Global Environmental Change 52 (2018) 314–324

Contents lists available at ScienceDirect

Global Environmental Change

journal homepage: www.elsevier.com/locate/gloenvcha

Pursuing necessary reductions in embedded GHG emissions of developed nations: Will efficiency improvements and changes in consumption get us there?

Anders Bjørn[a,e,*], Pradip Kalbar[a,f], Simon Elsborg Nygaard[b], Simon Kabins[b], Charlotte Louise Jensen[c], Morten Birkved[a], Jannick Schmidt[d], Michael Zwicky Hauschild[a]

[a] The Technical University of Denmark, Department of Management Engineering, Building 424, 2800, Kgs. Lyngby, Denmark
[b] Aarhus University, Department of Psychology and Behavioural Sciences, Building 1350, 8000, Aarhus C, Denmark
[c] Aalborg University, Department of Planning, A.C. Meyers Vænge 15, 2450, Copenhagen SV, Denmark
[d] Aalborg University, Department of Planning, Rendsburggade 14, 9000, Aalborg, Denmark
[e] CIRAIG, Polytechnique Montréal, 3333 Queen-Mary Road, H3V 1A2, Montréal, QC, Canada
[f] Centre for Urban Science and Engineering (CUSE) and Interdisciplinary Programme in Climate Studies, Indian Institute of Technology Bombay, Powai, Mumbai, 400 076, India

ARTICLE INFO

Keywords:
Climate goals
Paris Agreement
Embedded emissions
Consumption patterns
Frozen policy
Emission intensity

ABSTRACT

The COP21 summit in Paris led to a policy commitment of limiting the global temperature increase to 1.5–2.0 °C and this can be translated to a global annual greenhouse gas (GHG) emission budget that is shrinking rapidly throughout the 21st century. Here, we estimate the reductions in GHG emission intensities of technologies that will be required for the embedded GHG emissions of a developed nation to stay within its fair share of a global emission budget in the year 2050. The estimates are made for different conceivable developments in consumption patterns in the case of Denmark, based on a large survey of current consumption patterns. To evaluate whether the required emission intensity reductions are likely to be met, they are compared to historic time series of emission intensities and to projections for 2050, based on policies currently in place, for ten technologies that have a high contribution to current GHG emissions.

We estimate that emission intensities must be reduced by factors of 2–12 and 5–14, depending on the development in consumption, for the 2.0 and 1.5 °C climate goals, respectively. Of the ten selected technologies, only electricity supply is projected to, partially, meet the most strict reduction target, applying to a scenario where all inhabitants in 2050 consume as the most consuming inhabitants today.

The results indicate that both a change in “consumption as usual” and in “business as usual” is needed for developed nations to meet equitable climate targets. This has implications for national and international policies targeting GHG emission intensities and may require a new orientation of policies to consider the societal structures around consumption.

1. Introduction

Research in sustainability science typicallytakes either a technology- or a consumer perspective. Technology-oriented research addresses the question of how to reduce the environmental pressures associated with producing predetermined quantities of goods and services and uses concepts and tools such as life cycle assessment (LCA) (ISO, 2006a, 2006b), eco-design (McAloone and Bey, 2009) and environmentally extended input output (EEIO) analysis (Wiedmann, 2009). Technology-oriented research either considers environmental pressures within defined territories or pressures “embedded” in goods and services and occurring in multiple territories throughout their supply chains (sometimes called consumption-based accounting (Kokoni and Skea, 2014)). By comparison, consumer-oriented research uses a variety of scientific disciplines, such as economy, psychology and sociology, to address the question of how individuals and groups of people can consume in less environmentally harmful ways (Creutzig et al., 2018). Policy interventions targeting technology and consumers can be seen as two levers for attempting to ensure the conditions for sustainable development by preventing the transgression of

* Corresponding author.
E-mail address: anders.bjoern@polymtl.ca (A. Bjørn).

https://doi.org/10.1016/j.gloenvcha.2018.08.001
Received 5 April 2017; Received in revised form 31 July 2018; Accepted 19 August 2018

environmental carrying capacities (Rees, 1996; Sayre, 2008) or planetary boundaries (Rockström et al., 2009; Steffen et al., 2015). Lately, there has been a strong focus in sustainability science on the policy commitment of the Paris Agreement to limiting global temperature increase to 1.5–2.0 °C. Climate change science and integrated assessment modelling has led to a translation of this climate goal to proposals of a global annual GHG emission budget that is shrinking rapidly throughout the 21st century (van Vuuren et al., 2011).

Absolute emission budgets, and carrying capacities in general, poses a challenge for the common division of sustainability science into technology- and consumer oriented research: Solely taking a technology perspective in estimating how much the efficiencies of technologies must increase (see, for example, Girod et al. (2013) and PwC (2015)), means neglecting the potential effect of a pathway that diverges from “consumption as usual”. Likewise, solely taking a consumer perspective in exploring how, physically and practically, a person or a household can live within what may be considered its “fair share” of carrying capacity (see, for example, GFN (2018) and Laakso and Lettenmeier (2014)), means disregarding the effect of efficiency improvements of technologies on the solution space. In other words, while the potentials of using either the technology- or the consumer related policy intervention lever for staying within carrying capacities have been separately studied, their combined potential is not well-understood.

