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207 The Impact of the Urban Environment on Consumption-Based Carbon Footprints of Climate Concerned Urban Dwellers

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Abstract

The Nordic countries are held as green due to their low-carbon energy systems. However, their global climate impacts are among the highest when the emissions are allocated based on consumption, particularly that of the urban residents. The purpose of this study is to examine and test methods to study if different types of urban environments influence on the consumption of the citizens of Helsinki metropolitan area. It is known that the urban environment has an affect on consumer behaviours and that climate concern might be related to lower carbon footprints. In this study the aim is to better understand how consumption is related to local urban characteristics and how it could be studied, how strong these connections might be and could climate concerned citizens consume differently based on the characteristics of their living environment. Could some urban environmental characteristics support low-carbon lifestyles of their residents, and could this connection be found by using our methods? In this study we are testing our methods by utilizing our carbon footprint pilot survey data, to later study consumption of climate concerned urban dwellers in different types of urban environments by using our upcoming carbon footprint survey data. Novel statistical approaches in the research field are used in this study, such as a factor analysis to study different climate change concern variables as well as GIS analyses to study the spatial aspects. The main source of data is our carbon footprint pilot survey, executed in Finland. As the sample size is limited, exploring and testing the methods for our future studies remains as the main purpose of this paper. The results are going to show if it seems like the urban environment could have an impact on consumption habits of urban dwellers in addition to their climate concern and if these connections can be found by using the methods of this study.

Keywords: Carbon Footprints, Sustainable Cities, Climate Change Concern, 1.5 degrees

Introduction

The current climate change is one of the biggest threats of our times, getting close to transgress our planetary boundaries (Rockström et al. 2009; Steffen et al. 2015). Stopping the global warming at 1,5 degree Celsius level would require both rapid and radical changes from humans (IPCC, 2018). Consumption-based carbon footprints are a tool to quantify the impacts of the current globalized trade exchange and to reduce those impacts. Cities, being the centres for economic growth, can be seen as the main drivers for global warming (Edenhofer et al. 2014; Glaeser & Gottlieb 2009; Glaeser & Kahn 2010). As the centres of consumption, cities are driving three quarters of the global greenhouse gas (GHG) emissions directly or indirectly (Satterthwaite, 2008; Kennedy et al. 2012). Urbanization as such seems to increase environmental burdens when the indirect impact of the consumption is allocated to the final consumers in the cities (Ottelin et al. 2019; Wachsmuth et al., 2016; Heinonen & Johannesson, 2019; Heinonen et al., 2013 a-b; Wiedenhofer et al., 2013).

In this study, the aim is to examine if climate concerned urban dwellers could have significantly different GHG emissions of consumption on different types of urban living environments. Could some urban environmental characteristics support low-carbon lifestyles of their residents more than others? On the global scale, Nordic countries are among the highest polluters when it comes to GHG emissions form consumption. Hence, studying the consumption in Nordic contexts provides a great base to study these differences and the possible impact of the living environment. The purpose of this paper is to test our research questions and our methods to later study the topic more comprehensively by utilizing our upcoming carbon footprint survey data and methods and research questions presented in this paper.

This conference paper provides a preliminary overview on how the consumption patterns and carbon footprints of climate concerned urban dwellers may differ on city centres and other urban localities in Helsinki metropolitan area, based on our pilot data of our upcoming carbon footprint survey. As the pilot data provides us with a smaller sample size than the upcoming survey, we are going to separate our analysis of variance of climate change attitudes (Chapter: “Climate Change Attitudes Results and Discussion”) from the spatial analysis of the individual GHG emissions of consumption of goods and services of the urban dwellers (Chapter: “The Impact of the Urban Environment on Consumption Based GHG emissions of Climate Concerned Urban Dwellers”). Due to the limited sample size, exploring and testing the methods for our future studies remains as the main purpose of this paper.

