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Towards Low Carbon City Planning in a Medium Sized Low Density City

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Abstract

Adelaide is a medium sized low density city located in south eastern Australia. Typical of highly urbanized Australia, where abundant land and low cost private transport contribute to urban sprawl in all major cities, Adelaide is poorly placed to move to a low carbon future, despite access to abundant renewable resources and a favourable policy environment. Australians have some of the highest emissions per capita in the world. This study examines the spatially explicit nature of CO_2 emissions across the metropolitan area and explores the relationships between emissions and a range of socio-economic variables. Contrary to findings from other westernized cities, incomes, rents and housing prices are not well correlated with distance from the city centre or train stations. Household emissions are strongly correlated with household size, rooms per household and number of motor vehicles per household. Household emissions are therefore highly associated with private car use and daily commuting distances. Public transport is poorly utilized and many urban residential areas surrounding the most heavily used public transport routes also have very high household emissions. Attitudinal change to car and public transport use is therefore essential if Australian cities such as Adelaide are to move towards a low carbon future, and governments must design and implement policies which can achieve such change.

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1. Introduction

Both land use change and ecological change are likely to occur in Australia as a result of spatially explicit changes in climate and resource availability, particularly water. Identifying responses, and modelling and planning for change will form the basis of effective adaptation and mitigation while also informing resource allocation and policy. The aim of this project was to consider the CO_2 mitigation effects of different urban policy scenarios within the Adelaide Metropolitan Area. In doing so it focusses on the

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spatial distribution of CO_2 emissions from the residential and transport sector using the latest available census and emissions data. Using the models it is possible to predict the impacts of, for example, increased photovoltaic energy use, new transport options, urban landuse and development changes, and changes to household structure.

2. Materials and Methods

Data layers were developed within a GIS framework using data from a range of sources. 2011 and 2006 census data were obtained from the Australian Bureau of Statistics (ABS), particularly relating to household composition and characteristics, income, geographical classifications. Transport network data and Journey to work data (2006) were obtained from the Department of Transport, Energy and Infrastructure (DTEI). Australian emissions intensity tables were used with household expenditure survey data for South Australia to calculate household CO_2 emissions. Photovoltaic installations data was obtained from the Australian Greenhouse Office and zoning and urban development data was obtained from South Australian Department of Planning. A range of transformations and combinations were carried out on the original data to generate the required datasets.

2.1. Direct and Indirect CO_2 Emissions Estimation

Household CO_2 emissions are a combination of both direct and indirect emissions. Average CO_2 emissions were determined for each polygon across metropolitan Adelaide at SA1 level, using household type composition, household expenditure survey data and emissions intensity data. Household types were based on the classifications used by [1], adapted to suit ABS data and Australian household types. The six household types used for Adelaide were: 1. One person household, 2. Couple no children, 3. Couple with children, 4. One parent family, 5. Group household, and, 6. Other family type

To calculate CO_2 emissions for each areal unit, equation (1) was used, adapted from [2], with $ values substituted for Yen.

$$CE_i = \sum_j H_{ij} [\sum_k E_{ijk} (ic_{ik} + dc_{ik})] \quad (1)$$

CE_i: annual CO_2 emission in each zone i (kg-CO_2/year)
H_{ij}: the number of type j households in zone i (household) [National Census]
E_{ijk}: annual expenditure to the item k by type j household type in zone i (yen/household/year) [HES]
ic_{ik}: emission intensity of indirect CO_2 for the item k (kg-CO_2/yen) [3EID]
dc_{ik}: emission intensity of direct CO_2 for the item k (Gas, kerosene and gasoline) (kg-CO_2/yen)

Emissions intensity in terms of kg-CO_2/$ were calculated using weekly household expenditure data by household type for South Australia. The emissions intensity categories closely followed those of [3] in their cross country comparisons of household emissions intensity. From these, annual expenditures were calculated, as given in Appendix 1. Emissions per $ were then calculated using the emissions intensity tables for Australia, given in [4] with adjustment for inflation using annual inflation rates from the Australian Treasury. Some aggregation of the classification types in the emissions intensity data was carried out to match the classifications in the household expenditure survey.

A number of exploratory analyses were undertaken to determine the relationship between household CO_2 emissions and a range of socioeconomic variables. These help provide an understanding of the areas which need to be targeted by government in reducing household CO_2 emissions.

