LAPPEENRANTA-LAHTI UNIVERSITY OF TECHNOLOGY LUT
School of Energy Systems
Department of Environmental Technology
Sustainability Science and Solutions
Master's Thesis 2020

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ANALYZING THE POTENTIAL AND THE LIMITATIONS OF PERSONAL CHOICES AND SOCIETAL ACTIONS IN THE REDUCTION OF CARBON FOOTPRINT OF AN AVERAGE FINNISH CITIZEN

Examiners: Assistant Professor, D.Sc. (Tech) Ville Uusitalo
Assistant Professor, D.Soc.Sc. Jarkko Levänen

ABSTRACT

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Analyzing the potential and the limitations of personal choices and societal actions in the reduction of carbon footprint of an average Finnish citizen

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Keywords: lifestyle carbon footprint, consumption, emission reduction, personal choices, societal actions

In Finland, almost 70% of consumption-based GHG emissions are related to household consumption. Emissions caused by household consumption can be evaluated by lifestyle carbon footprint which determines GHG emissions of an average citizen and considers direct and indirect emissions caused by consumption. Individuals have been studied to find possibilities to reduce their own lifestyle carbon footprint, but it can also be affected by societal restrictions or changes. The objective of this study was to find out what is the role of an individual's consumption choices and societal actions in terms of reducing an average Finnish lifestyle carbon footprint. Lifestyle domains included in the empirical part of the study were housing, mobility and nutrition. Based on the literature review and estimations about carbon footprint reduction potentials the emission reduction potential of personal choices related to lifestyle carbon footprint is slightly greater than the potential of societal actions. Actions are still needed from society as well since the implementation possibilities of some emission reduction actions are restricted by infrastructure or other factors. The reduction of lifestyle carbon footprint cannot only be based on technological development and actions made by societal players, but only the personal choices are not enough either. Both are needed.

TIIVISTELMÄ

Lappeenrannan-Lahden teknillinen yliopisto LUT
School of Energy Systems
Ympäristötekniikan koulutusohjelma
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Oona Saarinen

Yksilön valintojen ja yhteiskunnallisten toimien mahdollisuuksien ja rajoitteiden tarkastelu keskivertosuomalaisen hiilijalanjäljen pienentämisessä

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Kotitalouksien kulutuksesta aiheutuvat kasvihuonekaasupäästöt kattavat lähes 70% Suomen kulutusperusteisista päästöistä. Kotitalouksien kulutuksesta johtuvien päästöjen arvioimiseksi voidaan tutkia elämäntavan hiilijalanjälkeä, joka kertoo keskivertokansalaisen kasvihuonekaasupäästöt, huomioiden kulutuksesta aiheutuvat suorat ja epäsuorat päästöt. Yksilöllä on mahdollisuus tehdä toimia hiilijalanjäljen pienentämiseksi, mutta siihen voi vaikuttaa myös yhteiskunnalliset rajoitteet ja muutokset. Tämän työn tavoitteena oli selvittää, mikä on yksilön kulutusvalintojen ja yhteiskunnallisten toimien rooli keskivertosuomalaisen elämäntavan hiilijalanjäljen pienentämisessä. Empiriaosassa tarkastellut elämäntavan osa-alueet olivat asuminen, liikkuminen ja ravinto. Kirjallisuusselvityksen ja päästövähennyspotentiaaleista tehtyjen arvioiden perusteella elämäntavan hiilijalanjälkeen liittyvä yksilön valintojen päästövähennyspotentiaali arvioitiin olevan hieman suurempi kuin yhteiskunnallisten toimien potentiaali. Toimia tarvitaan silti myös yhteiskunnalta, sillä osa päästövähennystoimien toteutusmahdollisuuksista on rajoittunut infrastruktuuriin tai muihin tekijöihin. Hiilijalanjäljen pienentämisessä ei voida nojata pelkästään järjestelmien ja infran muutoksiin tai teknologiseen kehitykseen mutta ei myöskään pelkästään yksilön valintoihin.

ALKUSANAT

Tämän työn kirjoittaminen on ollut kiinnostava ja opettavainen matka. Olen mielettömän kiitollinen kaikille, jotka ovat tässä matkassa auttaneet. Haluan kiittää erityisesti tarkastajiani Ville Uusitaloa ja Jarkko Levästä mielenkiintoisesta ja ajankohtaisesta aihe-ehdotuksesta sekä kommenteista ja ohjauksesta työhön liittyen. Niistä on ollut valtava apua.

Haluan myös kiittää perhettäni ja ystäviäni kaikesta tuesta sekä tämän työn kirjoitusprosessin että koko opiskelujeni ajan. Korvaamattoman tuen ovat antaneet oman vuosikurssini ystävät, Hyypän kaverit, joita ilman tuskin olisin selvinnyt opinnoista tai saanut opiskelijaelämästä irti niin valtavan paljon. Olette kultaa.

Tämän työn myötä saan päätökseen myös opintoni LUT:ssa, joka on ollut mahtava paikka opiskella ja oppia. Olen nauttinut täysillä ajastani Lappeenrannassa ja olen kiitollinen saadessani valmistua juuri LUT-yliopistosta.

Helsingissä 25. toukokuuta 2020

Oona Saarinen

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LIST OF ABBREVIATIONS

BSI	British Standards Institution
CF	Carbon Footprint
COICOP	the Classification of Individual Consumption According to Purpose
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
EU	European Union
GHG	Greenhouse gas
GDP	Gross Domestic Product
GTAP	the Global Trade Analysis Project
GWP	Global Warming Potential
HE	Hallituksen esitys (governmental proposal)
ICAO	International Civil Aviation Organization
IGES	Institute for Global Environmental Strategies
IPCC	International Panel on Climate Change
ISO	International Organization for Standardization
LCA	Life Cycle Assessment
MEAE	Ministry of Economic Affairs and Employment
ME	Ministry of the Environment
MRIO	multi-region input-output
PAS	Publicly Available Specification
Sitra	The Finnish Innovation Fund Sitra
UNFCCC	United Nations Framework Convention on Climate Change
WIOD	World Input Output Database

1 INTRODUCTION

Environmental impacts of consumption have started to get more attention in both international and national level and it has been noticed to have important role in greenhouse gas (GHG) emission reduction (IPCC 2018, 95; Ministry of the Environment (ME) 2017). The present GHG emission reduction goals have been set mostly in production-based, also called territorial-based, for example, in national level. However, production-based accounting does not give understanding on how much lifestyle and consumption of certain regions residents can cause emissions since it does not take into account export or import (Salo et al. 2016, 44). In Finland consumption-based emissions are bigger than production-based emissions, which means that part of emissions caused by consumption are produced outside Finland (Ritchie & Roser. 2019). Approximately 66% of consumption-based GHG emissions in Finland are related to household consumption (Nissinen & Savolainen 2019, 19).

Consumption is closely related to society and existing systems, such as infrastructure, in which case existing infrastructure can set limitations to consumption choices and societal changes, and influence on consumption and emissions caused by consumption. Consumption choices have been found to potentially be influenced, for example, by policy instruments such as energy pricing, building regulations, transport infrastructure and information guidance (Salo et al. 2016, 45; Nissinen et al. 2012, 47-48).

In this report the relationship of consumption and society is reviewed using lifestyle carbon footprint. Carbon footprint is a tool to determine lifecycle greenhouse gas emissions, usually calculated using lifecycle assessment or input-output analysis (Krey et al. 2014, 1297-1299). Carbon footprinting can be used to determine GHG emissions of products, organizations, nations, groups of societies or households and it is used for climate change mitigation research (Krey et al. 2014, 1297-1299). This report focuses on lifestyle carbon footprint which is close to carbon footprint of households. Lifestyle carbon footprint determines GHG emissions of an average citizen, in this case an average Finn, and it considers direct and indirect emissions caused by energy use and consumption of goods and services. Sustainability of lifestyle could also be studied, for example, by ecological footprint or material footprint but in this report the chosen application is carbon footprint, because of its close connection to GHG emissions and climate change mitigation.

1.1 Background

Human-induced global warming was assessed to have reached 1°C in 2017 compared to pre-industrial level and warming was estimated to continue at a rate of 0.2°C per decade with the current lifestyle and the emission mitigation plans. Changed global climate has already caused multiple impacts on natural ecosystems and human systems. Climate systems have changed, climate and weather extremes have increased, and natural ecosystems have experienced vast changes. Limiting global warming to 1.5°C is expected to limit impacts and projected risks on a several regions, as well as on a global scale, compared to effects of 2°C global warming. (IPCC 2018, 51, 177-178.) The latest report of Intergovernmental Panel on Climate Change (IPCC) adjusted the lowest possible level of global warming to have huge benefits. The scale of ocean and cryosphere changes can be limited and societies and ecosystems that depend on them can be protected by reducing greenhouse gas emissions urgently. (IPCC 2019, 1-4.)

The level of global warming in the future will depend on emission reduction actions since past emissions alone are likely to warm climate less than 1.5°C above pre-industrial level (IPCC 2018, 51). Limiting global warming up to 1.5°C, reducing risks and impacts of climate change and aiming to strengthen the global response to the threat of climate change, the Paris Agreement was created in 2015 by United Nations Framework Convention on Climate Change (UNFCCC). Parties to the Paris Agreement committed to keep the global warming well below 2°C above pre-industrial level and pursue efforts to limit warming to 1.5°C above pre-industrial level. (UNFCCC 2015, 3.)

GHG emissions over the next decades have a critical role in keeping global warming under 1.5°C. Scientists have identified pathways consistent with 1.5°C warming but achievement of those pathways depends highly on global cooperation, energy and land transformation and changes in consumption. (IPCC 2018, 51.) Responsible production and consumption are also one of the United Nations 17 goals for sustainable development, and the importance of sustainable lifestyle and sustainable patterns of consumption and production with developed countries were mentioned as well in Paris Agreement (IPCC 2018, 95, 450; UNFCCC 2015, 2). Thus, the role of lifestyle and consumption habits in climate change mitigation is acknowledged.

Total carbon budget is an estimation of the cumulative net global anthropogenic carbon dioxide (CO_2) emissions that can be emitted whilst limiting global warming to some level, for example, to 1.5°C, at some probability. Sharing the global carbon budget among countries involves equity question related to national circumstances and socio-economic factors and it can be divided between nations in different ways (Romanovskaya & Federici 2019). Currently there are large global inequalities in consumption and CO_2 emissions (Ritchie & Roser. 2019). When reviewing emissions from the perspective of consumption and lifestyle, carbon budget can be regarded with the concept called "contraction and convergence" along which emissions calculated for every country's individuals should be decreased in the way that emissions per person would be same at the end (IGES et al. 2019, 1-2). Despite the view of sharing the global carbon budget, it is clear that the lifestyle in developed countries like Finland is not on sustainable base and consumption patterns need to be changed to achieve carbon neutrality and climate targets (IGES et al. 2019; Ritchie & Roser. 2019). According to the report "1.5-degree lifestyles" (IGES et al. 2019), lifestyle carbon footprints in developed countries need to be reduced by 80–93% by 2050 to reach long-term carbon footprint targets which were set in that report along with the concept of "contraction and convergence" and Paris Agreement targets.

Energy use and emissions caused by consumption are significantly influenced by behavior, lifestyle and culture and therefore lowering consumption and consumption-based emissions by changing behavior and lifestyle have a high mitigation potential (Schanes et al. 2016, 1033). Finnish lifestyle carbon footprint has been researched lately in reports "Carbon footprint and raw material requirement of public procurement and household consumption in Finland" by Finnish Environment Institute (Nissinen & Savolainen 2019) and "1.5-degree lifestyles: Targets and Options for Reducing Lifestyle Carbon Footprints" (later 1.5-degree lifestyles) by Institute for Global Environmental Strategies, Aalto University and D-mat ltd (IGES et al. 2019). Later mentioned report also assessed potential actions for low-carbon lifestyle and the impact of such actions for reducing lifestyle carbon footprint (IGES et al.

2019). One aspect that the report did not consider, is the influence of society and infrastructure on individuals decision making and actions towards low carbon lifestyle.

The role of consumers is recognized in generating and changing everyday practices towards sustainability, but consumers' practices are shaped by understandings, meanings, infrastructures and sociotechnical systems and they are embedded in current structures, physical environments and existing networks. Governance and political contexts, social norms and culture and infrastructure are steering lifestyle choices and limiting individual's ability to do independent decisions. For example, existing systems related to household energy consumption and transport are limiting consumers' possibilities to reduce emissions in those areas. (Shove & Walker 2010, 476; Gotts 2009, 1) The most effective GHG emission reduction will need structural changes but changes from producers, governments and final consumers as well (Schanes et al. 2016, 1035).

Consumption habits locked in existing systems, decrease individual's possibilities to make better choices, but it also means that consumption can be affected via regulations, guidance and system changes (Salo et al. 2016, 45; Nissinen et al. 2012, 47-48). In this report weight is on infrastructure, sociotechnical systems and political context and their effect on lifestyle choices. Individuals have the possibility to choose what kind of food they buy, so it is easier to change their diet towards a low carbon diet but the energy form of a household can be set by infrastructure or low carbon transport options and it may be hard to put into action because of the urban structure or availability of public transport (IGES et al. 2019; Salo et al. 2016b, 202). At the same time, for example, changes in national energy system or building regulations can cause effects on consumption and therefore also the lifestyle carbon footprint (Nissinen et al. 2012, 47-48).

The connection of GHG emission mitigation and consumption has gotten more attention in Finnish policy making, and household consumption is part of Finnish Energy and Climate Strategy as well as government's Medium-Term Climate Change Plan to 2030 (Ministry of Economic Affairs and Employment (MEAE) 2017; ME 2017). Those reports mention the role of consumption habits in national GHG emission reduction but also recognize the influence of societal systems on consumption choices. Many structural aspects are behind the consumer choices. (MEAE 2017, 53-54; ME 2017, 98-101.) This also means that the consumption-based GHG emissions can be reduced by influencing consumer behavior and consumption by policy instruments such as energy and fuel pricing, building and renovation regulations, transport infrastructure, traffic pricing and information guidance (Salo et al. 2016, 45; Nissinen et al. 2012, 47-48). However, consumers have a significant potential to influence GHG emissions through altered behavior (Schanes et al. 2016, 1041).

1.2 Objective and Scope

This study focuses on lifestyle carbon footprint of an average Finnish citizen and its relationship to society. The study uses consumption-based view instead of production-based view. The data, that is used as a basis of this study, about the current lifestyle carbon footprint of Finns, is from the report "1.5-degree lifestyles" (IGES et al. 2019). In that study estimations about the Finnish lifestyle carbon footprint are based on households' quantitative consumption. Lifestyle carbon footprint is defined as a carbon footprint of an average citizen including direct emissions from fuel consumption and indirect emissions embodied in products and services used in households. The carbon footprint considers also other greenhouse gases, not only carbon dioxide emissions. (IGES et al. 2019, 2-3.) Lifestyle domains covered in the empirical part of this study are housing, mobility and nutrition which are the biggest three lifestyle domains in Finnish lifestyle carbon footprint.

So that the lifestyle carbon footprint of Finnish would be on sustainable level, it should be reduced significantly. Individuals influence their lifestyle carbon footprint by making certain lifestyle choices, but these decisions are more or less shaped by society. Influenced factors of lifestyle are determined to be motivations, drivers and determinants (Akenji & Chen 2016, 15). Drivers include personal situation, external socio-technical systems and physical and natural boundaries. Determinants refer to attitudes, facilitators and infrastructure. (Akenji & Chen 2016, 15, 19.) In this study the focus is especially on infrastructure and some socio-technical conditions which have been noticed to easily limit and steer individuals' lifestyle choices. The whole framework about influencing factors of lifestyle are discussed more in detail later.

Individuals have studied to have a lot of possibilities to reduce their own lifestyle carbon footprint, but some of the lifestyle choices are shaped by existing systems and may not be affected by the individual itself. In addition, changes in societal systems can cause influence on lifestyle carbon footprint without any individual's action. The role of these societal restrictions and changes are not much researched, especially not in studies related to the reduction of carbon footprint of Finnish citizens. According to this knowledge, the objective of this study is: What is the role of an individual's consumption choices and societal actions in terms of reducing an average Finn's lifestyle carbon footprint.

The study analyzes the potential and the limitations of personal choices and societal actions in reducing the Finnish lifestyle carbon footprint. It is based on literature research and estimations about the GHG emission reduction potentials of certain lifestyle choices and actions in society. The examination is done by observing an individual's possibilities to implement emission reduction actions presented in literature and searching for potential societal changes that are influencing an individual's lifestyle carbon footprint. The study aims to recognize the role of personal choices and the societal actions in different lifestyle domains.

To figure out the carbon footprint reduction potential of personal choices and societal actions an estimation is made about the emission reduction potential of a few chosen actions. Chosen actions do not represent the total potential of personal choices or societal changes but they are supposed to represent the role of personal choices and society by way of examples. Estimations about the emission reduction potential of certain personal and societal changes consider the potential of changes achievable by 2030.

2 LIFESTYLE CARBON FOOTPRINT

Carbon footprint, also called GHG inventory, is a tool to calculate GHG emissions of products, organizations, countries, regions and households, and to assess their global warming potential by using life cycle assessment or input-output analysis (Krey et al. 2014, 1297-1299). Global warming potential describes the radiative forcing impact of GHG emissions represented as an equivalent unit of carbon dioxide over time (PAS 2070:2013, 4). The aim of carbon footprinting, that is based on life cycle assessment, is to calculate significant GHG emissions and removals caused over the product's life cycle (ISO 14067:2018, 14). Carbon footprint estimated according to environmentally extended input-output analysis is based on combination of financial flow data from regional economic statements and environmental account data (PAS 2070:2013, 4).

Product carbon footprint is a sum of GHG emissions produced through a product's life cycle from the raw material extraction to the end-of-life stages. First international standard of carbon footprint was Product Life Cycle Accounting and Reporting Standard, published in 2012 by Greenhouse Gas Protocol. This standard is based on a bit earlier published PAS 2050, Publicly Available Specification (PAS) for the assessment of the life cycle greenhouse gas emissions of goods and services, and life cycle assessment (LCA) standards 14040 and 14044 published by International Organization for Standardization (ISO). (GHG Protocol 2011, 21). In 2013 ISO published its own standard for carbon footprint of products, ISO 14067 (ISO 14067:2018), which was updated in 2018. Both of these standards provide principles and guidelines for the quantification of GHG emissions for products, goods and services. (GHG Protocol 2011; ISO 14067:2018.)

The standard of GHG Protocol and ISO 14067 connects product carbon footprint closely to LCA even though GHG Protocol also uses input-output analysis as a consequential approach (GHG Protocol 2011, 22; ISO 14067:2018). If the purpose is to determine carbon footprint for households, organizations, nations or regional entities, the common type for modelling is input-output analysis. Input-output analysis is more suitable when assessing GHG emissions associated with final consumption, since it redistributes emissions caused by production to final consumption. Multiregional input-output models have been seen as tools to quantify the role of consumption and to provide regional analysis for public institutions and companies to set mitigation efforts. Multiregional view is necessary for the growth of globally sourced production to advocate national production patterns and technologies and to quantify the amount of total CO_2 emissions embodied in the international trade. That kind of models can provide estimations of emissions associated with different consumption categories such as mobility, nutrition and consumer goods. (Krey et al. 2014, 1297-1298).

When assessing carbon footprint of organizations, for example, ISO 14064-1 can be used (ISO 14064-1:2018) as well as A Corporate Accounting and Reporting Standard of GHG Protocol (GHG Protocol 2004). A well-managed and implemented organizational carbon footprint serves a possibility to manage GHG risks and see reduction opportunities, report publicly, participate in GHG programs, mandatory reporting programs and GHG markets and recognize early voluntary action (GHG Protocol 2004).

National GHG inventory analysis can be done, for example, according to IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006) or The UNFCCC Annex 1 inventory review guidelines which require each United Nations Annex 1 Party to do individual inventory annually. GHG emissions of cities or other communities can be evaluated, for example, according to PAS 2070 (PAS 2070:2013), Global Protocol for Community-Scale Greenhouse Gas Emission Inventories by GHG Protocol (GHG Protocol 2014) or Consumption-based GHG Inventory of C40 cities (C40 Cities 2011). Carbon footprint of nations and cities considers emissions caused in certain geographic area and can be divided into sectors such as stationary energy, industrial processes and product use, transportation, waste, agriculture and forestry and other land use (GHG Protocol 2014, 10).

