The Impact of Transportation on Household Energy Consumption

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The authors computed the values in this paper in British thermal units (Btu). These have been converted into in Joules and MegaJoules.
1 Btu = 1055.06 J = 252 calories
1 MJ = 947.81 Btu = 238.85 kcal

Abstract

This paper examines transportation energy costs as an integral part of total household energy consumption. A typical suburban household is found to expend more than half its total annual energy budget on operation of household motor vehicles. In contrast, households located in traditional, pedestrian-oriented neighbourhoods are found to use far less energy on transportation. For an instructive contrast, two household budgets were generated using a standard computer program and then compared. With transportation energies included, a household living in an 88 year old ‘energy hog’ house located in a traditional pedestrian friendly neighbourhood is shown to expend less total annual energy than a suburban household living in a highly energy efficient modern house. Studies and statistics developed in the Pacific Northwest are used as documentation for travel-related behaviour.

Keywords

Energy, Houses, Modal choice.

Background and General Approach

AT A TIME when home-buyers’ and architects’ interest in energy-saving technology and design strategies is once again on the increase, residential neighbourhood typology and its profound impact on levels of household energy use and pollution ironically remains an almost negligible concern for many ‘green’ practitioners and consumers. The intent of this paper is to examine annual transportation energy use as an integral part of total household energy budgets and to suggest certain changes as a result of our findings. Statistics and climatic conditions for the Pacific Northwest have been used, but the conclusions of the paper are applicable to all regions of the U.S.A.

Land use patterns that reinforce travel in single occupancy vehicles (SOV) are increasingly the Pacific Northwest’s, and America’s, preferred context for single-family residential development (Figure 1). As would be expected, vehicle kilometres travelled (VKT) per capita have also been steadily growing during this period of suburban expansion (Figure 2).

Figure 1: Populations of Idaho, Oregon & Wasghington living in cities and suburbs areas, 1950-90 (From US Census)

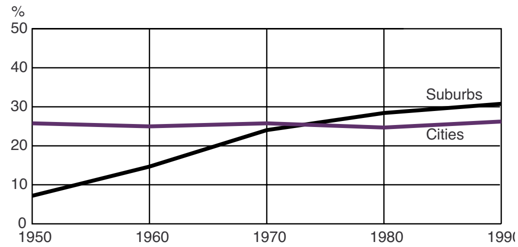
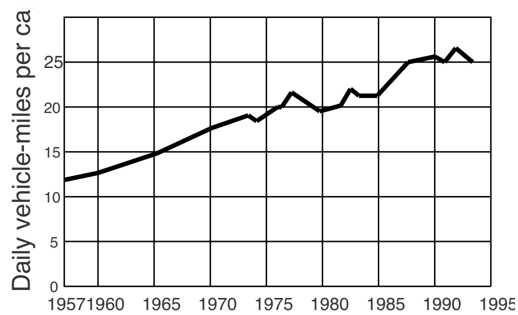


Figure 2: Daily distance driven per capita in Idaho, Oregon & Washington, 1957-95 (From FHWA Highway Statistics)



To document what fraction of a typical annual household energy budget is currently devoted to transportation, both automobile and household operating budgets have been converted to common units - Joules. Calculations included the energy lost as waste heat during the process of generating and delivering smaller quantities of useful energy. Thus, the energy consumed by an automobile is estimated by multiplying the number of litres of gasoline consumed by the entire average energy content per litre (36 MJ). In a similar way the energy lost when

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Figure 3: Suburban house used in comparison modelling

generating electricity and firing a gas furnace (central heating boiler) is also included in the total budgets. The efficiency for electric power generation and delivery is estimated at approximately 38% and furnace efficiency is estimated at 70% (including fuel transmission loss).

