REPORTS OF THE FINNISH ENVIRONMENT INSTITUTE 30 | 2017

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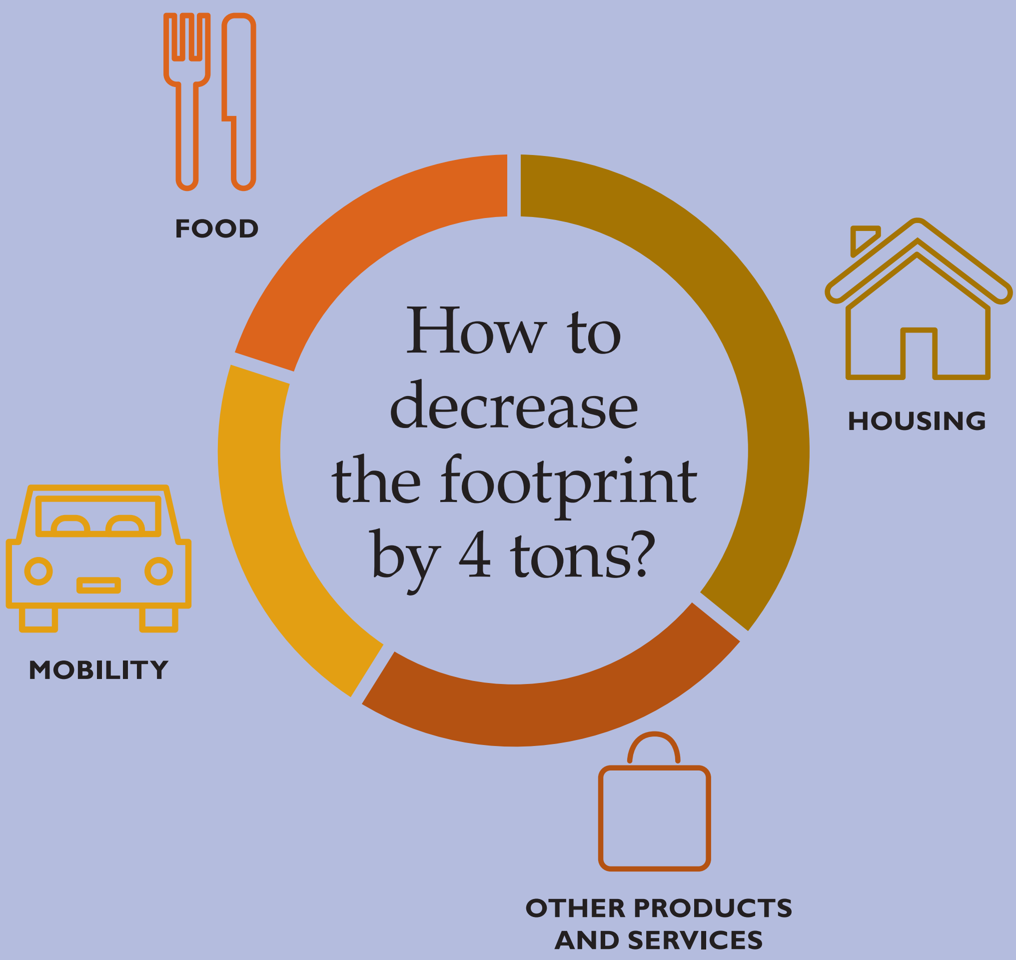

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ABSTRACT

Consumption choices to decrease personal carbon footprints of Finns

Climate change mitigation requires action in all spheres of society. The role of household consumption is often overlooked. However, 72% of global greenhouse gas (GHG) emissions are related to household consumption, while the rest stem from government consumption and investments. The result from a Finnish study is quite similar: households accounted for 68% of the GHG emissions of domestic final consumption in Finland, whereas government consumption and investments were responsible for the other 32%

The key question in this report is: *How much can a typical Finn decrease one's GHG emissions with consumption decisions?* To address this question, we took the average GHG emissions from consumption as a starting point. In Finland in 2010, the average per capita GHG emissions from consumption expenditure was 11.5 tonnes of CO_2e. Between 2000 and 2013, the average per capita GHG emissions fluctuated from 9.6 tonnes to 11.8 tonnes. The per capita consumption carbon footprint in Finland is on the high end of the European scale but smaller compared to Australia and the United States, for instance.

We listed measures that an ordinary Finnish consumer can use to decrease their GHG emissions with existing technology and solutions, and estimated the potential to avoid emissions with these activities. We focused on the most important sources of GHG emissions in Finland, including housing and especially energy-related emissions, private car travel and food choices. We also examined the consumption of goods and services, although in that particular category the emissions consist of a wide range of goods and services, and the potential of single or small numbers of actions is challenging to define.

The GHG emissions include housing, travel, food, consumption of other goods and services. We used the consumption perspective, i.e. the emissions of consumption in Finnish households were taken into account regardless of their geographic origin. Therefore, the embodied emissions of imported goods were included. We estimated that the carbon footprint of an average Finn could be decreased from 11.5 tkg of CO_2e to 7.2 tkg. In this paper, we present the measures for housing, travel, food, and goods and services that can be used to reach these savings.

While consumption choices have potential in mitigating climate change, we note that there are barriers in reducing GHG emissions with consumption choices. The solutions to overcome the barriers can be market-based, i.e. business models in which the product or service produces less GHG emissions. Informational measures such as labelling help consumers choose products and services with lower GHG emissions. Public policies also play a role in speeding up product development, as shown by the examples of energy labelling of home appliances and phasing out inefficient lighting solutions. Informational measures can also include tools such as carbon footprint calculators and campaigns to raise awareness and engage people to take action.

In this report we focused on the GHG emissions. However, other environmental footprints and indicators also show the unsustainability of current consumption patterns.

Keywords: household consumption, carbon footprint, measures, housing, travel, food, goods, services

TIIVISTELMÄ

Kuluttajan valinnat hiilijalanjälkensä pienentämiseksi

Ilmastonmuutoksen hillintä edellyttää toimia koko yhteiskunnassa. Kotitalouksien osuutta kasvihuonekaasupäästöistä ja vaikutusmahdollisuuksia päästöjen vähentämisessä ei aina huomioida. Kuitenkin 72 % maailman kasvihuonekaasupäästöistä aiheutuu kotitalouksien kulutuksesta. Suomalaisen tutkimuksen mukaan osuus on samaa luokkaa myös maassamme: kotitalouksien kulutus muodosti 68 % kotimaan loppukäytön kasvihuonekaasupäästöistä. Loput 32 % syntyivät julkisesta kulutuksesta ja investoinneista.

