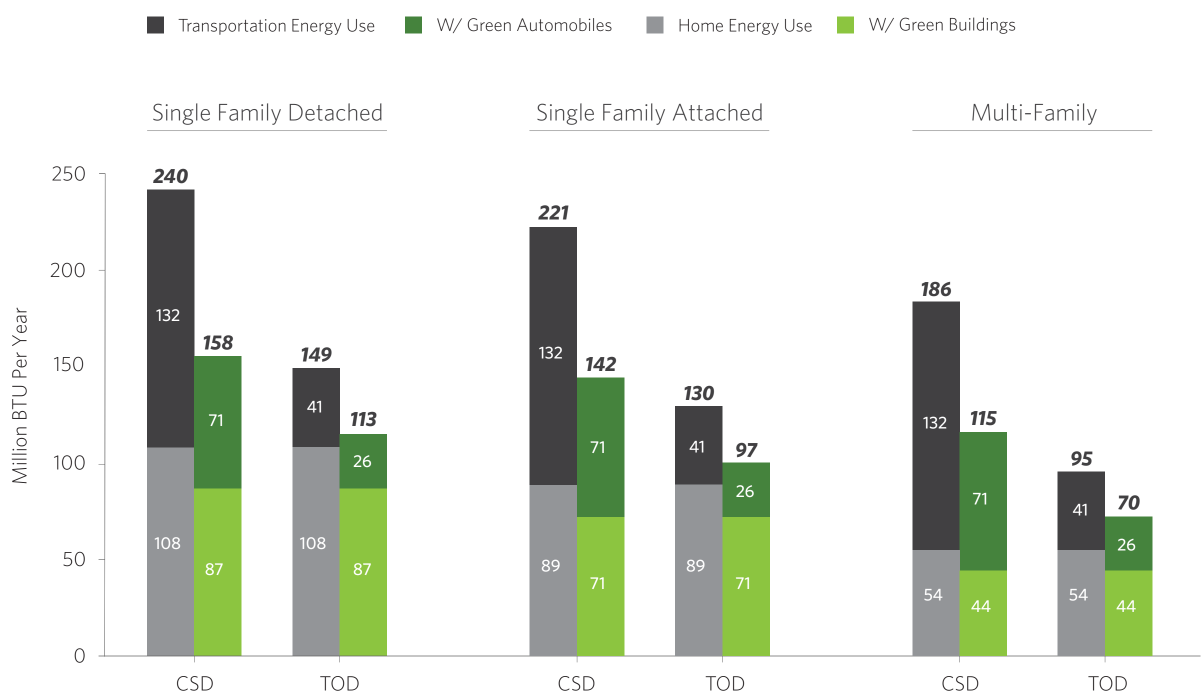
Location Efficiency and Housing Type

Boiling it Down to BTUs



CSD - Conventional Suburban Development

TOD - Transit Oriented Development

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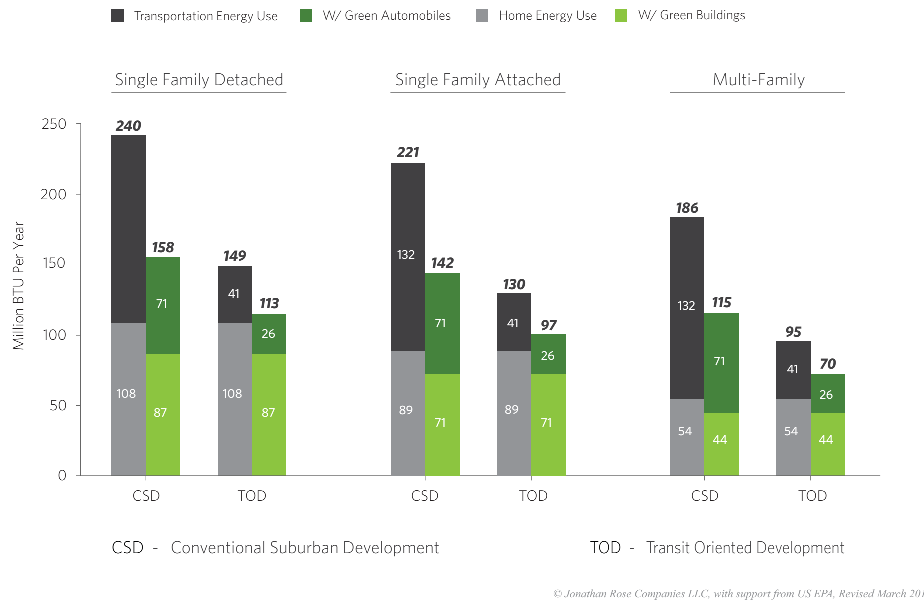
I. Introduction



Location Efficiency: Household and Transportation Energy Use by Location

Executive Summary

The purpose of this white paper is to create a well-supported yet simple illustration of the relationship between household energy consumption and residential development patterns. For the purpose of this illustration, residential development patterns are generally described by housing location and housing type. The paper also takes into account energy efficiency measures in homes and vehicles as factors that affect household energy use.

