Zeroing in on Net-Zero Buildings: Can We Get There?
How Will We Know When We Have Arrived?

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ABSTRACT

The objective of this paper is to encourage dialogue about and scrutiny of definitions of net-zero energy and their relationship to specific environmental outcomes.

The goal of net-zero energy buildings has gained astonishing momentum over the past few years, and for good reason. The operation and construction of buildings account for 39% of greenhouse gas emissions in the United States (Stern 2007) and comparable fractions in virtually all other developed countries.

The Intergovernmental Panel on Climate Change (IPCC) goals require overall U.S. emissions to drop by 80% before 2050. Given buildings' considerable share of overall emissions, reaching or approaching net-zero energy use in buildings is imperative.

However, there is neither consensus on the definition of zero energy, nor an adopted understanding of where to draw the boundaries of a "building" for the purposes of energy analysis. Furthermore, there is no agreement on what sources of energy (construction, operations, transportation, etc.) should be considered in the "net energy" equation.

Merely setting a goal of net-zero energy does not provide the policy means for achieving it. Different actors may control different aspects of building energy use which could create multiple layers of "zero."

This paper addresses these issues, and notes how a failure to evaluate building energy use comprehensively could frustrate progress towards the ultimate goal of approaching zero emissions.

It is vital to examine the policy basis behind both the definition and the scope of the goal. Our broad definition provides a meaningful metric of efficacy for meeting climate goals.

The Importance of a Net-Zero-Energy Building Goal

The United Nation's Framework Convention on Climate Change (UNFCCC) commits the world to "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" (UNFCCC 1992). In 1992, the United States (under President George H.W. Bush) signed this agreement, which according to the Intergovernmental Panel on Climate Change's (IPCC) most recent analysis will require stabilizing global concentrations of CO_2 at 450 ppm (Stern 2007). It is widely accepted that the United States must reduce its emissions to 80% of current emissions by the year 2050 to achieve its fair share of the global savings goal and mitigate climate catastrophe. This effort will require major reductions in emissions-causing energy use in all sectors.

The building sector is arguably the largest sector of U.S. energy consumption, accounting for 39% of total primary energy use and 75% of electricity use (Lave et al. 2009). This energy use accounts for an almost commensurate level of American greenhouse gas emissions (slightly lower because a small fraction of greenhouse gas emissions come from gases other than CO_2).[1] A quick glance at these numbers indicates that without reductions of 80% or greater in the energy demand from buildings, climate goals will be unachievable at any reasonable cost. Even if the numbers were not as stark, the percentage reduction goal for buildings should still be higher because significant reductions in the building sector from identified energy efficiency measures are already available and cost effective. An investment of $440 billion in available energy efficiency measures can produce an annual savings of $170 billion, or a projected savings whose present value exceeds $1.5 trillion (Lave 2009, 46). This dramatically favorable cost/benefit-ratio is generally higher than that found for most other sectors and much higher than other emissions abatement opportunities, justifying a greater-than-80% savings responsibility for the building sector in order to meet the IPCC goal.

Although the work of Ed Mazria and others pioneered the concepts of low- and net-zero energy buildings within the private sector late last century, zero-net energy (ZNE) buildings have only recently received increasing public policy attention. In August of 2008, as a result of the Energy Independence and Security Act of 2007, the Department of Energy launched the Zero Net Energy Commercial Buildings Initiative. The Department of Energy adopted goals for all new commercial buildings to be ZNE by 2030, half of all commercial buildings by 2040, and all commercial buildings by 2050. The Zero Energy Commercial Buildings Consortium[2] was formed in 2009, allowing organizations like the American Society of Heating, Refrigeration, Air Conditioning Engineers (ASHRAE) and the US Green Building Council (USGBC) to adopt the same goals. In 2008, the California Public Utilities Commission and California Energy Commission adopted the goal to have all new residential construction in California be net-zero by 2020, and all new commercial construction by 2030.

