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Transport and Stationary Energy and Greenhouse Gas Emissions Scenarios for Melbourne 2031

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Abstract

In 2009 the Victorian Department of Transport published a report entitled 'Macro-Urban Form, Transport Energy and Greenhouse Gas Emissions: An Investigation for Melbourne', which looked into the relationship between large-scale urban form and sustainable travel outcomes: i.e. a number of scenarios were developed outlining various possible future city shapes for Melbourne, and examination was made of the relative impact of these particular city shapes on transport energy and transport-related greenhouse gas emissions.

On the basis that transport-related energy and emissions outcomes are, however, only part of a 'sustainability' story when it comes to city-shape, this paper uses recent Australian research into in-dwelling energy and related greenhouse gas emissions to refine the above scenarios to also include non-transport-related outcomes.

1. Introduction

In 2008/09 the Victorian Department of Transport published a report into the impact of Macro-Urban Form – i.e. 'city-shape' – on Melbourne's future transport energy and emissions outcomes. To determine this impact the study employed integrated transport and land use modelling to explore the kind of travel patterns generated by a range of future urban form and transport infrastructure scenarios for the year 2031. The scenarios themselves, as outlined below, were designed as 'ideal-types' or 'extreme versions' of the kinds of urban development that Melbourne could hypothetically experience in the future, the idea of the study being to highlight how much city-shape *per se* might be able to play a role in influencing travel demand and the sustainability of that travel in terms of its energy and carbon-intensity.

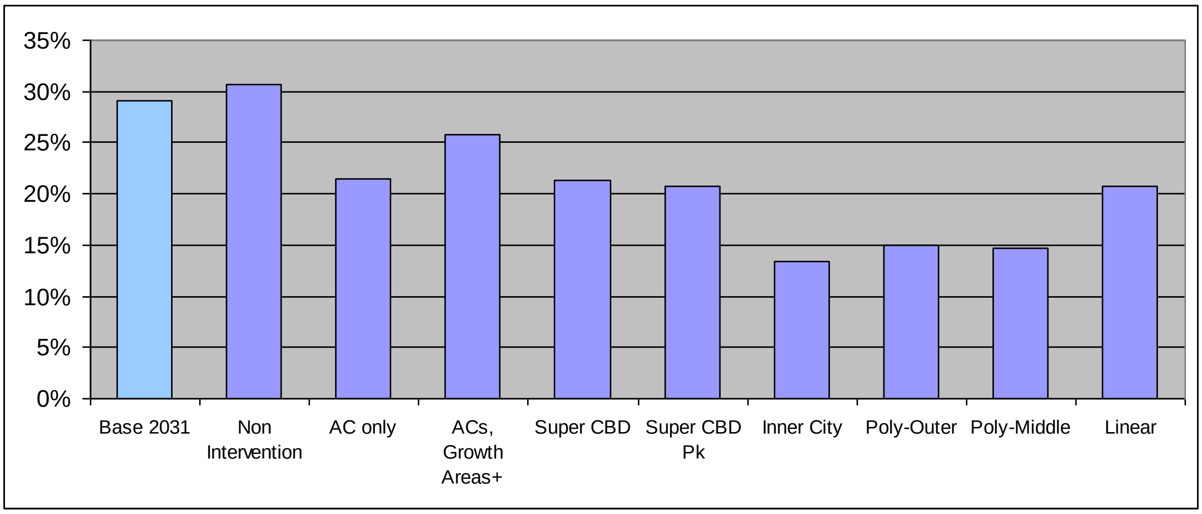
1	Current Trend/Base Case 2006 & 2031	Continued urban development according to current patterns, with no change to existing policy or implementation programs (as of 2008).
2	Non-Intervention	Current policy and implementation programs are reversed and development occurs without high-level planning intervention or Urban Growth Boundary (UGB).
3	Activity Centres (AC)	Strong infrastructure investment and high-level planning interventions focused on Melbourne 2030's Principal and Major Activity Centres (without further development of existing Growth Areas)
4	Activity Centres (AC) Growth Areas Plus	Strong infrastructure investment, and high-level planning interventions as outlined in Melbourne 2030, including development of urban fringe growth

		areas.
5	Super CBD	Half of future population growth and all future employment growth concentrated in an enlargened CBD.
6	Super CBD – Parking Prohibition Variant	As above, but with no new off-street parking permitted in this larger CBD area.
7	Inner City	Future growth directed to the inner-city, ‘transport-rich’ areas of Melbourne, including the CBD.
8	Polycentric City: Outer Centres	Urban growth directed toward key outer suburban centres, while primacy of CBD maintained.
9	Polycentric City: Middle Centres	Urban growth directed toward key middle ring suburban centres, while primacy of CBD maintained.
10	Linear Development	Large-scale residential and employment development confined to within 400 metres of a railway station or tram-stop, with expansion in public transport capacity.