Housing that is located in a walkable neighborhood near public transit, employment centers, schools, and other amenities allows residents to drive less and thereby reduces transportation costs. Development in such locations is deemed to be "location efficient," given a more compact design, higher-density construction, and/or inclusion of a diverse mix of uses. If American families can reduce their necessity to drive through better housing and transportation options, then commute times and household energy costs will drop. This paper illustrates how housing location and proximity to transit is a major variable for household energy consumption.

Housing type also has a major impact on energy consumption and household costs. Residents in multifamily and single family attached homes in higher density neighborhoods usually use less electricity per unit and drive less than residents of low-density areas. Multifamily and single-family attached homes generally have smaller square footage per unit and shared walls, thus requiring less energy for heating and cooling than their detached counterparts. This paper illustrates how housing type is a variable for household energy consumption.

This paper also takes into account the impact that energy efficient building and transportation technology can have in further reducing household energy consumption and costs. Use of energy efficient design and fuel efficient vehicles has a notable impact on reduction of household energy use.

Energy consumption data, collected as broad national averages, were examined for housing location, type, and transportation variables and translated into BTUs (British Thermal Units) of energy in order to illustrate the relative differences in energy consumption. Use of national averages, by definition, aggregates information for wider relevance and application. It does not, therefore, allow for the fine-grain analysis that more location-specific, in-depth studies of any of the variables in this white paper would yield. Indeed, one anticipated outcome of this paper is to encourage further, more detailed study that is geographically specific. However, given the purpose of this paper and its intended use for a national audience, the patterns that emerged from the national averages are sufficient, and in fact necessarily broad, to illustrate the relationship between housing location, type, and energy consumption.

This study illustrates two key points about the effect of compact, location efficient development on energy consumption:

1. A home's location relative to transportation choices has a large impact on energy consumption. People who live in a more compact, transit-accessible area have more housing and transportation choices compared to those who live in spread-out developments where few or no transportation options exist besides driving. Choosing to live in an area with transportation options not only reduces energy consumption, it also can result in significant savings on home energy and transportation costs.

2. Housing type is also a very significant determinant of energy consumption. Fairly substantial differences are seen in detached versus attached homes, but the most striking difference is the variation in energy use between single-family detached homes and multifamily homes, due to the inherent efficiencies from more compact size and shared walls among units. Moderate energy-efficient building technologies, such as those qualifying for Energy Star performance, also generate household energy savings that are notable but not as significant as the housing location and type.

Background

In June of 2009, the U.S. Environmental Protection Agency (EPA), U.S. Department of Housing and Urban Development (HUD), and U.S. Department of Transportation (DOT) entered into an interagency Partnership for Sustainable Communities. The goal of this partnership is to help improve access to affordable housing, expand transportation options, and lower transportation costs while protecting the environment in communities nationwide.[1] Six Livability Principles (see box) guide

1 US Environmental Protection Agency (EPA). "HUD-DOT-EPA Interagency Partnership for Sustainable Communities": http://www.epa.gov/smartgrowth/partnership (accessed on March 9, 2010).

the partnership's efforts to coordinate federal housing, transportation, and other infrastructure investments to create communities that are more economically and environmentally sustainable. This paper supports the goals of the partnership by illustrating the importance of location, transportation choice, and energy efficiency measures in homes and vehicles to create more sustainable, less energy intensive communities in the future.

Livability Principles for HUD-DOT-EPA Interagency Partnership for Sustainable Communities

1. Provide more transportation choices
2. Promote equitable, affordable housing
3. Enhance economic competitiveness.
4. Support existing communities.
5. Coordinate and leverage federal policies and investment.
6. Value communities and neighborhoods.

This paper and accompanying graph illustrate the energy consumption benefits that a more location and energy efficient development approach can have when compared to conventional low-density development. Location efficient sites are located near transit and use compact design to facilitate pedestrian access to transit, linking people to a range of services, amenities, and employment centers. They include a mix of uses, and offer comfortable and convenient transit service, thereby increasing the number of viable transportation options available to residents to commute to work, school, or other destinations. In short, this development can be termed "transit-oriented development" (TOD), and is compared against the prevailing dispersed, low-density pattern of growth, termed "conventional suburban development" (CSD) for this paper. In both TOD and CSD patterns, homes can be constructed to be energy efficient, and fuel efficient cars can be purchased. Both strategies can contribute to an overall development approach that seeks to reduce energy, and create more sustainable communities; however energy savings from location efficient housing can be enhanced with energy efficient construction methods and green cars. This paper's graphic representation of location efficiency in BTUs can be utilized to facilitate discussions on the ways in which development of location efficient housing and neighborhoods with transportation options can save energy and deliver other benefits for the economy, the environment, and the community as a whole.

