Sustainable Consumption, Promise or Myth?

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Case Studies from the Field

Edited by

Jean Léon Boucher and Jukka Heinonen

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We would like to dedicate this book to those—on an apparently fragile planet—who, themselves, dedicate much of their energy to thinking and/or working towards a vision of human-environmental sustainability.

—Jean and Jukka

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PREFACE

JEAN LÉON BOUCHER AND JUKKA HEINONEN

While assembling into one volume a number of recent case studies, this collection touches upon the promise and challenge of sustainability, sustainable consumption, and sustainable lifestyles; it visits certain dimensions of society as well as some perspectives on policy and instances of social transformation. Besides critiquing certain myths of sustainability, this text, at multiple scales—individual and societal, also reports from diverse cultural sites, from Europe to the hemispheric Americas.

This book will be of interest to anyone attracted to possibilities in sustainable consumption, be the person an individual consumer or academic, or an industry professional—from private or public sectors to non-governmental organizations. It can also fit for classroom use with its case studies, empirical examples, and diverse perspectives.

Overall, this volume documents recent scholarly attempts to critique and improve understandings of consumer lifestyles, certain environmental and societal consequences of such lifestyles, and some insights into transitions toward more sustainable human-environmental interactions.

CHAPTER ONE

INTRODUCTION: THE URGENT NEED FOR HUMAN-ENVIRONMENTAL SUSTAINABILITY

JUKKA HEINONEN AND JEAN LÉON BOUCHER

At present, human consumptive behavior is severely exploiting the material and ecological services of planet Earth; as a result, our species is on the verge of causing irreversible damage to our planet's regenerative biocapacities (e.g., Barnosky et al. 2012; Ceballos et al. 2017; Steffen et al. 2015). The Earth's climate is reportedly changing more rapidly, biodiversity loss has accelerated at an alarming rate, and scientists warn of the beginnings of a new mass extinction (Ceballos et al. 2017; Chapin et al. 2000; Rockström et al. 2009; Steffen et al. 2015). At the same time, population growth continues, and while a debated driver of many ecological problems, it may also be fueling broader social problems.

Many scholars are theorizing urbanization and urban centers as a primary source of these problems, but also, in contrast, these centers are seen as critical to designing global solutions (e.g., Grim et al. 2008). More than 50% of the world's population currently live in these urban areas (UN 2015) requiring more and more land area (Seto et al. 2011), and this figure is growing. These centers have been assessed as major drivers of climate change and, indirectly, of current environmental degradation. However, clear solutions are not immediately in view, particularly at the global level. Neither is it known who the primary change agents are, for example, bottom up grassroot movements or top-down policies. Grassroot actors may be more progressive in their demands and actions, but their overall impact is most likely limited.

Even if a sustainable future is beyond the present human view, new initiatives keep appearing that potentially improve the chances of solving the present puzzle. Furthermore, these initiatives appear in all forms: from intergovernmental high-level treaties such as the Paris Accord; nation-state

activities (e.g., the Climate Mayors agreement in the USA); municipal agreements—at both the global and local levels (e.g., C40 Cities Climate Leadership Group and the International Council for Local Environmental Initiatives [ICLEI]); and grassroots activist movements and organizations, some of which extend internationally (e.g., WWF, Greenpeace, and others) while others are critical to low-impact, regenerative technologies, or the promotion of more sustainable lifestyles.

Reports from the global field: Individuals, movements, and communities

In this book, we provide a collection of "reports from the field," mostly case studies of different initiatives in the broad field of sustainable consumption, inclusive of grassroots interventions, community-level assessments, and even the individual consumer. This volume is not meant to be a comprehensive selection but offers new thoughts and ideas through a set of *cases from the field* that are not covered by previous publication. These reports touch upon several different scales in the research field of sustainable consumption: from cities to individuals, from communities to social movements.

Sustainability and the Consumer

Consumer choices are important drivers of present societal functioning, they influence the production of goods, but also the negative environmental impacts of such production. Especially when it comes to affluent societies, consumers can have particularly costly preferences—both economically and environmentally—as they strive toward higher and higher levels of material satisfaction. Consumers also decide how they live, reside, if they will travel—where, when, and how—and who will be their political leaders; leaders who may or may not set policies for greater environmental sustainability. In this book, we consider some of the different perspectives of the consumer as a driver of consumption culture, practices and policies; through these case studies different insights may be gleaned.

