Inspiring, informing, and influencing sustainable urban planning processes through consumption based emissions inventories

Christian Solli[1,*], Rolf André Bohne[2] and Hogne Nersund Larsen[1]

[1]MiSA AS, Trondheim, Norway

[2]Norwegian University of Science and Technology, Trondheim, Norway

*Christian@misa.no

Abstract This paper describes how a tool for household carbon footprint estimates is used in the context of urban planning to foster new ideas and approaches for low carbon solutions. One disadvantage with many of the existing approaches to green community development is the limited focus on transport, materials and energy (for the house). Most fail to capture the fact that the global GHG emissions are caused by a multitude of consumed products and services. By introducing a tool that presents the total carbon footprint of household activities split into several consumption categories, city planners are forced to expand their perspective to include what happens "between the houses", instead of merely focusing on transport, materials and energy. The tool has been used in a parallel urban planning competition in Trondheim, Norway. The holistic approach introduced by the tool significantly influenced suggested solutions.

1 Introduction

There is considerable research focusing on the environmental impacts of cities. Many studies focus their effort on the direct use of energy in buildings, as well as the energy and direct emissions connected to delivering transport services or drive personal vehicles [1, 2]. Some also include materials for construction and operation of dwellings [3]. Others use a production based approach to emissions accounting (as opposed to the consumption based approach used in this study) to arrive at emissions estimates at a city level [4]. Since industry is usually located outside the cities, such studies tend to find cities to be cleaner on a per capita basis. Consumption based studies, on the other hand, tend to find city households more emissions intensive than their rural or suburban counterparts [5].

Few studies include the total emissions embodied in all the services and goods that the inhabitants of the city cause through their consumption. Gray et. al. [6] discuss this issue, and point out that while some types of emissions may go down in denser populated areas (such as fuel use), other types of consumption often more than offset these reductions. Income level is generally the most important driver for household embodied emissions, as indicated in other studies [7-9]. However, some of the studies reveal quite large variation in individual household carbon footprint at similar expenditure levels [9, 10], indicating there is clearly a potential for structural improvement in consumption. Some studies focusing on city form and city planning have included a broader view; this includes the work by Holden [11, 12] and Høyer [13], where the effect of housing characteristics on household consumption was examined in surveys. The focus is still leaning towards transport and energy, potentially missing a large part of household consumption, but indicating more air travel among people in densely populated areas. The trends found in these studies seem to be partially confirmed by an Austrian study [9, 14] where households that voluntarily live in a car free settlement in Vienna spend more of their income on (amongst other things) air travel, partially offsetting the gain from reduced emission from car use. These effects are often termed “rebound effects” [15].

A new development area in the city of Trondheim, Norway, has been chosen as a so-called climate friendly settlement. The overall plan states that the area should be developed in such a way that it facilitates a vision of living with a total household carbon footprint of less than 3 tonnes CO2-eq. per capita per year. This

is about a quarter of the current footprint from households. Improvements need to be made in all areas of consumption, from energy used for heating, transport, material use and the general use of goods and services.

The area planning was initiated by a parallel competition of four teams of architects. In order to ensure them to focus on the "total consumption package" rather than just energy and materials for the houses, they were presented a tool for calculation of total household carbon footprints. The tool includes the aforementioned rebound effect, forcing the teams to take it into account and address it. It was presented to the teams in the form of an Excel-sheet.

In this paper we describe the tool itself, as well as results obtained from it. We then describe some of the suggestions the teams came up with to reduce emissions, and how the tool can be used to evaluate their effect or indicate their overall importance as measures to reduce the total carbon footprint. Finally we present the feedbacks given by the architects on the use of this holistic and quantitative approach in the planning process.

2 Emissions caused by consumption in Norwegian households

As mentioned in the introduction the goal of this study was to introduce city planners to a tool for quantification of total household global warming impacts, including all the indirect emissions

The reason was to see if the planners could come up with concepts for planning the city that could (through reasonable assumptions) lead to a reduction in emissions, not only from energy use in buildings, but also materials, transport, consumption of holiday travels, food and other types of equipment. As an additional challenge the teams were forced to spend the average household budget in full, i.e. they could not just adjust down the volume of consumption but had to adjust the structure of the consumption and how different types of products and services are delivered.