Contribution of Housing Location and Type to Energy Consumption and Emissions

The contribution of buildings to total energy consumption and greenhouse gas emissions is significant. Buildings account for approximately 40 percent of domestic energy use,[2] and in 2008 the U.S. residential sector accounted for 21 percent of total

2 US Department of Energy (DOE). "Energy Efficiency Trends in Residential and Commercial Buildings," October 2008: http://apps1.eere.energy.gov/buildings/publications/pdfs/corporate/bt_stateindustry.pdf (accessed on March 9, 2010)

CO_2 emissions in the country.[3] The pattern in which homes are built and their proximity to transit directly affects their rate of energy consumption and emissions. Preliminary findings from the 2009 National Housing Transportation Survey indicate that households in areas of very high density (5,000 – 9,999 households per square mile) produce about half the emissions of households in areas with very low density (0 – 50 households per square mile).[4] The survey also notes that households very close to transit lines produce about one-fourth the emissions of households without close access to transit.[5]

House type is another key indicator of energy use, and according to the 2005 Residential Energy Consumption Survey (RECS), approximately 80 percent of residential energy consumption is by single-family homes while 15 percent is by multifamily dwellings and the remainder by mobile homes. The data show that an average multifamily unit uses half the energy of an average single family detached home.[6] Most residential energy use goes to space heating,[7] thus smaller units in multifamily buildings that share walls and require less heating and cooling consume less energy than single-family detached homes. The connection between house type and energy consumption also shows that energy consumption is not driven simply by on-site design (such as energy efficient fixtures, light-colored roofs, compact-fluorescent lighting, and so forth) but largely by location and transportation factors.

Energy and Climate Change Benefits Associated with Location Efficient Development

In an era faced with the need to reduce energy consumption and climate change emissions, it is useful to consider the potential for reductions that can be achieved with a more sustainable approach to development. In particular, energy efficiency can have a significant impact on reducing dependence on fossil-fuel based energy. Additionally, there are a number of resources that illustrate the energy and climate change benefits associated with energy efficiency measures in homes and cars. However, such benefits are also generated by a more compact, location efficient, transit-oriented form of development, primarily because it leads to shorter and/or less frequent vehicle trips.

Several studies have examined the vehicle travel generated by homes in compact, transit-oriented neighborhoods in comparison to levels of vehicle miles traveled (VMT) produced in more traditional neighborhoods. Although the studies find a

3 US Environmental Protection Agency (EPA). "2010 Draft US Greenhouse Gas Inventory Report," March 2010: http://epa.gov/climatechange/emissions/downloads10/US-GHG-Inventory-2010-Chapter-Executive-Summary.pdf (accessed on March 9, 2010).

4 US Department of Transportation (DOT), Federal Highway Administration. "NHTS (National Household Travel Survey) Brief", March 2009: http://nhts.ornl.gov/briefs/Carbon%20Footprint%20of%20Travel.pdf (accessed on March 9, 2010). (Note that complete 2009 NHTS figures were not available at the time of this paper's authorship. Preliminary findings were available in this brief referenced in Footnote 4.)

5 It is likely that houses closer to transit have lower energy consumption due in part to the fact that they are located in more compact neighborhoods, and may therefore be physically smaller in size, than those without proximity to transit.

6 Energy Information Administration, *2005 Residential Energy Consumption Survey.*

7 *Ibid*.

range based upon the varying location of the transit oriented housing examined, studies consistently find a reduction in VMT of 25 to 57 percent per household.[8] In line with these findings, *Growing Cooler*, a book published by the Urban Land Institute[9] reviewed the body of research on compact development and its effect on vehicle miles traveled (VMT), finding that TOD can reduce VMT by anywhere from 20-40 percent per capita, relative to sprawl.[10] Based on the amount of new development that is expected by 2050, and the percentage of that development that could be expected to be in compact, walkable neighborhoods, *Growing Cooler* authors estimated that compact development could reduce greenhouse gas emissions by 7 to 10 percent in 2050.

