APPENDIX 1 Urban Consolidation Challenge – Review of Environmental Impacts

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Executive Summary

As part of a larger project to reinvigorate the debate in favour of urban consolidation in Sydney, the Total Environment Centre[1] commissioned the Institute for Sustainable Futures to review studies which compared the environmental impacts of different types of urban development, preferably in the same city in Australia.

Overview of results in studies

The Institute was able to locate a range of studies which cast useful light on the question of the differential environmental impacts of different types of urban development.

ENERGY AND GREENHOUSE: It is now well established that *per capita transport* energy and emissions are lower in high-density parts of cities and in more compact urban forms (Newman and Kenworthy, 1999). This result appears to hold on a *per household* basis when the analysis is extended to include the embodied and operational energy and emissions of both *housing and transport* (Perkins, 2001).

Two other studies reviewed raise the question of whether the relationship between energy use, emissions and population density extends to *per capita housing and transport* energy and emissions (Troy *et al*, 2002) or to the inclusion of the direct and indirect energy required for the production and supply of goods and services for *all forms of final household consumption* (Lenzen *et al*, 2002).

URBAN AIR POLLUTION EXPOSURE: Urban forms with the lowest greenhouse gas and urban air pollutant *emissions* are not necessarily the same as those with the lowest urban air pollutant *exposures*, because of weather patterns (Newton, 1997). The methodology of this study would need to be re-applied to the Sydney air shed to draw specific conclusions about Sydney.

WATER: In results analogous to those in the energy and greenhouse studies, water consumption *per household* in inner suburbs appears to be lower than in outer suburbs (Robinson and Cordell, 2002). However, in a result that contradicts work by the Institute for Sustainable Futures[2], Troy *et al* (2002) appear to show that *per capita* water use of medium density housing is very little different to that of people living in houses.

Lundie *et al* (2002) show that alternative delivery of water and wastewater services in new urban areas can substantially reduce environmental impacts.

Methodological limitations

The results of the reviewed studies are not sufficiently robust to support policy development. The studies do not provide an adequate basis to answer the policy relevant question of which types of new urban development in Sydney have lower environmental impacts (or smaller "ecological footprints"). Each study has some or all of the following limitations.

1. Failure to compare "like with like"

Most of the studies reviewed here did not match the areas compared for the social, demographic and economic characteristics of the populations, such as age, household size and income. Some of the studies state that their samples were similar on one characteristic, but not on others. Hence, these studies were not comparing like with like in terms of the people and households in the areas studied. Because of the complex sifting process that takes place in urban housing markets, it is unlikely that the types of people and households who would otherwise purchase in new fringe developments would directly switch to new urban consolidation and change their

1 On behalf of PlanningNSW, Sydney Water Corporation, LandCom and Delfin Lend Lease.
2 The Institute for Sustainable Futures also conducted this review.

consumption patterns accordingly[3]. Hence, unless study samples across different types of development can be matched on key characteristics, the best way to compare like with like would be to ask what types of medium density development have lower environmental impacts compared to standard practice for similar market segments, and what types of low density development have lower environmental impacts compared to standard practice for similar market segments.

2. Differences in system boundaries, inclusions and exclusions

The difference between full Ecological Footprint analysis and partial impact assessment is critical. What is included or excluded affects the size of the footprint. More importantly for studies comparing different types of urban development, it affects the *relative* size of footprints. Figure 1 illustrates how the studies reviewed here differ greatly in where they draw the system boundary.

The argument for limiting studies to the environmental impacts of the use of *buildings and transport only* is that these two are within the influence of urban planning policy, whereas most other forms of consumption are not. However, this is a partial view. If the objective is to use urban planning to reduce overall environmental impacts, then a more comprehensive view is needed. The results of the studies reviewed here at least raise the question that a more comprehensive view may yield a different answer to the partial view. If this is the case, reliance on the partial view may be an inadequate basis for policy development.

3. *Per person* and *per household* comparisons yield different results

Some of the studies reviewed here compare environmental impacts on a *per capita* basis; others compare on a *per household* basis. As households tend to be smaller in inner urban areas and medium-high density developments, per household comparisons may be open to misinterpretation. Smaller households simply mean that more households are needed to accommodate the same population. Hence, per capita (or the total for a stated population) is a fairer basis for comparison, except in the case of water where outdoor use is related more to housing type and garden size than to the number of people in the household.

4. The failure to analyse new urban developments, as against established areas

Many of the studies reviewed analyse existing urban areas. Care is needed to extrapolate results from existing urban areas to new developments and redevelopments. For example, one cannot assume that households moving into new urban consolidation will have the same consumption profile as households in existing inner areas or existing medium density housing.

5. Few of the studies were in Sydney

Some results are robust across different cities, but care is needed to extrapolate from other cities in many impact categories. Also, some of the non-Sydney studies depend on small numbers of case studies which may be heavily influenced by the particular social, economic and demographic patterns in the study city.