Tässä raportissa pyrimme selvittämään, *kuinka paljon tavallinen suomalainen voi pienentää kulutuksen kasvihuonekaasupäästöjä omilla valinnoillaan*. Kokoamme yhteen aiempien tutkimusten ja selvitysten tuloksia. Lähtökohtana ovat vuoden 2010 suomalaisen kulutusmenoista keskimäärin aiheutuvat kasvihuonekaasupäästöt, 11,5 tonnia CO_2e per henkilö. Vuosien 2000 ja 2013 välillä suomalaisen keskimääräiset päästöt vaihtelivat 9,6 tonnista 11,8 tonniin vuodessa. Henkilöä kohden lasketut kulutuksen kasvihuonekaasupäästöt ovat Euroopan mittakaavassa korkeat, mutta pienemmät kuin esimerkiksi Australiassa tai Yhdysvalloissa.

Selvityksessä keskitymme sellaisiin päästövähennystoimiin, jotka ovat toteutettavissa olemassa olevilla teknologioilla ja ratkaisuilla. Tarkastellut ratkaisut liittyvät kulutuksen tärkeimpiin päästölähteisiin: asumiseen ja energiankäytön päästöihin, henkilöautoiluun ja ruokaan. Raportissa käsitellään myös tavaroiden ja palveluiden kulutusta. Tavaroiden ja palveluiden kohdalla haasteena on kuitenkin se, että kategoria muodostuu laajasta joukosta hyvin erilaisia tuotteita.

Kulutuksen kasvihuonekaasupäästöt koostuvat asumisesta, liikkumisesta, ruoasta ja muista tavaroista ja palveluista. Kulutusnäkökulma tarkoittaa sitä, että huomioimme suomalaisten kulutuksen riippumatta siitä, missä päin maailmaa tavarat on tuotettu. Näin ollen päästöissä ovat mukana koko jalostusketjun elinkaariset päästöt. Tässä raportissa esitämme keinoja vähentää kulutuksen kasvihuonekaasupäästöjä 11,5 tonnista 7,2 tonniin vuodessa. Vähennykset koostuvat asumisen, liikkumisen, ruoan ja muiden tavaroiden ja palveluiden kulutuksen valinnoista.

Kotitalouksien kulutusvalinnoilla on siis merkitystä ilmastonmuutoksen hillinnässä. Valintoihin vaikuttaa monia tekijöitä, jotka estävät tai hidastavat vähähiilisen kulutuksen yleistymistä. Vähähiilistä kulutusta voidaan vauhdittaa esimerkiksi liiketoimintamallien muutoksilla (kulutuksen siirtyminen tuotteista palveluihin) ja informaatio-ohjauksella (kuten ympäristömerkit). Myös julkinen ohjaus vaikuttaa tuotekehitykseen. Tästä esimerkkejä ovat kodinkoneiden energiamerkinnät ja tiettyjen paljon energia kuluttavien lamppujen poistaminen markkinoilta. Informaatio-ohjausta ovat tuotemerkintöjen lisäksi kansalaisille suunnatut kampanjat ja työkalut, kuten hiilijalanjälkilaskurit.

Tässä raportissa pääpaino on kasvihuonekaasupäästöissä. Kulutuksen kestävyyttä, tai kestämättömyyttä, voidaan tarkastella myös muiden ympäristöjalanjälkien ja indikaattorien näkökulmasta.

Asiasanat: kulutus, hiilijalanjälki, keinot, asuminen, liikkuminen, ruoka, tavarat, palvelut

SAMMANDRAG

Konsumtionsval för att minska finländares personliga koldioxidavtryck

Bekämpningen av klimatförändringen kräver åtgärder av hela samhället. Hushållens andel av växthusgasutsläppen och deras möjligheter att bidra till minskade utsläpp uppmärksammas inte alltid. 72 % av världens växthusgasutsläpp orsakas ändå av de privata hushållens konsumtion. Enligt en finländsk undersökning är andelen ungefär densamma även hos oss; de privata hushållens konsumtion stod för 68 % av växthusgasutsläppen i Finland. Resterande 32 % uppstod till följd av offentlig konsumtion och investeringar.

I denna rapport försöker vi utreda *hur mycket en vanlig finländare kan minska de konsumtionsrelaterade växthusgasutsläppen genom sina val*. Vi sammanställer resultaten av tidigare studier och utredningar. Utgångspunkten är den genomsnittliga mängden växthusgasutsläpp som finländarens konsumtion orsakade år 2010, 11,5 ton CO_2e per person. Mellan åren 2000 och 2013 varierande finländarens genomsnittliga utsläpp mellan 9,6 och 11,8 ton per år. De konsumtionsrelaterade växthusgasutsläppen per person är höga med europeiska mått mätt, men mindre än i exempelvis Australien och USA.

I utredningen fokuserar vi på sådana åtgärder för att minska utsläppen som kan genomföras med hjälp av existerande teknologi och lösningar. De granskade lösningarna berör de viktigaste konsumtionsrelaterade utsläppskällorna, det vill säga boende och energianvändning, privatbilism och livsmedel. I rapporten behandlas även konsumtion av varor och tjänster. När det gäller varor och tjänster utgör det faktum att kategorin består av ett stort antal väldigt olika produkter dock en stor utmaning.

De konsumtionsrelaterade växthusgasutsläppen uppstår genom boende, transport samt konsumtion av livsmedel och andra varor och tjänster. Konsumtionsperspektivet innebär att vi beaktar finländarnas konsumtion oavsett var i världen varorna producerats. Utsläppen under hela förädlingsprocessen räknas därmed med. I rapporten presenterar vi åtgärder för att minska de konsumtionsrelaterade växthusgasutsläppen från 11,5 till 7,2 ton per år. Minskningarna sker genom val som berör boende, transporter samt konsumtion av livsmedel och andra varor och tjänster.

