Investigating Energy Consumption of Coastal Vacation Rental Homes

by

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In 2007, vacation rental properties in the United States accounted for more than 22% of the domestic lodging market. These properties are a unique segment of the lodging industry due to their residential design and commercial use. Coastal vacation rental properties represent the largest supply, demand and value of the nation's vacation rental supply. In the case of North Carolina's Outer Banks, tourism is the area's largest source of income, with vacation real estate agencies being the largest accommodation provider. This study uses a multiple regression analysis to investigate the energy consumption of 30 vacation rental homes on Hatteras Island. Hatteras Island's abundant supply of vacation rental homes provided a diverse sample to study energy consumption with a wide range of houses regarding size, age, and location. Since very little research has been conducted on the energy consumption of vacation rental homes, this study aims to contribute detailed information regarding the energy consumption of unique accommodation sector.

Investigating Energy Consumption of Coastal Vacation Rental Homes

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M.S. in Sustainable Tourism

by

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CHAPTER 1: INTRODUCTION

Overview

Within the confines of a popular destination dependent on mass numbers of visitors and visitor expenditures, unless under unusual circumstances, many of the negative impacts to the natural environment can be attributed to tourism. As the tourism phenomenon happens within an area, many changes occur to the area's physical, economic, and social assets. As Fridgen (1984, p. 20) stated: "Tourism and the environment are inseparable". Nearly three decades later, this statement is increasingly significant in pristine coastal areas considering the amount of physical development that has continued surrounding natural attractions. As demand increases for usage of destination areas, the tourism industry often attempts to fulfill the demand by increasing the supply of accommodations (Buckley, 2011) such as hotels, resorts, and second homes. As these accommodations are constructed and occupied, more resources are consumed and more waste is produced. This activity places a great deal of stress on the natural environment causing negative impacts such as carbon dioxide emissions due to transportation and power plants, water pollution from ground contaminants and surface runoff, and depletion of drinking water sources (Davenport & Davenport, 2006; Williams & Ponsford, 2009).

Coastal areas are the nation's leading tourist destination, with approximately 89.3 million people visiting U.S. beaches every year and 37% of U.S. households traveling to domestic beaches, where one third of those households spend seven nights or more (NOAA, 2006). According to PhoCusWright (2009), vacation rental properties are a key accommodator and accounted for more than 22% of the lodging market in the United States in 2007. Coastal vacation rental properties represent the largest supply (46%), demand (53%) and value (64%) of the nation's total vacation rental supply. The PhoCusWright study found that vacation rental homes are of particular importance to the south Atlantic region, which is home to three of the top five states with a significant vacation rental market with Florida being the first (22%), North Carolina the second (7%), and South Carolina the fourth (5%).

In the case of North Carolina's Outer Banks, one of the state's most well-known and popular destinations, development and infrastructure have nearly met their maximum carrying capacity thus lessening the need for research in green innovation for new construction. North Carolina's Outer Banks consists of a chain of barrier islands that are approximately 200 miles in length beginning at the North Carolina-Virginia boarder and extending south through four counties (Currituck, Dare, Hyde and Carteret) of North Carolina's coast. In addition to the area's beaches, major attractions include the Wright Brothers Memorial located in Kill Devil Hills, Jockey's Ridge in Nags Head, the largest natural sand dune on the east coast, and historic lighthouses including Currituck, Bodie Island, Cape Hatteras, Ocracoke, and Cape Lookout. Fishing is another major attraction that brings tourists to the Outer Banks. Charter boats out of the Oregon Inlet Fishing Center have the closest access to the Gulf Stream and Cape Hatteras is one of the most popular surf fishing attractions on the east coast.

The majority of development on the Outer Banks consists of second and vacation rental homes that are occupied by owners and tourists on a weekly basis during the summer months and are the largest form of accommodation in the region. As described in the North Carolina Vacation Rentals Act (1999), renting private homes for a week at a time to tourists is a unique business. Vacation rental homes are designed to be private residences, yet they operate commercially, serving as a source of income for the homeowner. The houses are used differently each week since different families have their own variety of needs and lifestyles. Due to the high rental cost of Outer Banks vacation rental homes during the peak season, these properties are usually filled to their maximum carrying capacity so that family members can distribute the rent between more people to make it more affordable. This results in extensive and oftentimes wasteful energy and water consumption and more solid waste production. These vacation rental homes make up the foundation of the local economy on the Outer Banks and are one of the region's largest consumers of non-renewable resources.

This study focuses on energy consumption of Outer Banks vacation rental properties and uses a multivariate regression analysis to determine how a sample 30 vacation rental properties on the Hatteras Island consumes energy. Independent variables such as location, orientation, size, age, seasonal energy efficiency ratios (SEERs) of heating, ventilation, and air conditioning (HVAC) systems, use of efficient lighting, and use of EnergyStar appliances will be used to determine the energy consumption of these properties. These variables and the methods of this study will be discussed in detail later in Chapter 3.

Problem Description

There are no current standards in place that require vacation rental properties to implement pollution prevention practices such as installing energy efficient electrical appliances, water heaters, lighting, heating, HVAC equipment, or low flow water fixtures. Vacation rental properties are a unique segment of the lodging industry due to their residential design and commercial use, and little research has been conducted to investigate their energy consumption patterns.

In many cases, small island destinations such as Hatteras Island have a fragile natural environment that is the foundation of their tourism product (Thomas-Hope & Jardine-Comrie, 2007). The construction and continuous occupancy of vacation rental homes contribute to the abuse of natural resources of the area such as the disruption of natural dunescapes and vegetation, erosion, surface water runoff, and fresh water consumption (Gill, Williams, & Thompson, 2010; Vinson et al., 2011). Many vacation rental homes on Hatteras Island are large luxury homes and contain private swimming pools, gas and electric pool heat, hot tubs, saunas, elevators, and commercial icemakers that contribute to a higher level of energy consumption than most residential properties (Andersen et al., 2008).

The energy consumption trends for vacation rental homes differ from those of conventional residential properties. Due to the constant change of tenants throughout the rental season, weekly consumption patterns can differ each week for the same house. Additionally, many coastal areas, including the Outer Banks, are seasonal tourist destinations. This means that many of the vacation rental properties are not in use during colder months, causing them to use significantly less energy during the off-season.

