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Influence of Energy Benchmarking Policies on the Energy Performance of Existing Buildings

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Abstract

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by

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MSc, Oxford Brookes University

BSc, University of Khartoum

Dissertation Submitted in Partial Fulfillment

of the Requirements for the Degree of

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Public Policy & Administration—Local Government Management

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Abstract

Energy benchmarking and disclosure policies exist in several local and state governments to manage the energy consumption of existing buildings and encourage energy efficient retrofits and upgrades, yet little is known about whether these efforts have improved overall energy efficiency. The purpose of this repeated-measures study was to examine the influence of New York City's (NYC's) Benchmarking Law (LL84) on the energy performance of the city's existing commercial buildings through investigating whether the energy performance of the city's existing commercial buildings significantly improved after the implementation of this policy. The study was based on Ostrom's institutional analysis and development framework. Paired-sample *t* tests were performed to statistically analyze the annually disclosed energy benchmarking data for 1,072 of NYC's existing commercial buildings that were benchmarked in both 2011 and 2016. Compared to 2011, the study results revealed statistically significant improvements in the energy performance of NYC's commercial buildings by 2016. On average, their site energy use intensity (EUI) significantly reduced by 5%, source EUI significantly decreased by 10%, greenhouse gas emissions significantly dropped by 12%, and ENERGY STAR performance rating significantly improved by 5%. However, these improvements were primarily achieved in 2012, 1 year after the city's energy benchmarking data were publicly disclosed. Additional measures should be considered to maintain continuous energy savings and greenhouse gas mitigation patterns. Positive social change implications include the potential to promote energy-efficient upgrades and inspire the adoption of sustainable building concepts.

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Dedication

This dissertation is dedicated to my family for all the love, care, and support you have accorded me through the years. You all provided me with the motivation and desire to complete this work.

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I wish to express my sincere appreciation to my committee chair and the best professor ever, Dr. Linda Day, for her dedication, patience, wisdom, and support throughout my entire dissertation journey; I will always remain grateful. I am also grateful to my committee member, Dr. Raj Singh, for his professional expertise, and to my URR committee member, Dr. Lynn Wilson, for her professional guidance.

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Chapter 1: Introduction to the Study

Introduction

Buildings are contributing to continuously rising global energy demands and greenhouse gas (GHG) emissions worldwide. Activities in the building industry involve the use of land, depletion of materials/resources, and consumption of energy (Gruber et al., 2015; Hsu, 2014a). Recent statistics from the United Nations Environment Programme's Sustainable Building and Climate Initiative (UNEP-SBCI, 2014) indicate that buildings are estimated to consume approximately 40% of global resources and 60% of the world's electricity. The rapid growth of urban communities across the world in addition to the rising costs of energy led to a growing demand for sustainable buildings in order to reduce the great impact of the building sector on the environment (Gruber et al., 2015; Ma et al., 2012). Although most new buildings are constructed in compliance with energy-efficiency codes, existing buildings are considered an ongoing cause of energy resource depletion and GHG emissions in cities with considerable numbers of older buildings. Because it is difficult to mandate energy-efficient retrofits of privately owned existing buildings, energy benchmarking and disclosure policies are implemented to measure the energy use of existing buildings. The policies are intended to provide a reliable source of energy information that makes it possible to track and compare the energy performance of existing buildings (Palmer & Walls, 2015). This study is socially significant because it may help to publicize the notion of energy efficiency within the existing building sector in particular, as well as enhance the sustainable building concept in general. Although energy benchmarking and disclosure policies have been in place for almost a decade, the effect of those policies on the energy performance of existing buildings is still unknown. This study assessed the effectiveness of the policies by examining and comparing the energy performance patterns of existing buildings after the policies' adoption. The results of this study provide information concerning whether or not energy was saved, and precisely how much energy was saved.

In this chapter, a brief summary of the research literature related to the study topic is presented, and the relevant gap in knowledge leading to the need for the study is identified. In addition, the purpose of the study is further explained, and the research question and hypotheses are stated. The theoretical framework on which the study is based is identified, and the research design and methodology are briefly summarized. Furthermore, definitions of key terms are provided, and study assumptions and limitations are identified.

Background

Buildings around the world are responsible for 40% of global energy consumption; they consume one-fourth of global water, and as a key contributor to global carbon emissions they represent the source of one-third of global GHG emissions (UNEP-SBCI, 2014). The building sector in the United States is the largest single energy consumer in the nation. U.S. buildings represent the primary users of electric power; they account for around one-third of the nation's natural gas consumption (Energy Information Administration [EIA], 2015), and they are responsible for 36% of the nation's total GHG emissions that are related to climate change (Environmental Protection Agency [EPA], 2014). In many major U.S. cities that have a larger stock of old buildings, the building sector contributes up to 75% of GHG emissions (Institute for Market Transformation [IMT], 2013). Reducing the great impact of the building sector on the ecological system and thereby maintaining sustainability requires the reduction of existing buildings' energy consumption. Establishing proper energy governance methods and processes to improve the energy performance of existing buildings is critical for governments at all levels to meet their energy-saving and carbon-emission goals (Mattern, 2013). Improving the energy performance of existing buildings can provide a significant opportunity to save energy (UNEP-SBCI, 2014).

A variety of public policies were recently implemented in the United States and across the world to regulate the building industry and integrate energy efficiency within the building sector (Gruber et al., 2015; Mattern, 2013). Among these policies are the energy benchmarking and disclosure policies that were recently adopted by several states and local governments throughout the nation to emphasize sustainable urban development of U.S. centers. The policies focus on establishing an energy performance baseline to observe and track the energy performance of existing buildings over time and compare their average energy use to that of similar buildings (Cox et al., 2013; Hsu, 2014b). The policies also aim to tackle the issue of the energy-efficiency gap in the real estate market by creating reliable sources of standardized energy-efficiency data that will help building owners and managers to recognize energy-saving opportunities and encourage investments in energy-efficiency projects in the market (Cluett & Amann, 2013; Cox et al., 2013; Ma et al., 2012; Palmer & Walls, 2015). In addition to improving the energy performance of existing buildings, the policies have a wide range of benefits, including increased competition and market choice, job creation, and energy and cost savings (Palmer & Walls, 2015). Improving the energy performance of existing building stock allows cities to meet their energy-saving goals, cut their GHG emissions, and ultimately reduce the negative impact of the building sector on the environment (Cluett & Amann, 2013).

Problem Statement

There is a growing need to address the energy performance of the existing building stock in the United States. Currently, the building sector accounts for 41% of U.S. energy consumption and 36% of the nation's total GHG emissions, approximately half of which is attributed to the commercial building sector (EPA, 2014). Building codes and regulations set by many jurisdictions demand that new buildings achieve a minimum level of energy efficiency. However, it is very challenging to regulate and enforce energy retrofits to existing buildings, especially given that the average age of commercial buildings in the United States is 50 years (Commercial Building Inventory [CBI], 2012).

Recently, several major U.S. cities adopted policies mandating the energy benchmarking of commercial buildings and the disclosure of their annual energy use. Such policies aim to explain the energy use of commercial buildings, create reliable tools to measure the energy performance of existing buildings, and ultimately encourage energy efficient retrofits and upgrades by addressing information failures due to lack of reliable standardized energy-efficient consumption data in the real estate market (Cluett & Amann, 2013; Cox et al., 2013; Ma et al., 2012; Palmer & Walls, 2015). However, do these policies actually influence change in the energy performance of existing buildings?

Using a quantitative research approach, this study examined the influence of New York City's Benchmarking Law (LL84) on the energy performance of the city's existing commercial building stock by means of paired sample *t* tests to compare the means of the disclosed energy benchmarking information (energy performance indices) of NYC's existing commercial buildings over the past 6 years. The comparison made it possible to assess the influence of the adopted energy benchmarking policies on the energy performance of the existing building stock and provided an indicator of the effectiveness of the policies (Cox et al., 2013; Hsu, 2014; Kontokosta, 2013; Palmer & Walls, 2015).

Purpose of the Study

The purpose of this study was to quantitatively assess the influence of the energy benchmarking and disclosure policies on the energy performance of existing buildings. The study compared the energy performance patterns of NYC's existing commercial buildings over the past 6 years to examine the nature of the relationship between the policies and the energy performance of NYC's existing commercial buildings and determine whether the adoption of these policies is associated with improving the energy performance of the existing commercial building stock. Paired sample *t* tests were performed to compare the means of the annually disclosed energy benchmarking data (energy performance indices) between 2011 (the first year in which the NYC Benchmarking Law was enacted) and 2016 (the year for which energy benchmarking data were most recently disclosed). The study compared the annual energy performance pattern of existing commercial buildings in NYC and statistically evaluated the significance of the reductions in energy consumption during this period of time in order to assess the efficacy of the energy benchmarking and disclosure policies.

Research Question(s) and Hypotheses

This study examined whether annual energy benchmarking and disclosure of energy use data for existing commercial buildings influence their energy performance. The research question was as follows: Is there a statistically significant difference between the means of 2011 and 2016 energy benchmarking data?

Null Hypothesis 1: There is no statistically significant difference between the means of 2011 benchmarking data and 2016 data.

$$H_0: \mu_{2011} = \mu_{2016}$$

Alternative Hypothesis 1: There is a statistically significant difference between the means of 2011 benchmarking data and 2016 data.

$$H_1: \mu_{2011} \neq \mu_{2016}$$

where μ is the mean of the energy benchmarking data.

Theoretical Framework for the Study

The theoretical base of this study was the institutional analysis and development framework (IAD) developed by Elinor Ostrom (Sabatier & Wieble, 2014). The framework explains “how institutional rules alter the behavior of intendedly rational individuals motivated by material self-interest” (Sabatier, 1999, p. 8). This framework is based on the rational choice theory defined by Levin and Milgrom (2004) as the process of rationally weighing the available options in order to choose the most preferred choice based on certain criteria (gain/profit). The IAD framework can be used as a theoretical basis for examining individuals’ choices and their consequences within institutions. This framework involves the analysis of regular actors within the context of institutional interaction (Sabatier & Wieble, 2014). Based on the IAD framework, private sector building owners, operators, and prospective buyers consider disclosed energy benchmarking data to weigh the risks and rewards of their energy-efficient investment decisions. Thus, this theoretical framework allows for making choices—based on rational choice theory—to weigh benefits (e.g., future saving in running costs, higher occupancy rates, and property value) and limitations (e.g., initial cost of energy-efficient projects) in order to reach a decision that generates the most gains.

Nature of the Study

This quantitative study statistically analyzed the energy performance indices (the annually disclosed energy-use benchmarking data) of all existing commercial buildings that benchmarked in both 2011 and 2016 in the selected city (New York City, NY) and used paired sample *t* tests to compare the energy performance patterns of the city's existing commercial buildings over the past 6 years. This repeated measure design allowed to determine whether there was a statistically significant difference between the means of the paired observations — the annually measured energy performance indices between 2011 and 2016 that were publicly disclosed after implementing the energy benchmarking and disclosure policies (Frankfort-Nachmias & Nachmias, 2008). Hence, the detected differences in energy consumption rates between 2011 and 2016 records were assumed to be due to implementing the energy benchmarking policies. The broad scope of the study suggested the use of a quantitative approach to research to provide generalizable research findings (Creswell, 2009).

Definitions

Building energy use benchmarking: “A mechanism to measure energy performance of a single building over time, relative to other similar buildings, or to modeled simulations of a reference building built to a specific standard (such as an energy code)” (Office of Energy Efficiency and Renewable Energy [EERE], n.d., para. 1).

Energy disclosure: The process of releasing and reporting energy benchmarking information to another party—in most cases, to the government, prospective buyers, potential tenants, and/or lenders, and in some cases, to the public (IMT, 2016).

ENERGY STAR Portfolio Manager: “EPA's online energy management and tracking tool to measure and track energy and water consumption, as well as greenhouse gas emissions” (ENERGY STAR, 2016a, para. 1).

Energy use intensity (EUI): “The unit to express a building’s energy use as a function of its size or other characteristics. EUI is expressed as energy per square foot per year. It’s calculated by dividing the total energy consumed by the building in one year (measured in kBtu or GJ) by the total gross floor area of the building” (ENERGY STAR, 2016b, para. 2).

Site energy use intensity: “Energy use intensity as calculated by Portfolio Manager at the property site in kBtus per gross square foot (kBtu/ft^2), for the reporting year” (Benchmarking Data Disclosure Definitions, 2017, p. 2).

Weather normalized source energy use intensity: “Energy use intensity as calculated by Portfolio Manager at the source of energy generation in kBtus per gross square foot (kBtu/ft^2) for the reporting year, normalized for weather" (Benchmarking Data Disclosure Definitions, 2017, p. 2).

Total greenhouse gas emissions (GHG): "The total direct and indirect greenhouse gases emitted by the property, reported in metric tons of carbon dioxide equivalent (MtCO2e) for the reporting year" (Benchmarking Data Disclosure Definitions, 2017, p. 3).

Water use intensity (municipally supplied potable water—indoor intensity): "Total indoor water use at the property in gallons per square foot (gal/ft^2) for the reporting year" (Benchmarking Data Disclosure Definitions, 2017, p. 3).

ENERGY STAR scores: "1 to 100 percentiles ranking for specified building types, calculated in Portfolio Manager, based on self-reported energy usage for the reporting year" (Benchmarking Data Disclosure Definitions, 2016, p. 2).

Assumptions

This study is based on the assumption that energy use data annually reported to the NYC Mayor's Office of Sustainability are accurate and reliable, as the information disclosure is based on automated upload of energy use data through EPA's Portfolio Manager (NYC Mayor's Office of Sustainability, 2017).

Scope and Delimitations

This study was confined to existing commercial buildings located in New York City, NY. That geographical area was chosen for two reasons. First, NYC was among the first cities to implement energy benchmarking and disclosure policies in December 2009—a year after Washington, DC and Austin, TX—did so, which indicates the availability of sufficient data for the study. Second, NYC is the largest urban center in the United States, with the highest concentration of commercial office buildings nationwide (IMT, 2016). The total gross floor area covered by the NYC Benchmarking Law of 2.8 billion ft^2 presents more than 25% of the 10.7 billion ft^2 covered by all of the energy benchmarking and disclosure policies adopted nationwide (IMT, 2017). The large sample size enhanced the external validity of the research findings and the validity of the statistical inferences.

This study was further confined to existing commercial buildings with floor areas of 50,000 ft^2 or more, because the American urban landscape is highly dominated by commercial buildings that are responsible for 20% of U.S. energy consumption—approximately half of the energy consumed by the building sector (EIA, 2016). Excluded from the study were smaller buildings with floor area less than 50,000 ft^2, as the policy was not applied to commercial buildings with 25,000 ft^2 until 2017 (NYC Benchmarking Law LL84, 2016). In addition, newer commercial buildings—those built after 2011—were also excluded due to the requirements of the paired sample *t* test.

Finally, the current study was limited to the period from 2011 to 2016. This time frame was selected because it was in 2011 that the NYC Benchmarking Law (LL84) became effective, and 2016 energy benchmarking data were the most recent publicly reported data. As the study was limited to NYC, it is not possible to generalize the results of this study to other cities or municipalities; however, other cities may find this kind of analysis useful.

Limitations

A potential limitation of this study is that no cause-and-effect inferences can be made, as the paired sample *t* test does not imply causality (Ross & Willson, 2017). Only the difference between the mean of energy consumed by NYC's existing commercial buildings between 2011 and 2016 and the direction of change were signified, with no automatic indication of cause and effect. The research findings measured the changes in energy performance patterns of the benchmarked buildings after the implementation of the energy benchmarking and disclosure policies. Another potential threat to the internal validity of the study is the possibility that factors other than the policy implementation are also associated with the energy performance of NYC commercial buildings—such as changes in occupant behavior, occupancy levels, and operation management. Furthermore, despite the large sample size, there is a potential threat to external validity due to the geographical limitation of the study to one site (NYC).