Hushållens konsumtionsval har alltså en betydelse för bekämpningen av klimatförändringen. Valen påverkas av många faktorer som förhindrar eller bromsar utvecklingen mot ett mer miljövänligt konsumtionsmönster. Miljövänlig konsumtion kan främjas exempelvis genom förändrade affärsmodeller (en övergång från konsumtion av varor till konsumtion av tjänster) och informationsstyrning i form av exempelvis produktmärkningar. Offentlig styrning påverkar också produktutvecklingen. Exempel på detta är energimärkningar på vitvaror och avlägsnande av vissa lampor som förbrukar mycket energi från marknaden. Förutom genom produktmärkningar kan konsumenterna också få information och vägledning genom kampanjer och verktyg såsom koldioxidavtrycksräknare.

I denna rapport ligger tyngdpunkten på växthusgasutsläpp. Konsumtionens hållbarhet, eller ohållbarhet, kan också granskas med tanke på andra miljöavtryck och indikatorer.

Nyckelord: konsumtion, koldioxidavtryck, medel, boende, resande, mat, varor, tjänster

PREFACE

The primary goal of this technical report was to provide baseline information for Sitra´s Resourcewise Citizen focus area and for the COP22 meeting in Marrakech in November 2016, where the first findings were presented. We wanted to show the scale of the emissions of the average Finnish citizen compared to Finland's total emissions and how those emissions are allocated to our daily lives; furthermore, we also wanted to show how our emissions can already be reduced.

Instead of developing new information, our aim was to sufficiently reframe and simplify the scientific data so that the "average Joe" could understand and start making better choices for themselves and the globe. Though it is a bit too easy to get confused with what to do, there are some key messages to be found in all aspects of our daily lives, from housing, mobility and the food we eat to the items, such as clothing and tools, that we buy and use.

The scale of consumer emissions is similar in the western world, though some national variations exist. The bulk, almost ¾, of the emissions comes from the consumption of all of us. Therefore, we also have the power to begin reducing the emissions. The key is to first start from a few basics and only then dive deeper into the more precise calculations and variations of our lives – and not the other way around. If we start by trying to figure out the precise individual emissions too carefully, we might end up exhausting ourselves with too much information. As we know, information without action is not going to cut our emissions – so start from the actions that have the greatest potential to reduce our impacts and then move forward.

We hope that the report brings up a clear positive message - we can already now start to reduce our footprint by more than one third while we look forward to new, better and easier ways to achieve the required and globally equal target of 2 tonnes of carbon per capita.

Markus Terho	Liisa Lahti
Project Director	Specialist
Sitra	Sitra

CONTENTS

1 Introduction

In this report, we seek to answer this question: How much can a typical Finnish consumer decrease their GHG emissions with consumption decisions? By consumption decisions, we refer to housing, passenger travel, food, and the consumption of other goods and services. We focused on the solutions and technologies already available on the market.

Consumption matters in climate change mitigation. According to Hertwich and Peters (2009), 72% of global GHG emissions are related to household consumption, while the rest stem from government consumption and investments. The result from a Finnish study by Seppälä et al. (2009) is quite similar. Households accounted for 68% of the GHG emissions of domestic final consumption in Finland, whereas government consumption and investments were responsible for the other 32%. Household consumption therefore has vast potential in mitigating climate change (See also Ivanova et al., 2016; 2017).

Although international agreements are crucial in tackling climate change, and countries have an important role in introducing and implementing national policies to decrease emissions, consumption in a globalised world and economy is not limited by national borders. We consume food and goods manufactured in other countries and therefore, even if the territorial emissions within a nation's borders decrease, the consumption-based emissions can increase because territorial emissions do not take into account the embodied emissions of imported goods. The consumption-based GHG emissions take into account these trade-linked emissions (Nissinen et al., 2015).

Girod et al. (2014) modelled consumption (housing, passenger transport, food, goods and services) globally for the year 2050 to meet the 2 °C climate target. The analysis was based on existing technologies available for consumers. In table 1, we also present three key figures: The global average per capita GHG emissions in 2010; modelled per capita GHG emissions in 2050; and the Finnish average per capita GHG emissions. We use the same year, 2010, for our analysis for Finland which is used for the global analysis by Girod et al. (2014). The purpose of the table is to show the vast volume of the required change in the global and Finnish per capita emissions to meet the 2 °C climate target.

The per capita consumption carbon footprint in Finland was on the high end of the European scale but smaller compared to Australia (15.4 tonnes per capita) and the United States (20.5 tonnes per capita), for instance (EUREAPA 2011, data from 2004).

Table 1. Global average GHG emissions in tonnes of CO_2e per capita by consumption categories in 2010 and modelled emissions in 2050. Sources: Girod et al., 2014 for global consumption and the ENVIMAT model for Finnish consumption (ENVIMAT).

Consumption category	**Global average GHG emissions per capita (tCO_2e) in 2010**	**Modelled global average GHG emissions per capita (tCO_2e) in 2050**	**Finnish average GHG emissions per capita (tCO_2e) in 2010**
Housing	0.7	0.2	4.5
Travel	1.7	0.7	2.2
Food	1.5	0.4	1.8
Goods and services	2.1	0.8	3.0
Total	**6.0**	**2.1**	**11.5**

The results by Girod et al. show the vast magnitude of the required changes. Their study also suggested that the low GHG emissions of consumption are possible with existing technologies and solutions. The average GHG emissions per capita in Finland were 5.5 tonnes higher than the global average in 2010 (Table 1). Between 2000 and 2013, the average per capita GHG emissions of Finns fluctuated between 9.6 tonnes and 11.8 tonnes. The year-to-year fluctuation in emissions is especially due to weather conditions during the winter affecting the demand for energy and the emission intensity of energy production.

Also the availability of hydropower in each year affects the emissions of the energy sector and contributes to the emissions from domestic production.

The Eurobarometer (2015) indicates that 65% of Finns consider climate change to be a "very serious" problem. At the same time, 66% stated that they had personally taken action to tackle the issue. The three most popular measures are: reducing and separating waste, cutting down consumption of disposable items, and buying locally produced food. It is important to consider how the willingness to take action and make low carbon consumption choices should be directed towards the most significant actions, such as energy- and transport-related actions, which were mentioned by fewer respondents.

The study by Girod et al. (2014) and our earlier work (Nissinen et al., 2015) suggest that there is vast potential in consumption changes to decrease GHG emissions. These examples show how motivated consumers with the required knowledge motivation and financial resources are able to decrease their consumption carbon footprint. Therefore, consumers do not need to wait for future technologies or political decisions to start making a difference. However, there are barriers in realising the full potential of suggested low-carbon consumption choices. We discuss briefly these barriers and the possible solutions to tackle them in Chapter 4.5.