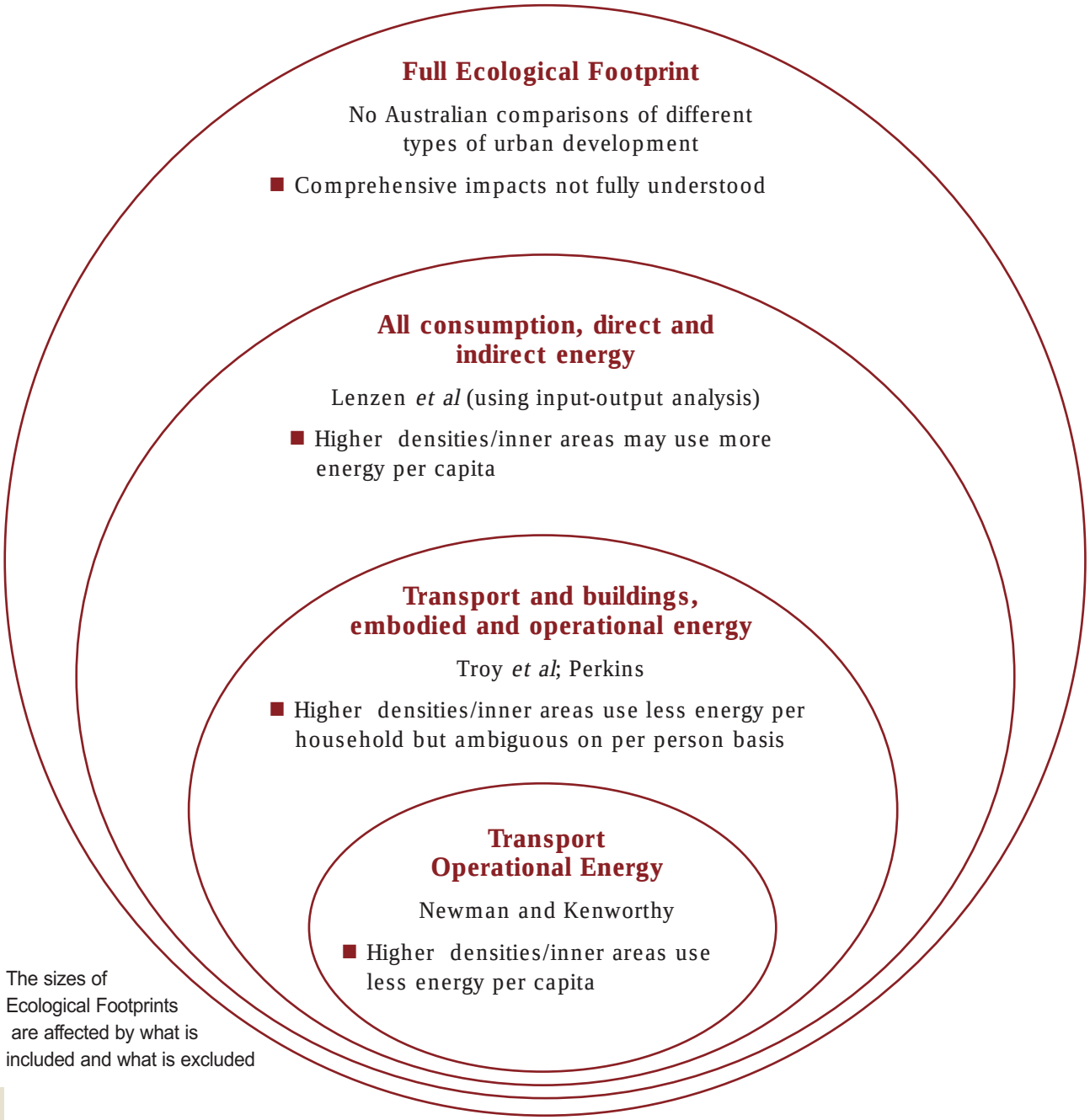
Application to Sydney

Future studies in Sydney could overcome these limitations in the following ways.

1. *Match* the people in the samples in the areas being compared for key social, demographic and economic characteristics, such as age, household size and income, *unless it can reasonably be assumed that the samples have similar characteristics.* It may be reasonable to assume that samples are similar when comparing different types and locations of medium density development with standard practice aimed at similar market segments, or when comparing different types and locations of low density development with standard practice aimed at similar market segments.

3 However, new urban consolidation provides greater housing choice and substitutes for new fringe development in the total metropolitan housing market.

2. Take a *comprehensive* view of consumption, *unless it can reasonably be assumed that discretionary consumption patterns would be broadly similar.* The main situation where this assumption could be made is where samples are matched for age, household size and income or similar key socio-economic characteristics. With matched samples, a partial analysis of the environmental impacts of the use of *buildings and transport only* may yield results that are useful for policy development. As suggested above, a further simplification is possible in those types of studies where it can reasonably be assumed that the samples would have similar characteristics e.g. comparing different types of medium density development for similar market segments.
3. Compare environmental impacts on a *per capita* basis, except in the case of water, for which both *per household* and *per capita* comparisons may be useful, for the reasons noted above.
4. Compare different types of *new* development or redevelopment, as against existing areas.



The sizes of Ecological Footprints are affected by what is included and what is excluded

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1 Introduction

As part of a larger project to reinvigorate the debate in favour of urban consolidation in Sydney, the Total Environment Centre commissioned the Institute for Sustainable Futures to review studies which compared the environmental impact of low density fringe development with medium-to-high density urban consolidation, preferably in the same city in Australia.

The brief stated that:

The study would present between five and ten Ecological Footprint studies with an emphasis on the Australian experience...Each study would be summarised and its underlying assumptions, supporting indicators and data reviewed. ISF would then discuss the results and their application within the Sydney context. A final analysis would provide a comparative assessment of each study and derive relevant lessons from the review. Furthermore, consideration would be given to the potential application of a particular ecological footprint model for Sydney.

2 Overview

The original brief to the Institute was expressed in terms of "Ecological Footprint studies." This could be interpreted in two ways: as the formal methodology with the same title, or as common language shorthand for studies of environmental impacts using a range of different methodologies.

The formal Ecological Footprint methodology was pioneered by Mathis Wackernagel and William Rees at the University of British Columbia[4]. Rees defines an Ecological Footprint as "the corresponding area of productive land and aquatic ecosystems required to produce the resources used, and to assimilate the wastes produced, by a defined population at a specified material standard of living, wherever on Earth that land may be located"[5]. Ecological Footprint analysis has been applied to countries[6], cities[7], institutions[8], corporations[9] and individuals[10]. The methodology itself has been the subject of vigorous debate[11].

