

Unintended consequences of current net zero energy building practice

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ABSTRACT: Within the built environment, the current term “Net Zero Energy” is often used to describe the balance in the operating energy of the building. Other forms of energy use besides the operating energy—relating to the transport of building materials, manufacturing, construction, repair, and maintenance—are normally not counted. However, the original concept of “net energy,” as used in the field of ecological economics, has a very different meaning. (Hernandez et al, 2010) In ecological economics, net energy relates to the whole life cycle energy accounting of an object or system and includes all the stages mentioned above, instead of focusing on the operating/use phase alone. While the high efficient building such as net zero energy building is a global trend and will help us to achieve the 80% carbon emission reduction by 2030, however, the attention to energy performance need to be broaden up in order to avoid unintended consequences. In this paper, an overall analysis is given of three key inadvertent consequences of the present-day net-zero movement in the built environment: the life cycle environmental impact caused by neglecting embodied energy, societal impact due to several characterizations of net-zero energy building, and overall ecological degradation caused by a sole focus on energy counting.

KEYWORDS: Net Zero Energy, social impact, embodied energy, ecological degradation, life cycle environmental impact

INTRODUCTION

Within the built environment, the current term “net-zero energy” is often used to describe the balance in the operating energy of the building. Other forms of energy use besides the operating energy—relating to the transport of building materials, manufacturing, construction, repair, and maintenance—are not counted. However, the original concept of “net energy,” as used in the field of ecological economics, has a very different meaning. (Hernandez et al, 2010) In ecological economics, net energy relates to the whole life cycle energy accounting of an object or system and includes all the stages mentioned above, instead of focusing on the operating/use phase alone.

From the 1970s concept of net energy flow to the current definition of a net-zero energy building, how far have we moved from its ecological origin? Howard Odum outlined the two principles of energy flow—energy hierarchy and self-organization—in his 1971 book *Environment, Power and Society*. The energy hierarchy is the fifth energy law that Odum proposed: “All systems are organized hierarchically. . . . Energy flows of the universe are organized in energy transformation hierarchies. Position in the energy hierarchy can be measured by the amount of available energy transformed to produce it (Odum 1977). A building or built environment can be viewed as a living thermodynamic organism following principles in the same way any natural or organic organism would follow. To optimize such energy flow and hierarchical organization, we refer to nature as an example, as it is the best method for documenting such hierarchy. For instance, the pattern of a small center aggregating toward a larger center can be found in tree trunks, leaves, pinecone seeds, rivers, and even air bubbles. Biologists have also found that this specific pattern exists in the animal kingdom as well, such as in termite and ant nets (refer to figure 1).

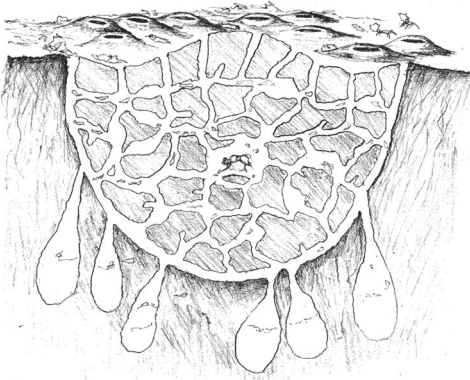


Figure 1. Hierarchical organization in an ants' net (Author 2005)

Self-organization is where “the downstream products have less energy to feed back and amplify. In the competition among self-organizing processes, network designs that maximize empower will prevail.”¹ Together, self-organization and hierarchy create a centralized hierarchical pattern in nature. Odum described the common systematic development and growth pattern found in the ecosystem: “Systems converge the transformation products to centers spatially, they concentrate these flows so that the feedback out from the centers is concentrated enough to have a strong effect by spreading its useful work over the contributing area.”² A typical example would be the water and stream flow.

When we examine maps of historical towns and cities across different cultures, regardless of location or environmental conditions, the outputs of small neighborhood centers move towards larger district centers. These district centers then move towards even bigger city centers at the next level. Larger historical metropolitan cities might have multiple city centers, with each center having its associated convergence pattern (see figure 2). This represents not only a principle of geography but also the connection between spatial organization and energy hierarchies.

This ecological principle and systematic thinking of sustainable building has undergone several changes, starting in 2000. Attention has been undividedly given to technologies, advanced building materials, and end-energy usage. The isolated attention and heavy dependency on individual products or advanced building systems was indeed a method to defy the ecological origin and principles of net zero. Despite a higher interest in integrated design and construction and interactions between different building systems, energy flow and building performance have been confined within the individual building boundary and operational phase.