A subsequent study entitled *Moving Cooler*, assessed the greenhouse gas reduction potential of a variety of transportation and land use strategies. *Moving Cooler* concludes that a bundle of land use strategies and improved travel options, including walkable neighborhoods, zoning that supports pedestrian-friendly and transit-oriented development, "complete streets" policies, better bicycling facilities and infrastructure, and improved and expanded public transit service, could reduce greenhouse gas emissions by 9 to 15 percent in 2050, depending on the strategies used.[11]

Household Financial Benefits Associated with Location Efficient Development

In addition to the energy and emissions reductions, where and how homes are developed also has financial implications for households. When energy consumption is reduced, household energy costs decrease. Location efficiency can contribute to or undermine a home's affordability,[12] and these impacts can also extend to a household's financial stability. One analysis of some of the causes behind the U.S. financial crisis suggests that vehicle ownership and a lack of access to public transportation may be just as predictive of mortgage foreclosure rates as low credit scores and high debt-to-income ratios. This conclusion is the result of a study commissioned by the Natural Resources Defense Council of foreclosure rates in San Francisco, Chicago, and Jacksonville, FL. The survey found mortgage holders were less likely to face foreclosure if they lived in compact neighborhoods with sufficient public transit to make owning a car optional. For example, a hypothetical borrower in the Chicago area with a credit score of 680, a debt-to-income ratio of 41 percent, and a 20 percent down payment would be 2.7 percent more likely to default if the home was in a sprawling suburb instead of a compact urban area.[13]

8 The Transportation and Environmental Impacts of Infill Versus Greenfield Development: A Comparative Case Study
Analysis, EPA 231-R-99-005. 1999.
Transit Cooperative Research Project, (2008) Report 128, Effects of TOD on Housing, Parking, and Travel.
Air and Water Quality Impacts of Brownfield Revitalization EPA Report.

9 Ewing, et al. *Growing Cooler: The Evidence on Urban Development and Climate Change*. Urban Land Institute, 2008.

10 Ibid, pg. 84-89.

11 Cambridge Systematics, Inc. *Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions*. Urban Land Institute, July 2009.

12 For an in-depth explanation on the relationship between housing and transportation costs associated with location, refer to Center for Neighborhood Technology's "H+T Index" website, at www.htindex.cnt.org.

13 Natural Resources Defense Council. *Reducing Foreclosures and Environmental Impacts through Location efficient Neighborhood Design*. Washington, DC. January, 2010.

Market for Location Efficient Development

This type of development is not only well-suited to respond to climate change, arguably the most pressing environmental challenge of the early 21st century, it is also well-suited to the demographic changes and shifting market preferences occurring now. A number of market studies demonstrate a growing demand for compact, smart growth development. A 2010 market analysis completed by RCLCO, for example, illustrates that demographic changes are underway which are leading to rapid growth in the number of households without children.[14] These households demonstrate a preference for more walkable, vibrant "urban" places with good transit access, even if that comes at the expense of lot and/or unit size. While there will still be a demand for single-family detached homes in traditional suburban neighborhoods, the RCLCO study shows that that demand is decreasing. Numerous other studies echo these trends, and speculate that due to policy and economic forces at work, an untapped market demand for smart growth currently exists, and will persist far into the 2020s.[15]

Uses for This Paper

This paper and related further research could be particularly useful for developers and planners who want to help communities find land use, housing, and transportation strategies that use energy more efficiently and reduce greenhouse gas emissions. Additional research on location efficiency could help state and local governments understand the potential for infill development by performing an inventory of available sites and reviewing regional plans and infrastructure improvement programs for consistency with energy and climate policy goals. Related studies could also help assess the cost-effectiveness of changing zoning to emphasize mixed-use, compact development patterns and to make it easier to build in a manner that is location efficient. Additionally, this research links housing location and affordability, and further study could give housing advocates, financial institutions, and policy-makers crucial information to consider as they address housing affordability, mortgage calculations for household finance scenarios, and housing accessibility.

14 Hewitt, Charles, "The Future of Smart Growth" PPT, March 12, 2010. Available at http://www.rclco.com/pdf/Smart_Growth_Alliance-RCLCO_Presentation-March_12_2010.pdf. Accessed May 7, 2010.

15 Leinberger, Christopher, "The Option of Urbanism: Investing a New American Dream" Island Press. 2008. Also, Arthur C. Nelson's "Planning Leadership in the New Era" Journal of the American Planning Association (Vol. 72, Issue 4) 2006.

II. Methodology

For this study, average energy consumption figures were collected to illustrate the relative impacts that household location and transit choice, housing type, and energy efficiency measures for homes and vehicles have on national household energy consumption.

Housing Location and Transit Choice

For the sake of illustration, housing location was broadly defined as either "conventional suburban development" (CSD) or "transit-oriented development" (TOD). CSD scenarios are characterized by low-density development patterns, and in this study they assume that there is no access to public transit and residents rely solely on the automobile for transportation. TOD, compact scenarios assume that public transit is widely available, easily accessible, and combined with transit ridership and shorter average vehicle trips, reduces VMT when compared to the CSD. As noted earlier, Growing Cooler and other research studies focused on the transportation impacts of CSD versus TOD show that compact VMT is reduced by 20 to over 50 percent in transit-oriented developments.[16] For purposes of this paper, an average reduction of 45 percent of CSD vehicle miles traveled was used in calculations for the TOD scenarios.