The modelling of these scenarios resulted in the following estimates of transport-related GHG emissions (see Figures 1 and 2, below). On the basis of these estimates, the following key conclusions can be drawn:

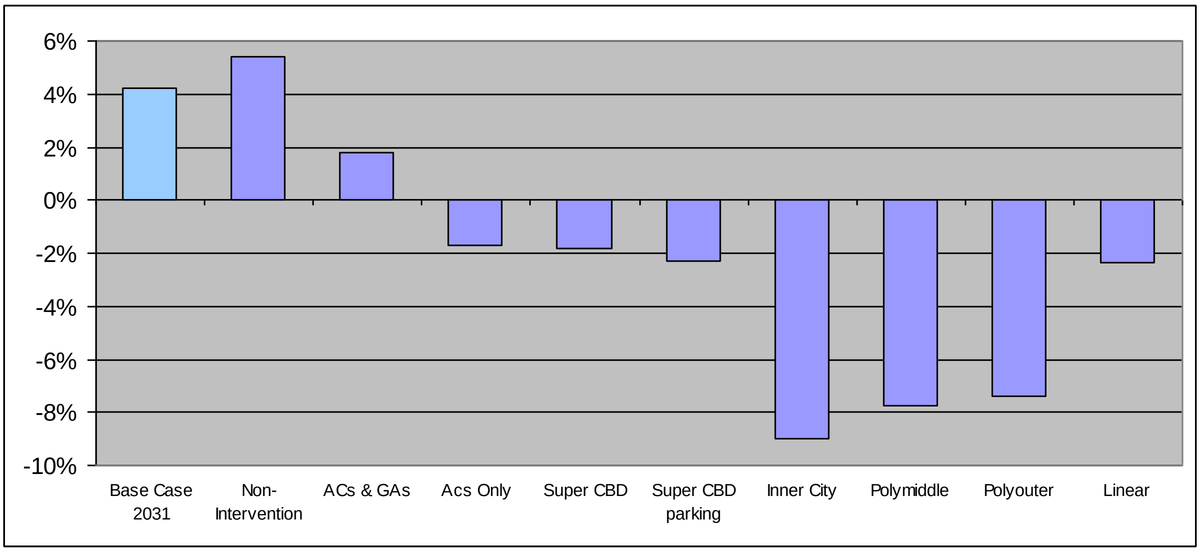
1. Macro-Urban form and transport infrastructure *can* have a significant and measureable impact on transport-related energy consumption and Greenhouse Gas (GHG) emissions;
2. Projected population increases mean that transport energy and emissions will (assuming the same vehicle fleet composition) increase by almost 30 per cent in the next couple of decades;
3. Therefore, ‘doing-nothing’ in terms of urban form is not an option, if we wish to address the emissions implications of continuing growth in Melbourne;
4. Inner City consolidation (preferably along tram routes) and polycentric centres are best placed to minimise this growth in transport energy & emissions;
5. A central city high-rise tower solution (the Super CBD scenario) for Melbourne performed relatively poorly in terms of Vehicle Kilometres Travelled (VKT) and GHG emissions; and
6. Outer Fringe single-use urban development remains a challenge.

Figure 1: Macro-Urban Form Scenarios – Percentage Increase in Transport GHG Emissions compared to 2006 Base Case



These study results, and conclusions, have obvious implications for future planning in Melbourne, i.e. they not only underscore the importance of more integrated transport and land use planning, but they also provide evidence in support of a focus on urban consolidation around transport nodes and along transport corridors.

