Current and Innovative Strategies in Energy Efficiency

A Case Study of Astrakhan State University

An Interactive Qualifying Project submitted to the Faculty of
WORCESTER POLYTECHNIC INSTITUTE
in partial fulfillment of the requirements for the degree of Bachelor of Science by

Michael Bodanza, Ching-Hsiang Chen, Nicole Chittim, and Ankit Kumar

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Report Submitted to:
Professors Oleg V. Pavlov and Thomas J. Balistrieri
Worcester Polytechnic Institute

Abstract

The purpose of this Interactive Qualifying Project was to conduct an energy audit on three buildings at Astrakhan State University in Russia and propose recommendations regarding ways in which electrical energy efficiency could be improved. After researching multiple energy-saving technologies, we recommend that Astrakhan State University install more efficient light bulbs and motion sensors. We also recommend Astrakhan State University implement piezoelectric flooring to become a leader in energy sustainability among universities in Russia.

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Authorship

Michael Bodanza was the primary editor of the report. He conducted primary interviews and assisted in the completion of the walk-through and standard energy audits.

Ching-Hsiang Chen was the primary researcher for the project. He conducted primary interviews and assisted in the completion of the lighting audit. He participated in the construction of the benchmark in addition to gathering all of the information and data needed to analyze the recommended solutions.

Nicole Chittim was the primary writer of the report. She assisted in conducting primary interviews and collected data during the walk-through and standard energy audits.

Ankit Kumar was the primary data analyst. He assisted in the completion of the lighting audit and analyzed all of the data collected. He participated in the construction of the benchmark and completed all of the cost-benefit analysis.

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Executive Summary

Problem

According to the U.S. Department of Energy Conservation, Russia is the third largest energy consumer in the world. In order to encourage the energy conservation movement, the Russian President passed legislation in 2008, declaring an energy conservation plan to "reduce the energy intensity of the Russian economy by 40 percent by 2020" (The Federation of Finnish Technology Industries, 2014). However, legislation in 2011 extended the deadline to 2035 (Ministry of Energy of the Russian Federation, 2010). Part of this legislation includes a policy that requires state-funded organizations to decrease their energy consumption by 3% each year (Gusev, 2014).

In order to comply with these laws, Astrakhan State University has decided to implement new, efficient, electrical technologies into three of its buildings. Energy conservation will be cost effective for the University and less deleterious to the environment.

Goal and Objectives

The goal of our project was to conduct an electrical energy audit of three older buildings at Astrakhan State University (ASU) and propose recommendations regarding ways in which the University could make the buildings more energy efficient.

To accomplish this task we developed five objectives:

1. Research efficient electrical technologies that are considered best practices for energy efficiency.
2. Interview technical professionals in the electric-power industry.
3. Establish a benchmark for the current state of the ASU buildings and conduct an electrical energy audit.
4. Propose recommendations that are in line with the University's need and budget.
5. Advise ASU on innovative solutions that can be implemented.

Our proposed recommendations will help further increase Astrakhan State University's energy efficiency as well as help establish ASU as one of the leaders in sustainability among universities in Russia.

Background

Energy production accounts for a large portion of Russia's economy. Russia has large, rich deposits of natural gas and petroleum that compose over 70% of Russia's energy production. This facet of the energy industry alone generates 50% of Russia's federal budget (U.S. Energy Information Administration, 2015).

According to reports in 2013, Russia ranks among the top 10 most energy intensive countries in the world (Kahraman, 2014). As many concerns for the nation, economy, and environment have increased, the government has taken an active role in increasing energy efficiency. In 2010, the Ministry of Energy of the Russian Federation enacted policies to decrease electrical intensity by 40% by the year 2030. If this goal is met, CO_2 emissions would be 20% below the 1990 levels. According to IFC, achieving Russia's energy efficiency potential would cost 320 billion USD (U.S. Energy Information Administration, 2015).

Methodologies
Our methodologies were selected as the most efficacious means of assessing the condition of Astrakhan State University and identifying solutions to increase its electrical efficiency. This was accomplished by researching best practices, conducting an electrical energy audit, and recommending solutions.

Our research of printed documents, such as books, articles, government documents and studies, led us to two important discoveries. First, we discovered legislation set by the government, mandating an increase in energy efficiency. Second, we found examples of best energy efficient practices implemented at universities and businesses throughout the world.

We interviewed three professionals in the energy industry. The interview transcripts can be seen in Appendix A. We used our research and Energy Star Portfolio Manager to establish a benchmark for Astrakhan State University.

We began the audit process with the Benchmarking Audit -- analyzing energy usage and cost, primarily using electrical bills. The Walk-Through Audit consisted of our physically walking through each building and analyzing the electrical systems and technologies used. The Standard Audit quantified the energy used by the electrical technologies. A detailed explanation of the audit is located in Appendix B, and the data collected throughout the audit can be viewed in Appendix C.

After the audit was completed, we proposed recommendations to Astrakhan State University. A cost analysis was done on each proposed replacement, and the analysis can be found in Appendices E-G. We also provided ASU with innovative solutions to improve their energy efficiency. As with the other recommendations, we provided a detailed cost analysis of these solutions, which can be found in Appendices H-J.

Recommendations
After careful consideration, we compiled two proposals for Astrakhan State University. The first proposal offered recommendations for easily implemented technologies. The proposal included an analysis of light bulb options, motion sensors, and the Siemens Desigo System.

The second proposal recommended innovative technological solutions for Astrakhan State University. These recommendations included technologies such as piezoelectric ceramic tiles, a vertical garden system, and eco exercise machines. A full list of all recommendations can be viewed in Appendices E-J, which includes a detailed cost analysis and a strengths and weaknesses analysis for each proposed technology.

Introduction: Energy Strategy of Russia

The world has experienced an increase in energy intensity (the amount of energy used per unit of GDP) over the years (IEA, 2015). As a result of this escalated energy consumption, harmful emissions are being released into the environment, destroying our planet. To combat this problem, governments have enacted energy efficiency policies, and research has been done to develop energy-smart technologies. Many countries, including Russia, have continued to set goals to decrease energy intensity (Coyle, 2014).

In 2010, the Ministry of Energy of the Russian Federation modified previous legislation by extending the goal of a national 40% decrease in energy intensity to 2030 (FFTI, 2014). Part of this legislation includes a policy that requires state-funded organizations to decrease their energy consumption by 3% each year over a five-year period (Gusev, 2014).

Astrakhan State University began a project in 2016 to decrease the energy consumption on campus. The University built a new academic building, which incorporated the Siemens' Desigo System; the new building contains light occupancy sensors, energy efficient lamps, and an efficient heating, ventilation and air conditioning (HVAC) system. After completing this building, Astrakhan State University intends to implement new energy efficient technology into the older buildings: two dormitories and an academic building.

The purpose of our project was to conduct an electrical energy audit of three older buildings at Astrakhan State University and propose recommendations regarding ways in which the University could make the buildings more energy efficient. In order to achieve this goal, we developed and followed the following objectives:

1. Research efficient electrical technologies that are considered best practices for energy efficiency.
2. Interview technical professionals in the electric-power industry.
3. Establish a benchmark and conduct an electrical energy audit for the current state of the ASU buildings.
4. Propose recommendations that are in line with the University's need and budget.
5. Advise ASU on innovative solutions that can be implemented.

By increasing its energy efficiency, Astrakhan State University will comply with Russia's goal of decreased energy consumption. If they choose to implement the innovative recommendations, Astrakhan State University will prove to be a leader in sustainability among universities in Russia.

Background: Conserving Energy

As concerns for energy sources and the environment increase, energy efficiency and sustainability are becoming more globally emphasized topics. Over the last few decades, governments have taken on the responsibility of increasing reforms in these fields. Russia has implemented several policies that aim at increasing national energy efficiency, with the most recent goal set for 2030 (Ministry of Energy of the Russian Federation, 2010). While improvements have been made over the past few decades, the country still requires further development. This chapter outlines the various concerns motivating increases in energy efficiency, solutions of related projects completed around the globe, and the benefits that are available for developing energy efficiency.

Energy Conservation: A Worldwide Problem

Historically, energy has been a key factor in the development of many countries. Various sources of energy have been realized and developed, including oil, natural gas, and renewable resources. These advances have spread from the more developed countries to less developed countries, improving living conditions. Between 1971 and 2013, the world has more than doubled its total energy consumption (IEA, 2015).

While rapid expansion of energy usage has been beneficial, governments, companies, and the environment have been burdened by this turn of events. A general trend has illustrated that many countries have experienced increases in energy intensity (the amount of energy used per unit of GDP) (IEA, 2015). In other words, more energy is being consumed than is required. This becomes a threat to the environment as an increase in harmful emissions is produced. Many reports indicate that the most effective way to improve conditions in terms of cost and the environment is improving energy efficiency (Lychuk, 2012; World Energy Council, 2013).

Incentive 1: Cost

Recent studies from the American Council for an Energy Efficient Economy (ACEEE) indicate that improving the energy efficiency of existing technologies results in a significant cost reduction. According to the report, researchers measured the cost of running energy efficiency programs in 20 states from 2009 to 2012. They discovered the average cost to be 2.8 cents per kilowatt-hour (Kiker, 2014). This is significantly less than other common power sources; nuclear and coal have an average cost of approximately 10 cents per kilowatt-hour (Molina, 2014).

Other studies have produced similar results and have identified high potential savings. According to a report published by South-Central Partnership for Energy Efficiency as a Resource (SPEER), the residential sector has the largest potential for savings. It reported that the residential sector in Texas consumed 1400 terawatt hours of electricity in 2009. If major household appliances (refrigerators, washers, dryers, etc.) were replaced with more efficient, modern designs, the state could reduce its consumption by 525 terawatt hours, approximately a 37.5% reduction (Walton, R., 2016). Energy efficient technologies remain a significant source of potential savings.

Incentive 2: Environment
It is an established fact that the use of fossil fuels releases harmful gases that negatively impacts the environment. Burning fossil fuels accounted for 80% of the world's primary energy sources in 2013 and released 30,000 Megatons (Mt) of CO_2 – nearly twice the emissions in 1971 (IEA, 2015). With continued emphasis placed on fossil fuels in energy production, the build-up of greenhouses gases (GHG) in the atmosphere could have irreversible effects on the environment.

Alternative energy sources have been discovered: renewable and nuclear. Many renewables have low impact on the environment and produce no emissions; they are considered to be a promising alternative energy source. However, many forms of renewables are restricted largely due to geographic conditions and high operational costs (IEA, 2015). Nuclear energy produces no greenhouse emissions. However, the fuel rods can pose a high risk to the environment and to life itself. Further measures must be taken to ensure safety of the environment and the future of the globe.

Energy Efficient Practices

With increasing support and dedicated research, energy-smart technologies have become increasingly available and affordable. In government offices, industries, and universities, many projects aimed at increasing energy efficiency have been developed and have demonstrated the benefits of increasing energy efficiency (Enerdata, 2015).

Technion Institute of Technology: Piezoelectric Flooring
Professor Haim Abramovich implemented piezoelectric flooring at the Technion Institute of Technology in Haifa. This floor harvests mechanical energy from roadways, sidewalks and indoor flooring and converts it to electricity. The electricity produced can be used immediately, or it can be stored for future use. In this case, the piezoelectric floor was placed six centimeters (cm) under a road at a distance of 30 cm apart. As vehicles drove over the road, the floor detected changes in weight, motion, temperature and vibration, and converted the mechanical energy to an electrical current. The current was then stored as electrical energy for later use. Assuming 600 vehicles pass this one-kilometer segment of road in one hour, the piezoelectric floor can generate 400 kilowatt-hours (kWh) of electricity -- enough to power 700 homes (Henderson, 2009).

National University of Singapore: Vertical Garden System
The National University of Singapore implemented a vertical garden system on buildings to reduce energy consumption related to heating and cooling. Vertical gardens consist of plants grown in trays that are then installed on the outside of buildings. These systems help to insulate the building while offering an aesthetic appeal. The National University of Singapore found that indoor areas where the vertical garden system had been installed stayed 7 degrees cooler than those without it. This resulted in a decrease in electricity used to power the air conditioning system (Suntory, 2015).

Cadbury House in Congresbury, England: Eco Machine
A gym in England is being called the world's first self powering gym after installing 42 eco machines -- these machines are self-powering exercise equipment. Once a person begins using the equipment, it generates enough electricity to power the machine, including the screen on the

machine. Any excess electricity produced is stored in a holding cell, or dynamo, and then is fed back into the energy supply for the building. On average, these machines will feed 100 watts of energy back into the energy supply for the building every hour. This technology has reduced the energy consumption of the gym by 30% (Edmonds, 2013).

Russia's Energy Conservation

As concerns for the nation and the economy have increased, the Russian Federal government has taken an active role in increasing energy efficiency. In 2008, Russian President Dmitry Medvedev determined energy efficiency to be a top priority of the nation and launched several policies with the goal of decreasing the country's energy intensity by 40% by the year 2020. In 2010, the Ministry of Energy of the Russian Federation redefined the policies and modified the target year to 2030 (Ministry of Energy of the Russian Federation, 2010).