The increasing awareness and adoption of net-zero goals raises the issue of definition to a more prominent position. Various implications of the definition of “zero energy” were analyzed by National Renewable Energy Laboratory and the Department of Energy in 2006 (Torcellini et al. 2006). They considered a site, source, cost, or emissions basis for zero (which we discuss in detail below) and the implications of those bases for fuel source choice, renewable energy generation size determinations, and the need for more appropriate site-to-source conversions and emissions factors.

Energy use from operations accounts for an overwhelming percentage of total building energy use in traditional building designs, rendering energy considerations from other aspects of a building insignificant from a policy perspective. Indeed, the amount of emissions from activities such as construction, maintenance, and landscaping can hover around 10% of the total impact of the building (Commonwealth of Australia 2008, 136). However as utility energy moves to zero, these other sources assume a greater and greater percentage of the remaining energy use. A broad body of research documents embodied energy’s share of total energy, ranging from 45 to 67 percent when utility energy approaches zero (Yohanis & Norton 2002; Thormark 2006; McIlwain & McIlwain 2007). To achieve net-zero, then, requires a holistic approach that should consider not only utility use, but also construction, process, and transportation energy (as will be discussed later).

For example, the energy to construct a building is typically assumed to be 10%, or at most 20%, of the energy consumed in annual operation. The range of uncertainty is large

[1] The ratio of fossil fuel combustion to GHG emissions is over 80%; much of the rest is a consequence of industrial processes that also produce CO2, and could also be reduced through efficiency (EPA 2010).
[2] Zero Energy Commercial Buildings Consortium. 2010 http://zeroenergycbc.org

because the data required for an accurate calculation for a broad range of materials and processes has never been available. Consider wood: the energy used to produce, cut, and ship framing lumber will depend on the forestry practices of the supplier, how far the lumber is shipped and by what means. Another example is water. Particularly in some jurisdictions, such as California, the energy needed to supply water for interior uses and landscaping, and the energy needed to process wastewater, will become more significant as energy use within the building itself drops. These kinds of Life Cycle Assessment (LCA) approaches are an important aspect of the net-zero question and should be pursued and developed further to allow for building-specific estimates and to reduce uncertainties.

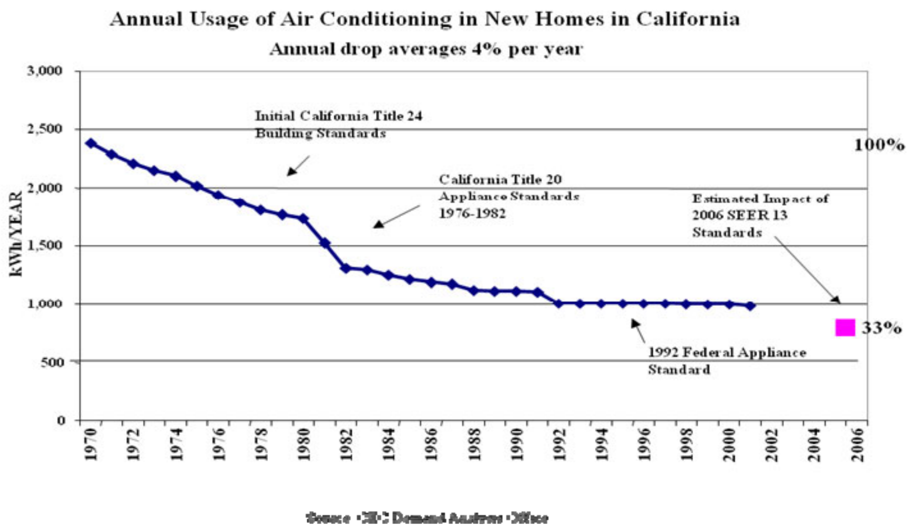
Hernandez and Kenny (2010) suggest the addition of embodied energy to the determination of net-zero energy. They discuss the application of the "net energy" concept to the building sector over the last century and note the development of exergy, emergy, and Life Cycle Assessment methodologies that may inform the usability of net-zero energy criteria. They suggest adding embodied energy to source energy (primary energy) to create the concept of "life cycle zero energy buildings" while noting the weaknesses of source energy determination in agreement with Torcellini. This clearly is an improvement, although Hernandez and Kenny do not discuss an important, largely ignored, aspect of building energy use: transportation.