1.0 UNINTENDED CONSEQUENCE ONE: ENVIRONMENTAL IMPACT ASSOCIATED WITH EMBODIED ENERGY

1.1. Missing embodied energy (EE)

Most net-zero building focuses on new construction instead of renovating existing buildings. This might be due to the public's perception that retrofitting existing buildings is difficult and uncommon as well a lack of awareness and knowledge about embodied energy. Embodied energy is defined as the total energy input consumed throughout a product's life cycle. Initial embodied energy represents the energy used for the extraction of raw materials, transportation to the factory, processing and manufacturing, transportation to site, and construction. Once the material is installed, recurring embodied energy represents the energy used to maintain, replace, and recycle materials and components of a building throughout its life. Architecture and engineering professions continue to drive down operational energy levels of buildings

1.2. Is new always better?

All buildings will become obsolete at some point. In fact, obsolescence affects a building at any location any time during its life cycle, and building users must adapt the building to every changing condition. Ultimately, as Wilkinson says, all buildings will eventually become obsolete and will require modification to adapt to changes due to environmental, functional, locational, and economic conditions. Then, the question becomes: which is better—constructing new buildings or retrofitting the old? The answer lies in the understanding of embodied energy.

Embodied energy has three different phases, including initial and recurring embodied energy, which were described earlier. The third phase, demolition energy, includes all the energy used to deconstruct a building, transport and process the debris, and dispose of or recycle the used building and assemblies. When the decision is made to raze an existing building and build new, the entire embodied energy of the existing building will likely be lost. Accordingly, the benefits of retrofitting existing buildings have captured the attention of many academics, and a large number of studies have focused on the comparison of different options including adaptive reuse. However, only a handful of countries have taken serious actions toward promoting adaptive reuse and energy retrofitting of existing buildings. For instance, in the United Kingdom, more work is undertaken on adaption than on new building (Egbu 1997, Ball 2002). The high proportion and amount of annual expenditure on building adaption in the United Kingdom and several other developed countries demonstrate the importance of adaption to business and commerce. However, these countries only represent a small percentage.

Adaptive reuse and conservation are frequently discussed in terms of economic, cultural, and design values. Existing historical buildings not only have cultural and historical significance, but preservationists also believe that such buildings carry environmental impact reduction benefits. For instance, a report published by the Preservation Green Lab of the National Trust for Historic Preservation included several relevant findings. In particular, the authors concluded as follows: “Significantly, even if it is assumed that a new building will operate at 30 percent greater efficiency than an existing building, it can take between 10 and 80 years for a new, energy-efficient building to overcome the climate change impacts that were created during construction.” (National Trust for Historic Preservation 2016)

2.0 UNINTENDED CONSEQUENCE TWO: SOCIETAL IMPACT – MORE SUBURBAN SPRAWL AND A GREEN LIFESTYLE?

2.1. Low-density development

New single-family detached houses are an easy target for net-zero energy building. Currently, the most employed renewable energy technology is still the photovoltaic panel, and production of electricity heavily relies on the amount of solar radiation and total roof area that can receive and collect solar energy. Building with a large footprint but less levels certainly presents the best candidate; furthermore, this type of building leads to low density development. One place with low density development is a suburb. People are attracted to suburbia for its bigger lots, quieter neighborhoods, and the idea of being close to nature. However, merely being surrounded by green does not translate to sustainable and health living. Several studies have revealed that the carbon footprint of a suburban neighborhood is much higher than that of a dense urban block. Norman and his research team studied two cases in the city of Toronto, and results indicated that, compared to a high-density urban core development, a low-density suburban development has a higher intensity of energy and greenhouse gas emissions, by a factor of 2–2.4, on a per capita basis. Moreover, the research also recognized that, despite a comparatively low transit ridership for the low-density case, normalized transit energy use/GHG emissions are higher in a low-density context, which is likely due to the greater travel distances required and heavy reliance on diesel buses instead of streetcars and subways (Norman et al, 2006).

A suburban house has a larger footprint and less compact building envelope and consumes more energy on heating and cooling per capita. Additionally, most suburban dwellers use automobiles as their daily commute method. Overall, low density and a large building footprint together create a very wasteful development pattern. James Howard Kunstler called suburbia “the greatest misallocation of resources in the history of the world.” (Kunstler 2006). In historical towns, following the law of thermal dynamic flow, the towns tend to have a hierarchical fractal-like pattern that helps create the most efficient energy flow without waste and all important public spaces act as subcenters that connect to one another. However, sprawling suburbia is based on a monolithic design principle, where low-density buildings stretch without a coherent or comprehensively derived pattern and are not connected to others. There are many societal impacts associated with suburban living, such as political fragmentation, a declining quality of community life, and lack of affordable housing. The widespread suburban sprawl has been viewed as an erosion of civic engagement and mutual trust; a loss called “social capital,” which has been studied extensively by professionals and research groups from different fields. Several researchers clearly attributed the decline of social capital in part to the suburban sprawl (Moe and Carter 1997, Calthorpe 1993). A number of forces could influence change on the unsustainable and soulless monotony of the modern suburbs, with energy related to financial costs at the top. More precisely, large households are associated with rising utility bills, and lengthy commutes not only result in increased fuel consumption and high carbon emissions but also increases individuals’ stress due to traffic jams.