Methods

The carbon footprint survey pilot data is used to study consumption, living place and climate change concern of urban consumers who participated to our survey's pilot round in Finland. The carbon footprint survey pilot data covers 60 responses, which does not yet allow us to interpret all the statistical approaches we are planning to use to further study this topic. However, the research question can already be tested on a simple two-class zoning in Helsinki metropolitan area by combining the spatial information with the carbon footprint survey pilot data and some supportive carbon footprint data. These are presented in detail in this Methods Chapter.

Carbon Footprint Survey Pilot Data

Our upcoming carbon footprint survey will provide us with detailed information about the consumption, lifestyles, climate change attitudes and behaviours of consumers living in Nordic countries. The survey will be executed in Iceland, Finland, Denmark, Sweden and Norway and it includes an inbuilt carbon footprint calculator and consists of 113 questions. However, for this study only the pilot survey data of this carbon footprint survey can be utilized.

Most of the pilot survey participants (60) live in Helsinki metropolitan area. Pilot survey questions about climate change attitudes (12 questions) and "Where do you live?" (OpenStreetMap, where the pilot survey participants mark their home location on a map with up to 200 metres accuracy) and the questions about diet and consumption of goods and services (see in further detail in Chapter: Calculating the GHG emissions of Consumption) are utilized in this study.

Pilot survey participants who live in the Helsinki metropolitan area (Helsinki, Espoo, Vantaa and Kauniainen) are separated from the pilot survey data by using an overlay analysis in GIS. From these, the climate concerned urban dwellers are selected to further studies by excluding those who answered "(1) not at all" or "(2) slightly" to the survey question "How worried are you about climate change?" Therefore, only participants who live in the Helsinki metropolitan area and are "(3) moderately", "(4) very" or "(5) extremely" worried about climate change are included in this study. After these measures, the sample size is 46.

As our carbon footprint pilot survey includes 12 different questions about participants' attitudes towards climate change, a preliminary factor analysis on climate change variables is also conducted and included in this study but due to low sample size it is not included in spatial analysis.

Calculating the GHG Emissions of Consumption

To get some indications about the consumption-based carbon footprints of our pilot survey participants, the greenhouse gas emissions of their consumption of goods and services is calculated. This includes their consumption of food (diet) and the following

consumption categories: Alcohol & Cigarettes; Clothing & Footwear; Interior Design & Housekeeping; Health; Recreation, Sports & Culture; Restaurants; Hotels; Electronics; Other Goods & Services. Housing and transportation were excluded from these pilot data based analyses but will be included in our future studies. All the other relevant consumption categories are included, and they are based on the Classification of Individual Consumption by Purpose (COICOP) categories (United Nations, 2018).

In our pilot survey, the participants were asked to estimate how much money they consume in these different consumption categories mentioned above, and to choose one of the following diets: vegan, vegetarian, pescatarian or omnivore. If they chose omnivore, the conditional question about "Please estimate which one of the following options best describes your daily/weekly meat consumption" is shown, among the following answer options to choose from: At least once or twice a day (300 g/day); Almost everyday (150 g/day); Two to three times a week (70 g/day); Maximum once or twice a week (50 g/day).

The greenhouse gas emissions resulting from the consumption of the pilot survey participants (excluding diet) is calculated by using Exiobase 2015, extrapolated model of Exiobase 2011 (Tukker et al. 2014). Exiobase category combinations are based on the paper of Ottelin et al. (2020) and are defined in Table 1. Exiobase basic prices are transformed to purchasers' prices and, in the case of Finland, the territorial GHG emissions are upscaled to match the total emissions in 2015 as reported by Statistics Finland (see Ottelin et al. 2021 for details). The fixed Exiobase coefficients used in this study are shown in the Table 1.

Table 1. Exiobase consumption categories and GHG coefficients used in this study.