Figure 2: Macro-Urban Form Scenarios – Percentage Difference in GHG Emissions Per Capita compared to 2006 Base Case

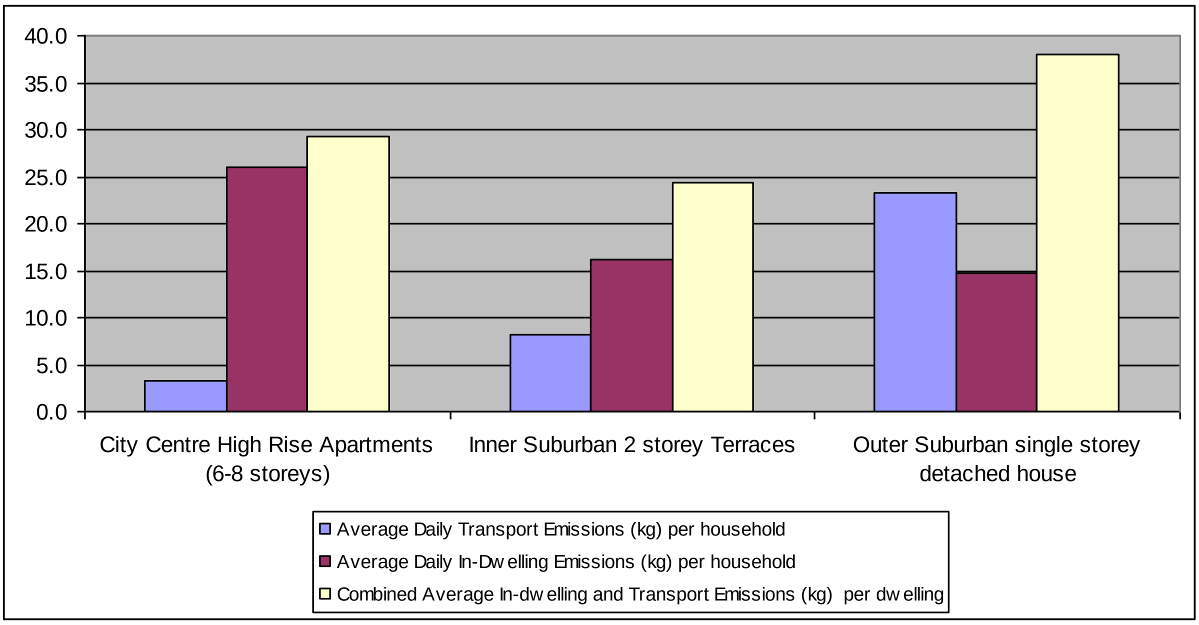


2. The importance of combining Stationary with Transport GHG Emissions

On this basis, it would be reasonable to argue that analyses of the GHG implications of ‘macro-scale’ urban development would usefully include those emissions generated by the particular travel demands associated with that urban development, particularly given the size of the transport contribution to GHG emissions. Yet, equally, it may be argued that while a focus on *transport-related* emissions is important, it should also not itself suffice as a measure of the sustainability of a particular example of urban development. Indeed, as some other recent work has shown, it can be argued that a consideration of the general merits of a particular urban form or city-shape in relation to sustainability ought to consider both transport and 'stationary' emissions together.[1]

One example of where this has been done is in the work led by Alan Perkins in Adelaide, this work has shown that while CBD households might have lower travel and transport-related emissions than households located further out (where travel distances tend to be greater), this locational benefit might well be undermined by other factors – namely, the stationary energy/emissions profile of that centrally-located dwelling (see Figure 3 below) (Perkins et al, 2007). As the work of Perkins and others has outlined, household energy audits have shown that high-rise apartment-type dwellings (i.e. that one might typically find in CBD settings) tend to show higher per household stationary emissions than single-unit detached dwellings (Randolph et al, 2007). In other words, while for transport emissions an increase in the density of dwellings and destinations will tend to produce lower transport-related emissions, according to Perkins this same increase in density, at least in terms of dwellings, will tend to produce higher rather than lower stationary emissions (although it should be noted that this conclusion is based on audits of only a small number of apartment blocks).