In this report we aim to answer this question: *How much can a typical Finn decrease one's GHG emissions with consumption decisions?* The structure of this report is as follows: After introducing the methods, we present an estimate of the GHG saving potential by consumption categories. Then, we discuss the potential barriers and how to overcome said barriers with the interplay of policies and an improving supply of low-carbon products and services. We conclude with a chapter on carbon and other environmental footprints and indicators and what they tell us about the sustainability of our current consumption.

2 Materials and methods

The main data sources of this study included the national account (household consumption expenditure) provided by Statistics Finland and the GHG intensities of consumption from the ENVIMAT model (Mäenpää and Siikavirta, 2007; Seppälä et al., 2009; 2011; ENVIMAT). ENVIMAT is an environmentally extended input-output model (EE-IO) developed in collaboration between the Finnish Environment Institute SYKE and the Oulu Business School at the University of Oulu. EE-IO models are widely used to assess the relationship between environmental impacts and the economy. The model uses monetary and physical input-output tables and life-cycle environmental impact assessment. In this study, we used the GHG intensities of consumption derived from the model. The intensities were defined as kg of GHG emissions per euro consumed in 66 product and service categories. The product categories follow the international COICOP classification.

The ENVIMAT model uses the life-cycle approach and includes both direct and embodied emissions of products, i.e. impacts of raw material extraction and manufacturing. The emissions of imported goods and their GHG emissions are included despite the geographic origin of the consumed products.

The ENVIMAT model has been further developed after the initial version described in Seppälä et al., 2011. A major improvement implemented by Professor Mäenpää and colleagues from Oulu Business School at the University of Oulu was to include the consumption of fixed capital, such as buildings, in the model. The development of the ENVIMAT model was briefly described in Salo et al. 2016a. In this report, we present results including the consumption of fixed capital. The main contribution of the improvement of the model was related to housing, which now includes the GHG emissions of the building (i.e. building materials and construction) in addition to energy use, i.e. heating and electricity.

Household consumption expenditure on each of the 66 product categories was multiplied by the GHG intensity factor from the ENVIMAT model. The emissions of the product categories were finally aggregated into the four categories presented in this report: housing, travel, food, and other goods and services.

The estimation of the potential to decrease the consumption GHG emissions with consumption decisions was based on literature sources, our own calculations presented in this publication and the Ilmastodieetti.fi carbon footprint calculator developed and hosted by SYKE (Salo et al., 2016b). The presented measures focus on the key aspects of each consumption category. The practical applicability of the measures naturally depends on factors such as the type of housing and transport options available. The purpose of this exercise was to present examples on how fairly simple actions using existing solutions can lower the GHG emissions considerably. In practice, tailored support and guidance to identify the applicable solutions and routines is needed to realise the potential in decreasing GHG emissions from consumption.

3 Results

In this chapter, we present an estimation on how a typical Finn can decrease GHG emissions with their consumption choices. Table 2 presents the composition of the average GHG emissions per capita in Finland in 2010 and the summary of the estimated potential to decrease emissions with changes in consumption. The emissions were calculated from the consumption expenditure with the ENVIMAT model. In the sub-sections below, we look into the measures of each consumption category to reduce GHG emissions.

Table 2. Average per capita GHG emissions from consumption in Finland in 2010 and estimated GHG emissions after low-carbon consumption choices. Source for the average GHG emissions in 2010: ENVIMAT.

Consumption category	Finnish average GHG emissions per capita (tCO_2e) in 2010	Estimated GHG emissions per capita (tCO_2e) after low-carbon consumption choices
Housing and energy use at home	4.5	2.5
Travel	2.2	1.3
Food	1.8	0.9
Goods and services	3.0	2.5
Total	**11.5**	**7.2**

3.1 Housing and energy use at home

Key points to take action on:

- Pick the low-hanging fruits to save heating energy: Turn down the thermostat in the winter to save 5% of energy per every 1 °C.
- Explore or hire a professional to find out how you can improve the energy efficiency and living comfort of your home by reducing heat losses and how you can increase the share of low-carbon energy sources.
- Check the water flows of taps and pay attention to your habits of using hot water, especially in the bathroom.

In 2010, housing accounted for 39% (4.5 tonnes) of the per capita consumption GHG emissions in Finland. Typically, the share of housing is approximately one third of the per capita consumption carbon footprint. The housing GHG emissions include energy used at home, the embodied emissions of the residential buildings, furniture and other items, as well as services for technical maintenance. Heating, electricity and house maintenance services accounted for 72% (3.2 tonnes) of the per capita housing carbon footprint in 2010. The rest (28%) is related to the building and renovations.

We estimated that a roughly 60% decrease in GHG emissions from energy use and maintenance (3.2 tonnes) at home can be achieved with consumption choices. The measures depend on the type of building, but they can include the following: Increasing the share of renewable energy sources in heating (e.g. heat pumps) and electricity, renovations to improve energy efficiency, using energy-efficient household appliances and lighting, and behaviour changes in energy consumption. See also Appendix 1 for examples. Table 3 lists measures to reduce energy consumption and the GHG intensity of energy used at home.

Table 3. Measures to save energy and reduce GHG intensity of energy consumption at home.*

	Start today	Easy and low-cost	Plan ahead
Heating	Turn down the thermostat and save 5% per each 1°C during heating season. 0.1 tonnes per person per yr.	Check windows and doors and fix insulation to avoid draft.	Improve energy efficiency (insulation heat recovery, replace windows, doors) when renovating property. 1.0 tonnes per person per yr.
	Save hot water in shower and bath. 0.1 tonnes per person per yr.	Install low flow taps and shower heads. 0.1 tonnes per person per yr.	In an apartment house, install water consumption meters in each home and charge according to real consumption. 0.1 tonnes per person per yr.
		Adjust or ask technician to adjust water pressure in the whole building to save hot water. 0.1 tonnes per person per yr.	
			Install renewable heating systems as a main or secondary heating system (heat pumps, solar), esp. to replace fossil heating energy such as oil heating. Estimation for detached houses (4 persons): 0.1– 2.0 tonnes per person per year.
Electricity	Check the use practices of consumption “hot spots” including: additional electric floor heating in bathroom, sauna, car engine heating in winter.	Avoid high consumption in peak consumption hours (esp. electric water heating boiler, sauna, oven and appliances with high consumption).	
		Buy electricity from renewable sources (Guarantee of Origin).	Install devices to produce renewable energy, e.g. photo voltaic system.
		Replace inefficient lights with LEDs.	
		Choose energy-efficient devices when replacing old ones.	
	Turn off power from devices not in use.	Use timers to control devices that can be turned off on certain times. E.g. outdoor lighting, extra electric heating systems.	