Category	Exiobase codes and calculations	kg CO2e/€
Alcohol & Cigarettes	([CP021&CP012] + [CP022])/2	0,15
Clothing & Footwear	[CP052, CP0311&CP0313]	0,09
Interior Design & Housekeeping	([CP054] + [CP0721 & CP055] + [CP0561])/2	0,37
Health	([CP123&CP061] + [CP124&CP063&CP062]) / 2	0,18
Recreation, Sports & Culture	([CP094] + [CP095])/2	0,15
Restaurants	[CP11]	0,16

Hotels	[CP11]	0,16
Electronics	[CP0914, CP0912, CP0911, CP082]	0,26
Other goods & services	[CP127, CP1211, CP0923, CP0915, CP0562, CP0533, CP0513, CP0444, CP0432, CP0322, CP0314])	0,11

Consumption of food is calculated separately to include the different climate impacts of different diets. To define the GHG coefficients for different diets, we use values based on the diagrams of Saarinen et al. (2019), accompanying one additional category for even higher meat consumption (300 g/day). Highest meat consumption has a coefficient value which is derived from the previous diet coefficient values from Saarinen et al. (2019). The values used to calculate the diet emissions are presented in Table 2.

Table 2. Greenhouse gas coefficients used to calculate the yearly climate impact of an individual's diet (Saarinen et al 2019).

Diet	Kg CO2e/2200kcal/day (Saarinen et al 2019)	kg CO2e/year
Vegan/vegetarian	3,1	1132
Pescatarian	3,5	1278
Omnivore 50g meat/day	4,2	1533
Omnivore 70g meat/day	4,6	1679
Omnivore 150g meat/day	6,9	2519
Omnivore 300g meat/day	(2519-1132)/2+2519	3213

Spatial datasets

The Finnish Environmental Institute's spatial datasets (2013; 2018) describing urban form are utilized in this study when analysing the connection between an urban form and consumption of climate concerned urban dwellers. The selection of the spatial dataset has a crucial role when studying the urban environment inside the city –

Helsinki's suburban districts for example are often considered as urban but at the same time they are sparsely populated when compared to city centres. Therefore, they can be divided into quite opposite regional categories depending on the dataset. In this study, the spatial dataset of city centres (Finnish Environmental Institute, 2018) is used to separate the cite centre-like urban environments from other urban localities, leading to two categories: urban localities and city centres. In this study, urban localities is a class for an urban area without city centre-like characteristics, which in Helsinki's context could be referred as suburban districts as well, after the city centres are separated from it.

The dataset used to identify the city centres in this study is based on a criterion that there is a mixture of jobs, residences and different services within a walking distance (Rehunen et al. 2014). Therefore, city centres do not only cover the actual, spoken language, city centre of Helsinki but also city centre-like urban environments in Helsinki metropolitan area. This kind of spatial dataset is ideal in a study like this where we specifically want to study the possibly different urban consumption environments. The two spatial datasets are presented in Figure 1, where these regions are also combined to some results from our carbon footprint pilot survey.

For the analysis of this paper, climate concerned urban dwellers are divided between these two regional classes by using an overlay geoprocessing tool in GIS, leading to 19 samples in urban localities -class and 25 in city centres -class. Two climate concerned pilot survey participants are left out from this study, as they are not overlapping with neither urban localities nor city centre areas but are not forming a big enough sample to include a third urban environment class either.

Results and Discussion

This chapter is divided into two separate chapters. First, we will go through our preliminary results about the impact of the urban environment on consumption based GHG emissions of climate concerned urban dwellers accompanying some discussion. Then, we will explore in further detail the climate change attitude questions and their potential in future analyses about the topic.

The Impact of the Urban Environment on Consumption Based GHG emissions of Climate Concerned Urban Dwellers

A minor difference between consumption related GHG emissions of climate concerned residents of Helsinki metropolitan area is shown from the carbon footprint survey pilot data when GHG emissions of the residents are compared between city centres and other urban localities (Figure 1). The average consumption related GHG emissions of the residents of the city centre region are 2084 kg CO2e/year while the average consumption related GHG emissions of the residents living in the other urban localities is 2150. Only those who answered "(3) Moderately", "(4) Very" or "(5) Extremely" to the

question “How worried are you about climate change?” were included in this analysis. Of them, the city centre area had an average value of 4,6/5 in “How worried are you about climate change?” answers, while other urban localities had an average value of 4,4/5. If the sample were larger, a conclusion could be drawn that the residents of city centres are more worried about climate change and consume less than those who live in other urban localities in Helsinki metropolitan area.