Research over the past 20 years has shown with increasing clarity how the location of buildings within neighborhoods and urban infrastructure determines the amount of driving required by residents, employees, guests, suppliers and customers (Ewing et al. 2008). If policies to promote net-zero-net energy *inside* the building ignore the unavoidable energy use of getting to and from the building, they will fail to meet our climate goals.

How Can We Get There?

Jurisdictions that have made a substantial effort to approach net-zero-energy buildings, whether as a conscious policy goal, or simply as a consequence of promoting cost-effective energy efficiency, have shown that dramatic progress is possible. Figure 1 shows the two-thirds reduction in cooling energy in a new home constructed in California over a 30+ year period. This is a particularly dramatic result, given that the average size of a new single family home increased 45% between 1973 and 2008. Similar (probably slightly better) results were achieved in heating. Indeed, if California had proposed a net-zero energy goal for heating and cooling in 1975 when the Energy Commission was established, the state would be more than two-thirds of the way there by now.

We see similar progress in other end uses on which policy attention has been trained: refrigerators, for example, showed a reduction in energy use of over three-quarters (for the same feature and size level) from the mid-1970's to 2008. In a newly opened rulemaking, the Department of Energy has found further efficiency potential for refrigerators of up to 45 percent (DOE 2009). These results were primarily due to equipment efficiency standards and building energy codes, but recently, incentives have also been introduced to support energy efficiency in the United States. A tax credit adopted in 2005 for new homes that cut 50% of heating and cooling energy leveraged an increase in the market share of this segment from well below 0.1 percent before the program began to 10% in 2009 (Baden 2010). Savings beyond this level, both for commercial and residential buildings, can be achieved by integrated designs that incorporate the heating, ventilation and air conditioning systems in a coordinated way with potential reductions in interior energy uses such as lighting, information technology, and food preparation/storage, as well as integration of daylighting into the design of all the remaining systems.



In Europe the “Passivhaus” design concept produces buildings that reduce heating and cooling by 80%-90% and 21,000 homes meet the specifications (Lang 2009). For commercial buildings, a large number of sources summarized in the National Academy of Sciences report “Real Prospects for Energy Efficiency in the United States” describe technologies just over the horizon of commercial availability that can make substantial reductions in energy use. The New Buildings Institute (NBI) describes buildings that have achieved 50% reductions (NBI 2010).

Yet economic progress in virtually all products, not just those that are efficiency-related, tends to come incrementally (Goldstein 2010). For example, consider a product in which technology change has been the most rapid: the personal computer. Computers were not invented for modern commercial application; they were developed for very limited scientific research goals and adapted incrementally over some five decades before they became a significant commercial product. Even after that, improvements in performance, while remarkably dramatic, have come incrementally. The specific methods and technologies for this improvement have not been predictable many years in advance; instead, the focus has been on what works in the next generation of products. For maximum effectiveness in transforming markets, we should design policies around accelerating trends to incremental improvement.

There is ample and well-documented information available about how to design buildings which save about 30% as compared with current use.[3] Much less information is available on how to construct buildings which achieve 50% in savings. Despite the fact that many of the designers who have worked on 50%-savings buildings agree that such buildings can be constructed with no increase at all in first costs, this fact has not be documented from peer-reviewed studies (Goldstein 2008). The only data available are anecdotal: case studies for particular buildings or particular projects, with too many outstanding questions about universality and broader cost effectiveness. Nonetheless, this lack of firm data is not an

[3] For example, see the following from New Building Institute, White Salmon, WA: Advanced Energy Code proposals to the IECC at http://www.newbuildings.org/codes-policy/energy-codes. & “Core Performance Guide” 2007, http://www.advancedbuildings.net/corePerf.htm.