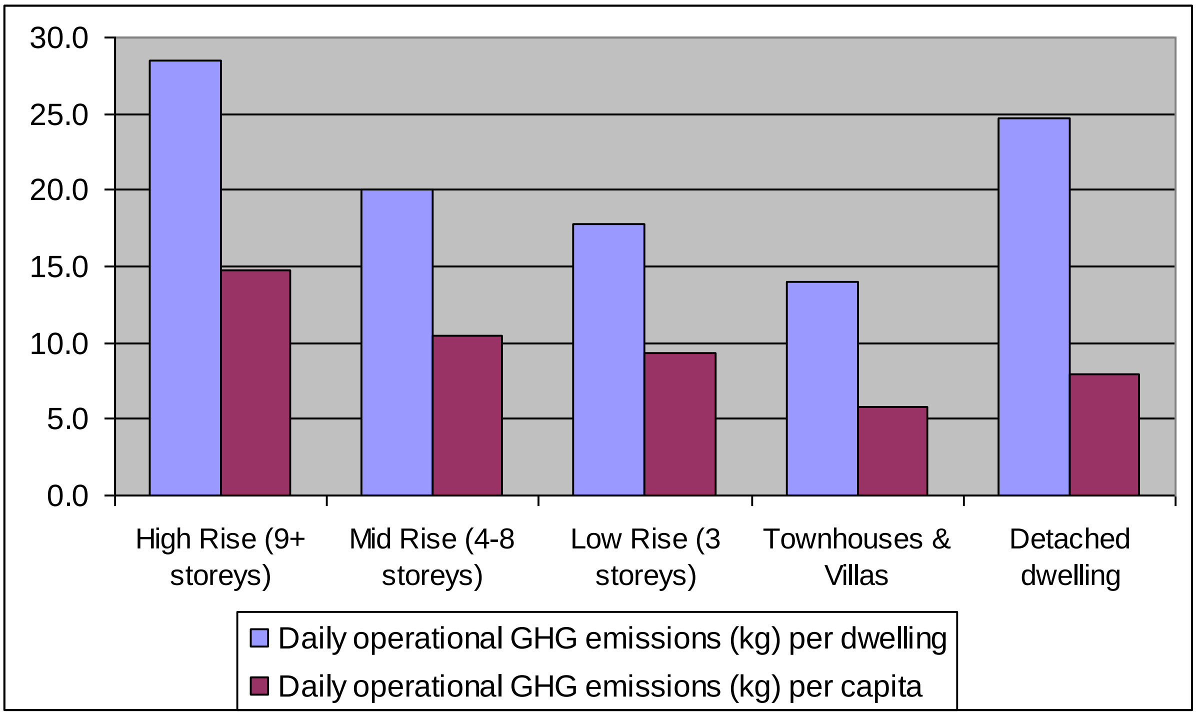
Figure 3: Transport and In-Dwelling GHG Emissions in Adelaide - Perkins (2007)



Another Australian study that looks at this kind of energy use and its associated emissions, led by Paul Myors of Energy Australia, found that *all* multi-unit dwellings among approximately 4,000 surveyed (except for those in apartment buildings nine storeys or above) produced less operational GHG emissions per household than detached, single-unit dwellings (Myors et al, 2006). When, however, the per capita figure was taken into account, the result was somewhat different - only the Townhouse and Villas category had lower emissions than the detached dwelling category (see Figure 4 below).

[1] By 'stationary' emissions we simply mean emissions not produced by the transport sector, i.e. those related specifically to household energy consumption (but not 'embodied' household energy, that related to the construction of households and household infrastructure, which is excluded from this analysis).

Figure 4: Dwelling Type and In-Dwelling GHG Emissions - Paul Myors et al (2005)



What all this work suggests is that, whether one is looking at per household or per capita figures, high-rise central city apartment living is, for one, unlikely to be the optimal solution as far as minimising combined transport and stationary GHG emissions. Further, it suggests that there is likely to be a point somewhere in the middle of the housing density range where the benefits to be derived from location are *not* outweighed by the stationary emissions implications of that particular dwelling type - a transport and stationary energy 'sweet spot', as it were.

All this naturally begs the question: how would the scenarios tested in the DoT Macro-Urban project fare should estimations of in-dwelling residential emissions be combined with the transport emissions results? Would it confirm the relativities between the various scenarios or alter them? In other words, what city-shape would tend to work best when *both* transport and stationary household emissions are taken into account?

3. Calculating Stationary GHG Emissions

In the absence of a comprehensive household-level audit of current residential energy usage throughout Melbourne, an answer to the above questions requires an estimation of the stationary emissions that might arise from the various macro-urban form scenarios.

This, it may be suggested, could be done in at least two ways: through an aggregate and/or a disaggregate method. In the first – aggregate - approach, one could obtain energy use and GHG emissions data currently for Melbourne, and then look for correlations between whatever smallest-area emissions totals are available and the proportions of different types of dwellings in such areas (as informed by the latest ABS data). If strong correlations were evident and the relationship was thus reasonably linear, one could then use this as a way of estimating the total stationary emissions for each of the 2031 scenarios (i.e. based on the understanding one would have gained about what proportion of multi-storeyed dwellings tends to be associated with what total amount of stationary household emissions).

