Travel Behaviour and Society 6 (2017) 10–18

Contents lists available at ScienceDirect

Travel Behaviour and Society

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

The climate impact of Norwegians' travel behavior

Borgar Aamaas *, Glen P. Peters

Center for International Climate and Environmental Research – Oslo (CICERO), PB 1129 Blindern, 0318 Oslo, Norway

ARTICLE INFO

Article history:
Received 23 September 2015
Received in revised form 21 April 2016
Accepted 22 April 2016

Keywords:
Climate impact
Travel behavior
Passenger transport
Emission metric
Mitigation
Norway

ABSTRACT

Transportation is the largest sector in Norway in terms of greenhouse gas emissions. The mitigation potential of this sector can be better understood by investigating the climate impact of disaggregated data on travel behavior. Here, we use travel behavior data for Norwegians travelling domestically and abroad in 2009 to explore mitigation potential in Norwegian transportation. The climate impact of this aggregated data is calculated by including the impact of all relevant long-lived greenhouse gases and short-lived climate forcers. The climate responses have been compared by using a range of emission metrics (both global temperature change and integrated radiative forcing, both pulse and sustained emissions for time horizons up to 100 years). For most choices, the total climate impact is dominated about equally by air (55 ± 20%) and car transport (36 ± 19%), with air transport having a slightly stronger impact for a majority of the cases. The highest income quintile causes a climate impact that is 240% larger than the lowest income quintile. The few trips longer than 100 km contribute to 68% of the impact. In addition, we analyze what the effect would be from several proposed mitigation policy targets in Norway and find that policies focused on technology have larger impacts than those on travel behavior.

1. Introduction

Transport is one of the key sectors contributing to climate change. Historical emission from global transportation contributed about 9% of the temperature change in 2000, and this share may increase in a variety of future scenarios (Skeie et al., 2009). Hence, efforts to avoid the global mean surface temperature to exceed the proposed 2 °C threshold need to address the transportation sector and travel demand (Girod et al., 2012).

On a global scale, previous studies have found that the absolute climate impact is largest from road transport, with aviation as the second largest contributor, and shipping leading to a short term cooling effect (Berntsen and Fuglestvedt, 2008; Fuglestvedt et al., 2008; Skeie et al., 2009). Another approach to compare transport modes is the specific Climate Impact (sCI), which normalize the impact per person kilometer (e.g., Borken-Kleefeld et al., 2013). Globally, rail and coaches have the lowest sCI, while air transport has the highest for short time horizons and car transport equals to air or higher for longer time horizons (Borken-Kleefeld et al., 2010). This information is valuable for evaluating mitigation options, but provides little specific information, particularly relating to travel behavior (Nicolas and David, 2009).

In Norway, transport stands for about a quarter of the territorial greenhouse gas emissions, increasing to a third when emissions from fishing, machinery for agriculture and construction, and other machinery are included (Brunvoll and Monsrud, 2013). Norwegians are among the Europeans that drive a car the longest, and among the Europeans that use public transport the least (Brunvoll and Monsrud, 2013). Transportation is among the sectors with the largest emission growth, the territorial transportation emissions have increased by about 30% since 1990 (SSB, 2015a). The government of Norway has a target of reducing greenhouse gas emissions in 2020 by 30% relative to 1990 (Ministry of Climate and Environment, 2012). The territorial emission cut has been estimated to 12–14 Mt CO_2-equivalents in 2020 relative to a business as usual scenario. Several mitigation measures and targets were presented by the Ministry of Climate and Environment (2012) and the Ministry of Transport and Communications (2013). One of the targets is that the growth in travel in the largest cities shall occur with public transport, walking and biking. Another target is to reduce the average emissions from new cars registered in 2020 to 85 g CO_2/km. Fridstrøm (2013) finds that CO_2 emissions from domestic transportation in Norway can be reduced by 60% from 2010 to 2050, driven by reductions from personal travel. However, he argues that such a CO_2 cut is not large enough if transportation is to take its share of mitigation to avoid global warming exceeding the 2 °C threshold.

While most studies only focus on CO_2 or a few greenhouse gases, the emissions from the transport sector consist of a large

* Corresponding author.
E-mail address: borgar.aamaas@cicero.oslo.no (B. Aamaas).

http://dx.doi.org/10.1016/j.tbs.2016.04.001
2214-367X/

mix. Some species are long lived and are controlled by the Kyoto Protocol (LLGHGs: CO_2, CH_4, N_2O, SF_6, HFCs, and PFCs), while short lived climate forcers (SLCFs) such as air pollutants (black carbon (BC), organic carbon (OC), and SO_2), ozone precursors (NO_x, VOC, and CO), and indirect effects (contrails and contrail-induced cirrus (CIC)) also affect the radiative balance of the atmosphere. For some transport modes, these SLCFs cause short term temperature perturbations similar in size as CO_2, such as contrails and CIC from aviation (e.g., Borken-Kleefeld et al., 2010). Hence, the total climate impact is better quantified by including the SLCFs. Since the climate system is perturbed in different ways by these processes, these emissions cannot be compared easily (Aamaas et al., 2013b; Fuglestvedt et al., 2003, 2010). The most common emission metrics in the literature are based on the integrated radiative forcing (the Absolute Global Warming Potential, AGWP) and temperature change (the Absolute Global Temperature change Potential, AGTP), which in normalized form become the GWP and GTP. These emission metrics are coupled with a time horizon. A short time horizon will put more focus on SLCFs, while a long time horizon makes the LLGHGs relatively more important. The Kyoto Protocol uses GWP with a time horizon of 100 years.