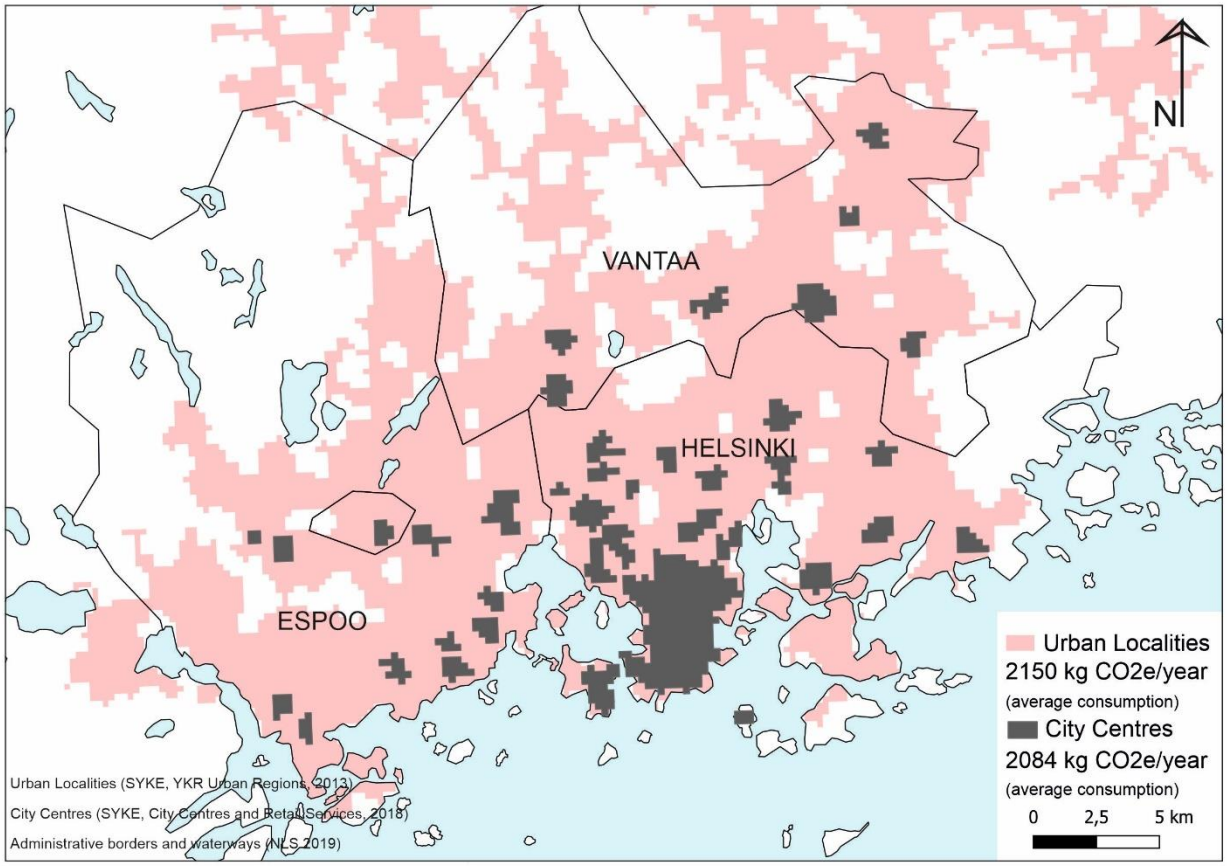

Figure 1. GHG emissions of consumption of goods and services by climate concerned urban dwellers on Helsinki Metropolitan Area’s city centres and urban localities. Only consumers who are moderately, very or extremely worried about climate change are included. Average consumption of climate concerned urban dwellers in city centres is 2084 kg CO2e/year while in urban localities the average consumption is 2150 kg CO2e/year.