The legislation establishes energy consumption guidelines and demands compliance to these regulations. The main goal of the guidelines is to implement energy-saving or low-energy intensive technologies, which will decrease Russia's reliance on the energy sector of the economy. The guidelines establish the required decrease in energy consumption for specific sectors, and are paraphrased as follows (Ministry of Energy of the Russian Federation, 2010):

- The concept of fuel and energy in relation to gross domestic product and to exports should decrease by a factor of at least 1.7.
- Energy exports should decrease by a factor of at least three.
- The total investments in fuel and energy should decrease by a factor greater than two.
- Total energy intensity should decrease by a factor greater than two, and electricity intensity should decrease by a factor of at least 1.6.

Part of this legislation also mandates state-funded organizations to decrease their energy consumption by 3% each year over the course of five years. The policy requires a 3% decrease in energy consumption annually, regardless of any previous decrease. For example, if an organization decreases its energy consumption by 15% in the first year, it is still required to decrease energy consumption by at least 3% for each subsequent year; the decrease percentage does not "roll over" (Gusev, 2014).

Astrakhan State University's Progress

Astrakhan State University is a state-funded university located on the Volga River in southern Russia. It is subjected to temperatures as high as forty-two degrees Celsius (107.6 degrees Fahrenheit) in the summer and as low as negative twenty-six degrees Celsius (-14.8 degrees Fahrenheit) in the winter (Weather Almanac for URWA, 2010). The University spans many campuses throughout the city, but the main campus contains four buildings: two dormitories (Hostel 1 and Hostel 3), one academic building (Academic Building 1) and the new building. As it is state-funded, the University must decrease its energy consumption by a minimum of 3% annually.

The Older Buildings: Hostel 1, Hostel 3 and Academic Building 1

The three older buildings on the main campus of Astrakhan State University are outdated; Hostel 1 and Hostel 3 were constructed in 1932. As a result, the lighting systems are outdated and inefficient. Additionally, the internal temperature of the buildings is controlled by window air conditioning units and portable heaters, which both require a significant amount of electrical energy. Personnel practices, such as running electrical appliances when they are not being utilized, leads to electrical energy inefficiency.

The lighting systems implemented in the older buildings of ASU vary throughout the buildings; there is no consistency across the campus. The buildings incorporate a traditional maintenance system, making it difficult to identify and replace worn out bulbs when necessary.

The older buildings also incorporate an outdated heating and cooling system; window air conditioning units and portable electric heaters are used to regulate the temperature in each room. These technologies drain a significant amount of electricity, and are often used when they are not necessary.

Astrakhan State University personnel are not utilizing proper, energy efficient behavior. Lights and air conditioning units are left on in unoccupied rooms, wasting electricity. ASU has attempted to conserve the wasted energy by posting signs like the one in Figure 1, telling students and faculty to turn off lights as they exit a room. However, according to current ASU students, these signs are routinely ignored.

Figure 1. A sign posted next to the doors in the older buildings of ASU. It tells students and faculty to shut the lights off when they leave the room to conserve energy.

The New Building

The new building on Astrakhan State University was built in 2016. It is nine stories tall and is attached to the main academic building on campus. The new building incorporates the Siemens Desigo V5 System, a building automation system that operates the lighting and ventilation systems at optimal efficiency.

Part of this system includes motion sensors for the lighting, which turns on lights in a room when there is movement and turns off lights when there has been no movement for an extended period of time. Since this is an issue in the older buildings according to ASU students, the motion sensors will prove to be an energy saving technology for the new building. Additionally, this system includes an alert that notifies the controller when light bulbs are worn out and not operating at optimal efficiency. This allows the operators to replace light bulbs immediately, increasing the energy efficiency of the building.

The system also includes a modern ventilation system. It incorporates the centralized control and efficiencies of a central ventilation system with the flexibility to control the climate of an individual room. The control system also ensures the temperature regulation is operating at the highest efficiency.

Figure 2 offers a visual on the juxtaposition of the new building relative to the three older buildings. The new building is modern and efficient, while the older buildings are outdated and inefficient. As a result, the University is hoping to update the older buildings and decrease the energy consumption in accordance with Federal Regulations.

Figure 2.a. Hostel 1 at ASU.

Figure 2.b. Hostel 3 at ASU.

Figure 2.c. Academic Building 1 at ASU.

Figure 2.d. The new building at ASU.

Methodologies: Identifying Inefficiencies and Solutions

Our goal was to conduct an electrical energy audit of three older buildings at Astrakhan State University: one academic building and two dormitory buildings. After conducting the energy audit, we proposed recommendations regarding ways in which the University could make the buildings more energy efficient. In order to achieve this goal, we developed and followed the following objectives:

1. Research efficient electrical technologies that are considered best practices for energy efficiency.
2. Interview technical professionals in the electric-power industry.
3. Establish a benchmark and conduct an electrical energy audit for the current state of the ASU buildings.
4. Propose recommendations that are in line with the University's need and budget.
5. Advise ASU on innovative solutions that can be implemented.

Initially, our team researched other universities and their strategies for developing energy efficient campuses. These best practices served as a guide to the available options for Astrakhan State University. The most effective energy smart campus initiatives had been built into a new building, whereas our project at Astrakhan State University would be viewed as a retrofit project. Additional research had to be conducted to evaluate if an effective comparison could be made with ASU.

Once we established the current best energy efficient practices, we had to establish the current state of Astrakhan State University. To do this, we created a benchmark using Energy Star Portfolio Manager, a website that allows the user to create a professional benchmark to manage the energy usage for any building. We entered data specific to ASU and were presented with analysis of the energy consumption.

As a continuation of our research, we interviewed three professionals in the field of energy:

- Elizabeth Tomaszewski -- Associate Director of Sustainability at WPI
- John Orr -- Director and Professor of Office of Sustainability at WPI
- David Litalien -- Licensed Electrician

Each interviewee was asked a series of questions to assess his or her familiarity with energy audits. The interview then developed into a discussion of the timing, documents needed, and basic steps of performing an energy audit. The full list of interview questions can be viewed in Appendix A, with transcripts of each interview found in Appendices A.1-A.3.

We were able to perform the first step in the energy audit before arriving in Astrakhan. This was a Type 0, or Benchmarking Audit. The Benchmarking Audit consisted of analyzing energy usage and cost, primarily through data collection using electricity bills. We completed this section of the audit in Moscow with the help of the Russian students at ASU. The Benchmarking Audit process involved us inspecting electric bills, blueprints and other documents from the buildings. From this, we were able to derive abstract conclusions regarding the energy efficiency of the University.

Upon arriving at Astrakhan State University, we performed a Type 1 and Type 2 energy audit on the three buildings: a Walk-Through Audit and Standard Audit, respectively. The Walk-Through

Audit was the second step in our energy audit process. It consisted of us physically walking through each building and analyzing the implementation of the lighting systems currently used. For example, during our Walk-Through Audit, we discovered lights that were left on in unoccupied areas. From this observation, a possible recommendation would be to use a motion sensor.

The Standard Audit was the final step of our energy audit process. The Standard Audit relied on the Walk-Through Audit and quantified the energy used by the electrical technologies implemented. The detailed steps of the entire energy audit process are explained in Appendix C.

We created a detailed spreadsheet to record specific data about each room during our audit, which can be seen in Figure 3. Using this, we were then able to compare the efficiency of the rooms. The completed documents for each building can be found in Appendix D. We used the data collected during the Standard Audit to analyze the technologies and perform calculations regarding the energy usage of each room.

Individual Room Data												
Building:								**Floor:**				
	Lighting				**Computers**			**Other Appliances**				
Room Number	Type	Count	Watt	Hours/Day	Count	Brand	Hours/Day	Type	Description /Model #	Count	Watt	Hours/Day

Figure 3. The headings to describe the data collected for individual rooms during the energy audit.

Using the information gathered during the audit and our previous research, we developed a series of recommendations regarding ways in which Astrakhan State University could increase its energy efficiency. We relied on Federal Regulations to illustrate the need for upgraded technology. For each technology we recommended, we provided the University with two analyses: strengths-weaknesses and cost, which can be viewed in Appendices E-G, based on each technology.

We also provided ASU with innovative solutions to improve its energy efficiency. This was done based on research regarding new energy efficient and sustainable practices. As with the other recommendations, we provided detailed strengths-weaknesses and cost analyses of these solutions, which can be viewed in Appendices H-J, based on each solution.

The proposed recommendations we drafted in collaboration with the team of students from Astrakhan State University helped to further establish the University in energy sustainability. If implemented, the solutions will also help to establish ASU as one of the leaders in sustainability among universities in Russia.

Results and Findings: Analyzing Possible Energy Saving Solutions

The results of our benchmark study for the Astrakhan State University buildings proved that ASU was energy efficient when compared with universities in the United States of America. Through our energy audit, we were able to collect data that was used to analyze the electrical usage of the buildings. From this, we found technologies that could be implemented into the buildings to improve energy efficiency. Our analysis and findings are presented here.

Benchmark

The Energy Star Portfolio Manager was used to establish a benchmark of each of the three buildings we examined at Astrakhan State University. The software used data gathered from each building and compared the buildings to those of similar size in the United States of America.

We were able to input information including gross floor area, percentage of building that is heated and cooled, number of rooms, and information collected from the energy meter bills for a year. The software used this information to find buildings of similar size in the United States of America and compare the ASU buildings. From the comparison, the Portfolio Manager developed a score for the ASU buildings ranging from 0 to 100 -- a number above 75 is energy efficient, a number from 50-75 is average, and a number below 50 is inefficient.

After analyzing the data for the three buildings, the Energy Star Portfolio Manager provided us with a score for each of the buildings: Hostel 1 had a score of 98, Hostel 3 had a score of 100, and Academic Building 1 had a score of 100.

At first glance, it appears that the three ASU buildings are extremely energy efficient based on the scores. However, we know that the buildings currently incorporate inefficient electrical technologies. For example, LPO 4x18 light bulbs are used in the buildings. These light bulbs have a power rating of 80W, which means the bulbs are very inefficient. Replacing LPO 4x18 light bulbs with Armstrong light bulbs, which have a power rating of 27W, would significantly increase the efficiency of the buildings.

As illustrated in Figure 4, the buildings used to compare to the ASU buildings consume significantly more energy than the ASU buildings. This is a result of a greater usage of technology in the United States. The buildings at ASU do not contain electrical technologies such as vending machines, clothes dryers, elevators, etc., which are common in the buildings in the US. Because the buildings at Astrakhan State University do not incorporate energy intensive technologies, they appear to be more energy efficient, even though the technologies that are incorporated in the buildings are not energy efficient.

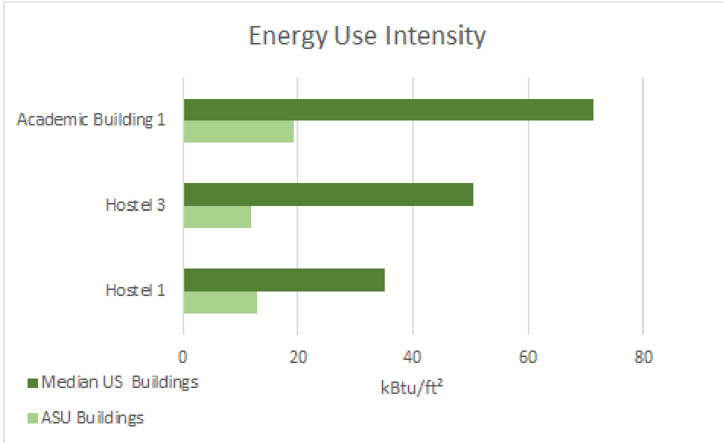

Figure 4. From top to bottom: Energy Use Intensity of a Median Academic Building in the United States vs. Academic Building 1, Energy Use Intensity of a Median Dormitory in the United States vs. Hostel 3, and Energy Use Intensity of a Median Dormitory in the United States vs. Hostel 1.

Additionally, Astrakhan State University is required by Federal Law to decrease its energy consumption by a minimum of 3% every year. Although the buildings may already appear to be very efficient and produce scores of 98, 100 and 100, the University must still improve their energy efficiency annually.

Electrical Energy Audit

The energy audit we conducted helped us to create two main analyses. The first was an analysis of the energy consumption of each building. The second used the current electrical cost to analyze the costs for each proposed solution.

Using the reports created during the audit, the energy consumption from each type of electrical appliance was calculated. The full calculation sheets for each building can be found in Appendices D.1, D.2 and D.3. This calculation allowed us to create a pie chart, seen in Figure 5, which illustrates the consumption of electricity of each electrical technology.

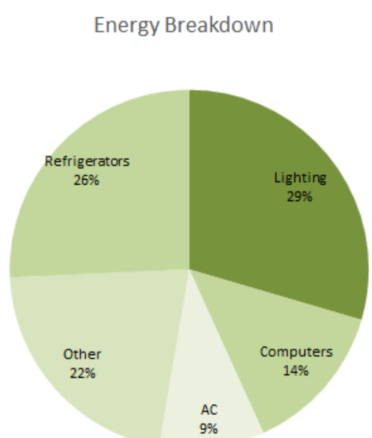

Figure 5. A pie chart illustrating the electrical usage for the three ASU buildings.

