Are Implementers and Evaluators Missing the Forest for the Trees?[1]

Winning the Battle and Losing the War from Embedded Energy Use and Location

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ABSTRACT

In early energy conservation and energy efficiency efforts, implementers and evaluators focused on delivering and analyzing the effects of individual measures. More recently implementers and evaluators have come to understand that measures are embedded in systems and that by taking into account the interactions among measures, through a whole systems or whole buildings approach, even greater energy savings are possible. Even more recently, regional and national market transformation organizations have broadened their scope by undertaking portfolio analysis to optimize the potential savings.

In this paper, we argue that while it is important to continue to evaluate programs as we have in the past, we also need to expand our focus to a meta-systems or societal level. Solutions leading to energy efficiency are embedded in a context. The goal of this paper is to discuss issues that arise when taking into account the larger societal context and to discuss the need for evaluators to broaden the scope of their thinking and to bring to bear their skills to influence local, regional, national, and international policies to reduce societal energy use.

Our current efficiency efforts may result in more efficient new residential and commercial buildings that reduce the rate of growth in energy consumption. Future efforts may result in net-zero energy buildings. Even with these savings, the geographic placement of such buildings and the nature of designs may result in huge energy expenditures to both construct infrastructure and transport the workforce that uses the building to and from the building. The energy burden imposed by locational decisions may far exceed the energy savings from making a building more efficient. Thus, without analysis of the energy implications of siting and infrastructure development and action to implement more energy efficient policies, we may create a landscape dotted with efficient buildings whose use cause increased use of energy.

The authors provide concrete analytic examples from the commercial building sector showing how the energy use from locational and other policy decisions associated with a commercial building can outweigh the energy to be saved from making commercial buildings more efficient. The authors will briefly review some of the existing work that has been done. They also discuss who else might be interested in these issues.

Introduction

The history of the conservation/energy efficiency movement since the 1970s can probably be characterized by three basic approaches: technology displacement or replacement, whole systems/buildings approaches, and, more recently, portfolio analysis.

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Technology displacement or replacement refers to the addition or substitution of a practice or new technology for an existing practice or technology. The replacement of incandescent lighting with compact fluorescents, the replacement of T-12 lighting with T-8 lighting and electronic ballasts, and the replacement of motors with premium efficiency motors are good examples. A 100-Watt incandescent bulb is replaced with a 27-Watt fluorescent resulting in nominal savings of 73 Watts per hour. Technology substitution has been a staple of the energy efficiency movement from the beginning.

By the late 1980s there was widespread recognition within the field of energy efficiency that while technology replacement produces savings, it often leaves behind significant additional savings that could be harvested. For example, it was increasingly recognized that while older lighting technologies such as FT40 fluorescent tubes and magnetic ballasts could be replaced by more efficient technologies, one-to-one replacement often left a space that was overlit. The lighting design could be changed so that lighting requirements and aesthetics were met through better designs that placed quality lighting where it was needed to meet those requirements. Furthermore, the efficiency community began to recognize the interactive effects between systems and technologies, for example, that efficient design of the building shell, the fenestration system, the use of shading devices, and the use of efficient lighting technologies, reduced the need for air conditioning, which allowed for a resizing of HVAC systems. Increasingly implementers began to think in terms of systems approaches. Thus, for example, we saw the emergence of programs in the early 1990s such as the PG&E Pacific Energy Center (Reed, 1997) and the California Savings by Design Program that attempted to focus attention on whole building concepts. In the industrial arena we began to see a focus on motor systems rather than motor replacement and process redesign and process improvement rather than component replacement programs.

More recently, the energy efficiency community has begun to examine energy efficiency programs in terms of a portfolio approach. In a portfolio approach, one establishes a set of criteria that are used to optimize the selection of efficiency programs. The goal of the portfolio is usually to select a set of programs that produce the most cost effective savings while meeting other requirements, for example, providing some equity with respect to services across the various sectors of society.

The programs and approaches have largely been focused at the system, building, or facility level. Facilities and buildings are components embedded within community, regional, national, and international systems. The location and design of buildings within these systems have implications for energy consumption, just as the interrelation of components in a building or facility has implications for energy consumption. As a result, we need to take into account how buildings generate energy use and consider that in our efforts to design new programs and develop new technologies and concepts to use energy more efficiently. The key point in this paper is that evaluators need to become much more actively engaged in analyzing technology choices and energy policies to assess the intended, unintended, and not yet perceived consequences of such technology choices and energy policies.

Buildings as Part of Larger Systems

Buildings interact with larger systems in at least two ways — through the *energy embedded* in buildings and through the locational context within in which buildings are placed. Both of these have significant potential to affect energy use.