insurmountable obstacle because policies to reduce energy use in buildings are incremental in the same way as most technological progress. As jurisdictions develop policies designed to reach net-zero-energy buildings, we see how they can be regularly adjusted to move in the direction of the goal. These policy options, which work best when considered in parallel, are:

- **Building energy codes**. States have a variety of Building Code revision schedules. Residential standards by both the International Codes Council (ICC) and the California Energy Commission (CEC) are regularly updated every three years. ASHRAE is on a slightly slower schedule for updating commercial building standards but also anticipates regular updates. The critical policy decision in each update is the stringency of the updated standard. A net-zero-energy goal can encourage larger savings in each upgrade cycle.
- **Normative or recommendation labels** (such as Energy Star and LEED certification). As codes increase in stringency, normative labels should increase their standards: a normative standard that can be met by all products has no use in the marketplace. Normative labels provide a distinct goal for groups that desire a simple but meaningful benchmark for their projects. A progressively more stringent normative system could help drive the market towards zero.
- **Informative labels**. The RESNET rating system (referred to as to the Department of Energy's Builders Challenge e-scale) identifies typical practice circa 2004 as a level of 100 and a net-zero-energy building as zero. Potential movement towards this approach in commercial buildings is being refined through the emerging COMNET guidance for modeling commercial building energy consumption.[4] Both are well-suited to measure progress towards net-zero-net energy and chart successes along the way.
- **Managed incentives.** These incentives, which are managed by utilities, state agencies, or other organizations authorized to acquire efficiency resources, are typically based on saving some fraction compared to codes or compared to previous consumption, so they will almost automatically update to push higher levels of performance. This drives the more aggressive portion of the buildings market in the right direction.
- **Long-Term incentives**. Incentives intended to transform markets can be set at very high levels, even levels we think are incapable of being met. As of this writing, the highest such goal for residential buildings is a Builders Challenge score of 50 (half way to zero, including the appliances, lighting, etc.);[5] these can be adjusted every few years based on progress in the market. These are important incentives to keep pushing the cutting edge while experimental practices become refined for mainstream use.

These policies are all very simple and straightforward in concept. But what is not so clear in the discussions in the U.S. Congress and in other policy making forums around the world is the need to develop and implement them as a comprehensive market transformation strategy. Each policy addresses a different part of a market adoption curve, and the pervasiveness of market failures requires that there be interventions all along the curve in order to facilitate a movement as dramatic as meeting a zero energy goal (Goldstein 2007).

[4] See Institute for Market Transformation. 2010. http://imt.org/coment.html. Washington DC.
[5] An example is S. 1637: "Expanding Building Efficiency Incentives Act of 2009," introduced by Senators Snowe (R-ME), Bingaman (D-NM) and Feinstein (D-CA).

What Is Net-Zero and Why Are Differences Important?

Achieving any goal requires that we understand how to measure success. A careless definition will lead to buildings that may meet the goal as defined, but fail to meet underlying societal goals, such as reducing greenhouse gasses or minimizing costs. As we will show, there are several dangers of "sub-optimization"[6] inherent in definitions of net-zero-energy buildings in which more progress towards the goal as defined leads to less progress towards the societal goals. These problems all revolve around where we decide to draw the system boundaries. There are key questions to ask that must inform the determination of the definition.

What Energy Uses To Consider?

Traditionally, we define percent energy savings in terms of heating and cooling only or heating, cooling, hot water and lighting energy, ignoring other uses such as landscaping and process water, construction-related energy or transportation. The traditional definition is a logical stepping stone towards net-zero, but will not address many of the important issues needed to meet emissions reductions goals. For example, in American residential buildings, about half of emissions result from uses other than heating and cooling (EIA 2005).

This presents only minor policy problems–there are only a few cases where trying to reduce space-regulated energy can be facilitated by increasing non-regulated energy. But for the cases that follow, drawing boundaries too narrowly results in larger and more widespread problems.

How Do We Count the Energy Uses We Consider?

Torcellini et al. analyzed some of the potential impacts of this decision.