In applying this 'aggregate' method, however, one presently encounters the following problems. Firstly, energy audit data for Melbourne households is currently available at no lower than an LGA level - arguably too large to reliably cross-reference for other factors - and then for only about half of the LGAs. Secondly, for these LGAs, the relationship between stationary emissions and dwelling types appears to be far from linear, for the basic reason that there are a number of important drivers of energy demand other than simple dwelling type and residential density - such as income, floor space, and the age of the dwellings themselves - the power of which, individually, is still unclear.[2] Finally, the ABS census data may not be quite fine-grained enough, in that it makes no distinction between 'mid-rise' and 'high-rise' dwellings (when the difference between these dwelling types on household emissions may well be significant).

The second – disaggregate – approach estimates upwards from population and dwelling density to overall household energy demand (with associated emissions). This basically involves two separate exercises: (1) translating the patterns of population as found in the various scenarios to their 'equivalent' built form in terms of average dwelling type or mix of dwelling types for a given transport zone (i.e. how many of what dwelling-types would be found where in each scenario); and (2) matching this built form against available energy / emissions data for different dwelling types. The first of these above two exercises may be undertaken by:

- assuming an average net dwelling floor space per person;
- multiplying this by the projected number of people (and jobs – to take into account commercial density) per zone; then
- dividing the figure by the amount of net residential land area available; to
- arrive at an estimate of floor space needed, plus a floor area ratio; from which one can
- assume a corresponding dwelling type (including number of storeys).

The derivations of the required assumptions (e.g. for floor space per person, the difference between gross and net residential land, etc.) can either be theoretical or based on existing Melbourne averages, or a mixture of both. The second exercise – matching the density data with the energy data - then merely involves multiplying the number of households by dwelling type and their corresponding energy consumption profiles, from which one can arrive at a 'total' figure for energy consumption and associated emissions production for Melbourne.

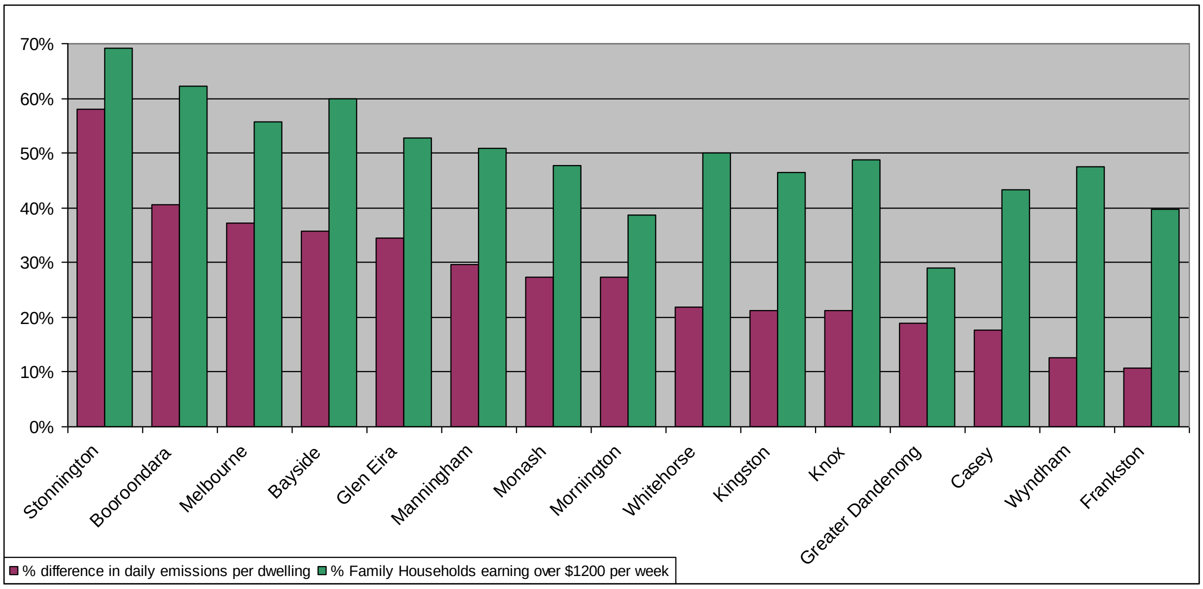
In this study the decision was made to estimate stationary household emissions according to the second, disaggregate approach. It was also decided to use the Myors energy audit data rather than that of Alan Perkins' study, for two basic reasons: (1) the former presents household energy and emissions data for the widest categorisation of dwelling types (making it easier to match the energy data to the dwelling density data); and (2), the number of households across the various dwelling types audited is substantially higher, and thus the Myors survey sample is far more likely to be representative at least of current 'average' households (even if the role of income is not factored into the analysis).

