ENERGY, HOUSING, PEOPLE AND ESTATES – A REVIEW

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This paper briefly outlines some of the considerations in improving the sustainability of residential development in terms of energy use. It firstly reviews the sources of energy and its uses in the urban environment. It then summarises the results of three recent studies into the use of energy, and explores the consequences of the results described. The next part identifies the kind of further investigations needed to improve the sustainability of urban development, before discussing some of the policy implications.

Energy sources and uses

The main sources of energy used by urban residents are in the form of gas, electricity, and fuel for vehicles. There are other forms of energy such as heating oil, wood and bottled gas. These are not used extensively in towns and cities. Further, while they can be translated into equivalent energy units except for the case of wood, the intermittent and episodic nature of their purchase makes comparisons with the annual flows of gas and electricity consumption difficult.

There has been extensive research and discussion on how the form and structure of cities might affect energy use. Most of this has focussed on how densities of development affect choice of travel mode by private car or public transport. This has shown that such densities and arrangements of land uses can influence travel habits and behaviour, but that there are many other factors which also determine how personal trips are made.

On the built form side, there has been a good deal of experiment and expertise in designing dwellings to minimise energy use, and in the layout of small groups of dwellings to do so, as in the AMCORD approach. It is important to measure both the operational and embodied energy in different kinds of urban development in making assessments about the contribution of built form to more sustainable use of energy. Operational energy is that used from day to day in the city to make it function in terms of living, production and distribution. Embodied energy is the store of sunk energy in the buildings, infrastructure and capital equipment of the city – its roads, pipes, wires, transmission lines and vehicles (Pullen, 2000). Over a hundred year period the embodied energy in a dwelling can amount to around 40% of the household's operational energy demands over the same period (Australian Greenhouse Office, 1999).

There has been extensive analysis of energy use at the macro scale – either by sector or state or city, mainly as a guide to the emission of greenhouse gases. Similarly there has been considerable research at the micro scale into the energy use of individual buildings, businesses or households. In between, at the meso scale there has been little investigation into the characteristics of energy use in different forms of urban residential development: old and new, separate or attached, big or small dwellings, intense or sparse in density. Judgements about the energy implications of different forms and locations of estate development are accordingly often more informed by ideology than evidence.

Recent research into the localised nature of embodied and operational energy use in Australia

Moriarty (2002) has recently published an article in which he analysed energy use in different spatial realms: the inner and outer rings of five state capital cities, other urban areas and rural areas. He found that inner city residents used less energy and water than their outer suburban counterparts when adjusted for income. However, when 'indirect' inputs were considered such as travel to outlying country areas, the differences were small. But at such a coarse spatial scale he was only able to make tangential reference to embodied energy. He did conclude that land use change to move travel to electric public transport and non-motorised forms of travel had important potential.