- Net-zero energy at the site or **"site energy"** could be the metric. Energy use from different sources (such as electricity and natural gas) is conflated into a single parameter, and the energy use of electricity is converted at its resistance heat equivalent of 3413 Btus/kWh. This metric considers one energy unit of electricity, which is a low entropy form of energy capable of producing much more than an energy unit of a fuel, and which typically requires the combustion of fuels at about 33% net efficiency, as equal to one unit of energy content of a fuel. But the problem of sub-optimization quickly arises: the easiest way to reduce site energy is to substitute electricity for natural gas or oil, a substitution which actually takes society farther from the goal of reducing emissions rather than closer to it. For example, a "site energy" calculation would lead a homeowner to use an electric stove rather than a gas stove, since the site energy contribution of an electric stove is smaller. However, on the margin, an electric stove is responsible for more primary energy and pollution emissions than a gas stove, and the net-zero user of a gas stove could have been able to sell electricity back to the grid. Instead the home merely achieves net-zero. This question of sub-optimization was one of the primary reasons the National Academy of Sciences recently recommended that DOE begin

[6] Sub-optimization means optimizing the performance of a subsystem of a more complicated system in ways that take the larger system farther away from optimal performance.

moving away from site-based analysis and towards full-fuel cycle, or a source-basis, for measuring energy use and environmental impact (NRC 2009).

- **Source net-zero** is also a possibility. This definition looks at energy use at the power plant or fuel source. If the goal is to produce net-zero impacts on society's energy resources, this metric clearly is better than site energy. This is the metric selected by Hernandez and Kenny from the perspective of ecological economics and Life Cycle Assessment. This metric is in need of more precise determinations of site to source conversion factors and clarity into the source fuel mix of the electricity generation, as identified by Torcellini et al. In addition, it may be relatively easy to reach the source net-zero energy goal in areas primarily supplied by renewable electricity, fostering inefficiency.
- **Cost-based zero energy** is another potential metric. Building codes such as California's Title 24 and ASHRAE 90.1 calculate energy use in terms of the annual energy costs imposed to power the building. This includes the consideration of time of use variation in cost. If the goal of a net-zero energy building is to reduce cost, or if a subsidiary goal is to be consistent with the structure of building codes, then this metric is more inclusive and makes more sense. However, cost reductions do not necessarily correlate with emissions reductions. A cost-based zero energy building goal is hard to defend in terms of internal consistency. If the goal is to reduce cost, why should a building be required to reduce all of its own energy on site? Arguably, it could be lower in cost for the user to achieve a net-zero economic goal by purchasing zero emission resources from off site.
- **Net-zero emissions buildings** could be quantified similarly to source energy, with similar weaknesses in data availability as identified by Torcellini et al. Clearly this metric is most consistent with emission reduction goals, but it also raises the same question about boundaries as cost based metrics. Why is it in society's interest to provide renewable energy resources on-site versus close to the site, versus at a long distance? What are the *geographic* boundaries?

Where Do We "Draw the Line?"

Imagine a developer trying to create net-zero energy buildings. For the sake of argument, we shall assume the goal is net-zero emissions. Will the developer require each individual building in a subdivision of homes, or an office park and retail mall to be net-zero? It is hard to see what would be the policy rationale for such a requirement. One might argue that if each individual unit has to achieve net-zero, some units will be better than net-zero and thus we save even more emissions. This argument is a strong one given the economies of scale of building all buildings to the same levels of efficiency. Ultimately, requiring *each individual unit* to be net-zero will result in a total *project* net generation: the well-sited buildings would beat the goal and the worse sites would just barely meet it. The mix might result in, say, 10% of net zero-emissions generation (today's) emissions. Why not, then, just set an overall subdivision goal of -10%? It seems clear from this discussion that requiring compliance with a net-zero goal on an individual unit basis within a large project could become sub-optimal, at least in economic terms.