During the literature search for this review, the Institute could not find studies in Australia which used the formal Ecological Footprint methodology to compare developments of different densities and locations within an urban area. One such study exists for Canadian cities[12]. Although not reviewed here because it was not in Australia, the methodology has the potential to be applied to Sydney.

4 Wackernagel, M. and Rees, W, 1995, Our Ecological Footprint: Reducing Human Impact on the Earth, New Society Publishers, Philadelphia, USA.

5 William Rees, 1996, "Revisiting carrying capacity: area-based indicators of sustainability", Population and Environment, 17, 3, pp. 195-215. Available from www.dieoff.com, accessed 19 August 2002.

6 For Australia, see for example Simpson, R.W., Petroeschevsky, A and Lowe, I., 2000, "An ecological footprint analysis for Australia", Australian Journal of Environmental Management, 7, pp.11-18.

7 For Sydney, see NSW Environment Protection Authority, 1997, New South Wales State of the Environment 1997, p.407.

8 For example, see Kate Flint, 2001, "Institutional ecological footprint analysis", International Journal of Sustainability in Higher Eduction, 2,1, pp.48-62.

9 For Sydney Water Corporation, see Manfred Lenzen, Sven Lundie, Grant Bransgrove, Lisa Charet and Fabian Sack, "Assessing the ecological footprint of a large metropolitan water supplier – lessons for water management and planning towards sustainability", Journal of Industrial Ecology, in press for 2003.

10 See for example, "Ecological Footprint Lifestyle Calculator", available from www.bestfootforward.com, accessed 19 August 2002.

11 For a summary of these debates, see for example, Lenzen et al, in press, as above.

12 Walker, L.A. and Rees, W.H., 1997, "Urban density and ecological footprints", in Roseland, M. (Editor), Eco-City Dimensions, New Society Publishers, Gabriola Island, BC, Canada, pp. 96-112.

Using ecological footprint as common language shorthand for studies of environmental impacts, the Institute was able to locate a number of studies which explicitly compared urban areas or developments of different densities, locations or forms. These are presented in this review, followed by a brief assessment.

The major difference between the formal Ecological Footprint method and most of the Australian studies reviewed here is that the formal Footprint method attempts to comprehensively assess a range of environmental impacts arising from all forms of consumption, including food, services and consumer goods. Most of the Australian studies reviewed here analyse one or a limited range of environmental impacts for a single or limited number of types of consumption, such as residential buildings and transport. The most comprehensive studies are the research by Lenzen *et al* (2002), which captures all forms of consumption but is limited to a single environmentally related throughput (energy), and the research by Lundie *et al*, which captures a wide range of environmental impacts for a single form of consumption (water).

The methodology used by Lenzen *et al* (2002) can also be extended beyond energy to analyse direct and indirect consumption of other environmentally related throughputs, such as water, waste, emissions of sulphur dioxide, oxides of nitrogen and carbon monoxide and other gases, or other environment indicators such as land disturbance or the full ecological footprint.

3 Methodology

The studies reviewed in this report were located through a combination of conventional literature and web searches and by contacting researchers known to be active in the field. This latter approach helped locate a number of very recent studies, some of which are yet to be published. The Institute assessed each study's methodology using the following questions.

Question about study's methodology	Explanation of question	Comment
1. Location?	Where is study located?	Some results are robust across different cities e.g. the relationship between urban density and transport energy use and emissions. Care is needed to extrapolate from other cities in other impact categories e.g. urban air pollution exposure which is dependent on city-specific wind patterns.
2. Environmental impact categories?	What environmental impact categories or indicators does the study cover e.g. greenhouse gas emissions, water use etc?	The studies reviewed do not attempt to measure all environmental impacts or to convert them into a common unit to communicate the results. Ecological footprint analysis, in contrast, tries to measure a range of impacts and convert them into a single unit, usually hectares of land appropriated to provide resources and waste disposal for a given population.

Question about study's methodology	Explanation of question	Comment
3. Sectors included?	What sectors of the economy does the study cover e.g. transport, buildings, other consumption etc?	The sectors included fundamentally affect the results. Many studies focus on particular sectors, so complete environmental impacts can only be determined by combining different sectoral studies.
4. Comprehensiveness of analysis?	How comprehensive is the analysis i.e. does it include operational, embodied and/or indirect effects of energy use, water use etc?	The comprehensiveness of the analysis also fundamentally affects the results. Again, results from different studies must be combined to gain a more complete picture of impacts.
5. Throughput or environmental outcome?	Does the study analyse the throughput of energy, water etc or does it translate this into an environmental impact indicator (greenhouse gas emissions, water pollution levels etc)?	Throughputs are not necessarily good proxies for environmental outcomes. A good example of this is the case of urban air pollution emissions and exposure levels, discussed below in the review of Newton (1997).
6. Existing vs. new development?	Does the study compare new developments of different densities or locations or does it compare existing low and medium-high density areas?	Care is needed to extrapolate from studies of existing urban areas to new (re-) developments. For example, one cannot assume that households moving into new urban consolidation will have the same consumption profile as households in existing inner areas.
7. Unit for comparison?	Does the study compare on the basis of per capita, per household or total environmental impacts?	As households tend to be smaller in inner urban areas, per household comparisons may be misleading. Smaller households simply mean that more households are needed to accommodate the same population. Hence, per capita (or the total for a stated population) is a fairer basis for comparison, except in the case of water where outdoor use is related more to housing type and garden size than to the number of people in the household.
8. Data sources?	Did the study use general-purpose statistics or did it collect specific purpose data?	General-purpose statistics are cheaper and easier to use, but in most cases cover the buildings and activities in existence at the time of data collection. Many inner, middle and even outer suburban areas contain a mix of new and old development. Hence, general-purpose statistics can only be used to compare new developments in the rare case study areas where the entire area is known to have been newly developed or redeveloped.