Community-scale GHG emissions can be categorized into three scopes based on where they occur, which helps to differentiate physical emissions occurring inside and outside of the community and grids which may cross regional boundaries. Scope 1 considers GHG emissions caused by sources located within the community boundary. GHG emissions from the consumption of grid-supplied electricity, heat, steam and cooling are categorized in scope 2. Scope 3 is for significant GHG emissions occurring outside the community boundaries as a result of activities happened within the community boundary. (GHG protocol 2014, 11; C40 Cities 2018, 3).

Similar approach can be used as a base of lifestyle carbon footprint that can be thought to be the household version of carbon footprint of organizations or the part of household consumption in carbon footprint of nations or cities (IGES et al. 2019, 3). Lifestyle carbon footprint is closely related to consumption which is why it is usually reviewed with consumption-based view and according to input-output analysis. In Finland household-based GHG emissions have been assessed, for example, according to ENVIMAT-model (Nissinen & Savolainen 2019). In addition to these earlier mentioned standards and guidelines, also other companies and institutions have published tools and instructions for carbon footprinting. However, it is important to remember that every carbon footprint considers only GHG emissions, not any other environmental or social impacts, and is created mainly for global warming mitigation.

2.1 Identification of greenhouse gases and units

Carbon footprint usually includes all emissions and removals from biogenic sources, non-biogenic sources and land-use change impacts caused within inventory boundaries. The assessment is usually done considering GHG emissions regulated under the Kyoto Protocol. Carbon footprint shall include emissions of the following GHGs: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulfur hexafluoride (SF_6), perfluorocarbons (PFCs), and hydrofluorocarbons (HFCs). Additional GHGs whose GWP values have been identified by the IPCC and that are emitted within inventory boundaries can also be accounted but those must be presented in the assessment report to improve transparency. (GHG Protocol 2011, 27, 85; PAS 2070:2013, 6.)

Carbon footprint accounting shall exclude direct GHG removals from the atmosphere. Those removals are typically caused by the sequestration in the soil and vegetation. Especially in LCA based GHG accounting, removals may also occur when production is using atmospheric CO_2, when a product use absorbs CO_2 from the atmosphere or when CO_2 removal occurs in any life cycle stage of the product. (GHG Protocol 2011, 27; PAS 2070:2013, 6.)

Total amount of GHG emissions in carbon footprint assessment is reported as CO_2 equivalents (CO_2e) per functional unit. To get CO_2 equivalents, emissions and removals shall be multiplied by respective global warming potential factors which are used to force impacts of GHGs in a comparable way. The most used global warming potential values (GWP values) by programs and policies, identified by the IPCC, are provided for 100 years and those values are also the most used in carbon footprint analysis. (GHG Protocol 2011, 85; PAS 2070:2013, 6.) When assessing carbon footprint according to input-output analysis, data is often expressed in t CO_2e/year, t CO_2e/capita/year or t CO_2e/GDP to provide benchmarkable results. (PAS 2070:2013, 6.)

2.2 Calculating lifestyle carbon footprint

Lifestyle is a social print of how people live, and it is formed by choices individuals make on their daily activities and ways of living. From a sustainable view lifestyle has an impact on the environment and it defines our footprint. This footprint causes a responsibility to keep our planet safe and livable for future generations and to further better human society. From the point of view of the planetary boundaries, it would be good to look at the overall impact of the lifestyle on the environment, from multiple perspectives not only the climate perspective. Approaches for defining boundaries for lifestyle are, for instance, environmental space concept, ecological footprint, environmental footprint and material footprint. (Akenji & Chen, 2; IGES et al. 2019, 2.) In this study focus is still on the climate since climate change is described to be one of the biggest threats human society has faced. Because of this view, effects caused by lifestyle are reviewed by the carbon footprint instead of any other footprint or concept.

2.2.1 Consumption-based approach

Household consumption practices cause direct and indirect emissions, of which the role of indirect emissions is significant in developed countries. Indirect emissions are embodied in products and occur in different parts of the supply chain and life cycle of products. Those embodied emissions have an important role determining the carbon footprint of households (also lifestyle) and have remarkable potential for climate change mitigation. (Schanes, K et al. 2016, 1035.) Both, direct and indirect GHG emission for goods and services consumed by households are possible to be captured by consumption-based approach. Consumption-based view focuses on economic final consumption and allocates GHG emissions of goods and services to final consumers instead of original producers. (PAS 2070:2013, 19.)

Production-based GHG accounting is a much-used and approved by countries to report national GHG emissions, but it does not consider the emissions embodied in international trade, only the direct emissions from domestic production. When evaluating GHG emissions via geographical or production-based accounting, the direct import of goods from high carbon intensity countries with lower production costs and environmental commitments may be promoted. This kind of accounting leads to the situation where a country with an economy supported highly by export has more direct emissions in relation to final consumption compared to an importing country. In other words, this accounting allocates lower amount of emissions to importing countries than are actually produced by the consumption of residents and it might distort mitigation potential and requisite efforts. (Caro et al. 2017, 142-143, 146) Finland is a net-importer country, which means more goods are imported than exported and part of emissions caused by consumption is produced outside of Finland (Ritchie & Roser. 2019).

Consumption-based inventories include GHG emissions resulted from fuels, electricity, goods and services consumed by households in certain area. That approach includes GHG emissions from imported goods and services that are consumed by the residents of the inventory boundaries and excludes GHG emissions from exported ones. (C40 Cities 2018, 4.) Consumption-based inventory, which evaluates the responsibility of final consumption, is recommended to do using an environmentally extended input-output analysis. This appropriate and consistent top-down method estimates GHG emissions based on economic final expenditures combined with emission intensity data. (Caro et al. 2017, 143; PAS 2070:2013, 19.). In consumption-based accounting, GHG emissions are most likely reported by consumption category instead of emission source category (C40 Cities 2018, 4).

2.2.2 Environmentally extended input-output model

Consumption-based approach is recommended to be combined with environmentally extended input-output model, which uses top-down method. It combines national or regional financial expenditure by households, sometimes also government and business capital, with environmental account data which reflects to average GHG emission factors (carbon intensity value) of each consumption domain or product. Another way to determine lifestyle carbon footprint is to use bottom-up approach that use households' quantitative consumption. (PAS2070:2013, 19-20; C40 Cities 2018, 7.) These approaches require the collection of national consumption data for each consumption domain covered in the assessment and carbon intensity factors of goods, services and activities. Carbon footprint for each product and service can be calculated by multiplying the amount of consumption of each item by the carbon intensity factor. Calculated carbon footprints of items shall be summed up to get carbon footprints of components and components are summed up again to get domains. (IGES et al. 2019, 12.) An example for lifestyle carbon footprint evaluation is presented in the figure 1. The example refers to the lifestyle carbon footprint estimation which was used as a basis for this study and in the later examinations.

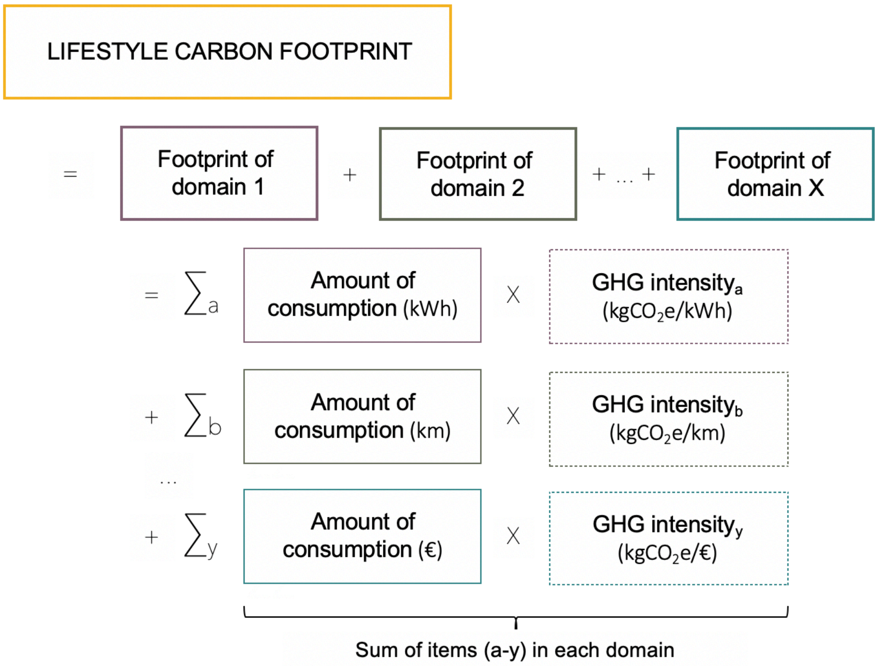

Figure 1 A simplified example of the lifestyle carbon footprint calculation that combines bottom-up and top-down approaches using example units (IGES et al. 2019).

Discussing the multi-regional environmentally extended input-output model, the assessment shall disaggregate emissions for regionally produced goods and services and imported ones, since the value of emission factor depends on the production location of goods and services. (PAS2070:2013, 19-20; C40 Cities 2018, 7.) Emission factor reflects on the emission intensity or carbon intensity of product and service determining the mass of emissions emitted in relation to the quantity or the financial expenditure of a product or a service (PAS2070:2013, 4). Global databases for carbon intensity data are, for example, The Global Trade Analysis Project multi-region input-output (GTAP-MRIO) database, World Input-Output Database (WIOD) and Ecoinvent database (Arto et al. 2014; IGES et al. 2019, 13)

Different categories are used to classify goods and services by two reporting frameworks called the Classification of Individual Consumption According to Purpose (COICOP) and the Global Trade Analysis Project (GTAP). The first one, COICOP, breaks results into 12 sector categories and the second one, GTAP, uses 57 household consumption categories. Category data can be combined with bottom-up assessments of each consumption domain for achieving more comprehensive results. Bottom-up assessments like life cycle assessment can enable more granular data of individual consumption category. (C40 Cities 2018, 11, 16.)

Even though consumption-based accounting, done by environmentally extended input-output analysis, has proved to provide several advantages, it is not widely used in national GHG emission reporting. Multi regional input-output models need a large amount of data beyond what is already available in national level since they use specific emission intensity data for each domain within national or regional economies. This data may also not be available for sufficiently long, continuous and updated time frames. At the end, this kind of accounting would lead to massive changes in the current GHG inventory methodology. (Caro et al. 2017, 143)

2.3 Boundaries of lifestyle carbon footprint

PAS 2070, which is created to evaluate carbon footprint of cities, uses consumption-based approach and covers GHG emissions caused by energy use in households and vehicles used by residents, and GHG emissions embodied in goods and services consumed by the residents, excluding GHG emissions associated with visitor activities and products exported from the city (C40 Cities 2018, 6). Lifestyle carbon footprint is like a household version of this. It is defined to be caused by GHG emissions directly emitted from households, such as a result of energy use, and indirectly resulted from all kind of household consumption.

Household consumption can happen inside or outside the nation boundaries and it is related to the residents' choices and actions from selection of products and services to their end-of-life. In addition to direct emissions of consumption, lifestyle carbon footprint considers embedded emissions resulting from the production and transportation induced by final demand of households but doesn't consider emissions caused by public consumption or capital investments. (IGES et al. 2019, 11.) Lifestyle carbon footprint boundaries are presented in the figure 2. That kind of view lets us get the overall picture of household emissions by focusing on the lifestyle.

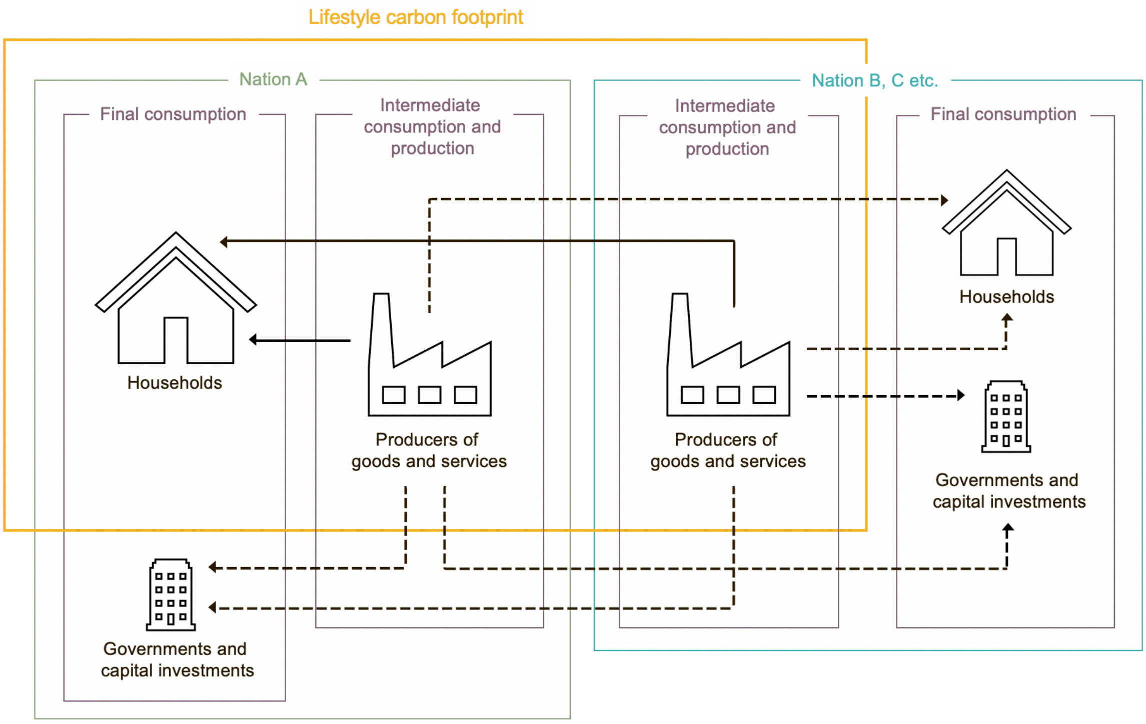

Figure 2 Boundaries of lifestyle carbon footprint. In the picture, production of goods and services include all kind of production including also, for example, energy and fuel production. (IGES et al. 2019, 11)

Assessing the lifestyle carbon footprint, final consumption is divided into key lifestyle domains that are identified to have the highest environmental impacts. Those are nutrition, housing, mobility, consumer goods, leisure and sometimes also services. (IGES et al. 2019; Akenji & Chen 2016, 5.) Nutrition, also presented as a food, includes the food we eat and drink, and its environmental impacts are linked to food production, processing and providing as well as food disposal. Choices around nutrition are connected to health, convenience, freshness, presentation and cost. Environmental impacts of housing consist of how and where we live including construction, heating and cooling of living spaces and use of water and electricity. Decisions related to housing are based on objective and subjective factors such as size and facilities of the building, aesthetics, neighborhood, available amenities, commuting distances and cost. The domain of mobility, or transportation, is made up of the form, amount and distance of transport including also impacts from supporting systems and infrastructure. Impacts of mobility are also affected by number of people traveling in the same vehicle, technology and energy efficiency and fuel type. Decisions related to mobility are based on access, time efficiency, convenience, cost, safety, cleanliness and aesthetics. (Akenji & Chen 2016, 5-8.)

The domain of consumer goods includes, for example, clothes, shoes, personal care products, jewelries, furniture, electronic devices and office supplies. Environmental impacts of consumer goods are related to materials used in producing products, type and quantity of them as well as the length of the lifecycle and the ways of using it. Leisure activities reflect different amounts of material consumption and social interactions. The contribution of leisure time to the environment depends on how people spend their leisure time and the choice of facilities, activities and tourism destinations. Services can be included in the domain of leisure or reviewed separately. (Akenji & Chen 2016, 9.) Lifestyle carbon footprint is therefore resulted in many parts from individual choices, but they are also affected by present day systems.

2.3.1 Motivations and drivers of lifestyle

Lifestyle choices and consumer practices are shaped by culture, norms, physical environments, political structures and existing infrastructure. This kind of societal systems can limit an individual's possibility to make independent decisions but also steer lifestyle choices. (Shove & Walker 2010, 476; Gotts 2009, 1.) In a deeper level lifestyle is actually affected by interlinked underlying lifestyle factors that are motivations, drivers and determinants (Akenji & Chen 2016, 15). Motivations are linked to certain actions and decision-making that people do according to their personal and social reasons and understanding. Drivers are a framework for aspects supporting motivation, making it practical and normalizing it. Key determinants, that are attitudes, facilitators and infrastructure, have possibly the biggest effect on lifestyle since they refer on the possibility to make certain lifestyle choices and consumer actions. (Akenji & Chen 2016, 15.)

Driving factors of lifestyle are inter-linked and may be contradictory behind the lifestyle. Drivers reflect personal situations including income, identity, values and education. Personal situation is formed under external socio-technical and economic conditions. Socio-technical system as well as an individual's needs and wants are allowed and constrained within physical and natural boundaries to stay within sustainable limits. These influencing factors are presented in overlapping layers, as in figure 3. These factors vary from the personal situation and decisions to wider external social and technical conditions and world scale ecological boundaries. Thus, the lifestyle is not only defined within the behavioral factor but also situational factors. (Akenji & Chen 2016, 18.)

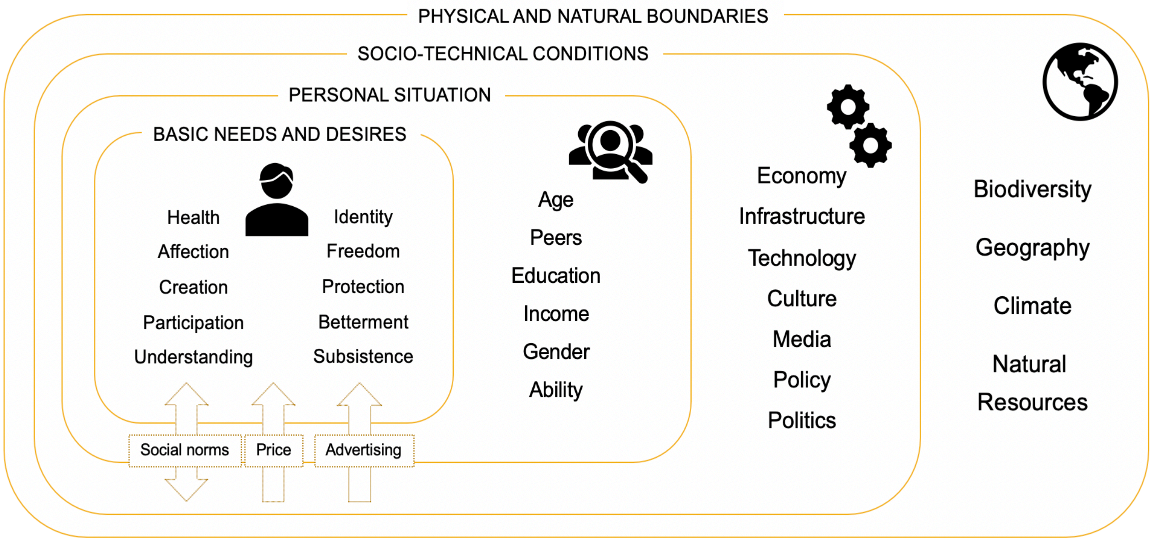

Figure 3 The driving factors of lifestyle presented in overlapping layers (Akenji & Chen 2016, 19).

The base of consumption is made up of people's need to meet basic needs necessary for life such as nutrition, health, housing and transportation to work for instance. Basic needs and desires may be difficult to determine since they evolve along the societal changes, when the society becomes more complex and affluent. In addition to consumption done by the reason to meet basic needs, people consume in different reasons to fulfill social functions to satisfy personal preferences, due to the marketing and due to lack of choices. (Akenji & Chen 2016, 13, 17.) The need to fulfill basic needs affects the reduction of carbon footprint since the ability to reduce the footprint is limited to basic needs. Fulfilling basic needs sets a framework for carbon footprint targets and need to be considered in the proportion where different lifestyle domains can be decreased. (Akenji & Chen 2016, 17; IGES et al. 2019b, 23.)