Significance

This study contributed to the emerging field of research about sustainable building that aims to reduce the negative impact of the built environment on the earth's ecological system. The study assessed the influence of NYC Local Law 84 on existing building owners' decisions to retrofit in order to improve the energy performance of their buildings (Cluett & Amann, , 2013). The results of this research filled the gap in the literature and provided initial information about the efficacy of the benchmarking and disclosure policies in addressing the issue of information failures due to lack of reliable, standardized energy-efficient consumption data to be incorporated into property values in the private building sector (Hsu, 2014). Furthermore, the study findings offer existing building owner/operators a constant scale to measure operations and maintenance in an effort to maximize the operational efficiency of buildings by investigating the benefits of understanding energy-use patterns in commercial buildings (Cox et al., 2013). This study provides information about the role of information in predicting future savings in operation and maintenance costs (running costs) based on actual disclosed energy data (Hsu, 2014). This study may further positive social change by contributing to a culture of sustainability through initial awareness of changes over the study period. It is hoped that the study will raise general awareness regarding the benefits of energy-efficiency investments, will encourage energy-efficient upgrades, and will promote greater understanding of sustainable building concepts. Such change may strengthen the commitment to the notion of sustainable development and inspire policy makers to encourage innovations that further reduce the environmental footprint of the building industry by reducing energy consumption and encouraging more efficient use of materials.

Summary

The American urban landscape is highly dominated by commercial buildings. The energy performance of existing commercial buildings significantly contributes to national energy demands and GHG emissions, in addition to negatively impacting the urban air quality of U.S. cities. The energy benchmarking and disclosure policies recently adopted by several states and local governments aim to provide reliable sources of standardized energy-efficiency data as an energy performance baseline to observe and track the energy performance of existing buildings over time and tackle the issue of energy-efficiency gaps in the real estate market (Hsu, 2014a). Due to the recent implementation of energy benchmarking and disclosure policies and the limited research in this field, the efficiency of these policies is still unknown. The purpose of this quantitative study was to assess the influence of energy benchmarking and disclosure policies on the energy performance of NYC's existing commercial buildings and determine whether the adoption of these policies is associated with improving the energy performance of the city's existing commercial building stock. The study was based on the IAD framework. Data collection consisted of obtaining NYC's energy benchmarking data that had been publicly disclosed on the NYC Mayor's Office of Sustainability website for the past 6 years. The data were statistically analyzed using repeated measure *t* tests to assess the efficacy of the energy benchmarking and disclosure policies. A detailed review of relevant literature that explains the connection between the energy performance of existing buildings and the implementation of energy benchmarking and disclosure policies in the current scholarly literature is presented in Chapter 2.

Chapter 2: Literature Review

Introduction

The energy performance of existing buildings impacts current energy use patterns and will dominate future energy demands due to the long lifespan of buildings. Efficiently managing the energy consumption of existing building stock requires measuring the energy consumption of existing buildings and providing reliable information about future energy savings (Hsu, 2014b). Energy benchmarking and disclosure policies have been implemented to explain the energy use of commercial buildings, create reliable tools to measure the energy performance of existing buildings, and ultimately encourage energy-efficient retrofits and upgrades by addressing information failures, also referred to as the *energy efficiency gap*, due to lack of reliable, standardized energy-efficient consumption data in the real estate market (Cluett & Amann, 2013; Cox et al., 2013; Ma et al., 2012; Palmer & Walls, 2015). Using a quantitative research approach, this study examined the influence of NYC Benchmarking Law LL84 on the energy performance of the city's existing commercial building stock by paired sample *t* tests to compare the means of the disclosed energy benchmarking information (energy performance indices) of NYC's existing commercial buildings over the past 6 years. The comparison allowed me to assess the influence of the adopted energy benchmarking policies on the energy performance of the existing building stock and provided an indicator of the effectiveness of the policies (Cox et al., 2013; Hsu, 2014; Kontokosta, 2013; Palmer & Walls, 2015).

Literature Search Strategy

Due to the interdisciplinary nature of the sustainable building issue—which has environmental, economic, and social aspects—the literature review was based on searching multidisciplinary research databases. The databases and/or scholarly resources searched for the literature review included ProQuest Central, ScienceDirect, Political Science Complete, Academic Search Complete, and Google Scholar. Combinations of the following key search terms relevant to the research topic were used to retrieve articles: *energy benchmarking*, *disclosure policies*, *energy governance*, *urban sustainability*, *energy efficiency*, *commercial buildings*, *information failures*, *building energy performance*, *ENERGY STAR*, and *policy implementation.*

Through the process of the literature review, I performed a comprehensive search of all available evidence in scholarly sources (such as peer-reviewed and indexed journal literature), covering recent research about the topic of energy benchmarking policies and the disclosure of benchmarking information. Moreover, I reviewed a variety of annually released government reports that analyzed disclosed energy benchmark data such as the NYC Mayor’s Office of Sustainability building energy benchmarking data analysis reports, Seattle’s building energy benchmarking analysis report, and IMT building energy performance policy factsheets. Additionally, I searched websites of government agencies with statistical records on the energy performance of buildings, including the U.S. Department of Energy (DOE), the EIA, and the EPA.

Institutional Analysis and Development Framework

The IAD framework—originally developed by Ostrom in the 1980s—was used as a foundation for this study. The framework explains "how institutional rules alter the behavior of intendedly rational individuals motivated by material self-interest." (Sabatier, 1999, p. 8). The framework questions the need for government regulation to manage common resources, given that people can collaborate across institutional and state boundaries to manage public resources, share benefits, and reach sustainability (Ostrom, 2005). The IAD framework offers a systematic approach to organizing policy analysis actions using a wide range of analytic techniques that are applicable to both physical and social sciences. Policymakers apply the framework to analyze and manage complex policy situations in order to achieve desired policy outcomes and avoid policy failures due to oversight and simplification (Ostrom et al., 2014).

Crothers (2010) defined the framework as

> a general language for analyzing and testing hypotheses about behavior in diverse situations at multiple levels of analysis … [that] concerns analyses of how rules, physical and material conditions, and attributes of community affect the structure of the action arenas, the incentives that the individuals face, and the resulting outcomes. (p. 261)

Based on this definition, the schematic representation of the IAD framework in Figure 1 serves as a conceptual map for the analysis of situations (action arena) in which users of common resources (actors) reach agreement (based on rules-in-use) to attain sustainability of common resources (outcomes) without state intervention to control the actors' behavior. On the other side, the action arena, the actors' behavior and the potential outcomes are highly influenced by a set of external variables that include material conditions (biophysical characteristics), community culture (attributes of the community), and rules-in-use (Ostrom, 2005). Accordingly, the action situation, the actors' patterns of interactions, and the potential outcomes are key aspects of the framework that allow the analyst to understand how the actors interact based on incentives and to evaluate potential outcomes of the interaction.

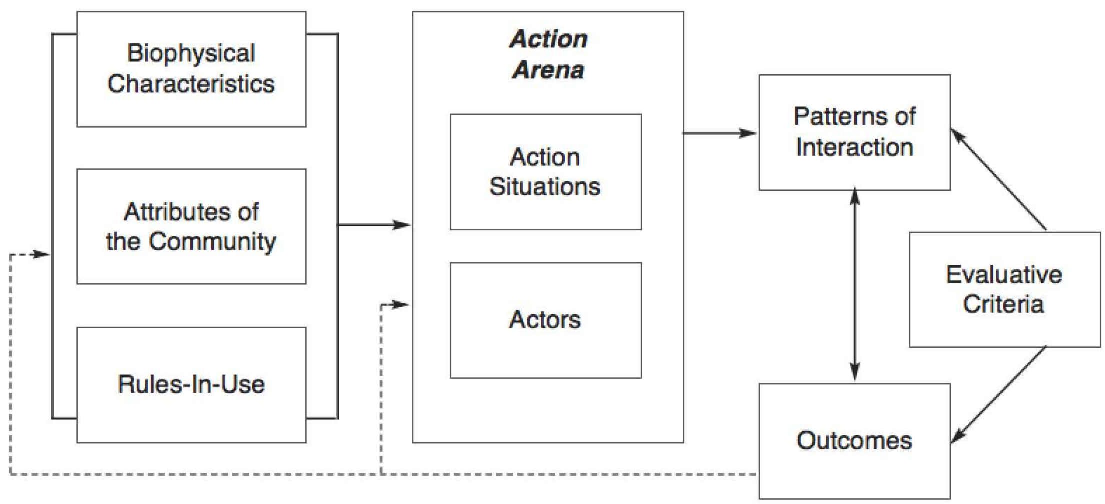


Figure 1. Institutional analysis and development (IAD) framework. From *Understanding Institutional Diversity* (p. 15), by E. Ostrom, 2005, Princeton, NJ: Princeton University Press.

This framework is based on rational choice theory, as defined by Levin and Milgrom (2004), who posited that individuals engage in a process of rationally weighing available options in order to choose the most preferred option based on certain criteria (gain/profit). According to this theory, human behavior is adaptive. Although individuals tend to compare and weigh benefits and costs, their personal values and social development also affect their rational choices. The focus of the IAD framework—based on rational choice theory—is explaining the influence of institutional rules in altering the rational behavior of actors when they seek personal goals based on their self-interest. It also allows recognition of the conditions that must be met in order for the actors to address the issue(s) without state intervention and provides empirical examples of this process (Ostrom, 2005). Within this context, individuals make their decisions based on offered incentives, although their analysis should be based on the whole situation structure and not limited to the individual behavior model. Accordingly, the IAD framework can be used as theoretical basis for examining individuals' choices and consequences within institutions, as this framework involves the analysis of regular actors within the context of institutional interaction, in terms of the cost of the actions and benefits of their outcomes (Sabatier & Wieble, 2014). When the IAD framework is applied to policy analysis, a comprehensive, thorough, and precise analysis of all aspects related to the specific policy problem is necessary to address the policy issue and successfully solve the problem. The multiple disciplinary perspectives required by this frame ensure a better understanding of the situation and provide a basis for building consensus among actors, which can lead to developing more effective policy solutions.

Based on the IAD framework, private sector building owners, operator,s and prospective buyers may consider the disclosed energy benchmarking data to weigh the risks and rewards of their energy-efficient investment decisions. This theoretical framework allows for making choices—based on rational choice theory—to weigh benefits (e.g., future saving in running costs, higher occupancy rates, and higher property values) and limitations (e.g., initial cost of energy-efficient projects) in order to reach decisions that generate the most gains. The IAD framework helps to identify the influence of energy benchmarking and disclosure policies on individuals' rational decisions as a democratic way to solve problems by changing the rules employed by participants at different levels of the institution.

The Energy Performance of the U.S. Building Sector

Energy around the world is primarily consumed by three major sectors: the building sector, the industrial sector, and transportation (EIA, 2016). According to the IEA, the building sector (including both residential and commercial sectors) is considered the largest energy consumer and is estimated to account for over 30% of the total energy consumed worldwide, 19% of which is consumed by the United States, which is the second highest energy consumer in the world after China (IEA, 2015).

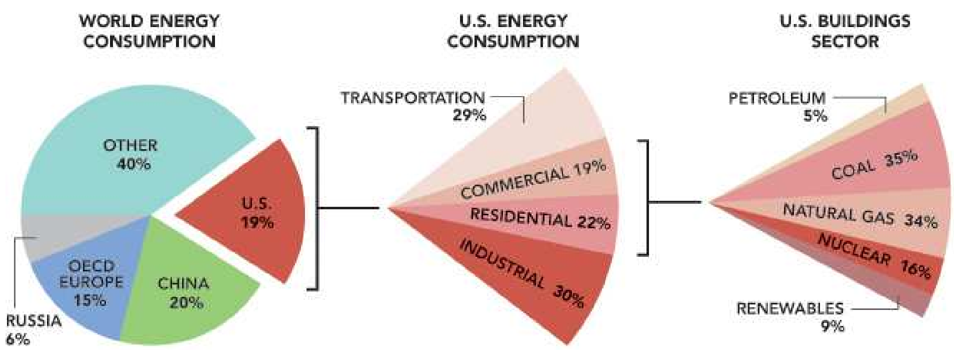


Figure 2. Building sector energy consumption. From *Buildings Energy Data Book* (p. 22), by U.S. Department of Energy, 2011, Washington, DC: Author (http://buildingsdatabook.eren.doe.gov).

The IMT (2016) has ranked the building sector as the largest single energy consumer in the United States. It is responsible for 41% of the country's energy consumption (more than the industrial and transportation sectors) and 7% of the world's overall energy consumption (DOE, 2012). Furthermore, U.S. buildings account for 38% of the nation's total GHG emissions that are related to climate change, while at the global level, the total contribution of the building sector is only 8% of global GHG emissions (EPA, 2014). In many major cities in the United States with a larger stock of older buildings, the building sector contributes up to 75% of GHG emissions (IMT, 2016).

Figure 3. Percentage of total carbon emissions from building sector. From "Building Energy Benchmarking and Disclosure in U.S. Cities," by Institute for Market Transformation, 2014 (http://www.imt.org). Copyright 2014 by Institute for Market Transformation. Used with permission.

The Energy Performance of Existing Commercial Buildings in the United States

Burr et al. (2011), Cox et al. (2013), Hsu (2014a), and Mattern (2013) described the negative environmental impact of the U.S. building sector and its energy consumption rates in general and of existing commercial building stock in particular, including existing buildings' contribution to GHG emissions related to climate change. According to the IEA (2015), the U.S. commercial building sector represents a large portion of the nation's economic activity and is considered the largest energy consumer in the world based on average per-capita income. At the national level, commercial buildings consume approximately 20% of U.S. energy—about half of the energy consumed by the building sector (EIA, 2016). The EIA (2016) has estimated that 72% of U.S. commercial buildings have existed for more than 20 years. Thus, a large portion of the commercial buildings were built before current energy codes and regulations were adopted.

Gruber et al. (2015) and Mattern (2013) indicated that the energy consumption of the existing building stock exceeds actual needs, noting that existing buildings are responsible for a substantial portion of the energy consumed by the commercial building sector. Furthermore, Cox et al. (2013) noted that the energy performance of existing buildings significantly impacts the urban air quality of U.S. cities. Lowering the energy consumption of the existing building stock could play a crucial role in reducing GHG emissions, minimizing the negative impact of the building sector on the environment, and eventually slowing climate change trends.

Hsu (2014a) argued that lack of reliable energy use information and misalliances of the financial incentives have deterred existing buildings' owners from investing in energy-efficiency retrofits. Efficient-energy policy measures are necessary to improve the energy performance of the existing building sector. Cox et al. (2013), Hsu (2014a), and Mattern (2013) agreed that a regulatory approach based on mandatory energy disclosing and benchmarking policies is critical to promote the concept of energy-efficient building, to reduce GHG emissions, and to maintain urban sustainability for U.S. cities.

Public Policies to Enhance Energy Efficiency in Existing Buildings

The publication of the Brundtland Commission Report *Our Common Future* in 1987 marked the starting point for the sustainable building movement and the association of sustainability with building processes and practices (including design, construction, and operation processes). The sustainable building movement focused on fostering the concept of sustainability within the context of the built environment, which was defined within the Brundtland Commission Report as “meeting today’s needs without compromising the ability of future generations to meet their needs” (World Commission on Environment and Development, 1987). Since then, the sustainable building movement has been further enhanced by a variety of public policies that tend to integrate energy efficiency within the building sector. Such governmental efforts have helped to regulate the building industry and have encouraged the incorporation of many innovative energy-efficient solutions into construction practices and building operations (Gruber et al., 2015; Mattern, 2013). Allcott and Greenstone (2012) indicated that the appropriate implementation of energy conservation policies—using a holistic approach to address the issue of energy efficiency gaps—could reduce projected energy demand in the United States by up to 23% by 2020. However, in order for states, cities, and municipalities to meet their energy-saving goals and lower their GHG emissions, it is crucial for these energy governance efforts to improve the energy performance of existing building stock (Northeast Energy Efficiency Partnerships, 2013). Among these policies are energy benchmarking and disclosure policies that were recently adopted by several state and local governments throughout the nation to emphasize sustainable urban development of

U.S. centers. According to Cluett and Amann (2013), Cox et al. (2013), Ma et al. (2012), and Palmer and Walls (2015), the policies aim to value energy efficiency in the real estate market by mandating the disclosure of energy usage information for existing buildings to the government, potential buyers, tenants, and, in some cases, the public.

