WHAT IT TAKES TO BECOME A NET-ZERO DEVELOPMENT: CASE STUDY OF SERENBE, GEORGIA

Abstract

With increased efforts toward planning for climate change mitigation, and design of carbon-neutral and Net-Zero (NZ) buildings, quite little has been improved regarding communities and nations. With integrated design and planning of primary sustainable measures, including energy generation, energy use in buildings, and energy use in transposition, Net-Zero Community (NZC) can be feasible. The purpose of this study is to generate a NZC Model residential development in the U.S. and to identify NZC sustainable planning and design measures. A case study at Serenbe, in north Georgia, is going to be evaluated to promote its sustainable measures toward NZC.
To understand NZC planning measures, two notable sustainable developments were studied, BedZED in London and UC Davis West Village in California, to identify their sustainable measures necessary to create a NZC. The existing communities are assessed in the power, building, and transportation sectors (PBT). The outcome will be an effective Model achieving NZC, through promoting major sustainable measures including agriculture, transportation network, density, housing typology, use of renewable energy, mixes of use, pedestrian and biking route, and land preservation.

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Keywords

Net-zero energy community, sustainable precedent studies, solution sets, net-zero indicators, design strategies

Introduction

With increases in world population, consumption at an alarming rate, continued reliance on non-renewable resources, energy-inefficient building systems, and inefficient transportation systems and modes (OICA, 2017; EPA, 2018; U.S. Department of Transportation, 2018) have negatively impacted the climate, specifically with global warming (NASA, 2019; Houghton et al., 1996; Houghton et al., 2001). The consequences have caused burning a significant amount of fossil fuels (NASA, 2019) which created severe environmental impacts (Tilman, 2001; Raleigh & Urdal, 2007) such as producing Greenhouse Gases (GHG) in the atmosphere and global warming (NASA, 2019), land degradation (Raleigh & Urdal, 2007; IUCN, 2015), natural resource depletion (Halofsky et al., 2015), increasing of natural disasters, and related health problems (Perera, 2017).

Based on Cook et al. (2016), 97% of climate scientists agree that climate change causes originated from human activities. Among those activities, PBT practices constitute a substantial portion that contributes to global climate change. According to the U.S. Energy Information Administration (EIA) (2018), the primary energy-consuming sectors in the U.S. are based on three sectors: power (38.1%), buildings and agriculture (33.1%), and transportation (28.8%). Also, based on the U.S. Environment Protection Agency (EPA) (2018), the primary sources of GHG emissions in the U.S. are based on electricity production (28%), buildings and agriculture (44%), and transportation (28%).

To ascertain that there is enough housing and facilities for human inhabitants, along with a healthier environment, this paper aims to provide developers, planners, architects, and engineers with a comprehensive set of NZ standards applicable to residential developments that are sustainable and energy-efficient.

Methodology

The methodology in this research is mixed methods, which comprises both quantitative and qualitative analysis using numerical data for evaluating indicators regarding PBT construction practices. First, the literature review will summarize the different existing definitions relating to NZC and the one that is defined for this research and its standards. Then the study will gather data from precedent NZ/sustainable cases to extract the major indicators and create a NZC Model (NZCM). A case study in Serenbe is analyzed to assess its current sustainable/NZ indicators and their outcome on reducing energy demand, the total energy need, and to assess the best alternative to generate energy on-site. Then the study will gather collected data to evaluate and compare the NZCM and the case study to show the essential indicators that a residential community would utilize to become a NZ. The outcome will be a NZCM derived from an integrated set of indicators that would be transferable to other residential communities with different contexts.

Literature Review

NET-ZERO COMMUNITY DEFINITION

There are multiple, diverse, and competing definitions of NZ building (NZB). However, the definition regarding NZB does not address some of the significant energy criteria, including community-scale systems for energy production, transportation energy-use reductions, and planning scale designs encouraging NZC. Even on a community-scale, there are different definitions; each implies a different approach and set of strategies that make it complicated for planners and designers to understand how to achieve their objectives. This lack of consensus over a definition causes uncertainties and conflicts in calling a specific community NZ. As such, National Renewable Energy Laboratory (NREL) defines NZC as, "one that has greatly reduced energy needs through efficiency gains such that the balance of energy for vehicles, thermal, and electrical energy within the community is met by renewable energy" (Carlisle et al. 2009). Based on the U.S. Department of Energy (DOE), NZC is, "An energy-efficient community where, on a source energy basis, the actual annual delivered energy is less than or equal to the on-site renewable exported energy" (The National Institute of Building Sciences, 2015). International Living Future Institute (ILFI) (2017) defines NZC as "One hundred percent of the community's energy needs on a net annual basis must be supplied by on-site renewable energy. No combustion is allowed." With careful consideration and analysis of different NZC definitions in different projects, the conclusion would be a group of energy indicators extracted from various sources.

