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Living within the 1.5-degree warming limit:

An analysis of consumption-based carbon footprints in the Nordic countries

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Abstract

To stay within the 1.5 degree warming limit, changes to lifestyle and personal consumption are necessary to mitigate the effects of climate change. From a consumptive perspective, the emissions from affluent countries and individuals are greatly exceeding this limit, even when individuals report having a high climate concern. This thesis examines the potential of different low-carbon consumptions options in the Nordic context to see what impact they have on consumption-based carbon footprints (CBCFs) as well as analyzing the affect climate concern and the motivation to reduce one's carbon footprint (climate motivation) have on CBCFs. This thesis aims to answer the question: how can residents of Nordic countries live within the 1.5-degree limits? To answer this, data from a carbon footprint calculator survey from the Nordic countries was used, which received around 8,000 responses. Overall, the average CBCFs of the respondents were above 1.5 degree compatible levels. The low-carbon consumption options that were associated with the lowest carbon footprints included having a vegan or vegetarian diet, not owning a car, and not flying. The rebound effects associated with many of the low-carbon actions were generally limited and insignificant. The participation in many of the low-carbon options was low and respondents mostly needed to engage in multiple low-carbon consumption options in order to have 1.5 degree compatible footprints. High climate concern, climate motivation and engagement with pro-climate actions were all associated with lower carbon footprints however the footprints were still not at 1.5 degree compatible levels.

Útdráttur

Breytingar á lífsstíl og neysluvenjum fólks eru nauðsynlegar til að draga úr loftslagsbreytingum og til að lifa innan 1,5 gráðu hlýnunarmarka. Neysludrifin losun hjá velmegandi þjóðum nær langt yfir þessi viðmið, þrátt fyrir miklar áhyggjur íbúa af loftslagsmálum. Þessi ritgerð skoðar mismunandi valkosti á neysluvenjum með lágu kolefnisfótspori í norrænu samhengi með það að markmiði að greina hvaða áhrif þær hafa á neyslutengd kolefnisfótspor fólks ásamt því að skoða hvernig áhyggjur af loftslagsmálum og hvati til að minnka kolefnisfótspor einstaklinga geti haft á neyslutengd kolefnisfótspor. Eftirfarandi rannsóknarspurningu verður svarað í ritgerðinni: hvernig geta íbúar á norðurlöndum lifað innan 1,5 gráðu hlýnunarmarka? Gögn úr könnun sem reiknaði út kolefnisfótspor íbúa á norðurlöndunum voru notuð til að svara spurningunni þar sem 8000 einstaklingur tóku þátt. Að meðaltali voru kolefnisfótspor þátttakenda yfir 1,5 gráðu samhæfðum mörkum. Lágkolefnisneysluvalkostirnir með lægstu kolefnisfótsporin voru meðal annars grænkerafæði, bíllaus lífsstíll og að sleppa því að fljúga. Neikvæð hliðaráhrif (e. rebound effects) í tengslum við þessar lágkolefnisaðgerðir voru almennt takmarkaðar og óverulegar, sem er í andstöðu við mikið af fyrri rannsóknum. Þátttaka í mörgum af kolefnislágu valkostunum var takmörkuð og svarendur þurftu að mestu að taka þátt í mörgum slíkum til að ná 1,5 gráðu samhæfðu fótspori. Miklar áhyggjur af stöðu

loftslagsmála, hvatning og þátttaka í loftslagsaðgerðum ýttu undir lægri kolefnisfótspor sem var þó ekki nóg fyrir 1,5 gráðu samhæfð stig.

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List of Publications

The thesis compilation is composed of five peer reviewed articles:

Article 1 (A1)

Heinonen, J., Olson, S., Czepkiewicz, M., Árnadóttir, Á. & Ottelin, J. 2022. Too much consumption or too high emissions intensities? Explaining the high consumption-based carbon footprints in the Nordic countries. *Environmental Research Communications*, 4(12), p.125007.

Article 2 (A2)

Olson, S., Heinonen, J., Ottelin, J., Czepkiewicz, M. & Árnadóttir, Á. 2024. The impact of low-carbon consumption options on carbon footprints in the Nordic region. *Consumption and Society*, 3(2), pp. 183-210.

Article 3 (A3)

Ottelin, J., Olson, S., Ballal, V., Árnadóttir, Á & Heinonen, J. 2024. Rebound effects flatten differences in carbon footprints between car-free households, minimal drivers, and green car owners. Accepted in *Environmental Research Communications*

Article 4 (A4)

Árnadóttir, Á., Abdirova, T., Olson, S., Heinonen, J. & Czepkiewicz, M. 2024. Does higher climate concern lead to a smaller carbon footprint? A study among the Nordic country residents. *Resources, Conservation and Recycling*, 205, p. 107543.

Article 5 (A5)

Olson, S., Szafraniec, M., Heinonen, J. & Árnadóttir, Á. 2024. Concerned about Climate Change and Ready to Take Action? An Analysis of the Pro-Climate Actions Individuals Are Motivated to Take to Lower Their Carbon Footprints. *Sustainability*, 16(16)**,** p.6755.

Contribution of the author:

Article 1: Too much consumption or too high emissions intensities? Explaining the high consumption-based carbon footprints in the Nordic countries.

The author was responsible for the analysis and writing the results section.

Article 2: The impact of low-carbon consumption options on carbon footprints in the Nordic region.

The author was responsible for the analysis and writing the article.

Article 3: Rebound effects flatten differences in carbon footprints between car-free households, minimal drivers, and green car owners.

The author participated in the analysis and was responsible for writing part of the methods and discussion sections.

Article 4: Does higher climate concern lead to a smaller carbon footprint?

The author was responsible for the analysis and for writing parts of the article.

Article 5: Concerned about Climate Change and Ready to Take Action? An Analysis of the Pro-Climate Actions Individuals Are Motivated to Take to Lower Their Carbon Footprints

The author was responsible for performing parts of the analysis and writing the article.

Abbreviations

CBA – consumption-based accounting

CBCF – consumption-based carbon footprint

EU – European Union

EV – Electric vehicle

GHG – greenhouse gas

HDI – Human Development Index

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1 Introduction

Unsustainable consumption patterns are the driver of many environmental problems including climate change (IPCC, 2023). The average annual greenhouse gas (GHG) emissions continue to grow and the detrimental effects of climate change can be seen globally (IPCC, 2023). Climate change is being driven by current patterns of consumption and in order to combat climate change, changes to lifestyle and consumption patterns are necessary (Cap et al., 2024, Creutzig et al., 2018, IPCC, 2023). Technological changes alone will not reach the deep reductions needed to limit emissions to levels that are compatible with the aspirational 1.5°C warming goals of the Paris agreement (IPCC, 2023, Capstick et al., 2020). There is a high potential for the reduction of GHG emissions from changes to personal consumption since around 70% of GHG emissions can be attributed to household consumption (Ivanova et al., 2016, Hertwich and Peters, 2009). There is, however, inequity in consumption and GHG emissions are not equally distributed globally (Ivanova et al., 2016, Hubacek et al., 2017). The GHG emissions attributed to affluent individuals significantly surpasses those of low-income individuals (Wiedenhofer et al., 2017, Wiedmann et al., 2020). On a country level, this can be seen as well with the consumption-based emissions of affluent nations greatly exceeding those of low-income nations (Hubacek et al., 2017, Ala-Mantila et al., 2023), so while some are overconsuming, many are not reaching a basic standard of wellbeing (Akenji et al., 2021).

The potential reduction in emissions from personal consumption is considerable, and it is estimated that, in high-income countries, consumption-based carbon footprints (CBCF) will need to be reduced by 60 to 80% by 2030 in order to stay with in the 1.5 degree warming limit (Koide et al., 2021b). Studies of demand-side actions have found that making consumption changes in the domains of diet, transportation and housing can lead to substantial reductions in CBCFs and can significantly contribute to the goal of the 1.5 degree limit, especially in the affluent context (Ivanova et al., 2020). The consumption options with the largest reduction potential (0.5 to 1.5 tCO_2e) include, within the area of diet, changing to a vegan or vegetarian diet, for transport, living car-free, shifting to driving an electric vehicle (EV), and less air-travel, and to reduce emissions from housing, switching to renewable electricity (Ivanova et al., 2020, Akenji et al., 2021, Koide et al., 2021b, Salo and Nissinen, 2017).

Being concerned about climate change or having pro-environmental attitudes can motivate individuals to take actions to reduce their GHG emissions, and this has been studied from various perspectives such as the relationship of climate concern and taking pro-climate actions (Bruderer Enzler and Diekmann, 2015, Bouman et al., 2020, Saari et al., 2021), the gap between climate awareness and taking action (Kollmuss and Agyeman, 2002, Li et al., 2021), and other values and sociodemographic factors involved in lifestyle choices which may conflict with climate concern when making consumption choices (Tolppanen and Kang, 2021). What has not been as extensively studied is how climate concern affects consumption choices and how this impacts the total CBCF. The studies that have focused on the relationship between climate concern and the total CBCF have found that climate concern had a relatively low importance as an explanatory variable for the total CBCF (Nässén et al.,

2015, Sahari et al., 2024) or there is a weak, positive association between the two (Han et al., 2021).

This thesis aims to look at CBCFs in connection with the 1.5 degree warming limit along with the impact of different low-carbon consumption options and how climate concern and climate motivation affect the CBCFs of individuals in the Nordic countries. The Nordic countries are an interesting case study since high CBCFs are found there (Hubacek et al., 2017, Clarke et al., 2017) and the Nordics are a highly affluent region yet they have some of the lowest income inequality in the world (Jokinen et al., 2020), which could allow for the identification of low-carbon lifestyles with a high standard of wellbeing (Leferink et al., 2023). The rest of this section includes an introduction to key concepts concerning 1.5 degree compatible lifestyles, CBCFs, the impacts of low-carbon consumption options and climate concern and motivation. Then the research questions and thesis entity are presented.