Especially socio-technical systems might easily lock into existing technologies and legislative structures and models and therefore, they can limit individual options. For example, the media has a strong influence on our values, social norms and lifestyle choices and it has an ability to spread and accelerate norms related to consumerism. Media and advertising can promote consumerism but with increasing exposure, the media also has a big potential to shape consumer preferences in a positive way. As social beings, humans are identifying themselves with groups, and they feel the pressure to fit in existing cultures and social norms and engage in same activities as others. The human behavior is much influenced by other human beings such as family, colleagues and social practices but some people also have a need to differentiate themselves and be unique. (Akenji & Chen 2016, 20.)

Policies and institutional frameworks are another powerful influencer on lifestyle directions. Policy instruments have the possibility to shift consumption patterns entirely since they can change market options, make less sustainable options unprofitable, promote more sustainable options and enable innovations by creating platforms for them. Policies and institutional frameworks have a significant role in wider context, having the possibility to change the law or improve public procurement processes for big projects incorporating sustainability issues in design. (Akenji & Chen 2016, 21.)

Infrastructure refers to buildings, water and sewage systems, waste management, energy and electricity systems, telecommunication networks and public transportation. These kinds of infrastructural systems tend to lock people into certain usage patterns and they also typically have a long lifecycle so designing them well at the beginning has an important role. Technology has a major influence on today's lifestyle, and it has changed the ways of doing things, for instance, by supporting products, creating new systems of provisions, improving infrastructures and modifying social practices. Uptake and use of technology are influenced by features like complexity, resource efficiency and cost. At the same time, when technology has enabled the raise of living standards, it is caused unsustainable production practices and consumption habits resulting the higher consumption of natural resources. (Akenji & Chen 2016, 20.)

The ability to use technology or buy any product is determined by prices. Higher price of a product or a service can easily make more sustainable alternatives less competitive compared to less sustainable options. On the other hand, higher income level will make people less predisposed for price variations and, for example, organic and fair-trade products with higher price became more accessible. (Akenji & Chen 2016, 20.) A Finnish research about the carbon footprint of Finnish households reviewed the influence of income level to consumption. As it can be assumed the carbon footprint increased when the income level increased. In more affluent income levels consumers pay higher prices for products and services but the amount they consume increases as well. Carbon footprint of nutrition and housing was two times bigger in the highest income decile compared to the lowest decile (in the ten-decile table). Emissions of mobility were almost four times bigger and emissions of consumer goods and services more than three times bigger between the lowest and the highest deciles. Relative differences may be resulted from the necessity of nutrition and the effect of the Finnish social security in the domain of housing. (Nissinen & Savolainen 2019, 41.)

2.3.2 Determinants of lifestyle

Motivations and driving factors determine the desire to make certain lifestyle choices but those are possible to be put into action only when particular determinants prevail. Determinants of lifestyle refer to circumstances where lifestyle practices can be or cannot be enabled and is also connected to the sustainability of them. Those three lifestyle determinants are attitudes, facilitators and infrastructure. Laws and political decisions are very strong facilitators and infrastructure and provision systems have a critical role towards sustainability, but stakeholders should also have the right attitude to make changes in their lifestyle. Determinants can be seen as macro-factors that shape an individual’s lifestyle at the system level but are beyond their control. (Akenji & Chen 2016, 22, 30.)

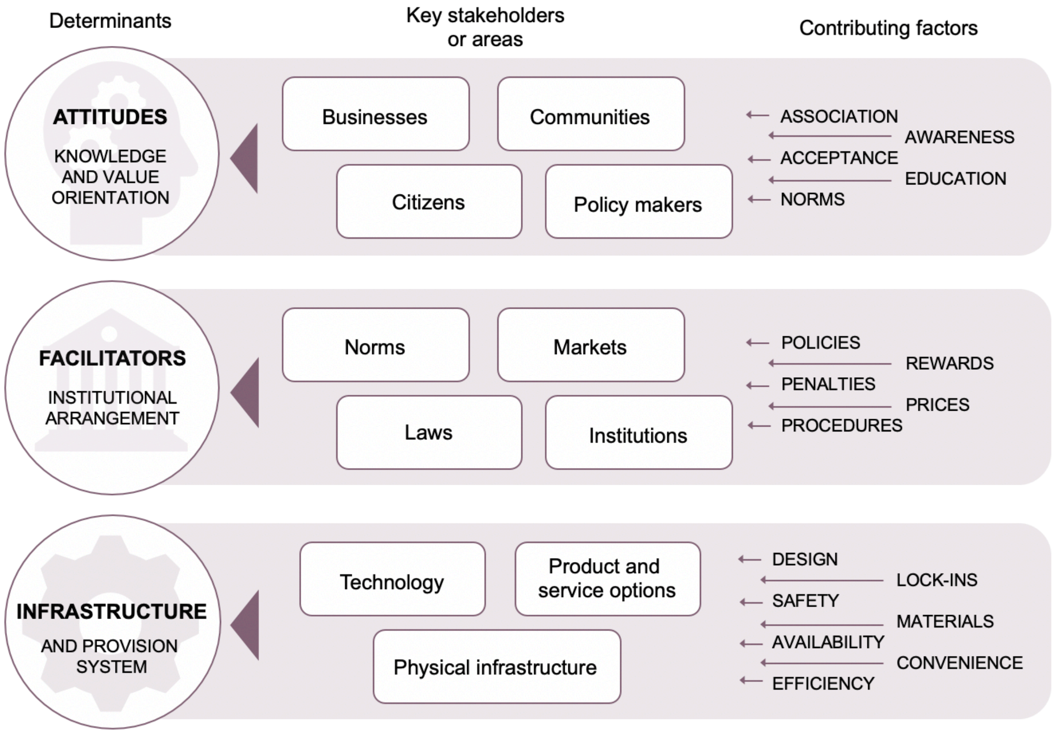

Figure 4 The determinants of lifestyle and their key stakeholders, areas and contributing factors (Akenji & Chen 2016, 22, 31-32).

Attitudes refer to an individual's value orientation and collective social values determining a person's preferences and consumption choices. Attitudes are much influenced by social movements and norms, culture, media, communities, businesses, political decisions, and many other influential stakeholders. An individual's knowledge and value orientation shape attitudes and understanding of impacts of their choices and need for change. Facilitators are connected to the access contributing the possibility to make certain behavioral choices and implement lifestyle. A consumer's lifestyle reflects to the availability of options and access of goods and services. Facilitators are mechanisms that provide options and incentives like regulations, laws and governmental policies, institutional systems, market facilities, prices and product standards. (Akenji & Chen 2016, 22, 31-32.)

Infrastructure refers to the physical infrastructure for housing and mobility, for instance, and the design of systems of provision including available technology and capacity of utility, as well as options and pricing of products and services. Design of infrastructure is remarkable especially for the domains of housing and mobility. Utility systems have an influence on the resource use at households effecting, for example, to the energy consumption. The need for transportation can be promoted by zoning laws and contributing the development of residential far from services and workplaces. Product options with similar quality, healthiness, accessibility and price are important enhancing more sustainable eating habits. (Akenji & Chen 2016, 22, 33.)

2.3.3 Lock-in effect

Sustainable innovations have been discussed to be blocked by technological and institutional lock-ins that result from prevailing unsustainable industrial economy. Similar lock-in effect is guiding consumer behavior and lifestyle choices. Lock-in effect refers to societal circumstances that lock consumers in certain behavioral models. This is the consequence of, for example, cultural, institutional or infrastructural circumstances and can be seen, for example, as a current lifestyle that is based on working and spending. (IGES et al. 2019, 26.) People do not consume only because they want to but also because they do not have a choice. Knowledge and awareness related to sustainable or low carbon lifestyle are not enough for intended action if there is no access to better options or actions are locked into existing systems. (Akenji & Chen 2016, 14, 17.)

Raising awareness is, of course, a part of change towards low carbon lifestyle but there must also be available and accessible low carbon options and possibility to get out of carbon intensive options. Actions promoting low carbon and sustainable lifestyle can be differentiated from the actions that are under the individuals' control and actions that cannot be implemented by the individuals themselves. (Akenji & Chen 2016, 38.) Therefore, lifestyle changes provide common actions in all sectors. Production processes need to be improved, the availability of low carbon products and services need to be increased and infrastructure needs to bring about a change. To implement these kinds of changes and enable options, more national policies may need to be introduced. Consumers with their individual choices are not alone responsible for changes in lifestyles. (IGES et al. 2019, 26.)

3 OVERVIEW OF A CURRENT LIFESTYLE CARBON FOOTPRINT OF AN AVERAGE FINN

In this report current lifestyle carbon footprint of an average Finn is reviewed according to the report "1.5-degree lifestyles" (IGES et al. 2019). In the report Finnish lifestyle carbon footprint was estimated mainly using bottom-up approach and combining carbon intensity values of major items with national statistics about households' quantitative consumption in 2017. To increase the coverage of estimation, the study was complemented with top-down approach using input-output analysis based data for consumer goods, leisure and services. The lifestyle carbon footprint estimation was based on households' quantitative consumption to help illustrate potential reduction points and possibilities for low carbon lifestyle choices. The carbon footprint of the three major domains has been estimated using physical units: weigh of food in nutrition, distance traveled in mobility and the amount of energy used in housing. Carbon footprint of consumer goods, leisure and services has been estimated using amounts of expenditure (IGES et al. 2019, 2, 12.)

The reference report classifies household resource consumption into six categories which are nutrition, housing, mobility, consumer goods, leisure and services. Nutrition includes the intake of all food such as vegetables, fruits, meat, fish, dairy products, cereals and beverages consumed in households and outside of the home. Emissions from the cooking at home are included in housing and emissions from the use of restaurants are part of the leisure. Housing is defined as a housing infrastructure, which includes construction and maintenance etc., and use of utilities like energy, heat and water. Mobility is made up of the use of residents' own transport equipment such as cars, motorbikes and bicycles, and transportation services such as public transport and air travel for personal purposes like commuting and leisure. Emissions caused by business trips are included in the use of products and services. (IGES et al. 2019, 11.)

This study focuses mainly on those three domains: housing, mobility and nutrition. Other domains are included only in the overall lifestyle carbon footprint examination. The extend of this study does not suffice to discuss the influence of the societal changes on carbon footprint domains of consumer goods, leisure or services. Research data is also restricted on those areas and those domains would need more research.

Consumer goods include the goods and materials purchased by households, excluding those covered in other domains and direct emissions from fuels and electricity used by consumer goods which are included under housing. Consumer goods cover, for example, clothes, furniture and daily consumer goods. The domain of leisure includes leisure activities done outside of the household such as sport activities and use of culture entertainment and hotel services. Services for personal purposes such as communication and information, insurance, ceremonies and public services are covered in the domain of services. (IGES et al. 2019, 11.)

3.1 Overall Picture of the Finnish Lifestyle Carbon Footprint

Lifestyle carbon footprint of an average Finnish citizen is estimated to be around 10.4 tCO_2e/capita/year (IGES et al. 2019, 14). In a global perspective, the carbon footprint remains high (Salo et al. 2016b, 201). When reviewing considered consumption domains, the largest impacts are caused by housing, mobility and nutrition which covers a bit more than two third of total carbon footprint. Mobility covers the largest part of the Finnish carbon footprint with a share of 27% (2.8 tCO_2e), followed by housing with a share of 24% (2.5 tCO_2e) and nutrition with a share of 17% (1.8 tCO_2e). (IGES et al. 2019, 14.) The domain of leisure and services can be thought to be divided into two sections, so the impact of each individual section is not that big. The lifestyle carbon footprint of an average Finn and the share of consumption domains are presented in figure 5.

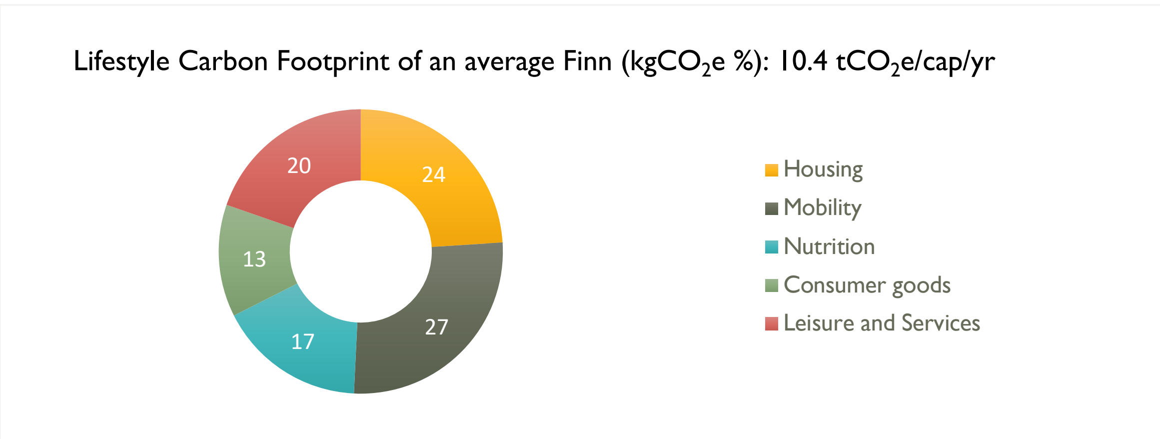

Figure 5 The lifestyle carbon footprint of an average Finn in 2017 and the share of different consumption domains (IGES et al. 2019, 14).

This study focuses on the three biggest individual domains which are housing, mobility and nutrition. These categories and the share of consumption domains in these areas are reviewed more detailed below. Even though the share of consumer goods, leisure and services is smaller than the share of the three biggest domains, the importance of consumer goods, leisure and services cannot be forgotten when reducing lifestyle carbon footprint. Those domains cover almost one third of the Finnish carbon footprint, so the potential of GHG emission reduction in those areas is also remarkable.

3.1.1 Housing

Carbon footprint of housing comes from the use of electricity, other energy and water and construction and maintenance. A floor space of an average Finnish home is 40.3 m^3 per capita and it causes a carbon footprint of 62 $kgCO_2e/m^2$. Direct energy use in average Finnish household is 10,800 kWh/cap annually which means that the energy use per living space is 270 kWh/m^2. Electricity and other energy use produce more than four-fifths of the carbon footprint of housing which can be seen in figure 6. This is a result of the substantial energy demand for heating which is affected by the large average living space and low outdoor temperatures during long winters. 65% of domestic energy use goes to indoor heating, 15% to water heating and 5% to saunas. (IGES et al. 2019, 17).

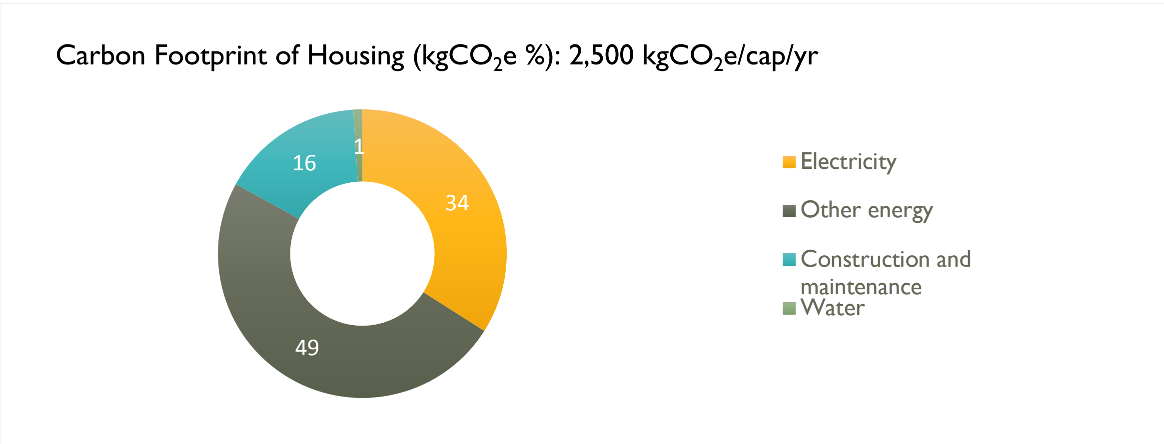

Figure 6 The share of carbon footprint of housing (IGES et al. 2019, 18).

The carbon intensity of direct energy demand for housing is about 0.19 kgCO_2e/kWh as 37% of energy is produced using renewable energy sources. The direct energy demand includes both electricity and heating as presented in the figure 7. District heating, which has relatively high carbon intensity, is a source of 48% of the energy used for indoor and water heating. In total direct energy demand district heating has a share of 33%. In Finland district heat is produced using wood and other biomass, peat, coal, natural gas, waste and oil. Wood is a source of 23% of households' total energy demand and 34% of energy used for indoor, sauna and water heating. Wood is defined as a carbon neutral source, excluding indirect emissions from production and transport so it produces very small carbon footprint even though it is second most used energy source. Instead, coal is one of the most carbon intensive energy source and it causes 21% of Finnish housing carbon footprint even though a relatively small amount is actually used. Peat and light heating oil have also high carbon intensity but the share in total carbon footprint is still only 10% per each, due to the little use. The share of other energy forms is not as remarkable due to low carbon intensity or little use. (IGES et al. 2019, 17-18.)

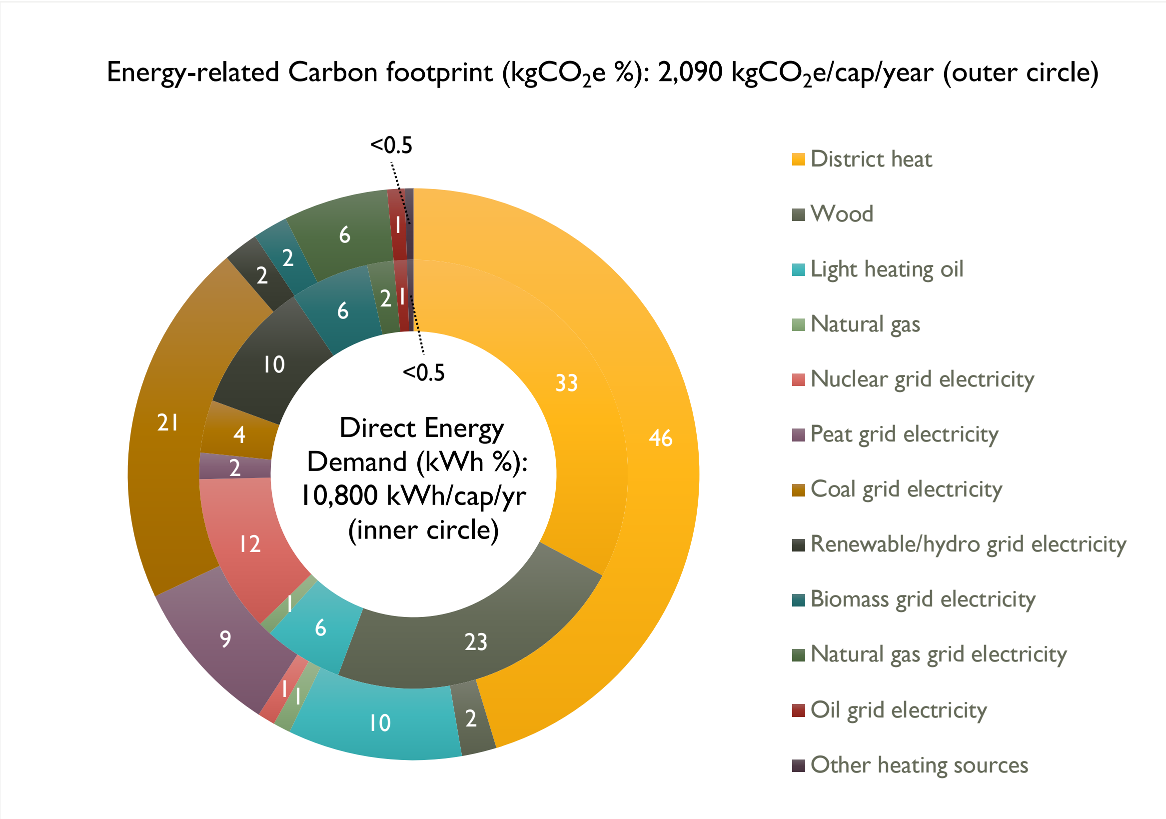

Figure 7 A comparison of energy demand of housing and the share of carbon footprint (IGES et al. 2019, 18).