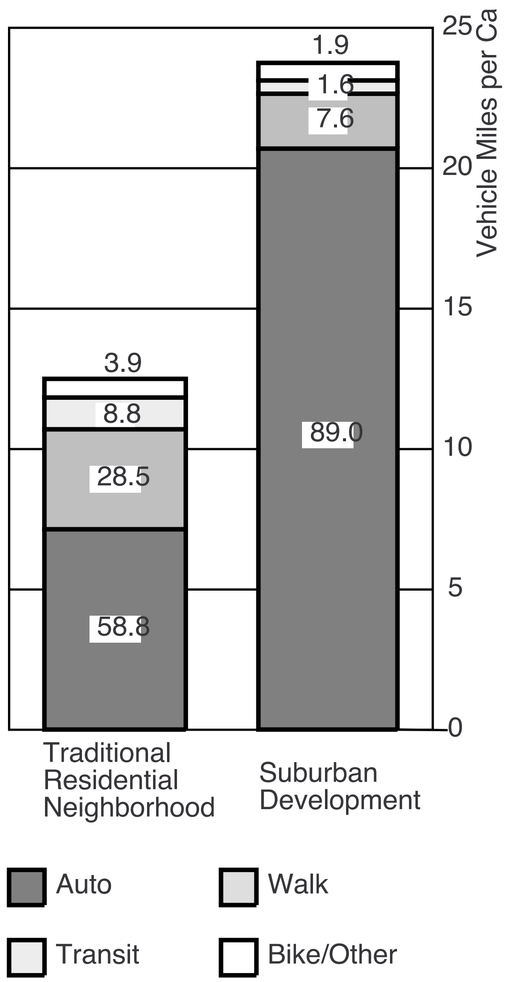
A Tale of Two Neighbourhoods

To illustrate how strongly neighbourhood type affects overall household energy consumption two contrasting residences in two different neighbourhoods have been selected. Reasonable household space heating budgets were generated using a standard computer program for building performance (Energy Scheming). Estimated yearly demands for all types of energy consuming devices and appliances using data from the Nevada Power Company were then itemised and added in to the basic calculations to arrive at total annual house energy consumption. Both houses were modelled with gas furnaces of equal efficiency, in use identical lengths of time, with thermostats set at the same temperature. All other energy consuming devices in each house were assumed to be electric, with equal loads, except as noted in the description of House #1 below.

Household #1 (Figure 3) lives in a 186 m^2 (2,000 s.f.) house (average size for new construction during 1995-96 in the six county area around Portland, Oregon) located in a suburban neighbourhood. Walking for utilitarian errands is not practical. Access to

Figure 4: Daily trip generation in the Portland area

(From Metro Travel Results, Portland, OR)



mass transit is inconvenient and use of a bicycle for transportation is intimidating. Based on averages from recent studies of aggregate odometer readings in this type of new suburban neighbourhood, household automobile usage is assumed to be 48,000 km (30,000 miles) per annum (Calthorpe, 1993).

The Bonneville Power Administration's 'Super Good Cents' building recommendations were followed in House #1, taking performance considerably beyond basic code minima, with a calculated space heating budget for northwestern Oregon of 44,210 MJ per annum. In comparison to Household #2, a slight but measurably greater desire for comfort has been assumed as regards the choice and use of household appliances. For example, Household #1 has a quick recovery water heater, while Household #2 does not. Household #1 has a 566 litre (20 cu. ft.) frost-free refrigerator, while Household #2 has a 453 litre (16 cu. ft.) manual defrost model. House #1, with all energy-using devices combined consumes a total 167,120 MJ per annum.

Household #2 lives in an 88 year old 130 m^2 (1,400 s.f.) frame house located in a traditional, inner city neighbourhood of Portland, Oregon. A wide range of retail shops and basic services are located within a few blocks of House #2, accessible by foot along pleasant, tree-lined streets. Mass transit is nearby and convenient. A typical trip to the regional centre of downtown Portland takes about 10 minutes by bicycle or bus. An in-depth travel survey conducted in 1996 by Metro, the Portland area's regional planning authority, used thousands of detailed 'travel diaries' to document individual transportation choices. Results showed that residents in Household #2's type of traditional, pedestrian-friendly neighbourhood not only drive less, but make substantially more daily trips without a car than their suburban counterparts (Figure 4). Automobile usage is assumed to be 24,000 km (15,000 miles) per annum for Household #2 (Calthorpe, 1993).

House #2 is an early 20th century 'energy hog' with no insulation, single-pane windows, poor south orientation and a large amount of infiltration coming in through almost 90 years worth of cracks and gaps in the exterior envelope. With the exception noted in the description for Household #1, the family of Household #2 owns all the same types of appliances, lights and climate control devices as Household #1 and uses them with equal frequency.

Household #2 has a calculated space heating budget of 141,380 MJ per annum, and the house, with all other appliances, etc. added in, consumes a total 248,570 MJ per annum. House #1 is therefore 149% more efficient than House #2 while also being 143% larger.

Under the assumption (currently being researched by the authors) that families facing increased driving demands, especially those with children, tend to choose somewhat larger, more commodious vehicles, Household #1 is assigned cars with fuel ratings in the current range of sport utility vehicles and family vans - about 11 litres/100 km (21 mpg). Household #2 is assigned the current normal passenger car average of 8.3 litres/100 km (28 mpg).

