Financially Viable Sustainability Solutions in Multifamily Residential Properties

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Abstract

Drucker and Falk is a family-owned real estate company that focuses on third-party fee management of multifamily properties. Through isolated LED retrofit projects, Drucker and Falk realized the environmental and financial benefits of sustainability projects and is now seeking to implement financially viable sustainability solutions for its whole portfolio of more than 350 properties. In order to provide solutions that work for all Drucker and Falk properties, this study created a best practices guide and interactive Excel-based models that Drucker and Falk can use to identify and analyze potential sustainability strategies. This project then conducted case studies, applying the provided tools to three Drucker and Falk properties in order to demonstrate the process and benefits of increased sustainability practices. The case studies revealed potential environmental benefits and cost savings in utility bill management, lighting retrofits, pool pump alterations, and future building design. The tools provided by this project, along with the case study findings, will be used as a foundation for additional analysis and implementation of sustainability projects across the entire Drucker and Falk portfolio.

Executive Summary

Drucker and Falk (D&F) is a third-generation, family-owned, real estate management company that focuses on third-party fee management of multifamily residential properties. D&F manages more than 30,000 multifamily units in nine states. As a company, D&F is dedicated to lowering its carbon footprint and has already implemented many sustainability projects including converting pools from chlorine to salt water and installing LED lighting. The potential to realize both environmental and financial benefits from these efforts has motivated D&F to continue implementing sustainability projects while measuring and verifying results. With this idea in mind, D&F has asked a Duke University Master's Project team (MP Team) to make recommendations on how D&F can implement "financially viable sustainability solutions" across their entire multifamily portfolio.

Because D&F manages hundreds of properties in nine states, visiting and analyzing all properties was beyond the scope of this project. Instead, the MP Team designed a "best practices" guide and four interactive excel models to allow the D&F team to analyze their properties and make data-driven sustainability investment decisions. To prove the validity of the methodology, the MP Team applied these tools to three property case studies and presented D&F with behavioral and retrofit suggestions that limit greenhouse gas emissions, save water, and save money.

The best practices guide includes technology guidelines such as lighting efficacy, occupancy behavior suggestions such as thermostat setpoints, and financial strategies such as internally adopting the social cost of carbon. This report has both detailed explanations of each strategy and a quick reference guide that can be used when making retrofit or policy choices.

The four interactive models include: 1) "Energy Diagnostics", 2) "Lighting & Plumbing Retrofit", 3) "HVAC & Building Envelope", and 4) "Rooftop Solar PV Simulation." These models are designed to take basic user inputs, calculate cost savings and environmental benefits, and display the results in a cash flow analysis. The models also determine whether a retrofit is technically feasible.

The property case studies used utility data, building walkthroughs, and building drawings to set a baseline for electricity and water use for each property. The MP Team then identified hotspots and used the interactive models to simulate retrofits that would lower electricity and water use and save money. The environmental and monetary savings at each property were presented.

At all three sites, lighting retrofits almost always offered the highest returns of any technology. While the magnitude of returns from lighting retrofits were higher, water efficiency retrofits utilize lower-cost technology that lasts many times longer than light bulbs. This tradeoff allows water efficiency measures to be implemented faster and with less risk than lights. Additionally, D&F has a major environmental and financial incentive to construct or convert all pools to salt water and employ specialty pump equipment that drastically reduces electricity consumption.

The MP Team also had general recommendations that should serve as a strategic framework when considering a new property for sustainability initiatives. First, the challenges and opportunities at a property are never similar enough to another site that a generic “cookie-cutter” solution can be applied. Sustainability managers at D&F should approach each property as a unique situation and always gather preliminary data without making prior assumptions. Second, when managers are beginning work on a property, they should always prioritize absorbing the knowledge and experience of the property’s tenants and staff, as many water and energy issues are nearly impossible to directly observe, and consistent long-term experience greatly increases the chances of detection. Finally, the introduction of more sophisticated data collection and analysis techniques will allow D&F to maximize their sustainability efforts.

The Nicholas School of the Environment will continue its collaboration with D&F in order to further improve the feasibility of deploying sustainability initiatives across all of D&F’s portfolio. To that end, the 2018 MP Team recommends that the future 2019 MP Team focuses on developing a business model that will prioritize the profitability and speed of scaling up the auditing, modeling, and technological best practices specified in this report. In support of this business plan, the 2018 MP Team also recommends research into additional sustainability topics, including waste management, landscaping, and building design. Furthermore, the 2019 MP Team can improve the universality of this report’s recommendations and models by auditing properties in different climatological regions. Additional collaboration can supplement the 2019 MP Team’s work, including client-based, independent study work where Nicholas School master’s students can conduct audits and sustainability workshops with D&F property staff.

Introduction

Drucker and Falk (D&F) is a third-generation, family-owned, real estate management company that focuses on third-party fee management of multifamily residential properties. They manage more than 30,000 multifamily units in nine states. Their headquarters is in Newport News, Virginia, and they have offices in Virginia, North Carolina, and Georgia.

D&F, as a company, is dedicated to lowering its carbon footprint and has already implemented many sustainability projects. These projects include switching some swimming pools to salt water rather than using chlorine and other chemicals, replacing incandescent and fluorescent bulbs with light-emitting diodes (LEDs), and installing low-flow water fixtures. These projects have lowered electricity and water use and saved money by reducing maintenance needs. While isolated projects have been completed, results have not been measured or verified. The potential to realize both environmental and financial benefits from these efforts has motivated D&F to continue implementing sustainability projects and measure and track the results.

In the 2017/2018 academic year, students from Duke University formed a master's project team (MP Team), to provide D&F with information and tools to help identify and evaluate potential sustainability projects for environmental and financial viability. The MP Team met this objective by providing the following:

1. Best practices guide including comprehensive information and concrete recommendations for behavioral and technological changes to improve the overall sustainability of each property
2. Interactive financial models for energy and water efficiency investments at D&F's multifamily properties. The following models were submitted to D&F:
    - "Energy Diagnostics"
    - "Lighting & Plumbing Retrofit"
    - "HVAC & Building Envelope"
    - "Rooftop Solar PV Simulation"
3. Three case studies applying the recommended best practices and financial models to three sample D&F properties

Background: Sustainability in the multifamily residential industry

Energy efficiency and sustainability initiatives are a significantly underutilized strategy for improving the affordability and reliability of resource consumption. Across all U.S. sectors, energy efficiency projects between 2017 and 2020 could yield an estimated $680 billion in net present value and abate up to 1.1 gigatons of greenhouse gases annually (Choi Granade, et al., 2009). Comparing sectors, residential properties are the third-highest energy consumer at 20,411 Trillion Btu in 2016, or 21% of the energy consumed by buildings and transportation (EIA, 2017).

Fannie Mae has recognized the impact that residential buildings have on the environment and created the Multifamily Green Initiative (Fannie Mae, 2012). This initiative seeks to implement sustainability solutions at multifamily apartments not only to reduce the environmental impacts, but also because it is believed that these initiatives may increase the financial value, overall quality, and lifespan of apartment buildings (Fannie Mae, 2012). This finding is echoed by the U.S. Department of Housing and Urban Development, which found that there is "unpicked low-hanging fruit," representing a possible 29% increase in efficiency in multifamily housing stock by 2020 (PD&R, 2011).

This interest in sustainable apartment buildings has also been supported by the tenants themselves. In a national 2014 survey, multifamily apartment residents were asked to rank the importance of certain sustainability features when selecting an apartment (J Turner Research, 2014). This survey revealed that tenants valued energy efficient appliances, having the apartment located in a pleasant and walkable area, the use of renewable energy, and low-flow toilets, with each factor scoring over 6.9 out of 10. This study showed that tenants desire sustainability features in apartments, creating a potential competitive advantage for real estate companies that can include sustainability features in their properties (J Turner Research, 2014). Furthermore, according to John Sebree, Director of Marcus and Millichap, millennials are coming to expect environmental features in apartments, and some are willing to pay more for it (Anderson, 2016).

Many companies have responded to this demand by implementing green design, natural landscaping, and sustainability features into their apartment buildings (Swanson, 2014; Durgin, 2014). These initiatives also predominantly provide cost savings to the company. For example, TIAA-CREF has implemented strategies to reduce common area lighting use, which saves the company over half a million dollars annually (Energy Star, 2016). Other notable companies that have introduced sustainability into their properties include United Dominion Realty and Alliance Residential Co (Durgin, 2014).

Best Practices: Sustainable solutions for multifamily real estate

The following guide presents an overview of behavioral, technological, and strategic recommendations for sustainable practices. Recommendations are sorted chronologically, from almost immediate payback to long-term investments. Each section has multiple recommendations and strategies, and a summary table of mandated requirements, maximums, and minimums can be seen in Table 1.

Note that utility expenses are strongly correlated to seasonal changes, and behavioral and retrofitting projects need to be tracked across seasons. To gain an accurate representation of the total benefits, a program should run for at least 12 continuous months, with a similar timespan of baseline data taken from before the program's start for comparison (Stenner, Frederiks, Hobman, & Fischle, 2016).

Summary of Recommendations

A list of recommendations can be found in Table 1. This list is intended to be a quick reference guide for decision making. For example, if a property is replacing the common area kitchen, this table can be used to select lightbulbs, faucets, and appliances. The research and calculations used to come to each conclusion can be found in the following sections.

Table 1. Recommended Specification and Technology Guidelines

Equipment	Minimum Recommended Specs	Page Reference
Lighting	60 lumens / watt Occupancy sensors paired with LEDs	13
Heat Pump	16 SEER and 9 HSPF	15
Thermostat	Summer Setpoint: 74°F Winter Setpoint: 70°F Programmable or NEST when possible	12
Ventilation Ducts	90% efficiency	15
Kitchen Faucet	1.8 gallons per minute (gpm)	15
Bathroom Faucet	1.6 gallons per minute (gpm)	15
Showerhead	1.5 gallons per minute (gpm)	15
Toilet	1.28 gallons per flush (gpf) Waste extraction score ≥ 350 grams	15
Financial Consideration	**Recommendation**	**Page Reference**
Internal Price of Carbon	$40/ton - Social Cost of Carbon	20

Short Term (0-6 months): Cost saving behaviors

Behavior-focused projects likely present the greatest net present value (NPV), due to negligible cost and the immediacy of results. With an estimated 16% of potential residential energy efficiency savings stemming from behavioral changes, influencing behavior relating to energy consumption should be the primary focus (Frankel, Heck, & Humayun, 2013).

Data Management: Benchmarking

In order to manage the sustainability of a property, the energy and water use must be closely monitored. Utility bills should be entered into a database each month and compared to the previous month and the same month in the previous year. This will allow managers to see trends and anomalies that could lead to savings. Without proper monitoring policies and data management, problems often go undetected and the impacts of changes or retrofits are untracked.

The exact means of tracking utility data is up to D&F. There are many "portfolio management" options that will help track utility consumption.[1] This can also be done simply in Microsoft Excel. Offered services vary greatly, but the MP Team suggest the following qualities are mandatory:

- **Responsive**: new data uploaded and accessible within 15 days of billing date
- **Available**: knowledgeable—and preferably dedicated—staff can satisfactorily respond to any D&F question within 24 hours
- **Active**: forecasting and alert systems should automatically notify D&F staff if an unusual event occurs
- **Comparative**: D&F should be able to see how a property compares to at least 20 similar properties, based on age, location, and design

Data Collection: Smart metering

D&F can further support bill analysis by installing "smart" power meters that can improve the granularity of data. All current energy data analysis of D&F properties relies on monthly bills, providing only 12 data points per meter per year. Low-cost technology now exists that allows organizations to monitor real time power flows, with one-second intervals of data, at either the meter-level, or for specific pieces of equipment (submetering). Similar meters also exist for water services. Connecting these devices to a network allows for remote-monitoring and decades of data storage. The MP Team recommends a limited pilot smart-metering project, targeting a property that is already known to have below-average performance. This initial strategy will increase the projects' NPV as there is a higher probability of identifying savings. As D&F improves its institutional knowledge of utility data management and collection, smart metering

[1] The U.S. Department of Energy maintains a list of private benchmarking companies that utilize resources from the DOE's **ENERGY STAR Portfolio Manager**. While the DOE does not make any guarantees about these companies, it does recognize those firms that it deems exemplary: https://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/save-energy/expert-help/find-energy-star-service-a-0

can be deployed to a larger portion of the portfolio, always prioritizing poorer-performing properties.

The smart metering market is diverse and innovative, with many new startup technologies currently being developed. The costs of installing these meters vary in a similar manner, though generally they are cost effective for targeted application at problematic properties, as described above. Cheaper devices such as the Stick'n Sense or Kill A Watt could monitor all loads in a typical D&F property clubhouse for less than $200, but the collected data is less detailed and possibly less accurate. [2,3] More advanced, long-term meters can collect detailed, more accurate consumption data. The Energy Detective can be reinstalled rather easily, while the eGauge and PowerLogic devices are suited for more long-term circuit breaker monitoring.[4,5,6] Monitors of this complexity level can still be installed by D&F staff with electrical experience, or otherwise would be a quick, cheap job for a third-party electrician.

Lighting

There are often situations where electricity is used for "wasted lighting," where the lighting provided is not being utilized. Examples include lighting empty or unused rooms, lighting areas that are naturally lit during the day, and having outdoor lighting on during the day. These inefficiencies can cost a significant amount of money while not benefitting residents or employees. As a result, reducing wasted lighting is easy, has no upfront costs, and can save

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[2] **Stick'n Sense** is a real-time, stick-on power sensor that doesn't require an electrician to install. This product is still young and just barely out of the development phase. Approximately $1 per circuit monitor, plus collection hardware: https://stick-n-sense.com/

[3] **Kill A Watt** is a cheap plug-load monitor for when you only need the total energy consumed over a period or want to take some local measurements of plugged-in equipment. Approximately $20 each: https://shop.p3international.com/p/kill-a-watt

[4] **The Energy Detective** is network-enabled with near-real-time monitoring. Approximately $160 to monitor 8 circuits: http://www.theenergydetective.com/spyder

[5] **eGauge** is a real-time, network-enabled monitor, storing data on an hourly interval, but reading it in once per second. Easily customizable so that it can monitor a wide range of equipment sizes. Approximately $500 to monitor 12 circuits: https://www.egauge.net/

[6] **PowerLogic** by Schneider Electric is an advanced meter, comparable to eGauge. Approximately $700 to monitor 12 circuits: https://www.schneider-electric.us/en/product-range/61336-powerlogic-em3500-series?parent-category-id=52500&parent-subcategory-id=52530&filter=business-4-Low%20Voltage%20Products%20and%20Systems

significant amounts of electricity and money. Wasted lighting can be combated through automation, lighting schedules, and staff awareness.

Automation is the most reliable method to reduce wasted lighting. Properties that implement photocells, room timers, and occupancy sensors will minimize wasted lighting and save electricity and money. These technologies are discussed more in depth in the Medium-Term section (Page 13). While automation technologies are the most reliable, they may have significant up-front costs associated with them. In situations where large amounts of money can be saved by reducing wasted lighting, sensors often pay back quickly. In situations where the wasted lighting is minimal, sensors may take longer to pay back, and behavioral changes, improved lighting schedules, and employee awareness may be better options.

A lighting schedule is an inventory of building lighting systems that indicates which lights should be on and which should be off at each time of the day. Lighting schedules are created by listing each separate area of the building and then noting the hours the lights should be on or whether that area has a sensor or timer. There are many reasons a light should be on, including aesthetics and safety, but often lights are left on because employees do not know they should be turned off. This is where a detailed lighting schedule can help reduce wasted lighting.

Lighting schedules for common spaces are important references for employees. While some employees notice wasted lighting, they may not turn lights off because they do not know if they should. With a lighting schedule, employees who notice wasted lighting can check to see if there is a reason the light must be on. As employees check the lighting schedule, they will become familiar with it and start to notice wasted lighting. Employees should also be urged to keep an eye out for rooms that are going unused, lights that are not being turned off, and equipment such as photocells and occupancy sensors that are not working properly. Staff members should frequently check photocells and sensors to ensure proper function and calibration.