In addition to the use of renewables, electrification of direct energy use in households can decrease the GHG emissions from housing, except in situations where electricity is produced by fossil fuels that can be less efficient compared to non-electricity energy sources. The reduction potential of electrification is due to the higher energy conversion efficiency of electricity-based home-heating systems like heat pumps in households. Power plants have relatively low conversion efficiency so fossil fuel-based grid electricity for household heating has usually higher carbon intensity than indoor temperature control systems using non-electricity energy produced with fossil fuels. In Finland electricity use covers 37% of households direct energy demand. Electrification of household energy consumption together with renewable-based energy should be contributed for lowering carbon footprint of housing. (IGES et al. 2019, 17.)

3.1.2 Mobility

An average Finn causes 2790 kgCO_2e in a year by mobility which is over a quarter, 27%, of their lifestyle carbon footprint. Total mobility demand in Finland is high in global scale, 16,500 km per capita per year where almost 70% is traveled by car. With its high carbon intensity car use causes a bit over three quarters of mobility carbon footprint. The share of mobility demand and carbon footprint caused by mobility is presented in the figure 8. Car use has high carbon intensity even though fuel efficiency has become better compared to many other countries and world average fuel efficiency in cars. Four-fifths of mobility carbon footprint is caused by fuel combustion and fuel production and the rest comes from vehicle production. 13% of Finnish transport demand is covered by air travel and 10% is done by land-based public transport, where about half by busses and half by train, metro and tram traffic. The carbon intensity of trains is very low since nine-tenth of trains in Finland run on renewable-based energy. Around 5% of mobility demand is covered by motorcycles, snowmobiles, quad bikes and microcars and only 4% together by cycle and walking. (IGES et al. 2019, 20.)

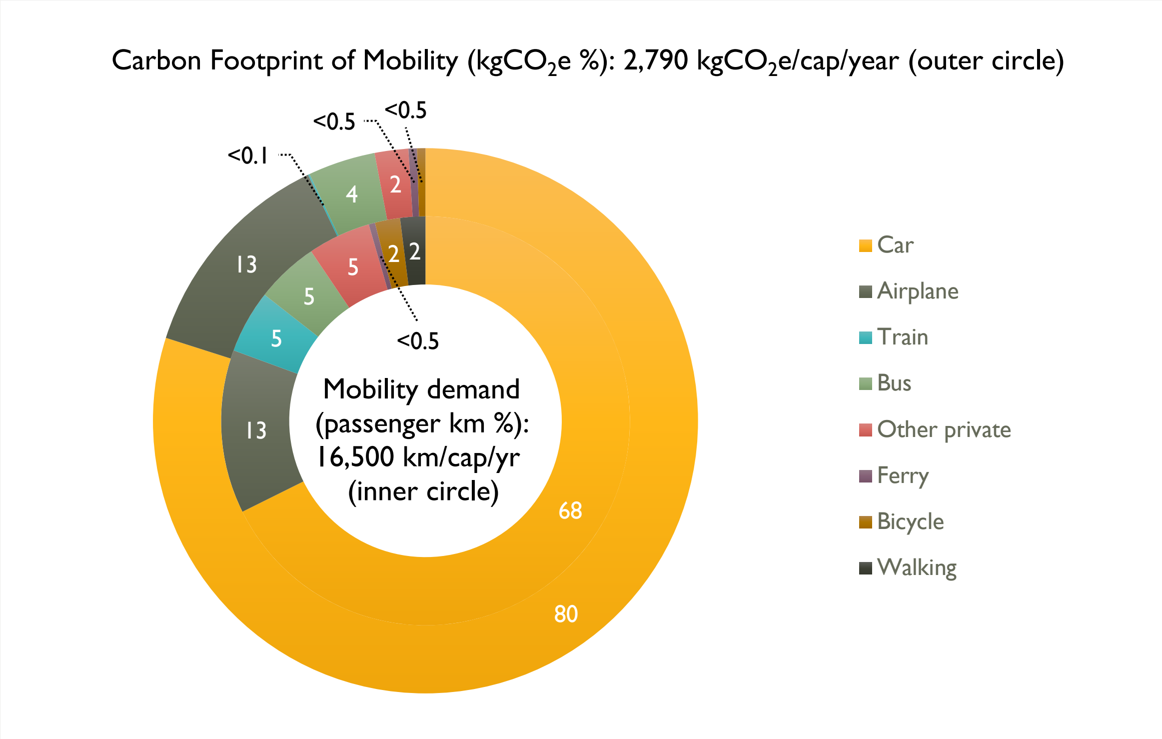

Figure 8 A comparison of mobility demand and the share of carbon footprint (IGES et al. 2019, 21).

High mobility demand in Finland is reflected to low population density, less people living in metropolitan areas and high consumption level being a well-being country. Especially the share of traveling done by car is very high and carbon footprint caused by cars is clearly the most remarkable. The second largest contributor is aviation which has higher carbon intensity compared to land-based public transport options. (IGES et al. 2019, 20-21.)

3.1.3 Nutrition

The average Finn consumes 940 kg of nutrition per year which produces carbon footprint of 1,750 kgCO_2e/year. Food loss at households is estimated to be 2.4% and it is considered in the food amounts consumed. Due to the very high carbon intensity of meat and dairy products, those two domains cover almost three-fourths of nutrition carbon footprint which can be seen in the figure 10. The amount of meat consumed is relatively small compared to its huge carbon footprint which is 37% of nutrition footprint. The biggest reason for this is the highly carbon intensive beef which causes 43% of footprint of meat despite its smaller proportion compared to poultry and pork. The second largest contribution is caused by dairy products with a share of 36%, mostly due to the consumption of cheese and milk. These two main domains are followed by beverages with 9% share of footprint mostly due to carbon intensive beer and coffee and other domains with a share of less than 4% each. Animal products together (meat, dairy, fish and eggs) produces 78% of footprint of nutrition even though the physical consumption of those is only a third of the total. This has a much higher impact on carbon footprint than the plant-based foods. (IGES et al. 2019, 14-15.)

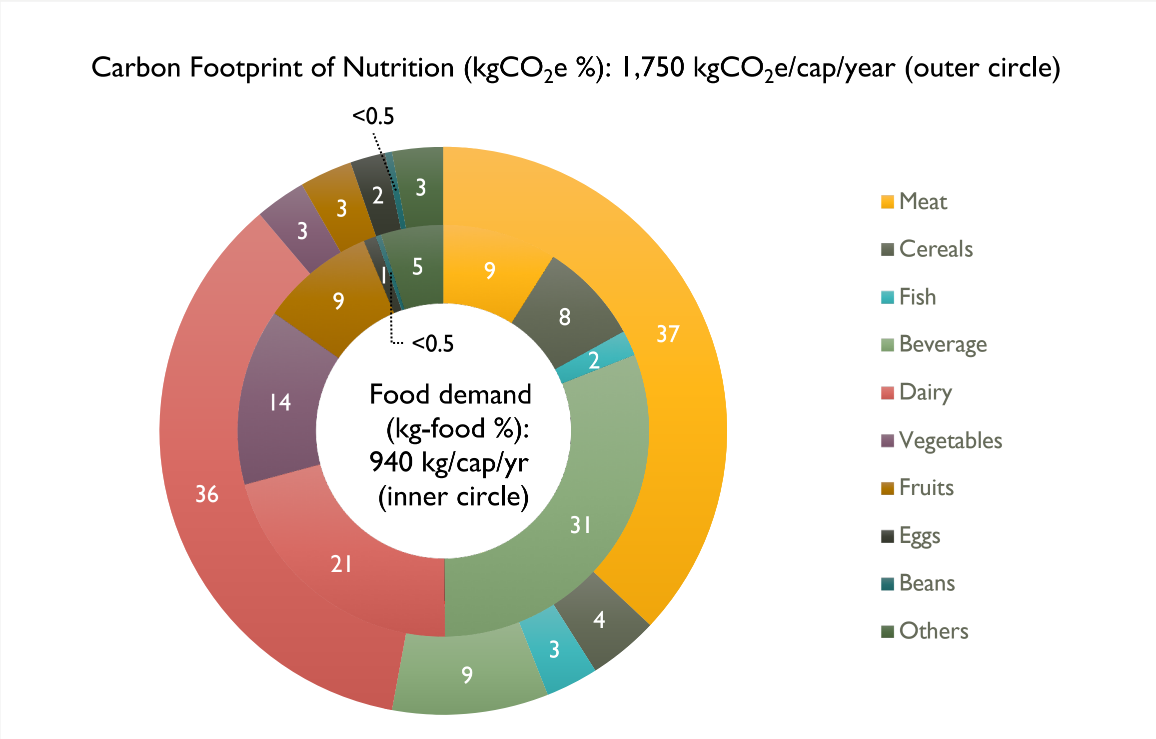

Figure 9 A comparison of food demand and the share of carbon footprint (IGES et al. 2019, 15).

The physical consumption of beans is very limited even though beans are a protein-rich food with a relatively low carbon intensity and therefore beans would be a climate-friendly food (IGES et al. 2019, 14-15). The role of plant-based protein sources is important when substituting the high carbon protein sources, for low carbon ones and still keeping the nutrition level of diet approximately in the same (Rikkonen & Rintamäki 2015, 68). In the figure 9 the category of beans includes also nuts, but these are not the only plant-based protein sources existing.

3.2 Reduction of lifestyle carbon footprint

To reach the international climate targets, global emissions should start to decrease immediately concerning also emissions caused by consumption. The role of lifestyle and consumption habits in climate change mitigation has been acknowledged. (IPCC 2018, 95, 450; UNFCCC 2015, 2.) Long-term targets for lifestyle carbon footprint are ambitious but consumers have a lot of consumption options to decrease their own lifestyle carbon footprint (IGES et al. 2019, 9; Schanes et al. 2016, 1033). The reduction of lifestyle carbon footprint requires anyway informed low carbon consumer decisions and active consumption behavior (Salo et al. 2016b, 202).

3.2.1 Long-term targets for lifestyle carbon footprint

The total carbon budget is an estimation of the cumulative net global anthropogenic carbon dioxide (CO_2) emissions that can be emitted whilst limiting global warming to some level, for example, to 1.5°C, at some probability. The already emitted and future emissions are part of the same total carbon budget, so the remaining carbon budget includes an estimation of the cumulative net global CO_2 emissions that can be emitted in the future while still limiting global temperature to the chosen level. Limiting the warming to 1.5°C, an estimated remaining carbon budget requires the CO_2 -emissions to reach carbon neutrality in about 30 years. The later emissions start declining during the next decade, the earlier carbon neutrality would need to be achieved to stay within the same carbon budget. (IPCC 2018, 24, 33.)

The report of “1.5-degree lifestyles” (IGES et al. 2019) determined globally unified equitable targets for lifestyle carbon footprint. Those lifestyle carbon footprint targets per capita were determined according to the concept of “contraction and convergence” and they were set to reach the Paris Agreement targets for climate warming (IGES et al. 2019, 33). In this study the reduction need of the Finnish lifestyle carbon footprint is also reflected on those global carbon footprint targets. Ranges of estimated carbon footprint targets for all greenhouse gases are:

- 2.5-3.2 tCO_2e/cap in 2030
- 1.4-2.2 tCO_2e/cap in 2040

- 0.7-1.5 tCO_2e/cap in 2050 (IGES et al. 2019, 9).

The ranges are a result of variable assumptions related to global average temperature targets being either 1.5°C or 2.0°C and negative emission technologies. The assumptions about negative emission technologies and human carbon sinks are connected to long-term availability of them considering uncertainty of technological development. The availability of negative emission technologies requires huge applications with uncertain costs, hence it being a risky strategy. Because of this, the lifestyle carbon footprint is proposed to decrease to the lowest level of ranges, which means the target of 2.5 tCO_2e/cap in 2030. This target is in line with the global aim to decrease GHG emissions immediately to limit global warming to 1.5°C according to Paris Agreement. The target of 2.5 tCO_2e/cap refers to 76% reduction compared to the current Finnish lifestyle carbon footprint. (IGES et al. 2019, V, 9, 33.)

The share of consumption domains will change with the reduction of carbon footprint since some domains are more essential and have less variation in current carbon footprints than others. Predicted lifestyle carbon footprint share of different domains have been estimated based on the regression model. The lifestyle carbon footprint target for 2030 (2.5 tCO_2e/cap) has been allocated to each domain according to the following shares: nutrition 29%, housing 31%, mobility 17%, goods 10%, leisure 4% and services 8%. (IGES et al. 2019b, 23.) The lately presented needs for carbon footprint reduction have been reflected to these targets.

3.2.2 Frameworks for reducing the lifestyle carbon footprint

Consumer behavior and lifestyle choices can be parts of the global emission reduction and climate change mitigation, but that requires voluntary lifestyle choices from consumers themselves. Informed low-carbon consumer decisions and active consumption behavior are crucial in reducing lifestyle carbon footprint. (Salo et al. 2016b, 202.) Consumers' motivations are then in a key role in changing consumption patterns even though they can also be influenced by social, infrastructural and institutional factors. Especially the embodied emissions can not only be tackled by efficiency improvements of processes or devices but also need adoption of concepts of circular and sharing economy (Schanes et al. 2016, 1042). To achieve remarkable impacts, changes in the consumption behavior have to be focused on high-impact consumption domains and actions with high emissions (Salo et al. 2016b, 202).

Consumption strategies and options for reducing carbon footprint in different consumption areas have been investigated in literature with a growing body. According to a different framework, an individual's options to reduce consumption-based emissions have been presented as a framework with four major categories: direct reduction, indirect reduction, direct improvement and indirect improvement. That framework has structured consumers' improvement options based on their way of impact on carbon footprint focusing on ambitious but feasible options and considering also embodied emissions, not only direct emissions. In the framework, four major strategies are divided into nine mitigation sub-strategies. (Schanes et al. 2016, 1033, 1035.)

The first major category, direct reduction, is based on the idea that the overall amount of consumption and over-consumption have caused the current climate crisis and can be easily reduced without decreasing personal wellbeing. Direct reduction includes sub-categories named consumption reduction, shift in consumption categories and curtailment. Consumption reduction refers to the decrease of the amount of goods and services consumed. Shifting between consumption categories means redirection of consumer expenditures from high carbon intensive domains like mobility to less carbon intensive activities like culture and education. Curtailment refers to using existing products less frequently or in more energy efficient way. (Schanes et al. 2016, 1035-1036.)

Indirect reduction, the second category, is linked to emission reduction through different action changes in acquiring, using and disposing products as part of the daily practices and organizational operations. Sub-categories under indirect reduction are changes in consumption patterns, changes in using behavior and changes in disposal patterns. Changes in consumption patterns refer to reusing and do-it-yourself practices. Changes in using behaviour can include sharing, renting, repairing and maintaining of products which increases utilization of durable assets and extends product's life cycle. Disposal patterns can be changed, for example, by donating and reselling products when that way the life cycle of the product can be extended. (Schanes et al. 2016, 1036.)

The last two categories, entitled direct improvement and indirect improvement are focused on forms of consumption and the end of life cycle. The aim of direct improvement actions is to decrease the amount of embodied emissions and reduce emissions caused in the use phase. This can be achieved by consuming more efficiently produced goods where the material and energy efficiency are better, and the production is less carbon intensive. The second subcategory is to purchase goods and services of which the use phase is more energy efficient and less carbon intensive. Indirect improvement as the last main category refers to disposal behavior in the end of a product's life where emissions can be reduced by changing disposal behavior, for instance by recycling or separating reusable waste. (Schanes et al. 2016, 1038-1039.)

Low carbon lifestyle choices can also be divided according to a broader framework which determines three approaches for the low carbon lifestyle decisions. These approaches are more related to the concept of carbon footprint that is estimated via the quantitative consumption and carbon intensity data. The first of these approaches is absolute reduction meaning the reduction of physical amount of consumption and avoidance of carbon intensive options. Physical consumption can be, for example, the amount of food consumed, kilometers driven, amount of energy used or the size of a living space. The second way to reduce the lifestyle carbon footprint is efficiency improvement that refers to technologies with a lower amount of emissions. Consumers can improve the efficiency by replacing less efficient systems by more efficient ones, for example, by changing to energy efficient vehicles or heating systems in households. The last approach is a modal shift that refers to shifting between consumption modes to gain less emissions. Changing consumption from one practice to a less carbon intensive one can be, for instance, a shift to renewable electricity or heating, preferring public transport over private cars or adopting a vegetarian diet. (IGES et al. 2019, 25.)

3.2.3 Rebound effect

The actions for carbon footprint reduction may result in a rebound effect, referring to a situation where technical improvements or reduced consumption in some domains lead to direct or indirect additional consumption (Salo et al. 2016b, 200; Schanes et al. 2016, 1041). This unintended consequence of these low carbon actions may even increase the total consumption and the total size of the carbon footprint by making consumption cheaper or releasing expenditures for use. The rebound effect is often connected to efficiency improvements, but it can also show up and must thus be considered also in other emission reduction approaches including absolute reduction and modal shift. (IGES et al. 2019, 25-26.)

Because of the rebound effect, the total amount of energy saved or emissions reduced by emission reduction actions, will be generally less than can conventionally be estimated (Sorrell 2012, 9-10). To avoid the rebound effect and achieve total emission reduction, changes in consumption patterns are essential (Salo et al. 2016b, 200). The total effect of emission reduction actions depends on the consumers' response and adoption of the lifestyle changes and available political support, in addition to, technological improvements (Schanes et al. 2016, 1041). However, estimating the consequences of the rebound effect in any particular instance, or the total emission reduction estimations, is very difficult (Sorrell 2012, 9-10). Further estimations about the emission reduction potentials do not consider possible rebound effect.

4 POTENTIAL PERSONAL CHOICES AND SOCIETAL ACTIONS IN REDUCING LIFESTYLE CARBON FOOTPRINT

Since a lifestyle is determined by personal attitudes, institutional arrangement and existing infrastructure, they all also have a role in reducing the lifestyle carbon footprint. In this study, actions for reducing lifestyle carbon footprint are divided between personal actions and societal changes. The roles of an individual and the society are examined by analyzing individuals' possibilities to make decisions related to their lifestyle carbon footprint and recognizing the role of society in different lifestyle areas. Potential carbon footprint reduction actions are based on low-carbon lifestyle choices presented in previous publications. Potential actions are reviewed especially from the point of view of an individual. The costs have only been considered as one of the aspects that are affecting the possibilities to make emission reduction actions.

4.1 Housing

To achieve the lifestyle carbon footprint targets, the reduction needed in the housing domain is 69% by 2030 and 93% by 2050. The targets could be reached by reducing consumption and addressing carbon intensity of energy production. (IGES et al. 2019, 18.) Energy and material efficiencies have already gotten attention in political decision making, and the regulations have tightened, but the residents' behavior and the energy consumption of appliances also have significant roles in reducing the emissions of housing (Salo et al. 2016b, 201). The most remarkable emission sources of housing are heating of the living space, consumption of warm water and electricity use of home appliances. In addition to the consumer choices, external factors like the electricity production mix and the district heat production have a massive role in the carbon footprint of housing. Increasing the share of renewable energy sources in production of electricity and heat would also affect the emissions of housing. (Salo et al. 2014, 44, 50.)

The potential of individuals' choices related to housing is highly connected to a housing type so tools and solutions applicable for reducing carbon footprint of housing vary among different households. The framework for some low-carbon actions and practices is set by the housing type since it has an effect on the relevant incentives and, for example, to energy issues. (Salo et al. 2016b, 202.) In 2017 about 45% of households were flats, making it the most common household type in Finland. Other types of housing were detached houses with the share of 40% and attached houses with the share of 14%. The rest, roughly 2% were covered by other types of housing. (Statistics Finland 2019.)

An owner of a detached house in Finland has typically a responsibility for the maintenance and renovations but the renovations and the quality of taking care of the house are of course shaped by owner's knowledge, ability and resources. Instead, the responsibility for the condition of flats and attached houses is on the housing companies and that kind of apartments are usually managed by a professional housing manager and a housing board. The manager and the board, which is comprised of representatives whom the flat owners choose by election, have a role in deciding the guidelines for the maintenance work and preparing major renovations. In flats and attached houses the costs of maintenance work and major renovations, as well as the space heating energy of the whole building including also the heating of water and electricity used in common areas, are collectively paid by the apartment owners. Every respective user is typically responsible for the costs of electricity used in the flats. (Salo et al. 2016b, 202.)