PRECEDENT STUDIES

The study investigates and draws from the exemplary examples of contemporary residential developments. In this paper, we study Beddington Zero Energy Development (BedZED) and UC Davis West Village (West Village).

BedZED is the largest mixed-use eco-community in the UK, located in Hackbridge, London. It was completed and occupied in 2002. The size of the project is four acres, including 160 homes, with the density of 40 dwellings per acre (BioRegional, 1999) (Figure 1).

Figure 1: Master plan of BedZED. (Source: BioRegional, 2003.)

The NZ definition in BedZED is defined as "producing at least as much energy as it consumes through only renewable energy sources." (BioRegional, 1999). The main goal of the project was to reduce the energy demand based on ventilation, cooling, and heating by 90% compared to a conventional home in the UK. To do so, the primary energy strategies were planned based on (1) solar photovoltaic panels on the roof to reduce 20% of the electricity demand (Hodge & Haltrecht, 2009) (Figure 2), and (2) 130 kW biomass Combined Heat and Power Unit (CHP) as backup heating and proving the rest of electricity (Arup, 2000) (Figure 3).

Regarding energy use in transportation, BedZED was committed to the Green Transport Plan (GTP). Based on this plan, BedZED committed to reducing car energy use by 50% in 10 years with promoting mixes of use, parking control enforcement, internet deliveries for supermarkets, etc. Also, the project utilizes various energy demand reduction strategies, including passive solar, natural ventilation, waste and recycling, green roofs, and so forth to minimize energy demands of the development based on space heating, hot water, and electricity (Figure 4).

West Village is the largest "zero net energy" residential development in the U.S. (Braun et al., 2011), located in Davis, California. The project was opened in 2011. The size of the project is 224 acres and designed for the ultimate 4,350 residents. Based on the definition of NZ in this project, "Zero net energy is achieved when the community generates 100% of the energy it uses over the course of a full year" (Braun et al., 2011). The main goal of the project was to minimize energy use and GHG production in the community through reducing buildings' energy use, producing on-site energy from renewable energy sources, and promoting the use of bicycles and public transit (Figure 5).

To do so, the primary energy strategies in West Village were designed based on (1) Utilizing 5.4 MW centralized PV (Figure 6), and (2) Renewable Energy Anaerobic Digester (READ), a 300 kW biogas fuel cell generator, to convert organic waste to energy as a backup for CHP (Figure 7).

Regarding transportation energy use, West Village encourages bicycle and public transportation by promoting mixes of use, automated shuttles, battery-coupled solar charging stations, electric car-sharing, etc. Further, the project utilizes various energy demand reduction strategies, including stormwater management, optimizing the capacity of the installed storage battery, cross ventilation, passive solar, etc. to reduce the energy demand by 50%.

CASE STUDY

Serenbe Community is a relatively new residential development and an example of new urbanism in the U.S., located southwest of Atlanta, Georgia. It was initially planned in 2001 with construction beginning in 2004. The project was designed for an ultimate build-out of 1,800 dwellings. There are currently about 400 dwelling units with a population of 700. The density varies from 2.5 dwellings per acre for estate homes to townhomes with a range of 20 dwellings per acre in the live-work clusters (Tabb, 2016).

Figure 2: Solar PV on the roof. (Source: BioRegional, 2016.)

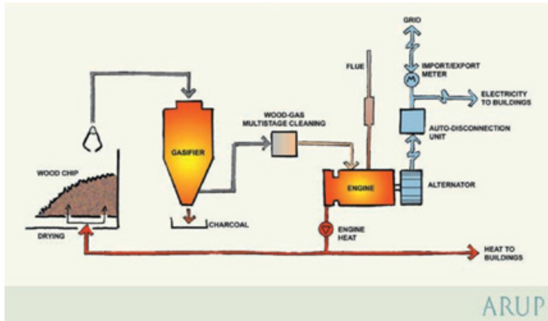

Figure 3: Bio-fueled Combined Heat and Power. (Source: ARUP, republished from BioRegional, 2003.)