1.1 Affluence, carbon inequity and the 1.5-degree limit

The level of carbon footprints is unequally distributed across the globe (Ala-Mantila et al., 2023, Hubacek et al., 2017). Globally, 34-45% the total of consumption-based household emissions can be attributed to the top 10% of households with the highest GHG emissions per capita whereas the middle 40% are responsible for 40-53% of emissions and only 13-15% can be attributed to the bottom 50% (IPCC, 2022). Affluence and wealth are strongly correlated with high carbon footprints (Wiedenhofer et al., 2017, Wiedmann et al., 2020) and the wealthy nations in Europe have carbon footprints that are at levels that are almost seven times the world average (Ala-Mantila et al., 2023). Within the Nordic countries carbon footprints have also been found to be well above the world average (Hertwich and Peters, 2009, Ivanova et al., 2016, Clarke et al., 2017).

In order to limit global warming to 1.5°C, emissions from household consumption need to be linked to the global carbon budget (Girod et al., 2014). The Intergovernmental Pannel on Climate Change (IPCC) defines the global carbon budget as the "maximum amount of cumulative net global anthropogenic CO_2 emissions that would result in limiting global warming to a given level with a given likelihood, taking into account the effect of other anthropogenic climate forcers" (IPCC, 2022). In this definition, the total carbon budget includes emissions from 1850-2020 and the remaining carbon budget is from 2020 until net zero emission are reached globally (IPCC, 2022). Climate change mitigation pathways include different scenarios, which include different temperature warming limits, policies enacted, and technologies employed (IPCC, 2022). Human behavior can strongly impact climate trajectories (IPCC, 2022, Bury et al., 2019), so it is important that GHG emissions associated with consumption be linked to the remaining carbon budget, (Girod et al., 2013) and the CBCFs connected to the aimed target levels and mitigation trajectories (Ala-Mantila et al., 2023).

Based on scenarios in the IPCC AR5 database, which do not rely heavily on negative emissions technologies, targets for the 1.5 degree compatible limits for lifestyle carbon footprints have been estimated to be 2.5 tCO_2e for 2030 and 0.7 tCO_2e for 2050 (Akenji et al., 2021). During the time of this study, to be on track to reach these limits, footprints would have needed to be around 3.6 tCO_2e following the world average. As more of the carbon

budget is used up, the projected carbon footprint targets will shrink (Akenji et al., 2021). The remaining carbon budget to not exceed 1.5 degrees is likely to run out in the next decade (Bednar et al., 2021).

1.2 Consumption-based carbon footprints

Consumption-based accounting (CBA) provides a beneficial perspective to study emissions from individual consumption since it includes emissions embodied in trade, which can better capture the emissions associate with people´s lifestyles (Girod et al., 2013, Afionis et al., 2017, Heinonen et al., 2020, Ottelin et al., 2019), whereas production-based accounting is often utilized when assigning responsibility for emissions internationally (Afionis et al., 2017, Ala-Mantila et al., 2023) and allocates emissions at the place that they were produced (Afionis et al., 2017). CBA allocates the GHG emissions to the end-user at the point of consumption (Afionis et al., 2017). This is important since around 30% of emissions are embodied in global trade (Kanemoto et al., 2014, Wood et al., 2018). Affluent countries are often net importers of goods (Ivanova et al., 2016, Afionis et al., 2017) and have outsourced their emissions and environmental impacts to lower-income countries (Kanemoto et al., 2014, Wiedmann et al., 2020), which is an example of carbon leakage (the outsourcing of emissions due to a relocation of production) (Heinonen et al., 2022b). Due to this carbon leakage, CBA can be useful for societies that rely on outsourcing production to meet their domestic consumption demands, so CBA is an appropriate approach for climate mitigation for these societies (Pang et al., 2020). CBA when covering GHGs becomes the CBCF which can be useful for identifying the climate impact of individuals and evaluating the climate compatibility of different lifestyles (Koide et al., 2021a, Ottelin et al., 2019).

CBCF studies have also shown that sociodemographic and other local contextual factors can have various impacts on CBCFs. Income has been found to be a strong driver in CBCFs (Hubacek et al., 2017, Wiedenhofer et al., 2018, Nässén et al., 2015). Lower carbon footprints have been associated with larger household size since economies of scale allow for lower mobility and housing emissions (Wiedenhofer et al., 2018, Ala-Mantila et al., 2016, Ivanova and Büchs, 2020), whereas single households may struggle to have low carbon footprints (Jack et al., 2023). Living in a more urban area can result in less direct emissions from housing and transportation, but the indirect emissions from the consumption patterns that accompany an urban lifestyle can cancel out these emission savings (Heinonen et al., 2013a, Pang et al., 2020). Gender, age, and education levels have been found to have small and mixed effects on CBCFs and men, women, elderly, young adults, and those with higher vs lower education levels may emit more or less in different domains. For example, women may have higher emissions in housing and men may have higher emissions in transport (Osorio et al., 2024, Büchs and Schnepf, 2013, Ivanova et al., 2018). Younger individuals may have lower energy needs (Ivanova et al., 2018), while older individuals' home energy emissions may remain high, but total and transport emissions are likely to be lower (Büchs and Schnepf, 2013). Higher education levels have been associated with more emissions related to travel (Ivanova et al., 2018, Büchs and Schnepf, 2013), but have also been associated with less carbon intensive diets (Nevalainen et al., 2023, Sundet et al., 2023). The size and composition of CBCFs can differ based on the region and local factors (Jones and Kammen, 2011, Koide et al., 2021a) For example, the energy mix, local food production, transportation culture, and existing infrastructure can greatly impact the CBCF.

1.3 The demand-side: Low-carbon consumption options

Demand-side mitigation actions, which include changes in the use of infrastructure, adoption of technology, behavioral and social changes, have the potential to reduce GHG emissions by 40-70% by end-users (IPCC, 2023). Several studies have found that the most important consumption categories that lead to the largest carbon footprint reductions are changes in consumption in the areas of transport, housing, and diet (Hertwich and Peters, 2009, Ivanova et al., 2016, Tukker and Jansen, 2006, Bjelle et al., 2018). According to the study by Ivanova et al. (2016), in European households, 27% of the emissions in the CBCF come from mobility, 26% from housing, and almost 10% from food.

Researchers have examined a variety of low-carbon consumption options that may lead to a reduction in CBCFs which include avoiding consumption (e.g. not taking long-haul flights), shifting to a lower carbon alternative (e.g. switching to a plant-based diet from meat-intensive diet) or improving efficiency (e.g. using more efficient appliances) (Capstick et al., 2020, Akenji et al., 2021). For example, in a review of studies of the mitigation potential of different low carbon consumption actions, Ivanova et al. (2020) found that the top ten low-carbon consumption options resulted in a cumulative mitigation potential of 9.2 tCO_2e. To study the potential of different low-carbon actions and consumption choices researchers can estimate the average CBCFs of different groups through their reported consumption of different goods and services along with the GHG intensity of these goods and services and replace a high-carbon good with a low carbon good and see the potential reduction in emissions (Carlsson Kanyama et al., 2021, Koide et al., 2021a). The impacts of the various low-carbon consumption options will vary based on the country where they are taking place since energy mixes, carbon intensity of goods, and consumption patterns can differ regionally, so an actions that might be climate compatible in one context might be less so in another (Akenji et al., 2021).

Several studies of CBCFs and mitigation options have found that some actions can have the potential lead to rebound effects (Bjelle et al., 2018, Ottelin, 2016). The rebound effect happens when money saved from decreases in consumption or increases in efficiency is re-spent on a carbon intensive activity, which negates the GHG savings from the initial action (Sorrell et al., 2020). For example, if someone gives up owning a personal vehicle and then spends the money saved by this action on flights abroad for leisure travel, which would cancel out the emissions saved from not driving their car.

The literature has shown that changing to a plant-based, vegetarian, vegan, or other low-carbon diet has been found to be a consumption option with high mitigation potential (Wynes and Nicholas, 2017, Grabs, 2015, Ivanova et al., 2020, Bjelle et al., 2018, Koide et al., 2021b), especially in more affluent and Western countries (Akenji et al., 2021) where often diets consist of a high quantity in animal products and a low quantity of plant based foods and overconsumption is an issue (Temme et al., 2020, Meltzer et al., 2024). Studies estimate the range of the mitigation potential of switching to a vegan or vegetarian diet to be between 0.2-1.5 tCO_2e (Andersson and Nässén, 2023, Carlsson Kanyama et al., 2021, Ivanova et al., 2020, Koide et al., 2021a, Koide et al., 2021b). Plant-based diets do not only have the potential to decrease the carbon footprint, but they can also reduce land and water footprints (Vita et al., 2019).

A large part of the carbon footprint can be attributed to emissions from transportation (Ivanova et al., 2016) especially in the top 1% of EU emitters where air travel is associated with 41% and land travel with 32% of the carbon footprint (Ivanova and Wood, 2020). Looking at different everyday transportation options, living car-free has the mitigation potential of 0.5-2.3 tCO_2e (Andersson and Nässén, 2023, Ivanova et al., 2020, Koide et al., 2021b, Akenji et al., 2021) and driving an EV could lead to a reduction of 0.06 to 2.0 tCO_2e (Ivanova et al., 2020, Koide et al., 2021a, Koide et al., 2021b). Living car-free could also support further GHG reductions in that it supports the need for less roads, parking spots and other infrastructure related to driving (Wynes and Nicholas, 2017) whereas driving an EV will not get away from the personal car dominating transportation in affluent countries, and the impacts of infrastructure needed to support the personal vehicle. Being car-free comes with the risk of the rebound effect since money saved on car ownership could be re-spent on more GHG intensive activities such as air travel (Ottelin et al., 2020). For EVs, it is important to consider the embodied emissions in the production of the vehicle and the battery as well as the source of electricity for charging the vehicle (Girod et al., 2014, Dillman et al., 2020), since, although EVs can produce less direct emissions, sometimes they can lead to overall higher lifetime emissions than their diesel counter parts (Dillman et al., 2020) or more overall emissions than changes in travel behavior (Dillman et al., 2021).