Purpose of the Study

This study will attempt to answer the research question: What aspects of vacation rental homes account for energy consumption? A series of hypotheses will be tested to form an answer to this question:

- H_1: Coastal vacation rental properties use more energy per square meter as they increase in age.
- H_2: Coastal vacation rental properties use more energy per square meter as the number of

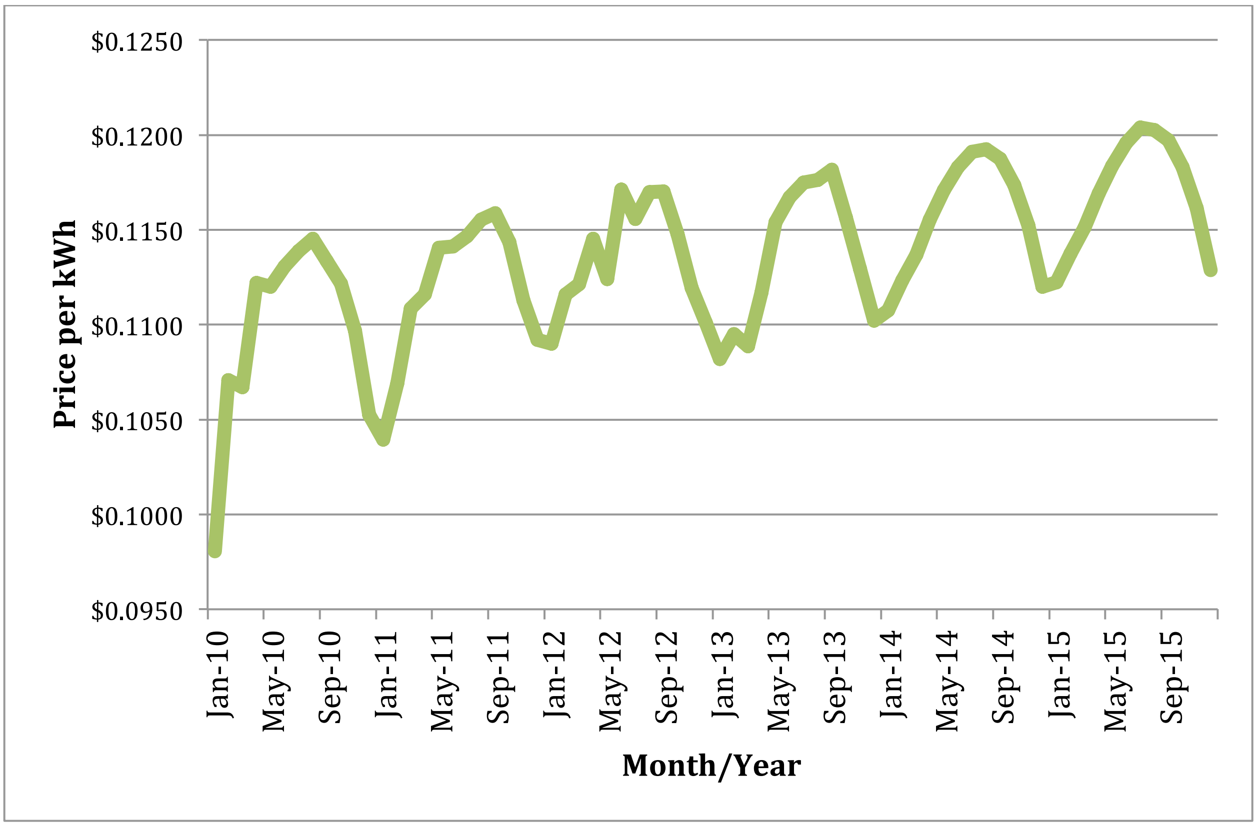
levels increase.

- H_3: Location relative to the main highway (ocean or sound side of highway 12) has a significant determination on energy consumption of Outer Banks vacation rental homes.
- H_4: Orientation of coastal vacation rental homes has a significant determination of their energy consumption.
- H_5: Coastal vacation rental properties with HVAC systems that have higher SEERs consume less energy than houses with HVAC systems with lower SEERs.
- H_6: Coastal vacation rental properties that generate energy for swimming pool heat with solar panels consume less energy than those that do not use solar energy.
- H_7: Coastal vacation rental properties with high efficiency lighting consume less energy than those without high efficiency lighting.
- H_8: Coastal vacation rental properties that use EnergyStar certified appliances consume less energy than those that do not use EnergyStar certified appliances.

These hypotheses will be tested by using a multivariate regression analysis with data collected from 30 vacation rental properties located on Hatteras Island. The findings will hopefully contribute to the tourism literature regarding accommodation sustainability by identifying, if any, relationships between different vacation rental characteristics and energy consumption. The results of this study could also present opportunities for vacation rental homeowners to reduce operating costs by encouraging them to implement sustainable practices within their properties to reduce energy and water consumption.

As pictured in Figure 1, energy prices are increasing and are projected to increase further due to the limited availability of natural resources, especially for the South Atlantic region. This adds more financial incentive for vacation rental homeowners to reduce their energy consumption. Therefore, retrofitting older properties to make them more efficient can potentially provide long term financial savings for vacation rental homeowners (Fard, Kibert, & Terouhid, 2012). Federal, state, and local governments have also provided tax incentives for sustainable energy initiatives for privately owned homes (Bourgeois et al., 2010). These incentives include rebates for solar and geothermal technology, EnergyStar certified appliances, and high efficiency lighting (Watson, 2009).

Figure 1: Historical Energy Pricing and Projections for the South Atlantic Region.



Source: U.S. Energy Information Agency, 2014

Greening vacation rental homes can also allow homeowners and rental agencies to market these homes as a more sustainable product than traditional rental homes. By doing so, this provides homeowners and rental agencies the opportunity to broaden their target market by attracting environmentally responsible tourists (Kim, Borges, & Chon, 2006). In a study by

Manaktola and Jauhari (2007), 66 people were surveyed to determine how they view the importance of green practices in lodging. Twenty-two percent of the respondents reported that they deliberately seek information about environmentally sustainable practices in lodging providers and make decisions accordingly while 55% at least pay attention to environmental initiatives. The remaining 23% are not concerned about environmentally friendly practices. This research suggests that the implementation of green practices can create a competitive advantage over companies who do not implement and market their green practices.

CHAPTER 2: LITERATURE REVIEW

Vacation Rental Dynamics

According to Frent (2009), "For some people using a second home as a type of accommodation could be an appropriate choice. If the second home is used for recreational and tourism purposes then it becomes a vacation home. Therefore, all trips to vacation homes can be counted as tourism". Although there is substantial literature on second home research, little has been done to study their energy consumption due to their use as weekly rentals.

It is a generally accepted concept that tourism development should implement sustainable practices whenever possible (Gössling et al., 2005). Therefore, when considering coastal accommodations, it is essential to manage for resource use reduction (Ghosh, 2011) in vacation rental homes not only for economic reasons but also for environmental purposes. "In the United States, the energy used in residential, commercial, and industrial structures produces over 40% of carbon dioxide emissions, 21% of which are from the residential sector alone" (Hoque, 2012). In 2010, homes that were used occasionally for recreational or seasonal purposes contributed to 3.5% of the total U.S. housing stock (U.S. Census Bureau, 2011), with 38% of these second homes located in the Southeast region of the country (Hall & Müller, 2004), where North Carolina has the lowest vacancy rate (see Table 1).