As seen in the chart, lighting is the largest consumer of electricity in the three buildings. As a result, lighting was the main focus for the recommendations offered to the University because it could offer the largest decrease in energy consumption.

Recommendations

The recommendations compiled for Astrakhan State University consisted of three major areas of improvement -- installing efficient bulbs, motion sensors and the Siemens Desigo building automation system. A cost analysis and efficiency analysis were conducted on each of the proposed solutions.

Efficient Bulbs
The energy audit revealed that the lighting system accounts for 29% of the total energy consumption of the three buildings. Because of this, simply replacing inefficient light bulbs is cheaper and easier than replacing an inefficient HVAC system. Modern LED bulbs are up to two times more efficient than older bulbs, and the light cycle is longer as well.

However, simply replacing the light bulbs may not be the best solution. Bad manufacturing quality could extend the payback period, and lighting fixtures may have to be changed as well. Additionally, many people dispose of old light bulbs improperly, which contributes to pollution.

Astrakhan State University Chief Engineer of Maintenance Services, Sergey Grigoryevich Muravyov, provided us with his recommendations for bulb replacement. Currently, the University uses six types of light bulbs: LPO 4x18, LPO 2x18, NPP 1x16, E27 1x18, LPO 2x36, and Chandeliers 1x50. The engineer proposed that each of the current types of light bulb be replaced with a more energy efficient model: Armstrong, LPO 2x9, DBP/Medusa, E27, DPO 2x18, and Foton G4, respectively. Table 1 analyzes the cost and efficiency of these replacements.

Light Bulb (Current and Replacement)	Wattage (W)	Efficiency (lm/w)	Price per Unit (RUB)	Replacement Cost (RUB)
LPO 4x18	80			
27 Armstrong	27	118	1100	150
LPO 2x18	40			
DPO 2x9	20	70	900	120
LPO 2x36	80			
DPO 2x18	40	88	1100	150
LPO 4x18	80			
27 Armstrong	27	118	1100	150
NPP 1x60	60			
DBP 7w	7	72.85	450	25
E27 1x18	18			
E27 1x7	7	71.4	180	25
E27 1x40	40			
E27 1x7	7	71.4	180	25
Chandeliers 1x12	12			
G4 LED	3	100	150	25

Table 1. A comparison of the current lighting systems used in the ASU buildings and the proposed changes.

Using the consumption data collected during the audit, the projected energy consumption and cost of replacing the light bulbs for each building was calculated. A detailed calculation can be found in Appendix E.

Figure 6 displays a bar graph that analyzes the difference in energy consumption by replacing the light bulbs according to the recommendations provided by the engineer. Using the recommended replacements, we can display the energy consumption before and after the replacement.

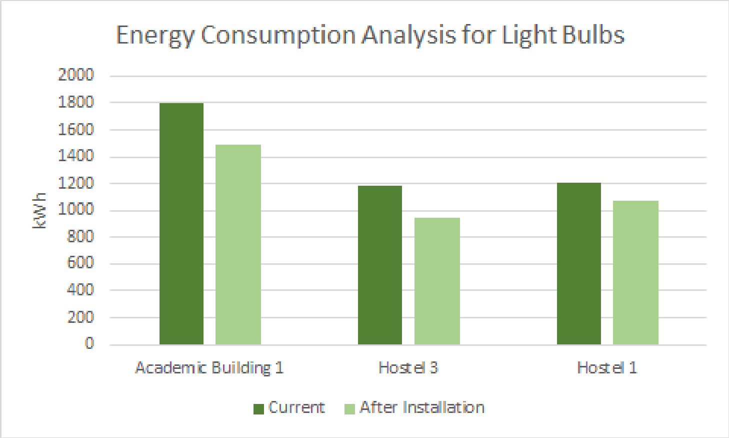

Figure 6. A graph comparing the energy consumption of the different buildings. The dark green bar indicates the energy consumed before replacing the light bulbs. The light green bar indicates the energy consumed after replacing the light bulbs. This replacement is projected to improve the total energy consumption by 16%. The detailed calculation can be viewed in Appendix E.

From the energy consumption data, the projected costs for replacement in each building was calculated. The result was then summarized to create a cost analysis graph. Calculations can be found in Appendix E, and Figure 7 illustrates the breakeven date for the replacement.

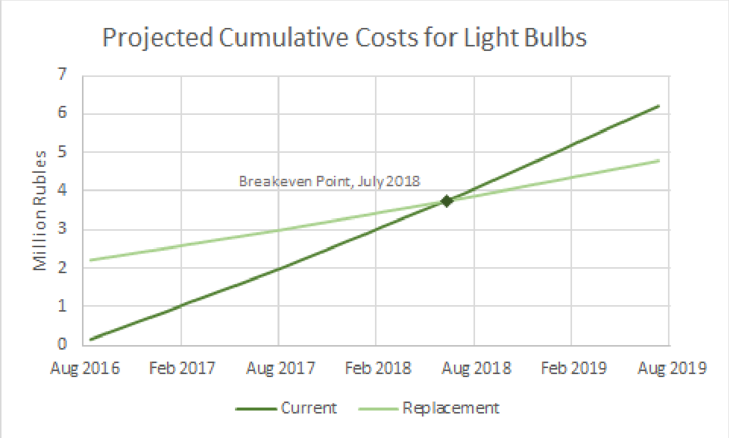

Figure 7. A cost analysis graph illustrating the cumulative cost of energy consumption before and after replacing the light bulbs over the next three years for all three buildings. The dark green line indicates the cumulative expenditure on the current lighting system over the course of three years. The light green line shows the cumulative projected expenditure on the lighting system if the bulbs are replaced. Initially the projected expenditure is higher as replacing the bulbs entails a one time replacement fee. In June 2018, the replacement costs will be paid back.

Motion Sensors

Motion sensors turn on lights in an area when motion is detected, and lights are then turned off after a set amount of time without any detected movement. Turning the lights off when no movement is detected saves an immense amount of energy. However, the sensors are not perfect, and occasionally the sensor might not detect movement to turn on lights. Additionally, if a person is still for a while, the lights may turn off.

To calculate the energy savings, it was projected that a total of 121 motion sensors would be installed in the three buildings. It was not practical to install motion sensors in each room of each building, so we proposed the sensors be installed in lobbies, corridors, bathrooms, laundry rooms, etc. A detailed breakdown of the installation criteria is located in the Appendix F.1.

It is estimated that there will be a 13% savings in lighting energy in the areas where motion sensors were installed (Carnegie Mellon University, 2013). Using this estimation, the total energy savings of the three buildings was calculated to be 1.23%. A detailed breakdown of the calculation can be found in Appendix F. Energy consumption and savings for the installation of motion sensors can be seen in Figure 8.

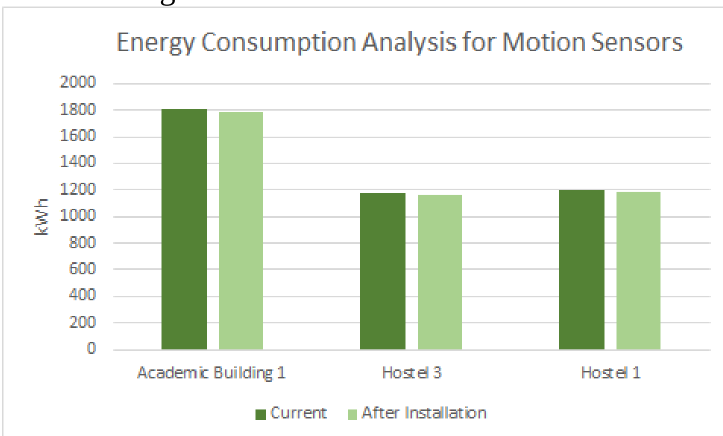

Figure 8. A graph comparing the energy consumption of the buildings. The dark green bar indicates the energy consumed before installing motion sensors. The light green bar indicates the energy consumed after installing motion sensors. This replacement is projected to improve the total energy consumption by 1.3%. The detailed calculation can be viewed in Appendix F.

It was estimated that a motion sensor would cost 1874 Rubles, or 30 USD (Zhao, 2013). Using the projected energy consumption, the expenditure for the next three years was projected. A cost analysis graph was created to compare the effect of installing motion sensors, which can be seen in Figure 9.

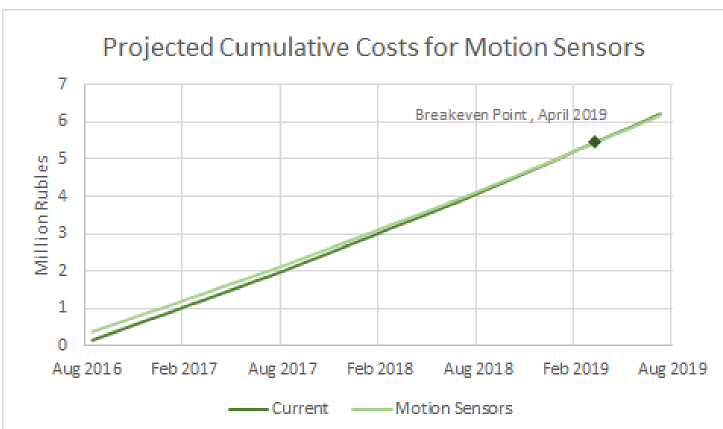

Figure 9. A cost analysis graph analyzing the cumulative cost of energy consumption before and after installing motion sensors for all three buildings. The dark green line indicates the cumulative expenditure on the current lighting system over the course of three years. The light green line shows the cumulative projected expenditure on the lighting system if motion sensors are installed. Initially the projected expenditure is higher as the installation requires a one-time fee. In April 2019, the costs will be paid back.

Siemens Desigo Building Automation System

The Siemens Desigo Building Automation System is the system implemented in the new academic building at Astrakhan State University. It controls the lighting and HVAC systems in a building and optimizes the energy consumption and productivity. Running these systems at top efficiency saves massive amounts of energy and extends the life of the equipment. Implementing the same system into the older buildings of ASU would be ideal because the manager is already familiar with the system, and there would be one master control system for all of the buildings. However, once the system is installed, the company will generally "lock the buyer into" a long-term service contract, which might not always be ideal.

Additionally, the Siemens System is not suitable for small and simple scale buildings, like the three older buildings under examination. For the calculation purposes, it was estimated that installing the building automation system in small- and medium-size commercial building would save 15% of lighting energy consumed (Brambley, 2013). A graph illustrating energy consumption savings can be seen in Figure 10.

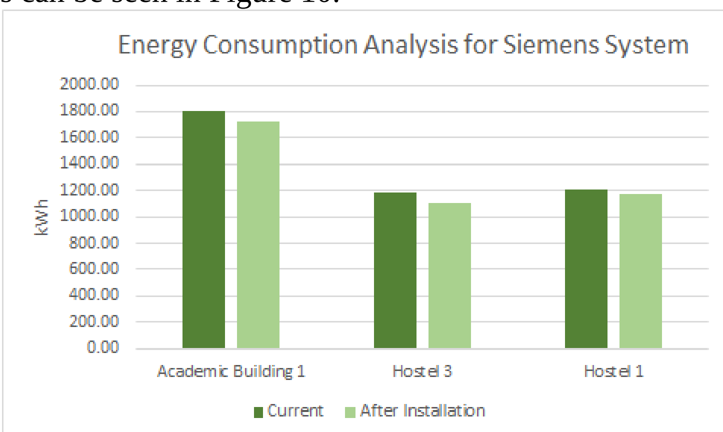

Figure 10. A graph comparing the energy consumption of the different buildings. The dark green bar indicates the energy consumed before installing the Siemens Desigo System. The light green bar indicates the energy consumed after installing the Siemens Desigo System. This replacement is estimated to improve the total energy consumption by 4.4% (Brambey, 2013). The detailed calculation can be seen in Appendix G.

Additionally, the software and hardware for this system is also very expensive to implement. The cost of installing the building automation system in the three Astrakhan buildings was expected to be 1 562 023 Rubles or 25,000 USD (Brambley, 2013). Using this information, the expenditure for the next three years with and without installing Siemens system was projected. Figure 11 illustrates a cost analysis graph comparing the effect of installing building automation system.

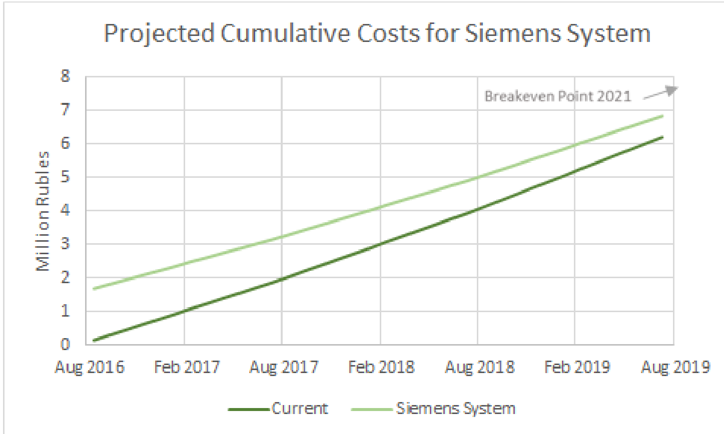

Figure 11. A cost analysis graph analyzing the cumulative cost of energy consumption before and after installing the Siemens Desigo System for all three buildings. The dark green line indicates the cumulative expenditure on the current lighting system over the course of three years. The light green line shows the cumulative projected expenditure on the lighting system if the Siemens System is installed. Over the next three years, this system will not be paid back.

