Evaluating the energy performance under the LEED-ND criteria by using EnergyPlus

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ABSTRACT: In present era, rapid technological changes are also expended through architectural practice. In this study, we focus on establishing a new framework to integrate the building energy performance evaluation into urban scale evaluation strategies. This study presents the results of a literature review on the principles of LEED for Neighborhood Development and sustainable urbanism. Moreover, two case studies – a commercial building and a small-scale neighborhood – have been simulated using EnergyPlus to evaluate the performance of the building after using the LEED-ND principles for green buildings.

Leadership in Energy and Environmental Design for Neighborhood Development (LEED-ND) is a system for rating and certifying green neighborhoods – developed by the United States Green Building Council (USGBC). LEED-ND integrates the principles of new urbanism, green building, and smart growth into the first national standard for neighborhood design, expanding LEED's scope beyond individual buildings to a more holistic concern about the context of those buildings.

1 INTRODUCTION

According to various approaches, sustainable urbanism makes towns and cities more desirable places for people to live (Beatley, 2012; Farr, 2008; Kelbaugh, 2002; McGeough, Newman, & Wrobel, 2004; Mostafavi & Doherty, 2015; Newman & Jennings, 2008). Those approaches have also helped to shape sustainable cities. Xiufeng Pang, Tianzhen Hong, and Mary Ann Piette (2013) state that implementation of well-developed energy efficiency measures and emerging technologies is slow, even though these to decrease energy consumption in buildings have existed for years. Also, they claim that unmotivated building owners, high implementation costs and operation difficulties are the reasons for the fact.

At the operational level, establishing a context by using accurate energy calculation tool helping building owners in obtaining best approach to improve existing building/s and new developments is the purpose of this study. Mainly, this study establishes a framework that shows flow toward sustainable urbanism aiming to reduce energy consumption in a neighborhood scale throughout *LEED* criteria by using *EnergyPlus* tool. Furthermore, best practice is to promote energy efficiency at the urban scale.

Sustainable urbanism requires both a naturalist and orientation to the regional and local ecology and an urban planning emphasis for development to occur. Sustainability occurs successfully when there is a balance among economic, social, and ecological (environmental) characteristics of towns and cities. There are many ways in which sustainability can be applied successfully in urban areas. The principles and elements of sustainability, planning policies, analysis and design methods, and green technology are all part of sustainable urbanism.

With growing population, ecological footprint is increasing accordingly. The amount of land that an individual needs to maintain himself is called an ecological footprint (Bovill, 2015). One of the essential consequences of ecological footprint is higher carbon dioxide emission by energy consumption. McGeough et al. (2004) refer specifically to American problems, such as overpopulation in big cities and unsustainable practices, providing percentage of growth in population and energy usage. This knowledge requires promoting sustainable/renewable energy sources. In fact, a sustainable environment can be created when different strategies are used and integrated into policies, regulations, and systems.

2 LITERATURE REVIEW

2.1 *Sustainable urbanism*

Many environmental issues exist at the different levels such as local, regional, and global. In 1987, the definition of sustainable urbanism was created, and the United Nations World Commission on the Environment and Development published a report called "Our Common Future" (McGeough et al., 2004). Human habitation affects environment in a variety of ways. It leaves behind an ecological footprint that indicates the water, energy, and materials that occupants have consumed. Overconsumption is a risk for these resources. Therefore, it becomes necessary to integrate new technologies into economic, environmental and social dimensions within the process of sustainable developments. "Sustainable development is the ultimate goal of the energy planning process" (Neves, Leal, & Lourenço, 2015, p. 111).

There are different types of energy that have been used in the US (**Figure 1**) such as petroleum, natural gas, coal, renewable energy (consisting of hydropower, wood, biofuels, biomass waste, wind, geothermal, and solar), and nuclear electric power (2015). According to monthly energy review, residential (22%) and commercial buildings (19%), industry (32%), transportation (28%), and electric power generators are the main energy users (2015). As it has seen non-renewable energy (89%) consumption is higher than renewable (10%) energy.

