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Decomposing passenger transport futures: Comparing results of global integrated assessment models

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ABSTRACT

The transport sector is growing fast in terms of energy use and accompanying greenhouse gas emissions. Integrated assessment models (IAMs) are used widely to analyze energy system transitions over a decadal time frame to help inform and evaluating international climate policy. As part of this, IAMs also explore pathways of decarbonizing the transport sector. This study quantifies the contribution of changes in activity growth, modal structure, energy intensity and fuel mix to the projected passenger transport carbon emission pathways. The Laspeyres index decomposition method is used to compare results across models and scenarios, and against historical transport trends. Broadly-speaking the models show similar trends, projecting continuous transport activity growth, reduced energy intensity and in some cases modal shift to carbon-intensive modes - similar to those observed historically in a business-as-usual scenario. In policy-induced mitigation scenarios further enhancements of energy efficiency and fuel switching is seen, showing a clear break with historical trends. Reduced activity growth and modal shift (towards less carbon-intensive modes) only have a limited contribution to emission reduction. Measures that could induce such changes could possibly complement the aggressive, technology switch required in the current scenarios to reach internationally agreed climate targets.

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1. Introduction

The increased use of motor vehicles and airplanes has led to a higher mobility, flexibility and accessibility of the current population. At the same time, this has also resulted in social and environmental impacts at both the international/national and local scales (GEA, 2012). At the local scale, transport activities cause urban air pollution, noise, congestion, water and soil degradation, asthma, obesity, road deaths and social and urban fragmentation (GEA, 2012). At the international/national scale, mobility contributes to greenhouse gas emissions, trans-boundary air pollution, and the depletion of oil resources. Global greenhouse gas emissions from transport doubled over the 1970–2010 period to 7.0 $GtCO_2$-eq, increasing at a faster rate than any other end-use sector (IPCC, 2014a). Strategies to decrease transport energy use, or even demand growth, can clearly lead to many co-benefits (Woodcock et al., 2009).

Integrated assessment models (IAMs) are commonly used to explore energy system transitions over the long term to meet global climate targets. Their strength lies in analyzing trade-offs and synergies across economic sectors, and providing insights in the costs and benefits of different policies (IPCC, 2014b). Due to the importance of the transport sector as a final energy consumer, most of these models also include a relatively detailed representation of developments in this sector and its potential to contribute to mitigating GHG emissions. Girod et al. (2013) and Pietzcker et al. (2014) have performed comparison studies of transport sector representation in energy system models, including IAMs. Both studies show that, in these models transport CO_2 emission reduction potential depends highly technological change and changing fuel composition, which would breakthrough in the second half of the century. However, there is a large difference across models regarding the relative potential of the sector to mitigate.

There are different possible interventions to reduce the impact of transport: (1) lower transport demand, (2) shift towards low carbon-intensity modes, (3) reduce the energy intensity of technologies and (4) reduce the emissions intensity of fuels (Creutzig, 2016). Creutzig et al. (2015) argue that limiting demand growth by shifting to low carbon-intensity modes and reducing the distance travelled has limited application in global IAM scenarios and emissions could be further reduced than currently suggested. Local studies, on the contrary, often show that behavioral and infrastructure policy interventions impacting modal shift, distance travelled as well as technological change could be effective measures to decrease emissions (Creutzig, 2016). Moreover these measures can already impact transport emissions in the short term and can in fact potentially avoid infrastructure path dependency (Creutzig et al., 2015; Banister et al., 2011).

In this study we look at a large set of IAM transport model projections and determine the relative contribution of intervention strategies through decomposition analysis. This allows us to improve the understanding of these scenarios and to compare the application of the models in a transparent manner, by relating model structure to scenario results. Moreover, the disaggregation can provide further insight into how specific projected components compare against historical transport trends and, by extension, can potentially improve translation into and comparison with local measures, such as those highlighted by Creutzig et al. (2015). Secondly, input data on technology costs are compared in an attempt to further understand uncertainties underlying model differences in projections of vehicle and fuel choice.

The article is structured as follows: Section 2 discusses the method applied. The subsequent Section 3 discusses the results of a GHG mitigation scenario that is evaluated against a common baseline, focusing on specific GHG mitigation interventions. In Section 4, specific attention is given to technology input data representation in the USA affecting light-duty vehicle (LDV) choice. In Section 5, the results and identified key transport model developments are discussed, and in Section 6 we come to our conclusions.

2. Method

2.1. Description of the Integrated Assessment models

Eleven IAMs were included in this study, namely AIM/CGE, DNE21+, GCAM, GEM-E3, Imaclim-R, IMAGE, POLES, MESSAGE, REMIND, TIAM-UCL and WITCH. A qualitative questionnaire was sent to the modelling teams to take stock of their transport sector representations. This section discusses the concept and solution method of these models, along with the transport modes accounted for. In addition, Tables A.1 and A.2 in the supplementary material provide a summary of the responses. Several papers in this special issue include more detailed presentations of the transport modelling in GEM-E3 (Karkatsoulis et al., 2017), MESSAGE (McCollum et al., 2017), AIM/CGE (Dai, 2017), Imaclim-R (Ó Broin and Guivarch, 2017) and WITCH (Carrara and Longden, 2017).

IAMs differ in the way they represent the transport sector. The ones with greater transport detail (i.e., compared to the ones described herein) use a hybrid approach to model the transport demand and use of energy in the transport sector. In the hybrid approach a top-down demand formulation, relating demand to population and economic growth, is combined with the explicit modelling of modes and technology options per mode. Clearly, the degree of detail determines how well models are able to represent the key dynamics of the various transport sub-sectors and the different ways to mitigate emissions.

Transport demand in AIM-CGE is derived using a top-down method, where energy demand is input to a production function driven by gross domestic product (GDP) growth. In WITCH, the service demand of the explicitly modeled LDV mode is related to GDP and population, while the rest of the transport sector is indirectly comprised in the more general non-electric sector which is an input to a nested constant elasticity of substitution (CES) production function. Also the REMIND transport