4.1.1 Model shift in heating systems and source of electricity

Heating systems and source of heating

The decisions related to heating systems are done when constructing new buildings or renovating old ones. These decisions and renovations are mainly done by the house owners which means the individuals have the possibility to decide on them and carry out changes mainly in detached houses. Some improvements like installing an air heat pump can be possible in apartment buildings or terraced houses with the permission of the housing company (Sitra 2017). In detached houses the main heating sources are wood, heat pump energy, electricity, light heating oil and district heating (Statistics Finland 2019b). Relative to the carbon footprint, the most remarkable ones are light heating oil, district heating and electricity if it is other than renewable electricity.

Cost effective improvements in heating systems depend on the heating systems that are currently existing in buildings. In the buildings that have water-to-air heat distribution system, the biggest emission reduction can be achieved by shifting to a geothermal heat pump, air heat pump, wood-based heating like pellets or low carbon district heating if it is available. In buildings that have used electricity for heating and therefore do not have heat distribution system the cost effective options for emission reduction, without a need to renew the whole heating system, are air heat pumps, additional fireplaces and solar collectors. The additional fireplaces are not in any way the best option because of the particulate emissions which have a negative effect on local air quality. A shift to use renewable electricity in buildings with electrical heating is not undisputed option hence efficiency improvements and additional heating system should be the primary means. The emission reduction potential of different modal shifts varies depending on the previous situation and the chosen improvements. (Salo et al. 2014, 48, 56.)

Financially the most effective device to improve the energy efficiency and to decrease the carbon footprint of housing is a heat pump. After an initial investment, air heat pump is an effective and cheap option to heat and cool indoor air. A geothermal heat pump has very low operating costs which lead to savings in the heating costs during its use, but the geothermal heat pumps need high initial investment which can make it an infeasible option for some people. In addition, the geothermal heat pump needs planning permission from a local authority, and it may be restricted by town planning or plot transfer rules. In district heat region and buildings that have connected to district heat it is not recommended to install geothermal heat pump. Another option for improved heating system is a solar collector. (Sitra 2017.) Solar collectors are a considerable option especially as an additional heating system (Salo et al. 2014, 50).

District heat's current carbon intensity is relatively high which makes it an inadvisable option for heating, relative to its average carbon footprint. The carbon intensity of district heat can however vary a lot regionally. Before 2019, a connection to district heating was possible to make compulsory by zone provision (HE 79/2018) which means the decision about the heating source in district heat areas has mostly been made by regional authorities. Despite the relatively high carbon intensity, district heat is still the recommended heating mode in buildings that are within reach of the district heat network (Salo et al. 2014, 50, 55). Both of these have promoted its large-scale use and have complicated an individual's possibility to choose low carbon heating systems instead of district heat. A shift to renewable-based heat would reduce an individual's carbon footprint significantly but the carbon intensity of district heat is beyond an individual's decisions since the consumers are bound to the regional heat supply (IGES et al. 2019; Salo et al. 2014, 55). The carbon intensity of the energy production is depending on the used fuels, and so the carbon footprint of heating would be affected by the used fuel mix (Salo et al. 2014, 50). The biggest emission reduction potential related to heating is in the carbon intensity of district heat, district heat being the biggest single domain in energy-related carbon footprint.

Even though the owners of detached houses could reduce their carbon footprint of housing significantly, for instance, by switching light heating oil and electricity heating to some low-carbon option, everybody is not ready to do that due to habits, the age of a building or the redundancy of renovation. Usually renovations are not done until the distinct need. Especially renovations for getting rid of light heating oil are proposed to be promoted through taxes, financing methods and information guidance. (Seppälä et al. 2017, 5-7.)

Source of electricity

It is clear that for tackling the emissions of electricity production, fossil fuel -based electricity needs to be substituted by renewable energy. As in the case of heat production, the electricity producers have a high impact on its carbon intensity but unlike in heating, consumers have a possibility to select renewable-based electricity instead of mixed electricity (Salo et al. 2014, 55). Renewable electricity sold to customers must have a guarantee of origin with which the origin of renewable electricity is verified (Motiva, 2019). This system has also been created to enhance the production of renewable electricity by the customers since the increased amount of renewable electricity purchased will increase the need for its production (Motiva, 2019). An electricity agreement is easy to change to include renewable-based electricity but will probably be a bit more expensive than purchasing mixed electricity (Sitra, 2017). A shift to renewable or other low-carbon electricity can also happen by the electricity producers without individuals' actions like in the case of heating as well.

4.1.2 Efficiency improvements and reduction of energy use

Change of energy consumption habits and efficiency improvement of home appliances

The electricity and energy needed for heating can be saved by consumption habits. The most efficient ways to reduce energy use are lower indoor temperature and reduction of the consumption of hot water. It has been estimated that the indoor temperature is possible to be 2°C lower and hot water could potentially be saved by one third of its current use. In addition to taking water saving showers, water use can be reduced by shower pledges and lowering water pressure. (IGES et al. 2019, 28; Salo et al. 2014, 51) Other changes in consumption habits to reduce energy demand are switching off electronic devices and shortening usage times, reducing the use of saunas, reducing the overuse of a preheater in heating of car engine, moving refrigeration devices away from the heaters and improving the efficiency of laundering. (Salo et al. 2014, 67.) The whole energy demand of housing could potentially be reduced approximately by 10% by changing consumption habits (Salo et al. 2014, 67; Seppälä et al. 2017, 8).

Electricity can also be saved by improving the efficiency of home appliances. The improvements are presented to focus on lighting and refrigeration devices. A shift to led lights is a cost-effective choice due to low operating costs but more efficient refrigeration devices usually need a bigger initial investment which may not be covered by the lower operating costs. The efficiency of home appliances is anyway possible to be improved only by replacing appliances, meaning that it is most likely to happen only when there is a real need to buy a new one. (Salo et al. 2014, 52.) In addition to the consumer choices, energy efficiency of home appliances can be enhanced by household goods' manufacturers (Sitra 2017). Consumer behavior can also try to steer towards more efficient energy consumption habits by information guidance and improving voluntary energy efficiency agreements (Soimakallio et al. 2017, 72).

Efficiency improvement of buildings

Renovations for efficiency improvements would possibly have one of the biggest emission reduction potential of the actions related to housing and they would lead to significant decreases in heating demand (Salo et al. 2014, 55-57; Seppälä et al. 2017, 10; IGES et al 2019, 28). The efficiency improvements of buildings refer to the reduction of heat losses that can be achieved by renovation of windows, supplementary insulation of external walls, renewal of ventilation including heat recovery and renewal of thermostats and heaters. However, efficiency improvements of buildings are connected to the need for renovations and they require investments. Even though renovations would anyway be required, the efficiency improvements including supplementary insulation of external walls, renewal of ventilation and renewal of thermostats and heaters would increase the costs of the renovations. Only the energy saving renovation of windows is possible to do without additional costs. (Salo et al. 2014, 46-48.)

In addition, the fulfilment of energy saving renovations are restricted and slowed down by several circumstances. Some buildings do not have a need for renovations during the next decades since they are already renovated without significant energy efficient improvements or they are in a good condition. Most of the apartments are also owned by individuals who may not have money or motivation to do expensive renovations. Renovations can also lead to an increased quality standard of buildings which increases energy consumption. Energy saving renovations could be enhanced by developing guidance and granting financial support. There is proposed to be financial support for household renovations, development of construction permit conducts, energy certificates and updating education of energy renovation surveys. (Seppälä et al. 2017, 10-11.)

4.1.3 Reduction of living space

The size of a living space has a connection to the amount of construction materials, home devices and furniture, need of maintenance and renovations and consumption of electricity and heat, which means that the housing carbon footprint is also possible to be reduced by reducing the size of the living space (Salo et al. 2014, 45; IGES et al 2019, 28). The reduction of living space is mainly possible to be achieved by reducing the average living space in stock of buildings or increasing the utilization rate of homes, meaning that the size of a living space is highly connected to existing infrastructure (Seppälä et al. 2017, 9). In addition, large scale reductions of living space would require significant changes in housing and a desire to change a residence. However, the size of a living space could get attention in new constructions and it could be directed by demand and consumer preferences. The increase of space efficiency can be contributed by modifiability, services of sharing economy and urbanization (Seppälä et al. 2017, 9). The reduction of a living space is also proposed to be reached by renting a guest room, but it requires someone to have the desire to rent a room and trust in renters (Sitra 2017).

4.2 Mobility

When reviewing the mobility carbon footprint related to the global targets, it should be reduced 85% by 2030 and 98% by 2050. (IGES et al. 2019, 20-21.) The reduction of the mobility carbon footprint requires the introduction of more efficient technologies and optional fuels but also consumers' changes in the need of mobility and the ways of transportation (Seppälä et al. 2014, 73). From the consumer perspective, the most essential parts of reducing mobility carbon footprint, are the reduction of private car use and flights or replacing those for low-carbon options and favoring low-carbon vehicles (IGES et al. 2019; Seppälä et al. 2014). In this study, the reduction actions of the mobility related emissions are approached according to three main categories: the reduction of mobility demand, the shift to low-carbon transport modes and the decrease of vehicle emissions.

Consumers are making choices related to the way of mobility every day, but the decisions related to transport options, private car owning and the need for traveling, such as the choice of living area, are done less frequently. Possibilities for using optional ways for the private car use are found to depend on zones of urban structure which is connected to the accessibility of public transport. Competitive ways for private car traveling usually exist in the city centres, border zones of cities and zones of public transportation. (Seppälä et al. 2014, 80.)

While the private car use is the most remarkable category in the mobility carbon footprint, prices of different transport options compared to current private car use are in an important role in changing the structure of transport modes. If the whole transport system changed from owning a car towards using transport services, more flexible options for private car use would probably be available more than today. In addition to the traditional public transportation like busses and rail traffic, transport services could include car sharing services and lift sharing enabled by applications, for instance. (Seppälä et al. 2014, 80). Related to the changes in the whole transport system the growth in passenger traffic demand has not been considered. By the shift towards a low-carbon lifestyle and society the growth should rather be stopped or even decreased until 2030.

Determining an individual's potential low-carbon lifestyle choices, current mobility demand has been reviewed with the help of National Travel Survey 2017 (Finnish Transport Agency 2018). The reduction potential of mobility demand is also linked to the necessity of traveling which can be considered in some areas such as the need for leisure trips and the possibility to increase telework. The purpose of a journey may determine the possibility to reduce mobility demand or shift from one vehicle to another. The purposes of journeys are presented in the figure 9.

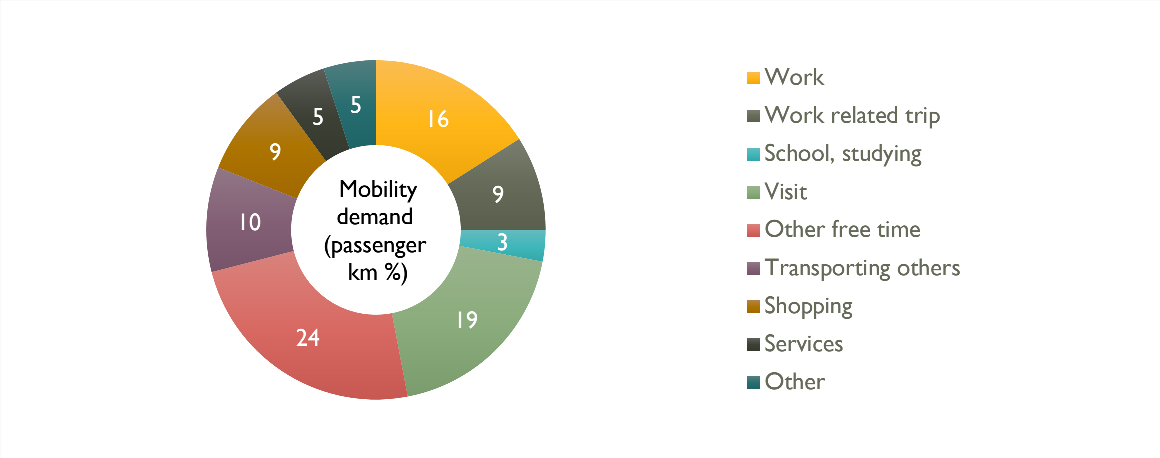

Figure 10 The share of the purposes of journeys relative to mobility demand (Finnish Transport Agency 2018, 44).

In terms of trips abroad, there are only statistics about the share of the purposes of journeys in respect to the number of journeys. The share of the trips abroad covers around 10% of the total mobility demand and most part of this is done by an airplane. (Finnish Transport Agency 2018, 111.) In this study the purposes of trips abroad are assumed to be divided according to the same proportion than the purposes of domestic journeys in relation to mobility demand.

4.2.1 Decreasing mobility demand

The reduction of demand is an effective way to reduce emissions. Lifestyle choices related to the mobility demand reduction can be favoring of local services and combining trips, closer leisure activities, dense living and telework (IGES et al. 2019b, 25; Seppälä et al. 2014, 80). The reduction of the mobility demand will also decrease costs since there is no need to pay for traveling as much anymore. In some cases, like favoring local stores with more expensive prices, costs may be increased in other areas, but this increase will probably be very limited compared to the savings achieved by reducing the need for traveling (Sitra 2017).

Favoring local services and activities and combining trips

Free time journeys cover one-third of Finns' domestic mobility demand including visits (19%), outdoor activities and exercises (4%) and other free time (20%) where the destination can be , for example, a restaurant, a bar, a culture destination, a summer cottage, a hotel, a nature area or a place for a hobby (Finnish Transport Agency 2018, 44, annex 1 (4)). One way to reduce the mobility carbon footprint is to favor closer destinations for hobbies. The emission reduction from shorter journeys to hobbies can be caused by reducing most of the distance and walking or cycling to hobbies instead of using a car or public transportation. (Sitra, 2017.) A thing to consider in the closer hobbies is the availability of them near people's homes, since more unusual ones may only be available in city centres and some hobbies may also only be possible far from cities (Sitra, 2017). In addition to favoring closer destinations for hobbies, other leisure time activities could also have potential for the mobility demand reduction, since leisure trips are not as necessary as work, school, shopping or service journeys, for example, reducing half of all free time journeys excluding visits would mean 12% reduction in the mobility demand.

The mobility demand has also been presented to be possible to be reduced by combining trips and favoring closer destinations for daily activities and services (Seppälä et al. 2014, 78, Sitra 2017). Limitations in local services could be the absence of some basic items in stores and limited availability of services or delivery options (Sitra 2017). Due to urbanization the availability of local services has also changed. Diminishing population and electrification of services have been cutting down the standard of services in smaller district centres. Availability of services may be defined by administrative players such as provinces, municipalities and cities but it is also highly related to purchasing power. (Ristimäki et al. 2017, 44.) Thus, the need for journeys related to leisure and services can be affected by societal structures and offerings but it also depends on individuals' choices.

Telecommuting

According to a study, 39% of working Finns had a possibility for telecommuting in 2018 (DNA 2018). Another study shows that 35% of the working Finns utilized telecommuting at least occasionally in the same year and 14% was working remotely every day or every week. The number of telecommuters has been increasing for several years. (MEAE 2019, 45.) Because of the modern technology possibilities for telecommuting are good and it could be utilized much more than today, even though some companies may have set limitations for the amount of telecommuting in a week (DNA 2018). The possibility for telecommuting has been noticed to increase work motivation and workers' well-being, save time due to a decreased need for commuting and help to make more flexible schedules (DNA 2018; Ruohomäki 2020). Downsides have been noticed to be a lack of work community, unsuitable working spaces at home and challenges in remote leading (Ruohomäki 2020). For example, three more telework days out of five working days would cause 60% reduction in commuting amongst the people who have the teleworking possibility. In addition to an individual's choice to increase teleworking it can also be furthered by employers who can enhance facilities for telework.

Dense living

Urbanization can lead to a reduced need for transportation when more people are living closer to centrals, workplaces, school and services (Ristimäki et al. 2017, 44). Dense living probably also leads to more efficient and more used public transport system and the infrastructure is usually more suitable for walking and cycling in densely populated areas (Salo & Nissinen 2017, 17; Seppälä et al. 2014, 81). Dense living has been be able to be increased by individuals by living closer to workplace and services, but it is also influenced by urban structure, zoning and building infrastructure (IGES et al. 2019; Ministry of Transport and Communications 2018 15, 20). Homes may be more expensive and harder to find in city centres and near services since the demand for housing is higher (Sitra 2017). The choice of a living area is not one of the everyday choices and it can be made only when people are moving. Moving closer to the workplace would require big changes and it is still shaped by the existing infrastructure.

Societal players can promote more dense living especially by land use planning and zoning (Ministry of Transport and Communications 2018, 15, 20). Changes in urban structure can lead to more efficient traffic system if it means forwarding supplementary construction and creating and utilizing good locations for new constructions. In growing urban regions workplaces and services can be directed to urban centres, subcentral areas and regions with a high accessibility of public transport. (Seppälä et al. 2014, 69.)

4.2.2 Shifting to low-carbon transport modes

Low-carbon choices in selecting transport mode can be an effective way to reduce the carbon footprint of mobility (Sitra 2017). In this case, the choices related to the low-carbon transport modes refer especially to the shift from passenger car use to options of public transport and favoring walking or cycling instead of other transport modes in shorter journeys. The reduction of mobility demand and the efficiency improvements are discussed separately. The most essential thing in selecting a transport mode is the accessibility of passenger traffic and travel destinations (Rinta-Piirto & Weiste 2019, 1). Accessibility is connected essentially to the possibility to reach destinations such as goods, services and facilities in certain time and/or with certain costs. It is made up of both a context which includes the traffic infrastructure and land use and consumers' attributes such as ownership of a car, capabilities and income level. (Rinta-Piirto & Weiste 2019, 1)

Walking and cycling in short journeys

Journeys under two kilometers by car are proposed to be substituted entirely by walking (Sitra 2017). The share of journeys under two kilometers is 18% of the number of journeys made by car (Finnish Transport Agency. 2018, 61). Even though the share of the number of journeys is remarkable, the distance of one journey is so short that the demand of journeys under two kilometers is very small in the whole mobility demand. Anyway, if favoring walking and cycling increased to involve all journeys under seven kilometers, it would be possible to achieve more significant emission reduction. In city centres and on the trips under seven kilometers, cycling is a faster, and also healthier, way to travel than driving (Sitra, 2017). The share of journeys under seven kilometers is around 51% of the number of journeys made by car and around 5% of the whole mobility demand (Finnish Transport Agency. 2018, 61).

In addition to the bicycle, there could be potential to use electric cycles in even longer journeys than up to seven kilometers since driving by an electric cycle does not require as much physical effort as driving by bicycle (Sitra 2017). When shifting to use electric bikes there is a need to buy one and it may be a big investment but compared to a car it is a very cost-effective option (Sitra 2017). However, there could be a lot of potential especially in shifting from driving a car to using electric cycles.

Possibilities to take walking and cycling into action in short journeys can be restricted by people's capabilities and travel time compared to other options but also by infrastructure and availability of walkways and cycling lanes (Finnish Transport Agency 2018, 68, 89-91;

Ministry of Transport and Communications, 2018). Walking and cycling can be promoted by land use planning, its diversion and development and combining the planning of housing and traffic. The community planning and zoning where distances are reasonable, and accessibility of public infrastructure is noticed are preconditions for increased share of walking and cycling. Therefore, dense living also promotes walking and cycling. (Ministry of Transport and Communications, 2018, 15, 18)

Car-free traveling using public transport

The accessibility of public transport has been researched previously regarding the share of people living in the zone of regional public transportation, since the extent of public transport zone is described by the possibility to run everyday tasks and missions by public transport. Especially a train rarely takes travelers to the final destination and even public transport chains may not cover the whole country (Sitra, 2017). On the grounds of resident data (2017) 71% of Finns live in the zone of public transport and 29% of them live outside the zone (Rinta-Piirto & Weiste 2019, 13, 31). The share of people living in the zone of public transport is evaluated to correlate quite well to the share of potential public transport users. In addition to the availability of public transport routes, the capacity of it is crucial. When consumers' want to decrease their carbon footprint by shifting from a passenger car to public transport the demand for public transport increases. The utilization rate of public transport in 2017 was only 25% calculated using the share of passenger kilometers and offered seat kilometers (Finnish Transport and Communication Agency Traficom 2019, 7), so the amount of passenger kilometers of public transport could be increased 75% with the current public transport capacity. The increase in available public transport capacity requires actions from the other stakeholders than individuals.