Heating & Cooling

A lot of energy can be wasted through poor thermostat practices. To reduce energy use, thermostat target temperatures (set points) should be identical across a property, excluding specific, sealed-off areas, such as storage areas (less-conditioned) and fitness centers (more-conditioned). Consistency prevents different heat pumps from running inefficiently by handling larger or smaller thermal loads than intended. In extreme but surprisingly common cases, separate systems can even compete by cooling and heating simultaneously. Additionally, heating and cooling systems use the most energy when they are ramping up. This means that large changes in set points (6+ degrees) throughout the day can cause more energy use. This is another reason that consistency is important in thermostat set points.

To maximize energy savings, set points should be higher in the summer and lower in the winter. While each property manager can choose the set point they desire, the recommended default set points are 74 or above in the summer and 70 or below in the winter. The "HVAC & Building Envelope" model can be used to determine the ideal winter and summer set points.

Education: Municipal offers for tenants and staff

Many utilities and municipalities have promotions designed to encourage energy and water efficiency. For example, the city of Durham offers residential customers a “Save Water Kit”, which includes a low-flow showerhead, low-flow aerators, leak detection dye, and more for just three dollars (City of Durham, 2018). In the past, Duke Energy has offered 15 free LED bulbs to residential customers (Duke Energy Progress, 2018). While these offerings will differ throughout D&F’s territory, the MP Team recommends that property staff research local offerings and educate their tenants. By making these options known to all tenants, D&F can reduce a property’s overall energy and water use.

Medium Term (6 months - 2 years): Upgrades and overhauls

Efficiency Retrofits

Lighting

Replacing inefficient lightbulbs with higher efficiency bulbs is often one of the projects with the shortest payback period and greatest cash-on-cash return. To address the rapidly changing lighting market, the MP Team recommends an aggressive minimum efficacy rating, rather than specific hardware choices. Efficacy is the most accurate metric for a luminaire’s “efficiency,” calculating the light produced per unit of electricity consumed:

$$Efficacy = \frac{lumens}{watt} = \left(\frac{brightness}{electricity\ used}\right)$$

This guide recommends a minimum efficacy of 60 lumens per watt. An efficacy of 60 disqualifies incandescent and halogen luminaires. Some efficient compact fluorescent (CFL) bulbs may still meet this requirement and be able to compete with the high-efficacy LEDs. However, typical LEDs last three times as long as CFLs and use 20-30% less electricity. Additionally, by using less electricity per lumen, LEDs produce less wasted heat. This can then lower the cooling costs of a building. Due to the lifespan and efficiency, LEDs' lifetime value almost always exceeds an equivalent CFL installation. Additionally, LED prices continue to drop dramatically, and are predicted to be at parity with incandescent bulbs by 2020 (EIA, 2014). At that point, LEDs' superior financial metrics will be assured.

Furthermore, the cheapest lumen is the one never used. As discussed previously, where safe and reasonable, automation technologies such as timers, occupancy sensors, and photocells present significant returns, especially if a sensor controls many bulbs. Versus manual control, automated lighting can yield 25-30% electricity savings (de Bakker, van de Voort, & Rosemann, 2017).

Current sensor technology utilizes infrared light and/or ultrasonic waves to detect the motion of people present in a space. The location of an installed sensor must be carefully considered, to avoid "false positives" from moving fans or very bright lights. D&F should also carefully consider the duration of sensor-controlled light, so that triggered lights remain on for the appropriate amount of time without an additional positive detection of a person. For example, gym sensors may only need 5-minute delays, as tenants working out will be in constant motion. Meanwhile, motion sensors in a parking garage benefit from a 10-minute delay, to account for tenants sitting in cars before or after driving. Timers and photocells are ideal for lower-traffic lights that need to be in the same state for long periods of time, such as outdoor lighting. While photocells will theoretically detect all times when outdoor lights are needed and not needed, they have a higher chance of malfunction than a simple timer that is manually adjusted twice a year for Daylight Savings.

All three technologies result in lighting with increased cycling—the act of a light turning on then off. LEDs have another advantage in this case, as CFLs suffer diminished lifespans from heavy cycling, whereas LEDs do not.

Electricity and cost savings of lighting retrofits and automation technologies can be predicted in advance of implementation using the "Lighting & Plumbing Retrofit" model which is provided along with this report. More information about the model can be found on page 25.

Water

In recent years, water utilities across the country have been updating rate structures and planning for significant infrastructure investments, with average U.S. water bills increasing annually by 6.3% since 2010 (Walton, 2017). In addition to increasing costs, these new experimental rate structures reveal a larger trend of increasing uncertainty in water supply and financing. Water efficient investments will provide short-term cost-savings, as well as long-term risk mitigation from changing policies on the federal and municipal levels. The possible investment opportunities include: low-flow fixtures, low-flow toilets, and efficient irrigation technologies. The water savings and financial returns for specific retrofits can be calculated using the "Lighting & Plumbing Retrofit" model, which is provided along with this report. More information on this model can be found on page 25.

Heating and Cooling

Average duct efficiency can be as low as 67%, meaning approximately a third of the energy consumed by the HVAC system is lost during air transfer without benefitting living spaces (U.S. DOE, 2004). Therefore, the most impactful first step when improving HVAC systems should be a thorough duct inspection followed by necessary sealing and insulation.

Energy savings can also be realized through improving SEER and HSPF ratings. SEER stands for "Seasonal Energy Efficiency Ratio" and is the measure of how efficiently the heat pump can remove heat from a building. SEER is measured in $\frac{btu}{kWh}$ [7], which is the amount of heat the pump can remove per kWh used. HSPF stands for "Heating Seasonal Performance Factor" and is an indicator of how efficiently the heat pump can add heat to a building. The units are still in $\frac{btu}{kWh}$ and measure how much heat can be added to a building per one kWh used.

[7] "Btu" stands for **British Thermal Unit** and represents the approximate heat given off by a match. "kWh" stands for **kilowatt-hour** and is a common unit of electricity consumption. This measure states how much heat can be removed from a space using one kilowatt-hour of electricity.

The mandatory minimum SEER rating set by the U.S. Department of Energy is 14 and the minimum HSPF is 8.2. As SEER and HSPF increase, so do the costs associated with implementation. The MP Team recommends a SEER 16 rating because it offers an ideal balance between higher CAPEX (capital expenditure) and lower OPEX (operating expenditures), particularly for the warmer southeast region of the U.S.[8] While even higher efficiencies are possible with heat pumps available as high as SEER 26, the increased upfront costs significantly extend the payback period. SEER 16 also exceeds the current minimum requirements, which reduces the risk of future regulation forcing early retirement of installed heat pumps.[9]

Heat pump selection will depend on the heating and cooling need of the property. Heating need is measured in heating-degree-days (HDD), which measures the total number of degrees of heating needed over a certain time. The same is true for cooling-degree-days (CDD). If the property is in a state that has more HDD than CDD, the HSPF should be considered more heavily than the SEER rating. The opposite is true for properties that have more CDD than HDD. For example, in Durham, NC, there are almost twice as many HDD each year as CDD. While SEER is the most often used metric for heat pump efficiency, property managers in Durham should be considering HSPF more heavily.

This guide recommends minimum SEER of 16 and HSPF of 9 for North Carolina. When selecting a new heat pump, the "HVAC & Building Envelope" model can be used to identify the potential savings from improved heat pumps and duct efficiency. Because the benefits of SEER and HSPF decrease as efficiency increases, this model can be used to find the balance between efficiency and cost effectiveness (CAPEX vs OPEX).

Pool Pumps

Pool pumps and filtration systems are designed to keep the pool clean for the tenants, prevent algae growth, and prevent the pool from freezing. The minimum water turnover to maintain the cleanliness of a public pool is established by the state or county health board (Indiana State

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[8] The supplementary models provided to D&F were used to calculate marginal costs and savings of variety of heat pump SEER ratings, using North Carolina climate data.
[9] National minimum SEERs are 10-14, depending on the heat pump size. North Carolina's current minimum is 14 (Goodman Company, 2018).

Department of Health, 2010). While the exact number of turnovers per day varies between health departments, the required rate is typically around four turnovers per day, which is higher than the minimum rate required to prevent freezing and algae growth (Florida Department of Health). This required rate, however, only applies during the months the pool is used.

Because most pool pumps only have one speed and are sized to meet the county health code during the pool season, most pumps are running more than they must in the offseason. On average, the water in a pool only needs to be turned over once per day in the offseason to prevent freezing and algae growth (Swim University, 2013).

To reduce electricity use in the offseason, the MP Team recommends installing either variable frequency drive (VFD) pumps, or pool pump timers. VFD pumps have multiple speeds and can vary their output to meet the desired turnover rate while minimizing electricity consumption. While VFD pumps can cost more up front, the savings from reduced electricity consumption can be substantial. For example, a 2-horsepower VFD pump would cost around $800, while a single-speed pump would cost roughly $400 (Google Shopping, 2018; EcoPump, 2018). This VFD, however would save roughly $200 annually, depending on the use and electricity rates (EcoPump, 2018). This gives it a payback period of 2 years.

If a new pump has just been installed, and a VFD pump is not an option, pool pump timers can be implemented. These timers can be programmed to turn the pump on and off at desired times. This can be used to reduce unnecessary electricity consumption during the off season. While these timers can help save money, they must be programmed correctly as to prevent freezing, maintain a chemical balance, and not disturb the priming of the system. Pool Pump timers can range from $50 to $500 and can yield substantial savings if programmed correctly (Google Shopping, 2018). Due to the concerns of proper programming, the MP Team recommends using VFD pumps when possible, and pool pump timers when a new pump cannot be justified.

Building Automation Control Systems

Centralized, computer-controlled systems are increasingly being utilized to optimize a building's water, lighting, and HVAC systems, all through a single terminal. However, only about 10% of buildings currently have building automation systems (BAS), and BAS are almost exclusively found in high-rise buildings due to their cost and complexity (Brambley, 2013). At this time, the

MP Team recommends D&F monitor the BAS market for breakthroughs in cost and simplicity that could make the technology more valuable to D&F's properties.

Incentive programs

In addition to updating policies in the short term, D&F can further improve employee buy-in by adding sustainability-specific incentives to current incentive programs. For example, these programs would link employee bonus to the following performance metrics:

- Percent reductions in energy/water spending
- Percent reductions in energy/water consumed
- Exemplary preventative maintenance during inspections
- Tenant feedback—environmental questions on customer satisfaction surveys
- Discretionary
  - Exemplary documentation, measurement and verification of sustainability projects
  - Successful marketing or promotional event campaigns, highlighting sustainability
  - Enrollment in and/or recognition from green certification organizations[10]

Business Model: Utilizing learning curve and economies of scale

D&F has an opportunity to increase the efficiency and subsequent returns of its sustainability practices by organizing the MP Team's recommendations and models into a streamlined service package for property owners. Bundling programs into a single capital project will allow D&F to implement more initiatives than a piecemeal approach, even allowing high-yield investments to support more qualitative or risk-focused investments that have little immediate cost-savings.

Additionally, repeatedly deploying an integrated business model will allow D&F to increase margins and project speed, positioning D&F as an industry leader in the growing sustainability subsection of real estate management.

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[10] In addition to certifications like LEED, an excellent resource is the U.S. Department of Energy's **Better Building Challenge**. Better Buildings currently has 293 multifamily and 694 commercial partners, helping them set goals and bring a sense of competition.
https://betterbuildingssolutioncenter.energy.gov/challenge/partner-list

Marketing

Effectively capturing and communicating the beneficial impact of sustainability initiatives is critical. In addition to cost-savings and risk mitigation, every dollar spent on sustainability additionally pays back in the form of creating a positive impact on human and environmental health. In marketing materials, D&F should be specific, quantitative, and holistic. Instead of general pledges of eco-commitment, concrete goals with deadlines increase impact and marketing traction. Internal stakeholders can more effectively plan milestones and measure progress, while consumers have a more unique, lasting impression of D&F's brand.

Marketing campaigns fall into three major categories of perceived value to a tenant:

- **Financial** – Tenant's utility cost savings
  - Electricity, gas & water
- **Lifestyle** – Improved Quality of Life
  - Natural materials & reduction of chemical in and around the building
  - Comfort & convenience
- **External Impact** – Environment & Supply Chain
  - Climate angle – carbon emissions reduction
  - Nature angle – impacts on ecosystems
  - Societal angle – fair trade; local/small business; community outreach events

Long Term (2-5 years): Development and investments

While cost-savings on behavioral and technological changes represent short-term payback, additional long-term value exists in aggressive, industry-leading initiatives that position D&F to thrive under changing demographic, economic, and environmental trends. The following measures are feasible for immediate execution but expect significant progress and payback to be long-term and ongoing.

Carbon Accounting

Standardizing Environmental Impact

As different industry sectors have highly diverse processes and outputs, leaders across industries have adopted the trend of converting environmental achievements into their avoided carbon-dioxide-equivalent emissions (CO_2e) (Science Based Targets, 2017). Many chemicals produce differing degrees of greenhouse gas (GHG) warming effect, the leading cause of climate change-related problems. Using a chemical's Global Warming Potential value, all relevant emissions can be converted into a single number of equivalent tons of CO_2e.

Reporting results as CO2e-avoided allows an organization to take the relative results of their efforts and convert them into an absolute value measuring their contribution to the fight against climate change. This concept of converting economic activity into emissions is the basis of a "Carbon Footprint." Everything has a carbon footprint, even water consumption, which uses significant amounts of energy during treatment and filtration. Many websites can provide manual calculations, the best of which always include the location of the energy consumption, which makes a significant difference in accuracy.[11] The MP Team's financial models also estimate CO_2e-avoided for their respective investments.

Carbon Pricing

Another rapidly growing trend of industry leaders is to internally price CO_2e associated with company activities (CDP Worldwide, 2017). By assigning a dollar value to direct and indirect (value chain) emissions, companies internalize GHG externalities, allowing them to track and reduce their environmental impact and mitigate risks of future environmental regulations (Ahluwalia, 2017). While companies rarely mandate a financial transaction due to CO2e emissions, assigning an implicit cost to each ton of CO2e makes emissions more understandable. When considering a new project, converting emission savings to dollar savings using the internal cost of carbon can put all savings in a common unit which allows for comparisons and reveals the "true value" of the project. Additionally, this pricing sheds light on the financial impact a federal carbon tax could have on their business operations and future projects.

There are many strategies and methods for carbon pricing, but the three major methods are displayed in Table 2. While the exact dollar amount assigned to each ton of emissions is decided by the individual company, in 2015 the EPA estimated that each ton of CO2e emissions had a

[11] The EPA's calculator uses up-to-date CO_2e data to accurately calculate location-specific emissions: https://www3.epa.gov/carbon-footprint-calculator/

societal cost of $36 (EPA, 2017). This is commonly referred to as the "social cost of carbon." Adjusting for inflation, the current social cost of carbon is around $40.

Table 2. Major Carbon Pricing Methods

Method	**Purpose**
Carbon Fee	Additional internal expense on business activity. Revenue streams from the fee usually fund sustainability projects.
Shadow Pricing	A theoretical cost, used as a risk assessment tool, to evaluate competing proposals and plan for future regulation.
Implicit Carbon Pricing	Retroactive calculation, to benchmark performance, or plan for different future pricing methods.

The MP Team recommends that D&F adopt the social cost of carbon as an internal cost of carbon. This value should serve as a shadow price to convert emissions and potential emission savings into equivalent societal costs and benefits. For example, if a project has the potential to reduce annual CO2e emissions by 100 tons and has a real cash flow of $5,000/yr, the total "societal cash flow" would be $9,000/yr. This tool can allow for project comparisons with similar real cash flows.

Carbon Offsets

While sustainability investments reduce the size of a carbon footprint, D&F can pursue even more aggressive environmental goals by purchasing carbon offsets. Carbon offsets allow companies to invest in another organization's efforts to prevent GHG emissions in order to "cancel-out" an equivalent amount of their own associated emissions.

To ensure maximum benefit, D&F should consult with groups like the Climate Action Reserve, who maintains standards that reduce inaccurate or fraudulent offsets.[12]

In general, offset sellers must guarantee the following aspects (Palmer, 2016):

- **Real**: genuine and fully operational
- **Verifiable & Enforceable**: 3rd-party verified & penalties if seller reneges

[12] CAR's mission: "To develop, promote and support innovative, credible market-based climate change solutions that benefit economies, ecosystems and society" (Climate Action Reserve, 2017).

