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Global warming impact of suburbanization: The case of Sydney

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ABSTRACT

Suburbs have naturally become a focal point of carbon mitigation for cities undergoing rapid suburbanization. This has created a debate over which urban form can more effectively lead to lower household carbon footprints (CF). Previous suburban-scale studies using economic input-output life cycle assessment with national average carbon intensities have demonstrated the mitigation potentials in households via urban planning. However, there is a need for suburban-scale multiregional input-output (MRIO) tables to model suburb-specific carbon intensities and thus to account for the heterogeneity of both production and consumption in different suburbs. This study explores the case of Sydney, Australia, and its many suburbs. The CF of households is broken down into 111 sectors and 248 spatial divisions of Greater Sydney by employing a suburban-scale MRIO model. The impact of domestic and overseas migration on household CFs is modelled during 2009–2010, and the CFs are allocated to different ethnic groups. The results suggest that residents in the densely populated city core have a comparable CF to residents living in outer city suburbs, thus contradicting previous studies supporting the notion that densely populated inner-city areas yield relatively lower CFs. The rapid growth of population increases household CFs in inner western suburbs. According to the study findings, the ongoing Sydney metropolitan development plan may therefore not be sufficient to provide a sustainable carbon emissions reduction strategy, if suburb density is increased without any constraints on resident consumption patterns. Urban planners need to consider policies to direct the investment brought by immigration towards a lower-carbon economy and infrastructure and also may take advantage of the sharing economy to change consumption behaviour.

1. Introduction

Cities are crucial in leading the global climate change mitigation strategies, with the alliance of the EU-based Covenant of Mayors and the UN-backed Compact of Mayors covering more than 600 million city dwellers (Bloomberg and Šefčovič, 2016). The action and regulation of cities is seen as an increasingly important alternative to national targets, particularly in the countries that have failed to ratify the Paris agreement. There is an urgent need for cities to take more ambitious actions against climate change, as estimates show that current national targets can only deliver about half of the carbon savings required to meet the Paris agreement goals (C40 and Arup, 2016).

City carbon footprint accounting methods include the community-wide infrastructure footprint (CIF) method (Chavez and Ramaswami, 2013; also see other examples in: Kennedy et al., 2015; Ramaswami et al., 2017a; Ramaswami and Chavez, 2013) and consumption-based accounting (CBA) (Wiedmann et al., 2016; also see other examples in: Athanassiadis et al., 2017Ala-Mantila et al., 2016; Dias et al., 2014; Mi et al., 2016; Millward-Hopkins et al., 2017). The CIF combines a bottom-up based process analysis for the territorial emissions with an input-output based life cycle assessment for calculating transboundary emissions (Ramaswami et al., 2008). In contrast, CBA allocates all carbon emissions to cities based on the national top-down city-scale input-output model, as exemplified in previous studies (Chen

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et al., 2016a, 2016b). A more detailed comparison between these two methods is provided in Hu et al. (2016). Though these methods provide comprehensive CF assessment at city scale, there is still a need for detailed suburban CF accounting for city planners.

Suburbs are the focal point of the emissions mitigation for cities. Many countries around the world are undergoing intensive but highly diverse suburban development (Hamel and Keil, 2016). In the United States, suburbs account for half of the nation's household CF (Jones and Kammen, 2014). The suburban-scale greenhouse gas (GHG) emissions vary up to 50% due to different housing types, resident characteristics and behaviour and transport options (Newton and Meyer, 2012). The prevailing paradigm arising from previous studies (Glaeser and Kahn, 2010; Lee and Lee, 2014), is that suburban sprawl offsets CF savings of densely populated urban cores, and suburbs are significantly higher in emissions per capita than the city core. This therefore drives the urban planning policy of targeting increases in the density of urban settlements and preventing urban sprawl (Davoudi and Sturzaker, 2017). However, some scholars argue that these studies tend to focus on transportation and/or housing energy, while the results could vary when the other forms of household consumption are taken into account (Heinonen et al., 2013a, b). Another study, Ottelin et al. (2015), even suggests that residents living in newer housing in outer urban areas may have lower CFs compared to those living in inner urban areas due to a lower level of overall consumption and more modern infrastructure and appliances.

Previous studies also demonstrate that energy consumption and CF per capita in the transport sector are higher in suburbs compared to the city centre (Guhathakurta and Williams, 2015; also see other examples in Lenzen et al., 2004; Zhang et al., 2016a). However, the lack of consideration for carbon embedded in infrastructure and purchases of private cars may hinder the comprehensive understanding of low-carbon developments in the transport sector. Other factors such as income, household size and lifestyles also have a significant influence on energy consumption and GHG emissions in different urban areas (Ala-Mantila et al., 2016; Heinonen, 2017; Heinonen et al., 2013a, b; Wiedenhofer et al., 2017).