The model that was used to arrive at the carbon footprint estimated for the households is based on an environmentally extended input-output model (EE-EIO). The methodology behind this type of model is thoroughly described elsewhere [16-19] and will not be explained in detail here. In short terms such a model includes linkages between all the sectors of an economy in terms of what

they purchase from each other. In addition it contains emissions per sector. Once built it provides an extremely efficient way of calculating embodied (indirect) emissions from an arbitrary final demand (expressed in EUR). The underlying input-output model used in this study is based on Norway 2007 for domestic production and Germany 2006 as a proxy for the average of import. Consumption of fixed capital is baked into the model.

To make such a model more relevant to household consumption linking to typical household purchases needs to be done, in addition to more technical adjustments such as adjusting for tax levels, trade- and transport margins and price fluctuations. The core input-output model is expressed in basic prices and the sectoral aggregation codes of NACE[1]. More relevant to consumer purchases is the classification scheme used in the consumer expenditure surveys (SCE), COICOP[2]. A linking between NACE and CIOCOP was hence established. The matching matrix, together with the tax- and margins adjustment, was tuned so that the total household expenditure of Norway covered in SCE matches the total household consumption in the national accounts. Trade and transport margins were distributed on trade and transport sectors according to the average structure of household consumption within these sectors.

As mentioned in the introduction, other studies have constructed similar models to calculate total carbon footprints for households. The input-output approach is probably the most used approach for calculation of household carbon footprints at the aggregate level, due to its completeness and consistency with national account data. Related methods such as process-based life cycle assessment (LCA) have advantages when it comes to detailed assessment of various consumption items, but lack the completeness and consistency obtained in the IO-models.

The resulting carbon footprint for Norwegian households is shown in Fig 1. The total footprint is around 23.7 tonnes CO2-eq. per household per year, translating to about 10.7 tonnes per capita. The figure shows which COICOP consumption categories that contribute to the footprint, as well as a rough indication of in which sectors the emissions occur, in addition to direct emissions in the household itself. Imports have been aggregated into one single category. We see that the main drivers of emissions are connected to providing food and clothes, constructing, heating and maintaining the houses, as well as transportation (incl. purchase of

1 Nomenclature generale des Activites economiques dans les Communautes europeennes

2 Classification of individual consumption by purpose

vehicles). Other services have a relatively low contribution to the total footprint. In addition there is a category of consumption that is not covered by the SCE. This represents the balance between the SCE and the household final demand in the national accounts. The reason for this discrepancy is manifold but boils down to systematic underreporting of certain types of consumption (Statistics Norway, personal communication).

3 Experiences from using the tool and conclusions for further work

The results were made available to the planners in a spreadsheet that also provided a way for them to scale the volume of consumption within each category, in addition to the emissions intensity of each type of purchase. If they suggested a new type of technology for emissions reductions, they should adjust the corresponding expenditure and emissions intensity accordingly. In addition they had to justify (and preferably document) these adjustments. The tool keeps track of the total expenditure and asks the planners to re-spend the remaining average household budget if money is saved within some consumption categories. This way the tool addresses the rebound effect.

The first response from the planners to the introduction of this way of thinking in a city planning process was skepticism, especially the focus on the total consumption basket of the households, the quantification of effects, and the rebound effect. Nevertheless the teams used the tool in the process, also as an inspiration to come up with new ways of influencing the household emissions. The teams had to visualize the future life(styles) in the area to a much larger degree than if the focus was on energy and transport alone. In essence new ideas emerged along the possibility of introducing people to ways of spending their money in a more sustainable way. Hopefully while maintaining a quality of life as good as, or better than, before. This was reflected in the area plans as a strong focus on facilitating local service production, local recreation and business opportunities. Other solutions that came up ranged from typical technical approaches like insulating the houses better, alternative energy systems, electric cars and strict parking regulations. The dwelling density varied significantly between the teams, indicating disagreement on whether high density actually gives lower emissions, or whether access to recreational areas fosters more sustainable consumption patterns. In that sense the teams captured issues discussed in the literature in a precise way [12].

