COMPACT DEVELOPMENT AND GREENHOUSE GAS EMISSIONS: A REVIEW OF RECENT RESEARCH

ERIC FRUITS

Economics International Corp. and Portland State University

Oregon's land use policies were originally promoted to reduce "sprawl" and to preserve agricultural land and open spaces. As climate change issues gained policy prominence, land use was called upon as a way to halt potential climate change. A staff member at Metro, the Portland area's regional government, explains how climate change thinking became one of the key justifications for policies favoring compact development:

> It was not a stated objective of the 2040 Growth Concept (1995) to reduce greenhouse gas emissions. In the years leading to its adoption, air quality, costs of public infrastructure, protection of farmland outside the UGB and re-vitalization or downtowns of the region were uppermost in the minds of regional leaders. But cities and counties, especially Portland and Multnomah County, began to address emissions reduction on a track that paralleled development of the Growth Concept. The city led the way by adopting the nation's first carbon dioxide reduction strategy in 1993. Eight years later, the county joined the city in a joint Local Action Plan on Global Warming (2001), setting a CO_2 reduction target of ten percent below the 1990 level by 2010. Each of these efforts identified the links among development patterns, vehicle miles traveled (VMT) and GHG

> emissions. Each called for more compact development as a principal strategy to reduce VMT and emissions.[1]

On its face, the linkage between compact development and greenhouse gas emissions seems obvious: (1) if individuals drive less, then vehicle emissions will decline, and (2) if families live in more compact developments, then they would likely drive less and use less energy, and therefore (3) compact development would reduce greenhouse gas emissions.

This article reviews the existing research with an eye toward identifying whether—and by how much—compact residential development affects greenhouse gas emissions. While many facets of "smart growth" may affect greenhouse gas emissions, this brief article focuses exclusively on the role density plays.

While the connection may seem obvious, there has been very little research to test whether a linkage between compact development and greenhouse gas emissions actually exists. There has been even less research attempting to quantify the relationship. Even worse, the little evidence that is available is contradictory or flawed. The result is development policy based on speculation, rather than evidence. Indeed, much of the data presented by researchers seems designed to justify policy prescriptions rather than to scientifically test for the existence or size of a relationship.

DOES COMPACT DEVELOPMENT REDUCE MOTOR VEHICLE USAGE?

The relationship between compact development and motor vehicle usage can be broken down into three broad, and sometimes overlapping, categories:

1. Number of trips;
2. Length of trip; and
3. Mode choice (e.g., bus vs. car vs. walking).

This breakdown is critical to understanding why the connection between compact development and greenhouse gas emissions is not obvious. For example, evidence suggests that more compact development is associated with shorter, but more frequent trips. As a result, the net impact is an empirical, rather than an obvious theoretical, issue.

Empirically, the results are mixed. On the one hand, some studies have found that more compact development is associated with greater vehicle-miles traveled.[2] On the other hand, one widely cited study finds the opposite relationship, but only

---

[1] Benner, R. (2009). Portland Metropolitan Region Turns a Climate Change Corner. Metro.

[2] Crane, R. (1996). Cars and drivers in the new suburbs: Linking access to travel in neotraditional planning. Journal of the American Planning Association, 62(1):51–65.

by assuming that there is no change in the number trips in more compact developments.[3] Other studies find no significant relationship between the built environment and travel behavior.[4] With such mixed results, it is impossible to have confidence that compact development in any way affects motor vehicle usage.

At a theoretical level there is no obvious connection between compact development and mode choice. While it is conceivable that one may be more inclined to walk or take public transit if he or she is closer to his or her job or to retail establishments, the connection between residential density and mode choice is not self-evident. This is borne out by real world observations. For example, density has almost no economically significant impact on car ownership.[5] Indeed, research summarizing the body of past findings concludes that measures of population density and job density have a virtually nonexistent relationship with individuals' choice to use public transportation or to walk.[6] For example, the researchers find that a 10 percent increase in household or population density would increase walking by only 0.7 percent and increase transit use by only 0.4 percent. The most recent research finds slightly greater impacts, but nevertheless concludes the impacts are "very small."[7] Such insignificant results indicate that compact development policies should not be based on expectations of reduced motor vehicle usage. Indeed, it is clear that compact development is not a useful tool for reducing greenhouse gas emissions. Rather, much of the progress in controlling greenhouse gas emissions has been, and will continue to be, through innovations in the technologies using fossil fuels.