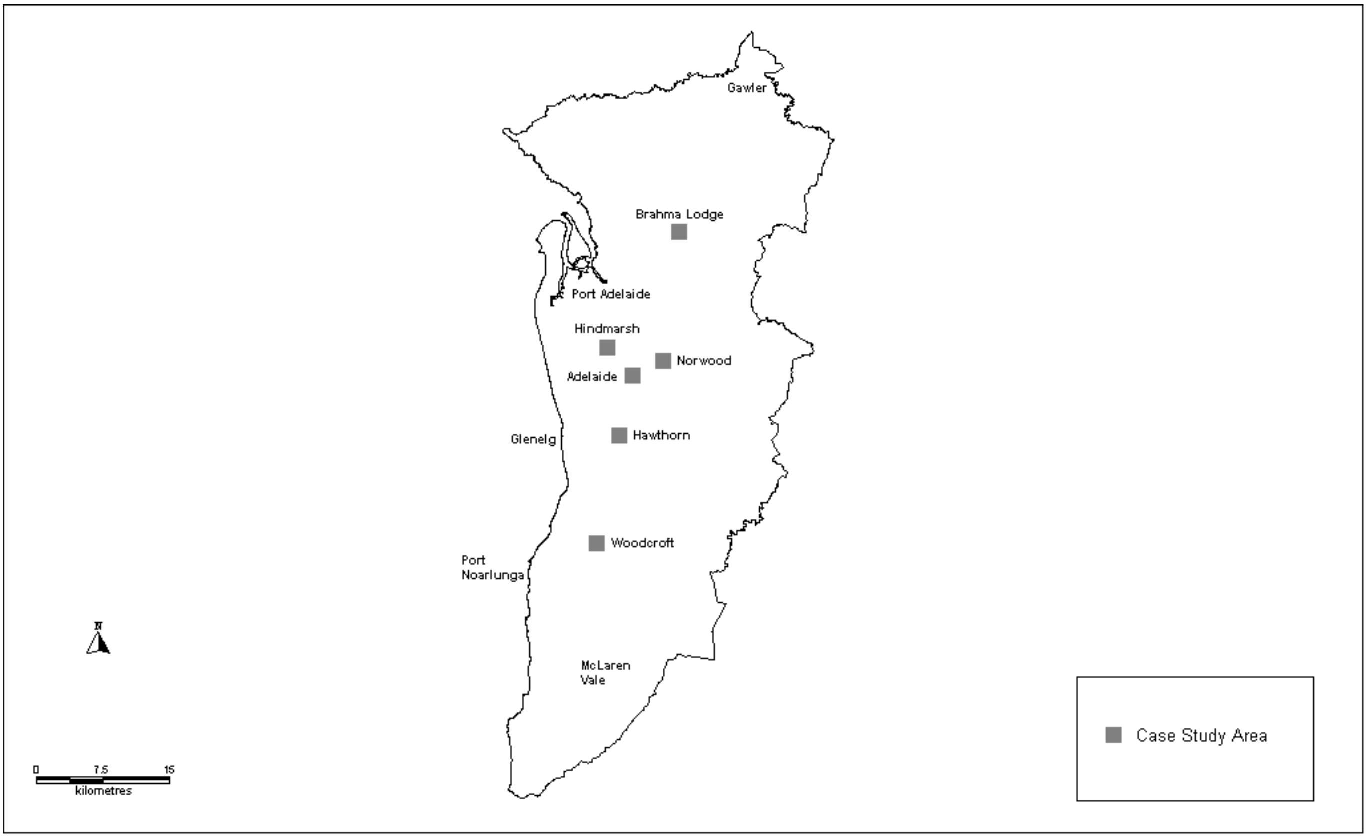
Another two studies were conducted in Adelaide and did make painstaking and comprehensive assessments of energy use in different areas. Perkins (2002 and 2003) compared the delivered energy use by households in a city fringe area and an inner city area. Delivered energy includes both operational energy and the embodied energy used in dwellings and motor vehicles over their life cycles. The embodied energy calculation was also extended to take account of on-site structures and paving and the road/footpath infrastructure serving the dwellings. These life cycle energy calculations were also converted into the resultant greenhouse gas emissions. Perkins's calculations were based on a sample survey of 212 households and dwellings located in an inner and outer suburb which were then used to measure the resulting life cycle operational and embodied energy/emissions contained in the whole of the transport and housing systems.

The difference in total life cycle delivered energy consumption between the two areas was significant. While energy consumption of all other kinds was slightly higher in the outer suburb, it was mainly due to the extra energy used in motorised travel that accounted for the fringe sample consuming nearly twice as much energy per household as the inner location. Statistical analysis showed that of the 'urban form' variables used, site area, location, number of shared walls, dwelling type, and dwelling energy efficiency rating were the most significant in explaining variation in delivered energy use - in that order. Urban form was more important in explaining variations in household's use of operational energy than embodied energy, although the latter was still significant.

Perkins's research showed no consistent influence of household size, age of residents or socio-economic characteristics on energy use, although other studies have found these to be of significance.

In similar vein, a pilot study by Troy *et al* (2002 and 2003) has been completed in Adelaide interrogating three data sets for six small areas, each comprising a Census Collector's District (or two in the case of one area). These data sets comprise aggregated measures of household energy consumption collected from the electricity and gas supply authorities; socio-economic and demographic data about households from the 1996 Census; and details about the characteristics of each building and its site from the property file held by Planning SA. The six case study areas were deliberately chosen as representative of Adelaide's development and character. Three are almost entirely residential and the others of mixed use character. They were developed at different times in the history of Adelaide and lie in different directions and distances from the centre as shown in Figure 1.