Question about study's methodology	Explanation of question	Comment
9. Geographic area for analysis?	Does the study compare at the level of Statistical Subdivisions (large), Local Government Areas (medium), Census Collectors Districts (small) or some other type of geographic area?	The larger the geographic area, the more heterogeneous it will usually be and therefore the harder to draw conclusions about different types of new developments. However, some useful data is only available on a large area basis e.g. household consumption survey results.
10. Matched samples?	Does the study match the samples compared for social, economic and other demographic characteristics?	Much of the variation in consumption levels and patterns is related to characteristics such as household size, income and age, rather than urban form. What is of interest is the difference in environmental impacts between different types of urban development for households with otherwise similar characteristics.

4 Energy Use and Greenhouse Gas Emissions

4.1 Energy requirements of Sydney households

Manfred Lenzen, Christopher Dey and Barney Foran, unpublished research-in-progress obtained by personal communication, September 2002. The lead author is contactable at manni@Physics.usyd.edu.au

4.1.1 Description

This research project is analysing the energy requirements of Sydney residents in different parts of the city for transport, housing and consumption.

4.1.2 Summary

This study, when published, will be one of the very few to analyse total energy requirements per capita, including the indirect energy requirements generated by the production and supply of goods and services for all forms of final household consumption.

Preliminary results suggest that inner suburbs of Sydney have larger energy requirements per capita than outer areas, primarily due to the indirect energy required for the production and supply of goods, housing, services and food. The levels and types of consumption are related to levels of discretionary expenditure, which in turn are related to household size, income and age, as well as location.

Comparing existing urban areas may give a different result to comparing new developments of different types and locations, though it is not clear whether this favours inner or outer areas. Care is therefore needed to extrapolate these results to new urban consolidation and new fringe development. For example, it cannot be assumed that households moving into new urban consolidation will necessarily have similar energy requirements per capita as households in existing inner areas.

Comparing energy rather than greenhouse emissions per capita will tend to favour inner suburbs over outer ones, because of the relatively larger amounts of more greenhouse-intensive electricity indirectly used in the production and supply of goods and services for final consumption.

4.1.3 Methodology

Question about study's methodology

1. Location?	Sydney.
2. Environmental impact categories?	Energy.
3. Sectors included?	All forms of household consumption, including but not limited to housing and transport.
4. Comprehensiveness of analysis?	Analysis extends to indirect energy embodied in consumption of all goods and services, as well as embodied and operational energy of housing and transport. Lenzen *et al* are using economic input-output tables to do this.
5. Throughput or environmental outcome?	Energy throughput.
6. Existing vs. new development?	Existing development.
7. Unit for comparison?	Per capita and per $ of income.
8. Data sources?	Regional household expenditure data; national input-output tables; national data on resource use and pollution.
9. Geographic area for analysis?	Statistical Sub-divisions of Sydney. Data is available to conduct analysis at the smaller level of Local Government Areas.
10. Matched samples?	Partially matched for income but not household size, for some results.

4.1.4 Results

Preliminary results suggest that:

- inner suburbs of Sydney have larger energy requirements *per capita* than outer areas;
- in contrast, inner suburbs have smaller total energy requirements *per household*, largely because of smaller household size;
- household size matters due to sharing i.e. larger households tend to have smaller total energy requirements per capita;
- total energy requirements per capita correlate strongly with income;
- like many other studies (including Newman and Kenworthy, 1999, reviewed below), per capita energy use for car travel is lower in inner suburbs; and
- in both inner and outer areas, over half of the total energy requirement per capita is the indirect effect of consumption of goods, housing, services and food, with less than half the energy requirement caused by direct energy use in the house and for transport (although direct use of electricity and petrol are the largest single items).

4.2 Life cycle transport and housing emissions

Perkins, Alan, 2001, *The Influence of Urban Form on Life Cycle Transport and Housing Energy and Greenhouse Gas Emissions,* Unpublished PhD Thesis, University of South Australia.

4.2.1 Description

The main research question addressed in this study is "What are the life cycle transport and housing energy and emissions implications of the choice between city compaction and city expansion?" The study addresses this question by comparing two small areas of Adelaide in detail.

4.2.2 Summary

This study is one of the very few to compare new urban consolidation with new fringe development.

The thesis research confirms that the compaction of urban form delivers savings in

operational transport and housing energy and emissions, and embodied transport and housing energy and emissions (p.355).

Presentation of the results on a "per household" basis (as against per capita) almost certainly favours urban consolidation over fringe development because of differences in household size (see review of Lenzen *et al*, 2002, above). Perkins claims that this does not have a strong influence on his results (p.332).

Limiting the analysis to transport and housing consumption only probably also favours urban consolidation because of higher levels of other types of consumption in inner areas (see review of Lenzen *et al*, 2002, above). Further, the study depends on only two case study areas which may be heavily influenced by the particular social, economic and demographic patterns in Adelaide.

4.2.3 Methodology

Question about study's methodology	
1. Location?	Two small areas in Adelaide.
2. Environmental impact categories?	Energy and greenhouse gas emissions.
3. Sectors included?	Transport and residential buildings.
4. Comprehensiveness of analysis?	Embodied and operational.
5. Throughput or environmental outcome?	Both energy and greenhouse gas emissions.
6. Existing vs. new development?	Compares two new developments.
7. Unit for comparison?	Per household.
8. Data sources?	Detailed survey questionnaires and travel diaries.
9. Geographic area for analysis?	Small new development area defined by researcher.
10. Matched samples?	No.