*Some of the measures overlap with each other. Therefore the total saving is not as high as the total sum of all the measures.

3.2 Travel

Key points to take action on:

- Walk or cycle short trips and combine with public transport on longer trips.
- If you need a passenger car, take a shared one for occasional use and choose a low-emission vehicle if you need to own one.
- Enjoy nearby activities and destinations for recreation and holidays.

The emissions of travel in this work included the operation and purchase of personal vehicles, transport services and package tours. Personal vehicles, mainly passenger cars, are responsible for 74% of the travel GHG emissions and for 14% of the total consumption carbon footprint.

We estimated that the potential to decrease GHG emissions from domestic transport is 0.9 tonnes per person per year. We likewise estimated that the decrease in GHG emissions can be achieved through multiple means, for instance by using a biogas-powered car (see Table 4). Also, combining the measures of walking, cycling and public transport, listed in table 5, with a decrease in the use of a fossil fuel powered car can result in an emission decrease of the same magnitude. On a personal level, the emission reduction is likely to result from more efficient vehicles (public, shared and private), the use of fuels with lower GHG intensities, and shifts in transport modes.

We present examples of saving potential from cars powered with low-carbon fuels and transport mode changes. Seppälä et al. (2014) estimated the potential of individual choices to decrease passenger transport GHG emissions with existing technology. First, we present an example of how the choice of a passenger car affects the emissions. In this case, the annual kilometres driven by the car are 17,000, and the car itself varies as the user chooses between different models of Volkswagen Passat (Table 4). Emissions refer to life-cycle emissions of fuels but do not include car manufacturing.

Table 4. Comparison of annual GHG emissions of driving with different models of Volkswagen Passat. Source: Seppälä et al., 2014.

Fuel and engine	**GHG emissions in tonnes of CO_2e per year (17,000 km)**
Biogas 1.4 TSi	0.7
Ethanol (RE85) 1.4 TSi (MF)	1.1
Diesel 1.6 TDi	2.3
Natural gas 1.4 TSi	2.4
Petrol 1.4 TSi	2.7
Diesel 2.0 TDi	2.9
Petrol 2.0 TSi	3.5

Table 4 illustrates how the type of car and fuel used makes a difference on a vehicle level. It should be noted that the emissions from ethanol, biogas and other fuels from renewable sources vary greatly from one product to another. In the example presented in table 4, biogas and ethanol are produced from waste streams and are available at Finnish fuel stations.

The electric car was not included in the comparison in table 4. If we assume that an electric car consumes 15 kWh per 100 km, the total electricity consumption would be 2,550 kWh per 17,000 km. With the life-cycle emissions of electricity in Finland, the GHG emissions would be 1.0 tonne of CO_2e per year and with renewable electricity 0.1 tonnes per year. As in table 4, we have excluded the manufacturing of the vehicle in our analysis.

We also looked into the potential changes in the transport mode and travel patterns. Passenger cars accounted for 73% of the domestic kilometres travelled (National Travel Survey 2010-2011) in Finland. While traveling by low-carbon car is part of the solution, the manufacturing of personal cars makes them more carbon-intensive compared to public transport (e.g. Girod et al., 2014). In addition, we point out the potential of economic driving. An example of how to reduce travel GHG emissions without investing in a new car is presented in table 5.

According to the Finnish National Travel Survey 2010–2011, people who had access to a passenger car (as a driver) travelled 15,000 km per year by car. Table 5 shows changes in travel patterns that decrease GHG emissions. In our example, the total kilometres travelled by car decrease from 15,000 km to 9,000 km per year. We estimated that the decrease in kilometres travelled is feasible. For instance, 1,500 km walking or cycling during one year equals roughly four km of walking or cycling per day.

Table 5. Measures to decrease GHG emissions of passenger transport on a personal level. Source: Seppälä et al., 2014.

Measure	**Avoided GHG emissions per year per person (tkg CO_2e) compared to average travel patterns**
Travel 3,000 km (20%) less with car and use bus and train instead	0.2
Travel 1,500 km (10%) less with car and walk or use bicycle instead	0.15
Travel 1,500 km (10%) less with car by combining trips and using services close to home, work or school	0.15
Economic driving (9,000 km)	0.1
Total avoided GHG emission per year per person	**0.6**

The listed measures would decrease transport emissions by 0.6 tonnes per person per year (-27%) with the current technology. The feasibility of the example (Tables 5 and 6) depends on the personal travel patterns and access to car, public transport and safe and convenient walking and cycling infrastructure, i.e. people typically have more opportunities to change travel patterns and modes in densely populated areas. However, the National Travel Survey shows that people who sometimes have access to passenger cars as a driver travel 6,400 km per year by passenger car and the other 7,000 km with other modes of transport. In table 6, we list practical measures from everyday to less frequent choices in reducing GHG emissions of domestic travel. Many of the measures listed in table 6, such as ride sharing, multimodal travel chains and car sharing, are becoming easier to adopt and use with new mobility-as-a-service (Maas) concepts.

Table 6. Measures to reduce GHG emissions of domestic travel.

	Start today	**Easy and low-cost**	**Plan ahead**
Car driving	Adopt economic driving practices.	Share rides with family, friends and colleagues or use ridesharing platforms.	
		Instead of buying a (second) car, use car sharing or rental services and choose efficient cars.	Choose an efficient car that uses fuel from renewable, low-carbon sources.
Transport mode shift	Walk and/or cycle short trips.	Plan and combine trips in order to travel less with private motorised transport.	Use bicycle or electric bicycle for trips up to 20 km.
		Use public transport, multimodal transport chains, park-and-ride facilities in major public transport nodes.	
	Use services from areas you can reach by walking, cycling and public transport.		Choose your place of residence from an area with good public transport connections and infrastructure for walking and cycling.

3.3 Food

Key points to take action on:

- Buy only what you use in order to avoid food waste. Utilise near end-of-date products and food that would otherwise go to waste at home, shops or restaurants.
- Favour vegetarian items, especially plant-based proteins and fish from sustainable sources. Decrease the amount of meat, especially ruminant meat, and dairy in your diet.