Emissions caused by air travel from leisure travel often dominate the personal travel emission of affluent individuals (Aamaas et al., 2013, Czepkiewicz et al., 2018b, Czepkiewicz et al., 2020) and reducing air travel would have a high mitigation potential (Ivanova et al., 2020, Andersson and Nässén, 2023) especially for high-income individuals (Jones and Kammen, 2011, Lacroix, 2018). The potential mitigation range of less air travel has been found to be 0.6 to 1.5 tCO_2e (Ivanova et al., 2020, Wynes and Nicholas, 2017, Bjelle et al., 2018, Capstick et al., 2020). Shifting holiday travel modes to less carbon intensive transport modes like trains or switching holiday travel to more local locations can have a substantial impact on consumption based carbon footprints (Carlsson Kanyama et al., 2021).

Home energy emissions can be reduced in a variety of ways including purchasing renewable electricity for the home which could lead to a reduction of 0.6-2.0 tCO_2e, switching to low-emission heating such as a heat pump which could result in a decrease of 0.07-0.8 tCO_2e, and other actions which include reducing household energy use, and implementing various renovations can also reduce emissions (Koide et al., 2021b, Koide et al., 2021a, Ivanova et al., 2020). For example, Salo et al. (2019) found that the average person in Finland could lower their carbon footprint by 2.5 tCO_2e by turning down the thermostat, saving hot water, increasing the household's share of low-carbon energy sources, and other home efficiency measures. Rebounds for housing mitigation actions have been found to be smaller than transportation rebounds (Bjelle et al., 2018, Chitnis et al., 2013).

1.4 Climate concern and motivation

Climate concern is an individual's awareness of climate change and perception that it is an important issue (Chan and Tam, 2021). Areas with similar qualities to the Nordic countries such as having high income, democratic government (Pohjolainen et al., 2021), low inequality and clean industries have been associated with higher climate concern (Peisker,

2023). Higher climate concern has also been related to younger and more highly educated populations (Peisker, 2023).

Climate concern can motivate people both directly and indirectly to take action against climate change including personal mitigation actions and supporting climate policies (Bouman et al., 2020, Bruderer Enzler and Diekmann, 2015, Saari et al., 2021). Higher climate concern has been associated with lower carbon footprints in some studies (Han et al., 2021, Schleich et al., 2024, Andersson and Nässén, 2023), but often it has been found to have a small effect and other factors such as income has been found to have a larger impact (Nässén et al., 2015, Han et al., 2021, Sahari et al., 2024).

Often, people prefer to engage more with low-impact pro-climate actions than high impact actions (Tolppanen et al., 2021, Gram-Hanssen and Christensen, 2012, Vadovics et al., 2024), even if they have a high level of concern and intent to act (Moser and Kleinhückelkotten, 2018, Sahari et al., 2024). For example, people are less likely to give up flying (Árnadóttir et al., 2021, Jack et al., 2023) or change their diets (Tolppanen et al., 2021, Vadovics et al., 2024) since these actions have been found to be habituated and highly influenced by social norms (Aasen et al., 2023, Aasen et al., 2024). People are also more likely to participate in low cost pro-environmental actions (Jakučionytė-Skodienė and Liobikienė, 2022). Individuals might engage with low-carbon consumption options for reasons other than climate concern such as having a plant-based diet for health reasons (Fehér et al., 2020) or buying second hand goods to save money (Howell, 2013).

People may over estimate the emission reductions of low-impact actions and may underestimate the emissions reductions of high-impact actions such as eating less meat (Wynes et al., 2020, Camilleri et al., 2019) or less air travel (Wynes et al., 2020). A mismatch between the perceived climate-sustainability of one's lifestyle and the actual carbon footprint can exist as well. Individuals with low levels of climate literacy, may tend to overestimate the climate-sustainability of their lifestyles, and those with higher levels of climate literacy, might better understand the size of their CBCF, but estimate their lifestyle as not very climate- sustainable even with lower actual CBCFs (Maczionsek et al., 2023).

Although individuals may be concerned about the climate and have the intent to reduce their emissions, there can be a gap between an individual's values and actual actions known as the value-action gap (Blake, 1999). Personal values and social norms may conflict with climate concern which can prevent individuals from taking pro-climate actions (Thøgersen, 2021) and individuals must navigate making these decisions within the context of society and socio-material arrangements (Wethal et al., 2024). Those with high climate concern may not act due to lack of options to participate in low-carbon consumption (Whitmarsh and O'Neill, 2010), which may include lack of financial resources or infrastructure. Carbon lock-in due to infrastructural and technological, institutional and behavioral factors can also prevent people from choosing low-carbon consumption options (Seto et al., 2016). Studies have found that people who engage in one pro-climate action may lead to less pro-climate actions in other domains since they feel that they have done their part to mitigate climate change (Sorrell et al., 2020, Árnadóttir et al., 2021). However, positive spillovers can also occur and these spillovers can also reinforce the initial action (Sorrell et al., 2020, Carrico, 2021).

1.5 Research questions

As has been shown above, climate change is an urgent problem that is being driven by consumption and the affluent of the world are responsible for a disproportionate amount of GHG emissions. Low-carbon consumption options have a high potential to reduce emissions and climate concern is on the rise, so how can footprints be kept at levels compatible with 1.5 degree warming limits?

As highlighted in the section above, climate concern can motivate some individuals to take action, but others, while being concerned about the climate, may not see reducing emissions as their responsibility and view government actions or technological innovations as more feasible solutions than individual action. Those who are motivated to take individual actions to reduce their carbon footprints, may make high or low impact consumption choices, might see a rebound effect in their carbon footprint, or have positive or negative spill over effects. It is important to investigate how climate concern and motivation impact the carbon footprint to see if these are if these are essential aspects for enabling 1.5-degree compatible lifestyles.

This study focuses on the Nordic countries, which are often seen as "green" yet they have high carbon footprints. They are also highly socially developed and have low-income inequality, which makes the Nordics an interesting case study to see how climate compatible lifestyles can be achieved within the context of high affluence and wellbeing.

There is a gap in the literature concerning the footprint levels and how they relate to the 1.5-degree warming limit, and how climate concern acts as a driver to engage in actions to reduce one's CBCF and how these actions impact the CBCF. To address this, this thesis focuses on these research questions:

1. How can residents of the Nordic countries live 1.5-degree warming compatible lifestyles?

2. How important are climate concern and motivation in reaching 1.5 degree compatible lifestyles?

The first question aims to see how residents of the Nordic region can live 1.5 degree compatible lifestyles by connecting the current CBCFs to selected 1.5 degree compatible limit levels. Additionally, the impact that different low-carbon consumption options have on the total CBCF will be explored to see what consumption options have the greatest mitigation potential and lead to the lowest CBCFs and to CBCF compatible with potentially climate sustainable levels.

Under the second question, concern about climate change is looked at from the perspective of how important a driver it can be for individuals to engage with low-carbon consumption options. The impact that climate concern has on the CBCF and the effect that climate motivation has on engagement rates with low-carbon consumption options will be analyzed to see how much a factor these can be in individuals living 1.5 degree compatible lifestyles or in reaching such lifestyles.

1.6 Thesis entity

This thesis consists of five peer reviewed articles which are utilized to answer the research questions presented in the section above. Articles A1, A2, A3, and A5 provide results that show the relationship of low-carbon consumption options to the CBCF and the results from articles A3, A4, and A5 show the impact of climate concern and climate motivation on the CBCF.

The introduction section laid out the key information for understanding the context of the study and how the topics addressed in the thesis are currently situated in the literature. In the next section, the Nordic country context is introduced further, followed by the methods section explaining the methodological approach and justifying why the methods chosen are appropriate to address the research questions. In the results section, the key findings from each article are given and pulled together to address the research questions. The discussion section goes on to explore the contribution of the thesis, evaluate the research, suggest policy implications, and recommend further research options.

2 The Nordic Context

The Nordic countries, consisting of Denmark, Finland, Iceland, Norway and Sweden in this study, provide a unique case to study. The Nordic countries have many similarities in how their societies are organized, and therefore they form a certain type of entity while also being independent countries. They are often seen as leaders in addressing environmental issues, and reaching sustainability goals, ranking in the top twenty of the Environmental Performance Index globally (Wolf, 2022). There is a large percentage of renewable energy in the stationary energy production in these countries, especially in Iceland and Norway (Jokinen et al., 2020) and the cold climate makes energy efficiency and decarbonization of heating systems for buildings important. The Nordics have taken different approaches to reducing fossil fuel use in transport such as policies supporting electric vehicle adoption in Norway, which has led to Norway being a leader in EV adoption and promotion of biofuels in Sweden and Finland (Greaker et al., 2019). Although the Nordic countries have committed to ambitious climate goals (Jokinen et al., 2020) and have high public support for these initiatives (Otto and Gugushvili, 2020), from a consumption perspective, the CBCFs found in these countries are well above the global average and the 1.5 degree compatible limit (Ivanova et al., 2016, Clarke et al., 2017).

The Nordic counties regularly rank high on international social and economic performance indices (Kautto and Kuitto, 2021) including the World Happiness Report (Rowan, 2023) and the OECD Better Life Index (OECD, 2017). The percentage of people with secondary education levels or higher is significantly higher than the OECD average (OECD, 2017) and there is a high level of social trust (Jokinen et al., 2020). The countries are all part of the Nordic welfare system. The key characteristics of the Nordic welfare model include universal social rights, valuing equality, low poverty rates, small differences in income, and the state taking responsibility for well-being of its residents (Pedersen and Kuhnle, 2017). The Nordic countries have high employment, which is well above the EU average (OECD, 2018, Jokinen et al., 2020) and high tax rates, which support the Nordic welfare system. The Nordics rank high on the Human Development Index (HDI) and even in environmental performance when updated with the HDI, however if CBCFs are taken into account to update the HDI, they are ranked significantly lower (Ala-Mantila et al., 2023).

3 Methods

This section will introduce the methodological approach and the specific methods used in this thesis and present the strengths and limitations of each approach and method. First, the use of case studies will be discussed, followed by the carbon footprint calculator survey, then the method used for the calculation of CBCFs, and finally the statistical analysis that was used. The evaluation of these methods and their fit with the study will be examined in the discussion section.