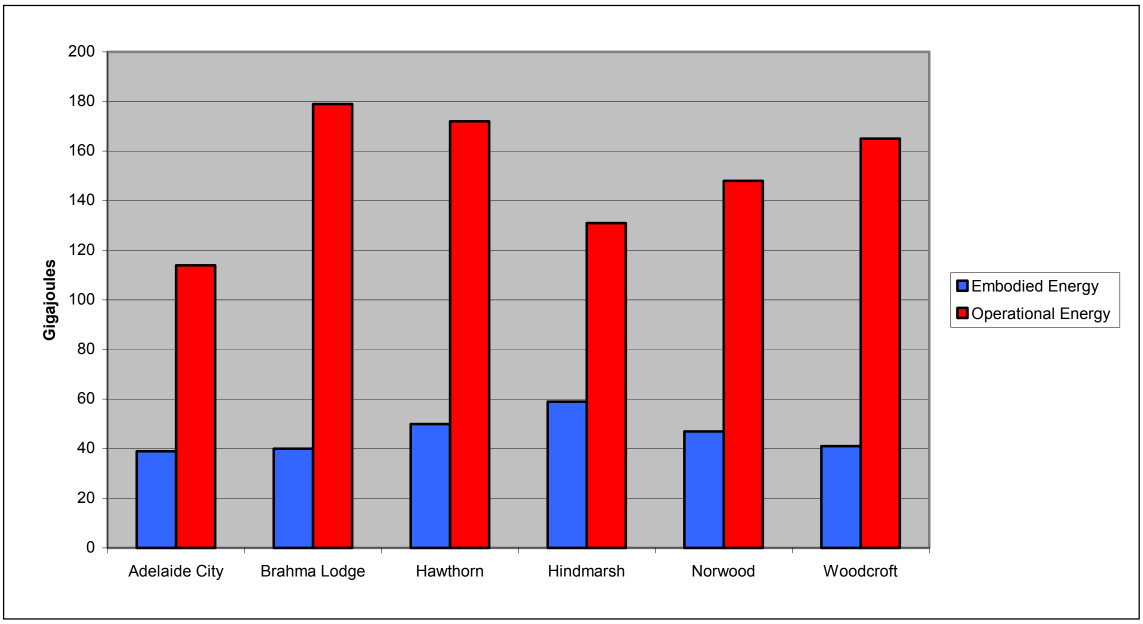
Figure 1: Location of the Case Study Areas used in the Troy et al study



As a pilot study, the Troy *et al* study deliberately set an ambitious framework. While its basic purpose was to see if the three data sets could be interrogated and associated in various ways to build up measurements of energy and water use in different localities, it also used these as a basis for far-reaching estimates of the *operational* and *embodied* energy used in these areas and the *primary* energy needed to produce the different forms of energy – vehicle fuel, electricity, gas – utilised for these purposes. Consequent greenhouse gas emissions were then calculated.

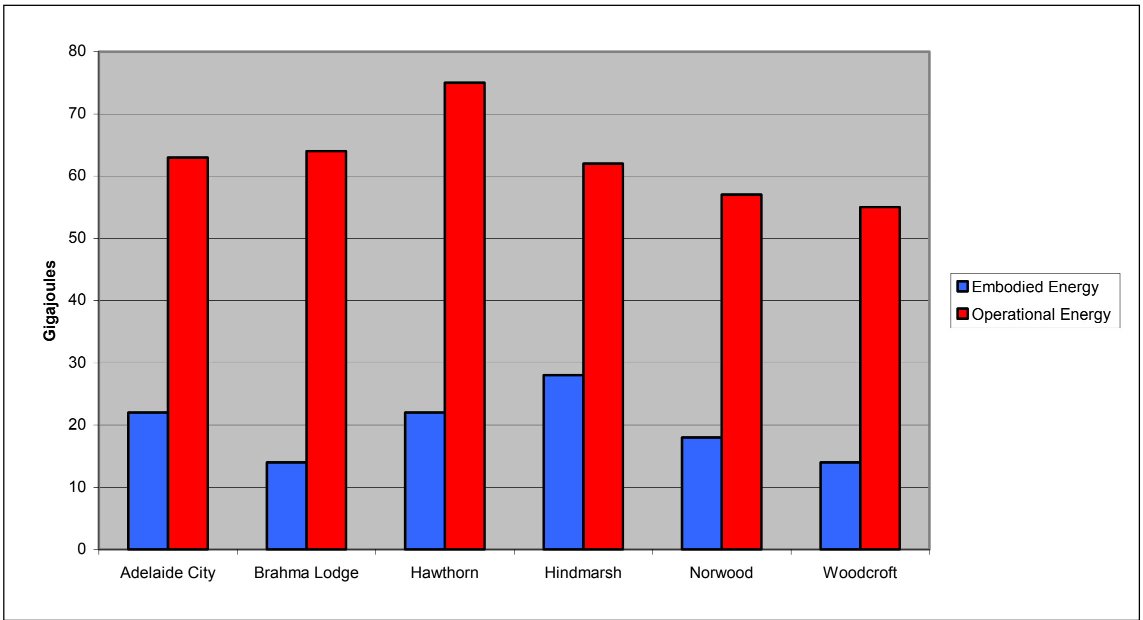
Figure 2 is a summary of the annual consumption of embodied and operational energy by households in the six case study areas in Adelaide. Operational energy measurements are those for gas, electricity and vehicle fuel in gigajoules. The figures for embodied energy include not only that used in the dwellings but in the supporting local infrastructure and vehicles. The data support Perkins's findings that differences in the use of operational energy reflect the greater use of cars in the outlying suburbs (Hawthorn, Brahma Lodge and Woodcroft) as compared with the inner suburbs and central city. Figure 3 shows, however, that on a *per capita* basis the differences in operational energy use are less significant because of the larger size of households in the outlying suburbs. The results reflected the mingled influence of built form and household characteristics on the use of energy, with socio-economic factors influencing consumption patterns.