Energy Benchmarking and Disclosure Policies

Energy benchmarking of commercial buildings is a regulatory approach that has been adopted by numerous U.S. cities over the past decade to understand the energy use patterns of existing buildings (Burr et al., 2011; Cox et al. 2013; Hsu, 2014a; Mattern 2013). Kaskhedikar et al. (2015), defined energy benchmarking of buildings as "the process of comparing and ranking the energy performance of a particular building against a distribution of buildings (along with their energy systems) with similar features" (p. 17). Energy benchmarking of buildings involves measuring and comparing energy efficiency between similar buildings by creating standardized metrics (Mattern, 2013). Cluett and Amann (2013) addressed the role of energy benchmarking and disclosure policies in integrating energy efficiency within the building industry and regulating the existing building sector. Hsu (2014b) explained how the policies aim to generate the information necessary to encourage energy efficiency upgrades within the existing building sector and improve the valuation of energy-efficient buildings in the real estate market. Cox et al., (2013) indicated that benchmarking can create a baseline accessible to building owners, prospective buyers, tenants, and utilities to compare the energy consumption data of benchmarked buildings. This allows the owners and occupants to understand the energy performance of their buildings and recognize opportunities to reduce energy waste (Cluett & Amann, 2013).

On the other hand, *disclosure* refers to the process of releasing and reporting the energy benchmarking information to another party – in most cases to the government, Prospective buyers, potential tenants, lenders, and in some cases to the public, (Cox et al., 2013; Hsu, 2014a). Florini and Saleem (2011) considered the disclosure of energy benchmarking data as an effective tool of energy governance that can either be voluntarily or mandatorily based on policy requirements. Cluett and Amann (2013) explained how the disclosure of benchmarking information can provide prospective buyers and potential tenants the information necessary to consider energy efficiency when making their decision to buy or rent.

Energy Benchmarking to Address Information Failures

Cox et al. (2013) recognized the role of the energy benchmarking and disclosure policies in addressing the various information failures in the real estate market due to the lack of reliable standardized energy efficient consumption data. Some of the major information failures that affect the commercial building sector are:

- *Information asymmetry*: This refers to the lack or inaccuracy of the energy efficiency information that causes the energy efficiency gap in the real estate market (Palmer & walls, 2015). Unlike buildings owners and/or managers, the prospective buyers and tenants have limited knowledge about the energy performance of the buildings that can lead to inefficient transactions within the real estate market (Cox et al., 2013; Florini & Saleem, 2011).

- *Principal-agent problems*: The nature of the commercial building sector provides limited incentive for the buildings' owners to invest in energy efficient projects. Cox et al. (2013) explained that the occupants/tenants (principal) always bear the consequences of the decisions made by the agent (architect, engineer, builder and/or the owner/landlord), as they make the decision regarding the equipment, duct systems, windows, appliances, and lighting fixtures while the future tenants/occupants pay the energy bills. However, when investing in energy efficiency projects the principal (occupants and/or prospective buyers) will share the benefits from the investment with the agent (Palmer &Walls, 2015).
- *Misleading research directions*: The energy performance of the existing commercial buildings is directly affected by how the building equipment is operated. Considering that the energy usage in commercial buildings represents approximately 30% of the operating costs, it becomes appealing for many existing buildings' owners to consider energy efficient investments to reduce their operating costs (Palmer &Walls, 2015). However, the cost of energy efficient equipment is far higher than the discount rates theoretically anticipated by research and there is not enough information to make informed decisions for such risky investments. The uncertainty about energy savings led to limited investment in energy efficient projects in the existing commercial building sector (Allcott & Greenstone, 2012).

- *Rational intentions*: Buyers tend to pay less attention to energy efficiency attributes due to the lack of energy efficiency information and the complexity of the real estate transactions and contracts. This causes inattentiveness to the energy efficiency qualities in the real estate market, (Allcott & Greenstone, 2012; Palmer &Walls, 2015).

Kontokosta (2015) argued that the uncertainty surrounding the energy performance measures and the complexity of accurately comparing relative energy performance led to the confusion around measuring energy efficiency in existing buildings. Energy benchmarking and disclosure policies can establish a reliable source of standardized energy performance information that is required as a baseline to address the information failures discussed above and alleviate the energy efficiency gap issues related to the commercial building sector. In addition, Cox et al. (2013) suggested that in order to provide accurate measures of the existing buildings energy performance, the benchmarking methodologies need to adequately model the actual patterns of energy consumption.

The Benefits of Energy Benchmarking and Disclosure Policies

Florini and Saleem (2011) emphasized the role of the energy information flow for successful energy governance processes and robust policy development. Based on a recent analysis by the U.S. Environmental Protection Agency, a 7% saving in energy consumption can be attained over 3 years period among benchmarked buildings, (EPA, 2015). The energy benchmarking and disclosure programs primarily aim to explain the energy use of the commercial buildings, create reliable tools to measure the energy performance of existing buildings, and ultimately encourage energy efficient retrofits and upgrades, (Cluett & Amann, 2013; Ma et al., 2012; Palmer & Walls, 2015). However, the appropriate implementation of the policies can have a great influence on the energy performance of the existing buildings and may motivate energy efficiency improvements in many ways:

- The policies can help improve energy management. According to the Institute of Market Transformation, in order to properly manage the energy performance of existing buildings, it is crucial to measure the energy efficiency of buildings (IMT, 2015). Besides tracking the buildings' energy usage patterns, comparing their energy performance with other similar buildings, and monitoring energy performance over time, Cox et al. (2013) indicated that energy benchmarking and disclosure programs can establish an energy performance baseline to recognize the energy efficiency opportunities, and verify the projected savings in energy cost. Furthermore, Palmer and Walls (2015) noted the benchmarking of energy use against other buildings might reinforce the "peer effects" among tenants and operators, thus motivate them to reduce energy consumption, (p. 9).
- Such energy policies can further boost market transparency. Hsu (2014a) discussed how the public disclosure of the benchmarking information enhances the transparency of the real estate market, drives competition and increases the demand for energy efficient buildings. This can allow building owners, buyers, and investors compare the energy performance of buildings,

predict their energy costs, and invest in energy efficient buildings – with lower energy bills. In addition, it empowers building tenants and operators to save energy and lower their utility bills (Palmer &Walls, 2015).

- Due to the growing awareness and increased demands for energy efficient buildings, new job opportunities can be created for businesses in the fields related to construction, engineering, design, energy assessment, and property management (IMT, 2015). Palmer and Walls (2015) also highlighted the technological advances and the related development in energy data analytics businesses that might further boost the energy efficiency movements within the building sector.
- Florini and Saleem (2011) argued that the policies – as a form of energy information provision - can help local governments better understand the energy performance of their building stock. This can allow policymakers to develop more effective energy policies and incentive programs to further minimize energy consumption and cost.

Energy Benchmarking and Disclosure Processes and Tools

According to Palmers and wall (2015) most benchmarking laws demand the annual reporting of the buildings energy use data (including natural gas, electricity, and in some cases water usage). Building owners are typically required to gather the energy usage data of their buildings (from the monthly utility bills), then report them together with some basic information about the buildings (such as size, location, age, number of occupants, number and type of equipment, etc.) to the U.S. Environmental Protection

Agency's ENERGY STAR Portfolio Manager website (ESPM) (Hsu, 2014a; Kontokosta, 2014). Hsu (2014a) also pointed out that the gathered energy information can either be benchmarked based on the buildings total energy use or their energy use intensity (EUI) in order to understand how the buildings energy consumption measures up against similar buildings nationwide.

ENERGY STAR Portfolio Manager Benchmarking Tool

While there are a number of tools that are used for energy benchmarking across the country and around the world, the primary energy management tool most widely used to benchmark the energy use of the existing buildings in the U.S. is the ESPM program. This is a free web-based energy benchmarking tool developed by the U.S. Environmental Protection Agency (EPA) in 1999, (ENERGY STAR, 2016a). The program is used to carry out energy benchmarking by the real estate industry, governments, and businesses. The software provides a numeric energy rating for the buildings with a score range between 1 and 100. The assigned score for each building is based on the ratio of the actual energy usage of the building compared to the model predicted energy use (Palmer & Walls, 2015). The resulting ratio per square foot is then compared to the typical ratio of the similar buildings, which was initially taken from a nationally representative building sample of the same type (Mattern, 2013). A score of 50 represents the median energy performance among the specific buildings type. While, a score higher than 50 indicates better energy performance (lower energy consumption rate). Buildings with an ENERGY STAR (ES) score of 75 and above are eligible to receive the ENERGY STAR certification, (ENERGY STAR, 2016a).

The score assesses how buildings are performing as a whole - based on actual, measured data about their assets, their operations, their use, physical characteristics, energy data, and how the people inside use the buildings – by comparing their performance to other buildings nationwide that have the same primary use. In order to calculate the Energy Star score, the scale algorithm estimates how much energy the building would use if it were the best performing, the worst performing, and every level in between based on data entered about the building design and occupants – such as its size, location, number of occupants, number and type of equipment, etc. (Palmer & Wall, 2015). Then the scale compares the building's actual energy data to the estimate and determines the building's ES rating, which indicates the building rank relative to its peers (ENERGY STAR, 2016a). The ESPM software benchmark the energy performance of the buildings based on their energy use intensity (EUI). This is a widely used standard measuring unit/index that **"**expresses a building's energy use as a function of its size or other characteristics"**.** EUI is "expressed as energy per square foot per year"- measured in $kWh/ft^2/yr$ or $Btu/ft^2/yr$. "It's calculated by dividing the total energy consumed by the building in one year (measured in kBtu or GJ) by the total gross floor area of the building", (ENERGY STAR, 2016b, para. 2). EUI tends to analyze the energy performance of buildings by "normalizing" the buildings energy use in relation to their floor area (square footage), (Kaskhedikar et al., 2015, p. 17).

For each type of building covered by ES performance rating, EPA goes through a rigorous process to ensure the quality and quantity of the data to support an ES score. This is done by "creating a statistical regression model that correlates the energy data to the property use details to identify the key drivers of energy use, then testing the model against thousands of buildings in Portfolio Manager" (ENERGY STAR Certification., n.d.). Despite the sophistication and comprehensiveness of the building and energy use data on which the ENERGY STAR tool based, several studies criticized the data sources of this tool and its scoring methodology. The critique offered by Hsu (2014b) highlighted that the data used by the ESPM tool is more than 10 years old. The data sources of the ESPM tool should be updated every five years – using the data collected through surveys performed by the Commercial Buildings Energy Consumption Survey (CBECS) and the Residential Energy Consumption Survey (RECS) - however, the currently used data was collected back in 2003 due to the sampling errors in the 2010 survey data. Additionally, Palmers and wall (2015) questioned the robustness of the Energy Star rating scale due to the sample distribution limitations that may affect the reliability of the tool within the local contexts. Kaskhedikar et al. (2015) highlighted the poor statistical significance of the correlation between the energy use and the various building characteristics used by the ESPM to model the energy performance of buildings. Kaskhedikar et al. (2015) also questioned the "accuracy and completeness" of the CBECS database, (p. 17). On the other hand, Scofield (2013) questioned the reliability of the ESPM benchmarking tool and the validity of its scores. Kontokosta (2015) referred the failure of the ESPM to its reliance on the energy use intensity (EUI) to measure the energy performance of buildings. He claimed that the EUI failed to explain the disparities among the physical and occupancy characteristics of the buildings when measuring the energy performance of buildings. Kontokosta (2015) also recommended developing specific benchmarking metrics for each city based on its local building data to achieve better results.

Timing and Extent of Disclosure

Energy disclosure is considered as an efficient policy tool to enhance energy efficiency in buildings (Kontokosta, 2013). Cluett and Amann (2013) pointed out the disclosure of benchmarking information helps to provide prospective buyers and potential tenants the information necessary to consider energy efficiency when making their decision to buy or rent. Within this context, Florini and Saleem (2011) assessed the efficiency of the currently used information disclosure mechanisms – including voluntary disclosure of energy data, mechanisms that involves users of information as the drivers of change, and disclosure mechanisms that based on engaging wide networks of information holders to change energy use behavior. These disclosure mechanisms can be considered as forms of regulation as well as tools of energy governance that are based on self-regulatory and more voluntary basis. Additionally, governmental transparency is critical for the effectiveness of the disclosure policies. The disclosure policies often specify the timing and extent for disclosing the benchmarking information. These policies primarily fall under two categories, triggered disclosure and scheduled disclosure. Florini and Saleem (2011) referred to the required disclosure of the energy benchmarking data at the time of selling, renting, or financing the property as triggered disclosure of the benchmarking information. Kontokosta (2013) explained the role of triggered disclosure in enhancing the real estate market valuation of the energy efficiency of buildings by helping potential buyers, tenants, and lenders understand the energy performance of the buildings they consider to buy, rent, or finance. On the other side, the scheduled disclosure refers to the regular disclosure of energy benchmarking data (typically on annual basis) to the local government, owner, tenant, and in some cases to the public (Kontokosta, 2013). Hsu (2014a) added that scheduled disclosure tends to boost and encourage energy efficiency improvements, as it provides the existing buildings owners and managers with the standardized energy information they need to make informed decisions about their future energy efficiency investments. In all cases the benchmarked data is required to be reported to the local government in order to further analyze the quality of the disclosed data (Palmer & Walls, 2015). Some localities require the disclosed data to be accessible to the public - on a public website (such as the cities of New York and San Francisco). In other cases (such as the cities of Austin and Seattle) the access to the disclosed data is limited only to prospective buyers and potential tenants during the time of transaction (Hsu, 2014a). General information about the energy use patterns of the existing buildings in each city can also be found in the annually governmental published reports.

Energy Benchmarking and Disclosure Policy Implementation

California was the first state to introduce the energy benchmarking and disclosure policies in 2007 mandating the rating and disclosure of the commercial building energy information at the time of sale, lease, and during financing transaction. The state of Washington implemented a similar approach in 2009 (CBEI, 2014). At the local level, 20 major cities adopted their own benchmarking and disclosure policies over the past decade. Washington, DC was the first city to pass energy benchmarking and disclosure initiatives in 2008, followed by Austin, Texas, later that year. A year later in December 2009 New York City enacted a benchmarking and disclosure law. Next to adopt the policies were Seattle, Washington in 2010 and San Francisco, California in 2011 in the West Coast region. Then, the cities of Philadelphia, Minneapolis, Boston, Chicago, Cambridge, Berkeley, Portland, and Kansas City followed between May 2012 and June 2015 in addition to Montgomery County, Maryland – the only county nationwide to adopt benchmarking ordinance of its own in early 2014 (IMT, 2015). Additional cities adopted similar benchmarking policies recently, including Atlanta, Denver, boulder, Orlando, Pittsburg, and Evanston. The policies require energy usage benchmarking for buildings - including municipal, commercial, and multifamily buildings – with threshold size of 10,000–50,000 ft^2 and larger (IMT, 2015). In addition to the benchmarking and disclosure of the energy data, some policies (such as the cities of Austin, New York, and San Francisco) also require conducting comprehensive energy efficiency audits to be performed by engineers licensed by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) (Palmer & Walls, 2015). Mattern (2013) emphasized the importance of coordinating among state regulators and local utility companies, in order to address the complex issues of energy regulation and benchmarking at all levels of governance – local, state, and federal levels. Nelson et al. (2015) explained that developing appropriate mechanisms to coordinate policies can enhance independence among jurisdictions and avoid policy conflicts.

Energy Benchmarking and Disclosure in New York City

NYC is among the leading municipalities to adopt benchmarking and disclosure policies. NYC Local Law 84: Benchmarking (LL84) was passed by New York City Council in 2009 (NYC Benchmarking Law LL84, 2009; City of New York, 2012). The law is based on the goals set by NYC to reduce GHG emissions 80% by 2050 and the energy efficiency policy efforts set by the Greener, Greater Buildings Plan (GGBP) to enhance the energy efficiency in large existing buildings by providing a reliable source of energy information to the city's policy makers to pursue cost-effective energy efficiency measures (Urban Green Council, 2017). NYC Benchmarking Law, which administered by NYC Mayor's Office of Sustainability, requires owners of privately-owned properties with single large buildings over 50,000 ft² or multiple buildings with combined floor area over 100,000 ft² (including non-residential and multifamily buildings) to annually measure and report energy and water use data to the city through EPA's ENERGY STAR Portfolio Manager in order to fulfill the requirements of NYC Benchmarking Law. The law was enacted in December 2009; however, the first compliance deadline for privately-owned buildings was in August 2011. According to 2016 amended LL84, beginning 2018 the list of properties required to benchmarked for energy and water efficiency is expanded to include mid-size buildings over 25,000 ft² (NYC Benchmarking Law LL84, 2016).

The law also mandates the public disclosure of the benchmarking data through NYC Office of Sustainability website. The annually collected benchmarking data is typically analyzed, and the analysis results are published in reports and visually presented in “NYC Energy and Water Performance Map” that developed by NYC Mayor’s Office of Sustainability and New York University’s Center for Urban Science and Progress (NYC Mayor’s Office of Sustainability, 2018). The publicly disclosed data also helped to develop energy efficiency policies and provided the tools and resources necessary to help building owners reduce their energy consumption and cost (Urban Green Council, 2017).