The methods commonly used in previous suburban-scale research are bottom-up life cycle analysis (LCA) or, increasingly, economic input-output life cycle assessment (EIO-LCA) at national scale using household survey data as a proxy for final demand (see comprehensive literature review in Table S1, Appendix). The assumption inherent in national scale EIO-LCA is that products purchased by regional households are produced regionally and nationally using a similar production recipe (Baiocchi et al., 2010; Lenzen et al., 2004). There is therefore a need for highly disaggregated suburban-scale multiregional input-output (MRIO) tables to model suburb-specific carbon intensity in order to account for the heterogeneity of CFs of production and consumption in different suburbs, a gap previously highlighted by Heinonen (2017). Our study is the first, to our knowledge, to employ a suburban-scale MRIO.

Understanding current differences in emissions is crucial for predicting future growth in emissions, the number one determinant of which is population growth. More than 80% of the forecasted increase in GHGs in 2020 will be attributable to increases in the Australian population (Birrell and Healy, 2009). While the five capital cities are likely to make up more than 80% of total Australian population growth, the largest and fastest growth is located in suburban areas (ABS, 2015). Under the current population growth trend, and given present consumption patterns, Australia is unlikely to achieve the five percent reduction below 2000 emissions levels by 2020 (Birrell and Healy, 2009; Bradshaw and Brook, 2016), though some scholars argue that it might be possible to achieve negative emissions by 2050 if drastic reductions can be achieved in the electricity and land use, land-use change and forestry (LULUCF) sectors (Hatfield-Dodds, 2015; Hatfield-Dodds et al., 2015).

Immigration and associated consumption patterns of new residents therefore play a critical role in shaping the trend of emissions in urban suburbs. As in other nations with large immigrant populations (e.g. New Zealand, Canada and US), the bulk of Australia's population growth (60%) comes from international migration (Parliament of Australia, 2016). The majority of immigrants tend to prefer the suburban areas, especially in the large capital cities (ABS, 2009–2010). These new residents gradually adopt a more local lifestyle and associated consumption patterns, thus contributing to high CFs associated with an Australian lifestyle. However, there is currently a lack of studies modelling the CF impacts of different ethnic groups across urban areas, despite a significant amount of research on other aspects of immigration (Australian Science, 2013). Our study makes a contribution to this area by considering the diversity in CFs between different ethnic groups.

The study makes a timely contribution to the urban form and household CF debate by employing a suburban-scale multiregional input-output model. Given its important role in the debate and the lack of previously detailed considerations in MRIO studies, the CF of the transport sector is accounted for in a comprehensive manner, distinguishing between direct private, indirect private, public and transport-related infrastructure. Sydney, a fast-growing developed world city, where suburbanization is occurring rapidly due to both international and domestic in-migration, serves as an ideal case study. The study findings have important implications in terms of prioritising mitigation options in ongoing metropolitan planning. The following section provides a detailed background for the city case study. It then outlines the methods in two sections: multiregional input-output analysis and global warming impact of suburbanization.

2. Methodology

2.1. Case study description and datasets

Greater Sydney had a total population of 4.6 million residents and contributed 28% of national GDP in 2015, and the city is expected to become home to an additional 1.6 million residents over the next 20 years (GSC, 2016).

To fit with the interest of ongoing metropolitan planning, this study adopts Greater Sydney's boundary based on the definition of the Greater Sydney commission (in Fig. 1). The boundary covers all the potential areas that fall under the jurisdiction of the metropolitan government including the city centre, surrounding suburbs and other rural areas. The areas with the highest population density are located in the city centre and surrounding suburbs, while the western suburbs show lower population densities (one dot = 5500 residents, Fig. 1). This study further separates Greater Sydney into 14 areas (SA4 level) in our MRIO model and display results for 248 areas(SA2 level) based on official Greater Capital City Statistical Areas (GCCSAs) published by the Australian Bureau of Statistics (ABS, 2012).

Geo-demographic information is extracted from the Mosaic dataset (Experian, 2013) to estimate local household consumption spending for all SA2 divisions covering 1,056,229 households living in Greater Sydney. Mosaic is a consumer classification system, which provides weekly household expenditure estimates across 594 household goods and services for 49 distinct socioeconomic groups (see the Mosaic sample categories in the SM (Experian, 2013),). The underlying data are based on the latest edition of the extensive household expenditure survey conducted by the Australian Bureau of Statistics (ABS, 2011). The assumption is that