However, these differences are so small, as is the sample size of our carbon footprint pilot survey, that no conclusions can be drawn to either direction. Equally, it could be very possible that the results of the upcoming carbon footprint survey will show an opposite pattern. A correlation between climate concern and higher GHG emissions have been found in previous studies for example related to trips abroad (Czepkiewicz et al. 2019). Ottelin et al. (2015) have shown that the residents of inner urban areas have higher carbon footprints while smallest carbon footprints were found in newly built outer and peri-urban areas, also when income level differences were taken into account.

While our upcoming carbon footprint survey will cover also the GHG emissions from housing, vehicle, local and long-distance travel, second homes and pets, this pilot data-based study is limited to include only the consumption of goods and services with a limited sample size – Hence, we cannot yet draw conclusions, but we can ask: Could climate concern predict lower carbon footprints? And on the other hand: Could living in a certain type of urban region predict higher carbon footprints?

Climate Change Attitudes Results and Discussion

As our carbon footprint pilot survey includes 12 different questions about participants' attitudes towards climate change, a preliminary factor analysis on climate change variables was conducted (Figure 2). As the data violated assumptions of normality, principal axis factoring with promax rotation was used. Based on the results, three factors, presented in Figure 2, were identified for the analysis. The 12 climate change attitude questions in the carbon footprint pilot survey are the following, with an answer scale from 1 to 5 (1 = not at all, 5 = extremely):

hwy= How worried are you about climate change?

hfg= How much do you think climate change will harm future generations of people?

hyp= How much do you think climate change will harm you personally?

hip= How important is the issue of climate change to you personally?

hai= How likely do you think it is that your actions will influence others to behave in ways that reduce greenhouse gas emissions resulting from their lifestyles?

hwc= How likely do you think it is that large numbers of people will voluntarily change their lifestyles to try to mitigate climate change?

imc= How important it is to mitigate climate change?

cfl= How climate sustainable would you think that your own lifestyle is?

kib= Do you feel that you are knowledgeable about the climate impacts of your consumption choices?

pcf= In your opinion, how important are the following in mitigating climate change? [Lifestyle changes to reduce one's personal carbon footprint]

gmm= In your opinion, how important are the following in mitigating climate change? [Governmental/municipal measures (limitations, regulations, funding allocations etc.)]

ted= In your opinion, how important are the following in mitigating climate change? [Technological development]

PAF	PA1	PA2	PA3	Comm.
hwy	0.02	0.24	0.53	0.53
hfg	0.04	0.10	0.78	0.76
hyp	-0.01	-0.15	0.89	0.63
hip	0.66	0.36	-0.01	0.84
hai	0.79	-0.14	0.00	0.51
kib	0.62	0.03	0.03	0.43
imc	-0.07	0.99	0.04	0.94
gmm	-0.02	0.88	-0.07	0.69
p. var	0.19	0.26	0.22	
c.var				0.66

Figure 2. Climate attitude factors. Factor loadings and communality values of climate change attitude variables of the carbon footprint pilot survey.

Since the sample size of the pilot data is low, the communality values for different variables remain relatively low as well. Out of 12 climate change attitude questions, 8 were included in the factor analysis and four were left out due to exceptionally low communality values. However, Figure 2 shows that after the implementation of the upcoming carbon footprint survey, the bigger sample sizes will most likely allow us to conduct and interpret the results of variance and linear mixed effect models analyses of climate concern and attitudes. Then, the results can be combined to consumption-based carbon footprints and urban form in the similar manner as we now used just a single “How worried are you about climate change?” question to include only climate concerned individuals to our spatial carbon footprint studies (Figure 1).

With bigger data samples, also more detailed spatial classifications could be used. The suburban districts could be separated to various other regional categories, e.g., in Helsinki the more sparsely built forest suburbs built in 1950s and 1960s could be separated from the newer, densely built suburbs built after 1970s and representing a relatively different urban environment which could be connected to climate change attitude factor analysis results as well. And, when including only extremely concerned urban dwellers, could the carbon footprints differ between city centres and other urban localities or even between sparsely and densely built suburbs?

