple environmental and societal benefits. Especially in cities, green spaces reduce the exposure of the residents to air pollution and provide open space for socialising and physical activities and thereby reduce illnesses and early deaths (WHO, 2016).

# CHAPTER 6: CONCLUSIONS

## 6.1 Summary and Findings

Transport plays a vital role in the socio-economic development and also forms an essential part of the healthcare systems. However, it is recognised as the most important sector for achieving net zero emission and improving air quality in the UK and Scotland. The present study was conducted through an extensive literature review, interviews, SWOT analysis and backcasting to design a roadmap for achieving “net zero emission” fleet vehicles at the NHSGGC. The study began with an objective to understand the policy context with regard to decarbonisation of transport in the UK and Scotland and went on to explore the role of electric vehicles in achieving the decarbonisation of the sector. Using SWOT analysis and backcasting techniques the key factors affecting decarbonisation of the transport and implications of achieving a “net zero emission” fleet were determined to identify interventions that are necessary for achieving net zero emission fleet.

From the experience of two leading countries, Norway and China in terms of mass adoption of electric vehicles, it was found that while policy incentives and adequate infrastructure is the key to ensuring mass adoption of EVs, share of renewable energy in the national electricity grid determined its effectiveness in achieving desired emission reduction benefits. Considering the highest level of political commitment, range of incentives for zero emission vehicles and majority share of electricity generated from renewable sources, EVs are a natural choice for decarbonisation of the road transport in the context of UK and Scotland. However, key challenges to decarbonisation of the fleet vehicles include the high investment cost, uncertainty in adequacy of infrastructure and EVs to deliver specialized medical services. While EVs are well recognised as the technological choice for decarbonisation of the sector, most of the models have emerged in the last 5-6 years and therefore are yet to be tried and tested. Therefore, although deployment of EVs has the potential to deliver, “net zero emission” fleet, deployment of EVs need to be conducted cautiously to avoid technological disappointments and avoid unintended impacts on the environment. The roadmap developed in the study thus, present interventions aimed at avoiding risks from adopting a technology that is yet to prove it full potential in generating sustainability benefits.

## 6.2 Limitations

- Quantitative analysis for the backcasting in the study is not a well-established method. It was done in the absence of adequate data.

- The backcasting exercise in the study was done predominantly through desk research and mostly independently and therefore the impact analysis likely contains inaccuracies and inconsistencies.

- The author developed the roadmap for the study independently and therefore it cannot be claimed to be comprehensive and realistic. There is need for more comprehensive analyses and consultations.

## 6.3 Future Work

The study developed a roadmap that is more generic and aimed mostly at ensuring a cautious uptake of EVs. Therefore, my recommendation for future work building on this study is to focus on more in-depth investigation of the EVs for delivering specialised healthcare services. It is highly recommended to conduct investigations through a whole life cycle impact analysis and not just on the technological capabilities.

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