[2] It should be noted that as the number of apartment buildings surveyed in Perkins' study is rather small (certainly, compared to Myors' study), the resulting audit data may well be influenced by the socio-demographic profile of the residents of the particular dwellings concerned. What Perkins' sample does reveal, however, is that income *can* be a powerful factor in per household energy consumption, in that one apartment block audited that had a lower income profile also had a significantly lower per household energy consumption.

4. Transport and Stationary Emissions by Scenario - Findings

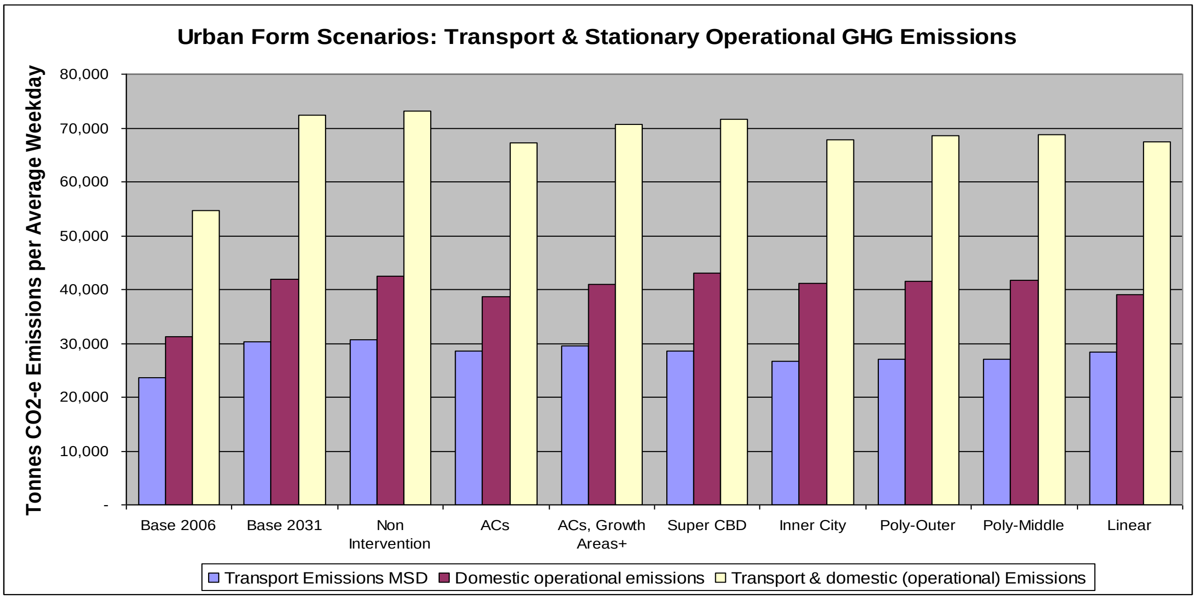
In reporting the results one should acknowledge here some major caveats – namely, that the estimations of energy consumption and emissions totals for the scenarios are likely be only ‘crude’ in nature, and may well be at considerable variance with what an actual Melbourne audit might reveal. Indeed, a comparison of the actual current Department of Sustainability and Environment (DSE) LGA audit totals for energy consumption / emissions against our 2006 Base Case (based on Myors data) reveals substantial and inconsistent variations (averaged at 28 per cent - see Figure 5 below) (Newton and Tucker, 2009). These variations may be attributable to a range of other factors for which no account has been made in the calculations (in either data source), such as the role of income and lifestyle, age and energy efficiency of existing infrastructure, etc. A strong correlation between the scale of difference between the 2006 Base Case and existing audit data for each LGA, and the proportion of households earning more than $1200 a week, may indeed be evidence of the role of income in accounting for the discrepancy.