Another aspect to consider in shifting to public transport is its cost compared to car use. The cost of a season ticket for public transport is studied to be able to cover the flat costs of owning a passenger car and after this there would still be money left for incidental use of shared or rental cars. In addition, savings would be caused by reduction of fuel costs. The costs of longer trips made by public transport are depending on prevailing ticket prices. (Seppälä et al. 2014, 79) The current saver tickets can however make public transport options even less expensive compared to a car (Sitra 2017). In addition to the costs, many social aspects are influencing the use of public transport such as less comfortable or easy use, slower traveling times, possibility to use own car and physical restrictions. Public transport is, for example, studied to be a competitive option for a private car when its total door to door traveling time maximum is one and a half of the traveling time of the private car. (Finnish Transport Agency. 2018, 68, 80, 89.)

From the point of view of the society, the use of public transport could be enhanced by improved public transport (IGES et al. 2019b, 25). A better accessibility of the public transport, availability of departures, improved capacity and competitive prices and traveling times could possibly lead to more used public transport (Liimatainen & Viri 2017, 9-10). All of these could be improved by different players in society not by individuals although functioning public transport system also requires users. Car-free traveling can also be promoted by financial measures like taxes and improving guidance and steering (Salo 2016, 34-36).

4.2.3 Efficiency improvements and low carbon vehicles

Ride sharing

Individuals can also reduce the need for passenger car trips by ride sharing and also then share those emissions with several passengers thus reducing their own mobility carbon footprint. The current passenger cars' occupancy rate is around 1.7 and the rate has been suggested to increase to be more than 2 persons per car. (IGES et al. 2019, 28; Seppälä et al. 2014, 79.) This would mean 15% reduction in passenger car kilometers. Ride sharing is only limited by people's different needs for traveling, so it could be promoted by changing attitudes. Ride and car sharing are becoming easier to adopt and take into action with transport services and mobility applications (Salo & Nissinen 2017, 17).

If the need for transportation decreased and the low-carbon transport options became more common, the need for passenger car use would decrease as well and therefore there would be less need for owning a car. When the need to use passenger cars is less frequent, it would be more reasonable to use car sharing services (Sitra 2017). If all people did not own a car, materials needed for car manufacturing would also be reduced. The possible carbon footprint reduction is estimated to be 5% when using a shared car four days a month instead of owning a car. (Sitra 2017.) Large-scale use of car sharing services would however require better availability of them.

Shifting to low-carbon vehicles

A choice of a new car is important relative to the mobility carbon footprint since vehicles are staying in use for a long time (Seppälä et al. 2014, 74). Potential options for conventional passenger cars are especially electric cars, hybrid cars and biogas vehicles (IGES et al. 2019, 28). The emission reduction potential of the hybrid cars is not as significant as the potential of electric cars (IGES et al. 2019, 28; Seppälä et al. 2019, 4-5). Biofuels like bio diesel and ethanol have limitations in their large-scale use since a sustainable source of raw materials and production of both are restricted. Biogas vehicle is a low-carbon option only if the share of biogas in fuel is high. Biogas production is estimated to be possible to increase tenfold compared to the current output. Instead, electricity is possible to be produced with low emissions using renewable sources and nuclear energy and because of this, electric cars seem to be the most potential option for lowering emissions of passenger car traffic. (Seppälä et al. 2019, 4-5.)

Cumulative emissions of electric cars are the highest in the manufacturing stage but will decrease rapidly during the use. Compared to a petrol car, a diesel car, a gas-operated car and a rechargeable hybrid car, the cumulative emissions of an electric car will be lower in three to five years depending on the number of driven kilometers in a year. (Seppälä et al. 2019, 3) Electric car is a low-carbon option but its manufacturing consumes more natural resources compared to a conventional car, although in the future, more improved recycling of batteries is evaluated to decrease their life cycle emissions. Electric cars are at the moment more expensive than most of the other cars hence buying one requires quite a big initial investment. Even though their overall costs will be lower after three to eight years, the initial investment may be too high for many people. (Seppälä et al. 2019, 3-4; Sitra 2017.)

Individuals basically have the possibility to choose an electric car when buying a new car but increasing the number of electric cars would require a more improved electrical loading infrastructure. To increase the number of electric cars and make them a more competitive option, high investment costs could be brought down by taxes and financial support. Electric car sale could also be promoted by information guidance about the electric car’s emission reduction potential and cumulative costs. (Seppälä et al. 2019, 2.) The government of Finland has set a high target for the increase of the electric cars but, for example, the loading infrastructure has been constructed mainly market-drivingly and concrete subsidizations have been low. However, electric car use has meant to be promoted by policy measures. (Soimakallio et al. 2017, 66.) In addition to the private cars, a part of vehicles are company cars which mean individuals may not have the possibility to choose the type of the car or it may be guided by companies. On the other hand, more and more companies want to act sustainably and therefore favor low-carbon vehicles. (Vehmas & Pesonen 2018, 60-65.)

Vehicle fuel efficiency improvements

Vehicle fuel efficiency improvements are much dependent on technological improvements by car manufacturers, but the efficiency could also be increased by consumers by considering the fuel consumption and emission levels of cars (Soimakallio et al. 2017, 67; Seppälä et al. 2014, 81). Vehicle fuel efficiency could be increased even with conventional moving powers if consumers chose low-emission vehicles instead of large and powerful ones. Vehicles with lower emissions are often even more affordable over purchase price and running cost so they would also be the more profitable option. Without buying a new car, consumers can reduce emissions by economic driving manners. Its emission reduction potential is estimated to be around 5-15%. (Seppälä et al. 2014, 78, 81; Seppälä et al. 2017, 15)

Car manufacturers and policymakers are also in the significant role via technological improvements and legislation (Soimakallio et al. 2017, 67; Seppälä et al. 2017, 14). Vehicle efficiency is possible to be improved by technological development, but it takes time since an increase in the vehicle fuel efficiency will require regeneration of a car stock and it may also lead to the rebound effect. The energy efficiency improvements may increase driving and make more powerful vehicles financially feasible to buy. To avoid such a situation there is also a need for consumption guidance in addition to technological improvements. (Seppälä et al. 2014, 81.) Until now a purchase of more efficient vehicles and a shift to vehicles with lower emissions, have been tried to promote by car and vehicle taxes based on CO_2 emissions of passenger cars and vans (Salo 2016, 34). The regeneration of the vehicle stock has also been discussed to be promote by policy measures (Soimakallio et al. 2017, 66-67).

4.2.4 Flights

The share of emissions caused by aviation covers 13% of the carbon footprint of mobility, making it the second biggest category after the car demand. The share of emissions caused by aviation is remarkable in those people's lifestyle carbon footprint who are flying, considering the fact that only a part of consumers is doing that (Seppälä et al. 2014, 80). One return trip to Asia by airplane causes emissions worth more than a half of the carbon footprint of an average Finn. Flying is also highly related to leisure time traveling when it is not about the necessarily procurement of goods or services such as food, living or the everyday mobility need. (Seppälä et al. 2014, 80.) Reasons for leisure time flights vary from tourism to visiting and other leisure activities (Finnish Transport Agency 2018, 111). Emissions caused by business flights should not be allocate to the individuals but to the companies since individuals may not have the possibility to influence them (Niemistö et al. 2019, 19, 31). Therefore, the reduction potential related to business flights cannot be thought to be in the individual's hands. Instead, the individuals can choose to reduce the amount of their leisure time flights or substitute them with low-carbon options like domestic trips done by public transportation (Niemistö et al. 2019, 19, 31; IGES et al 2019b, 25, 28).

In addition to an individual's actions, the carbon footprint of aviation can be reduced by regulative, technological, operational and financial measures. These are divided between different players of the society. For example, fuel efficiency improvements have increased the efficiency only by an average of 1.3% per passenger-km in a year and the potential of electric airplanes is restricted to the battery technology, which shows technological development being slow. Large-scale use of alternative fuels such as plant- and waste-based fuels are restricted by the limited potential of sustainable production. Remarkable financial policy instruments include especially Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) and the taxation of aviation. CORSIA has estimated to have a lot of potential but it will become obligatory for member states of International Civil Aviation Organization (ICAO) only from 2027. The passenger flight tax has also gotten attention recently, but challenges has been noticed in its introduction. The flight tax should be introduced in the large scale and the tax revenue should be directed to the reduction of environmental effects of aviation. The technological development of airplanes has faced a lot of pressure, but the net emissions of international aviation cannot even be limited to the emission level of 2020, with current technological improvements, since the emissions of aviation are growing so fast. (Niemistö et al. 2019, 33-45.)

4.3 Nutrition

To reach the lifestyle carbon footprint targets the nutrition carbon footprint should be reduced about 58% by 2030 and 80% by 2050. Nutrition is considered to be a necessity and there is less variation in the current nutrition footprints, so the estimated reduction target is lower than the targets for the other domains. (IGES et al. 2019, 20.) The most remarkable emission reduction potential related to nutrition is studied to be possible to achieve by changing eating habits and diets (IGES et al. 2019, 28; Roininen & Katajajuuri 2014, 91; Salo & Nissinen 2017, 18). Emissions caused by food consumption cannot be decreased significantly with technology solutions unlike in the case of transport and housing. Typically, 50-80% of food's lifecycle emissions are produced in the primary production depending on the production factors of each food product and the view of examination where the consumption phase can be included or excluded, for instance. (Roininen & Katajuuri 2014, 91.) In addition to the selection of food products, consumers can decrease emissions of nutrition by avoiding food waste and eating according to their real energy requirements (IGES et al. 2019, 28; Roininen & Katajajuuri 2014, 96; Salo & Nissinen 2017, 18).

Consumers make decisions related to nutrition based on different factors such as cost, healthiness and taste but those decisions are not much restricted by the society. The existing infrastructure or available technologies do not set physical barriers to nutrition-related, low-carbon lifestyle choices and the availability of low-carbon foods makes low carbon diets possible to implement. The costs of low-carbon diets are also assumed to be similar compared to the current situation since the plant-orientated diet is studied to be even more affordable than the current average Finnish diet (Roininen & Katajajuuri 2014, 95). The biggest barrier to low-carbon food consumption is probably caused by consumer preferences (Salo & Nissinen 2018, 22).

The consumer preferences related to food are tried to be directed by guidance and policy instruments which for now has included national nutrition guidelines, campaigns related to food loss reduction, more sustainable food, climate friendly lunches and different quality certifications for food production. (Salo 2016, 40-44) One possible policy instrument to direct food consumption towards low-carbon options has also presented to be higher taxes for carbon intensive products like meat and dairy, but such actions have yet only been suggestions. All of these are based on guidance and direction of consumption which real emission reduction potential is caused indirectly by consumer choices. The guidance or the policy instrument itself does not cause emission reduction.

4.3.1 Changes in diet

When changing eating habits towards lower-carbon diets, it is important to consider the nutrition value of the diet. The most remarkable reduction in the carbon footprint of nutrition can be reached when the amounts of carbon intensive and low nutritional value food products are minimized and substituted for relatively low carbon intensive but nourishing ingredients. Evaluating the climate impacts of different diets, it is reasonable to observe food products with similar nutritional value and evaluate their carbon footprints. (Roininen & Katajajuuri 2014, 93.) Considering only the health issues in a diet and completely ignoring the environmental impacts, the situation can even lead to a larger amount of emissions compared to the current situation since a healthy diet can include high-carbon items. On the other hand, many healthy food products also have a low carbon footprint, so it is easily possible to achieve a healthy and low-carbon diet at the same time. (Rikkonen & Rintamäki 2015, 70.)

Several studies have proved that the lowest climate impacts of nutrition can be reached with a vegan diet (IGES et al. 2019, 28; Roininen & Katajajuuri 2014, 91; Rikkonen & Rintamäki 2015, 70). Even though the vegan diet has the highest emission reduction potential it is not the only way to reduce the nutrition carbon footprint. It is also possible to be decreased with other kind of diets such as a vegetarian diet, choosing low-carbon protein sources like fish or vegetarian protein sources instead of red meat and shifting dairy products to plant-based products (IGES et al. 2019, 28; Rikkonen & Rintamäki 2015, 73). Preferring organically grown food or local food does not seem to have a significant emission reduction potential (Roininen & Katajajuuri 2014, 95).

In Finland, the sustainability of a diet relative to climate and health issues is studied to be possible to further with the following changes. The consumption of meat, especially ruminant meat, meat products and dairy products should be decreased and as well the consumption of alcohol beverages, sugar and coffee should be limited. Instead, food products that should be favored and added to the diet are outdoor plants and berries but also cereals and wholegrains. Berries have a lower carbon footprint than fruits and the role of cereals will increase in plant-based diets. Especially the consumption of products produced in greenhouses should be limited when comparing climate impacts of vegetables. (Rikkonen & Rintamäki 2015 72-73.)

Sweets, snacks and alcohol have a low nutrition value and they are excluded almost entirely in a healthy and balanced diet (Rikkonen & Rintamäki 2015, 68). Therefore, the consumption of sweets and alcohol is not a necessity and could be reduced, reducing also the overconsumption and emissions. Other goods in the current Finnish diet, of which consumption could easily be limited without significant nutrition loss, are coffee and tea where especially the carbon footprint of coffee is at a quite high level. The coffee consumption per capita in Finland is in the highest level on earth which is also connected to the amount of the coffee thrown out (Sitra 2017). In a low-carbon diet the role of coffee's emissions will increase when the total footprint of the low-carbon diet is smaller (Rikkonen & Rintamäki 2015, 72).

Reducing the over consumption of the food intake has also presented to be one possible lifestyle change in reducing the carbon footprint of nutrition (IGES et al. 2019; Roininen & Katajajuuri 2014, 95). In 2012 even every other Finn was overweight, and the average nutrition intake was higher than needed (Roininen & Katajajuuri 2014, 95). The overweight is also related to the quality of nutrients so possibilities for food intake reduction should be reviewed more deeply. If the consumption of sweets and alcohol would be reduced it already reduces the total amount of consumption.

4.3.2 Food loss reduction and efficiency improvements in food production

In addition to decreasing the nutrition carbon footprint by changes in the diet, it will decrease by avoiding food loss and improving food production efficiency. Food loss is produced in all sectors including primary production and the food industry, retail sector, food service sector and households (Katajajuuri et al. 2014, 324-325). Consumers have the biggest possibility to reduce food loss in households even though they can also affect food loss in food services by utilizing foods that are going to be disposed. Food loss in households contains mostly fresh and perishable ingredients or edible leftovers from dining and cooking (Katajajuuri et al. 2014, 325). Reasons for food disposal are food being spoiled or moldy, passed 'best before' date, leftovers from dining and excess of food prepared (Katajajuuri et al. 2014, 325). Therefore, the food loss in households could be entirely removed by utilizing food when it is still fresh and preparing the appropriate amount of food. In the carbon footprint estimation used in this study the amount of food loss in households was estimated to be 2.4% of the consumed amount of food (IGES et al. 2019).

Food loss is also happening in the food supply side like in the production, retail and service sectors. In the food service sector, food loss is mainly caused by service waste due to over production. In the industry and retail sector most of the food waste includes easily perishable products like fruits, vegetables, bread, dairy products, fresh meat and convenience food that usually cannot be sold after the 'best before' or 'use before' dates. A sustainable way to reduce food loss in the supply side may not be simple and requires co-operation within the whole supply chain and the government's support. (Katajajuuri et al. 2014, 325-326, 328.) The emissions of the food supply chain can also be reduced by improving production efficiency. The total emission reduction potential of food production efficiency improvements is studied to be 9.5% by 2030. This is estimated to mean 7.3% intensity-based reduction in a year. (IGES et al. 2019b, 27.)

5 CARBON FOOTPRINT REDUCTION POTENTIAL OF PERSONAL CHOICES AND SOCIETAL ACTIONS

The previous literature review shows that an individual's emission reduction actions and changes in the society both have a role in reducing the lifestyle carbon footprint. To examine the significance of those actions and changes, the carbon footprint reduction potential of a few emission reduction actions is estimated. Chosen personal lifestyle changes and societal actions are actions that are presumed to have a significant emission reduction potential but may not be the most remarkable ones. The examined emission reduction actions are based on the previous literature review.

The chosen individual's actions are:

- A shift to renewable electricity (housing)
- Energy demand reduction by changing habits (housing)
- Car-free traveling using public transport (mobility)
- Reduction of leisure flights (mobility)
- Plant-based protein sources instead of meat (nutrition)

The chosen societal actions are:

- Emission reduction of electricity production (housing)
- Emission reduction of district heat production (housing)
- Development of traffic infrastructure to favor cycling (mobility)
- Efficiency improvement in new cars (mobility)
- Food production efficiency improvement (nutrition)

The carbon footprint reduction potentials are estimated individually for each action and totally for the individual's actions and the societal actions related to each domain. At the end all the potentials are collected together to estimate the total emission reduction potential of the individual's actions and changes in the society. The carbon footprint reduction potentials are determined to be potentials that are achievable by 2030. Estimations do not consider the potential growth of population or the growth of nutrition, energy or mobility demand.

The potential carbon footprint reductions are based on a reduction of consumption (demand), a shift between different consumption domains or reduction of carbon intensity. Carbon footprint (CF) reduction potential of a certain action is estimated using the equation 1. Carbon footprint after the potential action is the difference between current carbon footprint and potential carbon footprint reduction. More detailed descriptions about carbon footprint reduction estimations are presented under each case and in the appendix II.

$$CF\ after\ reduction = \ current\ CF - demand_{act} \cdot carbon\ intensity_{act} \qquad (1)$$

where

$demand_{act}$ = demand on which the action has fallen: reduced demand or demand of domain which carbon intensity has changed (kWh, km, kg) *carbon intensity$_{act}$* = carbon intensity on which the action has fallen: carbon intensity of reduced consumption or changed carbon intensity (kgCO_2e/kWh, kgCO_2e/km, kgCO_2e/kg)

All of the chosen actions are assumed to be carried out amongst the average citizen. The carbon intensity values used in the reduction potential estimations are calculated using the carbon footprint and consumption data presented in the report IGES et al. (2019b). The carbon intensities are calculated using the same data which has been used as the reference data for the current carbon footprints. By doing so, the inconsistency between the current footprints and the estimated reduction potentials are tried to be avoided. The reference data and then carbon intensities are presented in the appendix I.

5.1 Housing

The potential of an individual's actions related to housing have been chosen to be evaluated according to a shift to renewable electricity by an electricity contract and a change of the energy consumption habits. Consumers' shift to purchase renewable electricity is assumed to substitute the demand of fossil fuel -based electricity (coal and natural gas) for renewable grid electricity according to IGES et al. (2019). In reality, the consumers are not able to substitute fossil fuel -based electricity for renewable electricity but they can switch a mixed electricity contract to a renewable electricity contract when the mixed electricity has been produced with any kind of fuel (Salo et al. 2014, 55; Motiva, 2019). Energy demand reduction by changing habits refers to a change in consumption habits with which the total energy demand of housing will be decreased by 10%.

The decreased carbon intensity of electricity and district heat production have been chosen to be possible changes that could happen in the society. The emission reduction potential of them is examined by reducing the carbon intensity of electricity and district heat by 30%. District heat is the biggest domain in the carbon footprint of heat demand. 30% intensity-based reduction is quite remarkable, but it may be possible, for example, by the significant reduction of fossil fuels and increase of renewable energy sources. The carbon footprint reduction potentials of these actions are presented in the figure 11. Descriptions of emission reduction actions and values of estimations are also presented in the appendix II.