Innovative Technologies

In addition to short-term recommendations to increase the energy efficiency of Astrakhan State University, we also analyzed more innovative technologies that ASU could implement. Through our research, we found three possible innovative technologies from which ASU could benefit: Piezoelectric flooring, vertical garden systems and eco exercise machines. A cost analysis and efficiency analysis were conducted on each of the proposed solutions.

Piezoelectric Flooring

Piezoelectric flooring is a polymer sheet that can be installed underneath normal flooring. It uses the force exerted on the flooring to generate electricity. The electricity produced can either be used immediately or stored in a battery for later use. Unlike with a solar panel, manufacturing piezoelectric flooring does not pollute the environment. Additionally, this type of flooring can withstand harsh outdoor weather conditions, including rain and snow. However, it is not as durable as wooden or ceramic flooring; piezoelectric flooring can only last for five years (Henderson, 2009).

Figure 12. Piezoelectric flooring installed in a nightclub (Mestanza, 2014).

Piezoelectric flooring is a newer technology, and is therefore expensive when compared with traditional wooden flooring. The price of the one square foot of piezoelectric floor is estimated to be 4 686 Rubles or 75 USD (Williston, 2013). It was projected that around twelve square feet of piezoelectric flooring would be installed in the campus entrance. The total cost of installation was calculated to be 56 232 Rubles. The power generated by each step on the tile is expected to be 5 Watts (Pavegen, 2016). The total expected energy generated per day was expected to be 100 watt-hours (Wh). This electricity generated could charge 20 cellphones per day. However, with the cost of installation being so high, the energy generated by the flooring does not pay back the installation cost. A detailed summary of the calculation could be seen in Appendix H.

Vertical Garden System

A vertical garden system is simply any plant that is grown along the outside wall of a building. Not only does a system like this appeal aesthetically, but it also helps to regulate the internal temperature of the building. For example, the National University of Singapore found that the internal temperature of a building with the vertical garden system was seven degrees cooler than a building without it. The system is also very efficient -- artificial soil is used so mud does not fall from the building, and it requires less water than a normal, horizontal garden. The cost of a typical vertical garden system ranges from 95 to 165 USD per square foot (Architek, 2016).

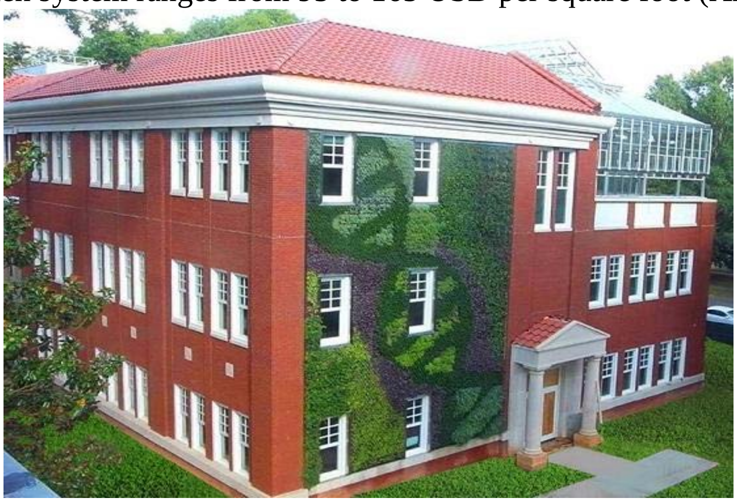

Figure 13. Vertical garden installed at Queens University of Charlotte features a double-helix design (Heffernan, 2013).

However, due to its orientation, the vertical garden system is more complicated to maintain than a normal garden. It is also more expensive to develop and build than a normal garden.

There are three structures for a vertical garden system: panel systems, tray systems, and freestanding systems. A panel system has plants pre-grown into plates that are then attached to the external or internal wall of a building. A tray system is similar to a panel system, but can only be attached to an internal wall of a building. A freestanding wall does not incorporate a plate system and is commonly used inside of a building.

Two types of watering systems can be used for a vertical garden: recirculating irrigation systems and non-circulating irrigation systems. A recirculating irrigation system has a dripping system from above. Water flows down the garden with the help of gravity and is collected in a tank at the bottom, where it is circulated through the dripping system again. The non-circulating irrigation system is similar, except it does not collect the water at the bottom. This is commonly used for outdoor systems.

Looking at the building plans, it was projected that the vertical garden system would be installed on the South and the West side of the Academic Building 1. The cost of installing and managing the garden was estimated. The vertical garden system is expected reduce the energy spent on heating and cooling by 23% (Lof, 2008).

Air conditioning accounts for 9% of the total electricity consumption of the Academic Building 1. Using this information, a cost analysis was done to compare the expenditure on the current cooling system to the projected expenditure if the vertical garden system was installed. The projected cost of installing the system was calculated to be 113 million Rubles. The total electrical energy savings of the Academic Building 1 was calculated to be 2.25%. Although this system saves energy, implementing the vertical garden system is expensive and does not pay back the installation costs. A detailed summary of the calculation can be found in the Appendix I.

Eco Machine

Eco machines are exercise equipment that generate electricity when used. These machines use the mechanical force applied by a user and converts it into electrical energy. Traditional exercise equipment can be replaced by eco machines in the University's gym to serve the user's need in addition to contributing to energy production. These machines can produce up to 100 watts an hour by an average user (Atkin, 2013).

Figure 14. Eco machines installed at a gym in Manhattan, New York. (Atkin, 2013).

However, these machines are currently more expensive than traditional machines. Additionally, the power generated from these machines is not significant.

The cost of each machine was estimated to be around 1.14 million Rubles (Atkin, 2013). It was estimated that the University would install five eco machines in the gym, and each of those machines would be used for seven hours per day. Using this data, a cost analysis was done to compare the cost of installing the machines and the energy produced by these machines. It was calculated that a total of 3.5 kWh energy could be generated per day from these machines. A detailed summary of the calculation can be found in Appendix J. The analysis proved that the electricity generated by these machines is not a worthwhile investment; the installation cost would not be paid back in a three-year period. Although the machine would not pay back the installation fee, one machine could generate more electricity than two 200-watt solar panels in one day (Rhymebus, 2013).

Recommendations and Conclusion: Change the Bulbs

After an extensive examination of the three older buildings at Astrakhan State University, we focused our research on three energy efficient technologies that would be easily implemented into the buildings and three innovative technologies. An analysis of the six technologies proved that changing the light bulbs is the easiest, fastest and most effective solution.

Our Recommendations

Solutions	Initial Cost	Payback Period	Energy Savings/Production
Efficient Bulbs	2 147 025 rubles	2 years	16.44% total savings
Motion Sensors	226 754 rubles	2.5 years	1.23% total savings
Siemens System	1 562 023 rubles	5 years	4.43% total savings
Piezoelectric Floor	56 232 rubles	Not in the next 5 years	0.1 kWh per day production
Vertical Garden	113 163 970 rubles	Not in the next 5 years	2.25% total savings on Academic Building 1
Eco Machine	5 680 023 rubles	Not in the next 5 years	3.5 kWh per day production

Table 2. Comparison of all technologies.

Efficient Bulbs
We recommend that Astrakhan State University change all of the light bulbs in each of the three buildings based on the chief engineer's suggestions. Although the light bulbs have an initial installation cost, we have calculated that it will be paid off within the next two years. Additionally, it will improve the lighting efficiency of the campus by 56% and overall electricity efficiency by 16%.

Motion Sensors
We recommend that Astrakhan State University install motion sensors into the lobbies, hallways, restrooms and stairways of the three buildings. Motion sensors are a cost effective solution; the initial setup is not expensive compared to other solutions, and the payback period is two and a half year. Motion sensors are not proven to increase energy efficiency significantly, but they will still help the university comply with annual energy consumption regulations.

Siemens Desigo Building Automation System
We do not recommend that Astrakhan State University install the Siemens Desigo Building Automation System into the older campus buildings. The cost of implementing the system is high compared to other similar solutions. The three older buildings we analyzed at ASU are not

as technologically advanced as the new building. Where the new building uses the system to control both lighting and HVAC systems, the older buildings would only use the system to control lighting. Additionally, the cost of the system cannot be paid back within 3 years. As a result, the Siemens Desigo Building Automation System would not prove to be a worthwhile investment.

Piezoelectric Flooring

We recommend that Astrakhan State University install 12 square feet piezoelectric floor tiles into the entryways of the three buildings. Piezoelectric flooring is a newer and expensive technology, and the price of the system has been decreasing exponentially in the past years. Rather than increasing the efficiency, this is an innovative technology that can produce electricity. We have proven that it would be difficult to pay back the installation cost of the flooring. We recommend that Astrakhan State University revisit this technology in two years to install additional piezoelectric floor tiles; this would allow the price of the flooring to decrease, therefore offering a more attractive payback period.

Vertical Garden System

We do not recommend that Astrakhan State University install a vertical garden system in the three buildings. The vertical garden system helps to increase the efficiency of the heating and cooling systems in the buildings. However, the current air conditioning system does not account for a significant percentage of electrical consumption. The total savings produced through this system would not be worthwhile when considering the initial cost of the technology. Although this is an interesting solution for energy efficiency, our team does not think it will offer significant energy savings for the University at this time.

Eco Machine

We do not recommend that Astrakhan State University install eco machines into their gym solely for the purpose of generating energy. The cost analysis proved that the installation cost for these machines cannot be paid back in the next three years. Additionally, the electrical energy generated by the machines does not significantly increase the energy efficiency of the University. However, if there comes a time when Astrakhan State University is purchasing new gym equipment, we would recommend that they purchase these machines.

Conclusion

After extensive analysis, we propose that Astrakhan State University change the lighting technologies in accordance to the chief engineer's suggestions. This is the fastest, most effective way to decrease the energy consumption of the University and would result in the most rapid payback period. We would also recommend that motion sensors be installed in the lobbies, hallways and stairways of the three buildings. Motion sensors are easily implemented and inexpensive, and would also decrease the energy consumption of the buildings.

If Astrakhan State University is willing to invest the money, we would also recommend that the piezoelectric floor be installed in the doorways of the buildings. Although it is currently expensive and would offer a longer payback period, the piezoelectric floor would also decrease the amount of external energy required in the buildings. If three tiles are placed in the doorways to the buildings, it would reduce energy consumption while also helping to establish Astrakhan State University as a leader in energy efficiency among universities in Russia.

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Appendix A. – Interview Questionnaire

<u>For Interviewee's with Energy Audit Experience</u>

1) What has your experience been with conducting energy audits?

2) What type of audit would be the best suitable for three academic buildings over a period of 1-2 weeks of data collection?

a) How long does it typically take?

b) Are there any tools required to complete the audit?

3) In your experience, what are the most important steps to conduct an energy audit?

4) What precautions should be taken, if any?

5) Is there any specific type of audit/step that we should account for since our focus will be on lighting equipment on the buildings?

Appendix A.1. – David Litalien

Michael: What has your experience been with conducting energy audits?

David: For the past 10 years, my experience with conducting the audits has been on a call-by-call basis where industry or residential has been looking to save money on electrical bills. What I do is I take the call and we go to the business or residence and see exactly what they have for what they are using for energy. What we normally do is we take the low fruit first, which would be the lighting -- get them into the mode of seeing what it is like to receive rebates, to get different types of lighting -- that's the easy part of the job. Then what can happen in the industry is that we can start motors on the compressors and bigger items on the machinery and everything else. So that being said, that it what my business is related to the energy audit -- to go in, gather all the information that is needed, and required by the individual power company -- each one has different formats -- we find out what they pay for the energy, put it into a mathematical process and we come out with a number. Normally what happens is there's a bottom line number to do the job, and then through the process of finding out what energy they use, how much they want to save, how much they pay per kWh, we give a rebate -- each individual power company is different. So let's say that the job is $1000, the power company might pay half… so the customer will pay $500 for an $1000 job. And there's the savings...per month so they get their $500 back.

Michael: What type of audit, as described as follows, would be the best suited for three academic buildings for a period of 1-2 weeks of data collection? We have an attached document with the three different types -- there's a benchmarking audit [explains], a walk-through audit [explains], and a standard audit [explains] and a computer simulation [explains].

David: The first thing you would want to do is go through and see what the highest unit of energy use would be… The first thing you would do is look at the lighting...to get a flavor of the audit… Step number one is "here is what your lighting consumption is" and you show the wattage… And then what we'll do is go into the HVAC, which is one of the big loads of the building. And we'll say this is what it is costing you in the summer, in the winter, etc.… We can find ways of replacing [the biggest draws of energy] -- that's the high end of the job. That is where the biggest cost and the biggest savings is… And then step two is we take all that information and we give it to the power company. The power company looks at what they've been using for energy for the past couple months, they look at our proposal for savings. Then they will approve the lower fruit, like the lighting… And then they'll start looking at the higher end changes, which is complicated… They have engineers that will come in and look at the equipment and examine our proposal… After all that has been approved, the next step is to actually do the work. We would go in and do the lighting change… Most companies look for one-year payback… We have to work real hard to put the right equipment in, whether that be fluorescent, LED, whatever we can put in for materials that will not jeopardize what they have now. We can go better, but we can't go worse.