- **Permanent**: purchased offsets project will not be cancelled, changed, or removed
- **Additional**: without purchase, GHGs from the offset would have been emitted

Although carbon offsets can help a company reduce its carbon footprint, the MP Team recommends that D&F wait to purchase carbon credits until all efficiency improvements have been considered. Because efficiency improvements often create positive cash flows along with emission reductions, they should be executed before D&F considers taking a negative cash flow to purchase offsets. If D&F has achieved all possible efficiency upgrades and desires further GHG emission reductions, offsets should be considered.

New Construction

When constructing a new building, there are many opportunities for energy efficiency and sustainability to be built into the design and construction budget. By executing these projects with the initial construction, retrofit costs can be eliminated, lowering the payback period of the investment. The sustainability and energy efficiency investments that the MP Team recommends considering for new construction include LED installations, electric vehicle charging stations, solar-ready surfaces, and features that encourage active and healthy lifestyles of the tenants.

LED Installations

While LED bulbs can cost more up front than the fluorescents, the payback tends to be short due to the decreased electricity and maintenance costs, and increased lifespan. However, retrofitting fixtures and areas with LED bulbs can be expensive due to any required wiring adjustments and fixture additions. Due to the elimination of retrofit costs, using lightbulbs with the highest efficacy and lifespan possible will help reduce future electricity and maintenance costs and typically have a payback period of 1-3 years.[13]

EV Charging Stations

The U.S. sales of plug-in electric vehicles increased by over 40% in 2017 (Shahan, 2017). This rise in sales is predicted to continue, with 6% of car sales between 2016 and 2020 being electric and 2% of all vehicles on the road being electric by 2020 (International Energy Agency, 2016).

[13] These payback periods were typical results seen at D&F properties and were calculated using the “Lighting & Plumbing Retrofit” Model.

Assuming these predictions hold true, the average property has 200 units, the average unit has 1 car, and the tenants of these properties are representative of the U.S. population, each property in 2020 will have four electric vehicles on the premises. The MP Team recommends at least four electric vehicle chargers at each new property to ensure adequate charging infrastructure as electric vehicles continue to increase in popularity.

Solar Ready Surfaces

Solar installations between 0 and 100 kW (about the size that would fit on a multifamily residential building), are currently expensive to install. While the exact price depends on the building and the installation quote, the MP Team assumed a base price between $2.13 and $2.93 per watt (installed) (Fu R. C., 2016). Using these prices and North Carolina solar data, the MP Team found that these solar projects would have positive net present values but would have payback periods of roughly 12 years. Due to the long payback period, the MP Team recommends waiting on solar installations unless an owner is enthusiastic about the addition of solar to a property and does not mind the longer payback period.

While the payback period is currently long, the installed price of solar is continuing to fall (Fu R. F., 2017). As the price continues to fall, the payback period may reach an acceptable range. Due to this, the MP Team suggests that all new buildings are constructed as "solar ready" buildings. A solar ready building is any building that has been built to allow for the installation of solar panels. Criteria for solar readiness include limited shading, adequate load capacity, and readiness of the necessary wiring. The National Renewable Energy Laboratory (NREL) has a solar ready checklist that the MP Team recommends using (Lisell, 2009).[14]

Healthy and Active Lifestyles

A thoughtful design of a multifamily complex can encourage tenants to be healthy and sustainable by making healthy decisions easier to make. This can be done by providing access to natural areas or a community garden, making the stairs accessible, and designing the building to use natural lighting.

[14] The solar ready buildings guide can be found at: https://www.nrel.gov/docs/fy10osti/46078.pdf

Providing natural areas such as open lawns, community gardens, and access to walking trails could encourage people who would prefer to rent a house with a yard to consider an apartment. By providing access to community garden plots, or a yard in which to relax, D&F can compete with rental companies that provide single family houses. These spaces also encourage residents to be healthier and more sustainable.

Interactive Models

In order to allow property and maintenance managers to see the environmental and financial benefits of building retrofits and renewable energy systems, four interactive excel models were provided to D&F. These models are designed to take basic user inputs, calculate cost savings and environmental benefits, and display the results in a cash flow analysis. Each model is explained below, but all models used some universal inputs. Those inputs are:

- **Tax Rate:** This is the corporate tax rate that the owner or property manager pays
- **Hurdle Rate:** Also known as the discount rate, this represents the minimum acceptable return the owner is seeking in a project investment
- **Utility Rate:** This refers to the rate payed for the utility in question. Units will be presented for clarification

Energy Diagnostics Model

The energy diagnostic model takes the area of all common spaces and the total energy use of those areas and calculates the building's energy use intensity (EUI). The EUI is a normalized number that shows the amount of energy a building uses per unit area (e.g., kBtu/ft^2). This is used to compare energy use between buildings of different sizes. The model then uses the age and square footage of the building to find the median EUI of peer buildings.[15] Using the median peer EUI, the model indicates whether the property should be a priority for energy efficiency

[15] These peer comparisons are from the Department of Energy's **Building Performance Database**. The database takes inputs such as location, use, year built, and square footage and returns the EUIs of similar buildings: https://www.energy.gov/eere/buildings/building-performance-database

upgrades. The case studies for this project revealed that properties with larger EUI discrepancies from their peers yielded higher net present values on energy efficiency projects.

Lighting & Plumbing Retrofit Model

The Lighting and Plumbing Retrofit models look at the financial and environmental benefits of retrofitting lightbulbs, light fixtures, showerheads, faucets, and toilets. Each model will ask for inputs from the current bulb or fixture, and the same inputs for the new bulb or fixture. The models will then calculate payback period, net present value, cash on cash return, and internal rate of return. Appendix 1 contains a complete list of inputs, calculations, and assumptions.

HVAC & Building Envelope Model

The insulation and HVAC model takes simplistic inputs of the building envelope and mechanical equipment and returns cash flows for window retrofits, insulation additions, heat pump changes, and thermostat set points. The model requires the building's surface area, an estimate of the buildings insulation quality, and the SEER and HSPF of the heat pump. The cash flow analysis uses this information to see the reduction in conductive heat loss/gain and solar heat gain. The model does not consider convective heat loss/gain due to the difficulty in establishing the air leakage of the building. This would require a blower door test to be performed, which was outside the scope of the project. Appendix 1 contains a complete list of inputs, calculations, and assumptions.

Rooftop Solar PV Simulation Model

The solar PV model takes basic inputs about the location, space type, space size, electricity load, and desired production, and returns a 30-year cash flow analysis for a solar PV system that is sized correctly for the building. This model considers the Federal Investment Tax Credit, an accelerated depreciation schedule, and routine and non-routine maintenance. This model can be used to assess properties for the financial viability of solar PV. Appendix 1 contains sample images of the model and all assumptions made.

The limitation of the model is that it assumes fixed solar resources for the location entered, and it also assumes the given area is unshaded and has direct sunlight. Improved results can be obtained using Project Sunroof by Google, a recommended resource to assess the actual solar resources available to be input into the model. Project Sunroof uses the address of the property to return an image of the solar resources. This can then be used to determine the sunlit area to be input into the model.

Property Audits

Methods

Property audits were performed on three D&F-managed properties. The audits used a combination of site visits, building drawings, electricity disaggregation, and interactive models to identify inefficiencies in electricity and water use and propose financially viable changes.

Site Visits

Each site was visited and toured. During the visit, the MP Team looked at all common spaces, mechanical equipment, and a model unit. While at the property, pictures of the building, building drawings, and all electricity consuming appliances were taken. An infrared camera was also used to capture images of heat emitting appliances and exterior surfaces that may be losing or gaining heat. During the visits, the MP Team also met with the property manager and maintenance manager to discuss the occupancy use patterns, appliance and lighting schedules, and any maintenance issues the property is experiencing.

Building Drawings

Building drawings containing floor plans, electric and lighting plans, mechanical plans, and wall and window types were photographed. These drawings were then analyzed to determine the building square footage, the number and type of light bulbs, and the insulation and solar heat gain values of the building envelope. These values were then used to disaggregate electricity use and as inputs in the interactive models.

Electricity Disaggregation

In order to disaggregate electricity use, utility bills from 2015 to 2017 were collected from each property. These bills were put into a spreadsheet and plotted to find annual and monthly trends and anomalies. Because the usage on the bill was known, the MP Team could then work backwards to identify which electricity loads were consuming the electricity.

Using the building drawings, each lighting type was counted. Assumptions on hours of use were collected from the property managers. Using the wattage and assumed hours of use, the MP Team was able to calculate the monthly electricity use from lighting. The same process was repeated with plug loads. The nameplate or model number of each appliance was used to determine the power draw, and the assumptions made by the MP Team and the property managers were used to determine hours of use. The power draw and usage were then used to calculate monthly electricity draw.

The swimming pool pump name plate was used to determine the power draw. Because the pumps run 24 hours a day, no assumptions were made, and the power draw was multiplied by 24 to get daily electricity use. This was then multiplied by the number of days in each month to find the monthly average pool pump electricity use.

After calculating lighting, plug load, and pool pump electricity use, these numbers were subtracted from the overall monthly electricity use. The remainder is the estimate of the cooling, heating, and mechanical load of the building. The "HVAC and Building Envelope" model was used to estimate the heating and cooling load, but due to the number of variables that contribute to heating and cooling loads, this is only an estimate.

Once the electricity was disaggregated, data visualizations were created to identify the hotspots of electricity use. The disaggregation was compared to the national commercial and industrial averages to determine areas that need improvement. After determining the hotspots of electricity use, the interactive models were used to assess potential retrofits.

Results

Property 1

Property Overview

Property 1 is a five-story, mid-rise apartment building located in a coastal North Carolina community. The property was completed in 2015 and contains over 100 one and two bedroom units. Due to its location and unit types, Property 1 attracts students, young professionals, and retirees.

The building complex has 17,982 ft^2 of conditioned common space which includes a café, a fitness center, a shared laundry room, and shared hallways. Property 1 also houses an outdoor veranda (934 ft^2) and a two-story parking deck that is lit but unconditioned (~30,000 ft^2). There are two staircases (located at the ends of each hallway) and two elevators (located in the main lobby) in the building. The property does not currently have a swimming pool.

Another mid-rise building is planned as a phase-two addition to Property 1. The construction dates have not been set. Phase-two is set to include a swimming pool and an additional fitness center.

Baseline Data

Property 1 uses electricity and propane (for outdoor grills), but there is no natural gas on the property. On average, the common areas of Property 1 use roughly 254,000 kWh of electricity per year costing about $17,500. Using the diagnostic model, Property 1 has an energy use intensity of 48 $kBtu/ft^2$. According to the Department of Energy's "Building Performance Database", multi-family apartment buildings built after 2000 have an average EUI of 40 $kBtu/ft^2$ (U.S. Department of Energy, 2018). This means Property 1 uses slightly more energy per square foot than a typical multifamily property but is within the normal distribution. The EUI comparison can also be misleading because it can fail to address differences in properties such as amenities. Knowing this, an EUI of 48 is an indication that building is operating semi-efficiently, but there could still be room for improvement.

Property 1 has a seasonal trend in electricity usage. There are peaks in both summer and winter. These make sense as the property uses electricity for both heating and cooling. On average, the electricity usage is highest in the month of July and lowest in March, with the average electricity use in March being 32% less than the average electricity use in July. The average annual load curve for Property 1 can be seen in Figure 1.

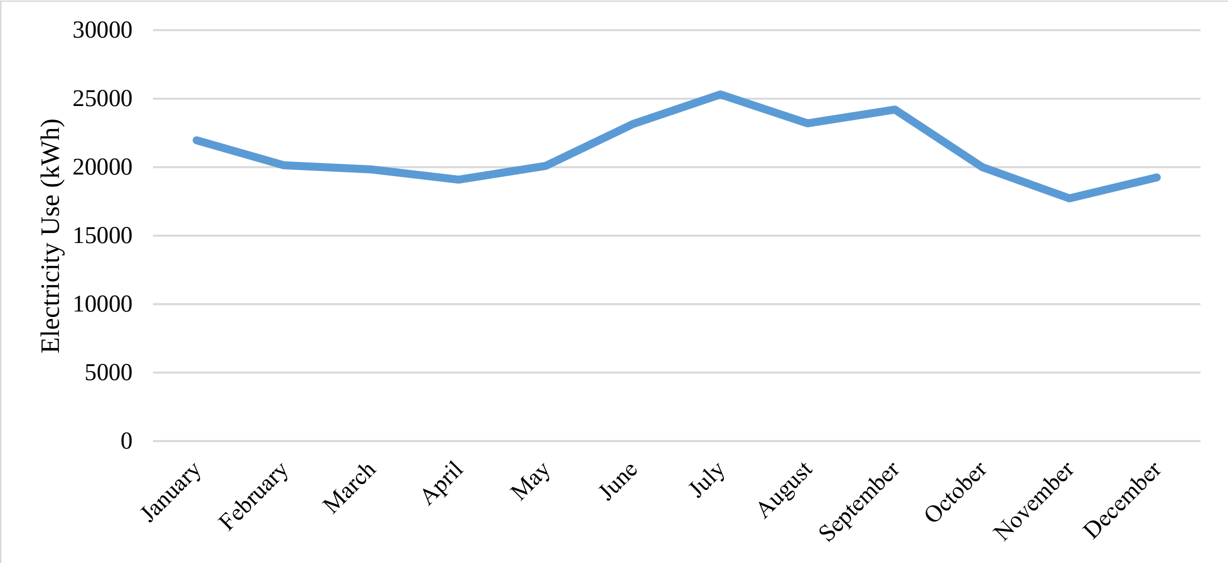

Figure 1. Property 1 Average Annual Electricity Load Curve

Hotspot Analysis

Through disaggregation of the electricity data, lighting is shown to be responsible for 50% of Property 1's annual electricity consumption (Figure 2). Climate control and miscellaneous mechanical processes account for 32% of the annual average electricity load, followed by plug loads at 14%, and elevator use at 4%.

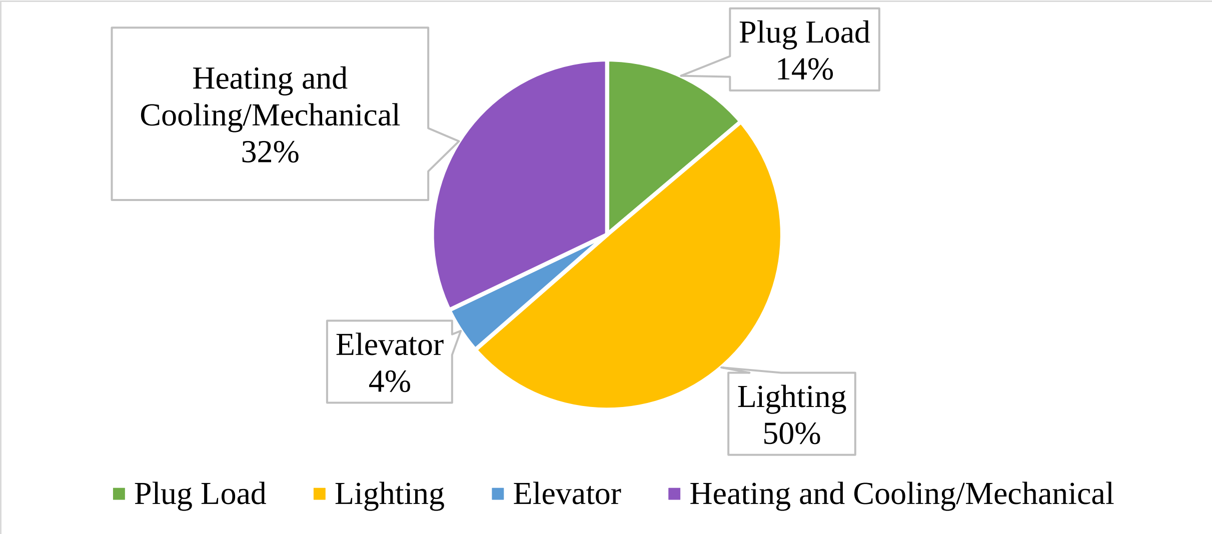

Figure 2. Hot Spot Analysis – Breakdown of Annual Average Electricity Use for Property 1

In 2012, the average commercial building energy breakdown was as follows: lighting accounted for about 10%, heating, cooling, and ventilation used 44%, and plug loads accounted for 8% (EIA, 2017). While these numbers do include manufacturing facilities and businesses with different energy needs, Property 1 uses significantly more electricity for lighting than the commercial average. Heating and cooling loads are lower than the commercial average, and plug loads are slightly higher.