4.2.4 Results

On average, for each household that is located at the fringe of Adelaide compared with the inner suburbs, approximately 95 per cent more delivered energy is expended on life cycle transport and housing activities (213 GJ compared with 109 GJ per household per annum). For the particular sample of households being analysed, the difference in GHG emissions was less marked, being on average 45 per cent higher for the fringe households than the inner urban households (21 t CO2-e compared with 14.5 t CO2-e per household per annum). (p.352)

It is likely that where you live, the density of your neighbourhood and the form of the dwelling you live in will have a major influence on the energy consumption and associated greenhouse gas emissions produced by your household, regardless of your income, the number of people in your household, age or the type of family you are a part of. Some of these other factors will also help to explain your household's transport and housing emissions, but not as well as the form of your neighbourhood and its location, and the type of dwelling you live in. (p.353)

The choice of promoting infill development is an important decision in the pursuit of greenhouse abatement, because inner urban locations, densities and housing forms provide more opportunities for residents to behave in ways that reduce their household emissions. When compared with a range of other emission reduction strategies, the choice of locating a new dwelling in an inner urban area rather than in a fringe location is a fundamental determinant of the energy consumption and emissions of a household. (p.346)

4.3 Pilot study of small area comparisons of energy and water use

Patrick Troy, Darren Holloway, Stephen Pullen and Raymond Bunker, 2002, *Towards sustainability: An Adelaide case study*, UWS Urban Frontiers Program Research Paper No. 14, University of Western Sydney, Macarthur.

4.3.1 Description

This paper describes a pilot study using information collected by water and energy utilities and government agencies to assess and map water and energy use and greenhouse gas emissions per household and per capita, on a small area basis.

4.3.2 Summary

Because it is a pilot study to test the effectiveness of extracting, analysing and mapping data from these sources, the study's authors are reluctant to come to firm conclusions. Nevertheless, the data on annual per capita greenhouse gas emissions, including both embodied and operational energy (p.58), suggest that[13]:

- the lowest emissions are associated with fringe and some inner suburban areas;
- medium levels of emissions are associated with other inner suburban and medium density central city areas;
- the highest levels of emissions are associated with a traditional "quarter acre" block middle suburban area.

This study depends on a small number of case study areas which may be heavily influenced by the particular social, economic and demographic patterns in Adelaide.

4.3.3 Methodology

Question about study's methodology	
1. Location?	Six small areas in Adelaide.
2. Environmental impact categories?	Water use; energy use; greenhouse gas emissions.
3. Sectors included?	Residential buildings and transport.
4. Comprehensiveness of analysis?	**Energy:** Embodied and operational. **Water:** Operational only.
5. Throughput or environmental outcome?	Both energy and greenhouse gas emissions; water use.
6. Existing vs. new development?	Existing development.
7. Unit for comparison?	Per capita and per household.
8. Data sources?	Uses a wide range of data from Property Registry, electricity, gas and water utilities.
9. Geographic area for analysis?	Census Collector's District (smallest geographic unit for published statistics in Australia).
10. Matched samples?	No.

4.3.4 Results

> ...the per capita *embodied* energy in [houses] is lower than it is for [medium density] dwellings except in Hawthorn and Norwood where the larger houses with lower occupancy levels influence the averages...The per capita *operational* energy consumption for those living in...medium density housing tends to be higher than for houses. (p.44)
>
> ...when the greenhouse gas production is expressed per capita the more traditional forms of development have lower levels of gas production, save for Hawthorn which has the highest median income of the six case study areas...we hesitate to come to firm conclusions about greenhouse gas production of different forms of development based on this Pilot Study and allow that socio-economic factors may 'explain' apparent energy consumption and greenhouse gas production of the different forms of development. (p.57)

Troy *et al*'s results for water are presented separately in section 6 below.

13 *These are the Institute's own interpretations of the data, not those of Troy et al (2002).*

4.4 Transport energy use and emissions

Peter Newman and Jeffrey Kenworthy, 1999, *Sustainability and Cities, Overcoming Automobile Dependence*, Island Press, Washington D.C. and Covelo, California.

4.4.1 Description

This book provides a summary of Newman and Kenworthy's groundbreaking work on the relationship between urban form and transport efficiency, particularly a summary of their study of 37 cities for the World Bank[14].

4.4.2 Summary

Newman and Kenworthy's work was groundbreaking in demonstrating the global consistency of the relationship between urban density and transport energy use and emissions.

However, the restriction of their work to transport energy and emissions strongly favours higher densities and inner areas. As other studies reviewed show (see reviews of Lenzen *et al*, 2002, and Troy *et al*, 2002, above), this relationship is not as strong, and may be reversed, when other forms of consumption are included.

The focus on urban air pollution emissions, as against exposure, also favours high density and inner areas (see review of Newton, 1997, below).

4.4.3 Methodology

Question about study's methodology	
1. Location?	37 cities globally, including Sydney, Melbourne, Brisbane, Adelaide and Perth.
2. Environmental impact categories?	Energy use, greenhouse gas emissions and urban air pollutant emissions.
3. Sectors included?	Transport only.
4. Comprehensiveness of analysis?	Direct operational energy use and emissions only.
5. Throughput or environmental outcome?	Includes both transport throughputs and greenhouse and urban pollution data, but most results presented in terms of energy and transport throughputs.
6. Existing vs. new development?	Existing development.
7. Unit for comparison?	Per capita.
8. Data sources?	Wide variety of published and government agency data.
9. Geographic area for analysis?	Three broad regions in all cities: central city, inner city and outer area.
10. Matched samples?	No.