The annual reports issued by NYC Mayor’s Office of Sustainability indicates that relatively high compliance rates with LL84 were achieved throughout the past six years. When the law was initially enacted in 2011, approximately 64% of the properties covered by the law complied with the benchmarking requirements by August 31 deadline. However, the compliance rate reached approximately 75% when the deadline was extended to December 31, 2011 (City of New York, 2012). The percentage of compliance increased to reach 84% in 2012 (City of New York, 2014). By 2015, more than 90% of the privately-owned properties complied with the benchmarking law requirement (Urban Green Council, 2017). More than 4,000 commercial buildings were benchmarked at first year of the law enactment with square footage of 670 million ft^2 (City of New York, 2012). More than 700 million ft^2 of commercial buildings were benchmarked in 2015 (Urban Green Council, 2017). According to the Institute for Market Transformation, the total gross floor area covered by NYC Benchmarking Law of 2.8 billion ft^2 presents more than 25% of the 10.7 billion ft^2 covered by all the energy benchmarking and disclosure policies adopted nationwide (IMT, 2017).

Summary and Conclusion

Over the past decade, the policies that involve the benchmarking and disclosure of the existing building stock energy data have been passed by two states, one county, and 20 major U.S. cities (Palmer & Walls, 2015). The benchmarking and disclosure policies aim to measure the energy use of the existing buildings to be compared to the average energy use of similar buildings. Cluett and Amann (2013) indicated that these polices allow the owners and occupants to understand the energy performance of their buildings and recognize the opportunities to reduce energy waste. Furthermore, Mattern (2013) explained how the energy benchmarking can create a baseline accessible to building owners, prospective buyers, tenants, and utilities to observe and track the energy performance of buildings over time, as well as compare the energy consumption data of benchmarked buildings to similar buildings in the market. Providing reasonable and convenient access to reliable standardized energy performance information is crucial to value the energy performance of buildings in the real estate market (Cox et al., 2013). The policies enhance market transparency and allow stakeholders to make informed energy efficiency investment decisions (Palmer &Walls, 2015). The appropriate implementation of energy benchmarking and disclosure policies allows policymakers to develop more effective energy policies and incentive programs to further minimize energy consumption and cost (Florini & Saleem, 2011). In addition to improving the energy performance of the existing buildings, the policies serve a wide range of benefits including increased competition and market choice, job creation, and energy and cost savings (Bergh, 2013b).

Most of the currently implemented policies involving the benchmarking and disclosure of the energy use information of existing buildings were adopted during the period between 2008 and 2014. Hence, this is considered as a new field of study, and therefore a lot of research is still needed in the field in order to determine the influence of these policies on the energy performance of the existing building stock. The common trend in this field of research so far is the qualitative case studies of the energy performance of the benchmarked buildings. Most of the case studies focused on the leading cities to implement such policies, especially the City of New York – as the largest urban center in the U.S. – as well as Austin and Seattle (Florini & Saleem, 2011; Hsu, 2014b; & Mattern, 2013). In addition, many cities that adopted the benchmarking and disclosure policies release annual reports analyzing the reported energy information of the specific year (City of New York, 2012-14; Urban Green Council, 2017). Such reports offer descriptive statistics of the reported energy performance indices, as well as analyzing the effect of the buildings characteristics (such as the building type, age, size, etc.) on their energy performance and evaluate the factors that determine the energy performance of buildings (Urban Green Council, 2016 & Urban Green Council, 2017). Hsu (2012) analyzed NYC 2011 benchmarking data and developed a data cleaning process to ensure the quality of the obtained benchmarking data. Kontokosta (2012) also analyzed NYC 2011 benchmarking data that involved developing predictive models to analyze the energy consumption of buildings, presenting an energy rating system for multi-family properties, and analyzing the special distribution of the city's energy consumption patterns. Recently, a number of empirical studies have been conducted to statically analyze the reported energy benchmarking information and evaluate the currently used benchmarking measures, develop new energy benchmarking tools, and model the future impact of the policies (Cox et al., 2013; Hsu, 2014a; Kontokosta, 2015; Ma et al., 2012).

Additional research in this field is required to examine the influence of the policies on the existing building owners' decisions to retrofit - in order to improve the energy performance of their buildings – based on the actual reported energy data (Bergh, 2013a). The current study filled the gap in the literature and examined the influence of the benchmarking and disclosure policies on the existing buildings' energy performance by statistically analyzing the annual energy performance patterns of NYC existing commercial buildings. It also provided the initial information about the efficacy of these policies in addressing the issue of information failures in the private building sector, almost a decade down the road (Cox et al., 2013).

This quantitative study used repeated measures *t* tests to analyze the disclosed annual energy usage data of NYC's existing commercial buildings over the past six years to determine the influence of the NYC benchmarking Law (LL84) on improving the energy performance of the existing buildings and generate predictions for the future energy use patterns. The focus of the following chapter (Chapter 3) will be on explaining the research design and methodology to conduct the study, in addition to describing the data collection and analysis procedures.

Chapter 3: Research Method

Introduction

The increasing energy consumption of existing commercial buildings compared to recently built buildings that were subject to greater energy-saving requirements in building codes is a major problem in the United States. It is difficult to mandate energy-efficient retrofits of privately owned existing buildings. Energy benchmarking and disclosure policies have been implemented to manage the energy consumption of existing buildings and encourage energy-efficient retrofits and upgrades. The efficacy of these policies has not been assessed. Accordingly, the current study was designed to examine whether NYC's Benchmarking Law had influenced the energy performance of the existing commercial buildings in the city. Based on the IAD framework, which is founded in rational choice theory, the study involved reviewing and analyzing the disclosed annual energy usage data of NYC's existing commercial buildings as reported to the NYC Mayor's Office of Sustainability over the past 6 years—between 2011 and 2016. In this chapter, I explain the research design and methodology, in addition to describing the data collection and analysis procedures.

Research Design and Rationale

A research design is a plan to conduct a study. An appropriate research design should address the research problem, answer the research question, test the hypothesis, and assist in pursuing approximately truthful inference regarding the relationships between variables (Creswell, 2009). A quantitative research design was selected to conduct this study because it involved the systematic investigation of data and their relationships (Frankfort-Nachmias & Nachmias, 2008). This research design was employed to examine the influence of energy benchmarking and disclosure policies on the energy performance of existing commercial buildings by assessing the relationship between the energy performance of NYC's existing commercial buildings (the dependent variable) and the city's implementation of the Energy Benchmarking and Reporting Program (the independent variable):

- *Dependent variable (criterion)*: The energy performance indices of NYC's existing commercial buildings (site and source EUI measured in kBtu/ft^2, greenhouse gas emissions measured in $MtCO_2e$, and ENERGY STAR score measured in a percentile scale ranges between 1 and 100).
- *Independent variable (predictor)*: The implementation of NYC's Benchmarking Law LL84 between 2011 and 2016.

The quantitative design was also appropriate to conduct the research because it aligned with the repeated measures design recommended to answer the research question, which addressed whether the mean annual energy use of NYC's existing commercial buildings reduced significantly after implementation of LL84. The research question was derived from the purpose of the study, which was to assess the influence of NYC Energy Benchmarking Law LL84 by comparing the mean energy performance indices of the city's existing commercial buildings during the period between 2011 and 2016. This was an observational form of research based on document analysis. The analyzed documents were the disclosed energy use data of NYC's existing commercial buildings that annually reported to the NYC Mayor's Office of Sustainability. For the purpose of this study, repeated measures *t* tests (also referred to as paired sample *t* tests) were performed to analyze those records of energy benchmarking data. This technique statistically evaluated the significance and direction of the difference between the means of the paired observations (the annually measured energy performance indices between 2011 and 2016) in order to determine the influence of the NYC Benchmarking Law. The paired sample *t* tests allowed to determine whether the energy performance of the city's existing commercial buildings significantly improved after the policy implementation and to analyze the annual energy performance patterns of NYC's existing commercial buildings. Paired sample *t* tests are commonly used in social sciences to determine the mean change in scores for a single group or one sample; (Frankfort-Nachmias & Nachmias, 2008). In this research, the difference between the means of the annual energy performance indices of NYC's existing commercial buildings were signified and the annual energy performance patterns were compared after adopting the energy benchmarking and disclosure policies between 2011 and 2016 in order to recognize trends and detect patterns in the data. The consistency of the research questions, design, and methodology enhanced the quality of the study and allowed the successful flow of the research processes (Creswell, 2009). However, the study was limited to the time frame between 2011 and 2016 because it was in 2011 that NYC Benchmarking Law LL84 became effective, and 2016 benchmarking data were the most recent publicly disclosed data available. This study was further confined to large existing commercial buildings with floor areas of 50,000 ft^2 or more. Smaller buildings with floor areas of less than 50,000 ft^2

were excluded because the policy would not be applied to commercial buildings with floor areas of 25,000 ft^2 until 2018.

Methodology

Population

The target population for the current study was existing commercial buildings located in all U.S. municipalities that implemented the energy benchmarking and disclosure policies (including 20 major cities, the states of California and Washington, and Montgomery County, Maryland) and built prior to the policies' adoption (see Table 1).

Sampling and Sampling Procedure

The accessible population for this study consisted of existing commercial buildings in NYC that were built before 2011 (the year that NYC's Benchmarking Law LL84 was enacted). This accessible population was determined based on a purposive sampling strategy, a nonprobability sampling technique that relies on the judgement of the researcher to select the research sample that represents the population based on certain criteria (Frankfort-Nachmias & Nachmias, 2008). Accordingly, NYC's existing commercial buildings were selected as a purposive sample to represent the population based on several criteria:

- NYC was among the leading municipalities to adopt the energy benchmarking and disclosure policies in 2009, following Washington, DC, and Austin, TX. This indicated that sufficient data were available for the analysis.

- NYC is the largest urban center in the United States, with the highest concentration of commercial office buildings nationwide (IMT, 2016). The NYC buildings benchmarked in 2011 represented 61% of the built space covered by all benchmarking laws nationwide at that time, including Austin, Seattle, San Francisco, Washington DC, the State of Washington, and the State of California (City of New York, 2012). Meanwhile, the total gross floor area of NYC benchmarked buildings in 2016 (2.8 billion ft^2) comprised more than 25% of the total gross floor area covered by benchmarking laws/ policies nationwide, as shown in Table 1 (IMT, 2017).
- Furthermore, NYC is considered one of the nation's sustainable urban centers. The 2015 median ENERGY STAR score of the city's office buildings of 75 was significantly above the national average of 50 (Urban Green Council, 2017).

Table 1

Target Population

U.S. municipalities implementing energy benchmarking and disclosure policies	Number of buildings	Gross floor area ft²
Atlanta, GA	2.900	402 million
Austin, TX	2,800	113 million
Berkeley, CA	257	13.7 million
Boston, MA	1,600	250 million
Boulder, CO	475	26 million
California	20,573	2.4 billion
Cambridge, MA	1,120	88 million
Denver, CO	3,000	360 million
Kansas City, KA	1,500	400 million
Chicago, IL	3,500	900 million
Evanston, IL	557	45.6 million
Los Angeles, CA	14,000	900 million
Minneapolis, MN	625	110 million
Montgomery Co., MD	750	68 million
New York City, NY	**15,300**	**2.8 billion**
Orlando, FL	826	125.6 million
Philadelphia, PA	2,300	350 million
Pittsburgh, PA	861	164 million
Portland, OR	1,024	87 million
San Francisco, CA	2,700	205 million
Seattle, WA	3,300	281 million
Washington, DC	2,000	357 million
Washington State	4,600	247 million
Total	**86,500**	**10.7 billion**

Note. Adapted from “Building Energy Benchmarking and Disclosure in U.S. Cities,” by Institute for Market Transformation, 2017 (http://www.imt.org). Copyright 2010-2014 by Institute for Market Transformation. Reprinted with permission.

The purposive sampling strategy required the entire population of the selected unit (NYC’s existing commercial buildings) to be included in the study using total sampling techniques (Frankfort-Nachmias & Nachmias, 2008). This strategy allowed for examination of the energy performance of the entire population of existing commercial buildings located in NYC. Having sufficient sample size is key to strengthening the scientific value of a study, enhancing the quality of statistical inferences and promoting the external validity of the research findings (Frankfort-Nachmias & Nachmias, 2008). Within this context, using any of the probability sampling techniques would not have been appropriate, in that they tend to select units from the population to be studied and therefore would not have served the ultimate goal of including the entire population of NYC's existing commercial buildings in the study that aligned with the purpose of the study. Therefore, there was no need to perform power analysis or use any sampling tools to calculate an adequate sample size for the study.

Data Collection

The study primarily relied on a secondary source of data (archival data)—the disclosed energy benchmarking data of NYC's existing commercial buildings between 2011 and 2016. The NYC benchmarking law mandates the public disclosure of energy data, and the reported data are accessible through the NYC Mayor's Office of Sustainability website (public website). Accordingly, no permission letters were required to request/gain access to the data. However, approval to conduct the study was requested from the Walden University Institutional Review Board (IRB approval number: 08-29-17-0273895). The required data consisted of the annually disclosed energy benchmarking information on NYC's existing commercial buildings with floor areas of 50,000 ft^2 or more, as reported between 2011 and 2017. The collected data included both property information that was self-reported by building owners/managers (basic information about the buildings such as size, location, year built, occupancy level, number and type of equipment, etc.) and usage output metrics and performance indices calculated by the ENERGY STAR Portfolio Manager. This information is annually reported (using automated upload methods) by the buildings' owners/operators to EPA's ENERGY STAR Portfolio Manager Website (ESPM) as required by LL84.

Data Analysis

This study examined whether annual energy benchmarking and disclosure of energy use for existing commercial buildings influenced these buildings' energy performance. The research question was the following: Is there a statistically significant difference between the means of 2011 and 2015 energy benchmarking data?

Null Hypothesis 1: There is no statistically significant difference between the means of 2011 benchmarking data and 2016 data.

$$H_0\text{: } \mu_{2011} = \mu_{2016}$$

Alternative Hypothesis 1: There is a statistically significant difference between the means of 2011 benchmarking data and 2016 data.

$$H_1\text{: } \mu_{2011} \neq \mu_{2016}$$

where μ is the mean of the energy benchmarking data.

SPSS 24 software was used to statistically analyze the collected data from the NYC Mayor's Office of Sustainability using repeated measures *t* tests (also referred to as paired sample *t* tests and dependent-sample *t* tests). According to Frankfort-Nachmias and Nachmias (2008), *t* tests are widely used "to assess the significance of difference between the means" of tested samples (p. 448). The means between two related observations measured on the same continuous dependent variable can be compared using paired sample *t* tests, as the tests allow examining a single group at two different points in time (Ross & Willson, 2017). Paired sample *t* tests are commonly applied to repeated-measures designs to evaluate the efficacy of policies by comparing the means of two sets of observations that measure the performance of a single group before and after policy implementation. The difference between the means of the paired sets can be statistically analyzed using paired sample *t* tests (Field, 2013). This study assessed the statistical significance of the means difference between 2011 and 2016 energy performance indices. Furthermore, the annual energy performance pattern of NYC's existing commercial buildings during the period between 2011 and 2016 was evaluated by determining whether there was statistical evidence that the mean differences between the annually measured energy performance indices were significantly different from zero. As the direction of the difference is not important (only comparing the difference between means), two-tailed tests of significance were performed (Ross & Willson, 2017). Assessing the annual energy performance patterns allowed me to make predictions about future energy consumption rates and anticipated future energy demands/savings.

Threats to Validity

External Validity

External validity refers to the ability to generalize study outcomes (Campbell & Stanley, 1963). The ample sample size used for this study enhanced the external validity of the research findings by including the annually reported energy benchmarking data of the entire population of NYC's existing commercial buildings of 50,000 ft^2 or more. that consistently benchmarked during the period between 2011and 2016. However, it is not possible to generalize the results of this study to other cities or municipalities due to the geographical limitation of the study to one site (NYC), although other cities might find this kind of analysis useful.