Table 1: National and State Vacation Rental Statistics

	All housing units	Vacancy rates for seasonal, recreational, or occasional use in the Southeast Region	
Florida	8,989,580	657,070	7.3%
South Carolina	2,137,683	112,531	5.3%
North Carolina	4,327,528	191,508	4.4%

Source: U.S. Census Bureau, 2010

Hall and Müller (2004) also explain that vacation homes in the United States have continued to grow in quantity since they have fallen within the financial capacity of more middle class citizens. This is especially true in the case of North Carolina's Outer Banks, as development associated with housing has recently met its peak due to the island's small developmental carrying capacity, causing a sudden decrease in new construction (Hao, Long, & Hoggard, 2013). Therefore, investigating the efficiency of energy consumption of existing vacation rental homes on the Outer Banks is the first step to identifying possibilities for pollution prevention practices within the area's built environment.

Sustainable Preferences of Customers

A review of the literature concerning tourists' behavior toward water and energy resources suggests that the majority of those who travel are not conservation minded, or do not implement the same practices as if they were at home (Borkovic, Kulisic, & Zidar, 2008; Garcia & Servera, 2003; Gill et al., 2010; United Nations, 1999). This increases the importance of installing efficient equipment and fixtures when possible. Management companies, homeowners, utility providers, and contractors have expressed interest in knowing the amount of money and resources that would be saved after retrofitting existing homes (Wall et al., 1983).

On the other hand, the demands of customers who are conservation minded have raised sustainability standards throughout the tourism industry, especially, in the accommodations sector (Sigala, 2014). These customers, along with other stakeholders such as governments, competitors, and environmental interest groups have pressured organizations to adopt sustainable practices that surpass the minimum requirements (Delmas & Toffel, 2004). A study by Millar and Baloglu (2011) found that out of a sample of 571 business and leisure travelers, both groups found green attributes to be an important factor in their hotel rooms such as energy efficient lighting, key card to control power use, linen and towel reuse policies, and green certification. Similar practices can be incorporated into the operations of vacation rental properties to satisfy the sustainable demands of such customers.

Energy Saving Practices for Residential Properties

Coastal vacation rental homeowners can reduce the amount of energy their properties consume by retrofitting certain items to more sustainable replacements. A sustainable retrofit is an improvement to an existing property with an associated cost that improves performance, adds value and reduces consumption for an extended period of time (Abraham and Nguyen, 2003; Allen, 2001; Menassa, 2011; Nelson, 2007; Tainter, 1995). The majority of Hatteras Island vacation rental properties are single-family detached homes with appliances, HVAC systems, lighting, and water fixtures that would typically be found in these types of properties. Therefore, similar methods of energy consumption reduction can be applied to vacation rental homes as other single-family detached homes.

Appliances, fixtures, seals, and other components of a residential structure degrade over time, causing the building's efficiency to decrease, which emphasizes the importance of retrofitting and proper maintenance for the purposes of reducing energy consumption (Heo et al., 2012). "There are many technologies on the market to improve the performance of the components of the building envelope, thus improving the overall performance of a house" (Cooperman et al., 2011). One vital aspect to consider when increasing the energy efficiency of a house is the installation of user-friendly devices, especially the HVAC system, which accounts for approximately 56% of the total energy consumption of a typical U.S residential structure

(U.S. Department of Energy, 2011). For instance, guests staying in a rental house must be able to easily program the thermostat so that the system operates properly (Peffer et al., 2011). Other common sustainable practices for residential properties can be found in Table 2.

Table 2: Sustainable Practices

Common Sustainable Practices for Single Family Detached Homes	
Sustainable Practice:	**Energy Savings:**
High Efficiency Lighting	75-80%
Occupancy Sensors for Lighting	30%
Tankless Water Heaters	27-50%
Insulating Jackets for Conventional Water Heaters	4-9%
EnergyStar Certified Appliances:	
Clothes Washer	20%
Dishwasher	10%
Refrigerator	15%
WaterSense Certified Water Fixtures:	
Showerheads	3.6%
Bathroom Faucets	1.6%

Sources: U.S. Department of Energy (2011), U.S. Environmental Protection Agency (2013), Lou (2010), Garg & Bansal (2000)

It is typically challenging for property owners and managers to accept the initial cost of retrofitting. However, retrofitting projects have proven to be money saving opportunities (Rankin, 2007). There is a large literature base on second home studies (Paris, 2009), but this work contains little information on their use as vacation rental homes and their energy consumption. There is also a good deal of literature on residential and commercial energy efficiency that shows how retrofitting can reduce energy consumption. Examples include works published by Chow (2012), Cooperman et al. (2011), Deerr (2012), Heo et al. (2012), Kumar (2011), and Yalcintas (2008). Similar concepts from these studies are used as a guide in this study to identify appropriate recommendations to increase the efficiency of the typical Hatteras Island vacation rental property.

For example, according to the U.S. Department of Energy (2012), changing traditional incandescent light bulbs to compact florescent (CFL) bulbs can save approximately 75% of energy consumption associated with lighting, and light emitting diodes (LED) typically use even less energy. Florescent tube lighting is frequently used in vacation rental houses, where T-12 bulbs are the most common. In most cases, these bulbs can be replaced by T-8 bulbs that consume less energy (Chow, 2012). In order to further reduce energy consumption associated with lighting, occupancy sensors can be installed so ensure that lights are only turned on when needed, which can decrease energy consumption associated with lighting by approximately 30% (Garg & Bansal, 2000).

Replacing traditional storage tank water heaters with tankless water heaters is another way to reduce energy consumption by a range of 27% - 50% (Luo, 2010). Adding an insulating jacket designed for an existing storage tank water heater can reduce energy consumption from 4% - 9% (U.S. Department of Energy, 2011). As shown in the bottom of Table 2, installing more efficient water fixtures can also reduce energy consumption. Reducing water consumption reduces the demand on water heaters, thus reducing their energy consumption (U.S. Environmental Protection Agency, 2013).

Another benefit that retrofitting provides is the emerging attraction of green buildings to the rental marketplace (Nelson, 2007). A study designed to identify how tourists' value energy saving practices reported that 87% of the tourists surveyed favored accommodations that invest in energy saving practices over businesses that do not; 77% of the tourists surveyed said they would be willing to pay more for accommodations that implement energy saving practices (Tsagarakis et al., 2011).

Energy Trends for Coastal Vacation Rental Properties

One of the main aspects of vacation rentals that differentiate them from traditional residential properties is the way they are occupied (NC Vacation Rentals Act, 1999). Since vacation rental properties on Hatteras Island are typically rented on a weekly basis by different tenants who are not responsible for any portion of the utility bill, energy consumption patterns for these properties tend to vary each week. These differences are based on the tenants' diverse perceptions of energy conservation practices and the behaviors they practice (or don't practice) on a daily basis regarding energy conservation (Barr et al., 2010). There is a gap in the literature in regards to energy consumption for vacation rental properties. Scholars who discuss energy conservation within accommodations (Borkovic et al., 2008; Manaktola & Jauhari, 2007; Nelson, 2010) mainly focus on hotels and condominiums. However, there has been some research focusing on energy consumption of second homes (Andersen et al., 2008), but many of these studies have been conducted in Europe where energy use policies vary in some cases substantially from the US and such studies do not focus on properties that are used for weekly rental purposes.