It becomes more complicated still as we ask, why should we require 200 individual homes built by 200 different developers to meet a net-zero goal on an individual basis, when if we combine them as a subdivision, they would only have to do it as a subdivision? This discussion then raises the question, why stop at the limits of a subdivision? Suppose that we are looking at a community in which 1,000 new homes are being built with a net-zero emissions goal. 1,000 new homes lie across the street from 1,000 existing homes, whose energy use is 130 on the Building America/RESNET scale: 130% of the energy of a home that meets the 2004 IECC. Suppose we can save 70% of the energy use (Builder's Challenge score of 39) in the new homes by using cost-effective energy efficiency features, and we would need to get the remaining 39% from photovoltaic cells or similar renewable source. Suppose, as is typical of current practice, that the PVs would produce peak power at $7,000 per installed kilowatt. Suppose, as we believe to be the case, that we could retrofit the existing homes across the street for $4,000/kW. It would then cost a lot less to achieve the same amount of emissions reductions by retrofitting the existing homes and omitting the photovoltaics from the new development. Of course, to meet the 2050 climate goal, we would want to do both, but the example raises questions about the utility of these assorted accounting systems and the importance of geographic boundaries.

If it makes sense to expand the boundaries of net-zero to include the possibility of saving power (and emissions) at $4/watt from existing homes across the street rather than $7/watt from renewables on site on the new homes, why would it not also make sense to allow the developer to meet a net-zero goal by constructing a renewable energy generator on the opposite side of a subdivision on land currently employed for agricultural purposes? Continuing along this line of inquiry, if it is acceptable to achieve a net-zero goal by renewables located on the adjacent property, what difference does it make if there are 1,000 kilometers of transmission line between the renewables facility and the new development?

How Do We Consider Indirect or Embodied Energy Use?

This question is posed by Hernandez and Kenny (2010). While there currently is no standard methodology for calculating energy used in a specific proposed building during construction, this is likely to change: several organizations, including Xerox and Wal-Mart, claim to be developing increasingly rigorous protocols for measuring carbon footprint up the supply chain. Yet, drawing the line at operational energy can clearly lead to some perverse results. Here are hypothetical examples (hypothetical because, as mentioned, we have no solid data on upstream impacts of construction materials):

Suppose our design goal is to create a multi-story house that uses zero energy for heating and cooling and minimal energy for artificial lighting. One design approach would be to use lots of fenestration area, particularly shaded south-facing fenestration, "clerestory" windows for daylighting, and thermal mass to allow cooling by nighttime ventilation and heating by passive solar. Typical designs employing passive solar use lots of concrete, because of its high-heat capacity, but glass and concrete may (hypothetically) be energy intensive construction materials, when compared to other alternatives, for a specific building. This multi-story building would also require increased structural strength to support the weight of the upper concrete floors, which would also increase embodied emissions. In this example, we would be getting closer and closer to net-zero on operational energy at the expense of supply chain energy.

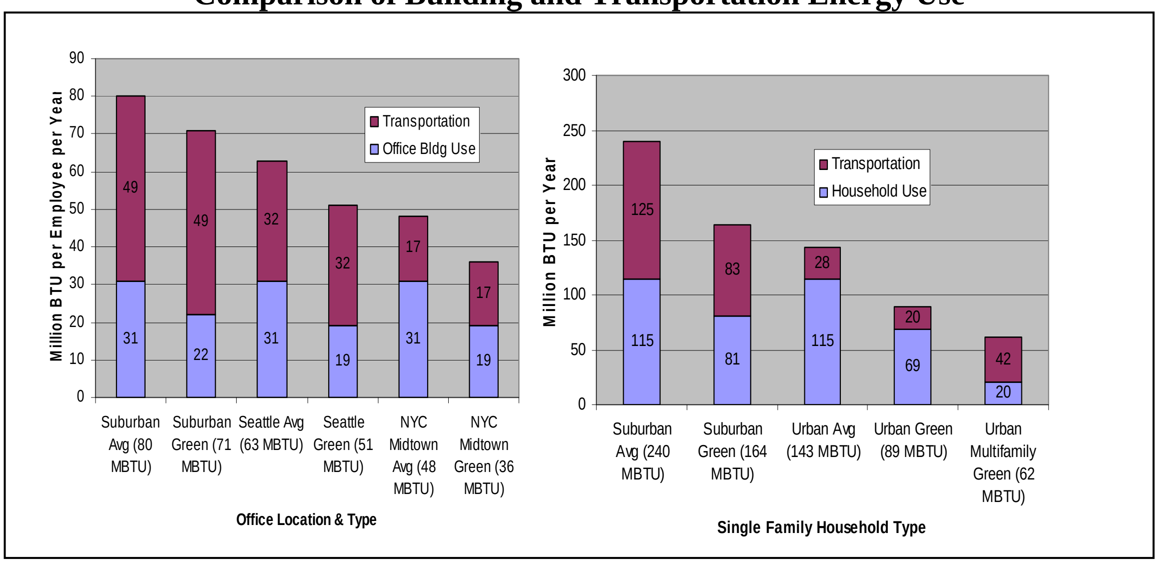
Another example of potential perverse results would be when the existing building requires substantial renovation or demolition and replacement. Demolition and replacement may result in lower operational energy use but probably much higher construction and supply chain use. A metric that is focused solely on operational use could lead to the wrong answer.