FIGURE 2: Annual Embodied and Operational Energy per Household



(source: Troy *et al*, 2002)

FIGURE 3: Annual Embodied and Operational Energy per Capita



(source: Troy *et al*, 2002)

The determinants of energy use by households

The examples of recent research discussed above shows the difficulty in separating and assessing the multiplicity of factors influencing energy use. A further difficulty is the fact that many of these are intercorrelated. For example, a household with children, especially younger children, has to ensure comfortable conditions for everyday living. Two young working adults comprising a household may be away from home more than they are in it. Elderly people have their own distinctive requirements and routines. Income is often a determining factor. The ABS latest survey of household expenditure shows spending on domestic fuel and power rising with income, but that is also associated with increasing size of household and decrease in average age of head of household (Australian Bureau of Statistics, 2000; Bunker and Holloway, 2003).

Equity should also be a consideration. Many low income households rent accommodation and are excluded from any capital improvements to minimise energy loss. Much of the older rental stock results in high consumption costs because of savings on building costs with lower standard materials or minimum insulation. The kind, age and size of dwelling, and its materials of construction are important factors influencing the use of energy.

Further research

More exhaustive work on a more comprehensive range of data would enable more incisive conclusions to be drawn, using for example stepwise multiple regression of the kind employed by Perkins (2002 and 2003) and Poulsen and Forrest (1988). This would further marry the property database, which gives good details on the physical characteristics of the dwelling with the energy consumption characteristics of households, and with data on the socio-economic characteristics of the population derived from the Census.

In pursuing this direction, it is however important to aim at a level of generalisation that does not distort the integrity of the data sets and their connection or association. This is also relevant for policy development, which has only broad instruments to influence behaviour and regulate the nature of the built environment.

All this however uses desktop data. To probe the determinants and consequences of energy use in the dwelling, it would be necessary to carry out household interviews of the kind conducted by Perkins. This could more clearly establish the reasons for the behaviour of different kinds of households in using energy, as it did in an exhaustive survey of 854 households in four different local government areas in Melbourne in 1981 (Centre for Urban Research and Action, 1984). This was not, however correlated with census collector district data. While this is an expensive and time-consuming exercise it is essential in complementing any area-based analyses. The area-based data would also serve as a frame within which to construct a household interview survey. It is important to disentangle these relationships for they affect the choice of policy instrument in influencing energy use. For example the elasticity of demand for gas and electricity can be calculated in relation to price and household income, as done for electricity in Sydney by Bartels (Bartels *et al*, 1985; Bartels 1988).

Policy options

Given the range of factors influencing energy consumption by households (Holloway and Bunker, 2003), policy responses exist in the field of regulation, transport and town planning, and pricing. Regulation to ensure more energy efficient forms of housing is widespread in terms of building and planning controls. These are essentially aimed at individual dwellings or groups of dwellings. Pricing tariffs have not generally been used to limit the use of energy, although they undoubtedly affect consumption by low income households. Widespread and increasing use of the car is as much a function of the unavailability or poor performance of public transport, as on low suburban densities.

Planning is about creative anticipation, and there are clear signs that our use of energy in the home and for travel, including the consequent emission of greenhouse gases will need to be subject to more control and direction. This will involve a range and combination of different measures.