Conclusions

This study presents some important research questions, methods and possible future results of the possible impacts of the urban environment on consumption-based carbon footprints of climate concerned urban dwellers by utilizing the pilot data of our upcoming carbon footprint survey.

The study implicates that those possibly significant differences between consumption-based carbon footprints on different types of urban environments among climate

concerned urban dwellers can be determined by further processing the methods and practices we utilized in this study by applying them to our upcoming carbon footprint survey data. With a larger data sample, even more detailed regional classifications in GIS can be connect to statistical analyses of climate change attitudes. Most importantly, GHG emissions from diet, housing, vehicle, local and long-distance travel, consumption of goods and services, second homes and pets can be included into our calculations of the consumption-based carbon footprints of the participants.

This kind of comprehensive study with a large data will also allow us to connect the results to the remaining global carbon budget for halting global warming to 1.5 degrees to see if some types of urban environments are supporting sustainable lifestyles more than others. This paper set the methodological framework for our future studies of the topic.

References

Czepkiewicz, M.; Árnadóttir, Á.; Heinonen, J. (2019): Flights Dominate Travel Emissions of Young Urbanites. *Sustainability*, 11, 6340.

Edenhofer, O.; Pichs-Madruga, R.; Sokona, Y.; Farahani, E.; Kadner, S.; Seyboth, K.; Adler, A.; Baum, I.; Brunner, S.; Eickemeier, P. (2014): Climate change 2014: mitigation of climate change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 511-597.

Finnish Environmental Institute (2018). City Centres and Retail Services. SYKE's open data collection (CC BY 4.0). Accessed 28/6/2021. *https://ckan.ymparisto.fi/dataset/%7B79B6DD92-3448-402D-95A9-D56B484CD6A1%7D*

Finnish Environmental Institute (2013). YKR Urban Regions. SYKE's open data collection (CC BY 4.0). Accessed 28/6/2021. *https://ckan.ymparisto.fi/dataset/%7BE3E29357-4333-4C11-8E0E-FCD7307F91EE%7D*

Glaeser, E.; Gottlieb, J. (2009): The wealth of cities: Agglomeration economies and spatial equilibrium in the United States. Journal of Economic Literature, 47(4), pp. 983-1028.

Glaeser, E.; Kahn, M. (2010): The greenness of cities: Carbon dioxide emissions and urban development. Journal of Urban Economics, 67(3), pp. 404-418.

Heinonen, J.; Jalas, M.; Juntunen, J.K.; Ala-Mantila, S.; Junnila, S. (2013a): Situated lifestyles: I. How lifestyles change along with the level of urbanization and what the greenhouse gas implications are — a study of Finland, Environmental Research Letters, 8(2).

Heinonen, J.; Jalas, M.; Juntunen, J.K.; Ala-Mantila, S.; Junnila, S. (2013b): Situated lifestyles: II. The impacts of urban density, housing type and motorization on the greenhouse gas emissions of the middle income consumers in Finland, Environmental Research Letters, 8(3).

Heinonen, J.; Jóhannesson, S. (2019): More Consumption, Less Production: The Low-Carbon Illusion of Cities, in Sustainable Consumption, Promise or Myth? Case Studies from the Field, [(eds): Jean Léon Boucher and Jukka Heinonen, Cambridge Scholars Publishing, UK].

IPCC (2018): Summary for Policymakers in Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1,5°C above pre-industrial levels and related global greenhouse gas emission pathways in the context of strengthening the global response to the threat of climate change sustainable development and efforts to eradicate poverty. [(eds): V. Masson-Delmotte, P. Zhai, H. O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, T. Waterfield]. World Meteorological Organization, Geneva, Switzerland, 32 pp.

Kennedy, C.; Demoulin, S.; Mohareb, E. (2012): Cities reducing their greenhouse gas emissions. Energy Policy, 49, pp. 774–777.

Ottelin, J.; Ala-Mantila, S.; Heinonen, J.; Wiedmann, T.; Clarke, J.; Junnila, S. (2019): What can we learn from consumption-based carbon footprints at different spatial scales? Review of policy implications. Environmental Research Letters, 14, 093001.