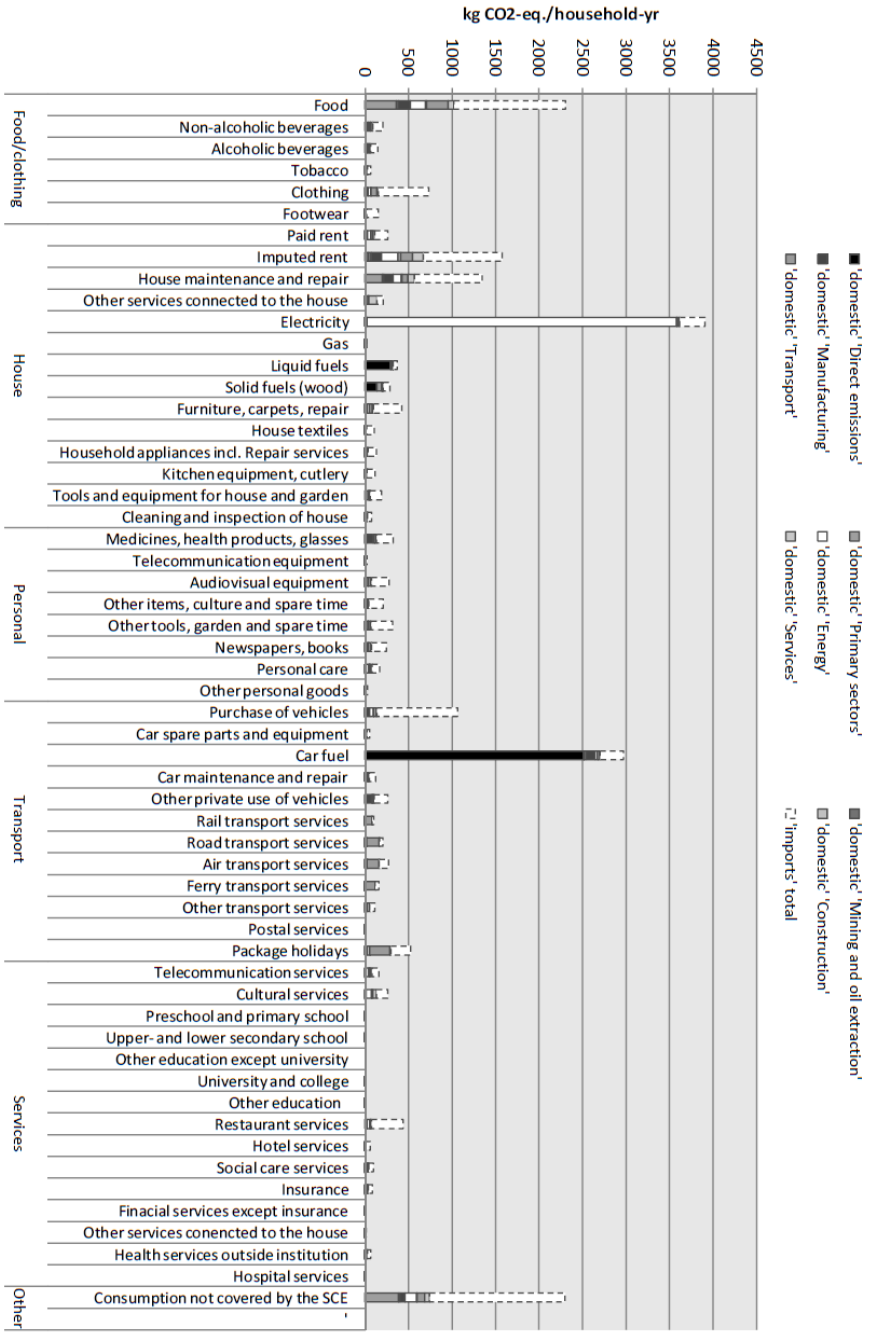

Fig 1: The annual carbon footprint of an average Norwegian household

Going through the tool results, it is apparent that the teams make too optimistic assumptions on the overall emissions reductions achievable with their suggested plans. In that sense the tool gives a useful reality check. It is clear that the tool influenced the process significantly and broadened the scope of the city planners; from a narrow focus on buildings and transport, to the entire household consumption.