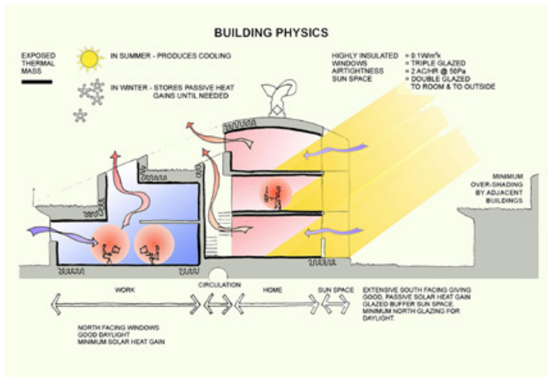

Figure 4: Building Physics. (Source: ARUP, republished from BioRegional, 2003.)

Figure 5: Master plan of West Village. (Source: Fleissig, 2013.)

Figure 6: PV arrays. (Source: Google maps.)

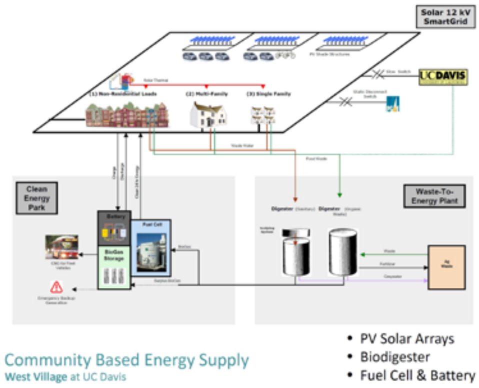

Figure 7: Community-based energy supply. (Source: England et al., 2014.)

Figure 8: Master plan of Serenbe. (Source: Tabb, 2019.)

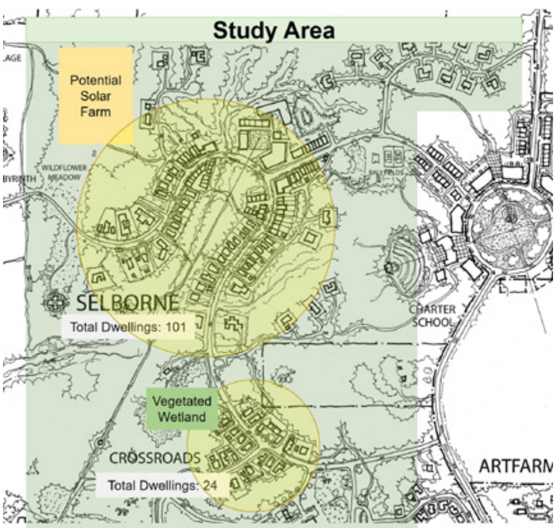

Figure 9: Master plan of Selborne. (Source: Tabb, 2019.)

One of the essential design objectives early on was land preservation to reduce the built portion of the development to only 30% of the total land area. This community is an example of sustainable residential development, representing active living, agricultural urbanism, pedestrian scale, mixed-use development, and biophilic design principles. Serenbe has achieved multiple awards, including the EarthCraft "Development of the Year," The Atlanta Regional Commission "Development of Excellence," and in 2008, Serenbe won the inaugural ULI Sustainability Award (Tabb, 2009).

The site comprises a 1,200-acre pattern of integrated omega-form hamlets, including Selborne (Artist Hamlet), Grange (Serenbe Farms), Mado (Health and Wellness), Spela (Play), and Education Hamlet (Figure 8). This paper only studies Selborne Hamlet.

Selborne Hamlet (including crossroads) is planned for 125 dwellings. The rationale for Selborne includes: (1) it is more than 90% completed (105 dwellings); (2) some of the buildings have geothermal and PV which make them a suitable case for energy analysis; (3) available space for PV farm (if required); (4) it is within a 1-mile diameter area for encouraging pedestrian movement; and (5) the hamlet has a mix of uses, including three restaurants, market, art galleries, charter school, yoga studio, and shops (Figure 9).

Zero energy definition in Serenbe is defined as the total amount of energy used in the Serenbe community on an annual basis, to be equal to the amount of on-site renewable energy supply.

Based on Steve Nygren (personal communication, July 1, 2019), the founder of Serenbe, the main goal of the project is to reduce the individual home demand by 50% on average and by 70% in the newer sections. Thereby, the primary energy strategies in Serenbe were planned to be based on: (1) EarthCraft certification, which is a green building program to reduce energy demand and boost the buildings' energy performance, (2) Geothermal heating and cooling to save electrical energy use and reduces HVAC energy costs, and (3) 9 kW stand-alone PV on the roofs (Figure 10).