Michael: One thing you mentioned -- how do they typically look back at their usage?

David: As far as gathering what they have right now, the process of gathering that is looking at the electric bill… On your energy bill it shows your consumption… I have to go in and show the energy company this, and show them what I'm proposing. There has to be a difference in what they are actually using and what they are going to save… That's how the whole process works -- proving what they are using now and proving what you are going to do for a change, so they are going to use less energy without jeopardizing their business.

Michael: How long does it typically take to gather the information?

David: That all depends on where you are going and the amount of work the individual is looking at doing… I have to look at all the lighting in all the rooms. If its a fluorescent, I have to look at the ballast, I have to look at the wattage, I have to see what size. I'll gather all that from the rooms, and then I'll go into the common areas like the hallways, and then I'll look at the exterior lighting. So an office building with seven offices, common areas and exterior lighting would probably take about 4-5 hours… Then the paperwork end of it would probably be about another eight-hour workday to put everything together to present to the power company.

Michael: Are there any tools required to complete the audit?

David: There is tools required. If we go in with our lighting we have meters and we're going to measure the amount of light that they have now, and that's what our standard will be. We will have to either go above the standard or stay there, we cannot go below it. And the customer will tell us if they want to increase it or if they want it to stay the same… The tools that we use are light meters.

Michael: Can you tell me a little bit more about the light meters? Maybe what they measure?

David: What they measure is in lumen, there are different names for it. What that is starts at what the sunlight would be at that meter and starts to stray back from that. The highest reading is what the sunlight would measure and then it decreases from there… Every application is different. It basically finds the actual illumination from each fixture.

Michael: In your experience, what are the most important steps to conduct an energy audit?

David: The most important step is being accurate. When you actually go in to conduct the audit, you don't just guess, you really have to look into it… One of the other important things is the actual hours of usage.

Michael: What precautions should be taken, if any?

David: There's a lot of precautions that can harm. Nowadays, the industry is very strict about going into electrical panels, going into electrical fixtures, going into live parts. If you're going to be going into live parts and the company has conducted what is called an arc-fault energy audit, it will tell you on that item what you need to wear in terms of clothing, distances you need to stay away from it…

Michael: Is there a specific type of audit or steps we should account for since our focus will be on the lighting of the buildings?

David: The first step is to ask the customer for his electrical bill for the past two months -- the past three months would be better. Once we have that, then we can look into that particular building. We can gather wattages of all our existing lighting. The next step is what are we going to replace that with? What is the best way to replace that -- with different fixtures, bulb, lamps?... We figure out the cheapest cost of replacement without jeopardizing any lighting issues for the customer… Then put that together and run a spreadsheet to show the existing draw is, what the saving is, the total cost of the job, the rebate on the job, and how quick the payoff is… We give that spreadsheet to the power company and they will either say yay or nay… If they approve it, then you go in and do the job. The power company will then come in and look at the job, they'll approve the project and cut a check… After that's all complete, it is important to make sure the disposal is done properly, and there's a cost associated with that, which should have been put into the estimated cost of the job.

Michael: You had mentioned reading the bills -- does it break down and itemize the systems?

David: It doesn't. It is very important to get an accurate count of what the lighting is going to be. They'll base the rebate number on your calculates really. You really want to try to do it right to get the biggest bang for the customer's buck.

Michael: Good, I think that about does it, thank you for your time.

Appendix A.2 – John Orr

- Atwater Kent has had an energy audit earlier and the type of equipment were changed after the audit. It seems like AK needs another energy audit.
- We should look at an IQP on Gordon library a couple of years back: the IQP found good economic payback but it wasn't implemented. This is because when the library was built, asbestos was added in the walls, which is now proved to be carcinogenic, and so breaking building walls wasn't considered a good idea to expose that material.
- The step one for our procedure should be analyze the lighting fixtures: how efficient is it now? Think on the lines of how can lighting in a room be more efficient. Looking to retrofit this with change in lighting. Look into: 1) changing the bulb. 2) changing both the values and the bulb. Check one bulb and analyze and then conclude.
- Another step could be to change the light entirely: moving light around the room (maybe just have a desk light?)
- *Hallways are different than rooms - sensors can be used- they have both pros and cons
- Simple things like "turn off lights board" can have some impact in human behavioral.
- We should concentrate on good data capture while at the university. Cameras, pictures, data from the light fixtures --- light meters (Professor Orr could let us borrow his own).
- Do a dry run in WPI that could help us! Pick a building and walk around as if we were in Russia. Think how would we improve the efficiency!
- LED lighting has gained a lot of efficiency. LED has been super energy efficient in general and replacing old bulbs with LEDs could make a good impact.
- Beware of energy fraud out there: companies lying about their products reducing energy consumption.

Appendix A.3 – Elizabeth Tomaszewski

- If we want actual data there is a form to fill out
- Done retrofits in CC – substantially energy saving
    - Mostly LED lighting
    - Can look up report to see savings
    - Campus Center Walking Tour
    - Focusing lighting on room instead of on the ceiling
    - Sent us a brochure on how they improved the CC lighting
- Lots of reporting on energy saving in CC – mostly done on lighting
    - Will look through and look for reports and email them to us
- Sports and Rec center
    - Lighting in pool area – inaccessible
    - Replace with LEDs to last longer
    - Not sure if any reports exist, she will look
- Project done on replacing lights in library a few years ago
    - Anticipated 3 year payback
    - We found this and have used it in our background research
- Motion sensors
    - Sports and rec center sustainability
    - Lighting sensors and controls – made a big difference
    - Daylight sensor – side of light has a sensor that dims light when senses daylight
- Consider Glass, Windows, and Shades
    - Deflect solar heating and glare
- GreenerU involved with WPI
    - Worked together for many years, ended in 2015
    - Engaged in 2012
    - Tri campus council synergy Worcester
    - Ready to sign a new contract with GreenerU for energy saving in retrofitting
    - GreenerU will be working with WPI this summer on Alden, AK and Morgan
        - Not a lot of lighting retrofits
    - Will email contact information – Director of change management
        - May not be the best person to talk to, but will direct us to someone to help us more

Appendix B. - Benchmark

The following tables contain the electrical meter data from ASU campus buildings as well as the analysis provided by Energy Star Portfolio Manager Software. The large difference between the buildings at ASU and similar median buildings in the US is particularly noted

Table B.1: Monthly electrical meter data collected from ASU records for the past year.

Building Name		Academic Building 1	Hostel 3	Hostel 1
Start Date	**End Date**	Energy Consumed (kWh)		
9/1/2015	10/1/2015	25,334	30,950	12,051
10/1/2015	11/1/2015	32,815	24,778	12,981
11/1/2015	12/1/2015	38,392	29,092	13,977
12/1/2015	1/1/2016	43,497	22,260	14,825
1/1/2016	2/1/2016	24,926	8,077	14,879
2/1/2016	3/1/2016	31,014	43,721	11,856
3/1/2016	4/1/2016	35,626	28,814	16,492
4/1/2016	5/1/2016	36,686	30,062	14,699
5/1/2016	6/1/2016	26,996	21,575	11,945
6/1/2016	7/1/2016	41,257	25,487	14,003
7/1/2016	8/1/2016	40,640	15,018	14,850
8/1/2016	9/1/2016	44,000	19,135	14,960

Table B.2: Gross floor area (GFA) for each building.

Building	Academic Building 1	Hostel 3	Hostel 1
Floor	**Gross Floor Area (GFA) (m^2)**		
Ground	367.5	672.0	548.6
1	2224.9	1518.8	690.3
2	1823.3	1518.8	727.5
3	1207.6	1518.8	713.9
4	1283.3	1518.8	707.1
5	N/A	1518.8	713.2
Total	6906.7	8266.3	4100.6

Table B.3: Table of the assumptions used in the Portfolio Manager. Heating was assumed to be 0.0% as the heating system was not electric. Cooling was assumed low as the buildings had sparse window and wall units, rather than a central system. Lastly, occupancy was determined from determined from the amount of office space or dorm rooms when compared to other room types.

Assumptions			
Building	**Academic Building 1**	**Hostel 3**	**Hostel 1**
% Heated	0.0	0.0	0.0
% Cooled	40.0	40.0	40.0
% Occupancy	80.0	80.0	80.0

Table B.4: Energy Star Portfolio Manager analysis of Academic Building 1 with comparison to the median value of similar buildings in the US.

Building Name	Academic Building 1		
Metric	ASU Building (Current)	Median Property	% Difference
Energy Star Score (1-100)	100	50	
Energy Use Intensity (kWh/m²)	61	225	72.9
Energy Use (kWh)	421,166	1,552,707	72.9
Total GHG Emissions ($MtCO_2$)	236.6	872.2	72.9

Table B.5: Energy Star Portfolio Manager analysis of Academic Hostel 3 with comparison to the median value of similar buildings in the US.

Building Name	Hostel 3		
Metric	ASU Building (Current)	Median Property	% Difference
Energy Star Score (1-100)	100	50	
Energy Use Intensity (kWh/m²)	37	160	76.7
Energy Use (kWh)	298,957	1,277,366	76.6
Total GHG Emissions ($MtCO_2$)	168	718	76.6

Table B.6: Energy Star Portfolio Manager analysis of Hostel 1 with comparison to the median value of similar buildings in the US.

Building Name	Hostel 1		
Metric	ASU Building (Current)	Median Property	% Difference
Energy Star Score (1-100)	98	50	
Energy Use Intensity (kWh/m²)	41	111	63.0
Energy Use (kWh)	167,511	454,036	63.1
Total GHG Emissions ($MtCO_2$)	94.1	255.1	63.1

Appendix C. - The Energy Audit

To provide an understanding on how well a building performs, an energy audit is an integral preliminary step on the path to increasing energy efficiency. Described simply, an energy audit is an evaluation of the consumption and use of energy in a building, generally with the aim to improve the overall energy efficiency. Many systems in a building can be analyzed through this process such as the following: heating, cooling, generators, lighting, and appliances such as pumps and computers. The scope varies for the type of building being considered: for instance in academic and office structures, electrical, lighting, heating and cooling systems are the most important and have high potential energy savings.

The prescribed steps taken during an audit vary among sources and depend largely on the needs and constraints of the project. However, the following types of audits, adopted from Albert Thumann's *Handbook of Energy Audits*, build on each other and offer a clear path through the process of the energy audit (Thumann, 2012). The types of audits outlined are as follows: the benchmarking audit, the walkthrough audit, the standard audit, and computer simulation audit. These types are routine in practice, as was discussed with David Litalien, a licensed electrician. The following sections describe each audit in detail.

Type 0: The Benchmarking Audit

The most basic type of audit is the benchmarking audit. It provides a preliminary analysis of energy needs of a facility by initially examining billing records over a period of time, typically one to three years. This wide range of data allows the auditor to understand how energy demands may vary through seasons to predict average uses for future years. By comparing to standard energy needs in similar facilities, the auditor can understand how efficient the building currently is and quantify excess energy consumption. This type is cost-effective and requires only a minimum amount of time to analyze the data, as much of the work is done on paper. However, in this respect this type of audit is incomplete, as the full details of the facility can only be realized with closer and more personal inspection of the building.

Type 1: The Walkthrough Audit

The next type of audit is referred to as the walkthrough audit, as the auditor literally walks through the building, examining various energy-consuming systems (i.e. lighting, heating, cooling, etc.). This process aims primarily at categorizing the inventory of devices and models and maintenance practices, currently being used at the facility. In conjunction with the facility's energy consumption record, the auditor can identify some preliminary savings and steps for minor improvements. Compared to the previous type, this audit can take longer, depending on the size of the building and scope of the audit. Moreover, this audit will provide more preliminary information, and the auditor can determine if more detailed audits are warranted.

Type 2: The Standard Audit

The following type, the standard audit, is typically used in energy efficiency projects, as it provides further detail of the building and can lend to higher energy savings. In this audit various instruments are used to measure the usage and efficiency of energy systems. From the data gathered, an auditor can quantify the uses and losses of energy more adequately than the previous types. For example, to measure the output of lighting systems, a lux meter records the lighting level throughout a room to determine if the system provides an adequate level. Furthermore, this information can lend to renovations that can be more energy efficient and cost effective; recommendations are routinely made based on economic analyses. However, to conduct this type of audit, an auditor would require enough time to gather the proper amount of information. For example David Litalien, a licensed electrician, cites that a complete energy audit of all systems for a moderately sized office building could take up to two weeks even with a few auditors working on the project. Depending on the scope and scale of the project, a few weeks may be necessary to complete the audit.

Type 3: The Computer Simulation Audit

A more involved approach to the auditing process is the computer simulation audit. As the name suggests, a computer program is designed to predict the energy consumption for a cycle, typically a year period. This approach is typically implemented in complex environments where varying energy systems can interact with each other: an example would be the lighting system affecting the heating system or vice verse. However, as one can surmise, a complete set of data, consisting of weather patterns and other variables, would have to be captured initially to design the software around the given parameters. For an accurate simulation, the auditor would need at least a year's worth of data, if not more. This type of audit is the most costly of the ones described and requires a lengthy time span to implement. Due to this reason, this audit is best reserved more complex systems.