3.1 Case study

A case study can be defined as "an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident"(Yin, 2009). The case study is a valuable and suitable strategy for in depth investigations of complex, real-life phenomena and useful for addressing questions such as "how" or "why" (Yin, 2009, Eisenhardt, 1989) and can provide researchers with "concrete context-dependent knowledge" (Flyvbjerg, 2006). Single case studies are especially effective when researching unique circumstances (Yin, 2009). The aim of this study was to identify how affluent individuals with a high standard of wellbeing could live climate compatible lifestyles. The Nordic countries are unique and provide a real-life setting to study this phenomenon as well as provide a way to identify what consumption choices and attitudes may lead to climate compatible lifestyles, which is why a case study is an appropriate method to utilize to study this topic. Section 2 describes in detail the Nordic context and highlights the importance of studying consumption patterns in this setting.

3.2 Data collection

This study utilized a carbon footprint calculator survey with the aim of gathering high quality responses to calculate CBCFs and gather information on respondents' level of climate concern, engagement with pro-climate actions, climate motivation, self-reported well-being and other demographic information in order to identify those living 1.5 degree compatible lifestyles in the Nordic context. Carbon footprint calculators have been used by researchers and organizations to show the impacts of consumption, to guide individuals into more sustainable patterns of consumption and to study the impact that carbon footprint calculators have on consumption behaviors (Salo et al., 2019, Gram-Hanssen and Christensen, 2012). The calculators often focus on emissions from housing, diet, goods and services, and travel (Salo et al., 2019). Some calculators utilize information based on geodemographic factors and self-reported frequency of consumption behaviors (West et al., 2016) while others make use of financial transaction data to calculate the carbon footprint (Andersson, 2020). Carbon footprint calculators that capture physical quantities of consumption rather than just financial

transaction data can provide more data granularity, however this relies on self-reported data which can be prone to under or over reporting (Trendl et al., 2023) and the surveys are also limited by the number of questions that are asked as well as a trade off between complexity and usability (West et al., 2016). Carbon footprint calculators may attract users who are already concerned about the climate (West et al., 2016), which may not lead to a representative sample of the general population. It has been found that various carbon footprint calculators have produced different results and may be inconsistent with each other (Padgett et al., 2008).

Surveys, in general, are useful for measuring attitudes and gathering information about past behavioral experiences, seeing the prevalence of attitudes and behaviors and examining the differences between groups, however they are not useful for finding causation and response rates can be lower compared to other methods (Weisberg, Weisberg, 2007). The survey in this study was distributed online and promoted through social media. Online surveys are appropriate for descriptive studies and are low-cost (Nayak and Narayan, 2019), though online surveys can have lower response rate (Daikeler et al., 2020). Social media based recruitment can be a cost effective way to reach target populations especially populations that have high internet access, but may not generate representative samples of the general population (Beam, 2023).

The 1.5 degree lifestyles carbon footprint calculator (carbonfootprint.hi.is/) was designed to both calculate the CBCFs and link these footprints to different actions taken, as well as the respondents' levels of climate concern and motivation. The data was collected from the fall of 2021 to the spring of 2022 and reached around 8,000 full responses covering about 17,000 people when considering both the respondents and their household members. The data from the survey is openly available in a data repository (Iceland, 2024) and a table comparing the demographics in the sample to the national averages can be found in Leferink et al. (2023). The survey was written in English and then translated by native speakers into the main languages of each country. Participants were asked about their gross personal and household income and were given the option of 11 income brackets were taken from Eurostat (2018).

An extensive amount of information about the participants' consumption habits and attitudes about climate change was gathered through an online questionnaire. Two of the main benefits of using this survey design to gather data to estimate CBCFs over using data from a national budget survey or transactional data are that researchers can directly gather information on physical quantities of consumption, which can lead to better estimates of the emissions caused by transportation (leisure travel, personal vehicles, public transportation) (Heinonen et al., 2020) and housing energy (Girod and De Haan, 2010, Heinonen et al., 2020). With this method, researchers can also gather as information on attitudes and behaviors relating to climate change (Lange and Dewitte, 2019).

The questions about climate concern were based on the study by Chryst et al. (2018) which were designed to capture respondents' beliefs about risk perception, worry, expected harm to future generations, and personal importance of the issue of climate change. Other questions were included to capture respondents views of how sustainable their life might be or how knowledgeable they are about climate change as well as if they were motivated by lowering their carbon footprint to engage with certain actions, which could all be linked to their CBCF. The questions were asked on a scale of 1 to 5.

3.3 Calculation of consumption-based carbon footprints

CBCFs are calculated through an environmental input-output analysis (Baynes and Wiedmann, 2012, Heinonen et al., 2020), process-based approaches such as life cycle analysis (Steen-Olsen et al., 2016, Heinonen et al., 2020), or hybrid models (Kok et al., 2006, Heinonen et al., 2020). Input-output based models can assess average carbon footprints by combining expenditure data with GHG intensities from different sectors, however, this does not differentiate well between different goods and services from the same sector (Suh et al., 2004). Process-LCA approaches can more accurately assess emissions from specific goods and services, but this method suffers from a truncation error (Kok et al., 2006). Hybrid models combine the best features of these models to avoid the issues presented by the other methods (Kok et al., 2006). Data sources for calculating CBCFs can come from national budget surveys (Heinonen et al., 2020), self-reported information like carbon footprint calculators (Heinonen et al., 2022a, Lange and Dewitte, 2019) or from other sources such as financial transactions tracked in apps (Trendl et al., 2023, Andersson and Nässén, 2023). Calculating carbon footprints using expenditure data and following the assumption that emissions are proportional to the spending on each product category can lead to an overestimation of the carbon footprints of high-income individuals and an underestimation of low-income individuals when calculating carbon footprints (André et al., 2024).

Studies of CBCFs have generally followed two different allocation principals resulting in areal carbon footprints and personal carbon footprints (Heinonen et al., 2022b). Both include emissions embodied in trade, but when it comes to private consumption, areal carbon footprints include all of the emissions from all of the purchases or activities occurring within that area, regardless if the individual making those purchases resides there or not. On the other hand, personal carbon footprints include the emissions from an individual's consumption activities regardless of where that consumption takes place (Heinonen et al., 2022b). Government consumption and capital formation can be allocated uniformly in areal carbon footprints since public goods and capital are produced and consumed not only for and by the residents of the area, but would also serve any visitors to the area. Allocating government consumption and capital formation is problematic in the personal carbon footprint since an individual consumes these goods both as a resident and visitor to other areas, which is why is it commonly not included in studies using the personal carbon footprint (Heinonen et al., 2020).

The carbon footprints in this study were calculated with a hybrid method, where the majority of the footprint was calculated with physical quantity and only a small part of the footprint was calculated through an input-output model based on spending with Exiobase intensities. This method can help to avoid the problem of assuming linearity between spending and emissions since price does not always reflect the GHG emissions associated with a good or service (André et al., 2024, Ottelin et al., 2020). This approach may also capture the emissions from leisure travel, personal vehicles and public transportation more accurately since information was gathered about the mode, number and length of trips rather than expenditure data on transportation. For example, the differences in domestic and international air travel may not be captured when using data from national budget surveys which would significantly effect the CBCF (Czepkiewicz et al., 2018a) The emissions from

housing energy were estimated by the type of housing, size, decade of construction and heating and electricity sources for the home, which can lead to a better estimation since energy costs can be hidden in rental payments (Girod and De Haan, 2010). The footprints are personal carbon footprints and government spending, capital formation, and durable goods were not included, which may lead to an underestimation of total CBCFs (Heinonen et al., 2020), but this allows for the focus to be on personal consumption and enables a clear focus on emissions from lifestyles (Akenji et al., 2021).

3.4 Statistical analysis

Bivariate analysis was used to understand the levels and observe the differences in the CBCFs of various groups. Multi-variable regression analysis was used to see the impact of the different low-carbon consumption options and climate concern on CBCFs while controlling for factors such as income, household size, degree of urbanization, gender, age, and education level, which have been shown to have an impact CBCFs (Wiedenhofer et al., 2018). The regression analysis can reveal the impact of these factors and show the magnitude of the effects of these variables on the CBCFs. Regression analysis has been used in the study of CBCFs to see the effects of low carbon options (Shigetomi et al., 2021, Ottelin et al., 2017, Koide et al., 2019). Many factors impact consumption and regression analysis can help show the impact of individual variables, however, there are limitations due to the correlation of these variables (Lenzen et al., 2006, Weber and Matthews, 2008). There are also many variables that may impact CBCFs that are not included, so the results of the regression model must be interpreted with caution, as they may only show correlation and not causation.

To calculate the rebound effect in this study and to estimate the mitigation potential of different low-carbon consumption options, two groups are compared, those who engage in a low-carbon consumption option and those who do not. One issue with this method is that the two groups used to make this estimation are composed of different people and therefore their CBCFs might have differences caused by other group characteristics aside from the variables of interest (Ottelin, 2016). To control for some of these differences, control variables can be used in regression models. Although, this will not lead to an accurate prediction of the rebound effects, it can show whether the rebounds are high or low or positive or negative (Ottelin, 2016).

4 Results

Overall, the average CBCFs of the countries studied were well above the current 1.5 degree compatible level. The lowest footprints were found in Sweden and highest were found in Denmark and Finland. The CBCFs across the income deciles showed a flat to gradual increase until the last income decile where they increased significantly, which could be because the individuals in the top decile may have incomes far above those in the next decile below them. The carbon intensity per euro generally decreased across the income deciles due to the role of lower intensity services increasing in the consumption of wealthier individuals. Figure 1 shows the average CBCFs across the income deciles in each country.