4 Conclusions

The introduction of a consumption based carbon footprint tool for use in city planning provided new insights to the city planner. In particular the potential to influence how people spend their money provides an opportunity to be exploited. Only by addressing the total consumption basket, including potential rebound effects, can reduced emissions of greenhouse gases be realized. The most pronounced effect of the tool was not the results per se, but rather the pedagogical effect it served in the planning process, drawing attention from energy and transport, to a broader consumption perspective, as well as forcing the architects to quantify and justify their suggested sustainable or "green" solutions. Future work within the field should include gathering more data on actual consumption patterns and relate this to city form variables. The area used in this study could be used as an interesting sampling area.

5 References

[1] Karathodorou, N., D.J. Graham, and R.B. Noland, *Estimating the effect of urban density on fuel demand.* Energy Economics, 2010. **32**(1): p. 86-92.

[2] Perkins, A., *The Influence of Urban Form on Life Cycle Transport and Housing Energy and Greenhouse Gas Emissions*, in *School of Planning and Building, Division of Technology, Engineering and the Environment* 2002, University of South Australia: Adeleide.

[3] Norman, J., H.L. MacLean, and C.A. Kennedy, *Comparing High and Low Residential Density: Life-Cycle Analysis of Energy Use and Greenhouse Gas Emissions.* Journal of Urban Planning and Development, 2006. **132**(1): p. 10-21.

[4] Dodman, D., *Blaming cities for climate change? An analysis of urban greenhouse gas emissions inventories.* Environment and Urbanization, 2009. **21**(1): p. 185-201.

[5] Australian Conservation Foundation. *Consumption Atlas*. 2007 [cited 2010; Available from: http://www.acfonline.org.au/consumptionatlas/.
[6] Gray, R., B. Gleeson, and M. Burke, *Urban Consolidation, Household Greenhouse Emissions and the Role of Planning.* Urban Policy and Research, 2010. **28**(3): p. 335 - 346.
[7] Hertwich, E.G. and G.P. Peters, *Carbon Footprint of Nations: A Global, Trade-Linked Analysis.* Environmental Science & Technology, 2009.
[8] Hertwich, E.G., *Life Cycle Approaches to Sustainable Consumption: A Critical Review.* Environmental Science & Technology, 2005. **39**(13): p. 4673-4684.
[9] Ornetzeder, M., et al., *The environmental effect of car-free housing: A case in Vienna.* Ecological Economics, 2008. **65**(3): p. 516-530.
[10] Weber, C.L. and H.S. Matthews, *Quantifying the global and distributional aspects of American household carbon footprint.* Ecological Economics, 2008. **66**(2-3): p. 379-391.
[11] Holden, E., *Ecological footprints and sustainable urban form.* Journal of Housing and the Built Environment, 2004. **19**(1): p. 91-109.
[12] Holden, E. and I.T. Norland, *Three Challenges for the Compact City as a Sustainable Urban Form: Household Consumption of Energy and Transport in Eight Residential Areas in the Greater Oslo Region.* Urban Studies, 2005. **42**(12): p. 2145-2166.
[13] Høyer, K.G. and E. Holden, *Household Consumption and Ecological Footprints in Norway – Does Urban Form Matter?* Journal of Consumer Policy, 2003. **26**(3): p. 327-349.
[14] Hertwich, E.G., et al. *The Environmental Benefit of Car-free Housing Projects: A Case in Vienna*. in *Proceedings, The Third International Workshop on Sustainable Consumption*. 2004. Tokyo: Society for Non-Traditional Technology.
[15] Hertwich, E.G., *Consumption and the rebound effect: an industrial ecology perspective.* Journal of Industrial Ecology, 2005. **9**(1-2): p. 85-98.
[16] Leontief, W., *Environmental repercussions and the economic structure: An input-output approach.* The Review of Economics and Statistics, 1970. **52**(3): p. 262-271.
[17] Wiedmann, T., *Carbon Footprint and Input-Output Analysis - An Introduction.* Economic Systems Research, 2009. **21**: p. 175-186.
[18] Hendrickson, C., et al., *Economic Input-Output Models for Environmental Life-Cycle Assessment.* Environmental Science and Technology, 1998. **32**(7): p. 184A--191A.
[19] United Nations, *Handbook of input-output table compilation and analysis. Studies in Methods Series F, No 74. Handbook of National Accounting*. 1999: United Nations.