Property 1's annual average is a good indicator of the electricity breakdown, but the exact distribution varies seasonally as heating and cooling loads change. The average monthly breakdown for Property 1 can be seen in Figure 3. The figure shows that the electricity used for lighting ranges from 40% in July to 58% in March and November. July and September are the only months that cooling accounts for more electricity use than lighting. Elevator and plug load use stays relatively constant throughout the year when compared to the fluctuations in heating and cooling.

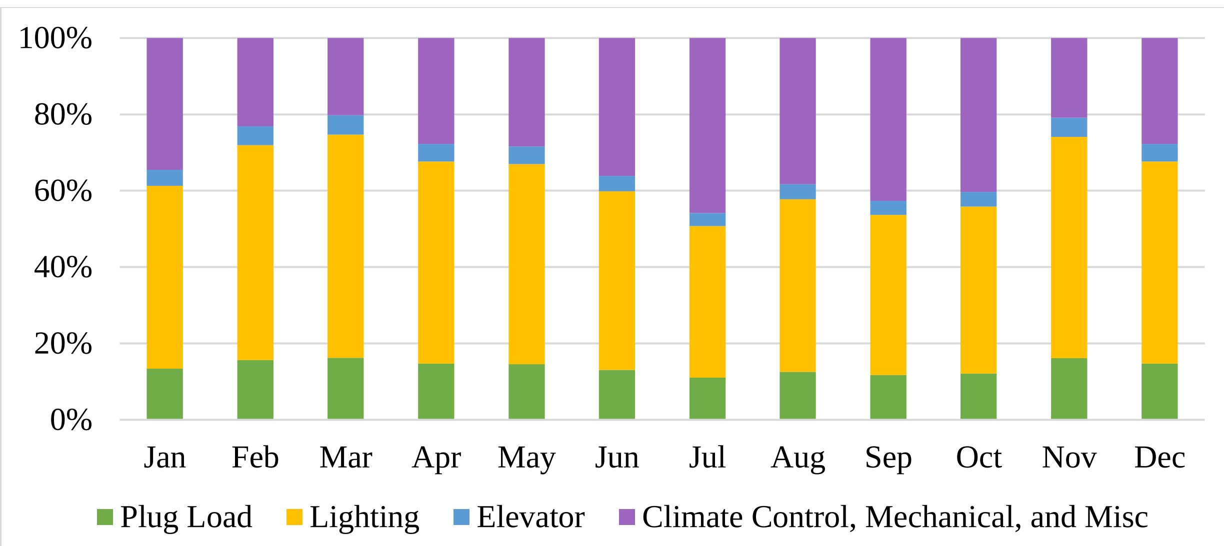

Figure 3. Average Monthly Breakdown of Electricity Use for Property 1

Recommendations

A summary table of all recommendations can be seen in Table 3, and each recommendation is discussed below in further detail.

Table 3. Summary of all Property 1 Recommendations

Recommendation	Initial Cost ($)	Annual Savings ($)	GHG Savings (MTCO2e)	Annual Cost of Carbon Savings ($)	NPV ($)
LED Retrofit – All Common Spaces (Phase 1)	$4,600	$1,500	10	$400	$2,200
Shorten Duration of Motion Sensors (Phases 1&2)	N/A	Dependent on settings	Dependent on settings	Dependent	Dependent on settings
Build Phase 2 Solar Ready	Dependent	Dependent	Dependent	Dependent	Dependent
LEDs Used (Phase 2)	$2,500	$830	5	$200	$1,000
More Visible Stair Cases in Phase 2	N/A	$73	1	$40	$310
Total	**$7,100**	**$2,403**	**16**	**$640**	**$3,510**

Current Building

Energy Efficiency

Lighting

Looking at the hotspot analysis in Figure 2, there is a significant opportunity for electricity savings through lighting retrofits. The breakdown of annual lighting use by space type can be seen in Figure 4. This shows that the largest users of electricity for lighting are the hallways and parking garages. This makes sense due to the high use of these areas and the importance of having these areas well lit.

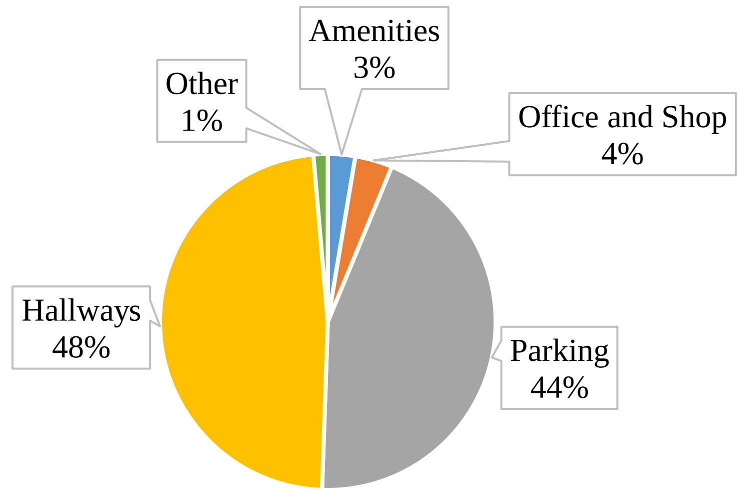

Figure 4. Breakdown of Annual Lighting Use by Space Type for Property 1

Currently, most of the building is lit with 32-watt fluorescent T8 tube lights. The exception to this is the use of 54-watt fluorescent T5 bulbs in the parking areas. The T8 bulbs emit 2,600 lumens, giving them an efficacy of 81.25 lumens/watt. The common areas of Property 1 use 418 T8 bulbs which can be used anywhere from 9-24 hours a day. The T5 bulbs produce 5,000 lumens, giving them an efficacy of 92.6 lumens/watt. Property 1 uses 148 T5 bulbs which are commonly on about 19 hours a day.

While both bulbs achieve the minimum efficacy requirement in Table 1, the number of the bulbs, and the heavy usage, indicates that switching these bulbs to LED tubes could provide both electricity and maintenance cost savings. The lighting retrofit model was used to determine the electricity savings, greenhouse gas savings, and payback of certain LED retrofits. The results are shown in Table 4.

Table 4. LED Retrofit Options

Description	Initial Costs ($)	Annual Savings ($)	GHG Savings (MTCO2e)	Cost of Carbon Savings ($)	NPV ($)	Simple Payback (yrs.)	Cash on Cash Return
Hallways	$3,560	$1,400	9	$360	$2,400	2.5	40%
Conditioned Commons	$4,600	$1,500	10	$400	$2,200	3.1	32%
Parking	$15,000	$1,240	8	$320	($9,700)	12.1	8%

Based on the financial analysis, it is recommended that Property 1 replace all 418 T8 fluorescent bulbs with 22-watt, 2400 lumen, LED T8 bulbs, or bulbs with similar qualities. When replacing the current bulbs, it is important to consider the lighting output (lumens), not just the wattage. Some bulbs may be cheaper, or more efficient, but fail to provide adequate lumens.

For the parking structure, it is recommended to stay with the current T5 light fixtures. Because there are no LED bulbs that would fit directly into the current fixtures and provide adequate lumens, more fixtures would have to be installed. The addition of new fixtures is why the net present value is negative. While the project would eventually pay off, the payback period would be too long to be considered bankable.

Instead of new bulbs, it is recommended that Property 1 adjust the motion sensors in the parking garage to stay on for a shorter period. Due to the number of residents and the differences in their schedules, people are coming and going for most of the day. With a long duration, motion sensors can cause lights to be on for long periods when no one is in the garage. Lowering the active timing on the sensor could save electricity without any retrofits. The exact savings are hard to predict and will depend on the settings chosen and occupant behavior. If the sensors are reset, this should be noted and trends in electricity data should be recorded to find the effect.

Plug Loads

As discussed earlier, plug loads at Property 1 consume roughly 14% of the annual electricity use, compared to the national average of 8%. While this is not as large of disparity as lighting, there is room for improvement.

The TV and sound bar in the café are reportedly switched on 24 hours a day. This converts to about 240 kWh of electricity use per month. Assuming the TV is only watched for 4 hours a day, only 40 kWh a month are needed. By educating tenants and turning off the TV when not in use, Property 1 could save roughly 2,400 kWh and save $159 a year. It is recommended that Property 1 employees check the Café to see whether the TV is being used and turn it off when the café is vacant. It is also recommended to put signs in the café suggesting tenants turn the TV off when not in use.

Water Efficiency

All water fixtures at Property 1 meet the standards set in the best practices guide, and no retrofits are recommended. As fixtures and toilets need to be replaced, it is recommended to use the best practices guide to select items that meet the minimum requirements.

Renewable Energy

Due to the urban landscape of Property 1, any renewable generation would have to be located on the rooftop. The rooftop is flat and is roughly 24,000 ft^2. While the total area is 24,000 ft^2, the heat pumps for all units and common spaces are located on the roof. This reduces the useable area to roughly 2,500 ft^2. This estimate would leave room to service both the solar PV system and the heat pumps safely and efficiently.

Using the 2,500 ft^2, Property 1 can install a solar PV system of approximately 25kW. This system would cost roughly $51,000 after the Federal Investment Tax Credit. A 25kW system would produce between 35,000 and 42,000 kWh a year depending on the specific technologies. This would offset roughly 16% of the annual electricity load for the Property 1's common areas.

Assuming a 5.5% discount rate and a seven year Modified Accelerated Cost Recovery depreciation system, this system would have a 30-year net present value of roughly $7,000 and an internal rate of return of 7.7%. The simple payback period of this project would be 10 years, and the NPV payback period would be 21 years. Due to the financial implications of this system, it is currently not recommended to pursue a solar PV system at Property 1.

Phase 2

While some of the retrofits mentioned for phase 1 were too costly to be deemed bankable projects, phase 2 presents a unique opportunity to add efficient technologies and designs during the building process. Because these projects will not require the removal of existing equipment and can be built into the budget of the project, energy and water efficiency projects should be considered when phase 2 is being designed and built.

Energy Efficiency

As seen in Table 4, installing LED bulbs can provide significant paybacks and environmental benefits, but can also prove expensive if installed later in the process. It is recommended that phase 2 uses LED bulbs in all fixtures. In addition to lighting electricity savings, the lower heat outputs of LEDs could potentially lead to a downsizing of HVAC equipment which would further increase the payback.

While the official plans have not been finalized, it is assumed that phase 2 of Property 1 will be roughly one-third of the size of the current building. Using this assumption, phase 2 will have 72 light bulbs in hallways and 50 light bulbs in parking areas. With these assumptions, using LEDs in the hallways and parking areas of phase 2 would increase material costs by roughly $2,500 and reduce annual electricity and maintenance costs by $830. This decision would have a payback period of 3 years, a net present value of $1,000, and an IRR of 16%.

In addition to installing LED bulbs, phase 2 should be designed to make the staircases more accessible. In the current building, the elevators are the only way to get from the main lobby to the residential hallways. In a conversation with the maintenance manager at Property 1, it was learned that many residents would take the stairs if it was an option but are forced to take the elevator. While this is more a building design element, having easily visible and accessible staircases could reduce elevator use which could result in lower electricity bills. On average, the elevators in the current building use an estimated 11,000 kWh a year. Even if more accessible stair cases reduced elevator use by 10%, this would result in a 1,100 kWh reduction in electricity use. This would reduce carbon emissions by 1,800 lbs. of CO2e per year.

Water Efficiency

It is recommended that phase 2 use the same water fixtures as are currently used. If new fixtures are chosen, they should remain under the limits set in the best practices guide.

Renewable Energy

While the plans for phase 2 have not been finalized, this report assumes the rooftop area would be at least 7,500 ft^2. If this area was left clear, this would leave room for roughly 75 kW of solar PV panels. Combined with the possible space on the original building, Property 1 could have a 100 kW array. This system could offset up to 64% of Property 1's current load. Because there are economies of scale with solar projects, the internal rate of return on this project would be 9.57%, compared to the 7.7% of the original project. The net present value would be roughly $58,000 and the simple payback would be nine years. These numbers would make this project more feasible than adding solar to just the current building but may still be too low to merit adding a solar system.

While the addition of a system may not be financially viable right now, falling solar prices could make this project feasible in the near future. Due to this, the roof of phase 2 should be built "solar ready". This means making sure the roof could bear the load of the panels, has easy access to wiring, and is not obstructed by mechanical equipment. To get this done, the heat pumps must be either clustered closer together or altogether removed from the roof. While having ground level heat pumps may not be preferred, it would make a solar project in the future much more feasible.

Summary

In total, the recommendations the MP Team recommends would cost Property 1 around $7,100, with an annual savings of $2,400 and a net present value of $3,510. These retrofits would reduce Property 1's emissions by 16 metric tons of carbon dioxide equivalents and bring the EUI of the property down to 44 kBtu/ft^2.

Property 2

Property Overview

Property 2 is a garden-style property consisting of apartments and townhouses, located in central North Carolina. Completed in 1999, the property is 44 acres and has 33 buildings which contain over 250 units. Property 2 attracts families and retirees due to the large units and great amenities.

The common areas are made up of 6,300 ft^2 of conditioned common space, including offices, a business center, a living room, a fitness center, and a shared laundry room. Property 2 also has a 90,000-gallon pool and an outdoor area with propane grills.

Baseline Data

Property 2 uses electricity and propane (for outdoor grills), but there is no natural gas on the property. On average, the common areas of Property 2 use roughly 138,000 kWh of electricity a year, costing about $13,500. Using the diagnostic model, Property 2 has an energy use intensity of 75 kBtu/ft^2.[16] This is 56% higher than the EUI at Property 1, and 83% higher than the EUI of comparable peer buildings (U.S. Department of Energy, 2018).[17] Knowing the EUI is almost double the comparable peer buildings means there is significant room for improvement and opportunities for high net present value investments.

Figure 5 shows the average annual electricity load curve for Property 2. This figure shows a relatively volatile electricity usage. While the peaks are in August and January, which is common, the slope of the load curve is steeper than expected. The average electricity use in July is almost twice the electricity use in April, indicating inefficient climate control systems.

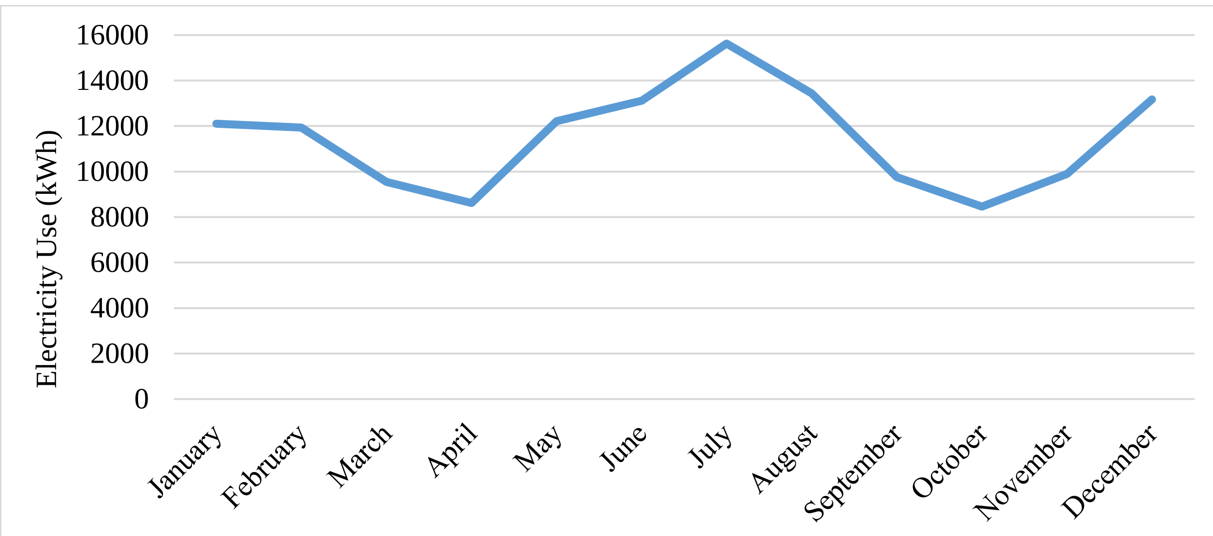

Figure 5. Property 2 Average Annual Electricity Load Curve

To investigate whether the volatility in electricity use is correlated to the outside temperature, monthly electricity use was plotted against monthly temperature data (in the form of heating degree days and cooling degree days) (Figure 6). Assuming that lighting, plug loads, and pool pump use stays relatively constant throughout the year, the monthly electricity use should be highest with high HDD and CDD values.