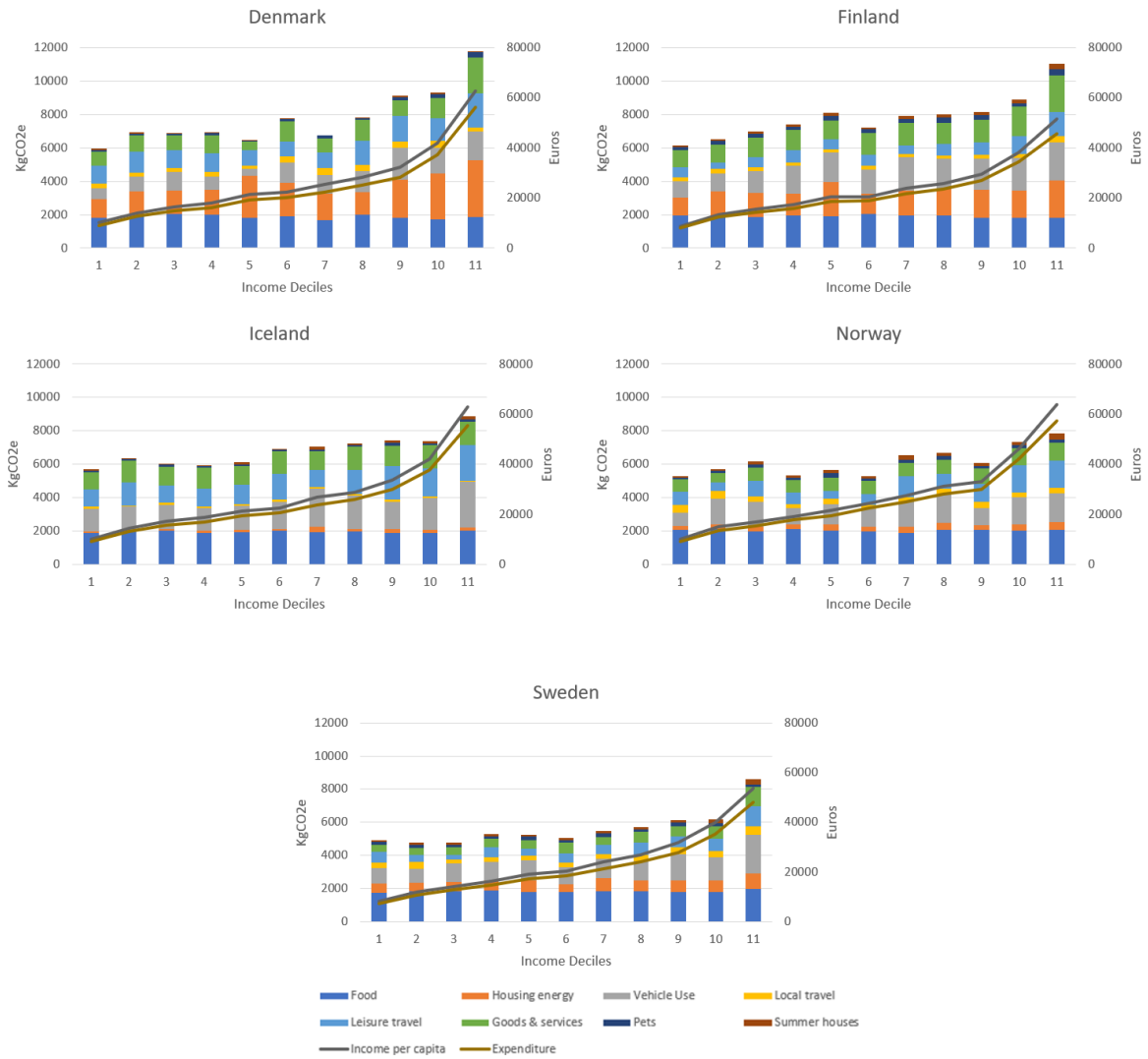

Figure 1. The average CBCFs of the Nordic countries across the eleven income deciles.

The groups who were identified as having a 1.5 degree compatible CBCFs (3.6 tCO_2e or lower), were found at all income levels and were participating in at least two high impact

low-carbon consumption options such as having a vegan or vegetarian diet, being car-free, taking no flights, or driving an EV, however, the number of people identified in these groups was small. Little to no rebounds were found in the groups engaging in the low-carbon consumption options of being a vegan or vegetarian and taking no flights. However when comparing low-carbon personal vehicle options of middle income respondents who owned an EV or other green vehicle, were car-free, or drove minimally, the CBCFs were found to be similar among these groups, which indicates a trade-off between car ownership and leisure travel or other consumption. Climate concern and motivation had an impact on the CBCFs, but it was not enough to bring the CBCFs to climate sustainable levels. Climate motivation was most strongly correlated with the actions people are least likely to change including avoiding meat and less air travel. This means that people were engaging more with these actions, which may be associated with bigger sacrifices or lifestyle changes, were doing so because they wanted to reduce their carbon footprint. Based on the key findings, it can be argued that 1.5 degree compatible lifestyles can be reached at all different income levels, when individuals participate in multiple low-carbon consumption options that have a high reduction potential. The participation in these high impact activities was low and high climate concern and climate motivation are related to lower CBCFs, however, this impact is small. Table 1 presents the study design and key findings from each of the articles that constitute this thesis. The results section then goes on to discuss how the low-carbon consumption options studied in each of the articles impacted 1.5 degree lifestyles, the impact of climate concern and motivation, and the participation rates in the low-carbon consumption options.

Table 1. The perspectives, study design and key results of the articles as related to the research questions.

	Title	**Perspectives**	**Study design**	**Key results that are related to reaching 1.5 degree compatible lifestyles**
A1	Too much consumption or too high emissions intensities? Explaining the high consumption-based carbon footprints in the Nordic countries	Analysis of GHG intensity per monetary unit of spending.	Country comparison across income deciles of carbon intensity per Euro spent and an analysis of consumption choices.	1.5 degree compatible CBCFs were found across all income deciles when groups where participating in two or more low-carbon consumption options, however, the number of individuals in these groups was small.
A2	The impact of low-carbon consumption options on carbon footprints in the Nordic region	The impact of low-carbon consumption options on CBCFs.	Country comparison of CBCFs from groups who participated in different low-carbon consumption options vs those who do not and checked to see if rebounds were present.	The combination of not owning a car and being vegan or vegetarian led to lowest footprints. The only 1.5 degree compatible CBCFs were found in Iceland when respondents were car-free and took no flights. Limited rebound effects were found and there was low participation in some of the most impactful consumption options.

(continued)

Table 1. The perspectives, study design and key results of the articles as related to the research questions (continued).

A3	Rebound effects flatten differences in carbon footprints between car-free households, minimal drivers, and green car owners.	The impact of personal vehicle choice on CBCFs	Comparison of CBCFs from eight respondent groups of various types of car ownership and no car ownership (including two car-free groups, one motivated by climate and the other motivated by other reasons).	All of the low-carbon options (car-free, EV, biofuels, minimal driving) led to similar footprint levels when controlling for income. Individuals who were car-free due to climate concern had slightly lower CBCFs than those who were car-free for other reasons. None of the average CBCFs from the groups were at 1.5 degree compatible levels.
A4	Does higher climate concern lead to a smaller carbon footprint? A study among the Nordic country residents	The impact of climate concern on CBCFs.	Country comparison of the total CBCF and the domains of respondent groups with low to high levels of climate concern.	Higher climate concern was associated with lower CBCFs, however none of the average CBCFs were at 1.5 degree compatible levels. Having higher climate concern was associated with lower emission in the diet domain, higher emissions in the public transport domain, and was not significant in the leisure travel domain or even resulted in more emissions in this domain.
A5	Concerned about climate change and ready to take action? An analysis of the pro-climate actions individuals are motivated to take to lower their carbon footprints.	Impact of actions and climate motivation on CBCFs.	Comparison of CBCFs from groups who participated in low-carbon consumption options at different levels of engagement and how climate motivation predicted levels of engagement.	Engagement in low-carbon actions correlated with lower carbon footprints and the lowest CBCFs were found in the groups highly engaged in avoiding meat or flying and these actions were both highly correlated with climate motivation. There was higher participation in the lower impact pro-climate actions. None of the average CBCFs were at 1.5 degree compatible levels.

Argument: 1.5 degree compatible lifestyles are possible in the Nordic countries across all income levels when individuals engage with multiple, high-impact pro-climate actions. However, the engagement found in these most impactful activities is low. High climate concern and climate motivation are associated with lower carbon footprints, but this alone will not reach 1.5 degree compatible CBCFs.

4.1 Low carbon-consumption options impact on the CBCF

The current 1.5 degree target (3.6 tCO_2) was met by some by engaging with combinations of being a vegan or vegetarian along with one of the other low-carbon consumption options of not owning a car, not taking any flights, or driving an EV across all income deciles and

for the all of the countries except for Finland (A1). Both Finland and Denmark have less decarbonized energy systems than the other countries in the study, which mostly explains why 1.5 degree compatible CBCFs were more difficult to achieve in these countries. Not owning a car and not taking any flights also led to climate compatible CBCFs and was particularly effective in Iceland (A1, A2) and in other groups was associated with CBCF that were 22-34% lower than participants who were not engaged with this combination of low-carbon consumption options (A2). Driving an EV was the one low-carbon consumption options by itself that resulted a few of the average CBCFs to be at the level of the of the 1.5 degree target in Iceland and Sweden (A1), however, in this analysis the vehicle production and maintenance were not included, which were included in the subsequent studies (A2, A3, A4, A5) and driving an EV was found to have less of an impact. The number of respondents who participated in each of these combinations of low-carbon consumption options and had 1.5 degree compatible footprints was low (see Figure 4). Figure 2 shows the average CBCFs of individuals participating in low-carbon consumption options along with the difference in CBCFs between those participating and those who did not.