The failure to consider embodied energy could also discourage material recycling. Some Life Cycle Assessments of buildings consider the value of the recycled content of the materials as well, with potential embodied energy savings of 35-40 percent (Yohanis & Norton 2002). Design for deconstruction, which is an uncommon strategy that would decrease energy waste through material reuse would also be implicitly discouraged.

How Do We Consider Transportation Energy Use?

Reaching net-zero in building energy use raises similar questions regarding transportation. For too long, "green" buildings have been viewed outside their context. What a growing evidence base tells us is that *where* a project is sited can have more of an environmental impact than how a project is constructed or even operated. Building energy use analysis should not only consider what a building is made of and how it is powered, but how much energy will be required by residents, employees, guests and customers to get to and from the building each day. As the graphs show for residential and commercial development, transportation energy is a significant part of a project's entire energy impact (Rose 2006).

Comparison of Building and Transportation Energy Use



Source: Jonathan Rose Companies, LLC

Leading proponents of green building and development have accepted the importance of transportation energy. The US Green Building Council, the Congress for New Urbanism and NRDC have released LEED-Neighborhood Development standards, the first effort to describe, catalog and verify what constitutes green development at the project and neighborhood scale. Much like recent updates to the California Green Building Code, LEED-ND endeavors to integrate planning and urban design into the evaluation of the environmental performance and energy efficiency of buildings. The National Green Building Standard, from the National Association of Home Builders and the International Code Council (NAHB 2009), has created similar metrics and criteria in their Chapter 5-Lot Design, Preparation and Development.

Given the significant role transportation plays in total building energy use, and the growing understanding of transportation in the analysis of building environmental impacts, conclusions about what net-zero actually is cannot neglect transportation. We know that residents of dense neighborhoods with convenient transit access generally drive less, but they do indeed drive. Perhaps emissions from such travel could be off-set by on-site energy generation and electric vehicles. We must also ensure that we accurately assign transportation energy "share" to the proper building type. Our understanding of transportation energy generation and travel behavior is strongest with respect to residential location and development (i.e. where someone lives). We must continue to strengthen our understanding of the transportation energy generation of other uses (work, shopping, recreation) and develop reliable methods to assign travel accurately.

Ignoring transportation energy can lead to sub-optimization. For example, dense neighborhoods can limit the potential for most on-site renewables, due to larger building footprints or higher buildings and shadows. To achieve the kind of density needed to cut driving in half, we require three-story buildings. However, it may be impossible to collect enough solar energy on the roof of a three story building to offset its energy use for uses other than climate control (which can be reduced to near-zero through efficiency and passive design), leaving an energy use that is still positive for the building itself before we even consider zeroing out the transportation costs. Torcellini and Crawley (2006) pointed out that the percentage of commercial floor area able to reach zero energy decreases exponentially with the increase in number of floors, as daylighting and solar energy potential decreases while plug loads increase relative to heating and cooling. They suggest that three story buildings can only meet zero energy goals for a little more than 10 percent of their floor area, a principle that is directly at odds with the goal of reducing transportation energy through high density development. A strict requirement for on-site generation of energy could result in *de-facto* density limits that require far more emissions from transportation and its infrastructure than is saved at the site. The on-site requirement inherent in the zero energy definition could also eliminate the use of rooftop area for personal open space, urban food production, or water collection.