The Embedded Energy Use in Buildings

The embedded energy in buildings is usually considered to be the energy that is required to produce the materials, assemble the materials, and then to actually build the building. It might also be considered to include the energy required for long-term maintenance. For instance, cement production requires the mining of materials, the shipping of materials for processing, the processing of materials, the shipment of materials to users, and then the use of the materials to produce the building or components that are then shipped to the site.

Evaluators and program implementers rarely examine this part of the process. The production and assembly of materials is almost always treated as a given. Perhaps this should not be the case, especially given the potential for improving buildings through the use of manufacturing.

Traditionally buildings have been "stick built" and/or have used pre-cut or partially put together materials that are assembled on site or manufactured and delivered as boxes. "Stick built" homes are produced en-masse or customized for individual buyers and built from materials delivered to the building site, individually cut, and then fashioned into a building. In the 1910s and 1920s, Sears Roebuck Company sold home kits that could be ordered from the catalog. Materials were pre-cut, the parts numbered, and then shipped in bundles to the building sites where they were assembled. Shortly after World War II, there were home kits made from steel but those did not catch on. What were called "mobile homes" and are now called manufactured homes have been around for 40 to 50 years. More recently, production builders have begun using pre-assembled components to speed the production of homes. The kit, manufactured, and production homes are or were typically based on a relatively small number of standard models that were or are "customized" by the addition of elements such as dormers, turrets, and add-on rooms. They were or are further differentiated from one another by the use of different materials for the façade: trim, shutters, paint, and other adornments to give the perception of a customized home.

This is beginning to change, especially in the residential sector where there is increasing interest in component construction. As we noted, the idea of manufactured components is not new. What is new is the increased potential to create fully customized homes made of high quality components that require precision installation at the site. Three dimensional drawing programs, computer-aided engineering programs, computer-aided design packages, and computer-aided manufacturing make it possible to generate high quality designs for unique buildings which are sent to the manufacturing floor electronically where automation is used to produce the components that are assembled at the building site. Technologies that are already in use or about to be used include pre-cast foundation panels, preassembled decking, structural insulated wall panels, pre-assembled interior wall panels, and structural insulated panel roof systems. Pulte (Petersen, 2005), a national homebuilder, now has two factories factories, one in Detroit and another in Northern Virginia, that are beginning to manufacture homes this way. In Sweden and Japan (Levy, 2005), manufacturers have plants where homes are being built in similar ways. We think of Toyota as an automobile manufacturer but in fact in Japan they are a large builder of homes whose components are constructed in sophisticated factories.

While the scale of homes lends itself to componentized construction, designers and builders of commercial buildings are trying the same methods. Kiernan and Timberlake (2004) have described the construction and use of manufactured components in commercial buildings that they have designed. They have also imagined a scenario in which commercial building components are being manufactured by a newly emerging industry and are commonplace by the year 2013.

At the present time, componentized construction makes for a more expensive building, but it is argued that buildings constructed in this way have a number of beneficial characteristics:

- Weather is reduced as factor in construction of such buildings both in terms of delays and in terms of damage to materials onsite.
- Shortages of skilled labor are reduced.

- The quality of the components is much higher than in site-built housing because there are fewer seams and control can be exerted over the assembly.
- The site assembly of such buildings is done to much finer tolerances than is normally the case. For example, the Pulte (Petersen) sets foundations to tolerances of one-quarter inch compared to 2 – 3 inches for site poured foundations.
- The increased quality of the components and the higher tolerances for assembly increase the efficiency. For example, Pulte (Petersen) reports that six-inch walls have an effective R-value of 17 compared to 13 for site constructed homes.
- Manufactured components allow for increased risk management by builders.
- Site assembled manufactured components significantly reduce callbacks. For instance, Pulte (Petersen) claims that callbacks for water problems in basements have been virtually eliminated by using pre-cast panels in contrast to poured foundations where there is a call back for nearly every home.
- Construction waste is reduced.
- There are materials that can be produced in a factory setting that eliminate the need for other materials — for example, pressure formed concrete foundation panels that are stronger, use less material, are less permeable to moisture, and eliminate or reduce the need for foundation coatings to keep out moisture.
- The manufactured components have the potential to be longer lasting thus reducing long-term maintenance costs.
- Manufactured buildings may significantly reduce the on-site labor content and the large amount of travel associated with it. Kieran (2004) reported a research exercise in which the estimated miles travel by the labor force was reduced by several hundred thousand miles.

We would argue that it is important to begin to evaluate the potential of these developments for energy efficiency. If the initial claims hold up, the reduction of the embedded energy in buildings could be significant. Further, buildings built in this way have the potential to reduce operational use of energy use by a significant amount. In recent years, there has been increased awareness that lack of quality construction is an obstacle to increasing energy efficiency. Indeed, Sachs, *et. al.* (2004) suggest that practices are an important frontier for energy efficiency. Current efforts to address commissioning issues are one reflection of this. The use of manufactured components may represent a significant opportunity to bypass much of the issue altogether.