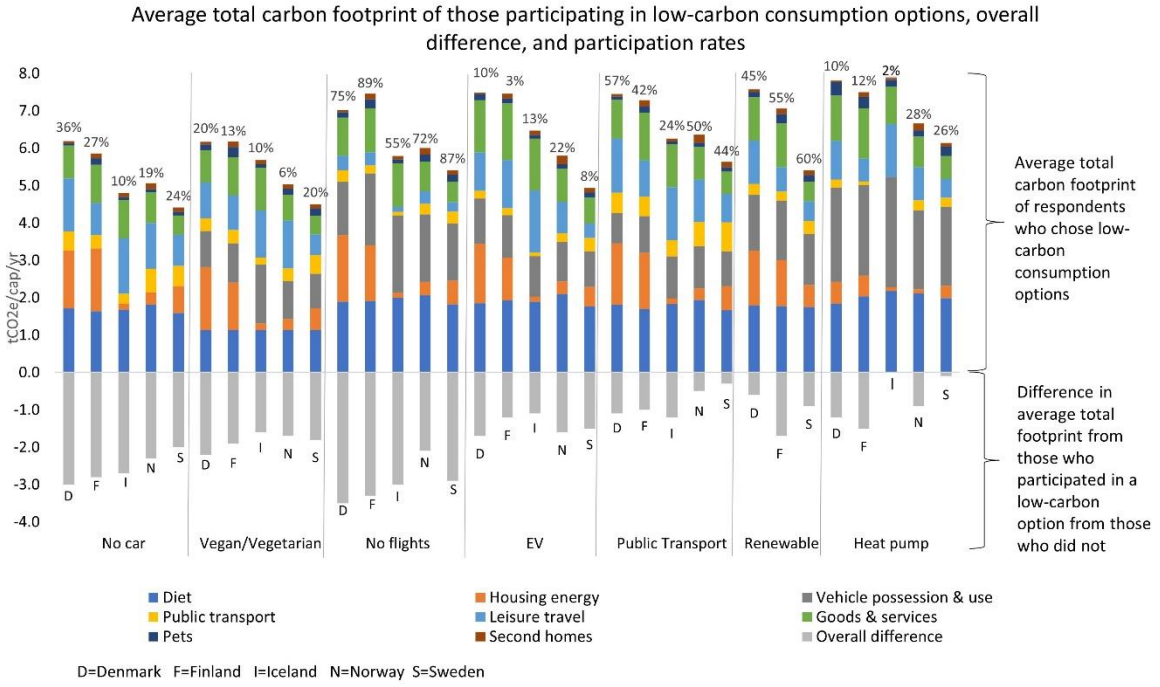

Figure 2. The total CBCFs, including the eight domains, associated with those who participated in a low-carbon consumption option. The grey bars signify the difference between the CBCFs of those who participated in a low-carbon consumption option and those who did not. The percentages indicate the participation in each consumption option in each country.

Engaging with the low-carbon consumption options was associated with lower CBCFs (A1, A2, A3, A5). Having a vegan or vegetarian diet or avoiding meat related to some of the lowest average CBCFs (4.5 to 6.2 tCO_2e) in the groups studied (A2, A5). Individuals who engaged with being a vegan or vegetarian or avoided eating meat were also more likely to not own a car, use public transportation, and buy renewable electricity for the home (A2, A5).

Not owning a car also led to some of the lowest average CBCFs (4.4 to 6.2 tCO_2e) in the groups studied (A2, A3) and was also associated with the biggest difference in emissions

when compared to those who owned a car (A2). However, when studying the type of low-carbon personal car options (EV, less driving, biofuel, no car), these options yielded similar results (total average CBCFs close to 6.0 tCO_2e) when controlling for income by comparing only the middle income respondents (A3). Car-free participants had a high leisure travel footprint (A3), which shows the potential for the rebound effect, since the emissions saved from not owning a car were offset by higher consumption in other domains the CBCF.

Taking no flights was associated with some of the largest differences in CBCFs than those who took flights (A2) and participants who reported completely avoiding flying resulted an average CBCF of around 5.9 tCO_2e (A5).

Looking at the low-carbon consumption options to reduce emissions from home energy, the countries with the least decarbonized energy systems, Finland and Denmark, saw the biggest impacts from buying renewable electricity for the home and installing a heat pump. Iceland and Norway are the countries with the most decarbonized energy systems of the five countries and have almost 100% renewable electricity, however, this did not result in them having the lowest CBCF in most of the settings studied.

4.2 Climate concern and motivation

Both climate concern and motivation had an impact on CBCFs and the level of engagement with low-carbon consumption options. Higher climate concern was related to lower carbon footprints (A4) and higher climate motivation in a particular action was a strong predictor of participation in that particular pro-climate action (A5). However, in the groups studied (those with low to high levels of climate concern and climate motivation) to see the effects of climate concern and climate motivation there were no average CBCFs that were compatible with the 1.5 degree current target as defined in this study. Figure 3 shows the level of climate concern in the sample.

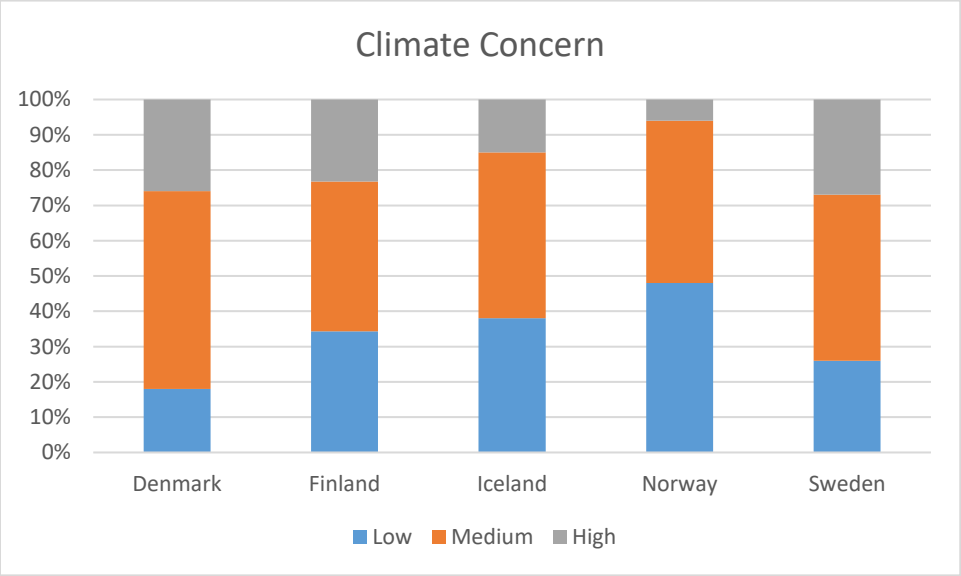

Figure 3. Level of climate concern in each country.

Being concerned about climate change was associated with lower carbon footprints in comparison to the other groups studied which had lower concern. Considering general climate concern, the difference between the CBCFs from the high concern and low concern group was between 1-2 tCO_2e per capita. When controlling for sociodemographic variables in a regression setting, climate concern was highly significant and of similar importance to income. Higher climate concern was associated with lower emissions in the diet domain and higher emissions in public transport and leisure travel domains (A4).

When looking at the motivation to do specific pro-climate actions to lower one's carbon footprint (climate motivation), interestingly, the highest correlation of pro-climate action engagement and climate motivation was found in the actions that are often the most difficult for people to change or least likely to give up which were avoid meat and try not to fly (A5). The actions that participants reported being the most motivated by climate to do were avoiding food waste, trying not to fly, and maximizing the lifetime of goods. In regard to personal vehicle ownership options, not owning a car for climate reasons led to the lowest carbon footprint in the study of different car ownership options (EV, biofuel, no car, least driving) (A3). The climate motivation of one action correlated with climate motivations of other actions, but engagement in pro-climate actions did not strongly correlate with each other (A5), which could indicate a potential spillover effect in that people might engage less with other pro-climate actions once they have engaged with one action and it may also illustrate a gap between the motivation to engage with a pro-climate action and actually engaging with the action. In a regression setting, climate motivation was found to be a significant and strong predictor of engagement in pro-climate actions (A5).

4.3 Participation

The number of individuals in the sample studied that had 1.5 degree compatible CBCFs were few (A1, A2). There was more participation in lower impact actions (A5) with the exception of taking no flights (A1, A2). Participation in buying renewable electricity for the home (A1, A2), using public transportation (A2), maximizing the lifetime of goods, avoiding food waste, and avoiding buying (A5) were some of the low-carbon consumption options that had higher participation level of the low-carbon consumption options. The most impactful actions on the CBCFs included having a vegan or vegetarian diet, being car-free, and taking no flights (A1, A2, A5). Figure 4 shows the percent of the total sample that engaged in different low-carbon consumption option combinations and the percent of the total sample that resulted in the average CBCFs that were compatible with the 1.5 degree current target.

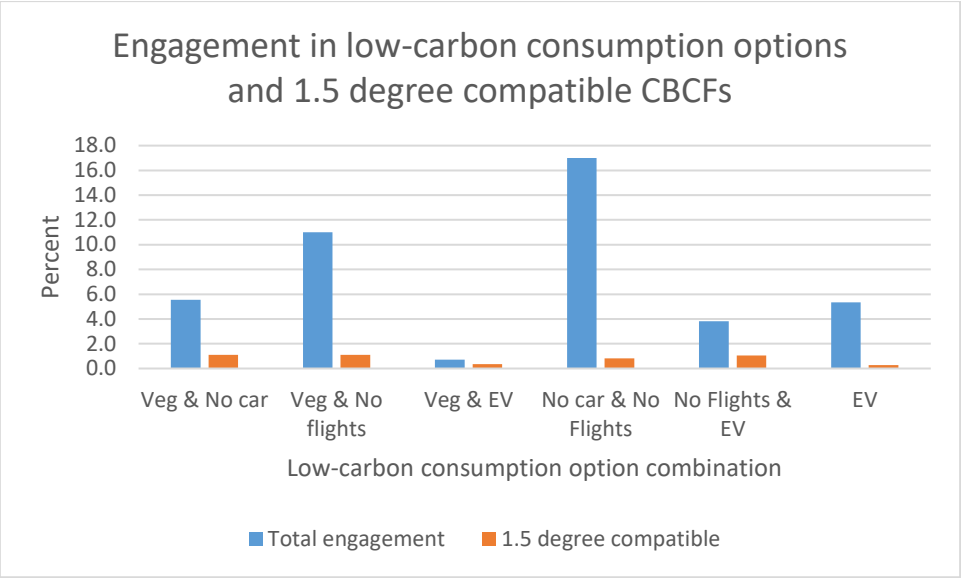

Figure 4. Participation in low-carbon consumption options and percent of individuals with 1.5 degree compatible CBCFs.