We also know that the transportation energy performance of a building can and will change over time. A building originally set off in previous open space and entirely car dependent could, over the course of years or decades of accompanying high quality land use and transportation planning, find itself surrounded by compact development and adjacent to new housing and transit. In that same period, average fuel economy for automobiles could also improve. In such a scenario, older buildings, which may actually perform more poorly than state-of-the-art buildings in utility energy, may actually perform better than new buildings with respect to transportation. Indeed, that is what we see now, when we compare some historic city centers to outlying suburban development.

It may also make more sense to consider solutions at the regional level, accepting the transportation system as a network while not holding individual buildings wholly responsible for the transportation they generate. California's SB 375, which requires comprehensive land use and transportation planning to reduce Vehicle Miles Traveled and associated emissions, is a step in this direction.

These questions relate directly to how a building is defined and where and how boundaries are set around individual "projects," both in space and time.

Conclusions and Recommendations

Achieving the necessary reduction of 80% in absolute emissions by 2050 will require dramatic improvements in energy efficiency and renewable energy production. Given the size and scope of the building industry, much of the dramatic improvement will need to take place in the building sector.

Attempts to reduce energy use in both new and existing buildings are driving significant progress to achieve net-zero buildings through well-understood policy mechanisms. Continuous incremental change is important; however, simple arithmetic shows that changes on the order of 10% reductions in energy use every 5 years are not large enough to meet the end goals. If we define net-zero as broadly as we are analytically capable—including operational, embodied and transportation energy-- this goal should promote both the leading-edge designs that already achieve some measures of net-zero as well as the leading-edge mass-produced designs that will eventually need to saturate the market.

As we come closer to achieving the goal of net-zero energy, we will have to examine the policy basis behind both the definition and the magnitude of the goal. It seems evident that the broadest definition we have described provides the most comprehensive metric of how well we are doing at meeting climate goals.

Regardless of the goal, there has been almost no analysis of whether a goal of net-zero is the most appropriate. An optimal development might be at net-zero in terms of operational energy use, but it might be at 90% savings, or 10% net production in export of energy. The result may depend on climate: perhaps a sunny area with low heating and cooling demand should be a net producer of energy while a cold, cloudy area, without much wind should not set a goal of precisely net-zero.

Evidently, including construction and transportation impacts in the metric will make it much more difficult to achieve net-zero. What we do not know is whether this means a goal with wider boundaries should be set at a more modest percent savings or whether net-zero total energy use is an appropriate goal. If we set a broadly defined net zero energy use as the goal, this implies that the project's operations must be highly net producing to compensate for other unavoidable energy usage, such as for transportation. We suggest avoiding strict determination of the definition of net-zero energy in policy today, but continued reassessment of the goal and process for obtaining the goal.

We see that a serious effort to meet any definition of zero energy use in buildings will require both a stronger, as well as a more comprehensive, approach to efficiency than has been taken to date. This paper outlines what this approach might entail.

We also see that mid-course corrections both in the definition of net zero and in the methodologies for assessing energy use are likely to be needed as we approach the goal, and that, to avoid errors of sub-optimization, many of the corrections involve expanding the scope of tracking of energy use. The data and analytic methods needed to measure energy use given this broader scope are not yet fully developed, and need to be refined.

Finally, the economic value of achieving any of the potential goals is not yet clear, so we need to track our progress at reducing energy use as measured by several of the metrics that we have discussed. But for now, setting a broad goal of near-zero energy will take us in the right direction, both for improving energy efficiency in an economically sound manner, for fostering continuous improvement in technology and design, and for tracking our progress.

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