Internal Validity

Internal validity affects a researcher's ability to support claims and draw inferences (Creswell, 2009). Within this context, I only compared the difference of means between the measured dependent variables and assessed the extent to which the implementation of the energy benchmarking and disclosure policies had influenced the energy performance of the benchmarked buildings. The statistical significance of the difference between the means of 2011 and 2016 energy performance indices does not imply causation. Additionally, the study only included the energy data for buildings that continuously reported throughout the period between 2011 and 2016. Structures that were built after 2011 or that started to report energy data after 2011 were not included to avoid threats to internal validity. Table 2 shows possible threats to internal validity and plans to address these issues in order to ensure the reliability and consistency of the research data.

Table 2

Threats to Internal Validity

Threats to internal validity	Plans to meet internal validity requirements
History: The effect of external events over time.	The effect of external events can be neglected due to the short term of the policy implementation.
Regression: The effect of extreme scores.	The ample sample size that included the energy benchmarking data of the entire population of NYC's existing commercial buildings of 50,000 ft^2 or more eliminated the effect of extreme scores.
Selection: The equal distribution of characteristics.	Including the entire population ensured the equal distribution of characteristics within the research sample.
Mortality: Changes in the sample size	Newer buildings (i.e., built after 2011) and those that started to report energy data after 2011 were not included.

Note. Table developed following a model provided by Creswell (2009).

Ethical Procedures

The study was based on archival data and did not involve recruitment of human participants to collect data. The collected electronic data were securely saved on a personal computer. Identifiable building information—such as street addresses and borough-block-and lot (BBL) numbers—was not revealed, and accordingly there is no potential risk of distressing research findings being costly to building owners, in terms of affecting their property value, real estate marketability, or rental rates.

Summary

The study was conducted based on a quantitative research approach using a repeated-measures design to assess the influence of energy benchmarking and disclosure policies on the energy performance of existing buildings. Information used to address the hypothesis consisted of archival data on the energy performance of NYC's existing commercial buildings based on energy benchmarking data annually disclosed to the NYC Mayor's office of Sustainability during the period between 2011 and 2016. The data were statistically analyzed using paired sample *t* tests to compare the difference between the means of 2011 and 2016 energy performance indices. In Chapter 4, the statistical analysis of the data is presented, and the study findings are reported.

Chapter 4: Results

Introduction

The purpose of this study was to examine the influence of the NYC Benchmarking Law (LL84) on the energy performance of the city's existing commercial buildings 6 years after the law was enacted and to assess the efficacy of the energy benchmarking and disclosure policies in improving the energy performance of the existing building stock. The law requires the owners/managers of buildings with gross floor areas greater than 50,000 ft^2 to annually report their buildings' energy and water use data to the EPA's ENERGY STAR Portfolio Manager (Local Laws 84, 2009). The latest benchmarking data disclosed by the NYC Mayor's Office of Sustainability in 2016 were compared to 2011 data to evaluate the statistical significance of the mean difference between the compared datasets and determine whether these policies actually influence change in the energy performance of existing commercial buildings (NYC Mayor's Office of Sustainability, 2017). Thus, the study was based on one overarching question: Is there a statistically significant difference between the means of 2011 and 2016 energy benchmarking data? Paired sample *t* tests were performed to compare the means of the dependent variables (2016 benchmarking data to 2011 data) to answer the research question and test the hypothesis. The null hypothesis stated that the mean difference between the 2011 benchmarking data and 2016 data is zero, and the alternative hypothesis stated that there is a statistically significant difference between the means of 2011 benchmarking data and 2016 data.

Data Collection

The data for this study were collected from the NYC Mayor's Office of Sustainability website (NYC Mayor's Office of Sustainability, 2017). The electronic data were accessed on August 29, 2017, when Walden University's IRB approval of the study proposal was confirmed (IRB approval number: 08-29-17-0273895). The 2016 dataset, which was posted to the public in mid-December 2017 on the NYC Mayor's Office of Sustainability website, was accessed on February 26. All of the publicly disclosed energy and water benchmarking datasets for NYC's buildings were captured in Excel spreadsheets to be analyzed. The retrieved datasets were reviewed and validated in comparison to NYC OpenData tables and LL84 benchmarking reports (which are accessible through the NYC Mayor's Office of Sustainability website) to ensure the accuracy of the data and eliminate any data entry transposition errors. The collected data consisted of benchmarking output information provided by the ENERGY STAR Portfolio Manager (ESPM). The data can be divided into two categories:

1. Property information that is self-reported by the buildings' owner/managers, including borough-block-and lot (BBL), building identification number (BIN), street address, total gross area, number of buildings on the lot, property use, and other building/occupancy pattern characteristics.
2. Usage output metrics, including the performance indices that were calculated by the Portfolio Manager based on the reported building information. These performance indices were used to analyze the energy performance of buildings. The number of output metrics calculated by the ESPM considerably

increased over the years; however, only the basic metrics originally used to measure the energy performance of buildings in 2011 were considered in this study to compare the means difference between the two datasets. These metrics included the following:

- *Site EUI*: This is one of the measures of energy consumption. It is the calculated amount of energy used per area at the property site. The metric measures the energy use intensity at the property site on a per-square-foot basis (kBtu/ft^2; Benchmarking Data Disclosure Definitions, 2017).
- *Weather-normalized source EUI*: This is another energy performance index that measures the weather-adjusted energy use intensity at the source of energy generation (referred to as *source EUI* in this study). It is the amount of energy required to generate the energy consumed on the property site. It considers the energy generation and distribution losses. The metric is measured in kBtus per gross square foot (kBtu/ft^2; Benchmarking Data Disclosure Definitions, 2017).
- *Water use intensity*: This metric measures the amount of water consumed per square foot (gal/ft^2 Benchmarking Data Disclosure Definitions, 2017).
- *GHG emissions*: This is the calculated direct and indirect GHG emitted by the property. It is measured in metric tons of carbon dioxide equivalent (MtCO_2e Benchmarking Data Disclosure Definitions, 2017).

- *ENERGY STAR scores*: This percentile ranking offers an overall energy performance rating calculated by the ESPM on a scale of 1-100 (Benchmarking Data Disclosure Definitions, 2017).

Results

NYC benchmarking law LL84 requires privately owned property owners/managers of a single building with a floor area of at least 50,000 ft^2 or multiple buildings on one lot totaling 100,000 ft^2 or more to annually benchmark their buildings' energy use information (NYC Benchmarking Law LL84, 2009). Commercial buildings comprise one third of NYC's benchmarked floor area. However, according to NYC's Energy and Water Use Report (2013), they account for approximately half of the city's energy consumption (Urban Green Council, 2016). A total of 4,082 privately owned buildings (with total gross floor area of 1.7 billion ft^2) were benchmarked in 2011 with a compliance rate of approximately 64% (City of New York, 2012). The number of benchmarked buildings significantly increased over the years, reaching 13,221 buildings (2.3 billion ft^2) in 2015 and 15,122 (2.4 billion ft^2) in 2016, with compliance rates exceeding 90% (Urban Green Council, 2017). Based on the research plan described in Chapter 3, the entire population of NYC existing commercial buildings that were benchmarked in both 2011 and 2016 were included in the sample. The focus of this study was primarily on examining the energy performance of existing commercial buildings; thus, the datasets were sorted and filtered to exclude multifamily buildings, which were outside the scope of this study. Only 2,547 buildings that fell under the commercial buildings categories were considered. These categories were based on the commercial-building classification developed by the Commercial Buildings Energy Consumption Survey (CBECS), which includes office buildings, hotels/resorts, retail, restaurants, warehouses, educational, and health care buildings (EIA, 2017).

Data Cleaning

Hsu (2012) developed data-cleaning steps to analyze and assess the quality of NYC 2011 benchmarking data. He removed building records with reported "EUI below 5 or above 1,000 kBtu/ft^2" and the "top and bottom 5% of EUIs" (Hsu, 2012, p. 5). Scofield (2013) followed a similar data-cleaning approach to eliminate data entry errors from NYC 2011 benchmarking data in his study to compare the mean energy performance indices of LEED-certified buildings to those of conventional NYC buildings. He eliminated building records considered "unbelievably high," with site EUI values higher than 1,035 kBtu/ft^2, or "unreasonably low," with site EUI values approaching 0.0 kBtu/ft^2 (pp. 519-520). The data-cleaning process adopted in this study was based on the data-cleaning approaches followed by Hsu (2012) and Scofield (2013) to remove building records with data entry errors. The benchmarking records of the 2,547 commercial buildings were further inspected to ensure the credibility of the data. Hence, repeated records that appeared more than once, building records that were not located in any of the NYC counties, records with missing information (such as floor area), and records that did not show energy use data were eliminated. Credible records of 1,730 commercial buildings were retained and further inspected to eliminate records with data entry errors. Additional building records were eliminated because they showed extremely high values (EUIs above 1,000 kBtu/ft^2 and GHG emissions higher than 20,000) or unreasonably low values (EUIs and GHG emissions approaching 0.0). Such records were considered not credible because they indicated data entry errors or unoccupied buildings. The remaining datasets were compared to exclude the buildings that were not benchmarked in both of the assigned years. It was found that the energy use data (both site and source EUI) and GHG emissions were calculated for 1,072 commercial buildings in both 2011 and 2016, with total gross floor area of approximately 300 million ft², as listed in Table 3.

Table 3

Sample Characteristics—Sample Distribution in NYC's Boroughs

	Number of buildings	Total gross floor area (ft²)
Manhattan	772	244,632,057
Bronx	47	10,938,054
Brooklyn	90	16,078,967
Queens	135	21,964,700
Staten Island	28	3,739,563
Total	**1,072**	**297,353,341**

Note. Energy benchmarking data from NYC Mayor's Office of Sustainability website.

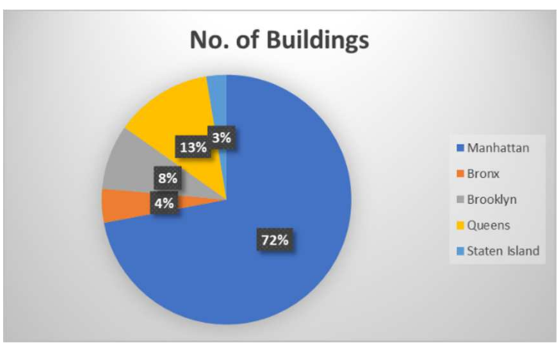
The overall energy performance rating (ENERGY STAR score) of 803 buildings out of the above 1,072 was calculated by Portfolio Manager, as this metric is only measured for specific building categories, such as offices, hotels, retail, and hospitals. However, water use intensity was not analyzed in this study due to the limited water consumption data filed in the 2011 calendar year, with only 147 building records.

Sample Characteristics

The analyzed sample was mostly located in in Manhattan. Seven hundred and seventy-two of the 1,072 commercial buildings analyzed in this study were located in

Manhattan, comprising approximately 82% of the tested sample gross floor area, and 47 buildings were located in Bronx, 90 were located in Brooklyn, 135 were located in Queens, and only 28 were located on Staten Island (see Table 3 and Figure 4). Although the sample was composed of commercial buildings in various categories, office buildings constituted 64% of the sample, followed by hotels, which represented approximately 7% of the tested sample, as listed in Table 4. However, Table 5 shows that the total gross floor area of the office buildings included in this study was 74.3% of the total sample floor area, with approximately 220 million ft². This can be attributed to the concentration of high-rise commercial office buildings in Manhattan.

(a)



(b)

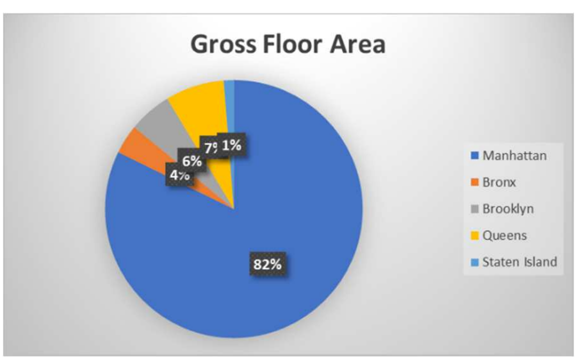


Figure 4. Sample distribution in NYC's boroughs—number of buildings (a) total gross floor area (b).

Table 4

Sample Characteristics—Building Categories

Building category	Number of buildings	Percentage %
Office	687	64.1
Hotel	74	6.9
Nonrefrigerated warehouse	58	5.4
Other	52	4.9
Retail store	41	3.8
Distribution center	32	3.0
Mixed use property	22	2.1
Other—Entertainment/public assembly	15	1.4
Self-storage facility	15	1.4
Financial office	11	1.0
College/university	8	.7
Manufacturing/industrial plant	7	.7
Other—Mall	7	.7
Supermarket/grocery store	6	.6
Automobile dealership	5	.5
Refrigerated warehouse	5	.5
Wholesale club/supercenter	4	.4
Enclosed mall	3	.3
Hospital (general medical & surgical)	2	.2
Movie theater	2	.2
Museum	2	.2
Other—Lodging/residential	2	.2
Repair services (vehicle, shoe, locksmith, etc.)	2	.2
Residence hall/dormitory	2	.2
K-12 school	1	.1
Medical office	1	.1
Other—Education	1	.1
Other—Recreation	1	.1
Other—Services	1	.1
Parking	1	.1
Social/meeting hall	1	.1
Strip mall	1	.1
Total	**1,072**	**100**

Note. Energy benchmarking data from NYC Mayor’s Office of Sustainability website.

Table 5

Sample Characteristics—Office Buildings Dominating the Sample

	Total number of buildings		Total gross floor area	
Building category	No.	%	ft^2	%
Office buildings	687	64	220,862,232	74.3
Other building categories	385	36	76,491,109	25.7
Total	**1,072**	**100**	**297,353,341**	**100**

Note. Energy benchmarking data from NYC Mayor's Office of Sustainability website.

Statistical Assumptions

The benchmarking data, originally captured in spreadsheet format, were imported to SPSS 24 to check the appropriateness of using paired sample *t* tests to analyze the data. The data met all the statistical assumptions to ensure the validity of the test results. First, the tested variables (building performance indices) were measured on a continuous level: site and source EUI measured were ratio variables measured in kBtus per gross square foot ($kBtu/ft^2$), total GHG emission was a ratio variable measured in metric tons of carbon dioxide equivalent ($MtCO_2e$), and ENERGY STAR score was a ratio variable measure on a percentile scale ranging from 1-100. The second assumption that required the independence of observations was met, in that the data collection process involved independent reporting of energy use data to ESPM. Additionally, the data consisted of matched pairs, with records for the same buildings appearing in both datasets (2011 and 2016). Third, the tested variables did not contain any outliers, as the data records with extremely high or unreasonably low values were eliminated earlier to avoid biased test results. Finally, the assumption of normality, which requires the normal sampling distribution of the tested variables for significance tests such as the paired sample *t* test

(Frankfort-Nachmias & Nachmias, 2008), was considered reasonably met by including the entire population of NYC's commercial buildings that consistently benchmarked in 2011 and 2016. According to Field (2013), based on the central limit theorem, using a large sample size ensures the normality of the sampling distribution. Field argued that "the data do not need to be normally distributed, but the sampling distribution of means does" (p. 174). Thus, fairly large samples are considered normally distributed regardless of data distribution.

Statistical Analysis

SPSS 24 software was used to analyze the data gathered for this study to answer the research question: Is there a statistically significant difference between the means of 2011 and 2016 energy benchmarking data?

Paired sample *t* tests were performed to determine the means difference between 2011 and 2016 energy performance datasets.

Null Hypothesis 1: There is no statistically significant difference between the means of 2011 benchmarking data and 2016 data.

$$H_0: \mu_{2011} = \mu_{2016}$$

Alternative Hypothesis 1: There is a statistically significant difference between the means of 2011 benchmarking data and 2016 data.

$$H_1: \mu_{2011} \neq \mu_{2016}$$

where μ is the mean of the energy benchmarking data.

These were two-tailed tests, as the hypothesis tested the mean difference between the two conditions with α level **= .05**, (Field, 2013). The statistical analysis was based on the performance indices calculated by ESPM (output metrics) because they tend to characterize the energy performance of the benchmarked buildings. The analysis results for each metric are discussed separately. The benchmarking data of 1,072 buildings were tested for energy consumption (both site and source EUI) and GHG emission, while the mean ENERGY STAR performance ratings of 803 buildings were compared. In addition, in-depth analyses of the annual energy performance pattern of NYC's commercial buildings consistently benchmarked between 2011 and 2016 were performed to assess the efficacy of the adopted benchmarking policy. Mean differences between NYC commercial buildings' energy performance metrics calculated by the ESPM were compared on an annual basis throughout the period between 2011 and 2016 using paired sample *t* tests. The analysis results generated by SPSS for each metric are discussed below.

