Comment on Reid Ewing and Fang Rong's "The Impact of Urban Form on U.S. Residential Energy Use"

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Abstract

Using a complicated stepped analysis, Ewing and Rong study the impact of sprawl on household energy use. They argue that dispersed land use brings about larger houses and more detached units, which consume more energy than the smaller houses and attached units typical of more compact communities.

This comment suggests that their conclusions are intuitive and obvious, but that their complex methodology linking three unrelated data sets renders their quantitative conclusions suspect. Further, a simple engineering analysis can show more meaningful results, sprawl is more likely to affect energy use through increased vehicle miles traveled than house size or type, and household energy use can be mitigated by increasing the efficiency of the building envelope, heating/cooling system, appliances, and lighting. Still, combining the effects of compact urban development with the effects of energy-efficient vehicles and housing unit design can be a real winner in our quest for more energy-efficient communities.

Keywords: Energy; Land use; Smart growth

Introduction

As we face the constraints posed by a carbon-rich and oil-poor future, energy use in cities and in the residential sector is a very important subject. There is substantial evidence that urban form affects energy consumption and that more dispersed forms increase per capita energy use (Kenworthy 2003). Countries (such as Canada and the United States) and states (such as Texas and Wyoming) with high per capita energy use are those with more dispersed forms of land use (Energy Information Administration [EIA] 2007, 2008). It is obvious that much of the higher energy use per household and the resulting greenhouse gas emissions from more dispersed land use patterns are caused by greater transportation energy from longer travel distances for commuting and commerce and fewer opportunities for more efficient modes such as transit, walking, and cycling (see, for example, the Center for Neighborhood Technology 2008).

It is also intuitive that sprawling forms of development have a greater proportion of larger and detached housing units than more compact forms. And it is easy to show by engineering calculation and observation that larger, detached housing units, built and operated under the same energy codes and conditions, use more energy for heating, cooling, and electricity than smaller and/or attached housing units (Randolph and Masters 2008).

Ewing and Rong's argument

Ewing and Rong focus on this latter issue: the fact that urban form affects energy consumption in residential housing and that dispersed forms potentially increase energy use in three different ways:

1. By larger and more detached housing units
2. By higher electricity transmission and distribution (T&D) losses
3. By the effect of urban form on the urban heat island (UHI): that is, fewer UHI effects with a more dispersed urban form and relatively lower temperatures resulting in less energy for cooling, but more energy for heating

They use four different databases to relate energy use to housing type and size, urban form, and UHI effect. They dispense with the effect of T&D losses, arguing that they are too small to matter because they involve "less than 7 percent of the total electricity generated in the United States" (7).

The use of four separate databases is both heroic and problematic. As Ewing and Rong acknowledge, no single database provides the information required to show how residential energy use varies with urban form.

1. They use EIA's 2001 Residential Energy Consumption Survey (RECS) (2004) to relate energy use to housing type, size, and age.
2. They use the U.S. Bureau of the Census 2000 Public Use Microdata Sample (2004) to relate urban form to housing type and the American Housing Survey (U.S. Bureau of the Census 1996, 2006) to relate urban form (through Ewing et al.'s 2003 sprawl index) to house size.
3. They use Kalnay and Cai's (2003) temperature and degree-day data from weather stations and from National Center for Environmental Prediction–National Center for Atmospheric Research Reanalysis to relate

urban form to degree-days and heating and cooling energy. (I should note that a better source for the effect of urban form on UHI is Stone 2007.)

The problem with these different databases is that they use very different sampling frames, making data comparison difficult. As a result, the study requires a complicated stepped analysis. The authors recognize this, citing caveats throughout the article, and they use a hierarchical nonlinear model to relate the results of the different regression analyses. Still, this makes for a very awkward analysis and instills little confidence in the results. This is exacerbated by the fact that the most important database, the RECS, is quite weak because of the small number of observations and the considerable variance.

Responses to the conclusions Ewing and Rong draw

Ewing and Rong's results include the following conclusions, given in italics, along with my comments on them.

Those living in multifamily housing consume 54 percent less heating and 26 percent less cooling than those living in single-family detached housing. Statements about percentages and especially about absolute reductions are misleading because of the range of factors involved, including size, levels of efficiency treatment, and behavior (such as thermostat setting). It would be better to qualify these results by specifying factors that have an influence. For example, what is varying here: just the size of the dwelling unit and attached common walls?

Those living in a 2,000-square-foot house use 16 percent more energy for heating and 13 percent more energy for cooling than those living in a 1,000-square-foot house. Engineering calculations following accepted American Society of Heating, Refrigerating, and Air Conditioning Engineers procedures yield larger percentages, especially for heating, so there must have been complicating factors in the data (Randolph and Masters 2008).

The odds of living in multifamily housing are seven times higher in a compact county than in a sprawling county, as measured by the sprawl index. "Houses are 21 percent larger in sprawling counties" (21) *than in compact ones.* Definitive statements such as these need some qualifications, stated assumptions, or an indication of confidence level.