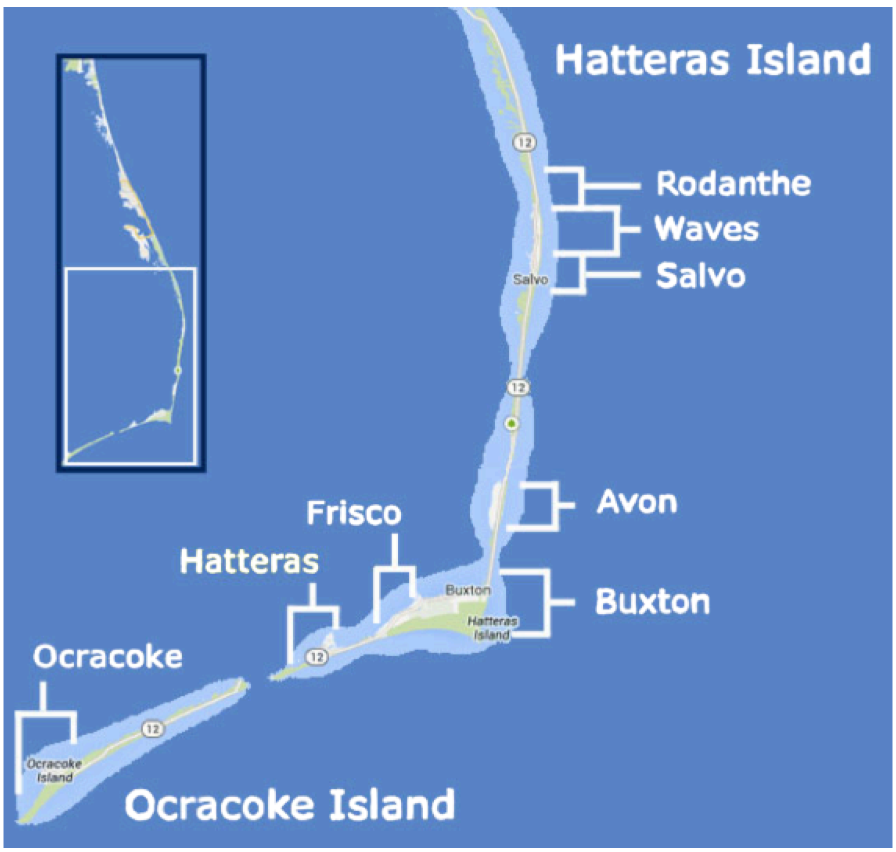
A clearer understanding of vacation rental energy consumption is needed in order to develop sustainable improvements to this portion of the accommodation supply. Along with investigating the energy consumption patterns of coastal vacation rental homes, this study also hopes to contribute to the tourism literature by narrowing the gap between vacation rental properties and energy consumption, allowing this study to be the first of its kind to observe and measure energy consumption patterns of vacation rental homes and identify variables to help explain these consumption patterns.

CHAPTER 3: METHODOLOGY

Study Area

This study aims to provide information of energy consumption patterns of Outer Banks' vacation rental homes by analyzing data from 30 properties on Hatteras Island (see Figure 2). North Carolina's Outer Banks contains nearly twenty thousand vacation rental homes, an abundant supply with a variety of sizes, ages, and amenities. This wide array of housing parameters provides an adequate set of characteristics by which to identify and compare the energy consumption of the typical Outer Banks vacation rental home.

Figure 2: Study Area



Source: http://www.outerbanks.com/hatteras.html

According to Hao, Long, & Kleckley (2011), vacation rental homes in Dare County, NC (from Duck, NC to Hatteras Island, NC) make up more than 70% of the county's total housing stock, causing the vacation rental industry to be the largest consumer of water and electricity and the largest producer of solid waste. Due to the lack of available land to build new houses on the Outer Banks, improving for efficiency of the area's vacation rentals really must focus on existing homes. As of 2011, there were 27,963 single-family detached homes in Dare County, with approximately 19,575 of them being vacation rentals (Hao, Long, & Kleckley, 2011).

Variables and Sample Description

The dependent variable for this research is the average monthly energy consumption per m^2 for each property. These figures were calculated by averaging the kilowatt-hours of electricity consumed per month for each property, which was then converted to megajoules (MJ) and divided by the area (m^2). These data were provided by the property management rental agency that provided access to the 30 vacation rental properties that were studied. Historical energy data were provided for homes in a time frame ranging from 12 to 24 months. Eight independent variables were used to explain the energy consumption of the housing sample. These included continuous variables such as age in years, number of stories, number of high efficiency light bulbs, SEER, and the number of EnergyStar certified appliances. Dummy variables were used to measure house orientation and use of solar energy. For example, for orientation, 0 = "not facing east" and 1 = "east facing", and for solar use, 0 = "does not use solar" and 1 = "uses solar". Another dummy variable was used to variable was used to measure location relative to the main highway. For this variable, 0 = "ocean side" and 1 = "sound side".

Figure 3: Sample Description - Area Ranges in m^2

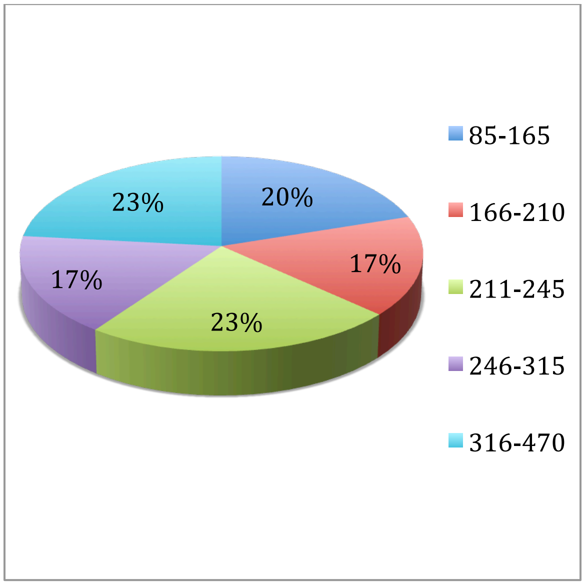
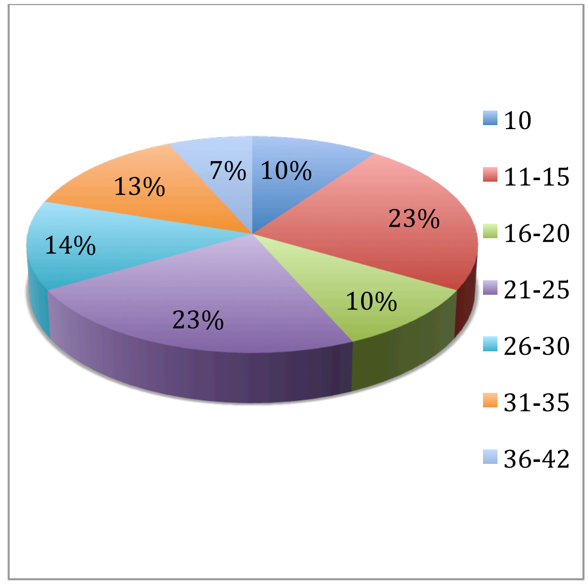