DOES COMPACT DEVELOPMENT REDUCE HOUSEHOLD ENERGY USE?

A substantial share of greenhouse gas emissions associated with residential development comes from motor vehicle usage. Yet, the weakness of a density-emissions connection invites an investigation of other potential sources of development related emissions.

---

[3] McNally, M. G. and Ryan, S. (1993). Comparative assessment of travel characteristics for neotraditional designs. Transportation Research Record, 140:67–77.

[4] For a summary of these studies see Lee, Y., Washington, S., and Frank, L. D. (2009). Examination of relationships between urban form, household activities, and time allocation in the Atlanta Metropolitan Region. Transportation Research Part A, 43:360–373.

[5] Bhat, C. R. and Guo, J. Y. (2007). A comprehensive analysis of built environment characteristics on household residential choice and auto ownership levels. Transportation Research Part B, 41(5):506–526.

[6] Ewing, R. and Cervero, R. (2010). Travel and the built environment. Journal of the American Planning Association, 76(3):265–294. The authors claim that their analyses are based on the most complete data available as of late 2009.

[7] Heres-Del-Valle, D. and Niemeier, D. (2011). CO_2 emissions: Are land-use changes enough for California to reduce VMT? Specification of a two-part model with instrumental variables. Transportation Research Part B, 45:150–161.

The relationship between residential energy use and greenhouse gas emissions is an indirect relationship. Typical household activities (e.g., cooking, cleaning, lighting, and heating) are associated with the use of fossil fuels which, in turn, emit greenhouse gases. Residential energy consumption accounts for 22 percent of the total energy consumption in the United States.[8] By reducing household energy consumption, greenhouse gas emissions can be reduced. Some research suggests that differences in land uses may affect household energy consumption. For example, it has been argued that higher density developments are more energy efficient and consume less energy than less dense developments.[9] The conclusions reached are sensitive to the metric being used (e.g., per square foot, per person). For example, in evaluating the differences in energy use between a "low" density development and a "high" density development, one study discussed below finds large differences in energy use on a per person basis, but found no measurable difference on a per square foot basis.

Research finds that energy consumption per unit of building area, is almost the same for both high density urban and low density suburban homes.[10] A study of annual energy consumption for buildings and transport in four Toronto neighborhoods finds that the three least dense neighborhoods show increasing energy consumption per capita with increasing density.[11] In other words, for these neighborhoods, greater density is associated with greater per capita energy consumption. At the same time, the "high density" neighborhood has the smallest estimated per capita energy consumption.

---

[8] Kaza, N. (2010). Understanding the spectrum of residential energy consumption: A quantile regression approach. Energy Policy, 38:6574–6585.

[9] See Wilkinson, P., Smith, K. R., Beevers, S., Tonne, C., and Oreszczyn, T. (2007). Energy, energy efficiency, and the built environment. Lancet, 370(9593):1175–1187.

See also Norman, J., MacLean, H. L., and Kennedy, C. A. (2006). Comparing high and low residential density: Life-cycle analysis of energy use and greenhouse gas emissions. Journal of Urban Planning and Development, 132(1):10–21.

[10] Norman, J., et al. (2006). The authors find that that low-density suburban development is more energy and greenhouse gas intensive than high-density urban core development on a per capita basis. When the functional unit is changed to a per unit of living space basis the factor decreases substantially, illustrating that the choice of functional unit is highly relevant to a full understanding of urban density effects. Such findings indicate that building occupants may "self select" into developments that are consistent with their demographics and lifestyles.

[11] Codoban, N. and Kennedy, C. A. (2008). Metabolism of neighborhoods. Journal of Urban Planning and Development, 134(1):21–31. Because of the small number of observations, it is impossible to account for variations in neighborhood characteristics and demographics. For example, the study describes the neighborhoods as (1) prewar "streetcar suburban," (2) postwar suburban, (3) contemporary suburban, and (4) contemporary urban. Without adequate accounting for variations in neighborhood type, it is difficult to draw any general conclusions.