This is a "radical" change for an industry that is reputed for the lack of rapidity with which it embraces new concepts and ideas. There are numerous issues that will need to be addressed. For example, Pulte (Petersen, 2005) has had to work closely with local code officials to gain acceptance for this type of construction. If this innovation is to rapidly take hold, a substantial rethinking of the current structure of building codes and standards may be needed. Current codes that are largely local will have to be standardized and many inspection and enforcement activities will shift from the site to the factory. In the commercial sector, we know that retail stores are refurbished every 7 to 10 years (Reed, *et. al.*, 2004). Manufactured and componentized construction may increase the difficulty of making such changes to existing buildings, so components may need to be designed to accommodate the need for frequent changes.

From an evaluation point of view, what is required is more market evaluation and/or formative policy evaluation. Evaluators need to be less reactive and think more in terms of the future and the nature of energy use in the future. Evaluators should begin to focus on techniques for reducing embedded energy and for constructing buildings in ways that lead to greater efficiency. Such evaluation can steer those making technology and policy choices in directions that can speed the movement of these technologies into the mainstream and perhaps more importantly, avoid choices that will delay or reduce the effectiveness of these technologies.

Building Efficiency Versus Locational Efficiency

Evaluators and program implementers have been most focused on substituting more efficient for less efficient technology and practices either from a component or whole building perspective. The environmental context in which buildings have been built has largely been ignored as an efficiency issue and the effects of building location on energy use have largely not drawn the attention of the energy efficiency community. The issue of locational efficiency has arisen in other disciplines such as planning and transportation. In the transportation arena, there is a growing interest in managing transportation demand, which is analogous to demand side management in the energy efficiency arena. The important drivers in transportation demand research relate to managing demand to mitigate the need for new highway capacity, air quality issues, and energy requirements, usually to the extent that they are related to air quality.

Two recent papers at the ACEEE Summer Study by Burer, *et. al.* (2004) and by Holtzclaw (2004) have drawn attention to this in the energy efficiency arena. The fact that this has not been widely discussed in the energy efficiency community probably reflects the strong orientation of the energy efficiency community to electricity and natural gas and the public goods charge funding that have become a mainstay of support for energy efficiency in the states and regions. What we have failed to see is the seamlessness of the context within which energy efficiency plays.

Building energy use and a building induced transportation energy use comparison. Although the comparison between building energy use and building induced transportation energy use is not easy to make, it is instructive to relate the energy used in a building to the energy use that is generated by its existence. There are numerous problems in making these comparisons including whether to use site or source energy for buildings and transportation, finding data that can be brought to bear in order to make the calculations understandable, and the variability in building use and siting which produces tremendously different results. To illustrate the point and the problems, we worked out a much simplified example for an office building. We assumed that users of the office building are limited to people who work in the building and that the workers traveled the national average distance to and from work.

From the most recent CBECS survey, we found that the site energy consumption per square foot of office space is about 90 kBtus annually. Various office surveys suggest that a workable office density is about 200 square feet per employee. By that standard, the average annual site[2] energy consumption per employee would be about 18 million Btus (90 kBtu/ft^2 multiplied by 200 ft^2). If source energy consumption per square foot is used, then consumption of energy for a worker associated with a building would be about 41 million Btus. CBECS data (1999) suggest that site energy consumption per office worker in US commercial office buildings is about double this estimate at about 38 million Btus annually per worker and that primary energy consumption per worker is about 91 million Btus.

From the *Transportation Energy Data Book* (Davis, 2005), we find that the average American commutes 6,306 miles to and from work annually. If we assume that average fuel economy is 19.66 miles per gallon then the average American worker uses about 321 gallons of gasoline annually going to

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[2] Site energy consumption is the amount of energy used at the site exclusive of generation and line losses. Primary energy consumption is the amount of energy including generation and line losses.

and from work. According to the *Transportation Energy Data Book*, the net energy in a gallon of gas is 115,400 Btus. If that is multiplied by the gallons of gasoline, then the energy used to get to and from work is about 37 million Btus. If the gross energy contained in a gallon of gas (125,000 Btus) is considered, then energy consumed for getting to work is 40 million Btus.[3] Depending on which energy values we use and what assumptions we make about the space allocated to workers, on average building energy use in a commercial office is somewhere between half and twice the transportation energy use required to go to and from the building.

The goal of this back of the envelope exercise is not to produce a precise estimate but to make the point that the transportation demands generated by a building may be on the same order of magnitude or even substantially larger than the energy use associated with the building. Building energy use is relatively fixed but energy use generated as a result of building location can be very large. If an office space is occupied by a doctor, then in addition to the employees, patients might generate an additional 32 trips a day (assuming four visits per hour multiplied by eight hours). A retail space can generate hundreds of trips per day. Depending on the retail shed, the energy use generated by these trips could be very large. Thus, location and accessibility are vitally important in overall energy use.