Figure 4: Sample Description - Age of Properties in Years



As suggested by Grafström and Schelin (2014), a sample for this type of study should be a miniature version of the population that it represents and cover each aspect of the population, which in many cases does not require a large (greater than or equal to 50) sample size. It is worth noting that the sample size has been addressed before in most empirical research. However, sample size problems are usually context dependent. The importance of increasing the sample size to account for uncertainties depends on practical and ethical criteria (Bartlett et al., 2001). Furthermore, sample size is not always the main issue; it is only one aspect of the quality of the research.

With regards to this sample, 30 audits were obtained out of a pool of about 250 options provided by the vacation rental management company. This sample size was chosen in order to provide a sample distribution that covers a wide variety of property sizes, ages, and locations while preserving quality of the research (Lenth, 2001). In this study, common statistical methodology was applied for analyzing the data obtained to offer a fair and balanced summary of results. The research is based on the assumption that the energy efficiency of the vacation rental properties reflects a normal distribution of energy use. If the assumption holds, and there is no reason to suspect that it does not, sample sizes of 30 to 60 have been found to be robust (according to most statistics books). While a larger sample size is always desired and a complete set of population data is ideal, the sample size used was based on cost and accessibility. Table 3 displays an overview of the sample which shows the distribution by orientation, location relative to the waterfront (ocean/sound side), number of levels, age in years, and area.

Table 3: Sample Overview

Orientation	**Number of Houses**	**Percentage**
East facing	18	60%
Not East facing	12	40%
TOTAL	30	100%
Location Relative to Ocean/Sound	**Number of Houses**	**Percentage**
Ocean side	20	67%
Sound side	10	33%
TOTAL	30	100%
Levels	**Number of Houses**	**Percentage**
1	3	10%
2	11	37%
3	13	43%
4	2	7%
5	1	3%
TOTAL	30	100%
Age in Years	**Number of Houses**	**Percentage**
10	3	10%
11-15	7	23%
16-20	3	10%
21-25	7	23%
26-30	4	13.5%
31-35	4	13.5%
36-42	2	7%
TOTAL	30	100.0%
Area in m^2	**Number of Houses**	**Percentage**
85-165	6	20%
166-210	5	17%
211-245	7	23%
246-315	5	17%
316-470	7	23%
TOTAL	30	100%

As shown in Table 3, the majority of the sample consists of east facing houses, an aspect that exists among many Outer Banks vacation rentals to accommodate for an ocean view. This variable was tested to determine if east-facing houses consume energy differently than houses that face in other directions. Although the majority of the houses in the sample contain two or three levels, this variable was tested since the number of levels could also be a contributing factor to higher energy consumption. Stairwells increase the climate-controlled area of the house, which could possibly cause the HVAC system to work harder than in other properties. Depending on the season, the rise of hot air and fall of cold air could also contribute to energy consumption of houses with multiple levels.

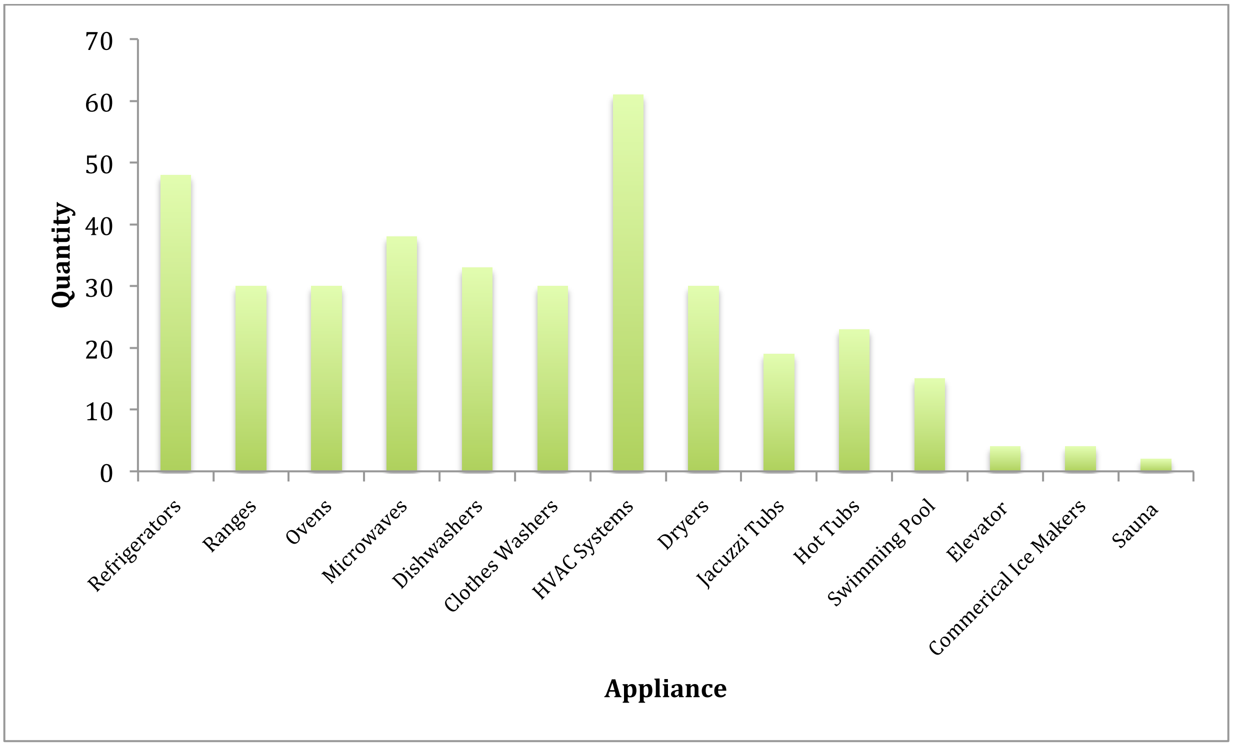
The area and age of each house were obtained from the Dare County property tax records. The presence of infiltration/exfiltration is another independent variable that will be tested to explain energy consumption. The number of appliances was also tested to explain energy consumption patterns. Table 4 shows the sample's average use of solar energy, high efficiency bulbs, EnergyStar certified appliances, and SEER of the HVAC systems.