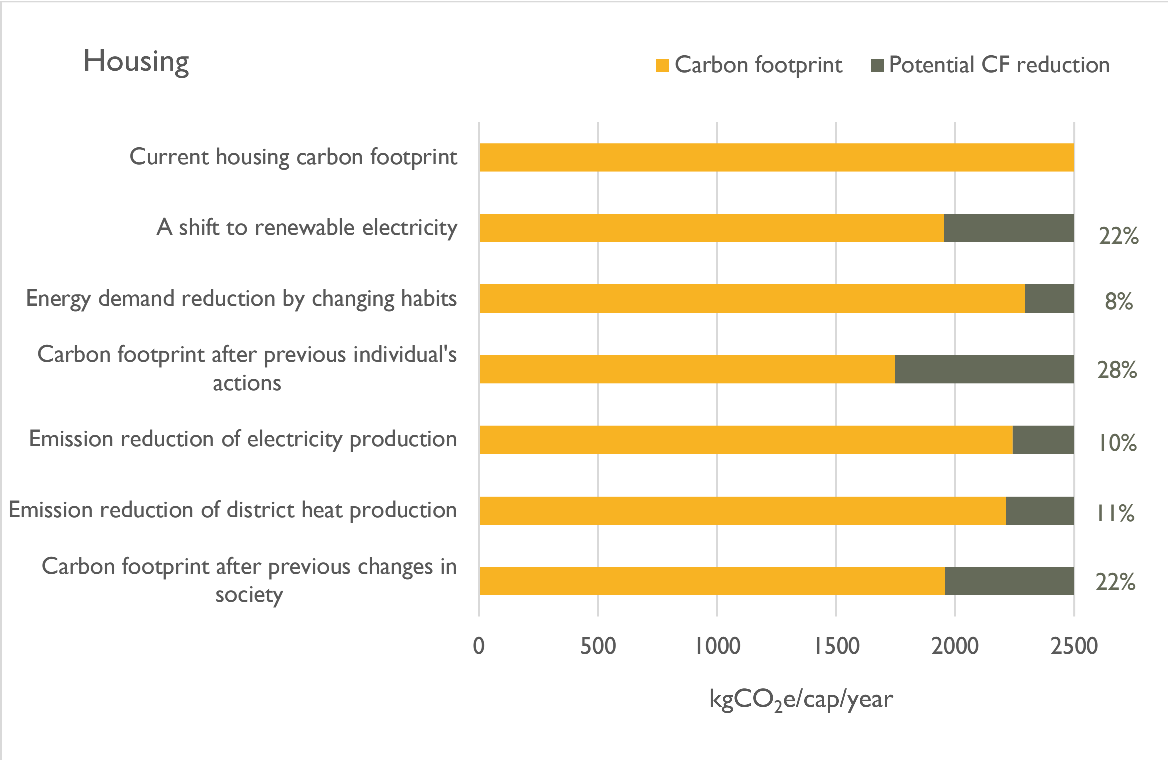

Figure 11 The estimated carbon footprint reduction potentials of chosen actions related to housing.

According to the estimations about the carbon footprint reduction potentials, the chosen individual's actions related to housing have a slightly bigger potential (28%) than the societal changes (22%). The carbon footprint of housing could anyway be reduced by both the individual's actions and the changes in society. The reduction potential of the shift to renewable electricity by an individual is estimated to be 22% and the reduction potential related to electricity production is estimated to be 10%. An individual's large potential to reduce emissions related to electricity comes from the assumption where fossil fuels are totally replaced with renewables which does not represent the real-world situation and where the reduction potential is overrated. The shift from fossil fuels to renewable electricity can be compared to the emission reduction of electricity production and could also happen as a result of changes in electricity production. If the demand of renewable electricity will increase over the supply, the shift will require development of renewable electricity production. Renewable energy contractions are anyway supposed to promote the development (Motiva 2019). Thus, the individuals and the society both have potential to affect the carbon footprint of electricity.

The energy demand reduction by changing habits is estimated to cause around 8% carbon footprint reduction. The advantages of changing habits are cost savings and a lack of investments since investments are not required to make and actions will not cause costs (Salo et al. 2014, 52). The emission reduction of electricity and district heat production would cause approximately a carbon footprint reduction of the same size. 30% intensity-based reduction by 2030 may be quite big for both the electricity and the district heat but the estimated carbon footprint reduction potentials show that the carbon intensity of energy production should decrease remarkably to achieve a significant carbon footprint reduction impact. The reduction of fossil fuels and the increase of renewable energy in accordance with the Finnish political targets would reduce the emissions of energy production but there is also existing uncertainty in achieving the targets and in the change of energy production (Soimakallio et al. 2017). The 30% potential reduction that was used in the carbon footprint reduction estimations is not based on the national targets since their total emission reduction potential is difficult to determine.

5.2 Mobility

Individuals have the possibility to decide not to fly, but the decision is mostly possible to do regarding leisure flights since business flights may be managed by companies or organizations. In 2017 most of the flights, around 87%, were international flights and the rest 13% were domestic flights (Niemistö et al. 2019, 19, 31). In the international flights the purpose of 72% of them were leisure traveling and 28% of them were business trips. In domestic flights 47% were leisure trips and 53% were done for business traveling. (Niemistö et al. 2019, 19, 31.) The potential emission reduction of flights is examined to be caused by halving the demand of the leisure flights. The carbon footprint reduction potential of this and the other chosen actions related to mobility are presented in the figure 12.

Another action an individual can do to reduce the mobility carbon footprint has chosen to be car-free traveling using public transport. 71% of Finns are living in the public transport zone and the utilization rate of the whole public transport has been around 25% (Rinta-Piirto & Weiste 2019, 13, 31; Finnish Transport and Communication Agency Traficom 2019, 7). If we think that the share of people living in the zone of public transport is connected to the share of people having a possibility to shift from passenger car use to public transport use, the current public transport capacity is the more restrictive factor. Here is also an assumption that the consumers have the possibility to use public transport within its current capacity. So potential increase in the public transport use is examined according to the capacity of public transport. The utilization rate of rail transport has been 40% which refers 60% potential increase in rail traffic use with the current capacity (Finnish Transport and Communication Agency Traficom 2019, 7). The utilization rate of busses has been 24% (Finnish Transport and Communication Agency Traficom 2019, 7). The potential increase in the public transport use has been assumed to be 60% over trains and 76% over busses resulting in a situation where 100% of train and bus capacity would be in use. This means that around 35% of car demand would be shifted to public transport.

Changes in the society that can reduce the mobility carbon footprint can be, for example, a development of traffic infrastructure and improvements in vehicle fuel efficiency. Traffic infrastructure can be developed to favor cycling which is assumed to lead to people using bicycles in commuting. The emission reduction potential of this is studied to result from a shift from motoring to cycling. The share of the potentially substituted commutes is estimated to be a half of the commuting that represents 16% of mobility demand. A part of the commutes is too long to shift to cycling and therefore a half of the commutes is estimated to reflect the share of short commutes that can possibly be ridden by cycle.

The EU has set ambitious targets for fuel efficiency improvements in new cars sold in EU. Between 2010 and 2017 the average CO_2 emissions of a new car sold in the EU fell by 15.5% being 0.118 kgCO_2/km in 2017 (European Commission 2019). The EU target for the emission level of new cars is 0.059 kgCO_2/km by 2030, expressed in NEDC (New European Driving Cycle) terms (International Council on Clean Transportation 2019). If the efficiency increased according to the targets, CO_2 emissions would decrease from 0.118 kgCO_2/km (2017) to 0.059 kgCO_2/km (2030) which refers to a 50% decrease until 2030 (European Commission 2019; International Council on Clean Transportation 2019). The average emission reduction of new cars sold between those years would then be 25% compared to the current situation if the reduction is assumed to be linear and the number of cars sold each year is assumed to be the same every year. With the current regeneration rate of the car stock, approximately 60% of cars will be renewed between 2017 and 2030. In 2017 the regeneration rate was around 4.4% in a year (Finnish Transport and Communication Agency Traficom 2020). According to these facts, carbon intensity of cars has assumed to potentially decrease by 25% in 60% of cars until 2030.

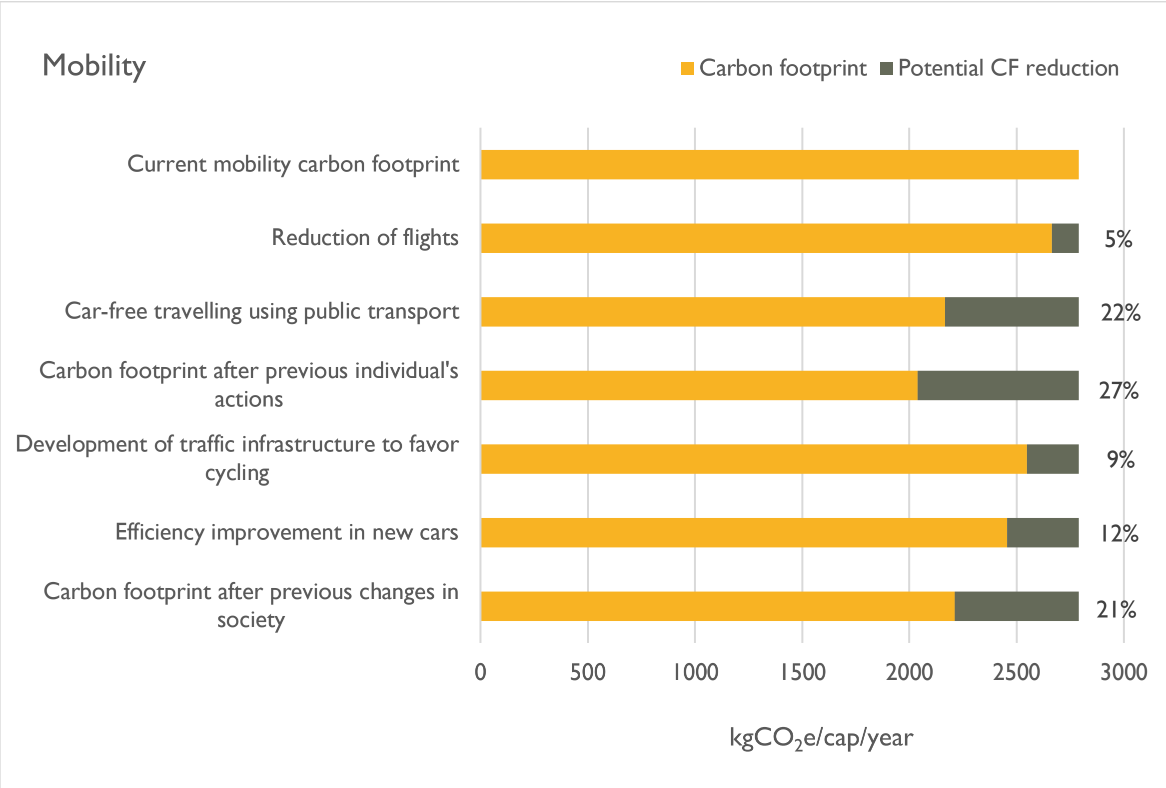

Figure 12 The estimated carbon footprint reduction potentials of chosen actions related to mobility.

The estimations about the carbon footprint reduction potentials show that individuals can reduce their average mobility carbon footprint by 27% with the chosen personal actions. The reduction of leisure flights would cause a 5% reduction and the shift to use public transport instead of a car would reduce the mobility carbon footprint by 22%. The large emission reduction potential of the increased public transport demand is resulted especially from the low-carbon rail traffic but shows action to be an effective way to reduce the mobility carbon footprint. The estimation did not consider that the free public transport capacity may not meet the demand of transport which may make its potential overrated. The increased use of public transport is also one of the targets for a more efficient traffic infrastructure and could possibly be enhanced also by the societal players (Seppälä et al. 2014, 4). The reduction potential of the reduction of flights was estimated to be around 5% but it is quite remarkable in relation to the current share of the carbon footprint of flights. The emissions of aviation are also quite difficult to reduce, for example, by technological improvements (Niemistö et al. 2019, 35-36). Both of the examined individual's actions related to mobility would be quite easy to put into action and not require large investments or massive changes.

The chosen changes in the society would cause a 21% reduction in the mobility carbon footprint where 12% would be caused by efficiency improvements in new cars and 9% would be resulted from the development of traffic infrastructure. The potential of an increased amount of cycling may be overestimated since the weather in Finland is not the most suitable for cycling and it is likely to only be done between April and November (Sitra 2017). The potential of cycling is also influenced by the distance of the journey and it was not considered closely. The shift from a car to a cycle is not happening only by the society but it also needs actions from the individuals. The increased amount of cycling is connected to the targets for more efficient traffic infrastructure with the increased public transport use, but those targets have been evaluated to be ambitious and require public investments (Liimatainen & Viri 2017, 4).

The efficiency improvement of new cars is estimated to have a 12% mobility carbon footprint reduction potential. This estimation may not answer the real emission reduction potential since there is a difference between the carbon intensities used in this study and the measured carbon intensities used for the basis of the passenger car emission targets. The emission targets for fuel efficiency, that are based on the measured emission reductions, may also not answer the real emission reduction potential (Liimatainen & Viri 2017, 20; European Commission 2019). Even though the measured emissions of new cars have decreased, several optimization measures have increased and there has been recognized to be an increasing divergence between the real emissions and the measured ones (Liimatainen & Viri 2017, 20; European commission 2019). By now the real fuel consumption has barely decreased (Liimatainen & Viri 2017, 20). Thus, the efficiency improvements in cars have uncertainties and the potential of technological development is probably overrated.

5.3 Nutrition

Individuals have different options to reduce their personal nutrition carbon footprint by doing changes in their diet. Since meat consumption is the biggest category in the nutrition carbon footprint, the individual's potential actions for the carbon footprint reduction have been chosen to be plant-based protein sources instead of meat. The consumption of meat will be substituted by beans/nuts and the amount of them will be two times the amount of meat. The consumption of fish and eggs will be the same. The amount of plant-based protein sources is increased to keep the protein content approximately the same, but the two times bigger amount of beans is only a rough estimation. To consider the real nutrition content of the alternative protein sources, a more detailed study should be done.

The nutrition carbon footprint reduction by changes in the society can be mainly caused by improving the food production efficiency. The total food production efficiency improvement is estimated to cause a 9.5% emission reduction by 2030 which means 7.3% intensity-based reduction in a year (IGES et al. 2019). The potential carbon footprint reductions of these actions are presented in the figure 13.

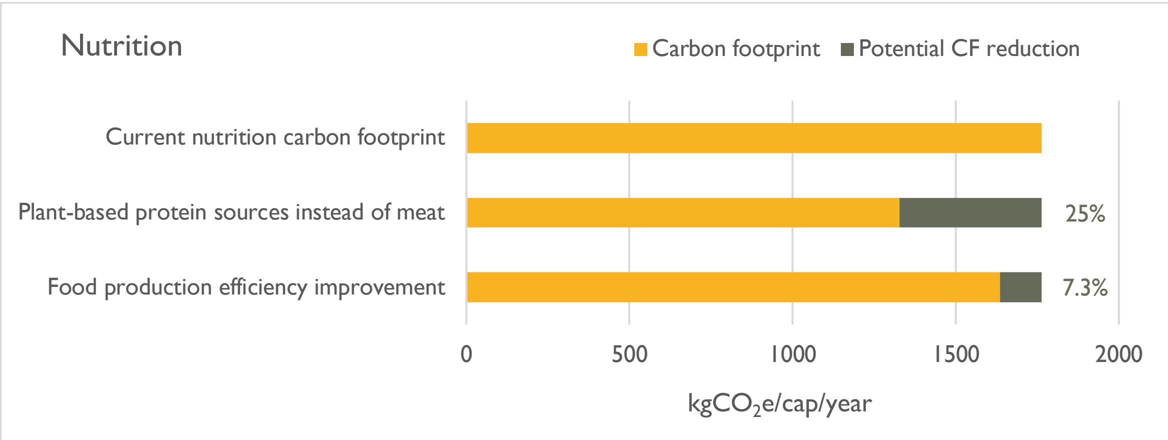

Figure 13 The estimated carbon footprint reduction potentials of chosen actions related to nutrition.

According to this study, substituting meat by beans and nuts would cause a 25% reduction in nutrition carbon footprint. The efficiency improvements in food production could potentially cause a 7% reduction. For the part of nutrition, only two potential reduction actions were examined. Based on these estimations, individuals seem to have more significant potential to effect on the nutrition carbon footprint by personal choices compared to the potential of societal changes. In addition to these chosen actions, personal choices related to diet would possibly have even bigger total emission reduction potential than the examined shift to plant-based protein sources alone has (IGES et al. 2019, 28; Roininen &

Katajajuuri 2014, 91; Rikkonen & Rintamäki 2015, 70). Instead, the societal actions seem to have a very limited possibility to influence on the nutrition carbon footprint. In addition to the food production efficiency improvement and food loss reduction in supply chain there are not many societal actions related to nutrition that could directly reduce emissions.

5.4 Total

The potential of the examined reduction actions is also calculated in relation to the current carbon footprint of housing, mobility and nutrition together and in relation to the whole current lifestyle carbon footprint. The total carbon footprint reduction potential of the examined individual's actions is approximately 28% and the potential of the societal actions is around 18% in relation to the current carbon footprint of housing, mobility and nutrition. The estimated carbon footprint reduction potentials for each domain are presented in the figure 14. According to these estimations and the chosen emission reduction actions, an individual's personal choices seem to have a bigger emission reduction potential than the societal actions. The potential of personal choices is bigger than the potential of societal actions in all three domains but especially in the domain of nutrition. The potential of the chosen individuals' actions related to housing equals the potential of those actions related to mobility. There is also a same situation in the potentials of societal actions related to housing and mobility. The emission reduction potential of actions related to nutrition is less significant since the examination related to nutrition includes only one personal action and one societal action unlike in the cases of housing and mobility for whose part there are considered two personal and two societal actions.

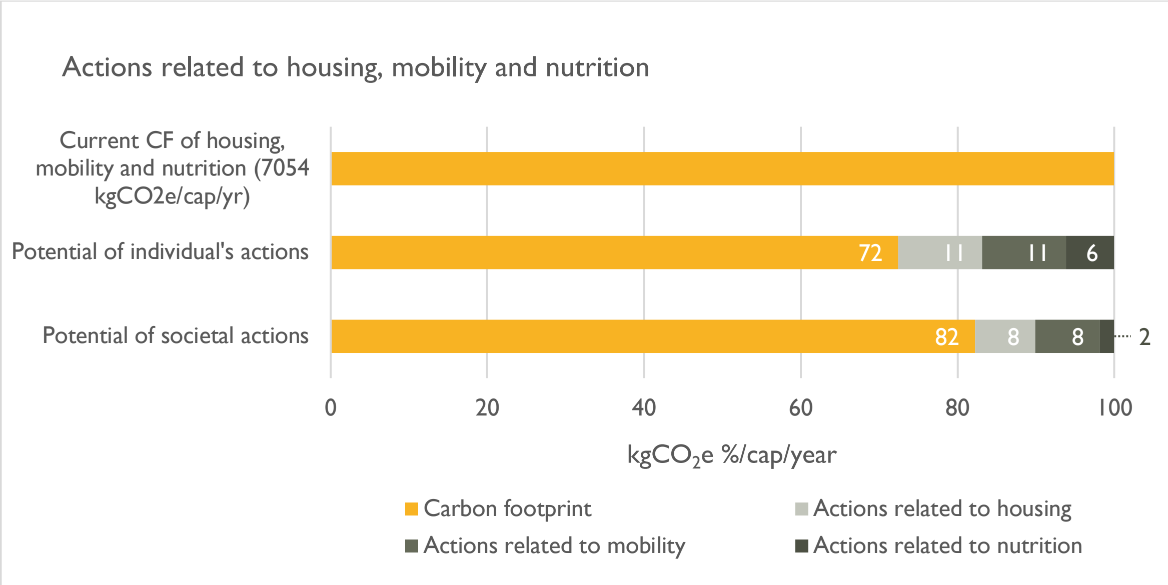

Figure 14 The total carbon footprint reduction potentials of chosen individual's actions and societal changes in relation to the current carbon footprint of housing, mobility and nutrition together.

In relation to the whole lifestyle carbon footprint, the reduction potential of the examined individuals' actions is estimated to be around 19% and the potential of societal changes around 12% as presented in the figure 15. The total emission reduction potential was here calculated separately for the personal and societal actions the since overlapping actions complicate the estimation about total emission reduction potential of several actions. Thus, the total emission reduction potential of an individual's personal actions and the societal actions do not refer to the sum of the personal and societal actions' potential. However, most of the examined actions are not overlapping and therefore the total emission reduction potential of all chosen actions is close to that sum. The potential carbon footprint reductions are comprised of previously examined actions that are focused on domains of housing, mobility and nutrition. The potential emission reduction actions related to consumer goods, leisure and services were not treated at all in this study. These domains cover one third of the total current lifestyle carbon footprint.