Surveys of detailed travel behavior are available for several countries, and studies on the greenhouse gas emissions from travel have been made globally (Girod et al., 2013) and for various European countries. In Oxfordshire, UK, the 20% highest emitters were responsible for 60% of the emissions (Brand and Preston, 2010). Long-distance travel (>100 km) and international travel take a significant share of the total emissions in Sweden (Åkerman, 2012) and Germany (Reichert and Holz-Rau, 2015). While people living in denser urban areas in Finland cause less emissions from their daily travels, emissions in total are larger due to more frequent flying (Ottelin et al., 2014). Aamaas et al. (2013a) were probably the first at estimating the temperature change of travel behavior when considering all relevant emissions and effects. They found that in Germany, the long-distance trips account for more than 60% of the total temperature change and that the total impact is driven equally by two dominating modes, air and car transport.

While CO_2 emission inventories are regularly published for transportation in Norway (e.g., Brunvoll and Monsrud, 2013), the climate impact (e.g., temperature) of Norwegians' travel behavior has not been sufficiently quantified. Similarly, the climate impact of different proposed mitigation policies has not been adequately assessed. In this paper, we analyze the climate impact of Norwegian transport, travel behavior, and mitigation options. In addition, we evaluate how sensitive our analysis is to different emission metric choices. We estimate the climate impact of Norwegians' travel behavior based on the 2009 national travel survey in Norway (Vågane et al., 2011). Both national and international travel by Norwegians is included. We build on the existing literature in two important ways. First, most studies focus on CO_2 or GHG emissions, but climate is affected by other species such as ozone precursors, aerosols, and contrails. Our analysis includes all climate relevant emissions and compares the implications of different methods of comparing the climate impact of different species. Second, the emissions from transportation are usually estimated using the fuel-based (e.g., Borken-Kleefeld et al., 2010; Loo and Li, 2012) or distance-based (e.g., Loo and Li, 2012; Sookun et al., 2014) approaches. Such calculations can be done top-down, e.g., considering fuel consumption of a vehicle fleet (e.g., national-level), or bottom-up focusing on travel by individual vehicles. We take a top-down approach, but our data are based on a survey of travel behavior and, thus, include bottom-up details. We then allocate the climate impact to different travel behavior, and, hence, our approach could be seen as a hybrid approach.

In Section 2, we present the methods and material, including travel behavior data, emission factors, and emission metrics. We also present several mitigation policy targets for the transportation sector in Norway. In Section 3, we present the results, where we also differentiate the travel behavior by income class and trip length. We also estimate how these mitigation options and targets from the Norwegian government will influence this climate impact. In the last part of this section, we discuss some limitations of our study, while we conclude in Section 4.

2. Material and methods

The total climate impact *CI* of travelling for group of people *g* is estimated as the product of the travel volume (*TV*), a sum of all individual trips, with a transport mode *m*, the average emission factor *EF* for pollutant species *s*, and the selected emission metric (*AM*) for this species, summed over all species emitted and all transport modes used in the period:

$$CI_g = \sum_m \sum_s TV_{m,g} \times EF_{m,s,g} \times AM_s \quad (1)$$

See Aamaas et al. (2013a) for further details.

2.1. Travel behavior data

The travel volume (TV) is mainly based on the Norwegian national survey in 2009 (Vågane et al., 2011). Approximately 29,000 persons with age 13 years and older were interviewed by telephone. The respondents were randomly sampled from different geographical home zones reflecting the age and gender distributions in each zone. The interviews were spread out over about a year to include seasonal variations. The survey contains detailed information on variables such as the purpose of travel, distance travelled, number of trips, and length of trips for a range of transport modes and segments of society. Business trips, defined as travel done in the course of business or work, are included.

The travel survey underestimates trips to and from abroad, as well as trips between international destinations (Vågane et al., 2011). This shortcoming has been corrected for by including estimates of international trips based on datasets from the same institute, such as border crossings (Vågane and Rideng, 2011) and a travel behavior study specific on air transport (Denstadli and Rideng, 2010). The travel volume for these international trips has been estimated as the sum of the trips with the respective modes and the average distances to the destinations that are most frequently travelled to with these modes. This adjustment is only minor for transport by train and coach, but adds some more travel volume for car and ferry. Air transport is the most affected, as about a quarter of all trips to and from abroad is with air, as well as these trips are in general much longer than trips with other modes. Hence, this adjustment results in some uncertainty in the estimated travel volume of air transport. Travel both within and outside Norway contributes significantly to the total annual climate impact. An overview of trips and travel volume is given in Table 1.

The travel data are differentiated in quintiles by groups of "household economic status". This grouping helps analyzing how travel behavior and climate impact differ between those in high-income groups from those in low-income groups. The economic status of a person is defined as his/her household's income divided by the weighted number of household members, giving an equivalent income relative to the mean domestic household income. The weighted number of persons is based on an OECD scale, where the first adult is given a weight of 1, all other adults a weight of 0.5, and everybody in a household below 15 years of age a weight of 0.3. The household gross income divided by the household size for those five groups from low to high is: 158,000 NOK, 275,000 NOK, 353,000 NOK, 434,000 NOK, and 667,000 NOK. We estimate