Appendix D. - Energy Audit Worksheets

This appendix contains all information collected from the three ASU buildings during the Standard Audit as well as the total energy consumption of each appliance on an average daily basis. The total energy consumption was calculated by using the following estimate daily uses:

1. Lobby lights were assumed to be on 24 hours/day.
2. Hallway lights were assumed to be on 12 hours/day.
3. Room lights and office equipment (computers, printers, fax machines, etc.) were assumed to be on for 6 hours/day.
4. Refrigerators and water coolers were assumed to be on for 24 hours/day.
5. AC's were assumed to be on for 1.5 hours/day, to account for when they are shut off during the heating season.
6. All other house equipment (ovens, microwaves, washing machines, TV's, etc.) were assumed to operate between 0.5 – 2 hours/day, depending on the equipment.

Table D.1 lists the average energy consumption of each type of device. These values were estimated from common values of devices (ABS Alaskan, 2008).

Device	Wattage (W)	Device	Wattage (W)
AC (wall)	1000	Laptop	75
AC (window)	1200	Microwave	1050
ATM	5520	Oven	2150
Bulbs	see Type Code	Printer	25
Computer	103	Radio	20
Computer (videographer)	1200	Treadmill	1800
Fax Machine	100	TV	150
Fridge	275	Washing Machine	500
Iron	1000	Water Cooler	650

Table D.1: Average wattage of standard devices.

Additionally, the following type codes (TC) were used to condense the size of the audit sheets (see Table D.2).

Type Code (TC)			
A. Incandescent	I. E27 1x18	R. Fry Table	AA. TV
B. Flourescent	J. Ranges	S. Refrigerator	AB. Printer
C. Mercury Vapor	K. Steam Table	T. Walk-in Freezer	AC. AC window unit
D. High Pressure Sodium	L. Freezer	U. Dishwasher	AD. AC unit
E. Low Pressure Sodium	M. Walk-in Fridge	V. Hood w/ exhaust fan	AE. ATM
F. Lamp 4x18	N. Infra-red Warmer	W. Washing Machine	AF. Radio
G. LPO 2x18	O. Microwave	X. Clothes Dryer	AG. Fax Machine
G1. LPO 2x36	P. Mixer	Y. Iron	XX. Other __________
H. NPP 1x60	Q. Oven	Z. Hair Blow Dryer	

Table D.2: Type code of each device cataloged in energy audit.

Appendix D.1 - Hostel 1

The following audit sheets catalog the electrical equipment present in each room for Hostel 1. For floors 1 – 5, we estimated that each room had identical equipment and usage. All remaining data was collected as prescribed in the methods.

Watt-Hours Consumed Per Day					
Building:	*Hostel 1*				
Floor	**Lighting**	**Computers**	**Refrigerator**	**Air Conditioner**	**Other**
Ground	29,520	19,776	26,400	7,800	4,280
1	41,988	27,000	99,000	36,000	2,625
2	25,488	31,500	99,000	42,000	21,850
3	43,260	31,500	99,000	42,000	21,550
4	34,548	31,500	99,000	42,000	21,550
5	39,996	29,250	92,400	39,000	21,950
Total	214,800	170,526	514,800	208,800	93,805

Table D.3: Summary of data collected from Hostel 1.

Individual Room Data - Ground Floor (1 of 1)															
Building:	*Hostel 1*								**Floor:**	*Basement 1*					
Room Number	**Lighting**					**Computers**				**Other Appliances**					
	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
1 - *lighting info for entire floor	G	10	40	12	4800	8	ViewSonic	6	4944	AB		1	25	6	150
	H	5	60	12	3600					AD		1	1000	1.5	1500
	F	22	80	12	21120					AC	General Climate, European class B	1	1200	1.5	1800
										S	Capatob	1	275	24	6600
										O	Hyuandai	1	1050	0.5	525
3						3	LG	6	1854	AB		2	25	6	300
										AF		1	20	2	40
5						5		6	3090	AB		3	25	6	450
										O	Hyuandai	1	1050	0.5	525
										S	Capatob	1	275	24	6600
										AD		1	1000	1.5	1500
6						8		6	4944	AB		2	25	6	300
										O	Fusion BpemR	1	1050	0.5	525
										S	Nord Standard	1	275	24	6600
										AD	General Climate	1	1000	1.5	1500
										AG		1	100	6	600
7						8		6	4944	AD		1	1000	1.5	1500
										AB		2	25	6	300
										AF		1	20	2	40
										S	Brand: Indesit	1	275	24	6600
										O	Brand: CRS	1	1050	0.5	525

Individual Room Data - Floor 1 (1 of 3)															
Building:	*Hostel 1*								**Floor:**	*1*					
	Lighting					**Computers**				**Other Appliances**					
Room Number	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
Lobby	F	5	80	24	9600										
	I	12	18	24	5184										
Left Corridor	F	3	80	12	2880										
Right Corridor	F	5	80	12	4800										
	G	1	40	12	480										
Kitchen 1	I	3	18	6	324					S		2	275	24	13200
										O		1	1050	0.5	525
Kitchen 2															0
															0
Dining Room & Kitchen	I	6	18	6	648					O		4	1050	0.5	2100
										XX	Commercial Cooler	1	275	24	6600
Lecture Hall 1	G	3	40	6	720										
Lecture Hall 2	G	3	40	6	720										
Lecture Hall 3	G	3	40	6	720										

Individual Room Data - Floor 1 (2 of 3)																
Building:	*Hostel 1*							**Floor:**	*1*							
	Lighting					**Computers**				**Other Appliances**						
Room Number	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
Lecture Hall 4	G	3	40	6	720										
Lecture Hall 5	G	2	40	6	480										
Apartment 101	I	12	18	6	1296	5	laptops	6	2250	S		1	275	24	6600
										AD		2	1000	1.5	3000
Apartment 102	F	3	80	6	1440	5	laptops	6	2250	S		1	275	24	6600
	I	3	18	6	324					AD		2	1000	1.5	3000
Apartment 103	I	8	18	6	864	5	laptops	6	2250	S		1	275	24	6600
										AD		2	1000	1.5	3000
Apartment 104	I	10	18	6	1080	5	laptops	6	2250	S		1	275	24	6600
										AD		2	1000	1.5	3000
Apartment 105	H	2	60	6	720	5	laptops	6	2250	S		1	275	24	6600
	I	11	18	6	1188					AD		2	1000	1.5	3000
Apartment 106	I	8	18	6	864	5	laptops	6	2250	S		1	275	24	6600
										AD		2	1000	1.5	3000
Apartment 107	I	8	18	6	864	5	laptops	6	2250	S		1	275	24	6600
										AD		2	1000	1.5	3000

Individual Room Data - Floor 1 (3 of 3)															
Building:	*Hostel 1*							**Floor:**	*1*						
	Lighting					**Computers**				**Other Appliances**					
Room Number	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
Apartment 108	I	8	18	6	864	5	laptops	6	2250	S		1	275	24	6600
										AD		2	1000	1.5	3000
	I	8	18	6	864	5	laptops	6	2250	S		1	275	24	6600
Apartment 109										AD		2	1000	1.5	3000
	I	8	18	6	864	5	laptops	6	2250	S		1	275	24	6600
Apartment 110										AD		2	1000	1.5	3000
	I	12	18	6	1296	5	laptops	6	2250	S		1	275	24	6600
Apartment 111										AD		2	1000	1.5	3000
	G	1	40	6	240	5	laptops	6	2250	S		1	275	24	6600
Apartment 112	I	8	18	6	864					AD		2	1000	1.5	3000
	H	3	60	6	1080										
Bathroom															

Individual Room Data – Floor 2 (1 of 4)															
Building:	*Hostel 1*								**Floor:**	*2*					
	Lighting					**Computers**				**Other Appliances**					
Room Number	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
Lobby	F	4	80	24	7680					AA	72"	1	150	2	300
Left Corridor	F	3	80	12	2880										
Right Corridor	G	5	40	12	2400										
Kitchen	H	2	60	6	720					S		1	275	24	6600
										O		1	1050	0.5	525
										Q		1	2150	2	4300
										Y		1	1000	1	1000
Bathroom	H	1	60	6	360										
Dining Room & Kitchen	H	6	60	6	2160					W		1	500	3	1500
	I	2	18	6	216					Y		1	1000	1	1000
										O		1	1050	0.5	525
										Q		1	2150	2	4300
Apartment 201	I	6	18	6	648	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
										AD		2	1000	1.5	3000

Individual Room Data - Floor 2 (2 of 4)															
Building:	*Hostel 1*							**Floor:**	*2*						
Room Number	**Lighting**				**Computers**				**Other Appliances**						
	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
Apartment 202	I	6	18	6	648	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
										AD		2	1000	1.5	3000
Apartment 203	I	6	18	6	648	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
										AD		2	1000	1.5	3000
Apartment 204	I	6	18	6	648	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
										AD		2	1000	1.5	3000
Apartment 205	I	6	18	6	648	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
										AD		2	1000	1.5	3000
Apartment 206	I	6	18	6	648	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
										AD		2	1000	1.5	3000
Apartment 207	I	6	18	6	648	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
										AD		2	1000	1.5	3000

Individual Room Data - Floor 2 (3 of 4)															
Building:	*Hostel 1*								**Floor:**	*2*					
Room Number	**Lighting**					**Computers**				**Other Appliances**					
	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
Apartment 208	I	6	18	6	648	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
										AD		2	1000	1.5	3000
Apartment 209	I	6	18	6	648	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
										AD		2	1000	1.5	3000
Apartment 210	I	6	18	6	648	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
										AD		2	1000	1.5	3000
Apartment 211	I	6	18	6	648	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
										AD		2	1000	1.5	3000
Apartment 212	I	6	18	6	648	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
										AD		2	1000	1.5	3000

Individual Room Data - Floor 2 (4 of 4)															
Building:	*Hostel 1*							**Floor:**	*2*						
	Lighting					**Computers**			**Other Appliances**						
Room Number	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
Apartment 213	I	6	18	6	648	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
										AD		2	1000	1.5	3000
Apartment 214	I	6	18	6	648	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
										AD		2	1000	1.5	3000

Individual Room Data - Floor 3 (1 of 3)															
Building:	*Hostel 1*								**Floor:**	*3*					
	Lighting					**Computers**				**Other Appliances**					
Room Number	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
	F	6	80	24	11520										
Lobby	H	2	60	24	2880										
	G	5	40	12	2400										
	H	1	60	12	720										
Right Corridor															
	G	6	40	12	2880										
Left Corridor	H	4	60	12	2880										
	H	5	60	6	1800					S		1	275	24	6600
	I	2	18	6	216					O		1	1050	0.5	525
										Q		1	2150	2	4300
Kitchen										Y		1	1000	1	1000
	H	1	60	6	360										
Bathroom	I	1	18	6	108										
	I	8	18	6	864					W		1	500	3	1500
										Y		1	1000	1	1000
										O		1	1050	0.5	525
Dining Room + Kitchen										Q		1	2150	2	4300
	I	11	18	6	1188	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
Dorm No 301										AD		2	1000	1.5	3000

Individual Room Data - Floor 3 (2 of 3)															
Building:	*Hostel 1*							**Floor:**	*3*						
Room Number	**Lighting**					**Computers**				**Other Appliances**					
	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
Dorm No 302	I	11	18	6	1188	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
										AD		2	1000	1.5	3000
Dorm No 303	I	11	18	6	1188	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
										AD		2	1000	1.5	3000
Dorm No 304	I	11	18	6	1188	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
										AD		2	1000	1.5	3000
Dorm No 305	I	11	18	6	1188	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
										AD		2	1000	1.5	3000
Dorm No 306	I	11	18	6	1188	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
										AD		2	1000	1.5	3000
Dorm No 307	I	11	18	6	1188	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
										AD		2	1000	1.5	3000

Individual Room Data - Floor 3 (3 of 3)															
Building:	*Hostel 1*							**Floor:**	*3*						
	Lighting					**Computers**				**Other Appliances**					
Room Number	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
	I	11	18	6	1188	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
Dorm No 308										AD		2	1000	1.5	3000
	I	11	18	6	1188	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
Dorm No 309										AD		2	1000	1.5	3000
	I	11	18	6	1188	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
Dorm No 310										AD		2	1000	1.5	3000
	I	11	18	6	1188	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
Dorm No 311										AD		2	1000	1.5	3000
	I	11	18	6	1188	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
Dorm No 312										AD		2	1000	1.5	3000
	I	11	18	6	1188	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
Dorm No 313										AD		2	1000	1.5	3000
	I	11	18	6	1188	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
Dorm No 314										AD		2	1000	1.5	3000

Individual Room Data – Floor 4 (1 of 3)