Jukka Heinonen and Sigurður Eyberg Jóhannesson present the first case study—the case of the "low-carbon illusion of cities": how urban centers are often reported as more sustainable than non-urban areas while this might not be the case in reality. The illusion arises when consumption in affluent cities continually expands, whereas production moves to lower production cost locations. City-scale territorial assessments may in such cases show decreasing emissions while the demand of the city actually drives more and

more emissions globally. Heinonen and Jóhannesson study Iceland and assess the consumption-based carbon footprints of different types of settlements accounting for all private consumption. Iceland makes an interesting case as it produces a very limited variety of consumer goods while its high affluence drives consumeristic lifestyles, particularly in the capital area and a few other centers. They find that carbon footprints are generally as high as in other Nordic countries despite the carbon-free electricity and heat production. Furthermore, emissions are the highest in the capital region, followed by other cities, which ultimately maintains the low-carbon illusion of the cities hypothesis.

The carbon footprint approach continues in the next chapter in which Juudit Ottelin, Jukka Heinonen and Seppo Junnila test the relationship between city compactness and consumption-based carbon footprints of residents. Their approach arises from the current contradictory beliefs about the impact of compactness. On one hand, compactness is expected to reduce greenhouse gas emissions. On the other, these dense urban areas are associated with agglomeration economies; increasing population leading to increasing productivity. They argue that this is a critical point as income is the main driver of personal carbon footprint and economic growth the main driver of global GHGs. Their study includes the 20 largest cities in Finland and depicts how, in this context, compactness is associated with increasing income and increasing carbon footprints. The emissions caused by driving decrease, but the emissions caused by other consumption increase and offset the gains from higher compactness. The authors argue that decision-makers should understand that the compact city concept might work directly against initiatives toward environmental sustainability.

While these early chapters focus on personal consumption and related GHGs, cars and driving are still a major emissions source, and probably the one for which most reduction schemes are designed. In Chapter 4, Paul Nieuwenhuis reflects on a consumer product with an immense environmental impact, the automobile. He approaches mobility and particularly personal car ownership and use from a systemic philosophical perspective; he argues that an understanding of the whole car system is central to any attempts toward its more sustainable consumption and production. He also states that the unsustainability of the car system should not be taken just as a technological issue, but also as a philosophical and sociological one; why do we possess cars as we currently do, why do they remain in use for such a short period, and how to affect these issues. He extends his discussion to the root drivers of the current unsustainable consumption economy and suggests solutions for the car system.

Jean Léon Boucher continues with the mobility issue by selectively analyzing cars, climate change attitudes, and social norms. His study arises from the ground set by the climate change crisis and how spatialized attitudes and norms may affect one of the major climate change drivers: the motor vehicle and its usage. In the context of the U.S., he finds that those "Alarmed" by climate change minimally reduce their driving related emissions and, though there is a certain "power of the social" that influences vehicle emission rates—more than usage itself, household income remains the more powerful determinant of carbon intensive behaviors. Though Boucher argues for more scholarly research on the "power of the social," the persistent income-carbon relationship and the "power to pollute" should also be addressed by policy makers.

Sustainability in Community

After the carbon footprint and mobility cases the book veers toward community-level action.[1] Community-level action plays an important role in the search for more sustainable ways to organize individual and collective lifestyles and in improving the equality among human communities. Eco-villages, car-sharing clubs, car-free neighborhoods, as well as urban gardening and other local-food initiatives are examples of community actions which may lead to greater collective sustainability, while possibly spreading to the wider society. More recently, "downshifting" types of communities seem to have gained some traction while warnings increase that the current fossil-fuel based economy is leading to ecological disaster.

This book covers three examples of community-level action towards sustainability and one community-level "environmental entrepreneur" case. In chapter six Spencer Harbo and Raymond De Young present a study on the motivations and conditions that facilitated community-based resource sharing in a community in Southeastern Michigan. They critique the current state of hyper-individualized consumption, where resource sharing is scarce and fossil-fuel dependency high. They find common motivations for sharing in frugality, social participation and meaningful action. Moreover, they find a spillover effect which leads sharing to other pro-environmental and pro-social behaviors, suggesting that a cultural shift toward community-based resource sharing may further influence human values, norms, and actions towards a "greener" society.

Next Chelsea Schelly presents the cases of two intentional communities and shows how alternative forms of economic organization offer a potential

[1] All these cases are multi-scalar, but we loosely try to cluster them.

for shifting economies away from environmentally catastrophic practices and toward a higher quality of life for more people. She presents two bottom-up case studies: Twin Oaks, a labor and income sharing community, and Dancing Rabbit Ecovillage. She describes how these communities reach significantly lower material and space requirements through sharing and a partial decoupling from the regular monetary economy. These case studies offer interesting policy-insights. Firstly, in an effort to reduce materialism and consumerism, what can practitioners and policy-makers learn from these communities? Secondly, Schelly identifies how current regulations largely prevent alternative communities from emerging. She suggests that the most valuable tool for environmental sustainability might be to allow for flexible experimentation in alternative forms of organizing residential life.