How to design an equitable and effective pricing regime is difficult. It would also have to take into account the differences in energy use brought about by varying climatic conditions. However, one principle flowing from the work conducted in Adelaide is to have a stepwise tariff with price per unit increasing above a basic threshold, which should comfortably cover the essential needs of all households. In early 2003, Sydney's two largest electricity retailers presented a bid to the Independent Pricing and Regulation Tribunal (IPART) in New South Wales to modify electricity prices so that households who use large amounts of electricity would pay more once their usage crossed a certain threshold (Sydney Morning Herald 2003). This was to remove the cross-subsidisation by residents of western Sydney of large residential consumers of electricity in the wealthier northern suburbs of Sydney. It was also to be accompanied by a pilot study designed to more fully understand effective and equitable ways of reducing home energy use.

If this principle of increasing cost of energy for increasing use were adopted, it might be applied to the use of electricity, whose generation involves more use of primary energy and more production of greenhouse gases than does reticulated gas. Gas is also used almost entirely for the basic requirements of water and space heating and cooking. However, even this theme would need some variation where there is extensive use of electricity for air conditioning in hot climates.

There also needs to be a comprehensive assessment of proposed types of urban development in terms of their likely energy use and consequent greenhouse gas emissions as a necessary planning tool to improve sustainability. The recent research in Adelaide has confirmed the potential for the use of existing data sources coded to census collectors' districts to calculate life cycle energy/emissions expenditure. This enables areas within and between cities to be compared over time. Finally energy expenditure on travel generated by proposed developments could be modelled as in current trip generation and distribution exercises of this kind.

At present this small-area research is limited to residential localities, but the method could be applied to future industrial and commercial enterprises by calculating typical building forms, methods of construction, size and materials to estimate embodied energy. Recent research and practice in the United Kingdom by Jones *et al* (2000) has shown that energy use and greenhouse emissions can also be calculated for various kinds of manufacturing processes enabling the extension of this kind of modelling into commercial and industrial proposals.

References

Australian Bureau of Statistics (2000) *Household Expenditure Survey – Summary of Results Australia 1998-99*, Catalogue No. 6530.0. Australian Bureau of Statistics, Canberra.

Australian Greenhouse Office (1999) *Australian Residential Building Sector Greenhouse Gas Emissions 1990-2010,* Australian Greenhouse Office, Canberra.

Bartels, R., Lopert, P. and Williamson, S. (1985) *The Residential Demand for Electricity in New South Wales*, Energy Authority of New South Wales, Sydney.

Bartels, R. (1988) *Household Energy Consumption: An Analysis of the 1984 ABS NSW Energy Survey*, NSW Department of Energy, Sydney.

Bunker, R. and Holloway, D. (2003) Improving Sustainability in Development Planning and Control, *Australian Planner*, 40, 3, 31-34.

Centre for Urban Research and Action (1984) *The Social Correlates of Domestic Energy Consumption,* prepared for Energy Victoria, Melbourne.

Holloway, D. and Bunker, R. (2003) *How Do We Use Energy in Our Homes – To Suit Buildings or Behaviour?* Issues Paper No.13, Urban Frontiers Program, University of Western Sydney, Campbelltown.

Jones, P., Williams, J. and Lannon, S. (2000) Planning for a Sustainable City: An Energy and Environmental Prediction Model, *Journal of Environmental Planning and Management*, 43, 6, 855-872.

Moriarty, P. (2002) Environmental Sustainability of Large Australian Cities, *Urban Policy and Research,* 20, 3, 233-244.

Perkins, A. (2002) *The Influence of Urban Form on Life Cycle Transport and Housing Energy and Greenhouse Gas Emissions*, Unpublished PhD Thesis, University of South Australia, Adelaide.

Perkins, A. (2003) *The Significance of Urban Form in Creating More Greenhouse-Friendly Cities*, Paper presented at the 2003 National Planning Congress: Leading with Diversity, Adelaide, March/April.

Poulsen, M. and Forrest, J. (1988) Correlates of energy use: domestic electricity consumption in Sydney, *Environment and Planning A*, 20, 327-338.

Pullen, S. (2000) Energy used in the Construction and Operation of Houses, *Architectural Science Review*, 43, 2, 87-94.

Sydney Morning Herald (2003) *Electricity Hogs to Pay for Luxuries*, 12th April, p. 25.

Troy, P., Holloway, D., Pullen, S. and Bunker, R. (2002) *Toward Sustainability: An Adelaide Case Study,* Research Paper No.14, Urban Frontiers Program, University of Western Sydney, Campbelltown.

Troy, P., Holloway, D., Pullen, S. and Bunker, R. (2003) Embodied and Operational Energy Consumption in the City, *Urban Policy and Research*, 21, 1, 9-44.