If we focus on the energy use of a building to the exclusion of energy use generated by the building, then we may win the battle and lose the war. Building a highly efficient new office building might save 30 or more percent of building energy use, but doing so without considering location may more than offset the savings from the building. Building a building on a greenfield, shifting the location of a building by a few miles, locating it near public transportation, or placing it in a more densely populated area can all influence the energy consumption generated by the building.

Sprawl creates energy use. In recent years there has been a great deal of concern about sprawl. As noted by Frumkin (2003), "sprawl is a pattern of urban regional development that features:

- Land-extensive, low density, leap frog development
- Separation of different land uses
- Low connectivity between land uses
- Extensive road construction and automobile dominance
- Economic and racial homogeneity
- Shift of development and capital investment from the inner city to the periphery
- Absence of regional planning"

Much can be said about sprawl. Without belaboring the issue, it is useful to point to two examples. The first is separation of land uses. The recent history of planning is one of separate uses — for example, office parks and housing. In the Washington area, we have office parks that are often strung along transportation arteries. Housing is seldom nearby, or, if it is, it was likely built after the office space. Office parks are designed for automobile and not pedestrian access. Thus, to go to the office means getting into the car. It also means that the office parks are devoid of people outside of business hours. In the most recent history of the Washington DC area, we are beginning to see intensified construction of offices and residences near transportation hubs.

One other example will help to highlight the issue. Price Waterhouse Coopers (PWC, 2001; Sobel, *et. al.* 2001) estimated that between 2001 and 2006, 300 to 400 regional malls nationwide would become economically obsolete and be ripe for redevelopment. These greyfield malls represent about 20 percent of the regional mall population. Some have become aesthetically or architecturally obsolete but

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[3] The gross energy in a gallon of gasoline does not include energy used to distribute the fuel. That could potentially increase the amount of transportation energy.

most are perishing because sales and occupancy rates are significantly below those of "healthy malls." In most instances, the population has moved on leaving these malls to struggle or larger and glitzier malls at some distance have displaced them. Some of the malls will be adapted for reuse (for examples of big box adaptive reuses, see Julie Christensen, 2005) but others will be demolished, perhaps after a period, to make way for alternative uses. The greying of the malls results in urban blight and the fraying of economic vitality centered on the mall. The demolition of malls and the blight that settles in the surrounding area results in the loss of the embedded energy but it also results in a reconfiguration of transportation patterns with the considerable likelihood that travel distances will be increased.

Increasing density: a solution for reducing energy use? Burer, *et. al.* presented a paper at the 2004 ACEEE Summer Study in which they discussed locational efficiency. The paper reviewed the literature on locational efficiency, and then, building on an earlier paper by Holtzclaw (2002), discussed the potential of "smart growth" to reduce energy consumption from vehicles. The early Holtzclaw paper showed that in selected areas of the country, annual vehicle miles traveled per household was inversely tied to the availability of mass transit and the number of households per acre. In other words, annual vehicle miles traveled increases with a decline in the availability of mass transit and a decline in the number of households per residential acre.

Using this and other information[4], Burer, *et. al.* (2004) estimated a business as usual case for selected neighborhoods and then compared this to policy cases where the neighborhood parameters were changed to produce lower demands for driving. The policy options included increasing in-fill, that is, increasing the density in existing neighborhoods. The results of this exercise were extrapolated to housing to be constructed in the US in the next ten years under the assumption that the housing would support the same pattern. Burer *et. al.* (2004), argued that the resulting national accumulated savings from smart growth investments could save nearly 50 billion gallons of gasoline, 44 percent of total US highway usage of gasoline in 2001; 1.18 million barrels of oil, 20 percent of US production of oil in 2002; and 595 metric tons of CO_2 emissions. Their bottom line was that "smart growth" policies rival the effects of current energy efficiency policies in producing energy savings.

Smart growth. Calthorpe and Fulton (2001) argue that the nature of cities is changing and in the era of the global economy they talk about regional cities. They argue that we no longer live in cities as we traditionally think of them, but rather we are citizens "of a region — a large and multifaceted metropolitan area encompassing hundreds of places that we would traditionally think of as distinct and separate 'communities'" (Calthorpe and Fulton, 2001 p. 15). In their view, the sprawl that has drained people from the cities to the suburbs is at an end and the new paradigm of the region is emerging.

Fundamental to their notion of the region is that we are part of a network economy and that economic success depends on access to all kinds of networks, "job networks, money networks, idea networks, and networks of vendors and services" (Calthorpe and Fulton, 2001. p.19). It is at the regional level that there is sufficient diversity so that networks can be sustained. Further, it is clusters of geographically based groups of businesses and industries that fix a place for a region in the global economy. Thus, for example there is Silicon Valley (computers), Washington, DC (government, biotechnology, and the Internet), and Boston (biotechnology and computers).