In the third community-level study, Rita Afonso, Cristine Carvalho and Bibiana Serpa examine three case studies in Brazil and ask if culture in the favelas could be considered as an ethical and sustainable field of production and consumption. Their research emerges from a quest for healthy and progressive living in an area where many people are still deprived of access to basic rights and resources. Their study offers insights into how cultural activities in favelas can be placed within the context of ethical and sustainable frameworks. They also offer ideas for improving the living conditions in such communities.

The study of the "environmental entrepreneurship," chapter nine by Vesela Veleva and Gavin Bodkin, examine from an entrepreneurial perspective some widely recognized drivers of unsustainable consumption: short product lifecycles, premature disposal, and often high repair costs. Veleva and Bodkin focus on furniture reuse and present the case of The Furniture Trust, a non-profit company in Boston, Massachusetts. The study looks into the possibilities of the "environmental entrepreneurial" business response to the problem of unused surplus furniture. They also analyze the main drivers, barriers and future opportunities for furniture reuse. They argue that there is a need for greater governmental support for environmental entrepreneurs—from funding to policy actions—in order to encourage more innovative business responses and a transition to more sustainable consumption.

Sustainability and Social Movements

Social movements are another key channel for sustainability initiatives, one which often is not bound by geographic or other boundaries, particularly in the current era of digital society. Likely boosted by the accumulation of

facts on global ecological degradation and the continued challenges of social sustainability, growing activism has emerged with the aim of altering both lifestyles and the organization of societies. Although the majority of initiatives may be categorized as the habits and actions of few individuals rather than actual movements, some are recognized globally and may impact the behavior of millions of people—while they renew efforts on both voluntary and more formal regulatory levels. The Buy Nothing Day, downshifting, permacultures, and even veganism can be taken as examples of movements of different types and scales with a common aim of improving the environmental state of the world. This volume includes three studies presenting very different perspectives to social movements.

First, Franziska Haucke discusses the Fairphone as a case for a lifestyle movement. While the Fairphone company strives toward a more ethical and sustainable smartphone manufacture, Haucke specifically concentrates on the political mobilization of Fairphone consumers, i.e., the potential transformation of individual sustainable consumption into a conscious political act and expression of ecological citizenship. With a user survey and interviews, she shows which aspects of Fairphone-usage relate to ethical and environmental responsibility and how users, through individual actions, can boost the wider movement for sustainability.

Next, Franziska Haucke, Jan Pollex and Andrea Lenschow concentrate on sustainable consumption patterns in the era of digital society. They are concerned that, despite the many attempts, there are no significant changes in current resource-intensive consumption patterns. In particular, they analyze the underlying mechanisms and structures that support individualized political actions in the context of sustainable consumption. Their focus is on the crucial role of the Internet and social media in facilitating new social dynamics, which in turn might foster new ways toward sustainability. They show how digital media has changed the premises of the emergence and subsequent power of movements toward sustainable consumption; they also argue for much stronger—replacing soft—policy measures.

In the last chapter, Satu Husso visits the role of social movements in the transition to sustainability. She notes that current actions toward sustainability have not affected contemporary consumerist lifestyles. She also examines the sustainability movement's role in tackling the issues of power embedded in the discourses and practices of pursuing a sustainable human-environmental relationship. She finds that the discourses and practices established by the sustainability movement—like Degrowth, Carrotmob, and buycott campaigns—aim to encourage people to adopt more sustainable lifestyles and to engage in broader systemic change. She

also claims that knowledge practices are essential in everyday consumption choices as well as for making broader institutional change.

A user's guide

What are the key takeaways from these studies? Though these chapters do not comprehensively converge on a singular issue, they do visit some of the different scales in sustainable consumption and provide insight for designing sustainability policy. They may also be read and "thought through" with other contexts, peoples and locations in mind. Such interactions may fuel new social initiatives and research projects aligned with the goal of creating a more sustainable future. Anyone working or teaching in the field of sustainable consumption should also be attracted to something in this diverse set of cases, from cars to Carrotmobs, from communities to consumers Additionally, as all these chapters are academically situated, the bibliographic references can serve to guide a newcomer or students trying to familiarize themselves with different facets of sustainable consumption research.