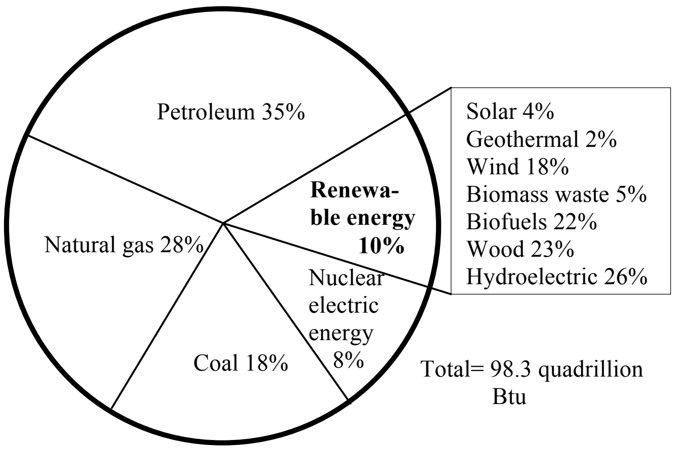

Figure 1. U.S. energy consumption by energy source, 2014 ("Monthly Energy Review," 2015)

The most important element of sustainable urbanism is the creation of smart cities, innovative cities, and green cities. Smart technologies include public transportation, district heating, and green building design (Beatley, 2012). According to Beatley (2012), sustainable development starts with the local government. Local activities are the major cause of the problems and solutions. Local governments also can achieve sustainable development within local government programs (Beatley, 2012; Farr, 2008). Farr (2008) states that it would be better if the integration of human and natural systems could take place within sustainable urbanism. In addition, sustainable urbanism supports this balance to create stronger cooperation between the two systems. He proposed a category that aims to support creating high-performance-buildings and neighborhood-scale infrastructure systems containing sustainable (alterative/renewable) energy systems. Fossil-fuel energy usage needs to be reduced, and energy-saving systems need to be commonplace. In this study, we are trying to present how we can make energy-saving systems as commonplace by encouraging LEED-ND certificate program to include accurate calculation tool (EnergyPlus) for energy consumption. This tool will give opportunity to provide results of before and after intervention (after upgrading with renewable energy resources) for building and/or neighborhood.

2.2 *Leadership in Energy and Environmental Design (LEED) for neighborhood development*

LEED-ND stands for Leadership in Energy and Environmental Design for neighborhood development. LEED-ND criteria offer ways to improve livability in the area by means of critical analysis and design practice. The purpose of certified green building is to support green infrastructure improvement in structures and buildings. Building structure needs to follow requirements provided by the IAF accreditation body ISO 17021, ISO/IEC Guide 65 and ISO/IEC 17065 (Congress, 2009). Some of the LEED-ND criteria that are emphasized in this study are ‘minimum building energy efficiency’, building energy efficiency’, ‘solar orientation’, ‘on-site renewable energy sources’ and ‘district heating and cooling’ under green infrastructure and buildings (GIB) (2009). Certified green building is for energy metric to provide sustainable energy usage for the target area within green building performance. Basically, the criterion serves to support green building practices (2009).

LEED-ND Solar Orientation criterion aims to encourage energy efficiency by generating optimum conditions for the use of passive and active solar approaches (2009, p. 96). The requirement to get one credit either for block or building orientation is to locate the project on existing blocks or design or orient 75% or more. According to this criterion, solar-oriented (**Figure 2** and **Figure 3**) buildings or blocks with east-west lengths (longer axis) should be equal to or greater than north-south axis, and east-west axis is within fifteen degrees of geographic east-west (2009, p. 96).