According to Calthorpe and Fulkerson, planning now must be done at a regional level. Regions are constructed of neighborhoods, hierarchies of centers, districts, preserves, and corridors. Even in the age of the Internet and networked communities, proximity is extremely important. To quote, "regions

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[4] US average for personal income, an assumed average household occupancy, pedestrian friendliness in average US infill and greenfield smart growth and sprawl developments.

need a balance between their communities of interest and communities of place" (Calthorpe and Fulton, 2001. p. 35). It is the neighborhoods that foster and foment interpersonal relations.

Viable regions are made up of neighborhoods that are connected to the equivalents of *village centers* that serve areas with a radius of a mile or more and five to ten thousand homes. Neighborhoods need to be highly walkable. There are *town centers* that are larger and more varied than the village centers that include a large number of offices and employment. There are also the *urban centers* with offices, cultural resources, and other amenities. In the Calthorpe scheme, the centers are interconnected by transit following corridors. *Districts* deal with special uses such as warehousing or colleges and universities. They argue that offices and certain other uses should no longer be constructed in parks away from village, town and urban centers.

Calthorpe's work is much too rich to be captured in these few paragraphs. A key point is the need for walkability. He argues that creating alternatives to the car is not just a matter of household income or density as might be implied from the preceding discussion. It is a matter of planning that increases the frequency of street intersections and direct paths, of creating greater densities of jobs in neighborhoods and centers, and of making the transit interconnections. Transportation planners tend to assume that density is the single requirement for transit, but Calthorpe points out that the centers with mixed uses are important as well. If you use mass transit, you have to get somewhere once you have used transit. If that requires a difficult transition to another form of transportation, people are unlikely to use transit. The success of transit increases with the directness and ease with which one can move from transit to one's destination. Calthorpe cites a Seattle study that shows that when walkability and density combine, there is less auto use, even though the average number of trips remains the same.

While there are many points to take away from Calthorpe, there are probably two key points with respect to energy efficiency. The first is the importance of planning. Planning must be done at the regional scale with macro designs done in such a way that they foster micro designs (that cannot be designed at the regional scale) for walkable neighborhoods that are interconnected by transit. The trick is not just one of creating density, but of creating mixed uses at centers that provide retail, service, and office uses and make centers destinations. Calthorpe does not advocate a complete mixing of uses. He notes, for example, that industrial and warehousing functions need to be separated in what he call districts. He also points out the big box stores are like warehousing and perhaps need to be co-located with each other and separated from other uses. To be avoided are designs that create density without mixed uses such as office parks and amenities and areas that inhibit walkability.

Maryland is promoting infill through its Smart Growth initiative. As a result, infill is occurring and in the Maryland suburbs of Washington there is rapidly increasing density around Metro transit stations. What is not clear is whether these developments are being done in such a way as to create the neighborhoods and the walkability that will generate the reduced energy use associated with automobiles.

Rather, these newly dense neighborhoods may succeed in increasing congestion. For example, some new neighborhoods are being built in greenfield areas within the built-up environment (infill). However, in many instances these neighborhoods are "self-contained" (Giles-Corti, 2005). One to two hundred houses will have a single outlet to the larger community and no connection to the next immediately adjacent community. There are situations where if you could take a direct path, you could reach a neighbor 50 yards away. Instead, one must travel the streets and sidewalks, if these exist, and the distance becomes a mile or more. It is not uncommon to go from the back of a development to a single entrance, traverse a primary street for 100 yards, enter the single entrance to the next development and then drive to the back of the development to a house 50 yards from where one started. It is not unusual to see parents in two developments 50 yards apart, loading the kids into the car to take them to the next development for a play date or to go to the same soccer game. Indeed, children now have identities that are tied to the development in which they live.

A question has been raised about whether self-contained neighborhoods provide for or promote other values such as security or increased familiarity of families living in such neighborhoods. As Giles-Corti (2005) notes walkable neighborhoods with interconnected street patterns encourage walking and that walkable neighborhoods tend to be safer neighborhoods. Proponents of urban redesign also place heavy emphasis on making available footpaths and bike paths. Much more work is needed with respect to the relationship of physical design of neighborhoods and the benefits associated with different design schemes.

This leads us back to one of the basic themes of this paper. We can build efficient homes, but these homes are embedded in a cultural environment, a system, and the design of the environment or system can either minimize energy use or increase it. The point is that we must understand the types of plans and designs for neighborhoods, village centers, town centers, urban centers, that help to achieve reductions and understand the implications of designs that lead away from energy efficiency. As evaluators of energy efficiency, it is important to broaden our focus from the building to include the design of the larger environment and its effect on energy use.