Food and beverages (excluding alcohol) accounted for 16% of the consumption carbon footprint in Finland in 2010 (ENVIMAT). The per capita carbon footprint of food was 1.8 tonnes per year. We estimated that a 50% decrease of GHG emissions of food is possible. The estimation was based on literature on GHG intensities of diets. In a report for the Finnish Climate Change Panel (Seppälä et al., 2014), Roininen and Katajajuuri summarised findings from scientific literature on the potential of dietary changes to decrease the GHG emissions of food consumption. According to the summary, the potential of dietary changes was reported to vary from 5–10% to 25–50%. A similar potential was presented in a review article by Hallström et al. (2015). A more radical decrease in emissions was presented in the paper by Girod et al. (2014), in which the global per capita food GHG emissions was modelled to decrease from the average 1.5 t CO_2e to 0.4 tonnes per capita per year. Measures to achieve the smaller food carbon footprint included vegetarian meat substitutes such as beans and tofu, avoiding vegetarian items transported by air or grown in greenhouses heated with carbon-intensive fuels, and replacing ruminant meat with other types of meat.

The food carbon footprint calculations in the Ilmastodieetti.fi calculator also suggest that halving the average food consumption footprint is possible. The footprint of a vegan diet is even less: 0.7 tonnes of CO_2e per year. A diet with emissions of 0.9 tonnes per year, half of that of the average Finn, can be achieved by cutting ruminant meat and GHG-intensive vegetables from the diet and halving the average dairy and poultry/fish consumption.

The study by Saarinen et al. (2011) showed that reducing the food GHG emissions of a single meal by more than half is possible. GHG emissions of exemplar meals varied from 0.6 kg CO_2e (faba bean patties, potatoes and salad made of cabbage and black currants) to roughly 2.0 kg CO_2e for many meals (e.g. chicken casserole with salad made of lettuce, cucumber and tomato).

In addition to replacing carbon-intensive ingredients with low-carbon ones in our diets, decreasing food waste and the consumption of items with a low nutritional value helps decrease food-related emissions. Roininen and Katajajuuri refer to estimates that five per cent of the food bought by Finnish households is wasted. Reducing the excess intake of food, especially snacks of low nutritional value, decreases the food carbon footprint.

Based on the literature, we conclude that halving the food consumption footprint from 1.8 tonnes per year per capita to 0.9 tonnes is possible with consumption choices. There are several ways to compile a low-carbon diet. Measures listed in table 7 include practices and choices to adopt a low-carbon diet.

Table 7. Measures to decrease carbon footprint of food consumption.

	Start today
Avoiding food waste and reducing unnecessary consumption	Buy only what you need and consume. Choose smaller packages if this helps avoiding waste.
	Use ingredients and foods that would otherwise be wasted, e.g. food that shops and restaurants would otherwise throw away soon. There are mobile applications to find meals for a reduced price and restaurants cooking from ingredients that grocery stores would otherwise throw away.
	Avoid snacks with low nutritional value. Choose portion size according to your personal energy requirement.
Replacing GHG-intensive ingredients	Choose a low-carbon meal in the canteen, restaurant and cafeteria. Ask for carbon labels and favour vegetarian options over meat, especially ruminant meat.
	Replace GHG-intensive ruminant meat and hard cheese with fish, poultry, pork and soft cheeses.
	Replace GHG-intensive meat and hard cheese with vegetarian protein sources such as beans, soy products, lentils, etc.
	Choose seasonal vegetables and fruits which are not transported by air (note that long transportation distance does not necessarily mean transport by air).
	Ask for carbon labels in food items and vegetables grown in greenhouses with renewable energy.

3.4 Goods and services

Key points to take action on:

- Buy less but of higher quality, and fix and repair to extend the lifespan of existing items.
- Rent and share items to enable using without owning.
- Look and ask for environmental labels such as the Nordic Swan, EU Flower and carbon-compensated products when buying new items or using services.

Goods and services accounted for 26% (3.0 tonnes per capita) of the consumption carbon footprint in Finland in 2010[1]. Goods and services categories include accommodation, cultural services, goods for recreational activities, travel expenditure abroad, clothing and electronic devices, for example. Due to the range of products and services in this consumption category, it was not easy to identify the most important measures to decrease the goods and services footprint.

We estimated that roughly a third of the footprint of goods and products including ICT-devices, clothing, goods for hobbies, alcohol and tobacco could be decreased. This would deliver roughly 0.5 tonnes of GHG savings per capita per year. We suggest that the saving can be achieved through extending the lifespan of goods that consumers already have. In practice, e.g. electronic devices would be replaced less frequently and the same applies for clothing. Also the number of different items would be decreased. Tools and other items that are rarely used could be borrowed or rented instead of buying a personal one.

The proposed saving is a rough estimate on making the carbon footprint of goods and services smaller. In addition to the decrease of the personal footprint, consumption choices give a signal to suppliers demanding low-carbon products and services. Therefore, we list (see Table 8) additional actions

[1] We have included the alcoholic beverages and tobacco (0.2 tonnes per capita) in the goods and services consumption footprint, not in the food carbon footprint. The goods and services footprint includes GHG emissions from education and health care directly paid (consumption expenditure) by households. However, the 0.3 tonnes per capita footprint included in the goods and services category does not fully cover the social services as they are provided in subsidised prices or for free. The rest of the social services footprint is included in the government expenditure footprint.

to reduce GHG emissions of goods and services consumption. Some of the presented choices have a contribution in another consumption category, e.g. housing through electricity consumption.

Table 8. Measures to reduce the carbon footprint of goods and services.

Start today	**Easy and low-cost**
Seek and ask for carbon or other eco-labels when buying goods and services.	Opt for electric devices with low power consumption.
Seek and ask for products and services made with renewable energy, e.g. the Ecoenergy label.	Try out and make use of product-service systems such as peer-to-peer or commercial services such as tools sharing or rental
Repair or use repair services to extend the lifespan of the goods that you own.	
Opt for second-hand items. The second-hand market has a range of options, from traditional flea markets to Facebook groups and curated collections of second-hand items.	
Opt for products made from reused and recycled materials.	