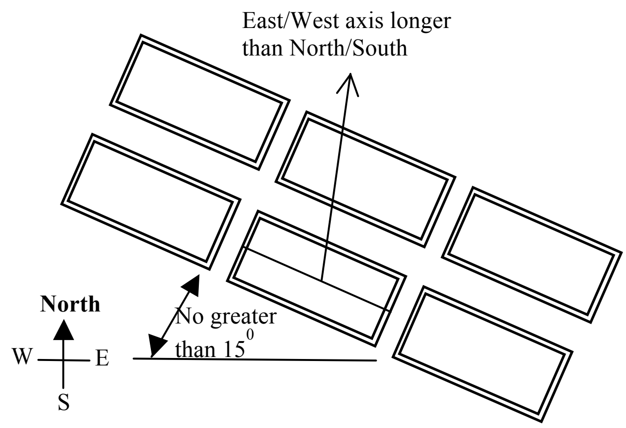

Figure 2. GIB: Solar orientation criterion for solar-oriented blocks (Congress, 2009, p. 97).

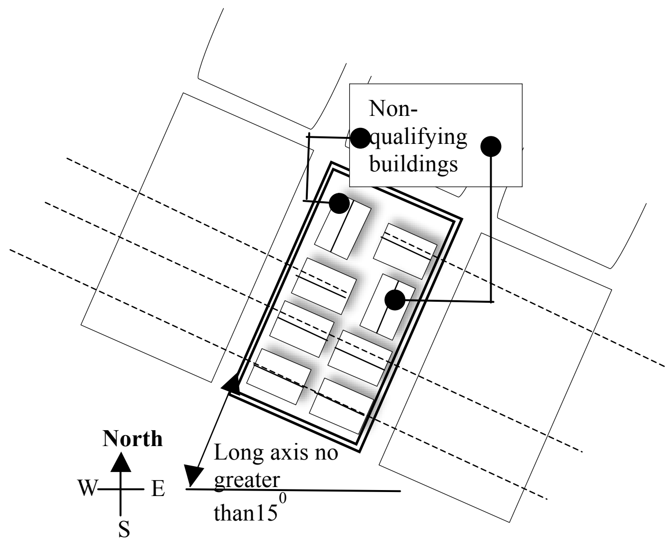

Figure 3. GIB: Solar orientation criterion for solar-oriented buildings (Congress, 2009, p. 97).

On-site renewable energy sources as a criterion of LEED-ND intend to encourage using renewable energy sources. These energy sources are solar, wind, geothermal, small-scale or micro hydroelectric, and biomass. Earning one credit is dependent on production capacity of used source. At least five percent of buildings’ electrical and thermal energy cost must be supported by renewable energy sources (Congress, 2009).

Sun orientation (Figure 4) of buildings is becoming a crucial for builders to reduce energy costs by using Sun’s free energy (Gromicko & Gromicko, n.d.). According to Gromicko and Gromicko, there are several advantages of solar orientation of buildings such as increasing the building’s appeal, marketability, and reducing the energy bills. They state that building orientation, along with daylight and thermal mass, are important deliberations of passive solar construction that can be combined into practically any new building design.

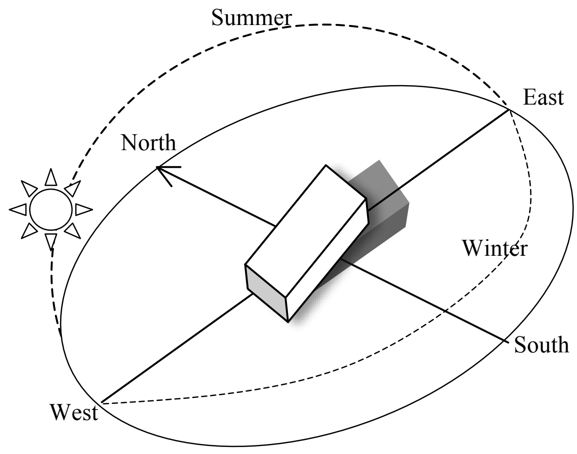

Figure 4. A single building solar orientation

Despite an overall view of LEED-ND criteria with a focus on the correlation among elements within each emphasized criteria set has strong basis, within the scope, there is lack of finding necessary data and programs/ software to utilize the criteria. In other words, LEED-ND program should indicate energy efficiency calculation tools such as EnergyPlus to assist projects before implementation. Also, implementation strategies can be shaped based on findings from specified tools. One of the other benefits of indicating specific tool/s is to reduce implementation cost by using various measurements of building and neighborhood to apply best practice.