Building:	*Hostel 1*								**Floor:**	*4*					
	Lighting					**Computers**				**Other Appliances**					
Room Number	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
	F	4	80	24	7680										
	G	2	40	24	1920										
Lobby	I	6	18	24	2592										
	G	3	40	12	1440										
Left Corridor															
	G	5	40	12	2400										
Right Corridor															
	I	4	18	6	432					S		1	275	24	6600
										O		1	1050	0.5	525
										Q		1	2150	2	4300
Kitchen										Y		1	1000	1	1000
	I	1	18	6	108										
Bathroom															
	G	2	40	6	480					W		1	500	3	1500
	I	8	18	6	864					Y		1	1000	1	1000
										O		1	1050	0.5	525
Dining Room + Kitchen										Q		1	2150	2	4300
	I	11	18	6	1188	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
Apartment 401										AD		2	1000	1.5	3000

Individual Room Data – Floor 4 (2 of 3)															
Building:	*Hostel 1*								**Floor:**	*4*					
Room Number	**Lighting**					**Computers**				**Other Appliances**					
	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
Apartment 402	I	11	18	6	1188	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
										AD		2	1000	1.5	3000
Apartment 403	I	11	18	6	1188	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
										AD		2	1000	1.5	3000
Apartment 404	I	11	18	6	1188	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
										AD		2	1000	1.5	3000
Apartment 405	I	11	18	6	1188	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
										AD		2	1000	1.5	3000
Apartment 406	I	11	18	6	1188	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
										AD		2	1000	1.5	3000
Apartment 407	I	11	18	6	1188	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
										AD		2	1000	1.5	3000
Apartment 408	I	11	18	6	1188	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
										AD		2	1000	1.5	3000

Individual Room Data - Floor 4 (3 of 3)															
Building:	*Hostel 1*							**Floor:**	*4*						
Room Number	**Lighting**					**Computers**				**Other Appliances**					
	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
Apartment 409	I	11	18	6	1188	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
										AD		2	1000	1.5	3000
Apartment 410	I	11	18	6	1188	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
										AD		2	1000	1.5	3000
Apartment 411	I	11	18	6	1188	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
										AD		2	1000	1.5	3000
Apartment 412	I	11	18	6	1188	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
										AD		2	1000	1.5	3000
Apartment 413	I	11	18	6	1188	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
										AD		2	1000	1.5	3000
Apartment 414	I	11	18	6	1188	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
										AD		2	1000	1.5	3000

Individual Room Data - Floor 5 (1 of 3)															
Building:	*Hostel 1*								**Floor:**	*5*					
	Lighting					**Computers**				**Other Appliances**					
Room Number	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
Lobby	F	4	80	24	7680										
	G	2	40	24	1920										
Right Corridor	F	4	80	12	3840										
	G	5	40	12	2400										
	H	1	60	12	720										
Left Corridor	F	3	80	12	2880										
	G	3	40	12	1440										
	H	1	60	12	720										
Kitchen	I	4	18	6	432					S		1	275	24	6600
										O		1	1050	0.5	525
										Q		1	2150	2	4300
										Y		1	1000	1	1000
Bathroom	I	1	18	6	108										
	H	1	60	6	360										
Dining Room + Kitchen	I	8	18	6	864					W		1	500	3	1500
										Y		1	1000	2	2000
										O		1	1050	0.5	525
										Q		1	2150	2	4300

Individual Room Data - Floor 5 (2 of 3)

Building:	*Hostel 1*								**Floor:**	*5*					
Room Number	**Lighting**					**Computers**				**Other Appliances**					
	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
Dorm No 501	I	11	18	6	1188	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
										AD		2	1000	1.5	3000
Dorm No 502	I	11	18	6	1188	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
										AD		2	1000	1.5	3000
Dorm No 503	I	11	18	6	1188	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
										AD		2	1000	1.5	3000
Dorm No 504	I	11	18	6	1188	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
										AD		2	1000	1.5	3000
Dorm No 505	I	11	18	6	1188	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
										AD		2	1000	1.5	3000
Dorm No 506	I	11	18	6	1188	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
										AD		2	1000	1.5	3000
Dorm No 507	I	11	18	6	1188	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
										AD		2	1000	1.5	3000

Individual Room Data - Floor 5 (3 of 3)															
Building:	*Hostel 1*								**Floor:**	*5*					
Room Number	**Lighting**					**Computers**				**Other Appliances**					
	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
Dorm No 508	I	11	18	6	1188	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
										AD		2	1000	1.5	3000
Dorm No 509	I	11	18	6	1188	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
										AD		2	1000	1.5	3000
Dorm No 510	I	11	18	6	1188	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
										AD		2	1000	1.5	3000
Dorm No 511	I	11	18	6	1188	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
										AD		2	1000	1.5	3000
Dorm No 512	I	11	18	6	1188	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
										AD		2	1000	1.5	3000
Dorm No 513	I	11	18	6	1188	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
										AD		2	1000	1.5	3000
Dorm No 514	I	11	18	6	1188	5	laptops	6	2250	AA	27"	2	150	2	600
										S		1	275	24	6600
										AD		2	1000	1.5	3000

Appendix D.2 - Hostel 3

The following audit sheets catalog the electrical equipment present in each room for Hostel 3. For floor 2, we estimated that each room had similar equipment to other floors. All remaining data was collected as prescribed in the methods.

Watt-Hours Consumed Per Day					
Building:	*Hostel 3*				
Floor	**Lighting**	**Computers**	**Refrigerator**	**Air Conditioner**	**Other**
Ground	15,840	0	0	5,400	29,140
1	99,384	29,664	46,200	0	141,280
2	106,776	0	158,400	0	0
3	78,312	12,713	85,800	0	0
4	93,888	29,664	52,800	3,600	450
5	90,768	50,358	46,200	3,000	300
Total	484,968	122,399	389,400	12,000	171,170

Table D.4: Summary of data collected from Hostel 3.

Individual Room Data - Ground Floor (1 of 1)															
Building:	*Hostel 3*							**Floor:**	*Basement 1*						
Room Number	**Lighting**					**Computers**				**Other Appliances**					
	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
	G1	33	80	6	15840					AF	radio	1	20	2	40
										AC		3	1200	1.5	5400
										AA	tv - LG, 47"	1	150	2	300
											fans	3	25	0	0
Gym										XX	treadmills	4	1800	4	28800

Individual Room Data – Floor 1 (1 of 4)

Building: *Hostel 3* **Floor:** *1*

Room Number	Lighting					Computers				Other Appliances					
	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
Lobby	F	6	80	24	11520	1		6	618	AA	LG, 36"	1	150	2	300
	I	14	18	24	6048					AE		1	5520	24	132480
Hallway	F	11	80	12	10560										
	G1	2	80	12	1920										
Medical Point	G1	4	80	6	1920										
6 - office	G1	2	80	6	960	3		6	1854	AB		2	25	6	300
7 - office	G1	2	80	6	960	3		6	1854	AB		2	25	6	300
8 - office	G1	2	80	6	960	3		6	1854	AB		2	25	6	300
11 - office	G1	2	80	6	960	3		6	1854	AB		2	25	6	300
12- office	G1	2	80	6	960	3		6	1854	AB		2	25	6	300
13 - office	G1	2	80	6	960	3		6	1854	AB		2	25	6	300

Individual Room Data - Floor 1 (2 of 4)																
Building:	*Hostel 3*							**Floor:**	*1*							
Room Number	**Lighting**					**Computers**				**Other Appliances**						
	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
14 - office	G1	2	80	6	960	3		6	1854	AB		2	25	6	300
15 - office	G1	2	80	6	960	3		6	1854	AB		2	25	6	300
16 - office	G1	2	80	6	960	3		6	1854	AB		2	25	6	300
17 - office	G1	2	80	6	960	3		6	1854	AB		2	25	6	300
18 - office	G1	2	80	6	960	3		6	1854	AB		2	25	6	300
19 - office	G1	2	80	6	960	3		6	1854	AB		2	25	6	300
20 - office	G1	2	80	6	960	3		6	1854	AB		2	25	6	300
21 - office	G1	4	80	6	1920	3		6	1854	AB		2	25	6	300

Individual Room Data - Floor 1 (3 of 4)															
Building:	*Hostel 3*								**Floor:**	*1*					
Room Number	**Lighting**					**Computers**				**Other Appliances**					
	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
22 - office	G1	12	80	6	5760	3		6	1854	AB		2	25	6	300
Female Locker Room	G1	2	80	6	960										
Male Locker Room	G1	2	80	6	960										
113 - office area in kitchen	H	4	60	6	1440	2	Acer	6	1236	AA	Samsung, 24"	1	150	2	300
										Y	Hausner	1	1000	1	1000
										AB	Brand: HP	1	25	6	150

Individual Room Data - Floor 1 (4 of 4)															
Building:	*Hostel 3*							**Floor:**	*1*						
Room Number	**Lighting**					**Computers**				**Other Appliances**					
	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
Kitchen	G	6	40	6	1440					N		2			0
	G1	40	80	6	19200					O		6	1050	0.5	3150
	I	2	18	6	216					Q	Brand: Piron	1			0
										Q	3-tiered oven	1			0
										Q	oven, stovetop	4			0
										Q	convection oven	6			0
										S	30 degrees	3	275	24	19800
										S	5.1 degrees C	1	275	24	6600
										S	commercial cooler	3	275	24	19800
										T		1			0
										U		1			0
										XX	Meat Grinder	2			0
										XX	Industrial Mixer	3			0
										XX	Standing fan	1			0
Dining Room	H	64	60	6	23040					AA	47"	1	150	2	300

Individual Room Data - Floor 2 (1 of 6)														
Building:	*Hostel 3*							**Floor:**	*2*					
Room Number	**Lighting**					**Computers**			**Other Appliances**					
	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
Lobby	F	4	80	24	7680									0
North Corridor	F H	9 6	80 60	12 12	8640 4320									0
East Corridor	F	11	80	12	10560									0
Room 1														0
Room 2	G1	2	80	6	960									0
Room 3	G1	2	80	6	960									0
Room 4	F	6	80	6	2880									0
Room 5	G1	2	80	6	960									0
Room 6	G1	2	80	6	960									0

Individual Room Data - Floor 2 (2 of 6)															
Building:	*Hostel 3*						**Floor:**	*2*							
Room Number	**Lighting**					**Computers**			**Other Appliances**						
	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
Room 7	G1	2	80	6	960									0
Room 8	G1	4	80	6	1920									0
Room 9	G1	2	80	6	960									0
Room 10	G1	6	80	6	2880									0
Room 11	G1	2	80	6	960									0
Room 12	G1	6	80	6	2880									
Room 13	G1	2	80	6	960									
Room 14	G1	4	80	6	1920									
Room 15	G1	2	80	6	960									

Individual Room Data - Floor 2 (3 of 6)

Building: *Hostel 3* **Floor:** *2*

Room Number	**Lighting**					**Computers**			**Other Appliances**					
	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
Room 16	G1	4	80	6	1920									
Room 17	G1	2	80	6	960									
Room 19	G1	2	80	6	960									
Room 21	G1	2	80	6	960									
Room 23	G1	2	80	6	960									
Room 25	F	14	80	6	6720									
Warehouse	G1	2	80	6	960									
Men's bathroom	H I	4 4	60 18	6 6	1440 432									
Women's bathroom	I	2	18	6	216									

Individual Room Data - Floor 2 (4 of 6)														
Building:	*Hostel 3*							**Floor:**	*2*					
Room Number	**Lighting**					**Computers**			**Other Appliances**					
	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
200	H	4	60	6	1440				S		1	275	24	6600
201	G1	2	80	6	960				S		1	275	24	6600
	H	8	60	6	2880									
202	H	4	60	6	1440				S		1	275	24	6600
	I	2	18	6	216									
203	H	8	60	6	2880				S		1	275	24	6600
204	H	4	60	6	1440				S		1	275	24	6600
	I	2	18	6	216									
205	H	4	60	6	1440				S		1	275	24	6600
206	H	4	60	6	1440				S		1	275	24	6600
	I	2	18	6	216									
207	H	4	60	6	1440				S		1	275	24	6600
	I	2	18	6	216									
208	H	4	60	6	1440				S		1	275	24	6600
	I	2	18	6	216									

Individual Room Data - Floor 2 (5 of 6)															
Building:	*Hostel 3*						**Floor:**	*2*							
Room Number	**Lighting**					**Computers**			**Other Appliances**						
	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	TC	Note/Brand	#	W	hr/day	ΣWh/day	
	H	4	60	6	1440				S		1	275	24	6600	
209	I	2	18	6	216										
	H	4	60	6	1440				S		1	275	24	6600	
210	I	2	18	6	216										
	H	4	60	6	1440				S		1	275	24	6600	
211	I	2	18	6	216										
	H	4	60	6	1440				S		1	275	24	6600	
212	I	2	18	6	216										
	H	4	60	6	1440				S		1	275	24	6600	
213	I	2	18	6	216										
	H	4	60	6	1440				S		1	275	24	6600	
214	I	2	18	6	216										
	H	4	60	6	1440				S		1	275	24	6600	
215	I	2	18	6	216										
	H	4	60	6	1440				S		1	275	24	6600	
216	I	2	18	6	216										

