Capacity Area B1 Topic 3.1 Deliverable 1

Household consumption model quantifying environmental impacts of mobility and other consumption areas for all Swiss households

A spatially highly resolved large-scale bottom-up model was developed which is able to derive a realistic environmental profile for each household in Switzerland. The model allows for investigating environmental impacts of mobility in the context of total household consumption. It also serves as a sophisticated platform to evaluate policy scenarios. Therefore, the overall model is an important starting point and prerequisite for the subsequent activities in the capacity area B1.3 and it will help to understand mobility behavior and associated environmental impacts of Swiss households.

The overall model has been presented in the dissertation of Andreas Frömelt [1] as well as at the SETAC-conference [2]. Sub-models contributing to the overall model were published in peer-reviewed scientific articles [3, 4].

Summary (mainly based on [1, 2])

Besides governmental consumption, household consumption is the main driver of economy and is thus ultimately responsible for the environmental impacts that occur over the whole life cycle of products and services that households consume. Therefore, assessing environmental footprints of households is an important basis to identify environmental policies. This study aimed to develop a comprehensive regionalized bottom-up model for Switzerland that is able to assess the environmental impacts induced by individual households. The purpose of this model is to provide a virtual platform for detailed scenario analysis, which shall support effective political decision making on different scales.

Three existing bottom-up models were merged: a building stock energy model [4], an agent-based transport simulation and a household consumption model [3]. All of them were tested and evaluated beforehand. The physically based building energy model establishes simplified energy balances for each residential building based on spatially and temporally resolved climate data, building characteristics and 3D-geometries. It provides estimates of space heating, hot water and electricity demand for each Swiss household. The mobility sub-model builds upon the results of an agent-based traffic simulation framework, which was applied to Switzerland and reproduces mobility patterns of Swiss inhabitants in space and time. The third sub-model pursues a data-driven approach and enables the quantification of consumption of food, consumables, and other goods and services for each Swiss household by means of data mining techniques. Linking these sub-models with environmental background data allowed for computing an environmental profile for each household in Switzerland.

The interlinked model assesses the current environmental footprints for all 4 million Swiss households as a realistic estimate taking into account the given circumstances of a particular household (Figure 1b shows the distribution of all household carbon footprints). The results of bottom-up models can be aggregated on any desired regional scale and thus, for instance, provide benchmarking maps of municipalities as shown in Figure 1a. In addition, different spatial structures can be compared. In Figure 1c, it becomes obvious that different degrees of urbanization exhibit similar total emissions per capita. However, the compositions of the footprints reveal that rural areas tend to cause larger mobility GHG emissions per person than urban regions. This is due to larger mobility demands and higher shares of car-driven kilometers. However, even more detailed analyses of compositions are possible: more than 200 different consumption areas can be investigated in the model's highest resolution. Moreover, our model is able to apply all life cycle impact assessment methods supported by the background databases. However, we only show carbon footprints in

Figure 1 to enable for comparison with existing top-down studies (e.g. [7]). Housing, mobility and food are identified as the most important consumption areas in both studies.

By covering the variability of household behavior and quantifying the demands and environmental footprints of households within a certain area, the model delivers important insights for local policymakers to derive targeted environmental strategies tailored to the specific problems and household types in a region. Furthermore, the high resolution of all three sub-models permits testing of policies and in-depth analyses of scenarios, ranging from detailed building refurbishment programs to future mobility solutions such as autonomous vehicle systems.

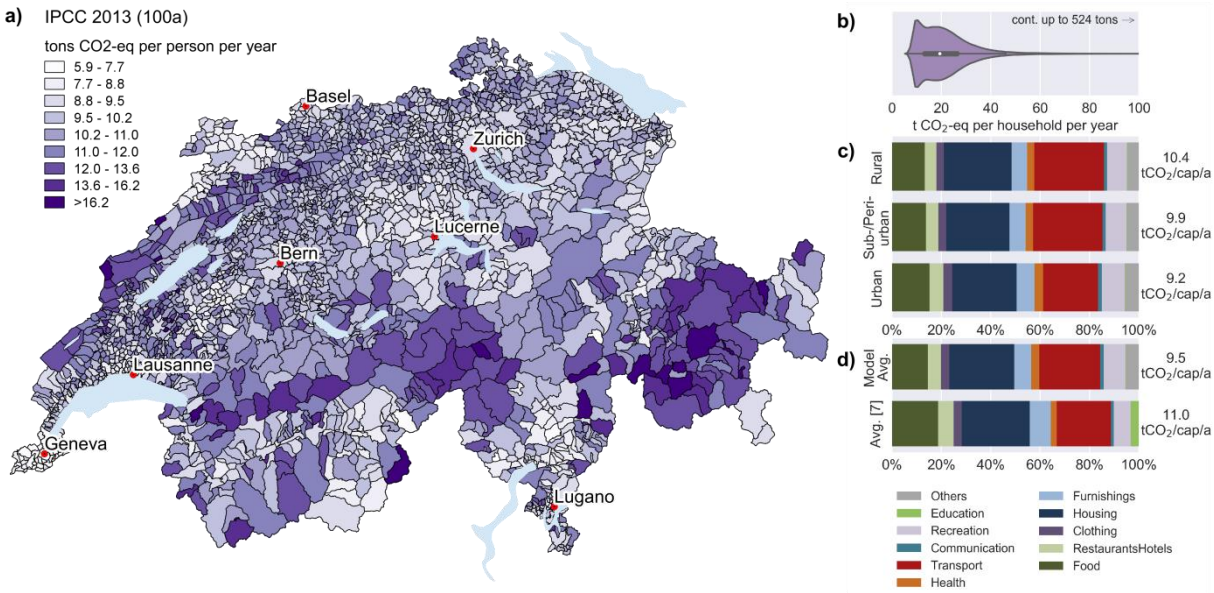

Figure 1: *Results for GHG: a) Average per capita emissions per municipality, b) Violinplot of the carbon footprints of all Swiss households, c) Comparison of different spatial structures on a per capita basis, d) Comparison of Swiss average with [7]. (This figure was published in [1, 2]).*

References

[1] A. Froemelt, *Data Mining Meets Life Cycle Assessment: Towards Understanding and Quantifying Environmental Impacts of Individual Households*, PhD Thesis, ETH Zurich, Switzerland, 2018.

[2] A. Froemelt, R. Buffat, N. Heeren, and S. Hellweg, *Assessing environmental impacts of individual households: A large-scale bottom-up LCA-model for Switzerland*, in *SETAC Europe 28th Annual Meeting*, 2018.

[3] A. Froemelt, D. J. Dürrenmatt, and S. Hellweg, *Using Data Mining To Assess Environmental Impacts of Household Consumption Behaviors*, *Environ. Sci. Technol.*, vol. 52, no. 15, pp. 8467–8478, 2018.

[4] R. Buffat, A. Froemelt, N. Heeren, M. Raubal, and S. Hellweg, *Big data GIS analysis for novel approaches in building stock modelling*, *Applied Energy*, vol. 208, pp. 277–290, 2017.

[7] N. Jungbluth, C. Nathani, M. Stucki, and M. Leuenberger, *Environmental Impacts of Swiss Consumption and Production. A Combination of Input-Output Analysis with Life Cycle Assessment*, Federal Office for the Environment (FOEN): Bern, Switzerland, 2011.