With each increase of 1 percent in the county sprawl index (i.e., 1 percent more compactness), heating degree-days (HDDs) decrease by 0.21 percent and cooling degree-days (CDDs) increase by 0.48 percent. For each 10 extra HDDs, heating energy increases 0.2 percent annually; for each 10 *extra CDDs, cooling energy increases 0.5 percent to 0.6 percent annually.* The article is vague about the methodology used to derive this result. I am skeptical of the authors' level of precision in relating the sprawl index to degree-days. The variation in UHI effect from urban to rural areas is very difficult to measure, and the best study on the subject to date (Stone 2007) found a difference of 0.5°C (0.9°F). Further, translating change in average temperature into percent change in degree-days depends on the base, which in turn depends on the location: For example, a one-degree change in outside temperature will have a much higher percentage effect in areas with lower degree-days than in areas with higher degree-days.

An average residential unit in a compact county would be expected to consume 17.9 million fewer British thermal units (BTUs) of primary energy (or 20 percent less annually) than one in a sprawling county due to house type and size and 1.4 million fewer BTUs (or 1 percent less annually) due to UHI. Again, how these bottom-line numbers were derived is unclear. However, the percentage reduction is consistent with the simple engineering calculations in table 1.

Compact development can lead to a 20 percent to 40 percent reduction in transportation energy use and emissions (Ewing et al. 2008) and a comparable reduction in residential energy use and emissions. Other studies have estimated reductions in vehicle miles traveled (VMT) (a proxy for transportation energy reductions) from smart growth development patterns. They range from 9 percent for Columbus (Stone et al. 2007) to between 10 percent and 20 percent for Puget Sound (Puget Sound Clean Air Agency, Climate Protection Advisory Committee 2004) to 25 percent for Sacramento (CA) (Sacramento Area Council of Governments 2005). But for individual households, the effect can be much greater: up to 60 percent (Center for Clean Air Policy 2004). Most of the energy argument for compact development lies in the transportation sector (Randolph and Masters 2008).

The argument for improved energy efficiency

Ewing and Rong's article was silent on the best way to reduce energy use and related carbon emissions in the residential building sector, namely, through improved energy efficiency. What attention it does give the subject of "energy efficiency through technological innovation" (2) is misleading. It assumes that efficiency "just means more service per fixed amount of energy delivered" (2). The authors seem to believe that all efficiency improvements will be offset by what has been called the "rebound effect," which assumes that faced with greater efficiency, consumers will find ways to use as much

Table 1. Calculating the Effects of "Suburban versus Urban" and "Average versus Green" Households on Typical Energy Consumption

	VMT/ Year	Vehicle mpg	Transport MBTUs/ Year	Thermal Index[a]	House Size	Heating Energy[b] MBTUs/ Year	Electric kWh/ Month	End-Use Electric kWh/ Year	Primary Electric MBTUs/ Year	Household MBTUs/ Year	Total Energy MBTUs/ Year
Suburban average	25,000	25	125	8	3,000	108	1,500	18,000	184	292	417
Suburban green	20,000	35	71	5	2,500	56	750	9,000	92	148	220
Urban SF average	8,000	20	50	8	2,500	90	1,200	14,400	147	237	287
Urban SF green	5,000	30	21	5	2,000	45	600	7,200	74	119	140
Urban MF	8,000	20	50	6	1,000	27	500	6,000	61	88	138
Urban MF green	5,000	30	21	4	1,000	18	400	4,800	49	67	88

[a] Thermal index = BTU/HDD-square feet; 8 reflects a standard code, 5 approaches a green building standard.
[b] Assumes 4,500 degree-days.
Notes: kWh = kilowatt hours; MBTUs = million BTUs; MF = multifamily; mpg = miles per gallon; SF = single family; VMT = vehicle miles traveled.

energy or more (by driving more, adjusting the thermostat, buying bigger houses and appliances, and so on). While the rebound effect is real, studies have shown that it is not as great as most critics claim (Geller and Attali 2005).

Ewing and Rong go on to state that "advances in technology alone will not achieve sustainable growth in energy use.…Hence demand-side measures will be required" (4). They appear to mean advances in *supply* technology alone, and there is confusion about what constitutes a demand-side measure. These generally involve technology applied to improving efficiency at the end use rather than technology applied to producing energy (Randolph and Masters 2008). Included are additional insulation, superefficient windows, high-efficiency furnaces and heat pumps, programmable thermostats, and high-efficiency lighting and appliances, among other things.

And efficiency improvements can have a far greater impact on residential energy use than urban form does. The calculations in table 1 show that "green" and efficient improvements in residences can save far more energy and emissions than the effects of urban form on housing size and type. Given the assumptions in the table, the suburban average household uses 45 percent more energy than the urban average household. This additional use results from more VMT (58 percent, despite higher miles per gallon for the suburban average due to more highway miles), more heating energy because of a larger house (18 percent), and more electricity use because of a larger house and more appliances and lighting (28 percent). But an urban average house can consume 30 percent more energy than a suburban green household and 100 percent more than an urban green household. In other words, while green measures can offset the impact of urban form on energy use, more compact urban form combined with green efficiency gives the lowest energy consumption of all. A smaller, urban multifamily, green household can consume one-fifth the energy of a larger, suburban average single-family household.

Conclusion

The energy and carbon emissions savings from compact development and energy efficiency are not mutually exclusive. More compact urban form and greater efficiency improvements have positive effects on both transportation and residential energy and emissions. We need to foster both in new developments through better codes, zoning standards, and economic incentives.

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