LEED-ND might encourage public and private sectors to provide data and make it accessible by institutions and development groups. Xiufeng Pang et al. (2013) presents a framework to encourage the large-scale energy efficacy by motivating building owners and decreasing the operational cost through data sharing and amending the process through the cloud-based real-time building energy simulation in their study. In their study, data-sharing process at each individual building is done over three mechanisms such as weather station network and client software and the Energy Management and Control System (EMCS). There is no current weather station network that could provide all the essential constraints. Xiufeng Pang et al. (2013) state, "The emerging low-energy technologies and urban energy systems, such as radiant heating/cooling, demand response, district heating/ cooling and renewable energy, require more weather measurements, e.g. global horizontal solar, direct and diffuse solar, wind speed and direction, to ensure their proper operations."

GIB should be stretched out to correspond larger scale by providing projected framework. In other words, a suggestion for LEED-ND is to resolve scale issues by evaluating criteria suitability depending on this particular framework.

2.3 *EnergyPlus tool*

EneryPlus, which goes beyond DOE-2 (building energy use and cost analysis tool), is the advanced energy modeling tool that is used by the Department of Energy (Bovill, 2015, p. 240). EnergyPlus can help to measure energy efficiency and passive solar design metrics, comparing mechanical system types and operating costs, performing ROI analysis of any sustainable characteristics, such as improved insulation or better windows, performing daylighting analysis of the building, calculating LEED energy reduction credits, showing compliance with ASHRAE 90.1, and so on ("EnergyPlus Energy Modeling," 2016).

2.4 *Establishing the framework*

Within the scope of this study, EnergyPlus tool is used to establish a framework for sustainable urbanism throughout considering LEED-ND criteria (**Figure 5**). This framework is adapted from 'fundamental objectives hierarchy' (Neves et al., 2015). It consists of three dimensions of sustainable urbanism (environmental, economic, and quality of life), related LEED-ND criteria, simulation software (EnergyPlus), and two different cases – one is small-scale neighborhood and one commercial building.

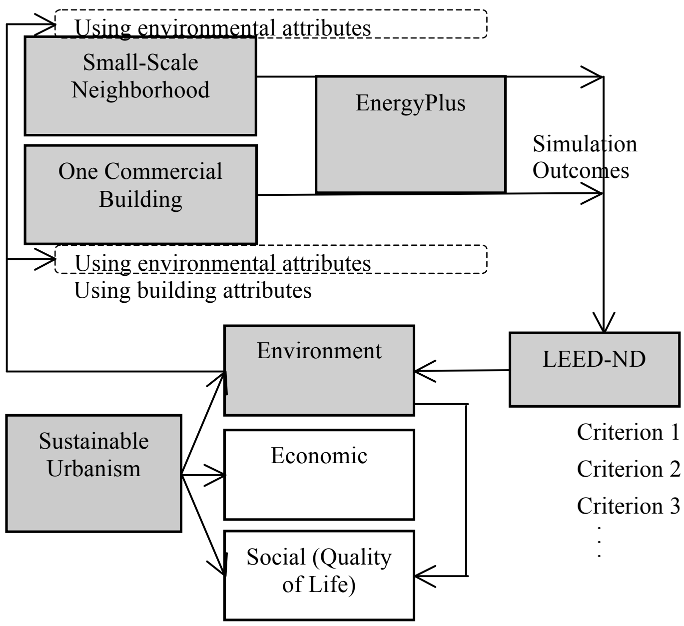

Figure 5. The proposed framework for urban scale energy efficiency regulation (defined attributes are remarked with grey boxes)

Mostafavi and Doherty (2015) mention two issues: first is affordability of the practices of ecological planning and sustainability; second is scale. The national standard for the evaluation of sustainable buildings is LEED, a program that is used throughout the country. However, urban systems are designed around a local scale, as opposed to being developed across region. The scope of urban responsibility includes both future and current needs that must be considered for sustainability.