Housing Type and Energy Use

In order to illustrate the energy use associated with housing (see Figure 1), average national figures were gathered along three distinct housing types. The Energy Information Administration's 2005 Household Residential Energy Consumption Survey (RECS) provides energy consumption data by several housing types. For this paper, the following three categories were chosen:

- **Single-Family Detached** categories use home energy data from the RECS *Single Family Homes – Detached* classification (108.4 million BTU per year), which is a weighted average for household energy consumption for single–family, detached homes ranging from one to five or more bedrooms.

- **Single-Family Attached** categories use home energy data from the RECS *Single Family Homes – Attached* classification (89.3 million BTU per year), which is a weighted average for household energy consumption for townhomes and row houses ranging from one to five or more bedrooms.

- **Multifamily** categories use home energy data from the RECS *Apartments in 5 or More Unit Buildings* classification (54.4 million BTU per year), which is a weighted average for household energy consumption for multifamily buildings such as four-story condos, or multi-story apartment buildings ranging from one to five or more bedrooms.

16 For details on numerous studies by these authors and others, see: Ewing, et al. *Growing Cooler: The Evidence on Urban Development and Climate Change*, Chapter 4, Washington, DC: Urban Land Institute, 2008.

Figure 1:
Energy Consumption Formula Used:

Housing-Related Energy Use + Transportation-Related Energy Use

The RECS data are broad national averages, and are therefore useful for illustrating relative differences in energy consumption across the spectrum of house types in the United States, independent of location. Each housing type was then considered within the CSD and TOD scenarios to demonstrate the relative impacts of housing location versus type on household energy consumption.

Figure 2:
Differences in Formulas Used for Energy Efficiency Measures in Homes:

Formula Used to Calculate Energy Consumption for Conventional Homes:

Energy Consumption in BTUs per HH
Formula Used to Calculate Housing Energy Consumption
for Energy Efficient Homes:

Energy Consumption in BTUs per HH* .80

In order to determine the amount of energy consumption reductions gained by use of energy efficiency measures in homes, this study relied on estimates stated by the Energy Star for Homes program. This joint EPA-DOE program estimates that new homes constructed according to Energy Star guidelines for energy efficiency typically are 20 to 30 percent more energy efficient than standard homes.[17] These strategies generally include insulating and sealing gaps in the home, ensuring that the home's heating and cooling systems are operating efficiently, and using energy efficient appliances and light fixtures. While these savings are based on Energy Star's estimates for new construction, they do not specifically include existing homes retrofitted with similar techniques. Further, these estimates do not reflect energy savings that could be gained by use of state-of-the-art energy efficient building technologies, such as high-performance building envelopes, photovoltaic panels, or "smart sensors" that detect and redirect energy in unused rooms. Further study might examine the relative impacts that high performance energy efficient construction technology might have on overall household energy. Such techniques are more likely to be found in projects that are certified at higher levels by proprietary rating and/or certification programs, such as LEED, EarthCraft, or NAHB's National Green Building program. These and

17 US Environmental Protection Agency (EPA), Energy Star Program. "Qualified New Homes": http://www.energystar.gov/index.cfm?c=new_homes.hm_index (Accessed March 9, 2010).

other techniques would likely generate far greater energy savings. To illustrate the impact that even moderate use of energy efficient measures that meet Energy Star guidelines can have on household energy consumption, household energy RECS figures were reduced by 20 percent in both the TOD and CSD "green" scenarios. (Figure 2).

Transportation Choice and Energy Use

In order to illustrate the impacts of transportation choice on household energy consumption (Figure 3), this study evaluated automobile fuel consumption for conventional and green household vehicles. The study also gathered data on average fuel efficiency per passenger mile for transit use, applicable only to the TOD scenarios.

To calculate the contribution of automobile use towards home energy consumption, this study used several data sources to arrive at a national average of BTUs consumed by the average household's vehicles, both for conventional and fuel-efficient models. Average VMT was divided by average miles per gallon (mpg) to yield gallons of gasoline, which was then converted into BTUs.

Figure 3:
Formula Used for Transportation-Related Energy Use:

Transportation-Related Energy Use in BTUs = Vehicle-Related Fuel Consumption per HH + Transit-Related Fuel Consumption per HH

For the conventional automobiles, this study relied upon existing miles-per-gallon data found in the Oak Ridge National Laboratory's Transportation Energy Data Book,[18] which listed an average fuel efficiency of vehicles of 20 mpg.[19] To further benchmark the average efficiency, the authors consulted the Energy Information Administration's Annual Energy Outlook 2010,[20] which listed the fleet fuel economy of light-duty vehicles as 20.9 mpg, based upon tested new vehicle performance.[21] As such, for purposes of this study, an average fuel efficiency for the conventional household vehicle of 20 mpg was used.