The interaction of energy efficient buildings and energy efficiency land use. There is another issue that falls out of this work. The US Department of Energy and others are busy trying to develop designs and technologies that will increase the efficiency of buildings. An announced goal is to develop zero energy homes, that is, homes that produce enough energy to offset the energy they use. There has been some discussion of the possibility and potential of zero energy commercial buildings as well. If through planning we attempt to reduce energy use by increasing density, we might want to ask how that might interact with the goal of developing zero energy buildings.

Shea Homes (Farhar, 2004; Coburn, 2004) has built a subdivision of "low," as opposed to zero, energy homes in San Diego. Shea incorporated active solar technology into many of the homes so that the energy generated on site met some portion of household energy needs.[5] These are single family residences on small lots. As one might anticipate, it was not possible to physically orient every home in the subdivision so that onsite generation would be cost effective. Therefore some homes do not have solar technology because it is not cost effective.[6] The experiment suggests that the combination of improved building and appliance efficiency, as well as renewable technologies, might allow many homes of the future to reach the goal of zero energy. Indeed, this eventuality is predicted to occur within the next year or two (Sachs, *et. al.*, 2005). This experiment also illustrates the fact that not every home can be a zero energy home within the limitations of existing technologies although homes can be low energy homes.

The placement of dwellings on small lots is certainly consistent with Smart Growth principles. At the same time, smart growth will require housing at much greater densities than placing housing on small lots. The question is whether zero energy designs will work for homes at much higher densities. If we take seriously the idea that increased density can be used to reduce energy use, then it is clear that a great deal of housing will be located in multi-story buildings with relatively small footprints. The small footprints will limit the generation potential from solar energy. Thus, at least for the foreseeable future, the design of such buildings is likely to significantly limit the potential to make dwelling units in

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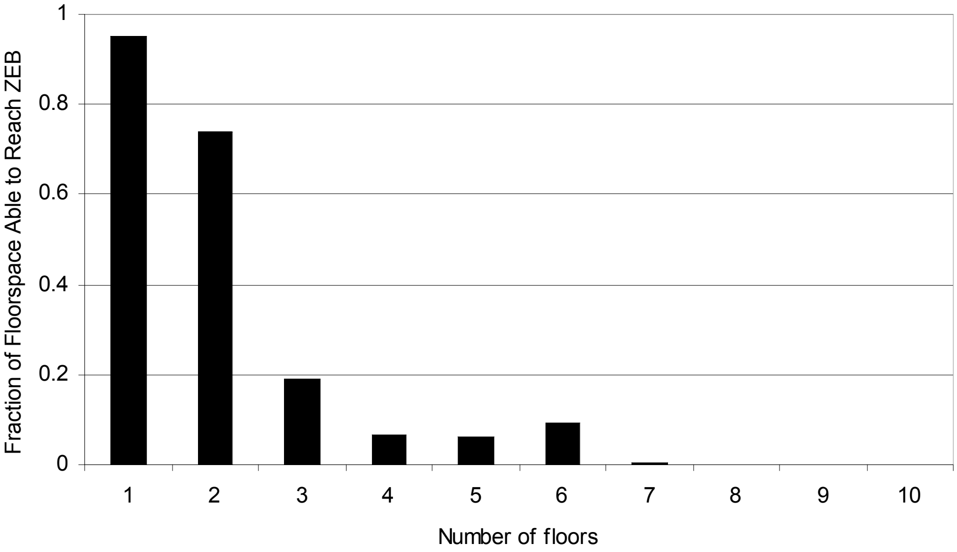
[5] "The SheaHomes at Scripps Highlands are . . . 38% more energy efficient than the strict California Title 24 guideline, and 293 of the 306 homes have solar water heaters. In addition, 120 of the homes have solar electric (photovoltaic, or PV) systems interconnected with the utility grid (thus, GPV systems)."

[6] There are also homes in the subdivision where the builder chose not to incorporate the renewable energy feature.

those buildings zero energy homes. This suggests the need for research on how to capture or to capture and reuse energy in dense urban environments.

DOE also has an effort underway to examine the potential to optimize commercial buildings to reduce their energy use while maximizing their potential to produce energy and thus reduce energy use of buildings from external sources. Based on the availability of current technology and simulations of retail buildings, there appear to be significant limitations on the types of commercial buildings that have the potential to be zero energy commercial buildings. Presently, it is projected that one could build a net zero 20,000 square foot single story commercial office building in Chicago. In order to reach this goal the form of the building had to be changed from a two story to a single story building (Griffith, *et. al.*, 2005).

A recent analysis of the potential for commercial building floor space by the National Renewable Energy Laboratory (Torcellini, personal communication, 2005) shows that the fraction of floorspace that has the potential for being in a zero energy building declines rapidly from 95 to 74 to 19 percent as the number of floors increases. The major factors are the daylight space and the roof area available for photovoltaics.