Site EUI. The mean of 2011 and 2016 energy use intensity measured at the property site of the 1,072 commercial buildings were compared to answer:

Q1.1: Is there a statistically significant difference between the means of 2011 site EUI and 2016 site EUI?

Null Hypothesis 1.1: There is no statistically significant difference between the means of 2011 site EUI and 2016 site EUI.

$$H_0\text{: } \mu_{2011\text{ site EUI}} = \mu_{2016\text{ site EUI}}$$

Alternative Hypothesis 1.1: There is a statistically significant difference between the means of 2011 site EUI and 2015 site EUI.

$$H_1\text{: } \mu_{2011\text{ site EUI}} \neq \mu_{2016\text{ site EUI}}$$

where μ is the mean site EUI.

Table 6 displays the descriptive statistics for the two tested conditions. The records of 1,072 commercial buildings were tested (*N* = 1072). The mean of 2016 site EUI (*M* = 84.72 kBtu/ft², *SD* = 56.90) was lower that of 2011 (*M* = 88.97 kBtu/ft², *SD* = 57.83). The site EUI histograms for 2011 dataset and 2016 shown in Figures 5(a) and (b) indicate that the site EUI records in both conditions were similarly dispersed. Table 7 shows the *t* value was 2.67. There are (1071) degrees of freedom (*df*) associated with the *t* test. The results indicate that the two means were significantly different as the value in the Sig. (2-tailed) row ($p = .008$) was less than .05. Accordingly, the paired sample *t* test revealed a statistically reliable difference between 2011 mean site EUI (*M* = 88.97 kBtu/ft², *SD* = 57.83) and that of 2016 mean site EUI (*M* = 84.72 kBtu/ft², *SD* = 56.90), $t(1071) = 2.67$, $p = .008$, $\alpha = .05$. On average, 2016 site EUI decreased by approximately 5% (4.25 kBtu/ft²) compared to 2011 site EUI. Thus, the null hypothesis can be rejected.

(a) (b)

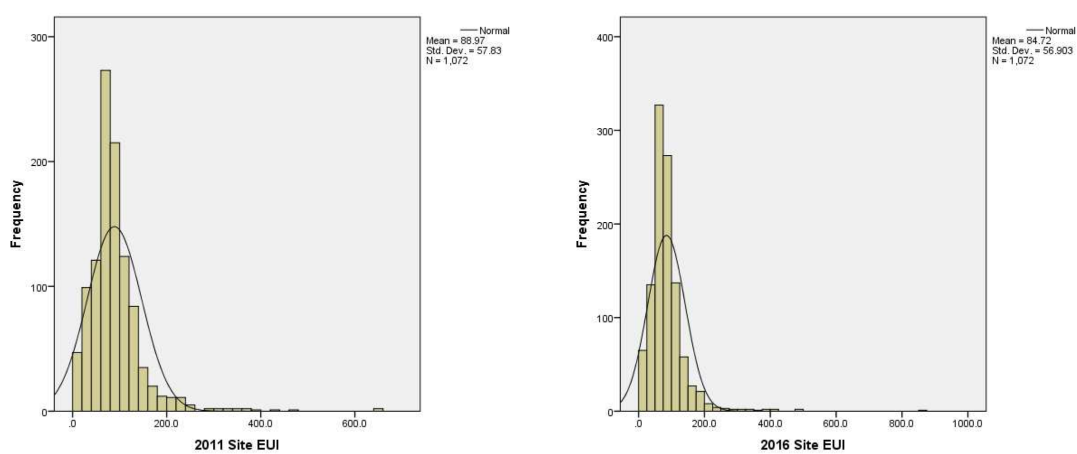


Figure 5. Site EUI histogram for NYC commercial buildings' 2011 benchmarking data (a) and 2016 data (b).

Table 6

Site EUI—Paired Sample Statistics

Pair	Mean	*N*	Std. deviation	Std. error mean
2011 site EUI	88.969	1,072	57.8296	1.7663
2016 site EUI	84.716	1,072	56.9028	1.7379

Table 7

Site EUI—Paired Sample Test

	Paired differences							
				95% confidence interval of the difference				
	Mean	Std. deviation	Std. error mean	Lower	Upper	*t*	*df*	Sig. (2-tailed)
2011 site EUI - 2016 site EUI	4.2529	52.0743	1.5905	1.1321	7.3737	2.674	1071	**.008**

The results of the annually-based analysis of the site EUI shown in Tables 8 and 9 present the mean difference between the consistently measured site EUI of 619 commercial buildings out of the 1,072 building sample during the period between 2011 and 2016. It can be seen that the energy consumed at NYC commercial buildings sites significantly dropped in 2012 - one year after the first energy benchmarking data disclosure from 92.76 kBtu/ft² in 2011 to 83.92 kBtu/ft² in 2012 - $t(618) = 6.07$, $p < 0.001$ (see Tables 8 and 9 - Pair 1). Note that the mean of 2012 site EUI in was actually lower than that of 2016 (see Table 8 - Pairs 1 and 5). The mean site EUI increased in the following 2 years by 6.79 kBtu/ft² and 1.65 kBtu/ft² in 2013 and 2014, respectively (see Table 9 - Pairs 2 and 3). It worth noting that the increase in 2013 was statistically significant $t(618) = -2.99$, $p = 0.003$. As shown in Table 9 (Pair 4), the mean site EUI dropped again in 2015 and 2016 by 2.47 and 2.02 kBtu/ft², respectively. However, only the decrease reported in 2016 was statistically significant $t(618) = 2.05$, $p = 0.041$, $\alpha = .05$. Although the analysis shows an overall drop of almost 5% (4.9 kBtu/ft²) in the average site EUI between 2011 and 2016 as explained earlier in this section, the consumption pattern was not consistent throughout the 6 years, as shown in Figure 6. Furthermore, the mean difference between 2011 and 2012 site EUI (8.8 kBtu/ ft²) was almost twice the mean difference between 2011 and 2016 (4.9 kBtu/ ft²).

Table 8

Paired Samples Statistics—Site EUI Annual Consumption Pattern From 2011 to 2016

		Mean	*N*	Std. deviation	Std. error mean
Pair 1	2011 site EUI	92.756	619	63.0637	2.5347
	2012 site EUI	83.917	619	53.3143	2.1429
Pair 2	2012 site EUI	83.917	619	53.3143	2.1429
	2013 site EUI	90.708	619	67.1094	2.6974
Pair 3	2013 site EUI	90.708	619	67.1094	2.6974
	2014 site EUI	92.353	619	61.0954	2.4556
Pair 4	2014 site EUI	92.353	619	61.0954	2.4556
	2015 site EUI	89.885	619	62.3195	2.5048
Pair 5	2015 site EUI	89.885	619	62.3195	2.5048
	2016 site EUI	87.866	619	63.4809	2.5515

Table 9

Paired Samples Test—Site EUI Annual Consumption Pattern From 2011 to 2016

		Paired differences							
					95% confidence interval of the difference				
		Mean	Std. deviation	Std. error mean	Lower	Upper	*t*	*df*	Sig. (2-tailed)
Pair 1	2011 site EUI - 2012 site EUI	8.8389	36.2572	1.4573	5.9771	11.7008	6.065	618	**.000**
Pair 2	2012 site EUI - 2013 site EUI	-6.7908	56.5650	2.2735	-11.2556	-2.3260	-2.987	618	**.003**
Pair 3	2013 site EUI - 2014 site EUI	-1.6454	64.8596	2.6069	-6.7649	3.4741	-.631	618	**.528**
Pair 4	2014 site EUI - 2015 site EUI	2.4682	41.2677	1.6587	-.7892	5.7255	1.488	618	**.137**
Pair 5	2015 site EUI - 2016 site EUI	2.0186	24.4743	.9837	.0868	3.9504	2.052	618	**.041**

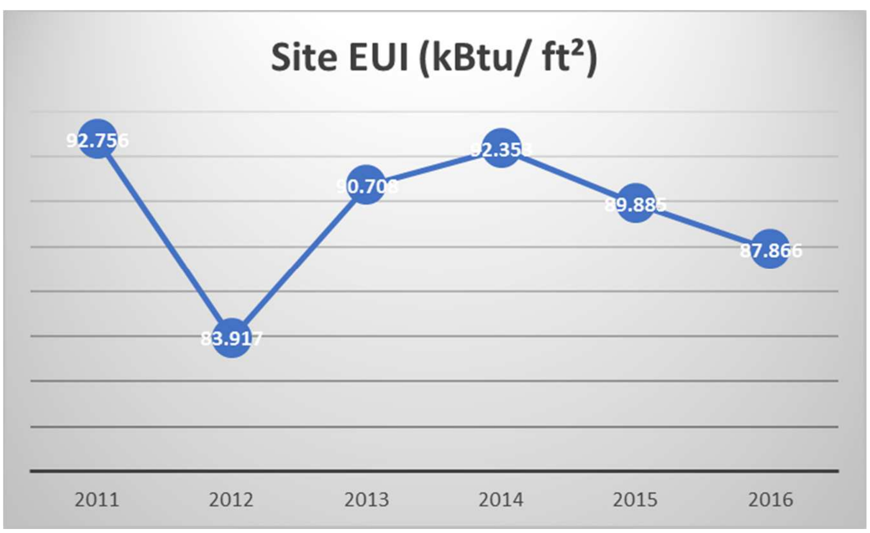


Figure 6. Site EUI annual consumption pattern from 2011 to 2016

Source EUI. The mean of 2011 and 2016 weather-adjusted energy use intensity at the source of energy generation measured for the 1,072 commercial buildings were compared to answer:

Q1.2: Is there a statistically significant difference between the means of 2011 source EUI and 2016 source EUI?

Null Hypothesis 1.2: There is no statistically significant difference between the means of 2011 source EUI and 2016 source EUI.

$$H_0\text{: } \mu_{2011 \text{ source EUI}} = \mu_{2016 \text{ source EUI}}$$

Alternative Hypothesis 1.2: There is a statistically significant difference between the means of 2011 source EUI and 2016 source EUI.

$$H_1\text{: } \mu_{2011 \text{ source EUI}} \neq \mu_{2016 \text{ source EUI}}$$

where μ is the mean source EUI.

The descriptive statistics displayed in Table 10 shows that the tested 1072 commercial buildings (N = 1072) had mean weather-normalized source EUIs of 213.03 and 192.46 kBtu/ft^2 in 2011 and 2016, respectively. The source EUI histograms shown in Figures 7(a) and (b) indicate the normal distribution of the source EUI data records in both conditions. As shown in Table 11, the t value of 6.40 was obtained with (1071) degrees of freedom (df) associated with the t test. The test results indicate that the two means were significantly different as the p-value denoted by "Sig. (2-tailed)" ($p < 0.001$) was less than .05. Thus, the null hypothesis can be rejected considering that 2016 weather-adjusted source EUI (M = 192.46 kBtu/ft^2, SD = 113.41) was significantly lower than that of 2011 (M = 218.29 kBtu/ft^2, SD =104.90), $t(1071) = 6.40$, $p < 0.001$. On average, 2016 source EUI dropped by 10% (20.57 kBtu/ft²) compared to 2011 source EUI, as shown in Table 11.

(a) (b)

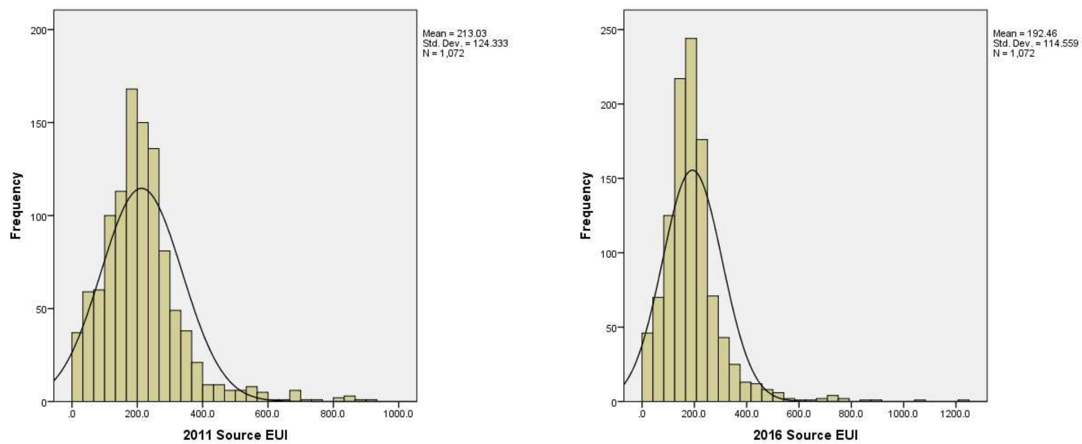


Figure 7. Weather-normalized source EUI histogram for NYC commercial buildings' 2011 benchmarking data (a) and 2016 data (b).

Table 10

Source EUI—Paired Samples Statistics

	Mean	*N*	Std. deviation	Std. error mean
2011 source EUI	213.027	1,072	124.3328	3.7974
2016 source EUI	192.459	1,072	114.5585	3.4989

Table 11

Source EUI—Paired Samples Test

	Paired differences							
				95% confidence interval of the difference				
	Mean	Std. deviation	Std. error mean	Lower	Upper	*t*	*df*	Sig. (2-tailed)
2011 source EUI - 2016 source EUI	20.5685	104.9025	3.2040	14.2817	26.8552	6.420	1071	**.000**

Table 12 shows the mean difference between the consistently calculated weather-normalized source EUI of only 471 commercial buildings out of the 1,072 building sample between 2011 and 2016. Tables 12 and 13 and Figure 8 show that the source EUI was continuously decreasing throughout the 6 years except for a slight increase that was reported in 2015 (see Table 13 - Pair 4). The average cut in source EUI was approximately10% (24.22 kBtu/ft²), which agrees well with the results achieved by the analysis performed earlier in this section. However, the only statistically significant drop was reported in 2012 $t(470) = 4.53$, $p < 0.001$, $\alpha = .05$, as shown in Table 13 (Pair 1). On average the tested buildings source EUI significantly dropped in 2012 by 6.6% (16.03 kBtu/ft²). Thus, 66% of the cut in source EUI was achieved in the first year after the policy implementation, as shown in Figure 8.

Table 12

Paired Samples Statistics—Source EUI Annual Consumption Pattern From 2011 to 2016

		Mean	*N*	Std. deviation	Std. error mean
Pair 1	2011 source EUI	228.664	471	135.5059	6.2438
	2012 source EUI	212.633	471	129.7016	5.9763
Pair 2	2012 source EUI	212.633	471	129.7016	5.9763
	2013 source EUI	206.881	471	114.6403	5.2823
Pair 3	2013 source EUI	206.881	471	114.6403	5.2823
	2014 source EUI	205.556	471	115.2185	5.3090
Pair 4	2014 source EUI	205.556	471	115.2185	5.3090
	2015 source EUI	206.256	471	125.8243	5.7977
Pair 5	2015 source EUI	206.256	471	125.8243	5.7977
	2016 source EUI	204.442	471	128.2617	5.9100

Table 13

Paired Samples Test—Source EUI Annual Consumption Pattern From 2011 to 2016

		Paired differences							
					95% confidence interval of the difference				
		Mean	Std. deviation	Std. error mean	Lower	Upper	*t*	*df*	Sig. (2-tailed)
Pair 1	2011 source EUI - 2012 source EUI	16.0312	76.8630	3.5417	9.0718	22.9907	4.526	470	**.000**
Pair 2	2012 source EUI - 2013 source EUI	5.7522	68.2013	3.1425	-.4230	11.9274	1.830	470	**.068**
Pair 3	2013 source EUI - 2014 source EUI	1.3246	63.3342	2.9183	-4.4099	7.0591	.454	470	**.650**
Pair 4	2014 source EUI - 2015 source EUI	-.7002	70.3207	3.2402	-7.0673	5.6669	-.216	470	**.829**
Pair 5	2015 source EUI - 2016 source EUI	1.8149	44.4291	2.0472	-2.2079	5.8376	.887	470	**.376**

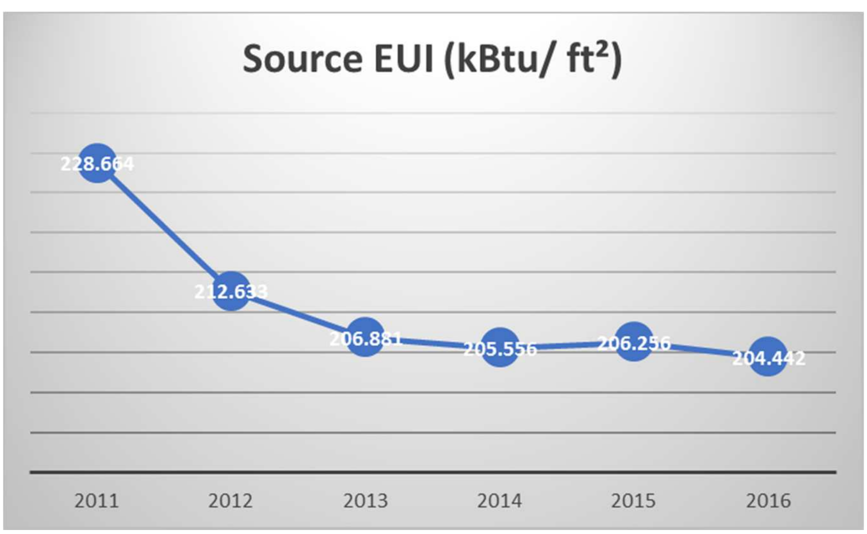


Figure 8. Source EUI annual consumption pattern from 2011 to 2016

Total GHG emissions. The mean of 2011 and 2016 direct and indirect greenhouse gases emitted by the 1,072 commercial buildings were compared to answer:

Q1.3: Is there a statistically significant difference between the means of 2011 GHG emissions and 2016 GHG emissions?