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CHAPTER TWO

MORE CONSUMPTION, LESS PRODUCTION: THE LOW-CARBON ILLUSION OF CITIES

JUKKA HEINONEN
AND SIGURÐUR EYBERG JÓHANNESSON

Abstract

This chapter presents an assessment of the consumption-based carbon footprints (CFs) in Iceland using an input-output based hybrid life cycle assessment method, including all private consumption and both direct and indirect emissions. Moreover, we compare the CFs in different types of settlements to test the "low-carbon illusion of cities" hypothesis. In territorial assessment schemes, highly urbanized areas are often reported as low-carbon areas in comparison to country averages or regional averages, but at the same time they are the key centers for consumption and actually just outsource/externalize the emissions they or their residents emit. Therefore, while cities often show reduced transport related emissions compared to less urbanized areas, the emissions from other forms of consumption typically increase and the overall CF can be greater in the densest settlements. What we found is that the CFs are the highest in the most highly urbanized areas and somewhat lower in more rural areas. Especially indirect emissions from services are significantly greater in urbanized and more affluent areas. With transport, the results also align with the hypothesis that higher population density reduces private driving, but as in several earlier studies, when all transportation related emissions are accounted for, the advantage of density is greatly reduced or disappears. Consumption power is the strongest driving factor of CFs, and affluence tends to increase in cities in comparison to less urbanized areas. Thus, when controlling for consumption expenditure, slight negative connection between density and CFs is found.

Introduction

No nation is self-sufficient in the raw materials and manufactured goods it or its residents require to fulfil their consumption needs. Actually, an increasing share of all the consumed goods are produced elsewhere than where consumed. Therefore, since the majority of all the environmental burdens of different goods are generated during the production and supply chain before the end-user (Matthews et al. 2008), a certain geographic unit often causes significant environmental pressures outside of its own area (Ivanova et al. 2016; Davis and Caldeira 2010; Chen et al. 2016).

This effect is likely to be stronger the smaller the unit analyzed. Cities and small island states are perfect examples of places where a major share of the consumed goods is imported. The resulting phenomenon can be called "the low-carbon illusion of cities," since along with urbanization and the quest for affluence, more and more consumption concentrates in cities while production is relocated to areas with lower production costs (Heinonen et al. 2013a; Wiedenhofer et al. 2013). Heinonen et al. (2013a-b) and Ottelin et al. (2015) have shown that the connection between reduced greenhouse gases (GHGs) and increased population density might not hold when accounting for the emissions embodied in imported goods. They also point out how much more complex the issue is and how policy aimed at lowering GHGs needs to take a much more holistic approach in order to truly work towards a low carbon future. Relatedly, there is evidence that many of the environmental problems in developing countries as well as a major share of their GHG emissions are "outsourced" emissions from the more affluent countries (Davis and Caldeira 2010; Ivanova et al. 2016). Nevertheless, current global initiatives to improve environmental sustainability predominantly rely on the traditional national emissions inventories, Kyoto Protocol being probably the best-known example.

Life cycle analysis (LCA) has been introduced by scholars as a more viable method to evaluate environmental impacts of systems and products. An LCA analysis not only attempts to assess direct environmental impacts but indirect impacts occurring along the whole supply chain. Carbon footprinting or assessments of GHG emissions using LCAs have become more popular in recent years (Baiocchi et al. 2010; Newman, 2006; Minx et al. 2013) as the emphasis on quantifying human GHG emissions, to inform public policy design, has gathered momentum (Laurent et al. 2012). Consumption-based carbon footprint (CF) assessments have become a more popular way of assessing the emissions caused by the consumption of goods and services of a certain geographic unit, regardless of where production takes place and emissions are actually generated. The key strength of this

method is its ability to account for carbon leakage from consumption-oriented regions, or their outsourced emissions—displaced from more affluent countries (Heinonen and Junnila 2011).

In this study, we aim to examine the consumption-based CFs in Iceland. Iceland makes an interesting case for such an assessment, since it produces very limited variety of consumer goods, but is highly affluent with its affluence concentrating mostly in the capital area and to the few other urban centers. The local energy system is near 100% renewables-based contributing to the local production-based emissions being low in global comparison. At the same time, however, many goods are imported and along with increasing affluence local life becomes more and more consumption-oriented. To realize our study, we utilize the 2002 U.S. Benchmark Purchaser Price Economic Input-Output Life-Cycle Assessment (EIO LCA) model, amended with local process data. We also use the Household Budget Survey to assess the CFs of average Icelanders living in different types of urban areas in the country. The results are cross-analyzed to understand the impacts of affluence and lifestyle differences within the country. Absolute footprints, income, region, and housing type are controlled and results are presented. Our findings strengthen the hypothesis of the "low-carbon illusion of cities."

Research methods

Life cycle analysis (LCA) is a method designed to evaluate negative impacts on the environment caused by production of products and services (Suh et al. 2004; Dong & Ng 2014). An LCA assessment includes not only direct impacts caused by the product in question but impacts associated with the whole supply chain from manufacture to disposal or re-use (cradle to grave / cradle to cradle). Vigon et al. (1993) have defined this process as:

> A concept and a methodology to evaluate the environmental effects of a product or activity by analyzing the entire life cycle of a particular product, process, or activity.