18 Oak Ridge National Laboratory. Transportation Energy Data Book, 28th Edition, available at http://www-cta.ornl.gov/data/download28.shtml. (Accessed March 9, 2010)

19 Oak Ridge National Laboratory. Transportation Energy Data Book, 28th Edition, Chapter 4, available at http://www-cta.ornl.gov/data/tedb28/Edition28_Chapter04.pdf. (Accessed March 9, 2010) This figure refers to average fuel efficiency during the time period of 1989-2007.

20 Energy Information Administration (EIA). Annual Energy Outlook 2010 Table A7, available at http://www.eia.doe.gov/oiaf/aeo/pdf/appa.pdf. (Accessed March 9, 2010

21 Additional sources consulted also supported an average vehicle fleet mpg of 20. Based on a December 2009 interview with EPA fuel economy expert Jeff Alston, the Corporate Average Fuel Economy figure is approximately 20 mpg for new cars sold during those same years based on tests of new cars conducted by the Department of Transportation. Finally, the Transportation Statistics Annual Report, published by the Bureau of Transportation Statistics, shows that the average fuel efficiency of cars and other 2-axle vehicles from 1995 through 2006 is 20.5 mpg.

In order to examine the impacts of use of fuel-efficient vehicles on household energy consumption, this study relied on an average based on EPA's SmartWay Elite criteria.[22] The SmartWay program evaluates cars and other products to determine their relative greenhouse gas emissions and air pollution effects. It does so by assigning points along ten-point scales for both Greenhouse Gas and Air Pollution. Cars that qualify as SmartWay "Elite" earn scores of nine or higher and have a fuel efficiency of 32 mpg or better.[23] To create a mpg estimate for the most fuel-efficient cars currently on the road, this paper calculated the mean fuel economy for vehicles that qualified as SmartWay Elite Green Vehicle Guide[24]. As a result, for purposes of this study, an average figure of 37 mpg was used for the fuel-efficient cars in the "green" TOD and CSD scenarios.

Figure 4:
Differences in Formulas Used for CSD v. TOD

Formula Used to Calculate Energy Consumption for Houses in Conventional Suburban Development:

Energy Consumption per HH + [((Avg miles per year per HH * # Autos per house)/ passenger MPG) * BTUs per gallon]

Formula Used to Calculate Energy Consumption for Houses in Transit Oriented Development:

Energy Consumption per HH + [((.55*(Avg miles per year per HH * # Autos per house))/passenger MPG) * BTUs per gallon]+[# of commuters per HH * Commute miles per person per day * BTUs per passenger mile]

To determine total fuel use in all scenarios, miles per gallon figures were multiplied by household VMT. To determine average VMT, this study used data from the 2001 National Household Travel Survey (NHTS)[25]. The average VMT for all personal automobiles (cars, SUVs, and light trucks) was divided by the number of vehicles on the road. The resulting number is an average of annual miles traveled per vehicle per year. This figure was multiplied by 1.9 vehicles per household for the CSD scenarios, which is based on the findings of multiple studies that compare vehicle ownership in TOD versus CSD scenarios in the US[26,27]. For TOD scenarios, 0.9 vehicles per household was used to calculate VMT, based on the same studies that show that vehicle ownership in TODs is lower than CSDs. Annual VMT yielded from these calculations were divided by the average miles per gallon (as noted, 20 mpg for the conventional vehicles and 37 mpg for the "green" vehicles). See Figure 4 for detailed

22 No standard average figure for a "green" or fuel-efficient car currently exists.

23 http://www.epa.gov/greenvehicles/Aboutratings.do#aboutsmartway

24 US Environmental Protection Agency, Smart Way Program. Data gathered from Green Vehicle Guide data found here: http://www.epa.gov/greenvehicles/Index.do;jsessionid=2d577ee00236fed2831cae6d856bf5de5abc29b9f729f5a43bec9bb06b069545. (Accessed on March 9, 2010)

25 At the time of this paper's writing, complete 2009 NHTS data was not available. Only a NHTS Brief had some summarized data, but for the purposes of VMT, complete 2001 data was used.

26 Center for Neighborhood Technology. "Pennywise and Pound Fuelish: New Measures of Housing and + Transportation Affordability", 2010. (http://www.cnt.org/repository/pwpf.pdf, Accessed on June 8, 2010)

27 Ohland, G. and Poticha, S. *Street Smart: Street Cars and Cities in the Twenty-first Century*. Available for order through Reconnecting America (http://www.reconnectingamerica.org). 2006.

explanation of formulas used.

For all vehicle travel, a conversion factor for BTUs per gallon was developed to convert fuel use to BTUs consumed. This study calculated this factor by taking averaging BTUs per gallon for summer and winter conventional gasoline (113,500 BTU) and BTUs per gallon for reformulated gasoline (111,800 BTU).[28] As a result, a conversion factor of 112,650 BTUs per gallon of gasoline consumed by vehicles was used.