Null Hypothesis 1.3: There is no statistically significant difference between the means of 2011 GHG emissions and 2016 GHG emissions.

$$H_0: \mu_{2011\ GHG} = \mu_{2016\ GHG}$$

Alternative Hypothesis 1.3: There is a statistically significant difference between the means of 2011 GHG emissions and 2016 GHG emissions.

$$H_1: \mu_{2011\ GHG} \neq \mu_{2016\ GHG}$$

where μ is the mean GHG emissions.

(a) (b)

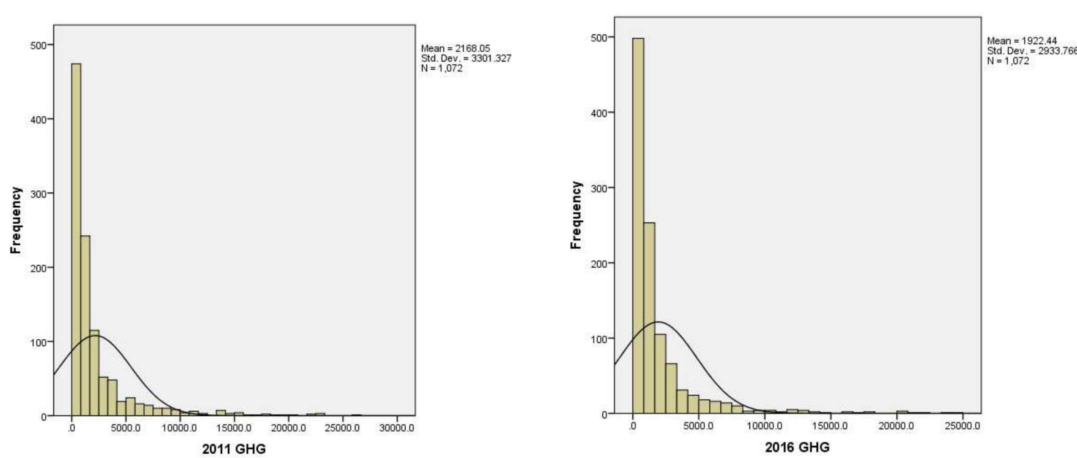


Figure 9. Greenhouse gas emissions histogram for NYC commercial buildings' 2011 benchmarking data (a) and 2016 data (b).

The descriptive statistics displayed in Table 14 shows that the mean amount of greenhouse gases emitted by the 1,072 NYC commercial buildings ($N = 1072$) was 2168.05 and 1922.44 $MtCO_2e$ in 2011 and 2016, respectively. As shown in Table 15, the *t* value of 5.18 was obtained with (1071) degrees of freedom (*df*) associated with the paired sample *t* test. The results indicate that the two means were significantly different as the p-value denoted by "Sig. (2-tailed)" ($p < 0.001$) was less than .05. Thus, the null hypothesis can be rejected considering that the amount of GHG emissions in 2016 (with an average of 1922.44 $MtCO_2e$) was significantly lower than in 2011 (with an average of 2168.05 $MtCO_2e$), $t(1071) = 5.18$, $p < 0.001$. The results revealed that, on average, the amount of greenhouse gasses emitted by NYC commercial buildings in 2016 significantly reduced by approximately 12% (245.61 $MtCO_2e$) compared to 2011, as shown in Table 15.

Table 14

GHG Emissions—Paired Samples Statistics

	Mean	*N*	Std. deviation	Std. error mean
2011 GHG	2168.048	1,072	3301.3272	100.8303
2016 GHG	1922.437	1,072	2933.7663	89.6041

Table 15

GHG Emissions—Paired Samples Test

	Paired differences							
				95% confidence interval of the difference				
	Mean	Std. deviation	Std. error mean	Lower	Upper	*t*	*df*	Sig. (2-tailed)
2011 GHG – 2016 GHG	245.6104	1551.7852	47.3952	152.6124	338.6083	5.182	1071	**.000**

Table 16 shows the mean difference between the consistently measured greenhouse gasses emitted by 671 commercial buildings out of the 1,072 building sample between 2011 and 2016. Tables 16 and 17 and Figure 10 revealed a steady reduction pattern in the amount of GHG emissions throughout the 6 years with an average reduction of approximately 13% (291.61 MtCO2e). These results agree well with the results obtained previously in this section. It was noted that the only statistically significant drop in the amount of GHG emitted by NYC commercial buildings was also was achieved in 2012 $t(670) = 4.09$, $p < 0.001$, $\alpha = .05$ (see Table 17, Pair 1), while no statistically significant cuts in GHG emissions were obtained during the period between 2013 and 2016.

Table 16

Paired Samples Statistics—Annual GHG Emissions Pattern From 2011 to 2016

		Mean	*N*	Std. deviation	Std. error mean
Pair 1	2011 GHG	2133.285	671	3180.9748	122.8002
	2012 GHG	1992.430	671	3030.8692	117.0054
Pair 2	2012 GHG	1992.430	671	3030.8692	117.0054
	2013 GHG	1934.744	671	2932.3602	113.2025
Pair 3	2013 GHG	1934.744	671	2932.3602	113.2025
	2014 GHG	1880.993	671	2717.2344	104.8977
Pair 4	2014 GHG	1880.993	671	2717.2344	104.8977
	2015 GHG	1849.706	671	2696.5517	104.0992
Pair 5	2015 GHG	1849.706	671	2696.5517	104.0992
	2016 GHG	1841.675	671	2531.2114	97.7163

Table 17

Paired Samples Test—Annual GHG Emissions Pattern From 2011 to 2016

		Paired differences							
					95% confidence interval of the difference				
		Mean	Std. deviation	Std. error mean	Lower	Upper	*t*	*df*	Sig. (2-tailed)
Pair 1	2011 GHG - 2012 GHG	140.8557	893.1235	34.4786	73.1565	208.5549	4.085	670	**.000**
Pair 2	2012 GHG - 2013 GHG	57.6853	819.2765	31.6278	-4.4163	119.7868	1.824	670	**.069**
Pair 3	2013 GHG - 2014 GHG	53.7516	1136.9001	43.8895	-32.4260	139.9292	1.225	670	**.221**
Pair 4	2014 GHG - 2015 GHG	31.2870	1253.2276	48.3803	-63.7082	126.2823	.647	670	**.518**
Pair 5	2015 GHG - 2016 GHG	8.0306	1191.7167	46.0057	-82.3022	98.3633	.175	670	**.861**

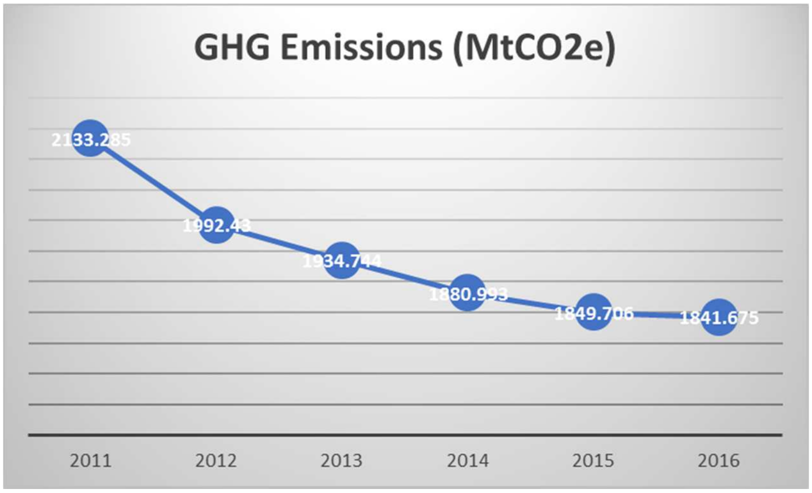


Figure 10. Annual GHG emissions pattern from 2011 to 2016

ENERGY STAR scores. The mean of 2011 and 2016 building performance rating of 803 out of the 1,072 commercial buildings calculated by the ESPM in a scale of 1-100 were compared to answer:

Q1.4: Is there a statistically significant difference between the means of 2011 and 2016 ENERGY STAR scores?

Null Hypothesis 1.4: There is no statistically significant difference between the means of 2011 and 2016 ENERGY STAR scores.

$$H_0: \mu_{2011\ ESS} = \mu_{2016\ ESS}$$

Alternative Hypothesis 1.4: There is a statistically significant difference between the means of 2011 and 2016 ENERGY STAR scores.

$$H_1: \mu_{2011\ ESS} \neq \mu_{2016\ ESS}$$

where μ is the mean ENERGY STAR score.

The descriptive statistics displayed in Table 18 shows that the tested 867 commercial buildings (N = 803) had mean ENERGY STAR score of 65.6 and 68.2 in 2011 and 2016, respectively. The reported standard deviations for 2011 dataset (SD =

25.10) and 2016 (*SD* = 24.74) indicate the normal distribution of the data records in both conditions. Table 19 shows that the obtained *t* value was -3.44 (the sign of t for a two-tailed t-test can be ignored). There are (802) degrees of freedom (*df*) associated with the *t* test. The results indicate that the two-means difference was statistically significant as the *p*-value denoted by “Sig. (2-tailed)” ($p = 0.001$) was less than .05. Thus, the null hypothesis can be rejected despite the slight difference between the mean ENERGY STAR performance rating of 2011 (with an average ES score of 65.6) and 2016 (with an average ES score of 68.2), $t(802) = -3.44$, $p = 0.001$. On average, 2016 ES scores increased by approximately 5% (3 points) compared to 2011 scores (see Table 19).

(a) (b)

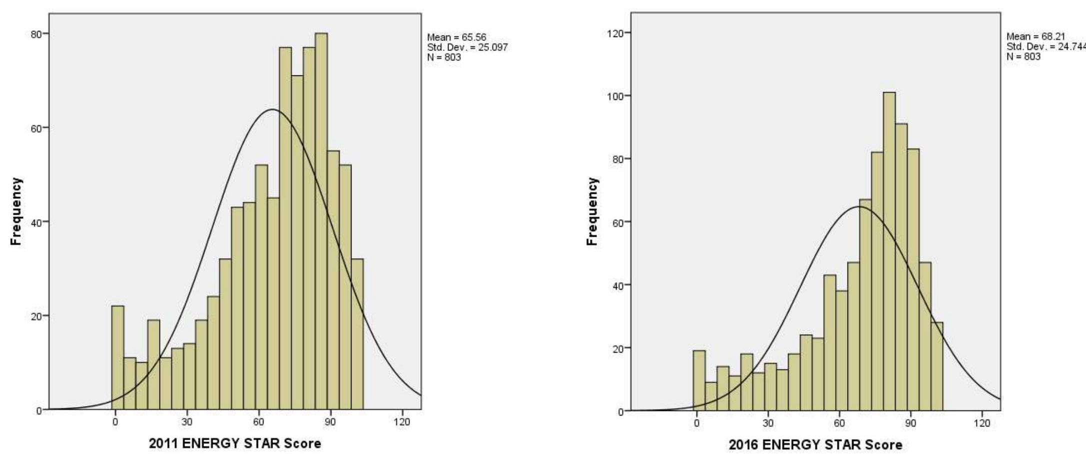


Figure 11. ENERGY STAR score histogram for NYC commercial buildings’ 2011 benchmarking data (a) and 2016 data (b).

Table 18

ENERGY STAR Score—Paired Samples Statistics

	Mean	*N*	Std. deviation	Std. error mean
2011 ESS	65.56	803	25.097	.886
2016 ESS	68.21	803	24.744	.873

Table 19

ENERGY STAR Score—Paired Samples Test

	Paired differences							
				95% confidence interval of the difference				
	Mean	Std. deviation	Std. error mean	Lower	Upper	*t*	*df*	Sig. (2-tailed)
2011 ESS – 2016 ESS	-2.654	21.860	.771	-4.168	-1.140	-3.440	802	**.001**

Table 20 shows the mean difference between the consistently calculated ENERGY STAR performance rating of 489 commercial buildings out of the 803 commercial buildings with ES scores between 2011 and 2016. As shown in Tables 20 and 21 (Pair 1), the average ES performance rating significantly improved from 65.3 in 2011 to 68.5 in 2012 $t(488) = -4.99$, $p < 0.001$, $\alpha = .05$. However, the average ES score significantly dropped to 66.4 in 2013 $t(488) = 3.53$, $p < 0.001$, $\alpha = .05$. An improved average score was obtained in 2014; however, the achieved improvement was not statistically significant, (see Table 21 - Pair 3). As shown in Table 20 (Pair 4), the average ES score slightly dropped again in 2015. Then it significantly improved in 2016 $t(488) = -3.74$, $p < 0.001$, $\alpha = .05$ (see Table 21 – Pair 5). This analysis shows an average improvement in ES scores of almost 5% (3 point), similar to the results obtained previously in this section. However, the improvement pattern was inconsistent, as shown in Figure 12.