Table 4: Averages for SEER, Efficient Lighting, and EnergyStar Appliances

Variable	Sample Average
SEER	12.6
Use of Efficient Lighting	25.4
Number of Energy Star Appliances	1.4
Use of Solar Energy	0.1

Figure 5 displays the totals of the different types of appliances located in the entire sample. Since the majority of the sample consists of multiple stories, most of the properties contain several HVAC systems so that each floor can have its own independent temperature setting. Some of the larger homes have more than one refrigerator, as recreation rooms with a kitchenette are common in Outer Banks vacation rental homes with multiple floors. These kitchenettes usually consist of a small sink, a full size or miniature refrigerator, and sometimes either a microwave, dishwasher, or both.

Figure 5: Appliance Schedule



The energy consumption data were collected from the property management company that rents and maintains these properties. Area measurements were converted from U.S. standard (ft^2) to metric units (m^2), and energy consumption was converted from kWh to megaJoules (MJ). A multiple regression analysis was used to display the relationships between the independent variables and energy consumption of coastal vacation rental homes.

CHAPTER 4: RESULTS

Data Description

This chapter discusses the results of the multiple linear regression analysis and displays the bivariate correlations between independent variables and energy consumption per square meter. The following analyses will help answer the research question: "What aspects of vacation rental homes account for energy consumption?" These findings and the following discussion will address the answer to this question as all as the hypotheses stated in Chapter 1.

Monthly energy consumption per m^2 ranges from 4 to 11 MJ/m^2. Location by town was coded geographically from north to south. 0 = Rodanthe, 1 = Waves, 2 = Salvo, 3 = Buxton, 4 = Avon, 5 = Frisco, and 6 = Hatteras. The age of the properties ranges from 10 to 44 years of age, number of stories ranged from one to five, area ranges from 278 to 1543 m^2, and the total number of appliances ranges from seven to 23.

With a mean energy consumption per m^2 of nine MJ per month and a standard deviation of two MJ, the majority of the sample (68%) falls into a range of 7 - 10 MJ/m^2 per month. When observing the location by town, 68% of the sample falls between Waves and Frisco, mainly due to one third of the sample coming from Avon. The mean age of the housing sample is around 22 years, and with one standard deviation away from the mean in both directions puts the majority of the sample between 13 - 32 years old. The mean number of levels for the sample is 2.6, since the majority of the sample (24 properties) consists of two and three story houses. The area of the sample has a mean of 794 m^2 with a standard deviation of 326 m^2, placing the majority of the sample between 468 - 1,119 m^2, thus providing a sample with a wide variation of house sizes. The mean for the number of appliances is approximately 12 with a standard deviation of four, placing the majority of the sample in a range between 8 and 16. These appliances include refrigerators, ranges, ovens, microwaves, dishwashers, clothes washers, HVAC systems, dryers, Jacuzzi tubs, hot tubs, swimming pools, elevators, commercial icemakers, and saunas (see Figure 3).

Existence of infiltration/exfiltration was coded “0” for minimal and “1” for severe. With a mean of .30, this shows that nearly one third of the sample contains some type of air leak that is above average. The team that examined the properties had an average of one hour to study each house, so the team walked through each property with a thermal imaging camera and scanned the interior and photographed noticeable leaks.

Two thirds of the sample is located on the ocean side of the island. The data were coded “0” for ocean side and “1” for sound side, explaining the mean of 0.3 for location relative to water. The majority (60%) of the sample included east facing properties which were coded “0” for non-east facing and “1” for east facing, providing a mean of 0.6. The mean SEER was around 13, the federal standard, with a standard deviation of two.

Results

As shown in Table 5, energy use intensity (EUI) ratios were used to compare energy efficiency across the sample. These ratios were calculated by dividing the average annual energy consumption by the area ($MJyr/m^2$). A lower EUI ratio means that a property is more efficient. These EUI ratios show that the largest house in the sample is the most efficient, suggesting that the area of a coastal vacation rental property does not have an impact on how energy efficient it is.

Table 5: Energy Use Intensity Ratios

Site No.	Area (m^2)	Annual Energy Consumption (MJ)	EUI Ratio
1	258	84,369.60	326.67
2	244	83,916.00	343.32
3	365	116,859.46	320.47
4	164	47,094.48	288.02
5	220	96,183.07	437.21
6	367	110,236.46	300.25
7	89	21,145.54	237.09
8	220	92,503.30	419.77
9	152	50,234.69	329.71
10	316	135,347.33	428.49
11	406	161,666.50	398.66
12	445	196,795.01	441.77
13	171	50,210.50	293.73
14	301	113,021.14	375.25
15	241	98,585.86	409.40
16	470	75,965.47	161.50
17	331	96,236.21	290.49
18	268	104,451.12	390.11
19	246	106,747.20	434.58
20	85	34,397.57	405.98
21	252	109,567.30	434.23
22	210	78,730.27	374.31
23	116	38,237.18	329.79
24	187	59,735.66	318.94
25	208	55,900.80	268.14
26	212	72,778.61	343.59
27	224	75,608.21	337.97
28	98	33,637.25	342.87
29	216	62,821.01	291.21
30	176	45,763.92	259.81

A multiple regression analysis was used to determine how the independent variables explain energy consumption. As shown in Table 6, the model explains 41.5% of energy consumption per m^2 for the coastal vacation rental properties observed in this sample. An *F* value of 1.96 (Sig. of 0.05) was used to measure the significance of the model. With a Sig. level of .129, the model as a whole did not significantly explain energy consumption. This is partially because the sample size is too small to achieve significant results, even though Sharmin et al. (2014) and Wierzba et al. (2011) used samples size of only 12 and 14 to measure energy efficiency in residential buildings. For this type of study, it is possible that a sample size larger than 30 may be needed in order to produce more significant results for the model as a whole, though other factors could also play into this such as the human factor, which looks at how different groups of tenants consume energy at the same property from week to week. Unfortunately, these data were not able to be collected since access to the properties was only allowed during the off-season.

Table 6: Model Summary

R Square	Adjusted R Square	F	Sig.
.410	.185	1.822	.129

Table 7 shows the relationships between each independent variable and monthly energy consumption per m^2. Two independent variables were removed from the model as they had high correlations with other independent variables, causing multicollinearity issues (Tabachnick et al., 2007). These two variables were Number of Appliances and Existence of Infiltration/Exfiltration. The rest of the independent variables do not have any multicollinearity issues, with all Variance Inflation Factor (VIF) levels under three and tolerance levels above 0.3 (Tabachnick et al., 2007).