Regarding transportation energy use, Serenbe plans to reduce between-place transportation by encouraging pedestrian and biking networks, electric car use, promoting mixes of use, etc. (Figure 11). Further, energy demand reduction strategies in Serenbe include favorable building orientation, passive solar heating, farm-to-table movement, agriculture, wastewater treatment using constructed wetlands, etc. to reduce energy demand in the community.

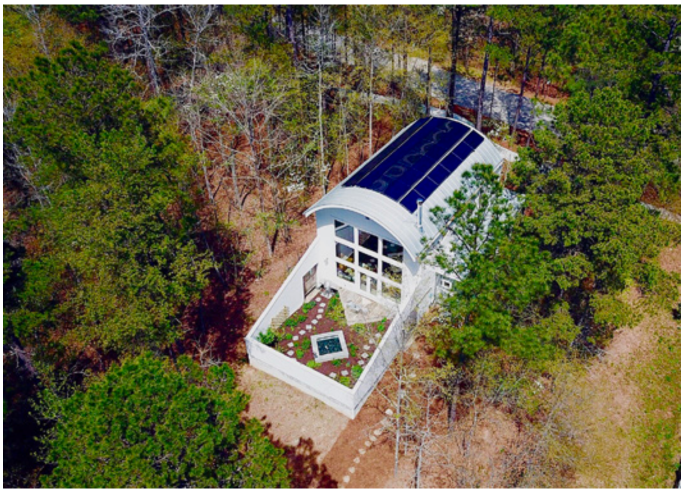

Figure 10: Stand-alone PV. (Source: Tabb, 2019.)

Figure 11: Serenbe. (Source: Photo courtesy of Ashley, J. Photograph.)

Results

ENERGY INDICATORS EXTRACTED FROM PRECEDENT STUDIES

The study investigates and extracts NZ measures from precedent studies and categorizes them based on PBT (Table 1) (Diagram 1).

Power	Transportation	Building
PV Field	Mix Use	Densification
MSW	Densification	On-site Hot Water
Planning for Solar Access	Clustering End Use	Passive Solar
Construction Standards	Public Transport	Geothermal
Electricity Load Reduction	Walking Distance	Planning for Solar Access
Heat Load Reduction	Electric Vehicle	Construction Standards
On-site Electricity	Pedestrian Orientation	Heat Load Reduction
On-site Power Production	Agriculture	Daylights

Table 1: PBT indicators from precedents.

MODEL APPLICABLE TO SELBORNE HAMLET

The study investigates and extracts NZ measures from precedent cases that are necessary to make Selborne Hamlet NZ (Diagram 2).

TRANSFERRABLE MODEL BASED ON PBT

The study investigates and extracts NZ measures from precedent cases that are transferable to other community contexts (Diagram 3).

Conclusions

The results from this research presents some of the planning measures and interventions that are necessary to achieve NZC including (1) incorporating a community-wide renewable energy power source and renewable infrastructure systems, (2) continuing to densify the community built form to reduce in-place travel distances, (3) adding more critical mixes of use to minimize between-pace transportation, (4) promoting alternative transportation modes (5) excluding gasoline-powered vehicles and providing parking lots at the perimeter of the community, (6) constructing smaller buildings with improved construction standards, and (7) retrofitting existing homes with stand-alone photovoltaic systems for passive survivability.

Diagram 1: PBT indicators from precedents.

Diagram 2: PBT indicators to make Selborne NZ.

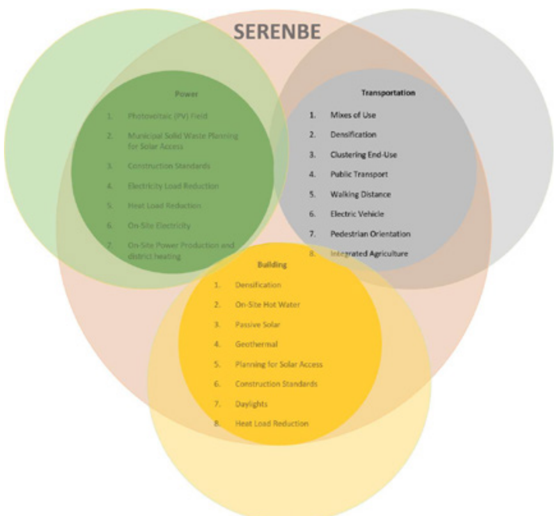

Diagram 3: PBT indicators that are transferable.

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