Source: Paul Torcellini, personal communication, June 2005.

Figure 1. Estimate of the Available Fraction of Floorspace That Has the Potential to Reach Zero Energy Use

With taller buildings, buildings with different footprints, and commercial buildings other than retail, the potential for a net zero energy commercial building may be diminished considerably. Retail and warehouse buildings have potential for being zero energy buildings because they tend to have low internal end-use intensities, tend to be single story buildings where it is possible to take advantage of skylighting or tubular daylighting devices, and tend to have footprints that would allow the introduction of solar technologies. On the other hand, the bulk of the space in new office structures (Reed, *et. al.*, 2004) tends to be multi-story, has relatively high internal end-use loads, and has footprints that make the use of daylighting and solar technologies difficult.

Thus, it appears that we have conflicting trends. On the one hand, we have movement toward more efficient buildings that incorporate renewable energy technologies. In the residential sector, the zero energy home on a small lot meshes well with the American cultural ideal and is potentially quite attractive to consumers. In commercial areas, single story buildings with relatively low internal end uses provide opportunities for zero-energy building.

On the other hand, there is the drive to limit energy use through “smart growth” by encouraging mixed uses and the intensification of density especially with higher rise buildings that may include retail, office, and residential. Our data suggest that the marriage of these two trends will require substantial research to understand how best to design low energy and zero energy buildings and how to do the planning, site design, and integration of use functions so that we can achieve low energy buildings and low energy use environments. At the present time, there is very little of this type of work being done. We also note that technological advances that reduce energy use or increase the potential for distributed generation may also increase the degree to which zero energy buildings are possible (Laitner and Brown, 2005).

Cultural Changes Leading to Other Forms of Energy Use

One of the points that we want to make in this paper is that cultural change can and does lead to changes in energy use. As evaluators, researchers and analysts, we need to be constantly alert to such changes and the effect they can have on energy use. There is not space for an in-depth examination of this issue. However, we can point to one or two examples to demonstrate the implications of cultural trends.

As Reed, et. al, (2004) have pointed out elsewhere, significant changes are underway in the food services industry. In 2002 the typical person (age eight and older) consumed an average of 4.2 meals per week or 218 meals annually away from home (Ebbin, 2000). The average household spent $2,127 per household away from home in 2000 (Ebbin, 2002a). The rate at which the members of households are “eating out” is increasing.

Likewise, there is increasing use of “takeout.” Takeout includes customers who pick up or take delivery of products. It is estimated that by 2007 takeout sales will be nearly a $200 billion a year industry and that between 1997 and 2007 the growth of takeout will be triple that of the growth of on-site sales (Oetzel, 1999). Quick serve restaurants are finding that take-out is an increasing portion of their business and that takeout now accounts for well over half (62 percent in 1997) of their business (Ebbin, 2002b).

Now it is not at all clear what the energy trade-offs may be. The trend toward eating out and take out probably reduces the amount of energy associated with obtaining, preparing, and cleaning up after home prepared meals. It is not clear whether food service establishments may use more or less energy to prepare foods than would be used to prepare the equivalent meals at home and how that might be affected by the continuous operation of cooking processes in food service establishments. Also, it is not clear how the number and length of vehicle trips may change. Intuition suggests that eating out and using take out may increase the number of trips but the length of trips may be reduced. In the preceding sections we discussed increased density and mixed uses. In a highly dense mixed use environment that includes restaurants, increased energy use from transporting meals might be minimized.

In addition, we should note that there are often wait times associated with takeout use. It is not uncommon to see lines of cars at take-out windows at peak hours. There is energy use and emissions associated with waiting. If we assume, for purposes of illustration, that there is an average of seven cars idling at a take-out window at peak hours and that peak hours occur three times a day for an hour and a half, that is the equivalent of 31.5 hours of car idling time. At 0.8 gallons of gasoline per idling hour, that represents 25.2 gallons of gasoline or about 3 million Btus energy consumption per day.[7]

Now, the point of this brief discussion about changing cultural patterns for dining in the US is not a rant about the evils of change. The forces of cultural change are not easily deflected. However, there may be things that can be done to mitigate the effects of change.

From the perspective of managers at a quick serve restaurant, long lines at takeout windows are a problem. The pressure to keep the line moving results in workers making mistakes, which in turn increases the wait. Some managers are beginning to experiment with call aheads to 800 numbers from cell phones, the use of credit cards. and having callers with picture phones send a picture so that the server at the window can visually identify the caller based on a picture on the bag. Such organizational innovation may also have the benefit of reducing the wait times and the energy use and associated emissions.

The point to take away from this discussion is that we need to constantly be examining patterns of cultural change in terms of their implications for energy use. Based on research and evaluation, we may be able to identify strategies that will mitigate the most negative environmental effects of such changes.