4 Discussion – System of low-carbon consumption

In this paper, we discussed the potential of consumption choices to mitigate climate change. The point was that motivated consumers can start decreasing their GHG emissions today, often without additional costs. However, the choices, their convenience and costs depend on and are influenced by various actors and circumstances in society. Is there a supply of low-carbon solutions, and how attractive are they compared to mainstream solutions? Figure 1 illustrates the system of production and consumption and the role of policy instruments in boosting both demand and supply of low-carbon products and services.

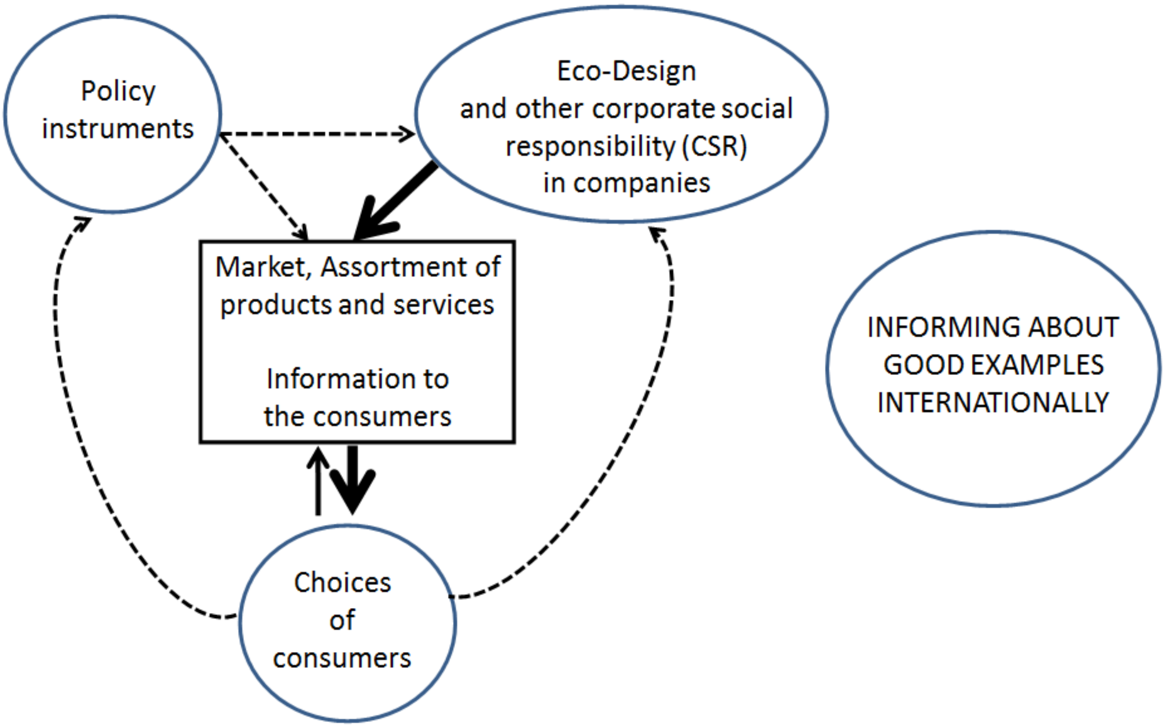

Figure 1. The system of consumption and production. Figure: Ari Nissinen.

4.1 How to make low-carbon choices more convenient and appealing?

In this report, we presented low-carbon practices, technologies and products that consumers can adopt to decrease their personal carbon footprint. The solutions can represent sufficiency, efficiency and low-carbon alternatives to current mainstream consumption practices. By sufficiency, we refer to cutting excess consumption related to e.g. energy use at home, kilometres travelled with motorised transport or food wasted. Efficiency, on the other hand, is related to e.g. energy efficiency at home or fuel efficiency of a private car. Low-carbon alternatives provide the same kind of product or service with lower GHG emissions compared to mainstream solutions. This is, of course, related to various aspects of efficiency. Examples of low-carbon products are private cars powered with renewable low-carbon fuels, eco-labelled electricity, or carbon-compensated products. Some solutions provide a service instead of replacing the product itself. Examples of services include car sharing and other mobility-as-a-service –solutions.

Although many low-carbon solutions exist, there are barriers to adopting low GHG consumption. Girod et al. (2014) propose that barriers of low-carbon consumption can be classified into four categories. The low GHG consumption option: 1) is against consumer preferences, 2) has higher total costs, 3) is more complex (i.e. product complexity), 4) requires higher capital expenditure. Understanding the barriers is important in order to develop business models and policies to make low-carbon consumption mainstream and the default choice.

While e.g. vegetable food and transport mode changes are identified as low-carbon choices, they were seen to be against consumer preferences. Girod et al. (2014) referred to projections that suggest growth in the consumption of animal products, car and air travel. Second, higher total costs of low-carbon consumption was highlighted in relation to low GHG and renewable energy and e-mobility. Third, product complexity refers to e.g. skills to identify the low-emission options and, for instance in case of housing, applying energy-efficient technologies and additional renewable energy production equipment such as solar panels. Product complexity was mentioned with almost every measure in the study of Girod et al, but it is especially highlighted with energy-efficient buildings and appliances, higher quality goods and energy-extensive but labour-intensive goods and services. Fourth, higher capital costs were related to solutions with higher investment costs and lower running costs. Examples included energy-efficient buildings and appliances, e-mobility and higher quality goods.

Policies tackling barriers of low-carbon consumption include taxation, financial incentives, standards and informational measures such as campaigns and labelling. Nissinen et al. (2015) estimated the impacts of policy instruments, such as pricing, minimum standards and public procurement policies, on GHG emissions in Finland. Nissinen et al. estimated that the application of these instruments would decrease GHG emissions by 4.5 Mt in Finland, which is more than 6% of Finland's average territorial emissions of 68 Mt for 2008–2012.

To tackle the product complexity, carbon labelling of e.g. food items and other products help motivated consumers identify low-carbon options. Also, labels can indicate use of renewable energy in the production process (see ekoenergy.org in Finland). The experiences from energy labels in home appliances are encouraging in terms of energy saving and the improved energy efficiency of devices. Labeling can be seen as a supply-side measure. However, the labelling scheme is based on policy, the EU's Energy Labelling Directive (European Commission, 2017a). This is an example of how to overcome the (potential) barriers of low-carbon consumption with public policies and supply-side solutions. Another example is an ongoing phase-out of low-efficiency lighting solutions and an increase of LED-lights.