This study examines the quantitative potentials of both levers in the pursuit of absolute targets for embedded GHG emissions. Our overarching research question is: “Can foreseeable efficiency improvements of technologies and conceivable changes in consumption patterns allow a developed nation to make its fair contribution to meeting the global climate goal of the Paris Agreement?” We explore foreseeable efficiency improvements of technologies through scenarios that are based on current policies (i.e. using a frozen policy assumption). Different conceivable changes in consumption patterns are developed from observed variations between current carbon footprints of individuals, estimated from survey data. While policy targets for GHG emissions are often of a territorial nature, e.g. in the context of the Kyoto Protocol and the Paris Agreement, emissions embedded in goods and services are of focus in this study. This means taking the perspective that a nation is responsible for GHG emissions occurring outside its territory because of its consumption. For convenience, we use the term “carbon footprint” for embedded GHG emissions throughout this study.

Denmark was chosen as a case due to the large availability of environmentally relevant data on Danish consumption and technology. Based on the overarching research question presented above, the following three technical research questions were developed:

1 What is the distribution of personal carbon footprints across the Danish population and what is the contribution of different goods and services to the footprints?
2 Which reductions in GHG emission intensities of technologies used to deliver goods and services consumed in Denmark will be required in the year 2050 to comply with the climate goal of the Paris Agreement for the range of consumption patterns currently observed in Denmark?
3 Are these reduction requirements likely to be met, judging from historical development in technological efficiencies and future projections based on policies currently in place?

We focus on the year 2050 because it represents a time where drastic reductions in global emissions, compared to current levels, will be required in order to meet climate goals (Rogelj et al., 2015), but also a time that is close enough to be relevant to current policy decisions (van Vuuren et al., 2015).

The novelty of this study primarily lies in its integration of a technology- and consumer perspective. An integrative approach was previously taken by Girod et al. (2014), who discussed policies for removing barriers that prevent individuals from choosing existing goods and services with low enough carbon footprints to meet a 2050 per capita emission target. In their work, however, it is unclear whether an individual that only consumes the identified low-carbon goods and services (e.g. resorts to biking for all transportation) can, in practice, function in current societies, i.e. whether the required consumption pattern is obtainable. Similarly, de Koning et al. (2016) and Grubler et al. (2018) considered the potentials of low-carbon technologies as well as changes in consumption to align global GHG emissions with an emission budget for 2050, but these consumption changes are largely theoretical. By contrast, this paper studies potential consumption changes that reflect self-reported actual consumption patterns from a large survey. Another novelty of our study is the comparison of the estimated required reduction in GHG emission intensity to historical and foreseeable future trends in emission intensities of important technologies. Further, we discuss the implications of our findings for climate change policies and we draw on practice theory (Røpke, 2009) to outline how policies may better consider the social dimension of consumption. Although the studied technologies and consumption patterns reflect a Danish setting, the conclusions drawn are relevant for many other developed nations and the methodological approach is universally applicable.

2. Methods

The aforementioned three research questions are addressed one by one in the following sub-sections. Fig. 1 offers an overview of the methodological steps involved in addressing the three questions, the types of data sources involved and the steps in which uncertainties are assessed quantitatively. Additional uncertainties are addressed qualitatively in Section 4.1.

2.1. Personal carbon footprints

The first step of the footprint calculations was to obtain information on quantities of, or expenditure on, goods and services consumed by a wide segment of Danish inhabitants during one year. We used survey results from Kalbar et al. (2016), who gathered responses from 1281 inhabitants living in urban areas during 1 year, stretching over 2013–2014 (Kalbar et al., 2016). The consumption data covers the seven categories of food, dwelling, thermal energy, electricity, road transport, air transport and additional goods and services. We assume that the carbon footprints to be calculated are valid for the year 2014 when later comparing them to time series of GHG emission intensities (see Section 2.3).

Next, a life cycle inventory (LCI) model for the 2014 consumption of each respondent was constructed based on the survey data. As a basis, we here adopted the LCI model constructed in Kalbar et al. (2016), which is based on a combination of the Ecoinvent 2.2 and 3.1 databases (Association Ecoinvent, 2018). Goods and services not covered by Ecoinvent were modelled by Kalbar et al. (2016) using the EEIO database FORWAST (Schmidt et al., 2010). For the purchasing of large consumer goods (such as a new house), production-related emissions were equally allocated to each year of the expected life times of these goods, so as to avoid variations in emissions between respondents caused by the timing of such acquisitions. Details of the LCI model adopted in this study are presented in Kalbar et al. (2016).

Embedded GHG emissions associated with public services (schools, roads, hospitals, etc.) were not covered by the LCI model of Kalbar et al. (2016). We here estimated emissions from all public services by using the Exiobase v3.3.8 hybrid input output (IO) database (Merciai and Schmidt, 2018; Stadler et al., 2018) for the year 2011, the latest year in the database. Exiobase is a global multi-regional EEIO model and was used in a hybrid version in this study. This means that the EEIO model is based on three different sets of supply use tables (SUT) in different units: monetary, mass (dry matter) and energy. The data and methods for constructing the SUTs in Exiobase v3 are described in detail in