Household #1's car energy budget is 190,080 MJ per annum, making a total (car + house) energy consumption for Household #1 of 357,200 MJ per annum. Car energy consumption is therefore more than 50% of the total. Household #2's car energy budget is 71,712 MJ per annum, making a total energy consumption for Household #2 of 320,282 MJ per annum. The comparison of these

Table 1: Amalgamation of the various calculations for the two households

	household #1	*off grid*	*household #2*	*upgraded*	*reduced car use*
size (m^2)	186	186	130	130	130
total for house	167120	0	248570	138110	138110
CAR					
distance travelled	48000	48000	24000	24000	17393
l/100km	11	11	8.3	8.3	8.3
fuel used (litres)	5280	5280	1992	1992	1443.6
energy MJ/l	36	36	36	36	36
energy consumed	190080	190080	71712	71712	51970.3
total for house	167120	0	248570	138110	138110
plus the car	190080	190080	71712	71712	51970.3
Grand Total	357200	190080	320282	209822	190080.3

household totals shows that the household in the traditional neighbourhood (Household #2), living with uninsulated walls, single-pane windows, etc., still uses approximately 10% less energy per annum than the 'Super Good Cents' suburban house, despite its R26 walls, R38 ceilings, U-0.30 windows, etc. Automobile use makes the difference, comprising 53% of the suburban household's total annual energy budget, but only 22% of the inner city household's budget.

If, through extraordinary measures, the suburban house goes off-line entirely, becoming a self-reliant 'earthship', while the traditional neighbourhood household merely upgrades to current Oregon energy code minima, calculations indicate that the suburban household can turn the tables on their traditional neighbourhood counterparts. In this scenario the suburban earthship household will have an energy budget of 190,080 MJ per annum, (car alone). After upgrading to energy code minima the traditional neighbourhood house energy consumption would be reduced to 138,110 MJ per annum, making a total (car + house) of 209,822 MJ per annum - just 11% more than the off-grid suburban earthship. By reducing VKT per annum by 6607 km, or about 27.53% of their annual total, the traditional neighbourhood household could, in conjunction with the aforementioned upgrades, equal the energy performance of the suburban earthship household.

Back to the Future - Tomorrow's house and yesterday's traditional neighbourhood

From these results we therefore conclude that for America's foreseeable future influencing household transportation choices offers the greatest opportunity for household energy conservation rather than implementing additional energy-saving architectural design features. Attempts to affect transportation behaviour are often dismissed as 'social engineering' and thus outside the proper realm of planners and architects. However, a growing amount of hard data, including the studies cited in this paper, document how the built environment in the form of neighbourhood typology influences travel behaviour. A single example is telling - according to the Metro travel survey walking comprises 7.6% of all trips in Portland's suburbs and 28.5% in mixed-use traditional neighbourhoods. Residents of this particular neighbourhood type are thus four times more likely to go by foot on a given daily errand than are their suburban counterparts.

Design and construction professionals concerned with reducing our profligate rate of energy use must begin to take a more proactive stance in favour of mixed use, pedestrian-oriented development. Although pollution and other adverse environmental impacts stemming from overuse of private automobiles have not been addressed by this paper, when these impacts are also considered, increased emphasis on pedestrian-oriented neighbourhoods becomes even more imperative for a sustainable future.

While design professionals are limited in what they can control, it is suggested that a first step towards promoting greater household energy efficiency should be to include estimated energy consumption by motor vehicles in presentations to clients and peers on the efficiency of specific design commissions. Information presented in this paper begins to show how average transportation costs could be estimated based on neighbourhood typology and then converted to units compatible with other expressions of residential energy consumption. In this way the 'invisible', but huge, energy cost of personal vehicles in non-urban environments would be made more generally apparent; those projects in pedestrian-friendly urban environments could likewise receive greater credit for their now often unrecognised role in energy conservation.

Many clients have a sincere desire to build in a sustainable fashion. However, expanding the consciousness of these clients to think of sustainable design not just in terms of building materials and operating costs is of vital importance. In many cases they may not have thought through the full impacts of transportation and how such energy costs can be incorporated into the design process. Architects and design professionals of all descriptions should be looking beyond the technics of construction and the property lines of a specific project site. We must begin educating our clients that where we build ultimately has more impact on our overburdened environment than what we build.

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