An LCA streamlined to include only GHG emissions can be called a carbon footprint (Wiedmann and Minx 2008). The most established version of LCA is the so-called process LCA where energy and mass flows are used to evaluate environmental impacts. Process LCAs are detailed, thorough accounts of inputs and discharges of any given production system or product, but on the downside, due to the level of detail, it is very time consuming and labor intensive (Hendrickson et al. 2006).

An alternative way of conducting LCA analysis is using monetary values to assess the environmental impacts of the life cycle. This kind of model is based on Wassily Leontief's economic input-output (IO) accounting, with the addition of an environmental extension. The upside of IO LCA is that compared to process LCA it greatly simplifies the assessment since the information the practitioner would have to gather from all the processes of the supply chain is now included in the input-output tables. The input-output tables are in most cases readily available as a part of national accounting. An IO LCA furthermore can include the impacts from the whole production and supply chain including capital goods or production infrastructure. On the other hand, the IO approach is based on averages and cannot produce the level of detail that a process LCA, at least in theory, can.

Practitioners and researchers often attempt to combine the best elements of these two approaches—mainly the scope of the IO with some of the detail of the process LCA—into a process/IO hybrid LCA model. These can take on various forms, but all are aimed at utilizing the benefits of the process and IO models while bypassing their biggest drawbacks (Suh et al. 2004; Hendrickson et al. 2006).

The assessment

Input data

The primary data source in this study was the most recent 2010-2012 Household Expenditure Survey of Statistics Iceland (2015). The survey provides yearly expenditure figures for different types of households located in different types of areas in Iceland. The survey captures the consumption of purchased goods and services over a year, and separates over 1,000 different categories of consumption based on an international CIOCOP classification. In addition, the survey includes a wide variety of background variables. The survey utilized in this study includes 1,765 households which include slightly over 5,000 residents.

Samples

The expenditure survey data includes a settlement type variable, which divides the settlements in Iceland into three categories: Reykjavik Capital Area (Capital), towns outside the capital area (Towns) and rural villages (Villages). These three settlement types were compared along with the housing types. Table 1 presents the samples and certain qualities related to

each sample. As the table depicts, the households are relatively similar in size, but the more affluent households live in the larger settlements and the housing types change significantly as well from the more rural types of settlements to the more urbanized.

Table 1. The samples and key qualities related to each sample.

	Capital	Towns	Villages
Sample size	1139	429	198
Average household size	2.8	2.9	2.9
Housing type			
- single family house	34%	64%	89%
- multi family house	66%	36%	11%
Annual expenditure (isk[1])	3,051,000	2,764,000	2,310,000
Possessed cars	1.3	1.4	1.4

Assessment model

We employed the U.S. economy-based EE IO model produced and published by the Carnegie Mellon University Green Design Institute, called the 2002 U.S. Benchmark Purchaser Price Economic Input-Output Life-Cycle Assessment model (EIO LCA) (CMU Green Design Institute 2010), adjusted with Icelandic data for some key local activities. The EIO LCA is among the most disaggregated models available with 428 economic sectors, which provides better sectoral fit between the model and the data than the majority of other existing models. Being a purchaser price model, the emission outputs are adjusted to the final end-user market prices. The classification follows the North American Industry Classification System (NAICS), but the fit is relatively good with the Classification of individual consumption by purpose (COICOP) system as well. The adjustments to the model are explained below and the uncertainties associated with the model selection are discussed in the discussion section.

EIO LCA assessment

Data matching and adjustments

167 EIO LCA sectors were found to match the input data with the IO model. Adjustments were made to the IO sectors to 1) account for the low-carbon energy production in Iceland (Karlsdottir et al. 2014), 2) include the

[1] Icelandic krona, average exchange rate over the data period 2010-2012: $1 = 123 isk.

emissions from fuel combustion, which typically do not appear in IO models—them being cradle-to-gate models (e.g. Lenzen 2000) and 3) adjust the US dollar-based model from 2002 to Icelandic data from 2010-2012.

Regarding building energy use, the EIO LCA model was not employed at all, but the GHG intensities of energy production were taken from Karlsdottir et al. (2014). The whole production system in Iceland is based on renewables, mainly hydro- and geothermal heat and power. Thus the GHG intensities are very low, arising mainly from the construction and maintenance of the production and delivery infrastructure: for heat 2 g CO2e/kWh and for electricity 11 g CO2e/kWh (Karlsdottir et al. 2014). There is virtually no oil or natural gas consumption in Iceland for electricity generation or for property-specific use like heating and cooking.

Petroleum combustion of private vehicles was assessed combining the EIO LCA petroleum production sector with the tailpipe GHGs from driving. Fuel price, 235.50 isk/l on average for 2010-2012, was taken from Statistics Iceland and the emissions from fuel combustion, 2.33 kg CO2e/liter from the U.S. Environmental Protection Agency. In the calculation the expenditure on fuel purchases was first used to assess the cradle-to-gate GHGs of petroleum production with the EIO LCA model and then again to add the emissions from fuel combustion based on fuel purchases following the process used by Heinonen and Junnila (2011) and Ottelin et al. (2015).