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[16] kBtu/ft^2 is the unit used for **energy use intensity** (EUI). It measures the energy used (in thousand British thermal units divided by the area (in square feet). EUI is a way to normalize energy use to compare buildings.
[17] The median EUI for Property 2's peers is 40 kBtu/ft^2. The data was collected from the Department of Energy's Building Performance Database.

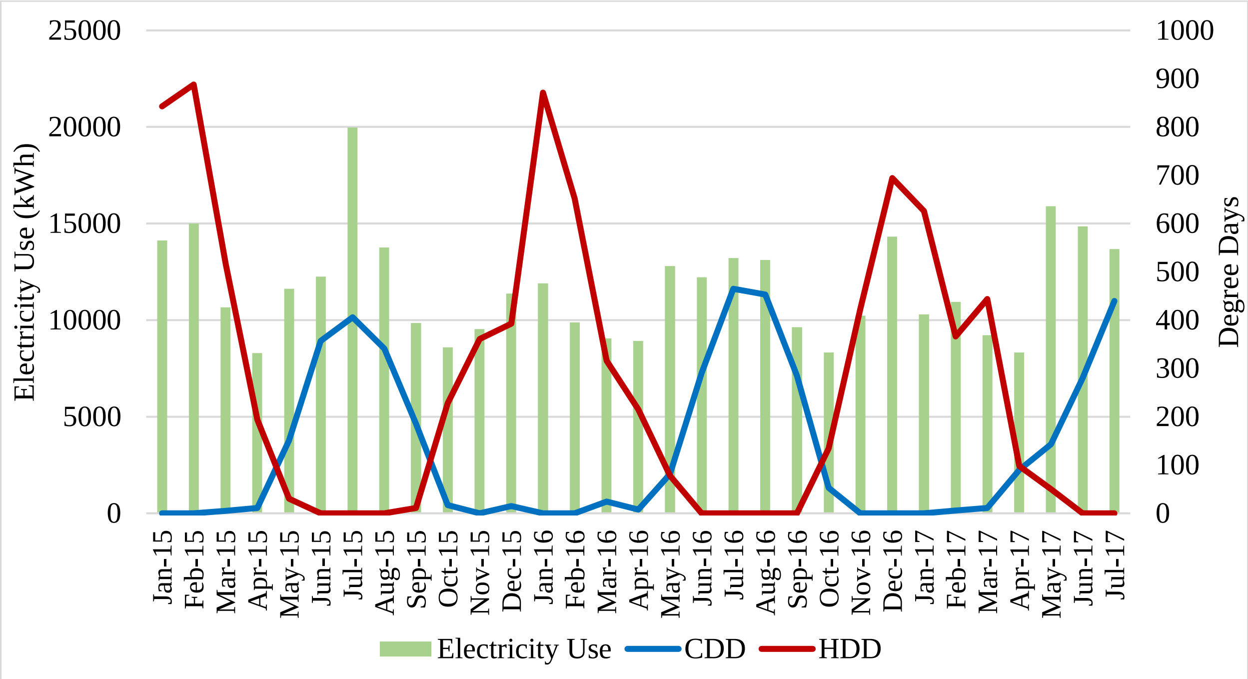

Figure 6. Monthly Electricity Use Vs. HDD and CDD at Property 2 Clubhouse

Figure 6 shows that electricity use tends to follow the number of heating and cooling degree days, but the changes are not always proportional. For example, July of 2015 used 62% more electricity than June of 2015 but only had 13% more CDDs. Conversely, January of 2016 only used 5% more electricity than December of 2015, despite a 120% increase in HDDs. Additionally, May of 2017 used 91% more electricity than April of 2017 despite almost no change in degree days. These findings are evidence that the general electricity load is dependent on the temperature, but electricity use anomalies are likely due to an equipment malfunction, or occupant behavior.

Hotspot Analysis

The distribution of electricity load is relatively evenly spread between heating and cooling, pool equipment, lighting, and plug loads. The exact breakdown can be seen in Figure 7. Compared to the national averages for commercial energy use, Property 2 uses less for heating and cooling, and more for lighting and plug loads.

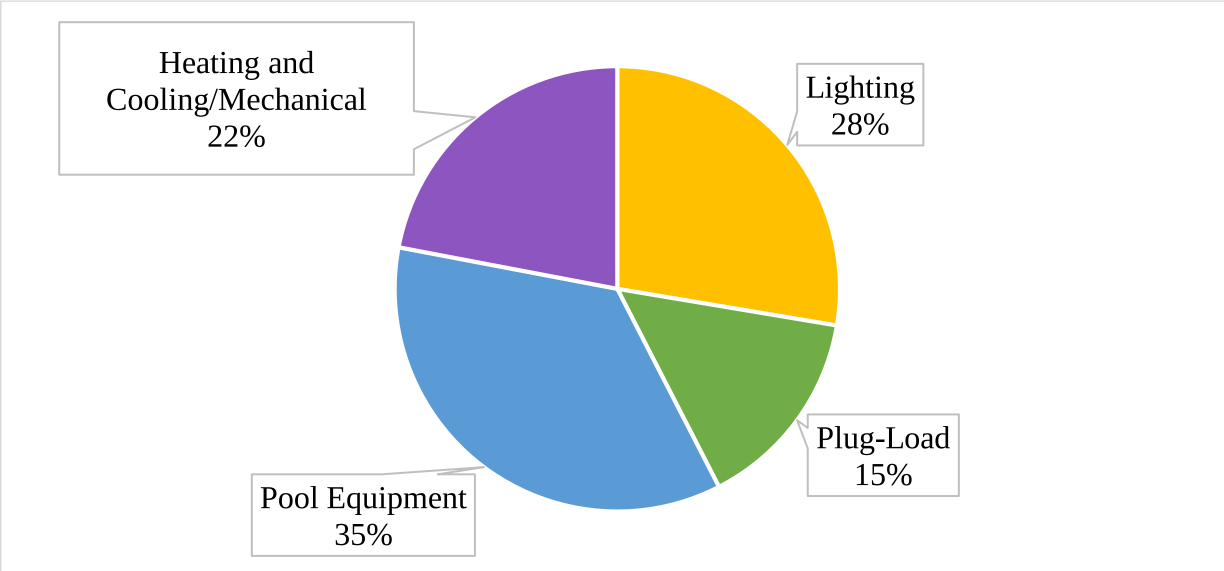

Figure 7. Hot Spot Analysis – Breakdown of Annual Electricity Use for Property 2

The annual average is usually a good indicator of the electricity breakdown, but due to the large fluctuations seen in Figure 5, there will be large seasonal variations in the breakdown. The average monthly breakdown can be seen in Figure 8. The figure shows that the electricity used for heating and cooling ranges from 0.2% in May to 53% in August. This is further evidence that the heating and cooling systems are inefficient, creating the steep load curve seen in Figure 5.

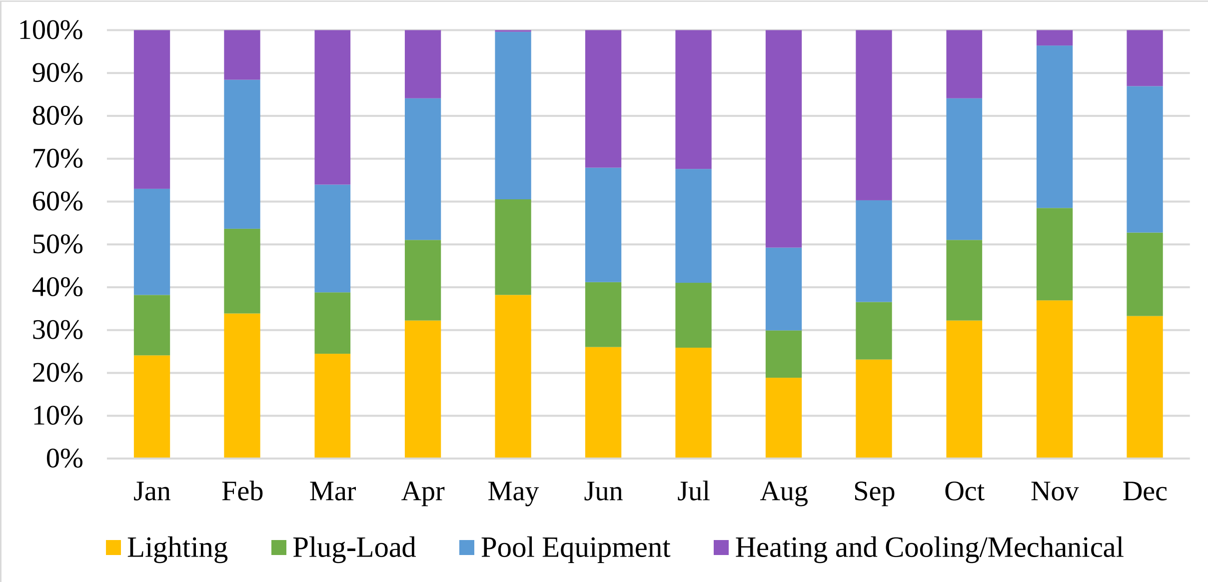

Figure 8. Average Monthly Breakdown of Electricity Use for Property 2

Recommendations

A summary table of all recommendations can be seen in Table 5, and each is explained in detail in the sections below.

Table 5. Summary of Recommendations for Property 2

Recommendation	**Initial Cost ($)**	**Annual Savings ($)**	**GHG Savings (MTCO2e) or Water Savings (gallons)**	**NPV ($)**	**Payback Period (yrs.)**	**Cash on Cash Return**
Bill Monitoring	N/A	Dependent	Dependent	Dependent	N/A	**N/A**
Replace Incandescent Bulbs	$180	$1,025	6 MTCO2e	$4,400	0.2	569%
Consistent Thermostat Set-point	N/A	Dependent	Dependent	Dependent	N/A	N/A
Low-Flow Water Fixtures	$39	$89	23,000 gallons	$1,220	0.4	228%
Pool Pump Timer	$500	$800	5.4 MTCO2e	$10,700	0.6	160%
Total	**$719**	**$1,914**	**11.4 MTCO2e 23,000 gallons**	**$16,320**	**0.4**	**266%**

Energy Efficiency

Bill Monitoring

The cost of the Property 2 clubhouse bills can be seen in Figure 9. This shows the bill in July of 2015 was almost $500 more than the bill in August of 2015, and the bill in December of 2016 was more than $300 more than either surrounding bill.

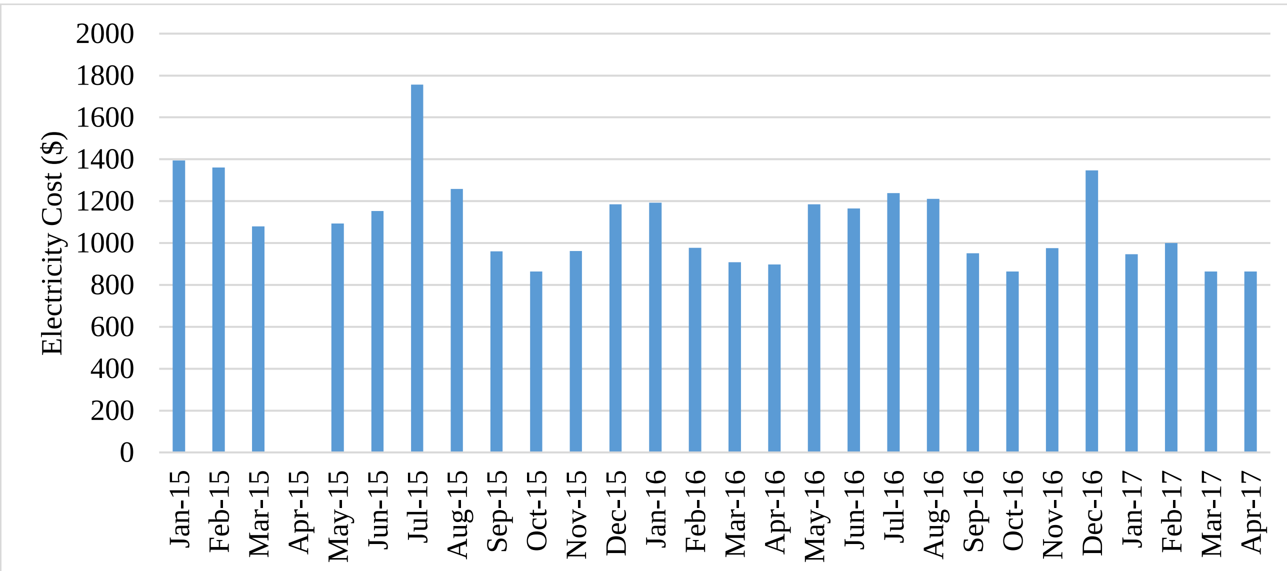

Figure 9. 2015 Monthly Spending on Electricity at Property 2 Clubhouse

The fluctuations in Figure 9 show the importance of disciplined tracking of monthly electricity expenditures. It is recommended that all electricity and water bills are put in a spreadsheet with an automatically updating graph. This would allow the property manager to see any anomalies and address them immediately. Putting the data in the spreadsheet and looking for trends may add 15 minutes a month to the manager's tasks but could help the property save hundreds or thousands of dollars if problems are noticed.

Lighting

The breakdown of annual lighting use by space type can be seen in Figure 10. This shows that the largest users of electricity were exterior and clubhouse lighting. The clubhouse electricity use makes sense due to the number of lights and amount of use. The exterior lighting, however, accounts for only 15% of the bulbs and uses 39% of the electricity for lighting. This discrepancy points to inefficiencies in outdoor lighting.

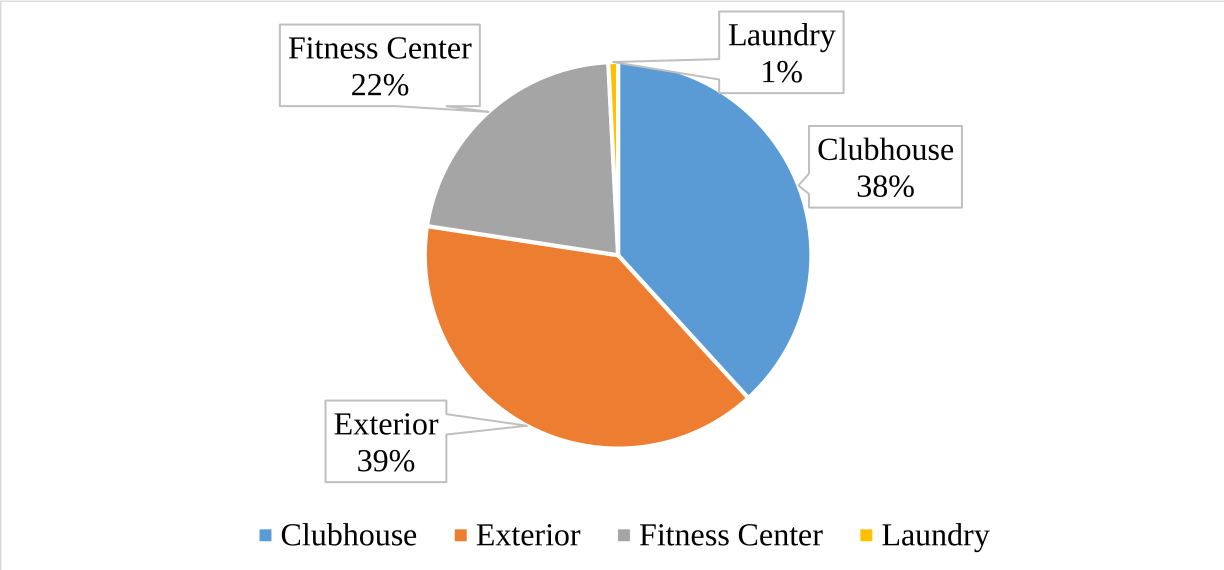

Figure 10. Breakdown of Annual Lighting Use by Space Type for Property 2

The exterior lighting (around the clubhouse) consists of 22 bulbs. 16 of the 22 bulbs are 100-watt incandescent bulbs and six are 60-watt high pressure sodium bulbs. Because 11 of the 100-watt bulbs are on the same circuit, and 4 of the bulbs are in a hallway that must be lit, all 11 bulbs are on 24 hours a day. It is recommended that all exterior 100-watt incandescent bulbs be replaced with 14.5-watt A-19 LED bulbs. The financial analysis of these retrofits can be seen in Table 6.