Table 7: Regression analysis for variables influencing energy consumption per squatter meter

Independent Variables	Unstandardized Coefficients	Standardized Coefficients	t	Sig.	Collinearity Statistics	
	B	Beta			Tolerance	VIF
(Constant)	6.570		2.033	.055		
Age in Years	-.012	-.067	-.283	.780	.504	1.984
No. of Stories	.201	.104	.408	.688	.431	2.323
Location Relative to HWY 12	.392	.108	.399	.694	.380	2.634
East Facing?	.397	.114	.433	.669	.405	2.472
Avg SEER	.097	.093	.399	.694	.513	1.950
Efficient Lighting	-.032	-.657	-2.331	.030	.353	2.831
No. of EnergyStar Appliances	.750	.618	2.394	.026	.422	2.367
Use of Solar Energy	1.550	.227	1.153	.262	.725	1.378

The variables Location by Town, Location Relative to Highway 12, and East Facing are all insignificant when explaining monthly energy consumption per m^2, suggesting that location and orientation of these Outer Banks vacation rental homes do not significantly impact their energy consumption. Age is another variable that does not significantly impact energy consumption for this sample, suggesting that the building quality regarding energy efficiency for these properties has not improved over the past few decades. The number of stories is another independent variable that is insignificant when explaining energy consumption. Since most of these properties are constructed on small lots, the only way to build a larger house is to add levels.

SEER is another independent variable that is shown to be insignificant when explaining energy consumption for the properties in this sample. This can be explained by looking at the sample. Only one house had a SEER that was significantly higher than the rest of the sample, which is not enough to show how this variable impacts the dependent variable. Most of the properties in this sample had an average SEER that was at or a near the federal standard (SEER of 13). Only one house has an average SEER of 19. The largest and most efficient house that can be found in Table 5 also has a SEER of 19. According to the North Carolina State Energy Report (2010), space cooling makes of 17% of the total energy consumption for the average home in North Carolina. Since the Outer Banks is located in a warmer climate zone, it can be assumed that the percentage for space cooling on the coast can be a higher than that of the average.

The use of solar energy is another variable that could not be used to explain energy efficiency for this sample. For this selection of properties, solar energy is used to generate heat for swimming pools, which means the property also consumes energy to operate the pool pump and lighting around the pool area. Most of these properties that have swimming pools also contain other energy consuming items such as hot tubs, multiple refrigerators, and elevators.

The two variables that are significant when explaining energy consumption for this sample are the use of efficient lighting and the use of EnergyStar certified appliances. The total number of CFL and LED bulbs was calculated for each property and entered into SPSS. There is a strong negative relationship between the use of efficient lighting and average monthly energy consumption per m^2, suggesting that the use of efficient lighting is one reason why some of these properties consume less energy per m^2 than others. According to the US Department of Energy (2012), lighting accounts for approximately 10% of the average American home's total energy consumption, and retrofitting to high efficiency lighting can reduce the property's total energy consumption (Chow, 2012).

Although the use of EnergyStar appliances has been a successful method of reducing energy consumption in residential buildings (Catania, 2012), the use of EnergyStar certified appliances showed a strong positive relationship with average monthly energy consumption per m^2. Even though EnergyStar certified appliances consume less energy, they still consume a significant amount. Therefore, more appliances, whether they are EnergyStar certified or not, means more energy consumption.

CHAPTER 5: DISCUSSION & CONCLUSION

This study was designed to investigate and identify energy consumption patterns of Outer Banks vacation rental homes. To do this, 30 properties on Hatteras Island were examined by collecting historical energy consumption data from the Cape Hatteras Electrical Cooperative with the help of Outer Beaches Realty, the company that provided the study sample. Other data were collected from each property such as makes and models of appliances, HVAC equipment, lighting, and other energy consuming items such as commercial ice makers, hot tubs, Jacuzzi tubs, saunas, and elevators. The area and age of these properties were collected from the Dare County tax website. Once the data were collected from the sample, they were used to answer the research question: What aspects of vacation rental homes account for energy consumption? The answers to this question can help vacation rental property owners and management companies to decrease the operating costs of these properties associated with energy consumption and shrinking their ecological footprint by reducing carbon emissions at power plants. A multivariate regression analysis was used to test eight hypotheses in order to answer the research question.

The analysis shows that the area of a coastal vacation rental property does not impact the property's energy efficiency. The same is true for the number of levels, mainly because more levels means more area. Many Outer Banks vacation rental homes are built on small lots, therefore the only way to increase area to accommodate more guests is by adding more levels. A property's age is another variable that was proven insignificant when measuring energy efficiency. This finding is supported by the work of Ryghaug and Sørensen (2009), which suggests that the quality of coastal vacation rental properties on the Outer Banks has not improved over the past few decades when it comes to energy efficiency. This allows for the rejection of H_1 and H_2: Coastal vacation rental properties use more energy per square meter as they increase in age and coastal vacation rental properties use more energy per square meter as the number of levels increase.

Variables pertaining to a property's location and orientation also do not seem to impact energy efficiency. Based on the regression analysis, houses that face east do not seem to consume energy differently than those facing other directions. There is also no difference in energy consumption patterns between ocean and sound side properties, thus allowing for the rejection of H_3 and H_4: Location relative to the main highway (ocean or sound side of highway 12) has a significant determination on energy consumption of Outer Banks vacation rental homes and orientation of coastal vacation rental homes has a significant determination of their energy consumption.

Although SEER did not show as a significant variable for energy consumption, only one house had a SEER significantly higher than the rest, which also happens to be the largest and most efficient, making it a large contributor for that particular property, but not the sample as a whole. Therefore, H_5: Coastal vacation rental properties with HVAC systems that have higher SEER consume less energy than houses with HVAC systems with lower SEER was rejected. There were similar findings for the use of solar energy, allowing for the rejection of H_6: Coastal vacation rental properties that generate energy for swimming pool heat with solar panels consume less energy than those that do not use solar energy. Only two properties use solar energy for swimming pool heat. It is possible that if a larger sample were used, more houses could be compared against each other to see how the use of solar energy impacts a house's total energy consumption.

The strong negative relationship between the use of efficient lighting and average monthly energy consumption per m^2 suggests that coastal vacation rental homes with CFL and/or LED bulbs consume less energy and save more on utility bills than those with traditional incandescent bulbs, allowing for the acceptance of H_7: Coastal vacation rental properties with high efficiency lighting consume less energy than those without high efficiency lighting.

Even though the use of EnergyStar appliances was a significant variable to measure energy consumption, there was a positive relationship that suggests more EnergyStar appliances increases energy consumption. A larger sample could allow for houses to be placed into groups into similar characteristics, such as the number of appliances they contain. Those that use EnergyStar could be compared against those that do not, showing the true impact of using energy efficient appliances. Since there was a positive relationship with the use on EnergyStar appliances with energy consumption in this study, H_8: Coastal vacation rental properties that use EnergyStar certified appliances consume less energy than those that do not use EnergyStar certified appliances was rejected.