Finally, to improve the model-data match, the EIO LCA sectoral GHG intensities were adjusted according to the sectoral inflation 2002-2011 data of the U.S. Bureau of Labor Statistics Consumer Price Indices. Then the intensities were changed to Icelandic currency according to the average currency exchange rate 2010-2012, $1 = 123 isk.

Expenditure survey data weaknesses

Consumption surveys generally describe well the daily consumption patterns of households, but the accurateness decreases with less frequently purchased goods and services. Especially the emissions from residential construction are not well reflected through expenditure survey data (e.g., Ottelin et al. 2015). In previous studies these have either been fully omitted (Bin and Dowlatabadi 2005; Athanassiadis 2016), added as constant amounts for all the households (Jones and Kammen 2011), by estimating the share of the mortgage or rental payments being actually the payment for the building construction (Heinonen and Junnila 2011) or according to the year of construction and the possessed square meters (Ottelin et al. 2015). In all of these options, the impact of the building construction sector has remained relatively low and the uncertainty related to the assessment is

high, so in the current study we decided to omit the emissions from residential construction. Since the majority of new residential developments take place in the biggest cities, this decision might lead to a slight underestimation of the CFs in the areas of rapid development.

Another issue is that rental and housing management payments often include utilities and will therefore distort the CFs attributed to those living in apartment buildings (e.g., Heinonen & Junnila 2014). In Iceland, however, due to the low-carbon energy system, the impact of energy use on the CFs is low and thus no action was taken to separate these payments from housing payments, but a zero emissions intensity was given to them.

Thirdly, the expenditure surveys do not include the consumption of free-of-charge services (public services paid through taxes). In Iceland, like other Nordic countries, education, daycare and healthcare services are heavily subsidized almost free-of-charge services and thus an input-output approach leads to a significant underestimation of the emissions from these. Especially healthcare, in some studies, has been shown to have some significance (Jones and Kammen 2011), but since no data is available to incorporate them in a reliable manner, and since they are likely to be similar in different locations, they were left out.

Results

Carbon footprints in Iceland

The per capita annual CFs appear to be the highest in the most urbanized and affluent area, the Capital, 11.6 tons of CO_2 equivalent (t CO_2e), but the Towns average 11.3 t CO_2e is very close (Figure 1). Moreover, similarly to the situation reported in Finland (Heinonen et al. 2013a), Australia (Wiedenhofer et al. 2013) and California (Heinonen, 2016), the lowest CFs are found in the more rural types of settlements, Villages, 10.2 t CO_2e.

The main sources of emissions are Transport and Food as Figure 1 depicts. Food is about 3 t CO_2e in each settlement type, and Transport from 3.5 t CO_2e in Villages to 3.6 in the Capital and 4.0 in Towns. Interestingly, the GHGs from transport do not decrease towards the denser settlement types. Fuel consumption is the highest in Villages, generating 2.3 tons of CO_2e compared to 1.8 tons in Villages and 1.9 in the Capital, but the difference is compensated by elevated emissions from vehicle purchases and especially from aviation in the more affluent Towns and the Capital. This finding aligns with earlier findings from Finland (Heinonen et al. 2013a; Ottelin et al. 2014). In Iceland it is noticeable that car-dependency is high all around the country, as the car possession data in Table 1 depicts.

These two categories together—Food and Transport—are responsible for well over 50% of the overall CFs.

Services play an important role as well, adding almost three tons to the CFs of Capital residents, 2.8 t CO_2e. In Towns they add 2.5 tons to the CFs, but in Villages only 1.9 tons. This is partially due to the income effect, the more affluent residents just being able to purchase more services. However, it also follows the hypothesis of Heinonen et al. (2013a) that in denser areas residents actually make a trade-off between possessed living space and services in close proximity, which can be used to extend the living space. This means that they accept smaller living spaces in exchange for the better service level of the surrounding areas, and spend less time at home and more time away using these services, such as restaurants, cafés, gyms, theatres and so on. Still the share of services is relatively high even in the least