In the clubhouse, there are 16, 75-watt, bulbs that are each used roughly 10.5 hours a day. It is recommended to replace these blubs with 10.5-watt A-19 LED bulbs. The financial analysis can be seen in Table 6.

Table 6. Property 2 LED Retrofit Options

Description	Initial Costs ($)	Annual Savings ($)	Annual GHG Savings (MTCO2e)	NPV ($)	Simple Payback (yrs.)	Cash on Cash Return
Exterior Hallway	$70	$720	3.5	$3,000	0.1	1029%
Other Exterior	$27	$165	1	$580	0.2	550%
Clubhouse	$86	$240	1.5	$820	0.3	300%
Total	**$183**	**$1,025**	**6**	**$4,400**	**0.2**	**569%**

Using Table 6, it is recommended that Property 2 replaces all incandescent bulbs with the appropriate A-19 LED bulbs. Not only do the LED bulbs require roughly seven times less electricity than incandescent, they also have ten times longer lifespans which reduces the need for maintenance.

Pool Equipment

As mentioned in the best practices guide, there is a significant saving potential in running pool equipment only when it is necessary. The pool equipment at Property 2 runs at full capacity all year, using roughly 40,000 kWh of electricity and costing almost $3,000. By lowering the off-season water turnover rate to one turnover per day, Property 2 can reduce electricity use while still preventing freezing and algae growth.

The MP Team recommends installing a timer on the pool pump that allows the pump to run fulltime in the swimming season and half-time in the offseason. This solution should be coordinated with the maintenance supervisor to optimize the pumping schedule and to ensure the timer would not affect any of the other pool equipment. When the pump eventually needs to be replaced, the MP Team recommends installing a variable frequency drive pool pump.

Purchasing and installing a pool pump timer would cost roughly $500 and create around $800 a year of electricity savings. This project has a net present value of $6,000 and reduces Property 2 annual CO_2e emissions by 4.4 metric tons.

Plug Loads

While looking at the plug loads recorded during the audit, there are none that stand out at as unnecessary power draws. The only plug load that was determined to consume a significant amount of electricity that may be unused is the TV in the clubhouse. The TV is usually on during the day but is rarely watched. By turning the TV off when not in use, Property 2 could save roughly 420 kWh a year.

While the records do not show a significant plug load, the volatile electricity pattern discussed above is reason to believe there could be seasonal or intermittent plug loads that help contribute to electricity spikes. These spikes could also be due to large appliances that are not properly going into sleep modes. It is recommended to unplug all large electronics when not in use and keep an eye out for appliances that are not properly sleeping during periods of inactivity.

Thermostats

Depending on the month, heating and cooling can play a significant role in the electricity use at Property 2. Because large spikes in HDDs and CDDs did not always trigger electricity spikes, it is apparent that the building can be semi efficient at maintaining temperature. The months with large heating and cooling loads are likely due to anomalies in occupant behavior or system malfunctions.

While on the property audit, it was noticed that the clubhouse thermostats were set at different temperatures and the doors between the zones were open. This can cause the thermostats to "fight" with each other, causing an increase in electricity use. It is recommended that all thermostats that have connected areas be set to the same temperature. It is also recommended that all doors be closed to rooms that are utilizing space heaters.

Water Efficiency

Using the best practices guidelines shown in Table 1, Property 2 has several fixtures that are over the maximum flow rate. These include the showerheads in the fitness center (2.5 gpm), the clubhouse kitchen sink (2 gpm), and all toilets (1.5 gpf). It is recommended to switch the showerheads to 1.5 gpm fixtures and add a 1.5 gpm aerator to the clubhouse kitchen sink. Retrofit options and financial analysis for showerheads and sink fixtures can be seen in Table 7. Toilet retrofits can be more expensive, and because the water use is not dramatically over the limit, retrofits are not recommended at this time. However, if new toilets are purchased in the future, it is recommended they are below 1.28 gpm.

Table 7. Property 2 Water Saving Retrofit Options

Description	Initial Costs ($)	Annual Savings ($)	Annual Water Savings (gallons)	NPV ($)	Simple Payback (yrs.)	Cash on Cash Return
Fitness Center Showers	$30	$85	22,000	$1,167	0.4	238%
Clubhouse Kitchen Sink	$9	$4	1,000	$53	2.3	44%
Total	**$39**	**$89**	**23,000**	**$1,220**	**0.4**	**228%**

Renewable Energy

Most of the property at Property 2 is occupied by units and trees so any renewable energy would have to be rooftop solar PV. The south facing roof area that is free of shade and obstructions is roughly 3,000 ft^2. This roof could support roughly a 30-kW system which would offset about 35% of the annual electricity load. The monthly electricity use and generation can be seen in Figure 11.

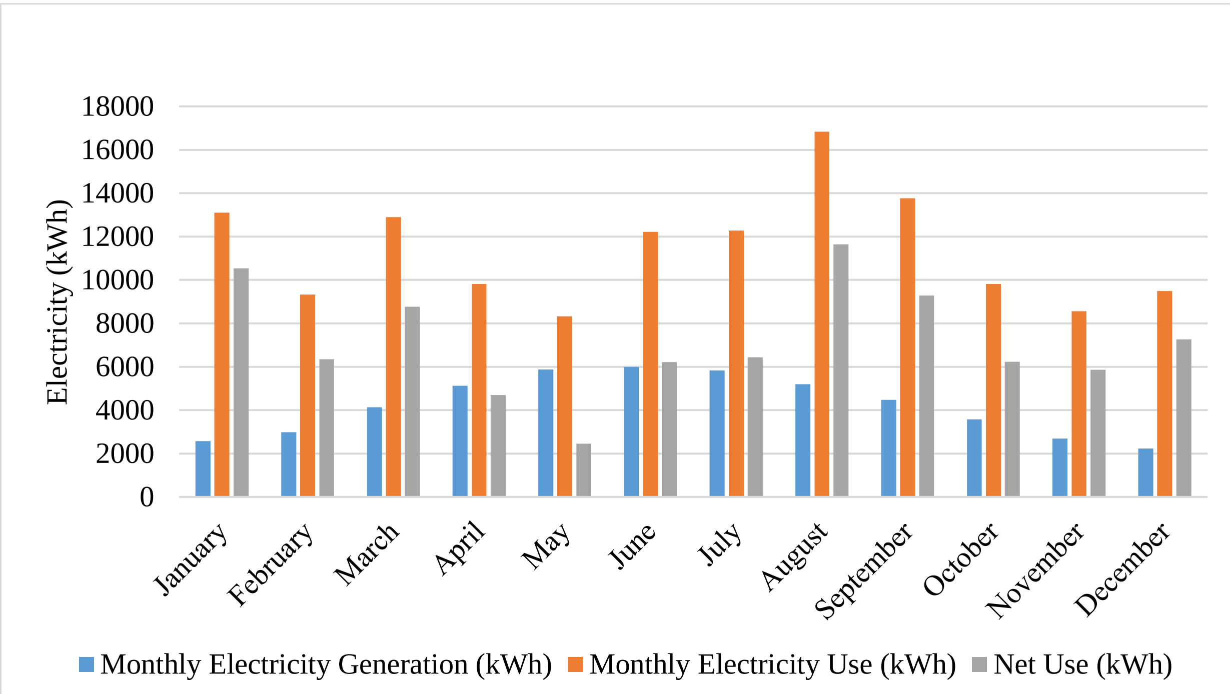

Figure 11. Monthly Electricity Use and Solar PV Generation at Property 2

This 30-kW system would have an initial cost of roughly $49,000. With an annual production of 50,000 kWh, this system would save Property 2 about $4,000 a year. The simple payback period is 12 years, and the project has a 30-year net present value of $15,000. While this may not be financially viable currently, this should be considered in the future as solar panel prices continue to fall.

Summary

In total, the recommendations for Property 2 would cost roughly $700 and provide an annual savings of around $1,900. These projects would yield a net present value of $16,320. Environmentally, these projects would reduce the property's emissions by 11.4 metric tons of

CO_2e and water use by 23,000 gallons each year. This would lower the property's EUI from 75 to 61.33 kBtu/ft^2.

Property 3

Property Overview

Property 3 is a garden-style property located in central North Carolina. The property was built in the 1970s and contains over 300 units, ranging from one to three bedrooms. Due to the location, range of unit sizes, and amenities offered, Property 3 attracts young professionals and families.

The clubhouse area is made up of 6,000 ft^2 of conditioned space which includes offices, a club room, a fitness center, and a business center. Property 3 also has an 84,000-gallon pool and a patio area that includes propane grills and a propane fireplace. Over the last year, Property 3 has been undergoing renovations including pool area improvements, clubhouse improvements, and LED retrofits.

Baseline Data

The Property 3 Clubhouse uses electricity and propane (for outdoor grills), but there is no natural gas on the property. On average, the clubhouse uses roughly 120,500 kWh of electricity a year, costing about $12,000. Using the diagnostic model, Property 3 has an energy use intensity of 68.5 kBtu/ft^2.[18] This is 43% higher than the EUI at Property 1 and 71% higher than the median of comparable peers (U.S. Department of Energy, 2018).[19] This EUI demonstrates that there is room for improvement at Property 3, meaning there could be significant cost saving potential.

Figure 12 and Figure 13 show the average annual electricity load curves for the Property 3 clubhouse and maintenance shop, respectively. Figure 12 shows a large difference between peak electricity loads and non-peak loads. While January and July have similar electricity averages, they are 64% higher than the average load in April. This likely demonstrates heavy electricity use for heating and cooling, pointing to building inefficiencies.

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[18] kBtu/ft^2 is the unit used for **Energy Use Intensity** (EUI). It measures the energy used (in thousand British thermal units divided by the area (in square feet). EUI is a way to normalize energy use to compare buildings.
[19] The median EUI of Property 3's peers is 41 kBtu/ft^2.

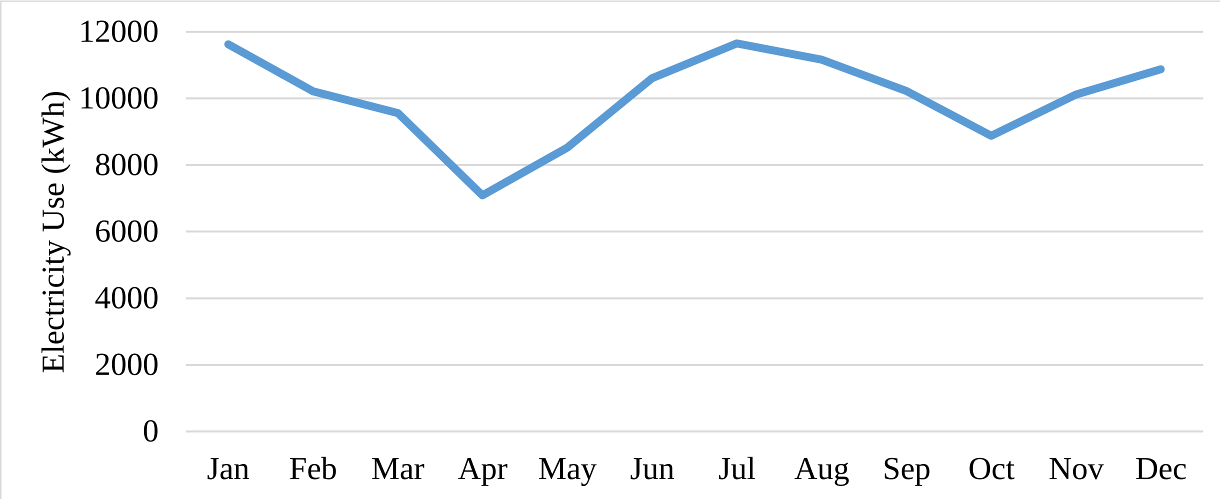

Figure 12. Average Monthly Load Curve for Property 3 Clubhouse

Figure 13 shows that the shop has an even greater disparity between peak and off-peak loads, with the average electricity use in January being over 150% higher than the average use in April and May. Additionally, the average electricity use in January is 48% higher than the average use in July. These large differences point to a heavy heating load and potential heating inefficiencies.

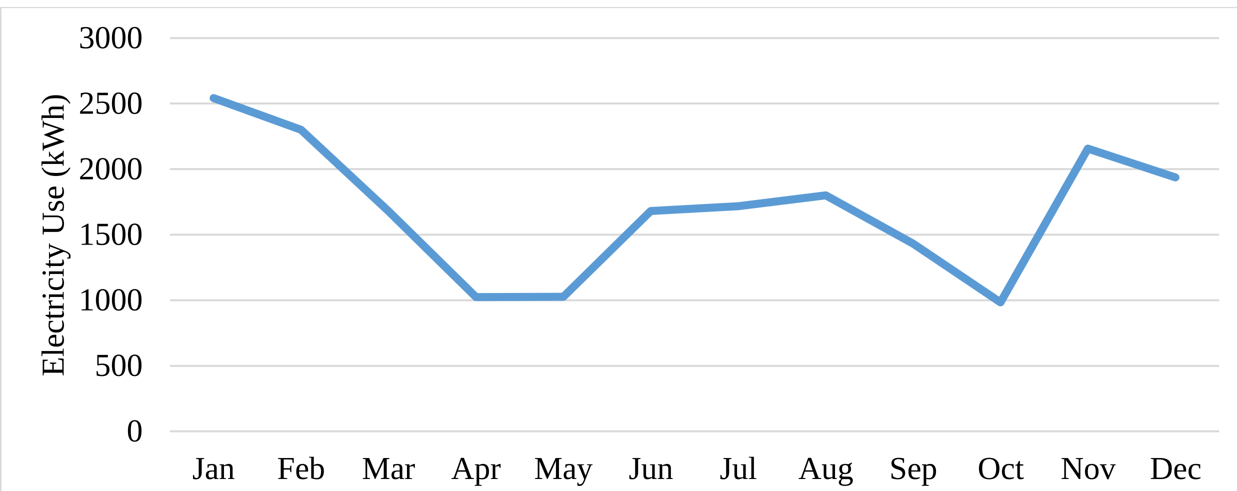

Figure 13. Monthly Average Load Curve for Property 3 Maintenance Shop

Hot Spot Analysis

The breakdown of average electricity use by space type can be seen in Figure 14. This shows that heating and cooling/mechanical is the largest consumer of electricity, followed by the pool equipment. In comparison to the previous two properties, both lighting and plug-load electricity use is relatively low.

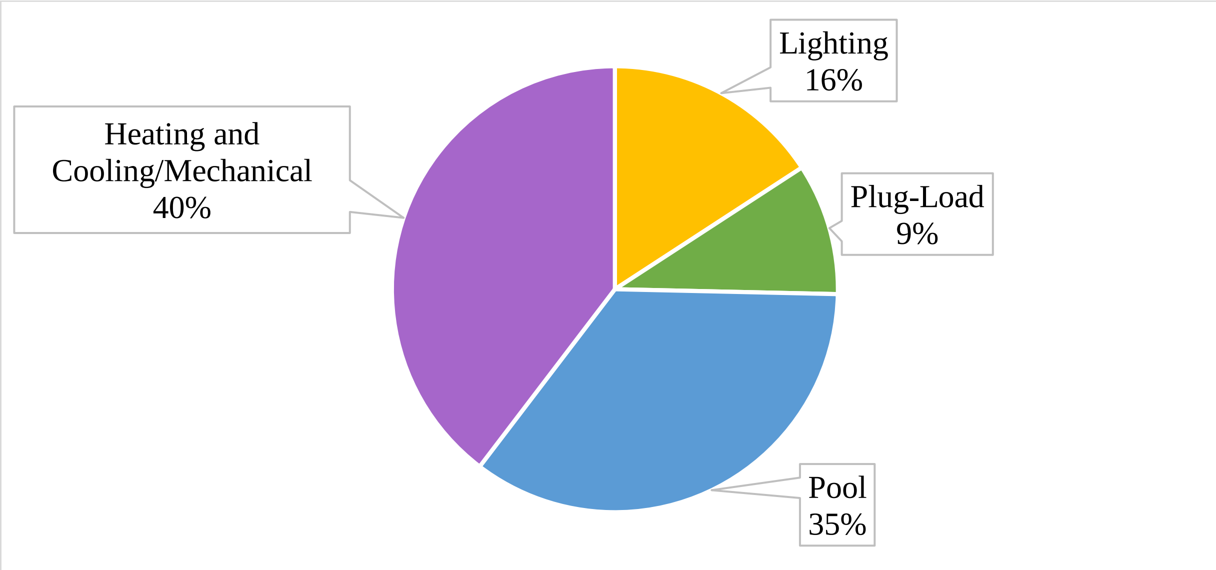

Figure 14. Annual Electricity Breakdown by Space Type for Property 3 Clubhouse

Due to the seasonal trends seen in the load curves for both the clubhouse and shop, seasonal variations were expected in the electricity disaggregation. These changes can be seen in Figure 15, and demonstrate a large seasonal variation in heating and cooling load. This variation is not as extreme as the variation seen at Property 2. Both the annual and monthly breakdowns of electricity use point to high heating and cooling loads which will be investigated further.