4.4.4 Results

Density patterns are obviously closely linked to transportation and therefore energy use... In all cases there appears to be a critical point (about 20 to 30 persons per hectare) below which automobile-dependent land use patterns appear to be an inherent characteristic of the city. (p.100)

[Newman and Kenworthy's] data suggest that driving is reduced 30 [per cent] every time density doubles. This implies that even sprawling suburban areas would benefit from only modest increase in density.[15]

14 *Kenworthy, J. et al, 1997, Indicators of transport efficiency in 37 cities, Report to the World Bank, Institute for Science and Technology Policy, Murdoch University, Western Australia.*

15 *John Holtzclaw et al, 2002, "Location Efficiency: Neighbourhood and socio-economic characteristics determine auto ownership and use – studies in Chicago, Los Angeles and San Francisco", Transportation Planning and Technology, 25, pp.1-27.*

5 Urban Air Pollution Exposure

5.1 Urban air pollution exposure: modelling Melbourne scenarios

Newton, P.W. (ed.), 1997, *Re-shaping Cities for a More Sustainable Future: Exploring the link between urban form, air quality, energy and greenhouse gas emissions*, Australian Housing and Urban Research Institute, Research Monograph 6, Melbourne.[16]

5.1.1 Description

This monograph reports the results of a modelling study of urban air pollution emissions and exposure levels in Melbourne. The study compares six scenarios for future urban form and growth, including a compact city (urban consolidation), fringe growth and focussing growth along corridors with upgraded public transit.

5.1.2 Summary

The importance of this study lies in the reminder that urban forms with the lowest greenhouse gas and urban air pollutant *emissions* are not necessarily the same as those with the lowest urban air pollutant *exposures*.

However, the air shed and weather patterns are different in Melbourne and Sydney, so it is not possible to extrapolate the specific findings of this study to Sydney.

5.1.3 Methodology

Question about study's methodology	
1. Location?	Melbourne (whole metropolitan area and air-shed).
2. Environmental impact categories?	Air pollution and greenhouse emissions; air pollution exposure; travel times and distances.
3. Sectors included?	**Urban air pollution:** All sources (transport and stationary). **Greenhouse:** Transport.
4. Comprehensiveness of analysis?	Operational only.
5. Throughput or environmental outcome?	Environmental outcomes (air pollution exposure and greenhouse gas emissions), as well as some transport throughputs (eg travel times).
6. Existing vs. new development?	Compares different scenarios for future new development and growth to 2011.
7. Unit for comparison?	Totals for given population in 2011: **Exposure:** parts per million-people-hours and microgram per cubic metre-people-hours. **Greenhouse:** total CO2 emissions.
8. Data sources?	Census journey to work data plus model-specific database.
9. Geographic area for analysis?	Detailed model-specific grids of air-shed, transport networks etc.
10. Matched samples?	Whole population modelled. All scenarios assume the same population and demographic profile.

5.1.4 Results

A summary of the four most interesting scenario findings follows. The other scenarios were business as usual growth and "ultra" city (focussing growth in provincial cities within 100km of the capital city). The study also tests the effect of increased telecommuting on all scenarios.

16 Available at Environment Australia Website http://www.ea.gov.au/atmosphere/airquality/urban-air/urban_air_docs.html (accessed 8 October 2002)

COMPACT CITY

- Locates all new residential and service activity in the inner city. It corresponds to recent trends for inner city living, including high-rise residential developments close to the city.
- Its consequences are low levels of pollutant emissions, greenhouse emissions, fuel usage, travel distance and travel time.
- The compact city is disappointing...Unfortunately it places all new residential and service activities in the area of very high urban air pollution, providing residents and workers with high dosages of air pollutants, and the highest excess dosages in winter months and second highest in summer months. A move to telecommuting makes little difference.

CORRIDOR CITY

- Locates growth on green-field sites in the three development corridors. It corresponds more closely to 1970s trends, and planning goals. It is connected to the existing city by radial rail and arterial/freeway links.
- It provides the best solution from the viewpoint of low excess dosages of summer and winter air pollutants (lowest in summer; equal lowest in winter) and low total emissions (second or third lowest for individual pollutants).
- It is less self-contained, but has low energy use, relatively high greenhouse emissions, second lowest distance traveled but longest travel time.

EDGE CITY

- Locates all growth of residential and service activities in edge cities - located around the metropolitan area and accessible by the new ring freeway/road. These centres are also on radial rail and highway, arterial or freeway routes.
- They build on existing centres such as Frankston, Dandenong, Ringwood, Melton and Werribee, providing medium to high density commercial centres and medium density residential in surrounding areas.
- The end result is relatively low levels of air pollutants and a medium performance on excess pollutant dosage exposure in summer (third worst) and winter (third best).
- It is the most self-contained of all scenarios; second best in terms of low fuel energy usage and greenhouse emissions, with moderately high travel distances but relatively short travel times.

FRINGE CITY

- Locates new population and activities primarily in the outer suburbs and fringe - with radial rail and arterial road/freeway links.
- This provides the second best solution for summer pollutant dosages above the limit and equal best for winter excess exposure, possibly because of the extension of development beyond the existing city into rural areas.
- Total [urban air pollutant] emissions, on the other hand, are high. Self-containment is low.
- Energy and fuel use, however, is relatively low, as are greenhouse emissions (third best results). Travel distance is the second highest but travel times are also low. (pp.121-5)

6 Water

6.1 Average residential water use in Melbourne Local Government Areas

James Robinson and Dana Cordell (eds), 2002, *Melbourne End Use and Water Consumption Influences Study*, Volume 1, Report to Water Resources Strategy Committee, Report prepared by University of Technology, Sydney, CSIRO and University of Waterloo for Retail Water Companies (Section 6.3 "Spatial characteristics of residential water use")

6.1.1 Description

As part of a comprehensive report on the end use of water in Melbourne, this study conducted a spatial analysis of residential water use across 34 local government areas in Melbourne.

6.1.2 Summary

The household annual consumption in the inner suburbs of Melbourne, except Stonnington, Banyule, Bayside, Manningham and Boroondara municipalities, is in the range 177–265 kL, whereas household annual consumption in the outskirts of Melbourne is in the range 265-350 kL.