Figure 5: Percentage 'underestimation' of daily GHG emissions per dwelling and percentage of Family households earning more than $1200 per week



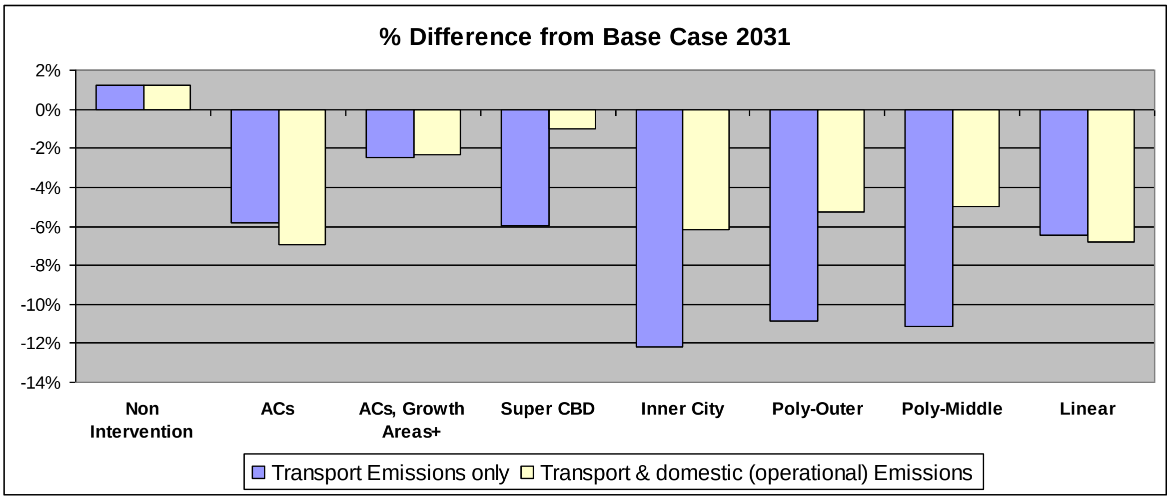
Notwithstanding, however, the potential inaccuracy in the size of the individual totals compared to existing audit data in Melbourne, the results of our calculations are useful in so far as they indicate the basic *relativities* between the scenarios in terms of the urban form and stationary energy relationship – and this is what, after all, is the focus of this paper. That is, it should be understood that as neither the stationary energy studies nor in our Macro-Urban form study attempt to control for income and/or lifestyle of residents, this paper can only report on the impact, hypothetically, of urban form on stationary energy aggregates exclusive of household income (and other demographic factors).

Figure 6: Scenarios: Transport & Stationary Operational GHG Emissions



On this basis, the main finding (see Figure 6 above and Figure 7 below) is that the relativities between the scenarios are indeed changed. When only transport-related emissions had been taken into account, the Inner City and Polycentric scenarios performed significantly better than the others (3-4 per cent better than the next best scenario); however, when transport and in-dwelling emissions were taken together, the results tended to be closer, with the Linear and Activities Centres Scenarios just emerging as frontrunners, with the Inner City Scenario close behind them and the two Polycentric Scenarios a little further behind.

Figure 7: Transport and Stationary Emissions - Percentage difference from Base Case 2031



It is not difficult to account for this changed picture. Of the scenarios without urban fringe Growth Area development, the Linear and Activities Centres Scenarios involve the widest distribution of population throughout the metropolitan area, with the consequent lowest overall densities. In other words, given that their respective urban development is focused around the largest number of transport nodes across Melbourne, they would have fewer of the high-rise apartments that tend to produce relatively higher GHG emissions per dwelling. Overall, their relative emissions would thus tend to be lower than those scenarios with a higher proportion of higher-rise dwellings.

5. Interpreting the results

The key issue here, one might pose, is how these results should be interpreted. Do they suggest that, given the respective scale of transport and in-dwelling related emissions, it is preferable that future urban growth be distributed more equally around a *larger* rather than more limited number of transport nodes throughout the metropolitan area? In other words, does it suggest that, ultimately, polycentric development and inner city intensification basically lack merit as 'optimal' future city-shapes for Melbourne?

The short answer, one might argue, is no. Firstly, it is necessary to recognise that there are factors that are likely to be taken into account in future city-planning, particularly given the anticipated growth in population we are likely to see in the next few decades, which may not be directly related to energy use and GHG emissions. One of the most important of these factors is network congestion, i.e. what effect major changes in urban form might have on congestion in our transport system. Another, related factor is accessibility – the capacity of people to conveniently access desired destinations for a variety of basic purposes, be it employment, education, obtaining services, shopping, recreation, and so on. Both of these factors can be considered as important factors in determining an optimum future city-shape for Melbourne.