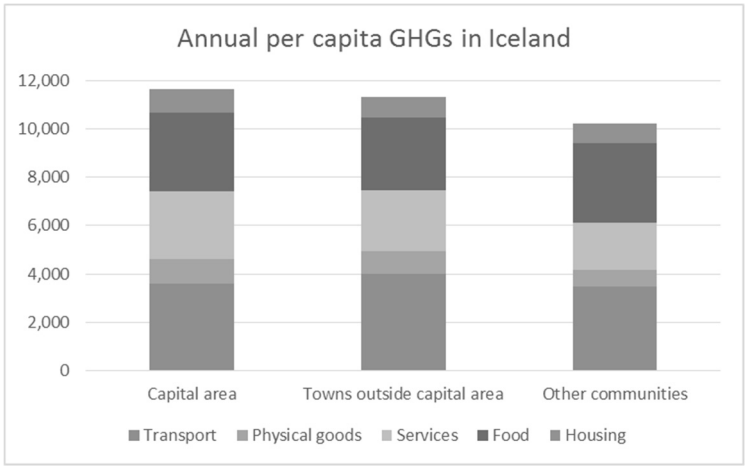

Figure 1. The annual per capita CFs in Iceland (kg CO2e).

urbanized areas suggesting that even if service consumption might be a preferable option to the consumption of physical goods, many services actually are very material-intensive and have relatively high GHG intensities. Particularly cafés and restaurants and cultural services are used more in the Capital, where their availability is the greater. Housing and Physical goods have the smallest shares, but especially with physical goods the emissions are significantly lower in the least urbanized settlements.

Urban sprawl and carbon footprints

As a crude measure, detached house living can be set to present urban sprawl in urbanized areas (Ala-Mantila et al. 2013). In Iceland, the most interesting area is the Capital, the most highly urbanized area and the area with the highest CFs in Iceland. Looking separately the detached house residents and apartment building residents of the Capital, somewhat surprisingly, the apartment building residents have the highest CFs of these two groups at 12.5 t CO_2e/capita whereas the CF of detached house residents remains at 9.5 t CO_2e/capita, as depicted in Figure 2.

In a similar comparison in the Helsinki Metropolitan Area in Finland, Ala-Mantila et al. (2013) found a reverse situation, but at the same time the situation in Reykjavik is similar to the comparison between city center residents and suburban residents in Finland presented by Heinonen et al. (2011). The key reason lies in affluence and intra-household sharing. The residents of apartment buildings are predominantly adult households without children, whereas the families with children locate to detached houses. Heinonen et al. (2013a-b) and Ala-Mantila et al. (2016) have shown how important the GHG impact of household size and intra-household sharing can be, and how difficult it is to have a low-carbon lifestyle in smaller household units.

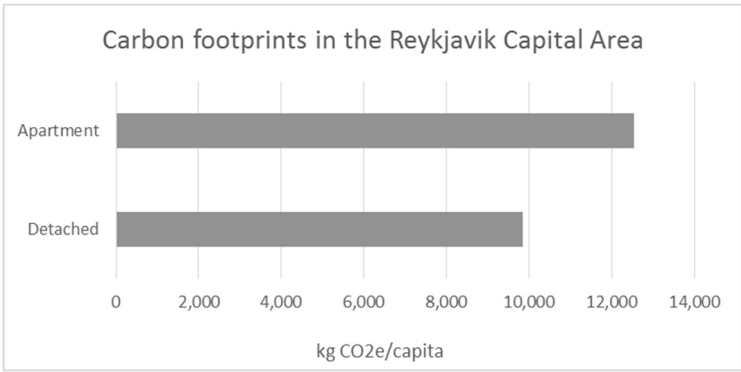

Figure 2. The annual per capita CFs in apartment buildings and detached houses in the Reykjavik Capital Area (kg CO_2e).

Relative effects of urbanity and housing type

Affluence is highly correlated with the CF of an individual. Those who are more affluent simply do more and use more to cause more GHG emissions. Affluence also generally concentrates to the more urbanized areas with the most diverse consumption opportunities, also evident in Iceland, as shown in Table 1. If we bracket-off the discussion about the sources of increased wealth in the more urbanized areas and the potential lifestyle impacts of living in certain types of settlements (see e.g. Heinonen et al. 2013a for an extensive discussion on the connections), we can analyze the relative impacts of the degree of urbanity and housing choices. In this manner, controlling for consumption expenditure and analyzing the relative impact of the degree of urbanity, living in more urbanized areas becomes the preferred option in terms of the average CFs. We use a non-linear model with natural logarithmic transformations for both the dependent variable, CF, and the independent variable, expenditure, following earlier literature (Lenzen et al. 2006; Kerkhof et al. 2009; Shammin et al. 2010; Ala-Mantila et al. 2014) and the three urbanity types from Table 1. This leads to the Capital showing the lowest relative CFs, 9% below those of Villages. Towns also have 5% lower relative CFs in comparison to Villages. Both differences are statistically significant at 0.001. R^2 is 0.94 meaning that the explanatory power of this analysis is high and the model explains the differences very well.

Table 2. The regression results for expenditure, level of urbanity and housing type.

	CFs	R^2	Sig.
Expenditure	0.94	0.88	0.001
Urbanity (ref. Villages)		0.94	
Towns	-0.05		-
Capital	-0.09		0.001
Housing type (ref. Apartment)		0.88	
Detached house	0.01		-

- (dash) indicates statistical non-significance.