3 METHOD

3.1 *Case studies*

The proposed cases provide a baseline for the LEED-ND program to improve energy efficiency measures to support sustainable urbanism. This study consists of two cases – one commercial building simulation and one small-scale neighborhood simulation – to examine the 'solar orientation' criterion. The case study buildings have been modeled using SketchUp and OpenStudio plugin. In the next step, the geometry files have been imported into the EnergyPlus tool to add the internal heat gains (people, light, and equipment), and HVAC systems to the model and develop the base case models based on the ASHRAE 90.1 2004. The outputs from both models are heating and cooling energy consumption.

The city of Raleigh, North Carolina is chosen as a location for case studies. Raleigh geographically locates on latitude of 35 degree 46 minute and 59 second and longitude of 78 degree 39 minute (Cornwall, Horiuchi, & Lehman, 2016). Both a single commercial building and a small-scale neighborhood were located in regard to similar physical conditions as well as solar orientation in the city of Raleigh locates in mid-Atlantic region.

4 RESULT

The two settings defined in the method section were simulated using the proposed framework and results are presented in this section. The focal objective of these initial results is to understand the energy consumption and energy savings process calculated by EnergyPlus considering solar orientation and on-site renewable energy sources criteria. We aimed to use Raleigh weather data file in EnergyPlus model calculate annual energy saving by taking into account LEED-ND criteria.

Table 1. Pairwise correlations analysis of one commercial building and a small-scale neighborhood

Variables		N	Coef.	*p*-value
SB cooling	SB heating	365	-0.5614	<.0001*
SN cooling	SB cooling	365	0.9736	<.0001*
SN cooling	SB heating	365	-0.5409	<.0001*
SN heating	SB cooling	365	-0.5809	<.0001*
SN heating	SB heating	365	0.9934	<.0001*
SN heating	SN heating	365	-0.5581	<.0001*

* Correlation is significant at the 0.01 level.
SB: Single commercial building; *SN*: Small-scale neighborhood

The results of the correlational analysis are presented in Table 1. There was a significant positive correlation between the variables: Single commercial building and small-scale neighborhood' cooling and heating energy use. In contrast, single building heating and small-scale neighborhood's cooling have a negative correlation as well as single building cooling versus small-scale neighborhood heating in terms of energy use.

5 CONCLUSION

This paper presents a framework that can potentially improve scope of LEEN-ND certification program and other urban scale energy efficiency regulations. Sustainable urbanism helps us to understand importance of energy reduction and leaning to renewable energy sources; and EnergyPlus helps us to accurately calculate energy consumption of buildings by using some of the environmental and building attributes. Today, cities that are growing fast need more land, water, energy, and resources to satisfy human needs. It is important to spear out energy efficiency strategies across the nation.

This study provides better understanding of sustainable urbanism elements and emphasizes possibility of replication energy efficiency strategies of single building in the same neighborhood. EnergyPlus software provides accurate results for both single commercial building and small neighborhood scale for the same measurements. The intention of this study was to analyze case studies a commercial building and a small-scale neighborhood's energy performance by using EnergyPlus in order to reduce building energy consumption by promoting energy efficiency measures. This study suggests the improvement in Green Infrastructure and Buildings (GIB) criteria under the LEED-ND principles that relates to energy efficiency such as 'solar orientation' and 'on-site renewable energy sources'.

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