Academic Implications

Since there has been very little research conducted that pertains strictly to vacation rental properties and the energy they consume, this study is the first to explore energy consumption patterns in coastal vacation rental homes in the United States, and hopes to serve as a starting point with more research to follow. In order to further the knowledge base on energy consumption for coastal vacation rental homes on the Outer Banks, more detailed data will need to be collected such as thermal performance of the buildings, similar to the work of (Wierzba et al., 2011). The findings of this study show that there is no difference in energy consumption when observing the age and area of different properties, which suggests coastal vacation rental properties have not been built to operate more efficiently over the past few decades. More research will need to be conducted to provide further details about these properties to pinpoint commonalities that can be improved upon. With more time and personnel, tests can be performed on the HVAC systems of these properties to locate leaks in ductwork, identify sizing issues, and whether or not the systems were installed properly (Rhodes, Stephens, & Webber, 2011).

Although this study was able to locate exfiltration/infiltration by using thermal imaging equipment, there was not enough detail to provide for a useful independent variable to measure energy consumption patterns. More detailed data can be collected by performing air-handler fan pressurization tests to locate exfiltration/infiltration through a building's envelope (Jeong, et al., 2008).

Industrial Implications

This study can assist property mangers and coastal vacation rental homeowners by addressing common areas within these properties that can be improved to be made more efficient. Based on this sample, Outer Banks vacation rental homes can be retrofitted with high efficiency lighting and tankless water heaters to make them more energy efficient. Sealing air leaks and installing occupancy sensors can also reduce energy consumption. Property managers can use these methods to attract new homeowners by showing them how they can save money on their utility bills by using their company. Companies can show homeowners how some of their commission can be returned to them through energy savings, a benefit that other companies are not offering. Managers can also attract green tourists that place eco-friendly practices as a high priority when choosing a vacation rental home (Kim et al., 2006). This would provide both the management company and the vacation rental homeowner with an opportunity to tap into a new market segment that they are not yet able to reach.

There are many sustainable methods for reducing energy consumption that were not found in any of these properties. A financial analysis was conducted for the sample to show various methods of reducing energy consumption for coastal vacation rental properties.

Table 8: Recommendations for Coastal Vacation Rental Properties

Installing High Efficiency Lighting			
Average Annual Savings	Average Payback in Years	Average Net Present Value	Percent of Homes This Recommendation Applies To
$130.75	1.2	$707.89	100%
Installing Occupancy Sensors for Lighting			
Average Annual Savings	Average Payback in Years	Average Net Present Value	Percent of Homes This Recommendation Applies To
$63.58	4.0	$825.84	90%
Replacing Storage Tank Water Heaters with Tankless Water Heaters			
Average Annual Savings	Average Payback in Years	Average Net Present Value	Percent of Homes This Recommendation Applies To
$177.83	5.2	$2,044.86	100%
Adding an Insulating Jacket to Existing Water Heaters			
Average Annual Savings	Average Payback in Years	Average Net Present Value	Percent of Homes This Recommendation Applies To
$28.95	1.0	$450.09	100%

Replacing incandescent lighting with more efficient bulbs and installing occupancy sensors are two effective methods of reducing energy costs associated with lighting. Installing insulating jackets to existing water heaters or replacing them with tankless demand water heaters can also reduce a property's energy consumption (Luo, 2010).

Limitations

Data collection for the study consisted of three team members examining 30 vacation rental properties over the coarse of three weekends, with approximately one hour to gather data from each property. The team could only gather exfiltration data with a thermal imaging camera and a hand held air velocity meter. With more financial resources to provide more time and manpower, more detailed methods of data collection could have been conducted such as blower doors tests and air-handler fan pressurization tests.

Even though this study contained a sample size that represented the size and age aspects of the population, a larger sample size would provide more information to show the impact having a more efficient HVAC system. The largest and most efficient house for this sample has the highest SEER. However, a larger sample could provide more houses with different SEER that could show how higher SEER impact energy consumption.

Data was also collected in the winter months where some of the properties were shut down for the season. Preparing these properties for examination was time consuming since the heat needed to rise to a certain temperature to find exfiltration. This portion of the study was unavoidable since many of these properties are fully booked during the summer months with only a few hours in between tenant change over. Hatteras Island only has one two-lane highway that gets congested during the summer, which would also make auditing difficult. There were also high winds with hard rain during most of the data collection period, preventing the team from taking thermal images from outside of the properties. It also prevented the team from capturing other images on the outside of the properties since tablets were used to take photographs.

Access was also restricted to some areas of the property such as locked utility closets that contain water heaters and air handlers. Some of the properties with swimming pools had the equipment locked in an outside building, which prevented the team from gathering energy consumption data from pool pumps and heaters.

Future Research

One of the main aspects of vacation rental energy consumption that future research could investigate is the human factor of these properties. Coastal vacation rentals are used by different groups of people each week, suggesting that they consume energy differently each week. Studies could be conducted to determine how tourists' energy consumption patterns differ from when they are at home. For example, instead of examining properties while they are not in use, researchers could take a social science approach and provide guests with a survey (Sütterlin, Brunner, & Siegrist, 2011) that they would turn in when they check out of their rental property. This would provide information that shows how tourists consume energy while they are on vacation. The energy that tourists consume in vacation rental homes is included in the rent; therefore they do not have to pay extra except for swimming pool heat on some occasions. This type of research could allow homeowners and vacation rental property managers to take a more efficient approach to managing coastal vacation rental properties to reduce operating costs and negative environmental impacts.

More detailed data can be collected from these properties by using equipment that can test for air leaks within the ductwork and the building envelope (Jeong et al., 2008). This would provide a more accurate measure to explain how exfiltration impacts energy consumption in coastal vacation rental properties. When these properties were examined, thermal imaging equipment was used to locate infiltration and exfiltration of heat throughout the houses. The data collection team scanned the interior of each property with a thermal imaging camera and took infrared images of any air leaks found in and around doors, windows, and walls. Infiltration refers to outside air penetrating through the building's envelope, while exfiltration refers to inside air escaping the building's envelope (Desmarais, Derome, & Fazio, 2000). Almost any house will have some type of air leakage around exterior doors and windows. The houses that were listed as having significant infiltration/exfiltration had leaks in other areas such as through walls, floors, or more severe leaks around exterior doors and windows when compared to other houses. Similar to most vacation rental properties on the Outer Banks, all of the houses in this sample are elevated off the ground. Some are elevated just a few feet, while others are elevated an entire story above ground to accommodate for storage and parking, as well as to reduce the impacts of potential flooding. This allows for wind to blow underneath the houses and alter the thermal conditions on the inside if there are gaps in insulation or cracks where air can leak through. More time to investigate these properties would also allow for researchers to take more thermal images to generate accurate calculations for existing exfiltration. Other research can be conducted by implementing energy saving practices and recording the effects, such as programmable thermostats and additional insulation (Suter & Shammin, 2013).

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