Figure 2 illustrated how CFs are highest for apartment building residents in the Capital. These residents actually have the highest consumption power, and thus it is not surprising that in relative terms, when consumption expenditure is controlled, there is no significant difference in CFs between the two housing types as depicted in Table 2. Table 2 shows how detached house living increases the CFs by 1% in the Capital when consumption

expenditure is controlled, but without statistical significance. Expenditure and housing type as independent variables again lead to high explanatory power (R^2=0.84).

Finally, Figure 3 presents the individual CFs and shows the strong correlation with the consumption volume and depicts how similar the CF distributions are. The spread between the highest and the lowest CFs is substantial at any consumption level, but far reaching conclusions should not be made, since we are using data covering a relatively short period of time. For more meaningful results, larger data samples are needed. Still, it is notable that the spread is the highest in the Capital.

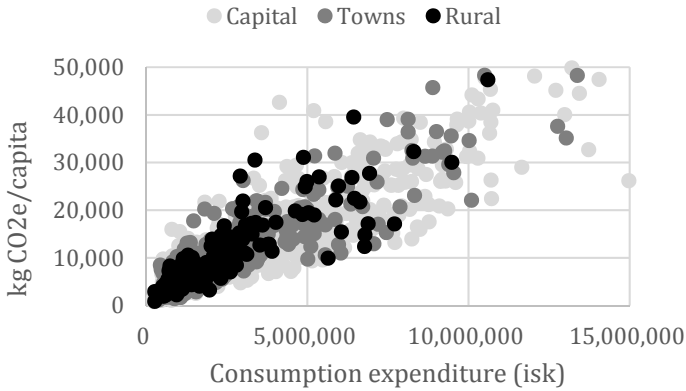

Figure 3. The individual CFs (kg CO2e/a) and the monetary consumption (isk/a).

Discussion

Main findings

The aim of this study was to assess for the first time the consumption-based CFs in Iceland taking into account all private consumption, and both direct and indirect emissions. Further, the study was set to compare the CFs in different types of settlements to test the "low-carbon illusion of cities" hypothesis, meaning that in territorial assessment schemes highly urbanized areas often show as low-carbon areas in comparison to country averages or regional averages, but at the same time they are the key centers for consumption and actually just outsource the emissions they drive. Thus, while cities often show reduced transport related emissions compared to less

urbanized areas, or denser settlements compared to less dense (e.g., Badoe & Miller 2000, Ewing & Cervero 2010, Naess 2012), the higher emissions from other forms of consumption cause CFs to be highest in the densest settlements. This has already been found by Heinonen et al. (2013a-b) in Finland with no other studies contradicting this finding (see Ottelin 2016 for a review of earlier studies). Still, the prevailing urban development principle for reducing GHG emissions from a settlement is to increase its population density, in Iceland as well.

What was found is that the overall average per capita CF in Iceland is approximately 11.3 tons of CO_2e/a (the share within the assessment scope). The CFs are relatively equal between the Capital and Towns at 11.6 and 11.3 t CO_2e/a, but somewhat lower in Villages with 10.2 t CO_2e/a. As was hypothesized, the indirect emissions from services use increase significantly from Villages to the more affluent areas. The average per capita annual consumption increases from 2.3 million ISK in Villages to 2.8 million ISK in Towns and 3.1 million ISK in the Capital and thus it is largely the consumption activity which drives the CFs rather than the settlement type as such, as suggested previously by Minx et al. (2013). With transport, the results are also in line with the hypothesis that higher density reduces private driving, but as in several earlier studies, when all transportation related emissions are accounted for, including flying, the advantage is greatly reduced or disappears.

The CFs in Iceland appear to be relatively high according to the study, given that housing, often one of the most influential categories (Heinonen et al. 2013a-b; Heinonen and Junnila 2011; Jones and Kammen 2011) causes very little emissions due to the low-carbon energy system in Iceland. The estimated Icelandic average CFs are approximately on the same level as those estimated for Finland (Heinonen et al. 2013a; Heinonen and Junnila 2011) even with the very low emissions from housing. In Heinonen and Junnila (2011) the same assessment model was used, so even if there was a bias associated to the model selection, which will be discussed below, the two studies are relatively well comparable.

Affluence plays a key role in explaining the CFs, as has been noticed in number of earlier studies. When we elaborated our analysis with a regression model controlling for expenditure, the Capital appeared to reduce the CFs by 9% and Towns by 5% in comparison to Villages. In interpreting these results, one should not ignore that cities work as engines of growth and affluence, but at least the relative effect of urbanity indicates that moving away from the more urbanized areas might lead to further increases in CFs.