3. Results

For most household types the majority of CO_2 emissions are due to domestic fuel and power use, food and transport. A two parent family with dependent children household type has the highest emissions of all household types. The average is about 27,000 $kgCO_2$/yr for all South Australian Households. Highest emissions in the range above 29,000 $kgCO_2$/yr occur mostly in areas at greater distance from the city centre but also occur in pockets within the city area. In terms of emissions per capita, the highest emissions in the range above 11,000 $kgCO_2$/yr per person occur mostly in the more densely populated and higher income urban area.

A number of exploratory analyses were undertaken between various socioeconomic variables. The correlations between the household variables examined for the models and household emissions are given in Table 1. There is a strong correlation between household emissions and household size and average number of rooms per household and the number of motor vehicles, and to a lesser extent income. This would be expected as household size, number of rooms, and number of motor vehicles are all likely to be strongly correlated. There is no great decline in rents with distance from the city centre, as would be expected in the majority of urban situations.

Table 1. Correlation between household emissions and household characteristics

Emissions per Household	R^2	Pearsons
Household Size	0.78	0.88
Rent	0.22	0.47
Property Value	0.00	0.03
Distance to city centre	0.02	0.14
Income	0.44	0.66
Motor Vehicles	0.66	0.81
Mortgage	0.26	0.51
Rooms per Household	0.83	0.91

4. Discussion

Emissions intensities vary between developed countries, depending to a large extent on geography, population density, household characteristics, dominant transport modes and electricity production [3]. Data by [5], for example, suggest emissions of 1276 kg CO_2/yr for an average Japanese household (direct). Published average household emissions for Australia are 14,450 $kgCO_2$/yr (direct) [6]. Some major differences include that Japanese data suggests 264 $kgCO_2$/yr per household for gasoline. At around 220g/km, this suggests that Japanese households only average around 1000 km per year by car. The average per car in Australia is 14,100 km/yr [7] and many Australian households have 3 or 4 cars. The average for Adelaide is 1.58 cars/household, resulting in 10,850 $kgCO_2$/yr (5034 $kgCO_2$/yr direct + 5816 $kgCO_2$/yr indirect). However, the indirect emissions associated with transport in Japanese cities are much higher, due to a higher level of public transport use: around 90% for Tokyo.

For electricity use, Australian households average 6570 kWhr/yr and for South Australia emissions are 0.79 $kgCO_2$/kWhr [8], or 5190 $kgCO_2$/yr. Income is not necessarily a driver of emissions patterns, and for Adelaide there is only a moderate correlation between income and household emissions. Similar analyses by [3] found high income households had high emission in Sweden and Norway, but the opposite was true for the UK and the Netherlands. Similarly, [9] in analyses of a range of developed and developing countries found no uniform relationship between emissions and household expenditure.

The strongest correlations between emissions and household characteristics for Adelaide, as determined from Census variables, are for household size, number of rooms per dwelling and number of motor vehicles. Household size directly effects household expenditure, particularly on food. Larger families with larger houses also spend greater amounts on domestic fuel and power, particularly for heating and cooling. Multiple cars per household contribute to high transport related expenditure and high emissions. Similar results were found in a study by [10] for household in Melbourne. They found however, that there is high degree of variability between individual households. Household food waste alone in Australia generates around 15.4 $MtCO_2eq$/yr, or 700 $kgCO_2$/pers [6], as waste disposal is 100% landfill. The average household size in Adelaide of 2.14, so 1498 $kgCO_2$/yr is generated solely from food waste.

Unlike most urban situations, high property prices, high rents and high mortgage expenditure are not correlated with distance to the city centre for Adelaide, and this has a strong influence on emissions patterns across the city. The relatively small size of Adelaide combined with relatively cheap transport costs and lifestyle choices relating to housing are likely contributors to these patterns.

5. Conclusion

This project has provided a range of insights into the spatial distribution of household CO_2 emissions for the Adelaide metropolitan areas and illustrated that significant differences exist between the spatial structure of Adelaide and typical cities in developed countries.

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Biography - Simon Benger is a Senior Lecturer in Spatial Information Systems. He specializes in applications of GIS modelling and remote sensing to a range of environmental issues, including water management, carbon farming, landuse change and emissions modelling.