Collaboration

The types of issues that we have raised in this paper might appear to be overwhelming. However, we are not alone in our concerns. What we need to do is to look more broadly in the larger community to find allies whose concerns mesh well with our own. We have already noted that urban and transportation planners have agendas that mesh well with the energy efficiency issue (Calthorpe, 2001). There are others as well. The heath community is increasingly concerned with the issues of sprawl, smart growth, and community planning (University of Cincinnati, 2003; National Institute of Environmental Health Sciences, 2004; Giles-Corti, 2005) and the linkages of these to obesity, asthma, and a long list of other health problems. The Environmental Protection Agency is concerned about this issue and the California Energy Commission is beginning to examine the issue of energy efficient community design. Some architects and engineers are beginning to recognize the need for new building materials and new ways of fabricating buildings (Kieran and Timberlake, 2004).

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[7] Fuel idling rates (DeCicco) are roughly proportional to engine size, about 0.13 gallons/second/liter of engine size. Table 7 of the 2004 SAE mass paper has idling emission rates for the Taurus at about 0.461 gallons/second. For an average Taurus-like car, the fuel consumption associated with vehicle stop, during City/Hwy ("CAFÉ") cycle is about 6 percent. However, this is mainly associated with traffic-light/stop signs, this may not be representative of "real-world" vehicle idling. (Feng)

Let's assume the average car on the road is 6 years old. From Table 4 of the 2004 EPA report, the 1997 statistic, for average LDV, of 199 CID, or 3.3. L (61 in3/L). Using 0.13 g/s/l for idling, this implies an average fuel use rate of 0.53 g/s. Gasoline weighs 2.8 kg/gal, so that works out to 0.54 gal/hour of idle time. Idling energy use is higher with accessory use, such as AC in the summer and defrosters in the winter, lights at night, radio etc. Let's assume an additional accessory load of 2 KW half the time, (AC in particular is a big load), or 1 KW on average, and convert to gallons by assuming the engine is 10 percent efficient at near idle (accessory only) loads, implying an additional hourly energy input of 10 kWh. Using the LHV of gasoline (113 kBtu/gal = 33 kWh/gal) implies another 0.3 gal/h. So that pushes the total up to about 0.8 gal/hour (Davis 2005) Typical regular unleaded gasoline contains 114,100 BTUs per gallon, (Davis, 2005) or 91,280 BTUs per hour for idling .

Summary and Conclusions

The main theme of this paper is that the energy efficiency implementer and evaluation communities need to refocus some of their efforts on the broader context of energy use. Implementers and evaluators now mostly focus on the energy use of buildings, but more attention is needed to the energy embedded in buildings. With the increasing sophistication of 3-D rendering, computer aided engineering, computer aided manufacturing, and the ability to exchange data, interest is increasing in the manufacture of mass customized buildings. Manufactured mass customized buildings would offer consumers an infinite number of design possibilities, potentially reduce the embedded energy in buildings, increase the quality of buildings, and improve their efficiency as well.

The move to manufactured mass customized buildings is a significant energy efficiency innovation. There are of course numerous issues and questions. Will mass customized building deliver on the promise of reducing embedded energy and long term energy costs? Mass customization is still in its infancy, and as yet, there has been little focus on the potential for delivering manufactured mass customized buildings with preinstalled electrical, plumbing, HVAC systems, and appliances. These have the potential to significantly address quality issues that are now not dealt with or are dealt with through commissioning. Additionally, there are questions of how such mass customized building systems would displace or integrate with existing building systems and culture including the trades, local code enforcement, union workforces, and other issues.

We have also argued that it is important to understand the context within which buildings are placed and the effects that placement has on energy use. The energy efficiency community has largely ignored locational issues. As we have tried to show, choices about the placement of buildings may amplify energy use many times. Other disciplines such as regional planners, transportation planners, and the health community are already addressing the issue of sprawl. Discussions of smart growth, which is often touted as an approach to mitigating the problems of sprawl, almost always make mention of energy efficiency as a benefit but seldom quantify the benefits. Smart growth strategies typically promote higher density development but do not necessarily address more fundamental design issues. From the standpoint of energy efficiency, high-density developments may not be entirely compatible with current strategies that focus on zero energy buildings. This needs further exploration. There may be potential within high density buildings to reuse heat generated from energy use, and it may be worthwhile to examine the potential for developing systems analogous to the district heating systems of old that could capture waste energy for reuse. It might even be possible to monitor, buy, and sell such heat flows.

Lastly, in this paper we call out the need to pay attention to cultural trends that may significantly influence energy use. While it is unlikely that cultural change can be directed, it may be possible to mitigate the negative energy aspects of such trends or to utilize such trends to capture energy efficiency benefits.

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