Product complexity related to new technology in smart and energy-efficient homes can also be tackled with better design and business models extending beyond the technological solutions. The key issue is convenience. As Ritola and colleagues (2015: 21) put it: ”In addition to leveraging natural resources in more efficient ways, consumer cleantech companies must be inherently smart: accessible, easy, and attractive to use.”

Co-purchasing practices, turnkey solutions, and service and funding schemes are measures to make adoption of low-carbon solutions easier. An example of a package of energy-efficient technology, services and funding scheme is provided by LeaseGreen, a Finnish company that works on energy efficiency improvements. Customers, i.e. owners of properties, pay a monthly fee over the project period. The fee is smaller than the savings from the energy efficiency improvements, i.e. the property owners do not need to invest capital in the beginning.

4.2 Measures to raise awareness of carbon footprint and engage consumers into action

In addition to e.g. the labelling of products and services, informational measures can include more comprehensive approaches. It can for instance include tools and campaigns on the consumption carbon footprint, the potential of consumption choices to make a difference in mitigating climate change, and engaging citizens to take action. Carbon footprint calculators can introduce the order of magnitude of different consumption categories and make the carbon footprint more personal. At the same time, we need to engage citizens to take action and make visible how others are also doing their bit (e.g. the widely cited study on how to encourage hotel guests to re-use towels by Goldstein et al., 2008).

In Finland, the Ilmastodieetti.fi carbon footprint calculator was launched by the Finnish Environment Institute in 2010 and is now linked with the Citizens climate pledge campaign (see the climatepledge.global website). The campaign, launched by a non-governmental organisation called Storm Warning in 2015, aims at encouraging citizens to take action on a personal level to reduce GHG emissions and show others that one is committed to halving their carbon footprint. To find out one's current footprint, the campaign suggests that Finns use the Ilmastodieetti.fi calculator to measure their footprint and citizens from other countries to use the Climate Neutral Now (climateneutralnow.org) calculator managed by the United Nations Framework Convention on Climate Change. There are also a number of other initiatives and campaigns on climate change in Finland, such as Protect Our Winters (POW), Carbon Neutral Municipalities (HINKU) and Hiilivapaa Suomi, to name a few.

4.3 Carbon and other environmental footprints and indicators

In this report, we focused on the GHG emissions (carbon footprint), which is one indicator to measure the environmental burden of our consumption and lifestyles. What do other indicators tell about our consumption and lifestyle?

Steen-Olsen et al. (2012) analysed the carbon, land and water footprints of the European Union from the consumption perspective. According to their analysis, the consumption of an average EU citizen in 2004 led to 13.3 tonnes of CO_2e, 2.53 global hectares (gha) of land and 179 m^3 of water. The global averages were 5.7 t CO_2e, 1.23 gha and 163 m^3 respectively, meaning that the EU average was more than double for GHG emissions and land use.

The results of the ENVIMAT model for Finland (Nissinen et al., 2007; Seppälä et al., 2009) demonstrated how the GHG emissions and eco-index, taking into account various environmental impact categories (climate change, ozone depletion, acidification, low level ozone, eutrophication, natural land and fresh water eco toxicity, human toxicity, particulate formation), tell a similar story about the environmental burden. However, in the case of food consumption, the eco-index indicated an even higher burden compared to GHG emissions due to e.g. eutrophication.

The scientific community has proposed more overarching concepts to tackle the multiple dimensions of environmental pressure, such as the footprint family (Galli et al., 2012) and planetary boundaries (e.g. the recent paper by Steffen et al., 2015). Multi-dimensional analysis and indicators are important in order to avoid shifting problems from one impact category to another. However, the aforementioned studies of Steen-Olsen et al. and Seppälä et al. suggest that various indicators point to the same direction. Clearly, there is a need to change our current consumption practices and patterns in order to simultaneously mitigate climate change and reduce other environmental burdens. From the supply-side measures, the development of the product environment footprint (European Commission, 2017b) is a potential avenue for improving product information.

Carbon footprint	Refers to life-cycle emissions of a certain good or service from raw material extraction until the end of the life-cycle. For instance the life-cycle emissions of car use cover, in addition to end-of-pipe emissions from driving, e.g. the manufacturing of the fuel and the vehicle and the emissions at the recycling and waste management phases. See also the ISO standard on carbon footprint of products (ISO/TS 14067:2013).
CO_2e	Refers to CO_2, methane CH_4 and nitrous oxide N_2O converted to CO_2 -equivalents.
Consumption carbon footprint	In this paper we use the concept when referring to the GHG emissions of household consumption expenditure.
GHG emissions	Greenhouse gas emissions, see CO_2e.
Household consumption expenditure	Refers to consumer (household) spending on goods and services expressed as consumer prices. The concept is used in the national account system.
Embodied emissions	Refers to the GHG emissions emitted in the production of the good or service. For example, residential buildings' embodied emissions consist of the emissions related to the building materials and building processes.

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APPENDIX 1

Example of housing GHG savings in two exemplar cases based on Seppälä et al. (2014) and Mattinen et al. (2016).

	Apartment 80 m^2 (2 persons) in tonnes of CO_2e	House 160 m^2, oil heating (4 persons) in tonnes of CO_2e
Baseline GHG emissions per year per household	6.0	13.0
Savings		
Insulation of outer walls and replacing windows	1.2	2.9
Heat recovery	0.7	1.7
Adjusting water pressure in the whole building to reduce (hot) water consumption.	0.1	0.4
Lower indoor temperature by 2 °C	0.2	0.3
Hot water saving (shorter showers)	0.1	0.3
Electricity savings, more efficient devices and LED lights	0.4	0.9
Renewable electricity	1.0	1.8
Total savings	**3.8**	**8.3**

In some cases the presented measures overlap, and this is taken into account. It is assumed that the renovation measures are done first and behaviour change measures are calculated after that. Therefore, the savings from e.g. lower indoor temperature would be greater without renovation measures.

The calculations are mainly based on life-cycle approach. An exception is the efficient devices and renewable electricity. It was assumed that devices and light bulbs are changed at the end of their life-cycle when they would need to be replaced in any case. GHG intensity of renewable electricity was assumed to be zero. In practice, renewable electricity also contributes to GHG emissions. There is variation of intensity depending on the source of the energy. Emissions could be estimated to be roughly 20 g CO_2e per kWh (Kopsakangas-Savolainen et al., 2015), which is less than 10% of the current GHG intensity of the Finnish electricity mix.

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