For TOD scenarios, transportation-related energy use associated with trips on public transit was also incorporated in order to illustrate the reduction in vehicle energy use when transportation choices are available. TOD residents may likely use public transit to commute to work, for example, but may still utilize automobiles for shorter trips to access public transit, or to reach local destinations within their communities. As cited earlier in the Methodology chapter, an average reduction of 45 percent of CSD vehicle miles traveled was used in calculations for the TOD scenarios.

Given this framework, this study assumes an average of 1.2 commuters per household.[29] This number was used in all TOD scenarios to estimate the number of people traveling daily on public transit. According to the FTA's 2007 National Transit Profile service consumption data, the average distance traveled per day based on two one-way, unlinked trips is approximately 10.4 miles.[30] Therefore, this study utilizes that average trip length to determine the annual passenger miles traveled. Thus, to extrapolate an annual BTU figure in each scenario that includes public transit, 10.4 miles traveled per day was multiplied by the number of commuters (1.2 people per household) and by the conversion factor for BTUs per passenger mile consumed by public transit.

The conversion factor used in this study is 2,184 BTUs per passenger mile. This reflects the fuel mix of public transit. To arrive at this figure, BTUs of energy consumed by public transit[31] was derived from the primary source for national transit data in the United States, the National Transit Database (NTD) of the Federal Transit Administration[32]. The annual fuel used in public transit was converted into BTUs and summed to arrive at the total energy consumed by public transit in the U.S. in 2009. Total energy consumed in BTUs by public transit was then divided by passenger miles traveled on public transit, thus resulting in the 2,184 BTUs per passenger mile conversion factor.

28 Ohland, G. and Poticha, S. Street Smart: Street Cars and Cities in the Twenty-first Century. Available for order through Reconnecting America (http://www.reconnectingamerica.org). 2006.

29 US Department of Transportation (DOT). "Federal Highway Administration's National Summary Statistics", Chapter 1. (Uses data from the U.S. Census in 2000): http://www.fhwa.dot.gov/ctpp/jtw/jtw1.htm. Accessed March 9, 2010.

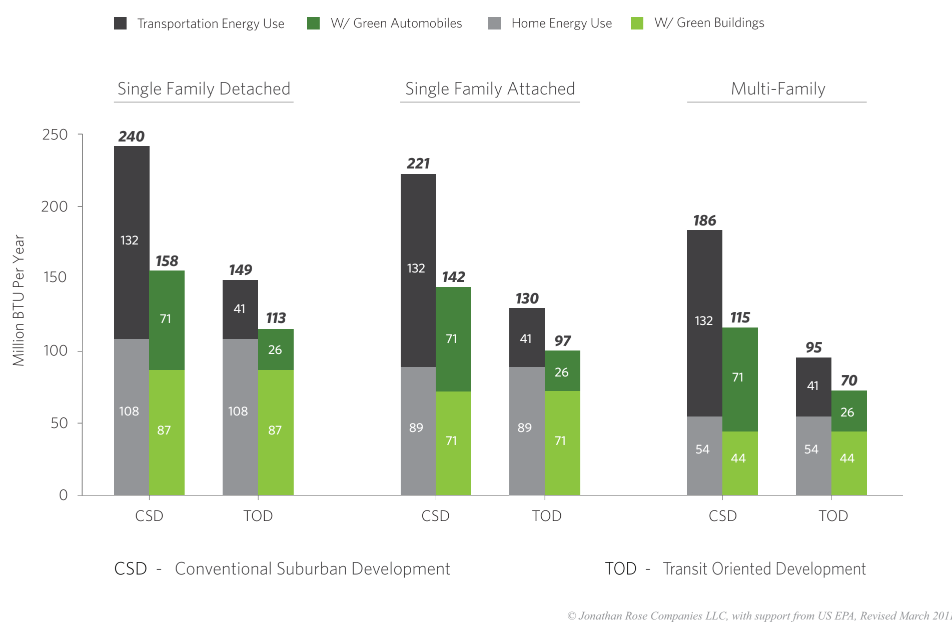
30 http://www.ntdprogram.gov/ntdprogram/

31 "Public transit" includes bus, light rail, heavy rail, monorail, ferry, and trolley.

32 The National Transit Database was selected because it contains national totals of fuel consumed by all forms of public transit in major metro areas across the U.S., including light rail, heavy rail, bus, and ferry. This revised paper (March 2011) uses updated transportation fuel figures from the 2009 database. http://www.apta.com/resources/statistics/Pages/NTDDataTables.aspx (Data Table 17). 2009.