Table 20

Paired Samples Statistics—Annual ENERGY STAR Score Pattern From 2011 to 2016

		Mean	*N*	Std. deviation	Std. error mean
Pair 1	2011 ESS	65.25	489	25.166	1.138
	2012 ESS	68.53	489	24.777	1.120
Pair 2	2012 ESS	68.53	489	24.777	1.120
	2013 ESS	66.41	489	24.915	1.127
Pair 3	2013 ESS	66.41	489	24.915	1.127
	2014 ESS	66.07	489	24.098	1.090
Pair 4	2014 ESS	66.07	489	24.098	1.090
	2015 ESS	66.89	489	24.253	1.097
Pair 5	2015 ESS	66.89	489	24.253	1.097
	2016 ESS	68.71	489	24.436	1.105

Table 21

Paired Samples Test—Annual ENERGY STAR Score Pattern From 2011 to 2016

		Paired differences							
					95% confidence interval of the difference				
		Mean	Std. deviation	Std. error mean	Lower	Upper	*t*	*df*	Sig. (2-tailed)
Pair 1	2011 ESS – 2012 ESS	-3.288	14.587	.660	-4.584	-1.992	-4.985	488	**.000**
Pair 2	2012 ESS – 2013 ESS	2.127	13.325	.603	.943	3.311	3.529	488	**.000**
Pair 3	2013 ESS – 2014 ESS	.342	12.579	.569	-.776	1.459	.600	488	**.549**
Pair 4	2014 ESS – 2015 ESS	-.828	12.110	.548	-1.904	.248	-1.512	488	**.131**
Pair 5	2015 ESS – 2016 ESS	-1.820	10.769	.487	-2.777	-.863	-3.737	488	**.000**

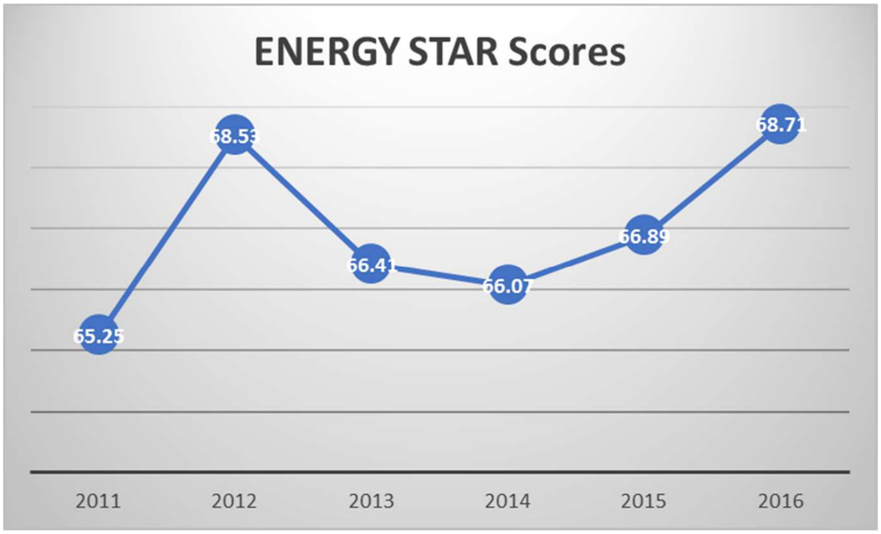


Figure 12. Annual ENERGY STAR score pattern from 2011 to 2016

Summary

Paired sample *t* tests were performed using SPSS 24 to compare the mean difference between the 2011 and 2016 energy benchmarking data of NYC commercial buildings based on the performance indices calculated by the ESPM. A total of 1,072 commercial building that benchmarked in both 2011 and 2016 were included in the study (803 buildings with ENERGY STAR performance rating). The study results revealed that in comparison to 2011, the average energy consumed by NYC commercial buildings in 2016, considering both the site EUI and source EUI significantly dropped by 5% and 10%, respectively. Furthermore, the total amount of GHG emitted by NYC commercial buildings was significantly lower than the amount emitted in 2011 by approximately 12% (246 $MtCO_2e$). The overall ENERGY STAR performance rating calculated by Portfolio Manager indicated that the energy performance of NYC commercial buildings significantly improved in 2016 by approximately 5% (3 points) compared to 2011). These results are in good agreement with the results reported in NYC's Energy and Water

Use 2014 and 2015 Report that also showed 10% drop in source EUI and 14% reduction in GHG emissions by NYC benchmarked buildings in 2015, (NYC Urban Green Council, 2017).

Additional statistical analyses of the city's commercial buildings annual energy performance patterns were performed in order to thoroughly understand the energy consumption pattern of NYC's commercial buildings and assess the efficacy of the adopted benchmarking policy. The mean differences between NYC commercial buildings energy performance metrics calculated by the ESPM were compared on an annual basis throughout the period between 2011 and 2016 using paired sample *t* tests. The annual analysis of the site EUI revealed a substantially inconsistent consumption pattern with fluctuating mean differences throughout the 6 years with the most significant decrease achieved in 2012 - the first year following the public disclosure of the benchmarking data. Despite the steady reduction in the source EUI pattern during the period between 2011 and 2016, the only statistically significant decrease was also obtained in 2012. Similar steady reduction pattern in the average amount of GHG emissions was obtained throughout the 6 years with the only statistically significant GHG emissions cut obtained in 2012. On the other hand, the ES scores analysis revealed an inconsistent pattern and fluctuating mean differences with the only significant improvements obtained in 2012 and 2016. Overall, 66% of savings in source EUI, 48% of cuts in GHG emissions, and 91% of the improvement in ES scores were achieved a year after the public disclosure of the benchmarking data. Additionally, the mean site EUI in 2012 was actually lower than that obtained in 2016.These results will be further discussed, conclusions will be drawn, and recommendations will be made in Chapter 5.

Chapter 5: Discussion, Conclusions, and Recommendations

Introduction

The focus of this quantitative study was understanding the influence of the energy benchmarking and disclosure policies that have been adopted by many local and state governments nationwide over the past decade. A repeated measures design was adopted to answer the research question, which addressed whether the mean annual energy use of NYC's existing commercial buildings significantly reduced after the city implemented Benchmarking Law LL84. Paired sample *t* tests were performed to compare the mean energy performance indices calculated by the ESPM of 1,072 of NYC commercial buildings that were benchmarked in both 2011 and 2016. The statistical analysis evaluated the significance and direction of the difference between the means of the paired observations and determined whether the energy performance of the city's existing commercial buildings significantly improved after the policy implementation. The annual energy performance patterns of NYC's existing commercial buildings were also analyzed.

The study results revealed that compared to 2011, the energy performance of NYC's commercial buildings had significantly improved by 2016, as their site EUI had significantly reduced by 5%, source EUI had significantly decreased by10%, GHG emissions had significantly dropped by 12%, and ENERGY STAR performance rating had significantly improved by 5%. However, inconsistent annual energy performance patterns were detected, and the statistically significant improvements were primarily achieved one year after the energy benchmarking data were publicly disclosed in 2012, as

66% of savings in source EUI, 48% of cuts in GHG emissions, and 91% of the improvement in ENERGY STAR scores were achieved in 2012. In addition, the average savings in site EUI achieved in 2012 was twice as much as that obtained over the 6 years.

Interpretation of the Findings

The study findings confirmed the body of knowledge in the research regarding the energy performance of NYC's benchmarked buildings reported in NYC annual benchmarking reports. The results obtained for this study agree well with those reported in NYC's Energy and Water Use 2014 and 2015 Report, which also showed a 10% drop in source EUI and 14% reduction in GHG emissions by NYC benchmarked buildings (including multifamily, office, and other building categories) in 2015 compared to 2011 data (Urban Green Council, 2017). The congruence between the results can be attributed to the fact that commercial buildings are considered the dominant building category in NYC, comprising more than 35% of the benchmarked gross floor area. Meanwhile, including 2016 benchmarking data in this study might have led to the slight difference between the obtained 12% drop in GHG emissions by 2016 and the data reported by the Urban Green Council (2017), which showed a 14% cut in GHG emissions in 2015.

Furthermore, the analyses of the annual energy performance patterns of NYC's commercial buildings revealed that 66% of reduction in source EUI, 48% of cuts in GHG emissions, and 91% of the improvement in ENERGY STAR scores were achieved in 2012. Likewise, the report by the Urban Green Council (2017) highlighted that 50% of the decrease in NYC large buildings' (including multifamily, office, and other building categories) source EUI and GHG emissions were achieved in 2012. Similar ENERGY

STAR score patterns showing the dramatic improvement achieved in 2012 with a 3-point mean difference between 2011 and 2012 (from 65 in 2011 to 68 in 2012) were also reported in the NYC 2013 Local Law 84 Benchmarking Report that showed median ENERGY STAR performance ratings of 64 and 67 for 2011 and 2012, respectively (City of New York, 2016). The substantial energy performance improvements achieved in 2012 can be related to the public disclosure of the benchmarking data, given that the study results indicate that the most statistically significant improvements were achieved in 2012, one year after the city's energy benchmarking data were publicly disclosed. Meanwhile, the energy performance patterns between 2013 and 2016 were inconsistent. Hence, additional measures that aim to motivate energy efficiency upgrades should be adopted to maintain continuous energy saving and GHG mitigation patterns and allow NYC to maintain long-term sustainability and achieve goals to save energy and cut GHG emissions by 80% by 2050.

Furthermore, Kontokosta (2015), Hsu (2014b), Scofield (2013), and Kaskhedikar et al. (2015) questioned the accuracy and reliability of the ESPM (EPA's benchmarking tool) and the validity of its scores. The analyses performed to examine the annual energy performance patterns further confirmed this issue. The obtained annual patterns of ES scores were not consistent with those of the source EUI and GHG emissions, except for the statistically significant improvements achieved in 2012. The mean ES score significantly dropped in 2013 (from 68.5 to 66.4), while the means of both source EUI and GHG emissions slightly improved. In contrast, when the average source EUI slightly increased in 2016, the ES score significantly improved (from 66.9 to 68.7). On the other hand, the obtained annual patterns of the ES scores were in good agreement with the annual site EUI patterns. The ES scores significantly dropped when the mean site EUI significantly increased in 2013, and they significantly improved when the site EUI significantly decreased in 2016. This indicates that the ES performance rating follows the site EUI rather than the source EUI, although, according to the EPA, the ES performance rating relies primarily on source EUI as the most accurate unit for the evaluation of energy performance because it measures the total amount of energy required to operate the buildings (ENERGY STAR, 2016b). Accordingly, the annual benchmarking reports provided by the NYC Urban Green Council and NYC Mayor's Office of Sustainability (Urban Green Council, 2016, 2017), as well as the research studies conducted on the energy benchmarking of buildings, all relied on source EUI to evaluate the energy performance of buildings (Hsu, 2014b; Scofield, 2013). These findings further doubt the reliability of the ENERGY STAR Portfolio Manager, which is currently considered the most widely used benchmarking tool nationwide.

Interpretation of Findings in the Context of Theoretical Framework

The study findings indicate that the energy benchmarking and public disclosure of benchmarking data generated the information necessary to encourage energy-efficiency upgrades for owners/managers of NYC's existing commercial buildings, resulting in statistically significant energy performance improvements over the 6 years of the policy's implementation. As the IAD framework allows for making choices—based on rational choice theory—to weigh benefits (future savings in running costs, higher occupancy rates, and higher property values) and limitations (initial cost of energy-efficient projects) to reach decisions that generate the most gains, existing buildings' owner/managers considered the disclosed energy benchmarking data that showed the energy performance of their buildings to weigh the risks and rewards of their energy-efficient investment decisions (Ostrom et al., 2014). Within this context, the IAD framework offered a systematic approach to organizing policy analysis actions using a wide range of analytic techniques, and the theoretical framework was applied to analyze and manage complex policy situations to achieve desired policy outcomes. Thus, the IAD framework allowed me to make inferences concerning the influence of energy benchmarking and disclosure policies on the individuals' rational decisions as a democratic way to solve problems by changing the rules employed by participants at different levels of the institution.

Limitations of the Study

The main limitation of this study is that the paired sample *t* tests did not imply causality and the obtained research findings only measured the changes in energy performance patterns of NYC's benchmarked commercial buildings after the implementation of the energy benchmarking and disclosure policies (Campbell & Stanley, 1963). However, the statistically significant difference between the mean of the energy consumed by NYC's existing commercial buildings between 2011 and 2016 and the direction of change, in addition to the significant drop in GHG emissions and significant improvement in their ENERGY STAR performance, all indicate the influence of the policies on the energy performance of the city's commercial buildings. Another threat to the internal validity of the study is the potential that factors other than policy implementation might also be associated with the energy performance of the NYC commercial buildings, such as changes in occupant behavior, occupancy levels, and operation management.

The use of a purposeful sample that limited the study to one geographical site (NYC) is regarded as a threat to the external validity of the study (generalizability). However, the fact that NYC is the largest urban center in the United States, with the highest concentration of commercial buildings, makes it a viable example to examine, and other cities might find this kind of analysis useful. The total gross floor area covered by the NYC Benchmarking Law of 2.8 billion ft^2 represents more than 25% of the 10.7 billion ft^2 covered by all of the energy benchmarking and disclosure policies adopted nationwide (IMT, 2014). In addition, the study analyzed a large sample that included the entire population of commercial buildings benchmarked in both 2011 and 2016. All of these factors enhance the external validity of the study, boost the validity of its statistical inferences, and support the generalizability of its findings.

Recommendations

Based on the strengths and limitations of the current study as well as the literature reviewed in Chapter 2, additional research is recommended in the following areas:

- *Enhance generalizability*: The initially stated overarching aim of this study was to assess the influence of currently adopted energy benchmarking and disclosure policies. Recognizing the limitation of the study sample, in that it was confined to one geographical site (NYC), I recommend that future research in this field include larger samples with multiple geographical sites covered by energy benchmarking and disclosure policies in order to enhance the external validity of the research and ensure the generalizability of the outcomes. Additionally, similar research methodology could be replicated in other cities and jurisdictions of the United States.

- *Direct effect of the policies*: As the research method adopted in this study did not imply causality, I recommend that future research focus on investigating the direct effect of the energy benchmarking policies on the energy performance of buildings, as well as evaluating the factors that determine the energy performance of buildings (Gruber et al., 2015; Hsu, 2014a). Additional research could compare the effectiveness of the energy benchmarking policies with and without the public disclosure of data to further investigate the effect of the public disclosure of benchmarking data.
- *Policy implementation*: Based on this study's findings, future research could further analyze the energy performance patterns of NYC's buildings in order to maintain long-term sustainability and achieve their goals to save energy and cut GHG emissions by 80% by 2050 (Urban Green Council, 2017). A qualitative or mixed-methods study that incorporates interviews with NYC policy-makers could examine additional measures to motivate energy efficiency upgrades and identify appropriate policy implementation, incentives, and financing programs that could be adopted to maintain continuous energy saving and GHG mitigation patterns (Cluett & Amann, 2013; Kontokosta, 2015, Ma et al., 2012; Nelson et al., 2014).

- *Assess the accuracy of ESPM*: Kontokosta (2015) recommended developing specific benchmarking metrics for each city based on local building data to achieve better results as he referred the failure of the ESPM due to its reliance on EUI to measure the energy performance of buildings. The current study findings also questioned the accuracy of the ES energy performance rating as it aligned with the site EUI rather than source EUI. Hence, future research in this field could involve evaluating currently used benchmarking measures and/or developing new energy benchmarking tools, particularly assessing the accuracy of the ENERGY STAR Portfolio Manager, as the most widely used energy benchmarking tool nationwide (Kaskhedikar et al., 2015; Kontokosta, 2015).

Implications

The current study examined a successful intergovernmental collaboration involving various governmental agencies, including the EPA, which used national data collected by the Commercial Buildings Energy Consumption Survey (CBECS) to develop the ENERGY STAR Portfolio Manager—the energy benchmarking tool adopted by the city of New York Benchmarking Law LL84—to measure the energy performance of NYC buildings. Such collaboration could potentially enhance the development of policy options that promote collaboration between key stakeholders to maintain policy coordination and cooperation at the national, state, and local levels. Meanwhile, at the local government level, NYC is considered one of the leading cities to adopt energy benchmarking policies and publicly disclose its benchmarking data. The statistically significant results obtained by the current study, which indicate the efficacy of NYC Benchmarking Law LL84, could encourage other cities and jurisdictions to follow NYC's lead and adopt similar policies to meet their energy saving and GHG mitigation goals. At the individual level, the study outcomes could help to promote the culture of sustainability, raise public awareness regarding the benefits of energy-efficiency building, encourage private building owners/managers to invest in energy-efficient upgrades, and promote positive overall perceptions of the sustainable building concept. Such changes may strengthen the commitment to the notion of sustainable development and inspire policy makers develop policies that further reduce the environmental footprint of the building industry by reducing energy consumption and encouraging more efficient energy use.

Conclusion

Improving the energy performance of privately owned existing buildings is critical to save energy, cut GHG emissions, and mitigate climate change. The results of this quantitative study indicate that the energy performance of NYC's existing commercial buildings significantly improved after the implementation of NYC Benchmarking Law LL84. The study findings could help public officials, policy-makers, and legislators understand the benefits of energy benchmarking and the role of publicly disclosing benchmarking data in saving energy, in addition to helping private buildings' owners/operators understand the benefits of measuring the energy use patterns of their buildings in order to maximize the operational efficiency of existing buildings.

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Appendix A: Copyright Permission Letter

HI Samar,

Yes, you have our permission to use the graphics. I believe we are in the process of updating the pie chart showing covered buildings, but I do not know when that will be complete.

Katie

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On Thu, Apr 12, 2018 at 7:32 PM, Samar Hamad <samar.hamad@waldenu.edu> wrote:

Institute for Market Transformation

Dear Ms. Weeks,

I am a doctoral student at Walden University currently working on my dissertation that examines the influence of the energy benchmarking and disclosure policies on the energy performance of existing commercial buildings. I would like your permission to include the materials in the attached files in this project, including:

- Percentage of total carbon emissions from building sector (see Attachment 1).
- Number of properties annually covered by benchmarking policies (see Attachment 2).

The material will be used in the literature review chapter to explain the negative impact of existing buildings on the environment and the number of buildings covered by the benchmarking policies nationwide. Permission includes one-time, nonexclusive permission for the requested use. I would greatly appreciate your consent to my request. If you require any additional information, please do not hesitate to contact me.

Sincerely,

Samar Hamad
PhD student in Public Policy and Administration – Local Government Management for Sustainable Communities

School of Social and Behavioral Science
Walden University
Student ID: A00273895