Aside from the relative impact of the scenarios on congestion and accessibility, one might also point to the income-bias in the existing stationary energy survey data for high-rise apartment buildings. In Perkins' study, for example, it is shown that household income as much as the built form of apartment buildings can contribute to relatively high household energy consumption (Perkins, 2007). If then one was to assume that in any of the consolidation scenarios for Melbourne, higher-rise apartments might involve a wider range of income brackets, it is possible that the stationary energy performance of more 'middle-income' apartment blocks may not be as bad overall as might be inferred from the work of Perkins, Myors, *et al*. In this case higher dwelling densities might not, in and of themselves, be quite as prejudicial to improved overall GHG emissions outcomes.

The other major issue that should be considered here, aside from the role played by income and lifestyle, is the role specifically of built form on stationary energy outcomes. If it is yet unclear as to the precise role of income and other demographic factors on household energy consumption, then the precise role played by built form itself is also yet to be satisfactorily determined (or at least accounted for in the studies noted above). For example, one might ask whether higher-rise apartment blocks, by virtue only of built form exigencies, will necessarily result in higher built-form-related energy consumption than, say, mid-rise apartments? In other words, *is* it necessarily less 'sustainable' to build taller apartment blocks?

There is also, however, a third question. Even if there *are* differences in the level of per unit stationary energy consumption related to current built form in our cities, what might be the capacity for future built form improvements in household energy efficiency – i.e. improvements that might reduce or even eliminate those differences? Here one need only look to the work of Peter Newton and Selwyn Tucker from Swinburne University of Technology, who have shown how it is possible over time for Melbourne's housing stock to become less and less carbon intensive in terms of its operational energy consumption (i.e. through the mandating of seven-star energy ratings for new housing and the upgrading of existing housing to an equivalent seven-star, or at least five-star, energy performance). They point out that with extensive local power generation (via solar cells, etc.), carbon neutrality in household operational terms is a realisable goal (Newton and Tucker, 2009). In this case, one might presume that it should not matter, in terms of per unit stationary energy consumption, how many storeys an apartment block may have.

The key point to take from this prospect of future, significant increases in household energy efficiency is that, with the associated reduction over time of household, in-dwelling GHG emissions, it would be possible to access a *much larger scale of benefit in overall emissions*, the kind of benefit that might otherwise be 'drowned out' if average household energy efficiency was not to change in any substantial way. The greater the shift towards less carbon-intensive or even zero-emissions households (across all housing types), the greater the possible benefit, in terms of a less carbon-intensive transport system, from location of new housing near major transport nodes. In other words, if nothing were to be done between now and 2031 to significantly improve household energy efficiency (or otherwise establish whether or not the sheer number of storeys makes a difference in per household energy consumption), one might suggest that a Linear or Activities Centre type scenario might be the best course to follow from a purely emissions perspective. However, in a situation where average household operational emissions could instead be reduced (hopefully close to zero), the Inner City and Polycentric Scenarios would again emerge as the better option overall, because they would then also offer better transport-related emissions benefits.

Similarly, if it were found that the differences in household energy consumption between certain dwelling-types were in fact related mostly to non-built form factors (income, lifestyle, etc.), this could be addressed by policy levers other than those specifically concerned with urban or built form – in which case there would be no disadvantage in promoting an urban form that would improve transport energy consumption per household.

6. Conclusion

In conclusion, one can say that what has emerged from this study is that, firstly, in order to obtain a more accurate picture of Melbourne's combined transport and stationary emissions, more detailed research is needed into the various factors that influence the consumption of stationary energy, including the precise impact of such factors as income, floor-space, age of dwelling, etc. What would be very helpful in this context would be a more comprehensive and small-area audit of Melbourne's energy consumption, in which these factors can be investigated at a household level. This would assist in determining how much the emissions profile of higher-rise dwellings is to do with income and lifestyle, and how much is to do with the built form itself, and thus what the possibilities and constraints might be in terms of improving that profile.

Secondly, the study has found that as far as reducing operational GHG emissions is concerned, transit-oriented development (i.e. development built near transport nodes) is most useful, and the potential gains from it more substantial, when it is accompanied by lower average household energy consumption. Without this combination, it would be far more difficult to leverage the same scale of benefits from locating housing and jobs not only closer together, but also closer to transport.

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