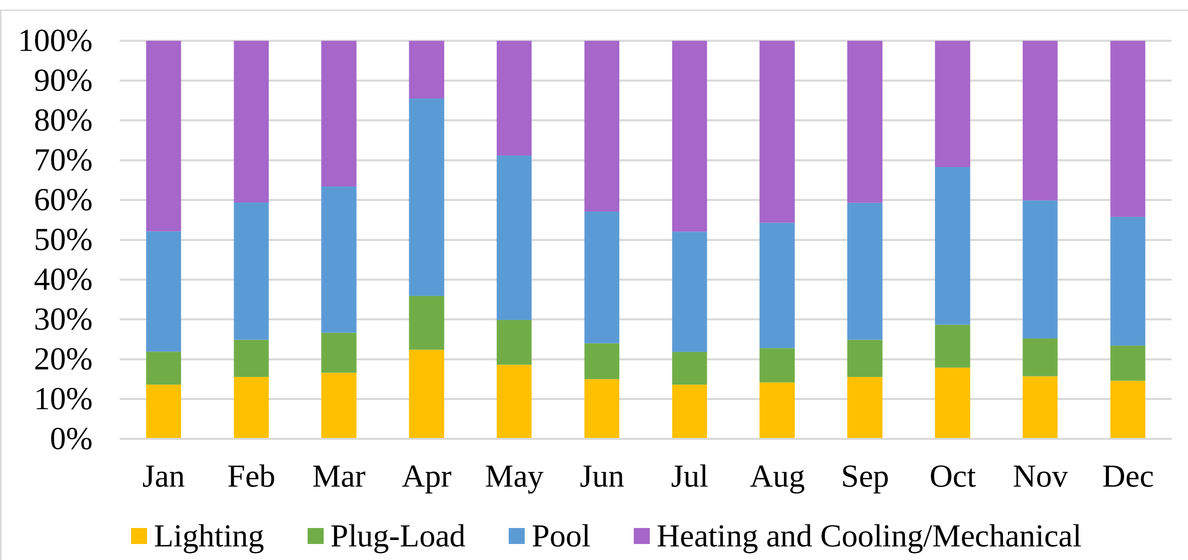

Figure 15. Average Monthly Breakdown of Electricity Use for Property 3 Clubhouse

Recommendations

A summary of the recommendations for Property 3 can be seen in Table 8, and each recommendation is explained in detail in the following sections.

Table 8. Summary of Recommendations for Property 3

Recommendation	Initial Cost ($)	Annual Savings ($)	Annual GHG Savings (MTCO2e)	NPV ($)	Payback Period (yrs.)	Cash on Cash Return
Bill monitoring	N/A	Dependent	Dependent	N/A	N/A	N/A
Thermostat set points and plug loads	N/A	Dependent ~$200	Dependent	Dependent	N/A	N/A
Pool Pump Timer	$500	$650	4.6	$9,100	0.8	130%
Sign Lighting Retrofit	$150	$180	1.1	$600	0.8	120%
Total	**$650**	**~$1,030**	**5.7**	**$9,700**	**0.7**	**151%**

Bill Analysis

As mentioned in the baseline analysis, the maintenance shop at Property 3 has a very volatile load curve. While some of this can be explained by weather, the volatility could also be caused by improper equipment schedules, occupant behavior, or equipment malfunctions. In addition to the electricity use volatility, the shop has a widely varying monthly peak demand. Figure 16 shows the monthly electricity use plotted with the monthly peak demand. While these series should track with each other, there are several months in which the shop at Property 3 had a low electricity use with a high peak demand. This is usually evidence of an improper equipment load or an equipment malfunction.

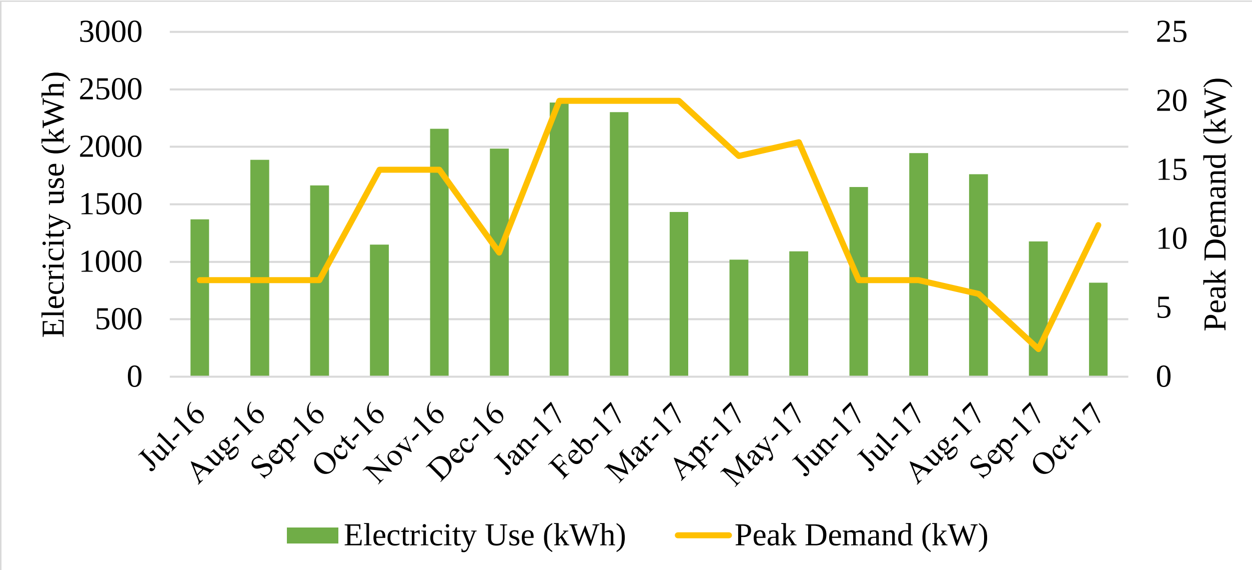

Figure 16. Electricity Use Vs. Peak Demand for Property 3 Shop

In addition to the peaks in the clubhouse and shop electricity use, there were 17 vacant or model unit electricity bills for Property 3 that were over $90 in the past three years. Of these, seven were over $140 and two were over $200. Additionally, there were several outdoor lighting meters that had the same number of bulbs but significantly different monthly bills. These instances all point to the need for bill monitoring and analysis.

As mentioned in the best practices guide, and in reference to Property 2, vigilant bill monitoring is an easy way to save money. By catching bill disparities and abnormally high bills, any equipment malfunctions and occupant behavior can be fixed to lower future bills. The MP Team recommends that all monthly bills be entered into a database that can be used to track and compare monthly bills in order to identify and address anomalies.

Plug Loads

A breakdown of plug load electricity use by space can be seen in Figure 17. This reveals the fitness center and the offices as the largest plug loads. The office plug load is justifiable due to the number of employees that are using computers, printers, and other appliances. There were no excessive plug loads noticed in the office area.

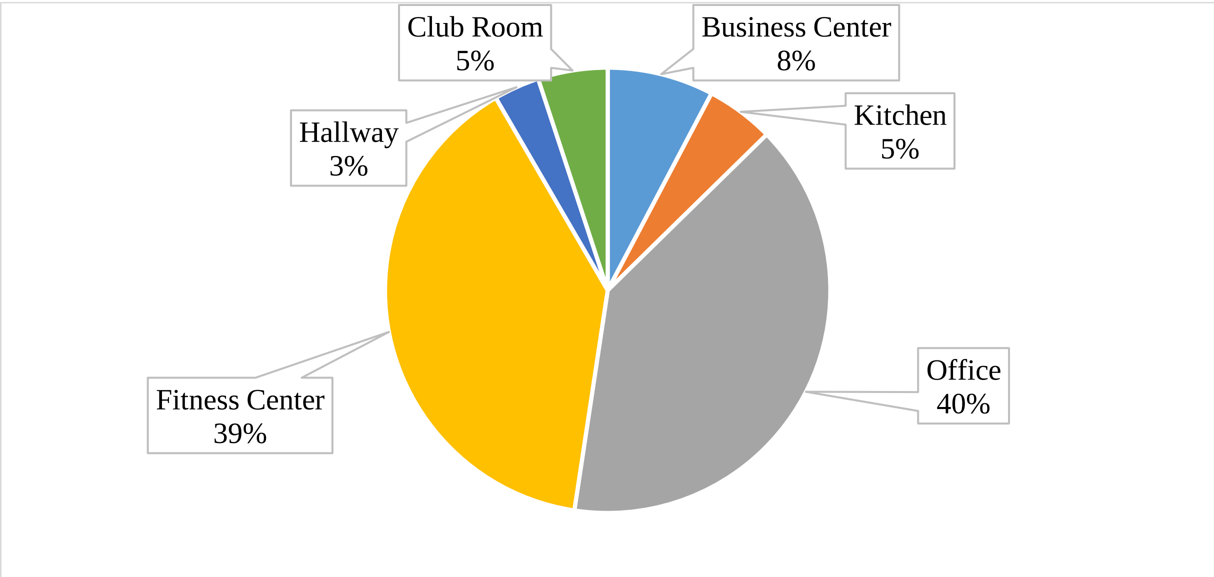

Figure 17. Plug Load Electricity Breakdown by Space Type for Property 3 Clubhouse

The fitness center, however, did not have high plug loads from regular use. There is a poorly sealed sauna in the fitness center that is contributing to the high plug load. Figure 18 is an infrared image of the sauna, which shows the hottest area of the exterior wall is almost 100 degrees Fahrenheit. This poor insulation of the sauna is not only causing a high plug load but is also contributing to the large need for cooling.

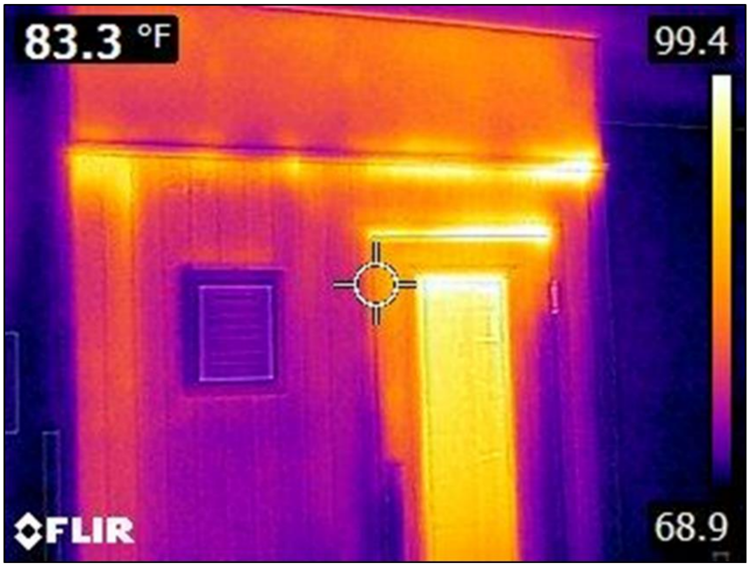

Figure 18. Infrared Image of Property 3 Sauna

It is recommended that the sauna be insulated and sealed in an attempt to reduce electricity use. The MP Team also recommends raising the thermostat setpoint in the fitness center as to not compete with the sauna.

The property audits also revealed 10 computers in the business center, four of which were set to never enter sleep mode. Due to relatively low use of the business center, having 10 computers is more than what is necessary to meet tenant need. This has since been remedied by removing excess computers and setting all computers to enter sleep mode when not in use.

Climate Control

During multiple visits, the MP Team noticed thermostats in the different rooms set at different set points. While there are doors between all rooms, these do not create perfect barriers and the thermostats can still compete. This difference in set points requires the heat pumps to work harder. It is recommended that all thermostats be set to 74 degrees Fahrenheit in the summer and 70 degrees Fahrenheit in the winter. The exception to this is the fitness center. Because the sauna adds a substantial amount of heat to the fitness center, it is recommended to keep the fitness center thermostat set to 75-76 degrees Fahrenheit in the summer and 65 degrees Fahrenheit in the winter.

Pool Equipment

Currently, the pool equipment at Property 3 runs at full capacity all year, using roughly 42,000 kWh of electricity and costing $2,650. As seen at Property 2, installing a pool pump timer can create significant savings, having a payback period of less than a year. Because Property 3's pool is a similar size, the MP Team recommends the same solution for Property 3. By lowering the off-season water turnover rate to one turnover per day, Property 3 can reduce electricity use while still preventing freezing and algae growth.

The MP Team recommends installing a timer on the pool pump that allows the pump to run fulltime in the swimming season and half-time in the offseason. This solution should be coordinated with the maintenance supervisor to optimize the pumping schedule and to ensure the timer would not affect any of the other pool equipment. When the pump eventually needs to be replaced, the MP Team recommends installing a variable frequency drive pool pump.

Purchasing and installing a pool pump timer would cost roughly \$500 and create around \$650 a year of electricity savings. This project has a net present value of \$9,100 and reduces Property 3's CO_2e emissions by 4.6 metric tons.

Lighting

Lighting is responsible for 16% of the average annual electricity use for the Property 3 Clubhouse. This is slightly higher than the national average for commercial buildings but does not stand out as a red flag. A breakdown of lighting electricity use by space type can be seen in Figure 19. This shows that the largest consumer of electricity is outdoor lighting.

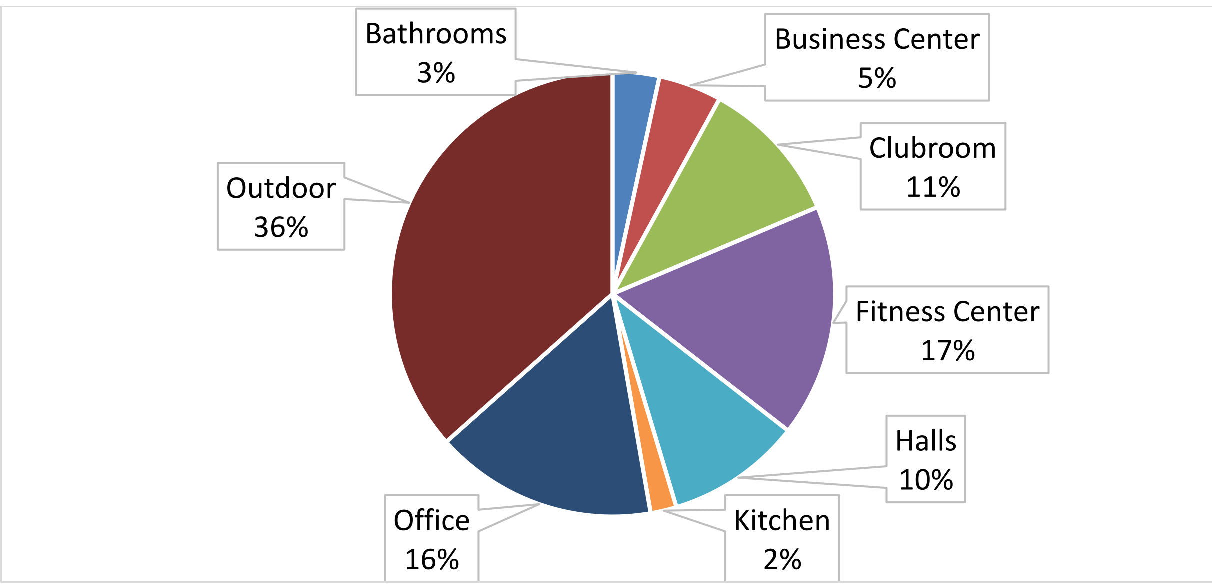

Figure 19. Breakdown of Electricity use for Lighting by Space Type for Property 3

The large share attributed to outdoor lighting makes sense because most of the interior lights have been fitted with LEDs. Property 3 is in the process of converting all outdoor lighting to LED bulbs, which will lower the overall electricity consumption for lighting. Due to these retrofits, the MP Team does not recommend any lighting retrofits at the clubhouse.