Presentation of the results on a "per household" basis (as against per capita) almost certainly favours inner suburbs over outer ones because of differences in household size (see review of Lenzen *et al*, 2002, above).

6.1.3 Methodology

Question about study's methodology	
1. Location?	Melbourne.
2. Environmental impact categories?	Water use.
3. Sectors included?	Residential.
4. Comprehensiveness of analysis?	Direct operational only.
5. Throughput or environmental outcome?	Throughput (water).
6. Existing vs. new development?	Existing development.
7. Unit for comparison?	Kilolitres of water per dwelling.
8. Data sources?	Water utilities.
9. Geographic area for analysis?	Local government areas.
10. Matched samples?	No.

6.1.4 Results

See summary above

6.2 Alternative scenarios for Sydney green fields development

Sven Lundie and Greg Peters, 2002, *Sydney Water WaterPlan21 Life Cycle Assessment*, Paper for the 3rd Australian LCA Conference[17].

6.2.1 Description

This assessment was commissioned by Sydney Water Corporation as part of its longer term strategic planning up to 2021. The study uses life cycle analysis to compare a base case and eight scenarios, one of which involves an alternative type of green field development.

6.2.2 Summary

[A] scenario for the alternative delivery of water and wastewater services in new urban areas [was examined]. This showed quantitatively that, since connecting new fringe suburbs to the existing system requires significant expenditure on energy for pumping, major improvements in the sustainability of water and wastewater systems can be achieved by using localised, water-saving alternatives. (p.1)

The study only compares two types of green field (fringe) development and is highly dependent on assumptions built into the scenarios modelled. The methodology could be used to compare other types of urban (re-) development, provided the water end use data existed for the types of development being investigated.

17 Obtained from the lead author at s.lundie@unsw.edu.au

6.2.3 Methodology

Question about study's methodology	
1. Location?	Sydney.
2. Environmental impact categories?	Nine environmental indicators and impact categories, including energy use, water use and global warming potential (greenhouse).
3. Sectors included?	Sydney Water Corporation (water supply and sewage/ wastewater treatment and disposal).
4. Comprehensiveness of analysis?	Direct and first order indirect effects of Sydney Water Corporation's activities.
5. Throughput or environmental outcome?	Environmental outcomes.
6. Existing vs. new development?	One scenario explores two types of green field development.
7. Unit for comparison?	Totals for Sydney Water's activities (expressed as percentage change from base case).
8. Data sources?	Detailed inventory data from Sydney Water Corporation
9. Geographic area for analysis?	New urban area to house 12000 people.
10. Matched samples?	Whole population modelled. Both scenarios assume the same population and demographic profile.

6.2.4 Results

> This [scenario] incorporated rainwater tanks for residential buildings, highly efficient (AAA-rated) household water appliances, and a combination of household primary (septic tank) sewage treatment with neighbourhood reticulated sand filters and irrigation of treated effluent. Data from a Sydney Water/CSIRO/UTS project examining designs for new urban areas was complemented with more detailed design and historical performance data published for the same type of system installed in the United States...The system was scoped for a new urban area to house 12000 people...
>
> ...the overall environmental impacts are lower where such systems are feasible. One of the key reasons for this is the significant distance which potable water and raw sewage needs to be transported from the central processing facilities in order to deliver a conventional solution to the water and sewerage service needs of urban fringe suburbs. (p.9)

Specific results include water use 73 per cent below conventional green field developments, global warming potential 18 per cent lower and aquatic eco-toxicity potential 93-98 per cent lower. These results are for the specific area of the green field development and "would have to be scaled down by a factor of approximately 0.25% to reflect the impact they would have on the overall environmental performance of Sydney Water." (p.9)

6.3 Pilot study of small area comparisons of energy and water

Patrick Troy, Darren Holloway, Stephen Pullen and Raymond Bunker, 2002, *Towards sustainability: An Adelaide case study*, UWS Urban Frontiers Program Research Paper No. 14, University of Western Sydney, Macarthur.

6.3.1 Description

This paper describes a pilot study using information collected by water and energy utilities and government agencies to assess and map water and energy use and greenhouse gas emissions per household and per capita, on a small area basis.

6.3.2 Summary

Because it is a pilot study to test the effectiveness of extracting, analysing and mapping data from

these sources, the study's authors are reluctant to come to firm conclusions. Nevertheless, they were able to conclude:

> The delivered water consumption [per household] for medium density housing is generally lower than for houses...[but] the per capita consumption of medium density housing is very little different to that of households living in houses. (pp.29, 52)

6.3.3 Methodology

See review above in Section 4 *Energy Use and Greenhouse Gas Emissions*.

6.3.4 Results

See Summary above.

7 Materials Use, Waste, Land Degradation and Biodiversity

The Institute was not able to find any studies which compared the impact of low and medium-high density urban development on other environmental outcomes, such as materials use, waste, land degradation or biological diversity. The methodology used by Lenzen *et al* (2002) (reviewed above) can be extended beyond energy to analyse direct and indirect consumption of other environmentally related throughputs, such as water, waste and land disturbance. In addition, there is an existing, though incomplete, database on waste generation by local government area[18]. This has not yet been used to investigate the pattern of waste generation across the Sydney metropolitan area, but it could be used for this purpose[19].

8 Assessment

8.1 Overview of results in studies

The Institute was able to locate a range of studies which cast useful light on the question of the differential environmental impacts of different types of urban development.

ENERGY AND GREENHOUSE: It is now well established that *per capita transport* energy and emissions are lower in high-density parts of cities and in more compact urban forms (Newman and Kenworthy, 1999). This result appears to hold on a *per household* basis when the analysis is extended to include the embodied and operational energy and emissions of both *housing and transport* (Perkins, 2001).