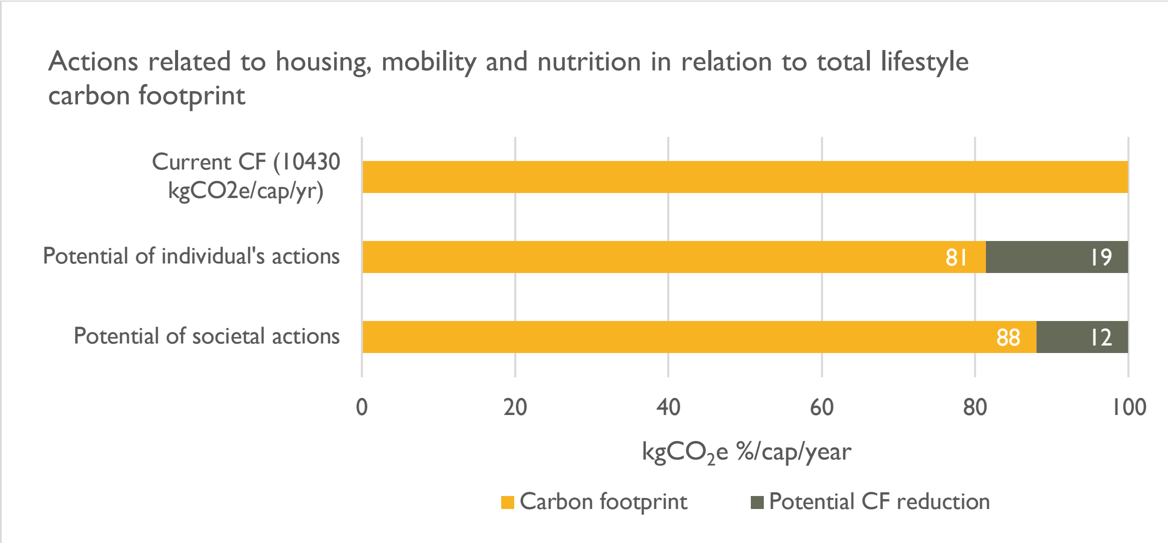

Figure 15 The total carbon footprint reduction potentials of examined individual's actions and societal changes in relation to total current lifestyle carbon footprint.

The total lifestyle carbon footprint should be decreased by even 76% by 2030 to reach the strictest lifestyle carbon footprint target set according to the Paris agreement (IGES et al 2019). Even though the total emission reduction potential for the examined individuals' choices and societal actions together was not estimated in this study there can be seen that the target for 2030 is not able to be reached only by these actions. For reaching the targets, wider changes in personal lifestyle and society would be required.

6 CONCLUSIONS AND DISCUSSION

This study analyzed the potential and the limitations of personal choices and societal actions in reducing the Finnish lifestyle carbon footprint. In the empirical part of the study, the potential carbon footprint reduction actions were examined in the three biggest lifestyle domains: housing, mobility and nutrition. Individual consumption profiles and possibilities to reduce the personal carbon footprint can vary compared to the average and therefore everybody should observe their own lifestyle carbon footprint and consider potential reduction actions. However, reviewing an average lifestyle and average emissions caused by consumption, there is a possibility to get a picture about the Finnish lifestyle carbon footprint, factors influencing it and possibilities for decreasing it.

Varying roles of an individual's choices and societal actions were examined by literature review and by doing estimations about the carbon footprint reduction potentials of ten potential actions. A half of the actions was chosen to be personal choices and another half societal actions, and they were connected to the different lifestyle domains. This study reviewed only a few emission reduction actions that were assessed to be remarkable but might not have been the most remarkable ones. Differently chosen actions may have given very different results. These results do not give us information about the most significant potential actions or the total emission reduction potential of personal choices and societal actions since the potentials of all the possible actions were not estimated. Total emission reduction potentials would have been difficult to determine because of the number of the potential actions and their overlapping emission reduction potentials.

The estimated carbon footprint reduction potentials were based on literature but some assumptions were also made. The estimations do not represent actions that are likely to happen but actions that could potentially happen under the societal and infrastructural limitations. Different limitations and factors influencing on the emission reduction actions complicate the evaluation of the real emission reduction potentials. The carbon intensity values used in the estimations were based on the consumption and carbon footprint data that was used as a reference data for the current lifestyle carbon footprint. By doing so, the inconsistency between current carbon footprints and emission reduction potentials were wanted to avoid but it also means that the carbon intensity values may not be exact. The carbon intensity data and the footprint estimations involve uncertainty in general as well (IGES et al. 2019. 13).

In the estimations about emission reduction potentials, actions were divided into the actions possible to be implemented by individuals and the actions possible to be implemented by the society, but they may not only be part of one. Actions may be possible to be implemented by both, the individual and the society, or require changes from each other. The domains of the consumer goods, leisure and services were excluded from the empirical part of this study. To get the overall picture about the different roles in the reduction of lifestyle carbon footprint these domains would need more research. According to the principles of the sustainable development it would also be essential to consider financial and social aspects like equity. For example, increasing energy prices can further social inequity (Soimakallio et al. 2017, 58, 64). Financial aspects could also be researched more than what was done in this study.

According to this study, the carbon footprint of housing is highly connected to energy production when the carbon footprint could be decreased by decreasing the emissions of energy production, regionally or nationally. This would however require a significant decrease in the energy production’s carbon intensity as the estimations about the carbon footprint reduction potentials showed. In part of electricity, consumers are able to choose the renewable electricity contraction, but the emissions of heating are often determined by the regional district heat supply or a housing type. Based on the estimations about the carbon footprint reduction potentials, individuals have a greater potential to reduce their housing carbon footprint but many emission reduction actions related to housing, seem still to be restricted by the housing type, living area, existing building infrastructure and need for renovation or they are connected to decisions that are made rarely or require investments. These aspects reduce individuals’ overall possibilities. For example, the actions related to energy efficiency improvements in buildings may be beyond an individual’s reach or difficult to realize. However, this is not the situation in all actions and the individuals still have possibilities to decrease emissions of housing by personal choices. On the other hand, many of the considered actions may not be easy to realize by the society either.

For reducing the mobility related emissions, consumers were found to have a lot of different possibilities, many of which were also alternative ones. The chosen mobility related individuals’ actions were estimated to have a greater carbon footprint reduction potential than the chosen societal actions. The emission reduction of mobility seems to also be possible to achieve quicker and with lower costs with the individuals’ actions. Societal restrictions for low-carbon transport choices are not that significant since the use of public transport could be enhanced within the available capacity and there are low-carbon vehicles already in the markets, for instance. The mobility demand would also be quite easy to be decreased by personal choices and may not even be possible by the society. However, the mobility related emissions could also be decreased by societal actions even though some of them, like technological developments, are uncertain. To reach the lifestyle carbon footprint targets, mobility related societal actions are required and certain changes, like increasing the use of low-carbon transport options and electric cars, must be enhanced by society. A zeroemission traffic system requires especially societal actions for more efficient traffic system and highly increased number of shared cars and electric vehicles (Liimatainen & Viri 2017, 4).

The role of an individual's choices became emphasized in reducing the carbon footprint of nutrition since only a limited emission reduction was estimated to be possible to achieve by improving food production efficiency. The overall potential of societal actions, like technological development related to food production, seems to be very restricted compared to the potential of personal choices. The potential of food related individuals' actions can be remarkable when only the shift from meat to plant-based protein sources was estimated to reduce the nutrition carbon footprint by one fourth. Also, previous studies have shown diet changes to have great potential to reduce the nutrition carbon footprint. Personal choices related to food are not much limited by the society but mainly by personal preferences.

Based on this study, individuals seem to have greater potential to reduce the lifestyle carbon footprint compared to the society. The most restrictive factors influencing an individual's choices were found to be related to housing, in which case the reduction of emissions caused by housing requires changes and support from the society, in addition to the personal choices. Low-carbon personal choices related to housing are still possible to be made as well. In part of mobility, individuals have already good possibilities to make low-carbon choices, but changes are also required to happen in the society. The reduction of the nutrition carbon footprint can be achieved mostly by the individual's choices and the society related emission reduction possibilities are quite limited in the domain of nutrition. Overall conclusions are anyway difficult to make since only a few actions were included in the emission reduction estimations. The variety of potential actions is also wide, and actions are influenced on various factors.

Even though the personal choices were estimated to have a greater emission reduction potential, also the societal changes will be needed to bring about reductions in lifestyle carbon footprint. Some political decisions that have already been made are affecting the domains of lifestyle. For example, national strategies and actions related to national energy production, fuels used in vehicles and energy efficiency of buildings will also affect the lifestyle carbon footprint. The need for changes in those areas is recognized in the national climate strategy (Soimakallio et al. 2017, 24). Even though some decisions have already been made, societal changes and emission reduction actions should be more significant and will probably require more investments from different societal stakeholders. In addition to the direct emission reduction caused by the societal changes, lifestyle related emissions can be reduced by consumption guidance and policies. The target for the lifestyle carbon footprint reduction is ambitious but by now the investments promoting low-carbon consumption and lifestyle changes have been low and the change will need support from other policy areas to be realized (Soimakallio et al. 2017, 78).

Since the societal actions for reducing consumption and promoting a low-carbon lifestyle are not sufficient, lifestyle changes are much needed to make out of the individuals' will. Individuals' would already have good possibilities to decrease their lifestyle carbon footprint with the existing systems and product options even though the actions may not be that easy in every area. A significant carbon footprint reduction could be achieved just by simple changes based on the reduction of consumption and shifts to existing low carbon options. Changes in the consumption patterns and lifestyle are also important in order to avoid the rebound effect and to achieve a real emission reduction (Salo et al. 2016b, 200).

In this study the emission reduction potential of personal choices related to the lifestyle carbon footprint was estimated to be slightly greater than the potential of societal actions, but actions are also needed from the society since the implementation possibilities of some emission reduction actions are restricted by the infrastructure or other societal systems. Many changes will also need actions from both the society and the individuals. The total effect of emission reduction actions depends on the consumers' actions and the adoption of lifestyle changes, technological improvements and political support. Since emissions caused by consumption should be decreased remarkably and the targets defined for the lifestyle carbon footprint are ambitious, the reduction of the lifestyle carbon footprint cannot only be based on technological development or actions made by societal players, but the personal choices alone are not enough either. The lifestyle carbon footprint targets cannot be reached by any single emission reduction action, but actions should be made in the whole society and in all lifestyle domains.

7 SUMMARY

The lifestyle carbon footprint is a tool to present GHG emissions of products and systems. It is defined to consider the GHG emissions directly emitted from the households and indirectly resulted from all kinds of household consumption, also from the consumption that is happening outside the national boundaries. This study analyzed the potential and the limitations of personal choices and societal actions in reducing the Finnish lifestyle carbon footprint based on example actions. It was based on literature research and estimations about the GHG emission reduction potentials of certain lifestyle choices and actions in the society. This study focused on the potential reduction actions in the three biggest domains: housing, mobility and nutrition.

Lifestyle is affected by interlinked, underlying lifestyle factors which are motivations, drivers and determinants. Motivations are linked to personal and social reasons and understanding. Driving factors start from the basic needs and desires. Basic needs can be fulfilled within a personal situation which is formed under external socio-technical and economic conditions and those again under physical and natural boundaries. Certain lifestyle choices are possible to be put into action only when particular determinants prevail. Those three lifestyle determinants are attitudes (knowledge and value orientation), facilitators (institutional arrangement) and infrastructure (and provision system). These lifestyle determinants can cause a lock-in effect which is guiding the consumer behavior and lifestyle choices. The lock-in effect refers to societal circumstances that lock consumers in certain behavioral models. Therefore, the society is affecting the individual’s lifestyle choices.

Based on this study, the roles of individuals’ choices and societal actions vary in different lifestyle domains. Overall, the individuals seem to have a greater potential to reduce their lifestyle carbon footprint compared to the society. Actions are still needed from the society as well since some of the emission reduction actions are restricted by the infrastructure or other societal factors. The most restrictive factors influencing individuals’ choices and the need for societal support were found to be in the domain of housing. The individuals would still have significant potential to reduce their housing carbon footprint. In part of mobility, the individuals already have good possibilities to make low-carbon lifestyle choices, but changes are also required to happen in the society. The nutrition carbon footprint can be reduced the most by the individuals' choices, and the possibilities of the societal actions are quite limited. In this study, the emission reduction potentials were estimated only for a few emissions reduction actions, so these results do not represent the overall potentials. The emissions reduction actions are also influenced by various factors which complicates the estimations. It can still be seen that the reduction of the lifestyle carbon footprint cannot only be based on the technological development and the changes happening in the society, but neither can the lifestyle carbon footprint targets be reached only by the individuals' choices. Both the individuals' personal choices and the societal actions are needed.

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The reference data and carbon intensity values

Table 1 Carbon footprint values for the total lifestyle carbon footprint of an average Finn (IGES et al. 2019b).

Overview	**Carbon footprint ($tCO_2e/cap/yr$)**	**Carbon footprint (%)**
Housing	2.50	24
Mobility	2.79	27
Nutrition	1.75	17
Consumer goods	1.33	13
Leisure and Services	2.05	20
	10.42	100

Table 2 The reference data and carbon intensities for the domain of housing (IGES et al. 2019b).

Housing	**Amount (kWh/cap /yr)**	**Amount (%)**	**Carbon footprint ($kgCO_2e/cap/yr$)**	**Carbon footprint (%)**	**Carbon intensity ($kgCO_2e/kWh$)***
Electricity	3940	36	860	34	0.218
Other energy	6850	64	1230	49	0.180
Construction and maintenance	40.3m^3	-	400	16	-
Water	51m^3	-	10	0.6	-
	10800		2500		
District heat	3570	33	950	46	0.266
Wood	2510	23	40	1.9	0.016
Light heating oil	680	6.3	220	10	0.324
Natural gas	70	0.7	20	1.0	0.286
Nuclear grid electricity	1330	12	20	1.0	0.015
Peat grid electricity	170	1.6	180	8.6	1.059
Coal and derivates grid electricity	410	3.8	440	21	1.073
Renewable/hydro grid electricity	1110	10.3	44	2.1	0.040
Biomass grid electricity	640	5.9	40	1.9	0.063
Natural gas grid electricity	210	1.9	130	6.2	0.619
Oil derivates/ waste grid electricity	70	0.6	20	1.0	0.286
Other heating sources	20	0.2	10	0.5	0.500

Table 3 The reference data and carbon intensities for the domain of mobility (IGES et al. 2019b).

Mobility	**Amount (km/cap/yr)**	**Amount (%)**	**Carbon footprint ($kgCO_2e$/cap/yr)**	**Carbon footprint (%)**	**Carbon intensity ($kgCO_2e$/km)***
Car	11200	68	2240	80	0.200
Airplane	2180	13	370	13	0.170
Train	750	4.5	0.1	0.03	0.000
Bus	890	5.3	52	1.9	0.058
Other private	810	4.9	120	4.2	0.148
Ferry	40	0.2	8	0.3	0.200
Bicycle	260	1.6	4	0.1	0.015
Walking	350	2.1	0	0	0.000
	16500		2790		

Table 4 The reference data and carbon intensities for the domain of nutrition (IGES et al. 2019b).

Nutrition	**Amount (kg/cap/yr)**	**Amount (%)**	**Carbon footprint ($kgCO_2e$/cap/yr)**	**Carbon footprint (%)**	**Carbon intensity ($kgCO_2e$/kg)***
Meat	80	8.6	650	37	8.13
Cereals	80	8.5	70	4.2	0.88
Fish	20	1.7	60	3.2	3.00
Beverages	290	31	160	8.8	0.55
Dairy	200	21	630	36	3.15
Vegetables	130	14	60	3.2	0.46
Fruits	80	8.7	50	2.6	0.63
Eggs	10	1.3	30	1.8	3.00
Beans/nuts	3	0.3	4	0.2	1.33
Others	50	4.8	50	2.9	1.00
	940		1750		

*Carbon intensities ($kgCO_2e$/kWh, $kgCO_2e$/km, $kgCO_2e$/kg) are calculated as the ratio of the carbon footprint and the amount

Carbon footprint reduction potentials

Table 5 Descriptions of carbon footprint reduction actions and results of reduction potential estimations in the domain of housing.

Potential action for reducing CF of housing	**Explanation of the reduction action**	**Remaining CF after reduction ($kgCO_2e$)**	**Potential CF reduction ($kgCO_2e$)**	**Potential CF reduction (%)**
Current housing carbon footprint		2500		
A shift to renewable electricity	Consumers will shift to renewable electricity which means fossil fuel based electricity (coal and natural gas) will be substituted for renewable grid electricity (IGES et al. 2019)	1960	550	22
Energy demand reduction by changing habits	Energy demand of housing will be decreased 10% by changing consumption habits	2290	210	8
Carbon footprint after previous individual's actions	The shift to renewable energy is happening after the energy demand reduction so that the energy demand that can be shifted to renewables is 10% lower than the current demand	1790	710	28
Emission reduction of electricity production	Carbon intensity of electricity will decrease 30%	2240	260	10
Emission reduction of district heat production	Carbon intensity of district heat will decrease 30%	2220	290	11
Carbon footprint after previous changes in society	Emission reduction potentials are assumed not to effect on each other	1960	540	22

Table 6 Descriptions of carbon footprint reduction actions and results of reduction potential estimations in the domain of mobility.

Potential action for reducing CF of mobility	**Explanation of the reduction action**	**Remaining CF after reduction ($kgCO_2e$)**	**Potential CF reduction ($kgCO_2e$)**	**Potential CF reduction (%)**
Current mobility carbon footprint		2790		
Reduction of flights	Citizens will remove half of their leisure flights	2660	130	5
Car-free travelling using public transport	Passenger car travelling will be shifted to public transport so that the whole current capacity of public transport is in use. Train demand will increase 60% and bus demand 76%.	2170	620	22
Carbon footprint after previous individual's actions	Carbon footprint after the reduction of flights and the shift to car-free travelling using public transport	2040	750	27
Development of traffic infrastructure to favor cycling	Traffic infrastructure will be developed to favor cycling so that half of commuting will be shifted to cycling. Commuting represents 16% of mobility demand. Cycling will replace car demand.	2550	240	9
Efficiency improvement in new cars	Carbon intensity of cars has assumed to potentially decrease by 25% in 60% of cars until 2030	2450	340	12
Carbon footprint after previous changes in society	Potential carbon footprint reduction after development of traffic infrastructure and efficiency improvement of fuel efficiency in cars	2210	580	21

Table 7 Descriptions of carbon footprint reduction actions and results of reduction potential estimations in the domain of nutrition.

Potential action for reducing CF of nutrition	**Explanation of the reduction action**	**Remaining CF after reduction ($kgCO_2e$)**	**Potential CF reduction ($kgCO_2e$)**	**Potential CF reduction impact (%)**
Current nutrition carbon footprint		1750	0	
Plant-based protein sources instead of meat	The consumption of meat will be substituted by beans/nuts and the amount of beans/nuts will be two times the amount of meat. The consumption of fish and eggs will be the same.	1310	440	25
Food production efficiency improvement	The total food production efficiency improvement will cause 9.5% emission reduction by 2030 which means 7.3% intensity-based reduction in a year (IGES et al. 2019).	1620	130	7

Table 8 Total potential of reviewed carbon footprint reduction actions in relation to the total carbon footprint of housing, mobility and nutrition and in relation to the total lifestyle carbon footprint.

Total CF reduction potential of chosen individual's actions in relation to the total CF of housing, mobility and nutrition		**kgCO$_2$e %/cap/year**
Current CF of housing, mobility and nutrition (7054 kgCO2e/cap/yr)		100
Housing	Potential CF reduction of chosen individual's actions related to housing	10
Mobility	Potential CF reduction of chosen individual's actions related to mobility	11
Nutrition	Potential CF reduction of chosen individual's actions related to nutrition	6
Total		27
Total CF reduction potential of chosen societal actions in relation to the total CF of housing, mobility and nutrition		
Current CF of housing, mobility and nutrition (7054 kgCO2e/cap/yr)		100
Housing	Potential CF reduction of chosen societal actions related to housing	8
Mobility	Potential CF reduction of chosen societal actions related to mobility	8
Nutrition	Potential CF reduction of chosen societal actions related to nutrition	2
Total		18
Current lifestyle carbon footprint (10430 kgCO2e/cap/yr)		100
Total CF reduction potential of chosen individual's actions in relation to the total lifestyle carbon footprint		18
Total CF reduction potential of chosen societal actions in relation to the total lifestyle carbon footprint		12