The sociodemographic variables utilized in the analysis of this study were not strong predictors of engagement, however some trends could be identified from the bivariate and regression analyses. Comparing the engagement with the pro-climate actions between the Nordic countries, there was less participation in pro-climate actions in Norway and Iceland, especially in not flying in Iceland (A1, A2, A5). Iceland and Norway also had the most respondents with low climate concern and the least number of respondents with high climate concern. However, those in Norway were more likely to engage with actions that required a financial investment such as buying an EV or installing a heat pump (A2). Engaging with a vegan or vegetarian diet was more often seen in Sweden and Denmark (A1, A2, A5). Lower income individuals were more likely to engage with most of the pro-climate actions especially the ones that were potentially cost saving such as not owning a car, avoiding flying, and buying secondhand. Those with a higher level of education were more likely to participate in all of the pro-climate actions except for avoiding flying. Within age groups, younger participants were more likely to have a vegan or vegetarian diet, be car-free, buy services rather than goods, and buy secondhand, whereas older participants were more likely to avoid food waste and reduce home energy. Rural and urban residents also tended to participate in different actions. Rural residents were more likely to have a heat pump, reduce home energy, avoid food waste, and avoid flying while urban residents were more likely to avoid meat and buying services rather than goods. Females were more likely than males to avoid meat and buy secondhand. Household size was usually not a strong predictor of engagement in pro-climate actions, but couples with children were more likely to invest in heat pump and drive an EVs and single respondents were more likely to not own a car (A2, A5).

5 Discussion

This thesis aimed to understand the relationship between CBCFs and low-carbon consumption options along with climate concern and climate motivation in the context of the Nordic countries to see how residents of the Nordic countries can live 1.5-degree warming compatible lifestyles. The main argument, drawn from the five articles which comprise the thesis, claims is that 1.5 degree compatible lifestyles are possible in the Nordic countries across all income levels when individuals engage with multiple, high-impact pro-climate actions. However, the engagement found in these most impactful activities is low. High climate concern and climate motivation are associated with lower carbon footprints, but this alone will not reach 1.5 degree compatible CBCFs.

The first research question looks to identify how the residents of the Nordic countries can live 1.5-degree warming compatible lifestyles through the relationship between low-carbon consumption options and CBCFs. The results of the study show a gap between the average CBCFs found in this study and the current 1.5 degree target. This is not surprising since the footprints of most highly developed countries such as the Nordics have been found to be well above the climate compatible limit (Ala-Mantila et al., 2023, Akenji et al., 2021, Ivanova et al., 2016). The range of CBCFs from this study was in line with other studies for the Nordic countries 5.7-13.6 tCO_2e (Sahari et al., 2024, Koide et al., 2021b, Salo and Nissinen, 2017, Ivanova et al., 2016, Clarke et al., 2017).

One of the issues with setting long term 1.5 degree per capita targets is that the carbon budget is always shrinking and GHG emissions and sinks are dynamic (Akenji et al., 2021), and the remaining budget to not exceed 1.5 degree warming is likely to be depleted within the next decade (Bednar et al., 2021). Furthermore, there is no absolute number for the remaining budget at any moment since all estimates contain uncertainty. The lower the tolerated uncertainty the lower the budget, and vice versa (IPCC, 2022). There is also the question of how to allocate the remaining budget. The target used for comparison in this thesis is based on a 50% likelihood and to an equitable distribution of the remaining carbon budget globally (Akenji et al., 2021). Other allocation methods which consider historical responsibility for emissions, capability, and developing countries rights (Van den Berg et al., 2020) could be considered on a consumption-based perspective (Ala-Mantila et al., 2023) since on at a national level, based on territorial emissions, it has been estimated that Europe and the United States may already have negative carbon budgets (Van den Berg et al., 2020) and consumption-based emissions are often found to be higher than production-based emissions especially in developed countries (Franzen and Mader, 2018, Fan et al., 2016). Another aspect to consider is to not just calculate the emissions caused by consumption, but also to include to the regenerative actions that individuals might engage with and how this impacts the carbon budget (Heinonen and Ottelin, 2021).

Affluence has been linked to high CBCF (Wiedmann et al., 2020, Wiedenhofer et al., 2017). Globally, the Nordic countries are highly affluent and it can be seen that even in the lowest income decile in this study that average CBCFs were not 1.5 degree compatible, however, some individuals were able to meet the 1.5 degree target within all of the income deciles when engaging with low-carbon consumption options (A1). Income has been found to be a

strong driver of CBCF (Wiedenhofer et al., 2018, Hubacek et al., 2017, Nässén et al., 2015), yet difference between the average CBCFs of each income decile showed a somewhat of a flat or slight increase until the last income decile where a larger increase could be seen, which could be due to the uncertainty of how high the incomes of those in the top decile actually are. Also, this may be due to the method used to calculated the CBCFs which may have reduced the overestimation of CBCFs for low-income individuals and underestimation of CBCFs for high-income individuals (André et al., 2024) or perhaps due to the low income inequality and level of affluence found in the Nordics, most residents may be able to consume at the same level.

Looking at the low-carbon consumption options, diet was an important factor in reaching the 1.5 degree compatible lifestyle. Similar to a study in Sweden of climate conscious individuals, adopting a vegan diet led to some of the lowest footprints in the study (5.2 tCO_2e) (Andersson and Nässén, 2023). As other studies have found, eating less meat can have a large reduction potential on the carbon footprint (Ivanova et al., 2020, Carlsson Kanyama et al., 2021, Bjelle et al., 2018). This is especially important in the Nordic context since like other Western countries, diets in the Nordic countries often consist of a high amount of animal products which heavily rely on imported feed, which leads to high food imports (Meltzer et al., 2024). Switching to a less meat-based diet and a shift to sustainable agriculture can not only reduce GHGs, but also open up land for reforestation and restoration (IPCC, 2023) and has the benefit of improving human health (Creutzig et al., 2022). Similar to the results of this study, in the Nordics, studies have found that characteristics such as being female, younger age (Andersson and Nässén, 2023), higher levels of education and living in an urban area more likely to eat less meat (Nevalainen et al., 2023, Sundet et al., 2023). Eating less meat was also a low-carbon consumption option which had some of the lowest engagement. Other studies of the Nordics have also found that this is neither a wide-spread nor popular behavior (Niva et al., 2014, Hielkema and Lund, 2021, Sundet et al., 2023), so there is high potential for higher engagement in this consumption option.

Driving an EV and not owning a car both had a strong impact on the CBCFs and were low-carbon consumption options that were associated with CBCFs that were climate compatible. Comparing all of the low-carbon personal vehicle options (EV, bio-fuel, less driving, being car-free), A3 found that all of the options led to lower CBCFs at similar levels, but the footprints were around 6 tCO_2e, which illustrates that many different low-carbon lifestyles are possible, however, the CBCFs associated with these option were still almost 2.5 tCO_2e above the current target used in this study. Similar to other studies, the emissions savings of not owning a car were offset by an increase in leisure travel emissions (Ottelin et al., 2017, Heinonen et al., 2013b) and the monetary investment in a green car, such as an EV, might have limited consumption in other domains, which is a theory that has been proposed by Font Vivanco et al. (2014). Interestingly, the lowest footprint found in A3 was from those who did not own a car because of climate reasons. A recent study by Mouratidis and Næss (2024) found that lower use of the conventional car and willingness to live without a car were strongly related to worry about climate change, but worry of climate change was unrelated to the use of an electric car. However, in a recent study of Finnish drivers, Sandman et al. (2024) found that EV drivers who were more eco-conscious had significantly lower carbon footprints than EV drivers who were not when both groups had similar incomes. The participation in driving an EV or not owning a car was low in this study. Iceland in particular had less participation in not owning a car as compared to the other Nordic countries in the

study, which could be due to Iceland having a car dominate culture (Heinonen et al., 2021) and less public transportation options compared to the other Nordic countries.

Not flying led to the biggest difference in emissions from those who participated and those did not. Not flying is one of the most high-impact climate mitigation options that individuals in affluent countries can do (Jones and Kammen, 2011, Lacroix, 2018). The participation in this low-carbon-consumption option was high in all of the countries except for Iceland. Iceland had less participation in no flights perhaps due to that they are an island without access to alternative low-carbon international travel options. This study was done during the COVID pandemic so participation in not flying may have been higher due to travel restrictions. Studies have found that people are often unwilling to give up air-travel for leisure even if they have high climate concern (Árnadóttir et al., 2021, Gram-Hanssen and Christensen, 2012). In this study, high engagement with avoiding flying was one of the pro-climate actions that had the highest correlation with climate motivation as compared to the other actions which is interesting because studies have found varying attitudes and behaviors surrounding air-travel in the Nordic countries. Iceland and Norway show high levels of air travel and flying is a habituated part of life that is supported by social norms (Aasen et al., 2023, Árnadóttir et al., 2021). In Denmark, Jack et al. (2023) found that that individuals with high CBCFs felt justified to frequently fly. In Sweden, the idea of 'flight shame' emerged recently and increased awareness of the impacts air travel has been observed (Gössling et al., 2020).

Making changes to home energy has a high mitigation potential (Ivanova et al., 2016). The Nordic countries provide an interesting case study in this regard since two of the countries in this study, Norway and Iceland, have almost 100% renewable electricity and Iceland uses mostly geothermal sources for home heating, yet their CBCFs are similar to other wealthy nations (Clarke et al., 2017, Ivanova et al., 2016). Decarbonizing energy systems is often a high priority in climate change mitigation policies in high-income countries and this can lead to the illusion that they are low-carbon nations (Clarke et al., 2017) when the emissions embodied in trade are not considered (Wood et al., 2018, Kanemoto et al., 2014). Renewable electricity and heat pumps did not have the largest impact on the CBCFs as compared to changes in diet and transportation, but participation in buying renewable electricity for the home was high. The calculation of the home energy in the CBCFs may have affected this relationship. For example, biofuels were not taken as zero as in some studies, so in the countries, such as Denmark or Finland, with a higher amount of biofuels in their energy mixes, the emissions reductions were not reflected in their CBCFs because of using biofuels. Considering buying renewable electricity as a low-carbon consumption option is also a bit problematic since the choice of buying renewable energy might just result in one customer paying a bit more while another customer pays the same price and the composition of the production of electricity does not change. However, if the demand for renewable electricity increases perhaps this will impact the market and steer investments toward increasing renewable energy production.