Two other studies reviewed raise the question of whether the relationship between energy use, emissions and population density extends to *per capita housing and transport* energy and emissions (Troy *et al*, 2002) or to the inclusion of the direct and indirect energy required for the production and supply of goods and services for *all forms of final household consumption* (Lenzen *et al*, 2002).

URBAN AIR POLLUTION EXPOSURE: Urban forms with the lowest greenhouse gas and urban air pollutant *emissions* are not necessarily the same as those with the lowest urban air pollutant *exposures*, because of weather patterns (Newton, 1997). The methodology of this study would need to be re-applied to the Sydney air shed to draw specific conclusions about Sydney.

WATER: In results analogous to those in the energy and greenhouse studies, water

18 The Australian Waste Database (AWD) is located at http://www.civeng.unsw.edu.au/water/awdb/awdb2.htm, accessed 18 October 2002.

19 Stephen Moore, Project Leader, Australian Waste Database, University of New South Wales, personal communication, 24 September 2002.

consumption *per household* in inner suburbs appears to be lower than in outer suburbs (Robinson and Cordell, 2002). However, in a result that contradicts work by the Institute for Sustainable Futures[20], Troy *et al* (2002) appear to show that *per capita* water use of medium density housing is very little different to that of people living in houses.

Lundie *et al* (2002) show that alternative delivery of water and wastewater services in new urban areas can substantially reduce environmental impacts.

8.2 Methodological limitations

The results of the reviewed studies are not sufficiently robust to support policy development. The studies do not provide an adequate basis to answer the policy relevant question of which types of new urban development in Sydney have lower environmental impacts (or smaller "ecological footprints"). Each study has some or all of the following limitations.

8.2.1 Failure to compare "like with like"

Most of the studies reviewed here did not match the areas compared for the social, demographic and economic characteristics of the populations, such as age, household size and income. Some of the studies state that their samples were similar on one characteristic, but not on others. Hence, these studies were not comparing like with like in terms of the people and households in the areas studied. Because of the complex sifting process that takes place in urban housing markets, it is unlikely that the types of people and households who would otherwise purchase in new fringe developments would directly switch to new urban consolidation and change their consumption patterns accordingly[21]. Hence, unless study samples across different types of development can be matched on key characteristics, the best way to compare like with like would be to ask what types of medium density development have lower environmental impacts compared to standard practice for similar market segments, and what types of low density development have lower environmental impacts compared to standard practice for similar market segments.

8.2.2 Differences in system boundaries, inclusions and exclusions

The difference between full Ecological Footprint analysis and partial impact assessment is critical. What is included or excluded affects the size of the footprint. More importantly for studies comparing different types of urban development, it affects the *relative* size of footprints. Figure 1 in the Executive Summary illustrates how the studies reviewed here differ greatly in where they draw the system boundary.

The argument for limiting studies to the environmental impacts of the use of *buildings and transport only* is that these two are within the influence of urban planning policy, whereas most other forms of consumption are not. However, this is a partial view. If the objective is to use urban planning to reduce overall environmental impacts, then a more comprehensive view is needed. The results of the studies reviewed here at least raise the question that a more comprehensive view may yield a different answer to the partial view. If this is the case, reliance on the partial view may be an inadequate basis for policy development.

8.2.3 *Per person* and *per household* comparisons yield different results

Some of the studies reviewed here compare environmental impacts on a *per capita* basis, others compare on a *per household* basis. As households tend to be smaller in inner urban areas and medium-high density developments, per household comparisons may be open to misinterpretation. Smaller households simply mean that more households are needed to accommodate the same population. Hence, per capita (or the total for a stated population) is a fairer basis for comparison, except in the case of water where outdoor use is related more to housing type and garden size than to the number of people in the household.

20 *The Institute for Sustainable Futures conducted this review.*

21 *However, new urban consolidation provides greater housing choice and substitutes for new fringe development in the total metropolitan housing market.*

8.2.4 The failure to analyse *new* urban developments, as against established areas

Many of the studies reviewed analyse existing urban areas. Care is needed to extrapolate results from existing urban areas to new developments and redevelopments. For example, one cannot assume that households moving into new urban consolidation will have the same consumption profile as households in existing inner areas or existing medium density housing.

8.2.5 Few of the studies were in Sydney

Some results are robust across different cities, but care is needed to extrapolate from other cities in many impact categories. Also, some of the non-Sydney studies depend on small numbers of case studies which may be heavily influenced by the particular social, economic and demographic patterns in the study city.

8.3 Application to Sydney

Future studies in Sydney could overcome these limitations in the following ways.

1. *Match* the people in the samples in the areas being compared for key social, demographic and economic characteristics, such as age, household size and income, *unless it can reasonably be assumed that the samples have similar characteristics*. It may be reasonable to assume that samples are similar when comparing different types and locations of medium density development with standard practice aimed at similar market segments, or when comparing different types and locations of low density development with standard practice aimed at similar market segments.
2. Take a *comprehensive* view of consumption, *unless it can reasonably be assumed that discretionary consumption patterns would be broadly similar*. The main situation where this assumption could be made is where samples are matched for age, household size and income or similar key socio-economic characteristics. With matched samples, a partial analysis of the environmental impacts of the use of *buildings and transport only* may yield results that are useful for policy development. As suggested above, a further simplification is possible in those types of studies where it can reasonably be assumed that the samples would have similar characteristics e.g. comparing different types of medium density development for similar market segments.
3. Compare environmental impacts on a *per capita* basis.
4. Compare different types of *new* development or redevelopment, as against existing areas.

Comparing scenarios for the whole of Sydney, assuming the same population size and characteristics in all scenarios is an attractive option, but it requires detailed information on the environmental impacts of different types of urban development as an input. The latter in turn can only be obtained from smaller scale studies using the types of matched samples discussed above.