Ottelin, J.; Amiri, A.; Steubing, B.; Junnila, S. (2021). Comparative carbon footprint analysis of residents of wooden and non-wooden houses in Finland. Environmental Research Letters.

Ottelin, J.; Cetinay, H.; Behrens, P. (2020): Rebound effects may jeopardize the resource savings of circular consumption: evidence from household material footprints. Environmental Research Letters, Volume 15, Number 10.

Ottelin, J.; Heinonen, J.; Junnila, S. (2015): New Energy Efficient Housing Has Reduced Carbon Footprints in Outer but Not in Inner Urban Areas. Science & Technology, 49 (16), pp. 9574-9583.

Rehunen, A.; Helminen, V.; Kosonen, P.; Viinikka, A.; Ahonen, O.; Käyhkö, H. (2014): Keskusta-alueet ja vähittäiskauppa kaupunkiseuduilla. Ympäristöministeriön raportteja 8/2014, Ministry of the Environment, 144 pp.

Rockström, J.; Steffen, W.; Noone, K.; Persson, Å.; Chapin, S.; Lambin, E.; Lenton, T.; Scheffer, M.; Folke, C.; Schellnhuber, H.; Nykvist, B.; de Wit, C.; Hughea, T.; van

der Leeuw, S.; Rodhe, H.; Sörlin, S.; Snyder, P.; Costanza, R.; Svedin, U.; Falkenmark, M.; Karlberg, L.; Corell, R.; Fabry, V.; Hansen, J.; Walker, B.; Liverman, D.; Richardson, K.; Crutzen, P.; Foley J. (2009): A safe operating space for humanity. Nature, 461, pp. 472–475.

Saarinen, M.; Kaljonen, M.; Niemi, J.; Antikainen, R.; Hakala, K.; Hartikainen, H.; Heikkinen, J.; Joensuu, K.; Lehtonen, H.; Mattila, T.; Nisonen, S.; Ketoja, E.; Knuuttila, M.; Regina, K.; Rikkonen, P.; Seppälä, J; Varho, V. (2019): Ruokavaliomuutoksen vaikutukset ja muutosta tukevat politiikkayhdistelmät - RuokaMinimi-hankkeen loppuraportti. Valtioneuvoston selvitys- ja tutkimustoiminnan julkaisusarja 2019:47. Valtioneuvoston kanslia, Helsinki, 160 pp.

Satterthwaite, D. (2008): Cities' contribution to global warming: Notes on the allocation of greenhouse gas emissions. Environ. and Urbanization, 20 (2), pp. 539–549.

Steffen, W.; Richardson, K.; Rockstrom, J.; Cornell, S.E.; Fetzer, I.; Bennett, E.M.; Biggs, R.; Carpenter, S.R.; de Vries, W.; de Wit, C.A.; Folke, C.; Gerten, D.; Heinke, J.; Mace, G.M.; Persson, L.M.; Ramanathan, V.; Reyers, B.; Sorlin, S. (2015): Planetary boundaries: guiding human development on a changing planet. Science, 347 (6223),1259855.

Tukker, A.; Bulavskaya, T.; Giljum, S.; Koning, A.; Lutter, F. S.; Simas, M.; Stadler, K.; Wood, R. (2014): The Global Resource Footprint of Nations: Carbon, water, land and materials embodied in trade and final consumption calculated with EXIOBASE 2.1. (Leiden/Delft/Vienna/Trondheim)

United Nations (2018): Classification of Individual Consumption According to Purpose (COICOP) 2018. Department of Economic and Social Affairs, Statistics Division. Statistical papers, Series M No. 99, 265 pp.

Wachsmuth, D.; Aldana Cohen, D.; Angelo, H. (2016): Expand the frontiers of urban sustainability. Nature, 536, pp. 391-393.

Wiedenhofer, D.; Lenzen, M.; Steinberger, J.K. (2013): Energy requirements of consumption: Urban form, climatic and socio-economic factors, rebounds and their policy implications. Energy Policy, 63, pp. 696-707.