At the entrance to the property, there are two signs. Each sign is lit with one blub, and on average, the combined cost of these two bulbs is \$150 a month. Using Property 3's utility rate, and the assumption that the lights are on 12 hours a day, the bulbs were calculated to be roughly 600-watts. These fixtures can be replaced with LED bulbs for roughly \$150 and would save about \$180 a year.

Outdoor Amenities

Property 3 has a large field located near the pool area. While this area is already used for outdoor recreation, there could be additional uses. The MP Team recommends putting in a community garden for tenants. This garden would encourage tenants to be healthier and more sustainable and could be a selling point for prospective tenants who desire a garden.

This space would also be a prime location for a solar array. Because this array would take away current recreational areas, this could be less appealing to tenants than a garden. Due to the current payback period for small PV systems, as seen at Properties 1 and 2, the array was not modeled. If the price of solar continues to fall, the MP Team recommends an analysis of a solar array on part of the field. This electricity could be used to offset the use of the pool equipment and other clubhouse needs.

Summary

In total, the recommendations for Property 3 would cost roughly $650 and provide an annual savings of around $1,000. These projects would yield a net present value of $9,700. Environmentally, these projects would reduce emissions by 5.7 metric tons of CO_2e each year. This would lower the property's EUI from 68.5 to 60 kBtu/ft^2.

Overall Results

While the monetary and environmental savings of each property are small, the impacts are amplified when the projects are viewed as a portfolio. When looking at these three properties together, all recommended retrofits will cost around $8,500, save $5,347 a year, and create a net present value of almost $30,000. Additionally, these projects would save 33.1 metric tons of CO2e and 23,000 gallons of water annually. Expanding this further, the MP Team extrapolated these results to a portfolio of 350 properties. Assuming these three properties are a representative sample of the portfolio, these investments would cost $988,000, save $624,000 a year, and provide a net present value of $3.45 Million. These results can be seen in Table 9.

Table 9. Overall Recommendations

Property	Initial Cost ($)	Annual Savings ($)	GHG Savings (MTCO2e)	Water Savings (gallons)	NPV ($)
Property 1	$7,100	$2,403	16	0	$3,510
Property 2	$719	$1,914	11.4	23,000	$16,320
Property 3	$650	$1,030	5.7	0	$9,700
Total	**$8,469**	**$5,347**	**33.1**	**23,000**	**$29,530**
Extrapolated to 350 Properties	**$988,000**	**$624,000**	**3,900**	**2.7 M**	**$3.45 M**

Discussion of Case Studies

The MP Team observed three major trends from the case studies that may likely be true at the majority of D&F multifamily properties.

Lighting: Major retrofit value

At all three sites, lighting retrofits almost always offered the highest returns of any technology. The notable exception to this trend were Property 1's parking deck fluorescent lights, whose high efficacy made any currently available LED retrofit cost-ineffective. This exception also supports the technology-blind, performance-based lighting metric used in the Table 1.

Water Efficiency: Low-capital, long-lasting

While the magnitude of returns from lighting retrofits are higher, water efficiency retrofits utilize lower-cost technology that lasts many times longer than light bulbs. This tradeoff results allows water efficiency measures to be implemented faster and with less risk than lights.

Swimming Pools: Multiple opportunities

Between the multiple caustic chemicals needed for chlorinated pools, and the constant pump operation, D&F has a major environmental and financial incentive to construct or convert all pools to salt water and employ pump equipment that drastically reduces electricity consumption.

Conclusion

Key Takeaways

In addition to specific trends and best practices, the MP Team has general recommendations that should serve as a strategic framework when considering a new property for sustainability initiatives. First, the challenges and opportunities at a property are never similar enough to another site that a generic "cookie-cutter" solution can be applied. To that end, the models and best practices have been made flexible and adaptable to allow for different scenarios that the MP Team did not experience at the three audited sites. In a similar manner, sustainability managers at D&F should approach each property as a unique situation, and always gather preliminary data without making *a priori* assumptions.

When managers are beginning work on a property, they should always prioritize absorbing the knowledge and experience of the property's tenants and staff. Similar to how poor engineering or maintenance can invalidate even the most thorough financial projections, technological quality or experience is less valuable than connecting with the people entrenched in the daily operations of a site. Many water and energy issues are nearly impossible to directly observe, and consistent long-term experience greatly increases the chances of detection.

However, even constant observation will not catch all issues. Big data is vastly underutilized in real estate management, and the introduction of more sophisticated data collection and analysis techniques will allow D&F to maximize their sustainability efforts, as well as indirectly improving other aspects of the company's operations via shared techniques and findings. In support of more robust metering technology as discussed on page 10, D&F would benefit from employing dedicated analysts to monitor and investigate utilities and other resource management data from the entire portfolio.

Future Research

The Nicholas School of the Environment will continue its collaboration with D&F in order to further improve the feasibility of deploying sustainability initiatives across all of D&F's portfolio. To that end, the 2018 MP Team recommends that the future 2019 MP Team focuses on developing a business model that will prioritize the profitability and speed of scaling up the auditing, modeling and technological best practices specified in this report. In support of this business plan, the 2018 MP Team also recommends research into additional sustainability topics, including waste management, landscaping, and building design. Furthermore, the 2019 MP Team can improve the universality of this report's recommendations and models by auditing properties in different climatological regions.

Further collaborative work can supplement the 2019 MP Team's work, including client-based, independent study work where Nicholas School master's students can conduct audits and sustainability workshops with D&F property staff.

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Appendix 1: Interactive model inputs, equations, and assumptions

Energy Diagnostic Model

User Inputs	
Model Outputs	

Inputs	
Building Information	
Year Built	2012
Square Footage	6,300
2017 electricity use (kWh)	137,867
2017 gas use (therms)	0
Pool Information	
Pool?	No
Salt or Chlorine?	Chlorine
Volume (gallons)	20000
Required Flow Rate (Gpm)	4
Pump Flow rate (GPM)	60
Horse Power	2.5
Timer or Variable Frequency Drive?	No

Outputs	
Diagnostic	
EUI	74.66701651
Average EUI Comparison	40
Performance	Needs Improvement
Pool Diagnostic	
Circulations per day	4.32
Pump Sizing	Good
Estimated Annual Savings from Timer	$ 371.63
Chemical Recommendation	Switch to Salt

Figure 20. Energy Diagnostic Model User Interface and Results

$$\boldsymbol{EUI} = \frac{\frac{kWh * 3412 \frac{Btu}{kWh}}{1000}}{Area}$$

$$\boldsymbol{Pool\ Turnover\ Rate} = \frac{Volume}{Pump\ Flow\ Rate * 60 * 24}$$

Rooftop Solar PV Simulation Model

USER INPUTS					
Space Type and Requirements			**Utility Data**		
Space Type	Rooftop	Jan	kWh used	13173	
Space Size (ft^2)	3,000.00		Peak kW Demand	46.8	
Space Shape	Rectangle	Feb	kWh used	9378	
Area Obstructed (ft^2)	0		Peak kW Demand	41.6	
Space Tilt	Gentle Slope	Mar	kWh used	12970	
Space Orientation	South		Peak kW Demand	41.6	
Tracking	No	Apr	kWh used	9860	
Ideal Percentage Offset	Max		Peak kW Demand	24.65	
Building Use Pattern	Office Hours	May	kWh used	8320	
Financial Variables			Peak kW Demand	42.8	
Tax Rate	21%	Jun	kWh used	12210	
Discount Rate	7.00%		Peak kW Demand	46	
Energy cost escalation	3.0%	Jul	kWh used	12269	
Covered Parking			Peak kW Demand	49.2	
# of Spaces	0	Aug	kWh used	16830	
Additional Charge ($)	0		Peak kW Demand	50.4	
Percent of spaces Filled	0%	Sep	kWh used	13760	
Days used per year	0		Peak kW Demand	49.2	
Total Annual Revenue	0	Oct	kWh used	9860	
Utility Rates			Peak kW Demand	48.8	
Utility Company	DEP	Nov	kWh used	8600	
Time of Use Rates?	DEP-Small General Service		Peak kW Demand	55.2	
		Dec	kWh used	9540	
			Peak kW Demand	47.6	

Figure 21. Image of Rooftop Solar PV Simulation Model User Interface

Solar Installation Basic Analysis	
System Size (kW)	30.00
NPV	$15,940
IRR	8.44%
NPV Payback Period	19 years
Simple Payback Period	12 years

Figure 22. Financial Outputs of Rooftop Solar PV Model

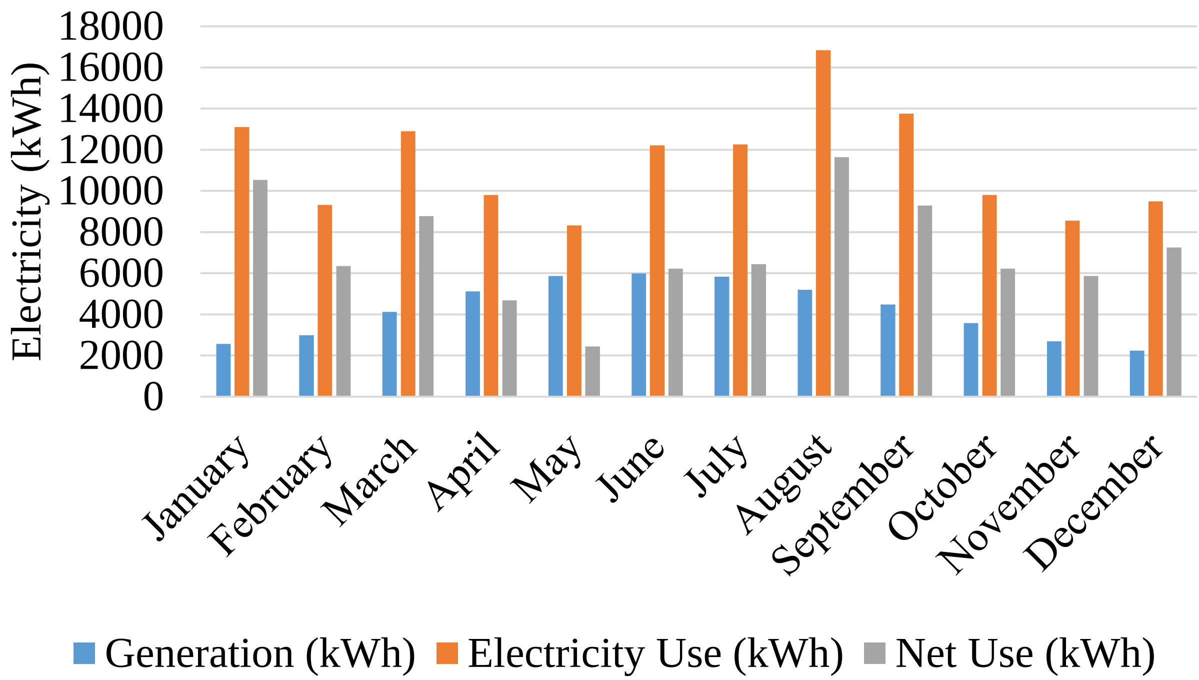

Figure 23. Generation Output from Rooftop Solar PV Simulation Model

Table 10. Assumptions made in Rooftop Solar PV Simulation Model

Topic	**Assumption**
Panel Efficiency	17-20%
PV Base Prices	Between $2.93 and $1.50 per W depending on size
Price Additions for Tracking	Additional 20% per W
Price Additions for Elevated Panels	Additional 10% per W
Price Additions for Roof Slope	Additional 10% per W for gentle slope and 20% per W for steep slope
Net Metering Policies	Under 100 kW systems can be net metered. Over 100kW use avoided cost rate

HVAC and Building Envelope Model

U Value: A measure of how well a material serves as an insulator. The units are Btu/(hr °F ft^2)

Solar Heat Gain Coefficient (SHGC): The percentage of solar radiation that passes through a window.

Area: This refers to the area of whatever surface you are using in the calculation. Depending on the calculation, area should either be in m^2 or ft^2.

SEER: A measure of how efficient a heat pump is at removing heat. Units are (Btu/kWh)

HSPF: A measure of how efficient a heat pump is at adding heat. Units are (Btu/kWh)

Duct Efficiency: A measure of how much heating or cooling makes it from the heat pump to the location

Set Point: What temperature the thermostat is set to match

Degree Days: The numbers of degrees of heating or cooling required over a certain period of time. For example, if five degrees of cooling are required every day for seven days, that week had 35 Cooling Degree Days (CDDs)

The equations for the HVAC and Building Envelope model include:

$$\boldsymbol{Degree\ Days\ (DD)} = Average\ Outside\ Temperature - (Set\ Point - 7)$$

$$\boldsymbol{Conductive\ Heat\ Gain\ or\ Loss\ (Btu)} = (U * A * DD * 24)$$

$$\boldsymbol{Radiative\ Heat\ Gain\ (Btu)} = solar\ radiation * SHGC * A * 3412\,\frac{Btu}{kWh}$$

$$\boldsymbol{Electricity\ Required\ (kWh)} = \frac{Conductive\ Heat\ Gain\ or\ Loss + Radiative\ Heat\ Gain}{SEER\ or\ HSPF} * \left(\frac{1}{Duct\ efficiency}\right)$$

$$\boldsymbol{Electricity\ Cost} = Electricity\ Required * Utility\ Rate$$

$$\boldsymbol{Electricity\ Savings} = Current\ Electricity\ Cost - New\ Electricity\ Cost$$

Lighting and Plumbing Retrofit Model

Fixture Type: This refers to what type of fixture the bulb plugs into. The options are 4-Pins, 2-Pins, Edison Base, or Tube

Number of Bulbs (#): This is the number of bulbs being considered for replacement.

Wattage (W): This refers to the power of the lightbulb, listed in watts.

Lumens (L): This refers to how much light the bulb emits, listed in lumens.

Lifespan (yr.): This is the expected number of years the bulb will last. The manufacturer should give a lifespan, but the model facilitator can make appropriate lifespan assumptions.

Hours Used per Weekday (hrwd): This refers to how many hours per day the bulb will be on during an average weekday.

Hours used per Weekend Day (hrwe): This refers to how many hours per day the bulb will be on during an average weekend.

The equations for the Lighting and Plumbing Retrofit model include:

$$\boldsymbol{Replacement\ Bulb\ Costs} = \# * Cost * labor\ cost\ per\ bulb$$

$$\boldsymbol{Replacement\ Fixture\ Costs} = \# * adapter\ costs$$

$$\boldsymbol{Total\ Costs} = Replacement\ Bulb\ Costs + Replacement\ Fixture\ Costs - Rebates$$

$$\boldsymbol{Electricity\ Savings\ (kWh)} = \frac{\# * W * \left((hrwd * 261) + (hrwe * 104)\right)}{1000} cur. - \frac{\# * W * \left((hrwd * 261) + (hrwe * 104)\right)}{1000} new$$

$$\textbf{Annual}\ \boldsymbol{Electricity\ Cost\ Savings} = Electricity\ Savings * Utility\ Rate$$

$$\boldsymbol{Annual\ Maintenance\ Savings} = \frac{(\%\ increase\ in\ lifespan * price\ of\ current\ bulbs * \#) + (Labor\ cost\ per\ bulb * \#)}{\frac{yr}{(hrwd * 261) + (hrwe * 104)}}$$

$$\boldsymbol{Annual\ Savings} = Annual\ Electricity\ Cost\ Savings + Annual\ Maintenance\ Savings$$