Another Toronto study estimates greenhouse gas emissions associated with building operations for each census tract.[12] The authors find peaks in electricity usage in the central core of the city and speculate that the peaks might be explained by additional energy loads and the higher space-cooling requirements of high-density development. For example, towers have elevators, higher occupancies, and lighting and cooling for common spaces, all of which demand energy and introduce more heat for the cooling system to overcome. In addition to these factors, the higher volume-to-surface-area ratio of towers might also increase their cooling demand.

A cross-sectional study of eight residential communities in Norway examined total household travel activity and energy consumption.[13] This is one of the few studies that add up effects across all transportation modes (including air travel) and the energy use of the housing itself. The findings indicate that compact residential development without "gardens" (e.g., backyards or front yards) generate offsetting travel and energy demand for recreation and international travel.

The second potential way in which residential development may be associated with greenhouse gas emissions is in the construction of dwelling units. While a connection is asserted by policy makers, very few studies exist on the relationship between residential construction activities and greenhouse gas emissions. The thinness of the literature likely is due to (1) construction activities being associated with a relatively small portion of a residence's life-cycle energy usage, and (2) the lack of an adequate or appropriate "but-for" alternative against which to measure construction activities.

Research on residential construction impacts have focused on "embodied" energy and the resulting estimated greenhouse gas emissions. One study concludes embodied energy and greenhouse gas emissions resulting from material production across the supply chain are approximately 1.5 times higher for a low-density case study than a high-density case study on a per capita basis.[14] However, changing the functional unit from per capita to per living area (square meters) alters these findings significantly. When considered on a unit living area basis, the high-density development scenario becomes 1.25 times more energy and emissions intensive in terms of material production than the low-density case. The study relies on only two observations, so no generalizable conclusions can be drawn.

An earlier study of embodied energy notes that the energy used in residential construction is often ignored due to the fact that it is considered small compared with the embodied energy of the building materials and because there is little

---

[12] VandeWeghe, J. R. and Kennedy, C. (2007). A spatial analysis of residential greenhouse gas emissions in the Toronto census metropolitan area. Journal of Industrial Ecology, 11(2):133–144.

[13] Holden, E. and Norland, I. T. (2005). Three challenges for the compact city as a sustainable urban form: Household consumption of energy and transport in eight residential areas in the greater Oslo region. Urban Studies, 42(12):2145–2166.

[14] Norman, et al. (2006).

information available.[15] The research cites previous studies suggesting that 7 percent to 15 percent of the total embodied energy was attributable to construction activity. The study relies on only 25 observations and studies only single family residences. Thus no generalizable conclusions can be drawn regarding the impacts of density or location on embodied energy used.

CONCLUSION

Oregon's land use policies favoring compact development were originally promoted to reduce "sprawl" and to preserve agricultural land and open spaces. More recently, the potential to halt climate change has been used as a key justification for encouraging more compact development. While the linkages between density and greenhouse gas emissions may seem obvious, available data indicate that the connections are weak, bordering on non-existent. Thus, it is clear that compact development is not a useful tool for reducing greenhouse gas emissions. Indeed, much of the progress in controlling greenhouse gas emissions has been through innovations in the technologies using fossil fuels.

The evidence to date also raises the question whether cities or regions are the appropriate level for fighting potential climate change. For example, the population of Oregon represents approximately one percent of U.S. population and an even smaller share of U.S. greenhouse gas emissions. The entire state can drop its greenhouse gas emissions to zero and the world would never notice the difference. While there may be some value to being a showcase for energy saving approaches, it is very easy for others to free ride off of the innovating region's initial efforts and investments. In this way, such regional efforts to slow potential climate change through compact development are little more than showy, but costly, curiosities. ■

Eric Fruits is President of Economics International Corp. and an adjunct professor at Portland State University. This article is based on research performed for a project sponsored by the National Association of Homebuilders. The complete study is available at nahb.org. Any opinions expressed are those of the author's and do not represent the opinions of any other individual or organization.

---

[15] Pullen, S. F. (2000). Energy used in the construction and operation of houses. Architectural Science Review, 43(2):87–94.