3.0 UNINTENDED CONSEQUENCE THREE: ECOLOGICAL DEGRADATION

The third unintended consequence is closely related to the previous two unintended consequences. There are two misleading concepts of net-zero building that may have ecological and environmental impacts. The first is the sole focus on the operating energy. The net-zero approach is generally viewed as a design method of balancing resources drawn from the natural ecosystem, such as energy and water, and the overall consumption of resources within a particular boundary, over a specified time period. More precisely, net-zero building produces the same amount of energy onsite from a renewable source as that consumed by the building. The idea of incorporating embodied energy in the net-zero building design and calculation is particularly important since most current net-zero building only focuses on the operating energy that will be consumed onsite and its associated environmental impact. The environmental impact and energy consumption caused by the production of materials, building construction, maintenance, and end of life are not included as part of the zero balance, although several green building rating systems have begun to show interest. Globally, most building regulations and codes have focused on building energy consumption, with insufficient practical guidance for design professionals about the environmental impact caused by buildings, which can lead to miscalculations. It is possible for a net-zero energy building design solution to have a considerably high environmental impact due to the building materials and construction methods that have been selected (Lützkendorf, et al 2015). For example, Middle Eastern countries rely heavily on foreign companies to supply the curtain wall for most of their high-rise buildings. The energy-intensive manufacturing process occurs outside the property boundaries, thus the transportation/shipping energy is often neglected. A net-zero energy glass building in those extreme conditions may still be possible, simply because the client can have many solar panels installed on the building property, generating electricity to offset the energy consumed.

The second misleading concept is the fact that people regard renewable energy as “free,” as mentioned earlier. Even though solar energy itself is free, it requires the purchase of materials and energy to harvest its energy, with the most popular device being the solar panel. To produce solar panels, we must extract raw materials that are then processed into different types of solar cells using energy. The solar cell manufacturing process also includes several hazardous materials that contain the same types of chemical compounds used in the general semiconductor industry, such as hydrochloric acid, sulfuric acid, nitric acid, etc. These hazardous materials pose a danger to workers, and the chemicals will eventually be released

back into the environment.⁵¹ As the thin-film solar cell becomes more popular due to its flexibility, awareness is needed of the potential environmental damage associated with the toxic materials in those cells.

4.0. POTENTIAL SOLUTION – ECO-DISTRICT

In order to shift generations' rosy view of suburbia living being a lifestyle close to nature, an ecological perspective is needed to further examine suburban living. The concept of zero energy is not restricted to individual buildings (Polly et al 2016) and has already been extended to campus, district, neighborhood and city levels. In dense urban areas, due to buildings having a high volume (height)-to-floorspace ratio, there is not adequate roof area for PV panels that can produce enough electricity for an entire building. The amount of renewable energy available within the building footprint is limited as well. Meeting the net-zero energy goal for an individual building becomes very challenging. Instead, approaching zero energy on a larger scale can provide the opportunity for district energy systems to exploit load diversity between buildings and access renewable energy sources in ways that may be impractical for individual buildings.¹⁵ These so-called eco-districts present the optimal scale to accelerate sustainability to achieve net-zero energy targets for buildings in urban settings with more constraints, and these cities will move from their current eco-districts to net energy districts over time.

CONCLUSIONS

Innovative design approach and advanced technology aim to serve humanity. There is no question that energy-efficient appliances, cars, and lighting fixtures help to conserve energy. Conversely, the high gas mileage of automobiles could indirectly encourage people to drive longer distances simply because of the cheap cost. Detached single-family houses that are one story, car-dependent, solar panel equipped, and scattered over a large area might have a higher chance of achieving the net-zero energy balance. But they require enormous quantities of gasoline for residents to commute between work and home as well as considerable embodied energy per house to construct, maintain, and repair, causing damage to large areas of land. Furthermore, even with energy-efficient appliances, mechanical systems, and high insulation, these scattered and detached houses lose heat and coolness to the surrounding air because they do not share walls, floors, or roofs with other structures. These unintended consequences described above are connected to the building industry's tendency to treat buildings as individual and independent developments. The current approach to achieve net-zero energy heavily depends on advanced technology and highly controlled building systems, which creates huge financial and technological barriers for many less resourceful projects and building owners. Meanwhile, zoning and planning guidelines do not provide clear direction on how the performance of individual buildings should be assessed based on their impact on surrounding areas or as part of a large urban scale. The limited attempts to create net-zero communities and campuses have hindered bridging the gap between individual building performance and city-wide sustainability.

Understanding the natural environment and human society as one holistic system means viewing parts, processes, and connections as the foundation for all building design types. If we trace the origin of net-zero energy back to its ecological roots, we can consider net-zero building as a guiding design principle for all buildings and a professional ethic for all practitioners. Consequently, it must be perceived as a core consideration and not as an add-on item.

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