Peer Review

This paper was evaluated by a panel of peer reviewers selected for their expertise in the areas of smart growth, location efficiency, transportation and energy use, housing type and location, planning, and environmental and land use policy. The panel was tasked with examining the accuracy of the data and the soundness of the methodology, assumptions, and analytical approach. The panel also provided insights on how useful this paper and its graph would be for advocacy and policy-and decision-making. Reviewer comments and suggestions on the paper and graph were incorporated to the greatest extent practicable.



Location Efficiency: Household and Transportation Energy Use by Location

III. Results

This paper examined national data to create a graphical representation of the relationship between housing location and type and energy consumption. The results show that household energy consumption associated with housing and transportation decreases significantly in smaller housing types located in compact, transit-oriented development when compared to similar housing types in conventional, largely automobile-dependent communities.

As the bar graph shows, if a household moved from a single–family, detached home in a conventional suburban development (CSD) to a house of the same size in a compact, transit-oriented neighborhood (TOD), its energy use would be reduced by 38 percent. If that home included Energy Star energy efficiency measures and if the residents drove a fuel-efficient car, then the household's total energy use would be reduced by 53 percent compared to the conventional, low-density suburban scenario.

The difference is also marked in the single-family, attached unit scenarios. A household living in a single-family, attached home in a CSD would use 41 percent more energy than one living in the same unit in a transit-accessible site. If that TOD single family attached unit were 20 percent more energy efficient and used only one green car, the household would reap energy savings of 56 percent over the conventional building and location scenario.

The biggest difference is seen when a multifamily home in a low-density development is compared to its transit-oriented counterpart. In that example, the household consumes nearly 50 percent less energy annually, simply by living in a compact location with convenient access to transit. If the multifamily unit incorporated some energy efficiency measures, and if the household drove a fuel-efficient car, then that family would consume 62 percent less energy than a conventional multifamily unit in a low-density development.

Deeper examination of the graph reveals even more interesting results. Conventional, non-"green" TOD households consume less energy (95-149 million BTU per year) than the same units in a CSD (186-240 million BTU per year). Even when comparing the most efficient of the conventional, non-green CSD households (186 million BTUs), they still do not match the least efficient conventional TOD scenarios (149 million BTUs per year).

A CSD single-family detached house uses 91 million more BTUs per year than the same house in a TOD location. The most energy efficient housing scenario studied (70 million BTU for an energy efficient TOD multifamily unit with a green car) consumes less than 30 percent of the total annual BTUs of the least energy efficient housing approach examined in this study (240 million BTU per year for a single-family, detached household in a CSD).

IV. Conclusion

The graph derived from this study illustrates the potentially drastic differences in energy consumption rates when housing development shifts from conventional, low-density development patterns to the more compact, transit-oriented, location efficient development patterns characteristic of many urban neighborhoods. The proximity of housing to transportation options plays a significant role in reducing energy consumption, household costs, and greenhouse gases. Based on this study's results, housing type also plays a substantial role in reducing energy consumption. There are energy efficiencies inherent in multifamily housing and attached single-family housing that do not exist in single-family, detached housing. While energy efficiency measures in homes and vehicles can make a notable improvement in consumption, the impact is considerably less dramatic than the gains possible offered by housing type and location efficiency.

Clearly location and housing type – as well as energy efficiency measures in homes and vehicles – all warrant a place in any discussion about how to develop more sustainably in the future. Such an approach will be motivated by the challenges of climate change, limited natural resources (including both land and energy), and the pressing financial costs associated with housing and transportation. This paper suggests that consideration of both where and how development occurs will better equip communities to address these challenges going forward.

Suggested Further Research

Further research and analysis could compare energy use among households using the same variables (housing type, housing location/transportation choice, and energy efficiency measures for homes and vehicles) at the regional level. Such a study might use data from several regions with large enough peer sets (for example, the Southeast, the Midwest, the Northeast, and so forth) to highlight regional differences associated with energy use, and inform a more robust and detailed national overview. Regional or local organizations may have more region-specific data that could give a more detailed assessment of these location efficiency issues.

Another useful approach could be to include variations in energy sources. For example, further studies could examine scenarios where advanced technology dramatically reduces the carbon footprint of fuels or where electric cars become widely adopted. These and other lifecycle analyses could be more detailed if developed at the regional scale, where subtleties of local development patterns and behavior can be incorporated into the research.

Additional research might also examine different the performance of buildings that go beyond moderate energy efficiency measures, as evidenced by achievement of top ratings in USGBC's LEED, EarthCraft, or NAHB's Green Building certification programs. It is reasonable to assume that with higher levels of energy efficiency measures in place, the relative importance of location efficiency as a part of total household energy consumption may change.

Finally, further research could explore the implications that these household energy savings have for affordability. Future studies could consider the varying prices associated with different types of energy sources most commonly used for home energy use (e.g. coal-based, hydroelectric, wind-powered, nuclear, etc.,) and extrapolate the affordability benefits associated with a more compact, location efficient approach to development.