The second research question focused on how important climate concern and motivation were in reaching 1.5 degree compatible lifestyles. Higher climate concern was associated with lower CBCFs, which has been seen in other studies, but with a bit more explanatory power than found in these studies, which found income as the strongest driver (Han et al., 2021, Nässén et al., 2015, Sahari et al., 2024). Individuals who are concerned with climate issues may have been more likely to participate in the survey, however, there were a number of respondents who reported having low climate concern (Figure 3) and motivation. The

countries with more respondents with lower climate concern also showed less participation in the low carbon consumption options analyzed. Interestingly, climate motivation was most closely tied to the actions people are usually least willing to give up, avoiding meat (Tolppanen et al., 2021, Vadovics et al., 2024) and air travel (Árnadóttir et al., 2021), but the respondents had the highest engagement with some of the less impactful low-carbon consumption options which has been observed in other studies (Tolppanen et al., 2021). Lower emissions from diet and eating less meat were both linked to higher climate concern and motivation. Other studies have also found that pro-environmental attitudes or high climate concern is related to low-carbon diets (Sahari et al., 2024, Andersson and Nässén, 2023). In the survey, only the level of climate motivation was measured for certain low-carbon consumption options. Other factors such as personal values or other personal characteristics which may relate to decisions about low-carbon consumption choices were not measured, which would provide a much more complete picture of individuals who are engaging in these actions.

Although not surprisingly, this study emphasizes the gap that exists between the CBCFs of the residents of the Nordic countries and the 1.5 degree target as well as the necessity to increase the participation in high-impact low-carbon consumption options. This study also linked climate concern to CBCFs and compared the footprints to the 1.5 degree limit. The climate motivation to engage with particular low-carbon consumption options was also investigated and found that the respondents were motivated by climate to engage with the high-impact actions of eating less meat and avoiding flying.

5.1 Evaluation of the research

In this section, the reliability and validity of this study are evaluated from different perspectives. Reliability refers to the stability of measures and internal consistency of the research results (Kimberlin and Winterstein, 2008). The online survey remained the same throughout the data collection. Each article looked at different groups within the sample and used different statistical methods and found that the patterns and trends remained the same and the results generally agreed with other studies. However, this study was based on self-reported data and is a non-representative sample which solely focused on GHG emissions, so it does not give a holistic picture of the other environmental or social impacts that are occurring because of the lifestyles in the Nordics.

The validity of the research considers if suitable and accurate measurements were made and if the chosen method measured the intended phenomenon (Kimberlin and Winterstein, 2008). The aim of the research was to study climate compatible lifestyles in the Nordic context, so the case study method and carbon footprint calculator survey were appropriate since these methods enabled the gathering of real-life consumption details and attitudes toward climate change from residents in the Nordic countries. The limitations of the methods used in the study have been described in each of the articles including that the survey was conducted during the COVID-19 pandemic, which not only affected people's travel behaviors, but also their other consumption patterns, such as their use of services. The change in consumption patterns during covid may have observed more in the CBCFs of urban inhabitants than rural inhabitants since lifestyles in urban areas often lead to more indirect emissions from consumption (Heinonen et al., 2013a) and these may have been lower due to the restrictions brought on by covid. The Nordic countries took different

approaches to managing the COVID pandemic (Irfan et al., 2022). Sweden generally had less strict restrictions than the other Nordic countries and did not introduce mandatory restrictions until December 2020. Finland, Norway and Denmark applied strict strategies early on including lockdowns and border controls. Iceland did not have a lockdown, but size restrictions on public gatherings and relied on a mass testing, contact tracing and quarantining strategy (Irfan et al., 2022). Throughout the pandemic restrictions changed and were lessened at times and increased at times, so consumption patterns may have fluctuated during this time.

The study is based on self-reported data which has limitations. Issues of biased under-reporting in consumption categories such as sweets, alcohol, medical emergencies, and various infrequent purchases are well known in expenditure and other surveys, so the total consumption reported may be less than the actual (Heinonen et al., 2013a, Steen-Olsen et al., 2016). Other sources of uncertainty in self-reported consumption and behavior data can include faulty sampling and recall bias (Min and Rao, 2018).The validity of self-reported data for pro-environmental behaviors can vary widely (Kormos and Gifford, 2014) and there has been some evidence that individuals may over report pro-environmental behaviors (Koller et al., 2023). The way the questions are asked may affect the under or over reporting of consumption, pro-climate behaviors, or attitudes toward climate change.

The internal validity includes how much of a cause and effect relationships exists, which with this research it is difficult to claim causation, however the correlation of variables can be seen. There are many factors which affect making a consumption choice. In this study, the climate motivation for engaging with some selected low-carbon consumption options could be observed, but not the myriad of other reasons that may go into making a consumption choice such as financial considerations, social norms, ethical reasons, habit, or availability of these options to the individual. The external validity considers the extend that the results can be generalized to other contexts. The sample used in this study was not representative of the Nordic population, however many of the analyses done in the study were comparing groups with in the sample who participated in a certain pro-climate action or had a low or high level or climate concern or motivation. Researchers have found that convenience samples can have varying impacts on the validity, replicability and generalization of results. (Goldberg et al., 2019). The generalization of these results should be done with caution and it should be considered if populations the results are being generalized to share the similar characteristics with the Nordic region such as affluence, low-income inequality, high wellbeing, decarbonized energy systems, geographic, and cultural similarities.

Overall, the validity of research adequate since it measured the intended phenomenon. Despite the limitations of the research, this study provides valuable insights to how residents of the Nordic countries can live climate compatible lifestyles.

5.2 Policy implications

Most national climate change strategies do not include the necessary mitigation measures related to personal consumption and lifestyles necessary to reduce emissions and focus rather on the supply-side with strategies that have a long-lag time and miss the opportunity to influence low-carbon lifestyles especially in the early stages of development (Salem et al.,

2021). Current demand-side policies often focus on the market to direct behavior change (while low-cost carbon intensive products are still on the market), and often focus on low-impact behaviors (Dubois et al., 2019) neglecting the most impactful options like diet and air-travel (Salem et al., 2021). The capacity to reject practices and institutions, which are incompatible with climate limits can be just as important as envisioning a climate sustainable future (Akenji et al., 2021). Policies should focus on lifestyle changes rather than only focusing on infrastructure and technology (Pang et al., 2020), since climate mitigation requires social change and not just technological changes (Wiedenhofer et al., 2018). When crafting policy it should be considered that climate compatible lifestyles must be facilitated by institutions, governments, infrastructure, and social norms- the responsibility cannot fall completely on the consumer (Akenji et al., 2021, Wiedenhofer et al., 2018). Systems focused options which are beyond consumer choices are also necessary, since if the option is not there then the individual cannot choose it, so behavior changes are limited in this scenario. CBCFs have not been widely utilized in policymaking, but researchers have made policy suggestions on how to incorporate consumption-based carbon footprints into policy making (Ottelin et al., 2019).

In this study, multiple low-carbon consumption options were necessary to reach the 1.5 degree compatible target, so policies that focus on a singular behavior will not make a big enough difference and should instead promote multiple pro-climate behaviors and involve multiple stakeholders (Gössling and Dolnicar, 2023) and consider the potential negative interactions of policies and the rebound effects that could occur from certain choices (Axsen et al., 2020). Transport policies need to not only increase public transport, active transport and low-carbon vehicle options, but also decrease transport demand (Montoya-Torres et al., 2023, Dillman et al., 2021). Policies should address the socially accepted and habituated behaviors of high meat consumption (Aasen et al., 2024) and frequent air travel (Aasen et al., 2023, Árnadóttir et al., 2021) by making the default options the most climate compatible ones instead of the least climate compatible (Akenji et al., 2021). Crafting policies which make the default or most affordable option the most climate-compatible could decrease the dependency of climate concerned individuals taking voluntary actions to reduce emissions and increase the equity in engaging with low-carbon consumption options.

Although, climate motivation was most highly correlated with some of the low-carbon consumption options that people are least willing to switch to, there are many factors that go into making consumption choices other than climate motivation. Tailoring messages to the different motivations of doing the various pro-climate actions as well as training the public to assess the quality of information (Vainio, 2019) and how to act on it (Schleich et al., 2024) is key to getting individuals engaged in low-carbon activities. Individuals often underestimate the amount of personal carbon footprint inequity that exists, especially among the affluent, which highlights the need to raise awareness of this problem to increase draw focus to social justice issues in climate policy (Nielsen et al., 2024). While promoting awareness is important and climate concern has an impact on CBCF, high climate concern and climate motivation alone will not lead to climate compatible lifestyles.

5.3 Future research

The results of this research could lead researchers in several different research directions. In this study, to see the effect of low-carbon consumption options on CBCFs, those who were

engaging with the low-carbon consumption options were compared to those that were not. An improvement to this study would be to do longitudinal studies to see the change in an individual's CBCF after switching to lower carbon options to see the reduction potential and check for rebounds. Additionally, it would be beneficial to see if these behavior changes remained constant over time since studies of reducing energy use or using a carbon footprint calculator have shown that the individual efforts to reduce emissions may decay over time even in individuals with high climate concern (Enlund et al., 2023).

Further research into the global impact of these low-carbon consumption choices happening in the Nordics is necessary to assess the potential social and environmental impacts other than climate change, such as biodiversity or land and water use changes, since often many of the impacts of these choices happen elsewhere in the world due to trade. Determining how these low-carbon choices interact with each other is another key factor to research to determine the synergies and conflicts that may exist with different options.

Although climate motivation was a strong driver of engagement in pro-climate actions, there was no other information available from the survey about other reasons why an individual might be engaging with a low-carbon consumption option. A future study could include some of the known strong drivers of consumption choices along with climate motivation and participant could rank these potential motivations to see how climate motivation compares to other motivations for pro-climate actions.

Since many factors affect CBCFs and decisions about consumption choices are complex, in-depth interviews with those who have climate compatible CBCFs would be beneficial to identify key factors which are enabling them to live climate compatible lifestyles that may not have been revealed through the survey questions. In-depth interviews could also reveal the impact that climate compatible lifestyles and how the various low-carbon consumption options have on wellbeing since an important aspect of 1.5 degree compatible lifestyles is that there is a fair consumption space where societies and individuals achieve a good standard of wellbeing (Akenji et al., 2021).

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Articles 1-5

Article 1 (A1)

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Article 2 (A2)

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Article 5 (A5)

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