Individual Room Data - Floor 2 (6 of 6)															
Building:	*Hostel 3*							**Floor:**	*2*						
Room Number	**Lighting**					**Computers**			**Other Appliances**						
	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
217	H	4	60	6	1440				S		1	275	24	6600
	I	2	18	6	216									
218	H	4	60	6	1440				S		1	275	24	6600
	I	2	18	6	216									
219	H	4	60	6	1440				S		1	275	24	6600
	I	2	18	6	216									
220	I	2	18	6	216				S		1	275	24	6600
221	I	2	18	6	216				S		1	275	24	6600
222	F	4	80	6	1920				S		1	275	24	6600
Staircase	G	2	40	6	480				S		1	275	24	6600

Individual Room Data - Floor 3 (1 of 4)															
Building:	*Hostel 3*								**Floor:**	*3*					
Room Number	**Lighting**					**Computers**				**Other Appliances**					
	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
Lobby	F	6	80	24	11520										
North Corridor	F	2	80	12	1920										
	G1	5	80	12	4800										
South Corridor	G1	7	80	12	6720										
Dorm No 1	G	1	40	6	240	5	laptops	6	455	S		1	275	24	6600
	G1	5	80	6	2400										
Dorm No 2	G	1	40	6	240	5	laptops	6	455	S		1	275	24	6600
	G1	5	80	6	2400										
Dorm No 3	G	1	40	6	240	5	laptops	6	455	S		1	275	24	6600
	G1	5	80	6	2400										
Dorm No 4	G	1	40	6	240	5	laptops	6	455	S		1	275	24	6600
	G1	5	80	6	2400										
Dorm No 5	G	1	40	6	240	5	laptops	6	455	S		1	275	24	6600
	G1	5	80	6	2400										
Dorm No 6	G	1	40	6	240	5	laptops	6	455	S		1	275	24	6600
	G1	5	80	6	2400										

Individual Room Data - Floor 3 (2 of 4)																
Building:	*Hostel 3*								**Floor:**	*3*						
Room Number	**Lighting**					**Computers**				**Other Appliances**						
	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
Dorm No 7	G G1	1 5	40 80	6 6	240 2400	5	laptops	6	455	S		1	275	24	6600
Dorm No 8	G G1	1 5	40 80	6 6	240 2400	5	laptops	6	455	S		1	275	24	6600
Dorm No 9	H	6	60	6	2160	5	laptops	6	455	S		1	275	24	6600
Dorm No 10	H	6	60	6	2160	5	laptops	6	455	S		1	275	24	6600
Dorm No 11	H	6	60	6	2160	5	laptops	6	455	S		1	275	24	6600
Dorm No 12	H	6	60	6	2160	5	laptops	6	455	S		1	275	24	6600
Dorm No 13	H	6	60	6	2160	5	laptops	6	455	S		1	275	24	6600
Student Union	F	2	80	6	960										
Office	F	2	80	6	960										

Individual Room Data - Floor 3 (3 of 4)															
Building:	*Hostel 3*								**Floor:**	*3*					
Room Number	**Lighting**					**Computers**				**Other Appliances**					
	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
Dining Room 1	G1	2	80	6	960										
Kitchen 1	G1	2	80	6	960										
Bathroom 1	H	4	60	6	1440										
Person on Duty Office 1	G1	2	80	6	960										
Laundry Room 1	G1	2	80	6	960										
Washroom 1	G1	2	80	6	960										
Shower 1	H	4	60	6	1440										
301	F	6	80	6	2880	11		6	6798						

Individual Room Data - Floor 3 (4 of 4)																
Building:	*Hostel 3*								**Floor:**	*3*						
	Lighting					**Computers**				**Other Appliances**						
Room Number	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
303	F	6	80	6	2880										
Person on Duty Office 2	G1	1	80	6	480										
Kitchen 2	H	3	60	6	1080										
Dining Room 2	G1	3	80	6	1440										
Shower 2	H	6	60	6	2160										
Bathroom 2	I	4	18	6	432										
Stairwell	G	2	40	6	480										

Individual Room Data - Floor 4 (1 of 5)															
Building:	*Hostel 3*								**Floor:**	*4*					
	Lighting					**Computers**				**Other Appliances**					
Room Number	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
Lobby	F	4	80	24	7680										
North Corridor	F	4	80	12	3840										
	G1	3	80	12	2880										
East Corridor	G	9	40	12	4320										
Student office	F	6	80	6	2880	3		6	1854	AC	Energy rating class B	1	1200	1.5	1800
										AB		1	25	6	150
Department of HR	F	12	80	6	5760	3		6	1854	AC		1	1200	1.5	1800
										AB		1	25	6	150
Storage	G1	2	80	6	960										
Archive 1	G1	8	80	6	3840										
Archive 2	F	6	80	6	2880										

Individual Room Data - Floor 4 (2 of 5)															
Building:	*Hostel 3*								**Floor:**	*4*					
Room Number	**Lighting**					**Computers**				**Other Appliances**					
	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
Archive 3	G1	14	80	6	6720										
Archive 4	G1	14	80	6	6720										
44 - class	G1	2	80	6	960										
45 - class	F	4	80	6	1920	0		6	0	AB		1	25	6	150
46 - class	G1	4	80	6	1920	0		6	0						
47 - class	G1	4	80	6	1920										
48 - class	G1	4	80	6	1920	0		6	0						
49 - class	G1	4	80	6	1920										
414 - class	F	4	80	6	1920										

Individual Room Data - Floor 4 (3 of 5)															
Building:	*Hostel 3*								**Floor:**	*4*					
Room Number	**Lighting**					**Computers**				**Other Appliances**					
	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
415 - class	F	4	80	6	1920										
Dispatch	G1	2	80	6	960	2		6	1236						
Dorm No 1	G G1	1 5	40 80	6 6	240 2400	5	laptops	6	3090	S		1	275	24	6600
Dorm No 2	G G1	1 5	40 80	6 6	240 2400	5	laptops	6	3090	S		1	275	24	6600
Dorm No 3	G G1	1 5	40 80	6 6	240 2400	5	laptops	6	3090	S		1	275	24	6600
Dorm No 4	G G1	1 5	40 80	6 6	240 2400	5	laptops	6	3090	S		1	275	24	6600
Dorm No 5	G G1	1 5	40 80	6 6	240 2400	5	laptops	6	3090	S		1	275	24	6600
Dorm No 6	G G1	1 5	40 80	6 6	240 2400	5	laptops	6	3090	S		1	275	24	6600
Dorm No 7	G G1	1 5	40 80	6 6	240 2400	5	laptops	6	3090	S		1	275	24	6600

Individual Room Data - Floor 4 (4 of 5)

Building: *Hostel 3* **Floor:** *4*

Room Number	Lighting					Computers				Other Appliances					
	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
Dorm No 8	G	1	40	6	240	5	laptops	6	3090	S		1	275	24	6600
	G1	5	80	6	2400										
Canteen	G1	2	80	6	960										
Laundry	G1	2	80	6	960										
Washroom	H	3	60	6	1080										
Shower	H	4	60	6	1440										
Bathroom 1	H	4	60	6	1440										
Kitchen	G1	2	80	6	960										

Individual Room Data - Floor 4 (5 of 5)															
Building:	*Hostel 3*							**Floor:**	*4*						
Room Number	**Lighting**					**Computers**				**Other Appliances**					
	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
Floor Butler	G1	2	80	6	960										
Bathroom 2	I	6	18	6	648										
Staircase	G	2	40	6	480										

Individual Room Data - Floor 5 (1 of 4)

Building:	*Hostel 3*								Floor:	*5*					
Room Number	Lighting					Computers + Monitors				Other Appliances					
	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
Lobby	F	9	80	24	17280										
North Corridor	F	4	80	12	3840										
	G1	5	80	12	4800										
East Corridor	G	8	40	12	3840										
500	F	9	80	6	4320	13	ViewSonic	6	8034						
501	F	9	80	6	4320	17	Samsung	6	10506	AA	flat screen, 20"	1	150	2	300
500A	F	9	80	6	4320	0		6	0						
502	G1	2	80	6	960	0		6	0						
504	G1	2	80	6	960	12	ViewSonic	6	7416						
505	G1	4	80	6	1920	0		6	0						

Individual Room Data - Floor 5 (2 of 4)															
Building:	*Hostel 3*							**Floor:**	*5*						
Room Number	**Lighting**					**Computers + Monitors**				**Other Appliances**					
	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
506	G1	2	80	6	960	0		6	0						
507 internet class	G1	4	80	6	1920	14	ViewSonic, RAMEC	6	8652	AD	Acer	2	1000	1.5	3000
508	G1	2	80	6	960	0		6	0						
509	G1	4	80	6	1920	0		6	0						
510	G1	4	80	6	1920	0		6	0						
511	G1	4	80	6	1920	0		6	0						
512	G1	4	80	6	1920	0		6	0						
513	G1	2	80	6	960	0		6	0						
Warehouse 2	G1	2	80	6	960	0		6	0						

Individual Room Data - Floor 5 (3 of 4)															
Building:	*Hostel 3*							**Floor:**	*5*						
Room Number	**Lighting**					**Computers + Monitors**				**Other Appliances**					
	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
Bathroom 2	I	6	18	6	648	0		6	0						
515	F	2	80	6	960	0		6	0						
Political Science room	F	2	80	6	960	0		6	0						
Stairwell	G	2	40	6	480	0		6	0						
Dorm No 1	G G1	1 5	40 80	6 6	240 2400	5	laptop	6	2250	S		1	275	24	6600
Dorm No 2	G G1	1 5	40 80	6 6	240 2400	5	laptop	6	2250	S		1	275	24	6600
Dorm No 3	G G1	1 5	40 80	6 6	240 2400	5	laptop	6	2250	S		1	275	24	6600
Dorm No 4	G G1	1 5	40 80	6 6	240 2400	5	laptop	6	2250	S		1	275	24	6600
Dorm No 5	G G1	1 5	40 80	6 6	240 2400	5	laptop	6	2250	S		1	275	24	6600

Individual Room Data - Floor 5 (4 of 4)															
Building:	*Hostel 3*							**Floor:**	*5*						
Room Number	**Lighting**					**Computers + Monitors**				**Other Appliances**					
	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
Dorm No 6	G G1	1 5	40 80	6 6	240 2400	5	laptop	6	2250	S		1	275	24	6600
Dorm No 7	G G1	1 5	40 80	6 6	240 2400	5	laptop	6	2250	S		1	275	24	6600
Warehouse 1	G1	6	80	6	2880										
Kitchen	G1	2	80	6	960										
Bathroom 1	H	4	60	6	1440										
Shower	H	4	60	6	1440										
Laundry	G I	1 1	40 60	6 6	240 360										
Bathroom 1	G1	2	80	6	960										
Shower	G1	2	80	6	960										

Appendix D.3 - Academic Building 1

The following audit sheets catalog the electrical equipment present in each room for Academic Building 1. All data was collected as prescribed in the methods.

Watt-Hours Consumed Per Day					
Building:	*Academic Building 1*				
Floor	**Lighting**	**Computers**	**Refrigerator**	**Air Conditioner**	**Other**
Basement	35400	9270	13200	0	2270
1	104736	61464	33000	34500	411375
1.5	42240	11406	6600	7500	5400
2	130572	75510	66000	43200	78975
2.5	28920	0	0	15000	540
3	105588	25788	33000	27000	38287.5
3.5	9600	1854	6600	3000	825
4	79152	94218	13200	45900	101175
Total	536208	279510	171600	176100	638847.5

Table D.5: Summary of data collected from Academic Building 1.

Individual Room Data – Floor 1 (1 of 5)															
Building:	*Academic Building 1*								**Floor:**	*Main floor, 1*					
Room Number	**Lighting**					**Computers**				**Other Appliances**					
	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
Lobby	I	36	18	24	15552	2		6	1236	AA	Toshiba, 72"	1	150	2	300
	E	8	30	24	5760					AE		2	5520	24	264960
										XX	Info Computer	1	5520	12	66240
Left Corridor	F	4	80	12	3840										
	E	13	30	12	4680										
Right Corridor	E	7	30	12	2520										
Bathroom	I	8	18	6	864										
100	F	6	80	6	2880	3	ViewSonic	6	1854	AB		3	25	6	450
										S		1	275	24	6600
										AC		1	1200	1.5	1800
										AD		1	1000	1.5	1500
101 - cafeteria	F	8	80	6	3840					S		1	275	24	6600
	G1	4	80	6	1920					O		2	1050	0.5	1050
	H	16	60	6	5760					S		2	275	24	13200
										AD		1	1000	1.5	1500
103	F	3	80	6	1440	5		6	3090	AB		2	25	6	300
										O		1	1050	0.5	525
										AD		1	1000	1.5	1500

Individual Room Data – Floor 1 (2 of 5)															
Building:	*Academic Building 1*							**Floor:**	*Main floor, 1*						
Room Number	**Lighting**					**Computers**				**Other Appliances**					
	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
	F	6	80	6	2880	6		6	3708	AB		1	25	6	150
104										AC		1	1200	1.5	1800
	F	4	80	6	1920	5		6	3090	AB		2	25	6	300
105															0
	F	2	80	6	960	5		6	3090	AB		1	25	6	150
107										O		1	1050	0.5	525
	F	8	80	6	3840	6		6	3708	AB		3	25	6	450
										O		1	1050	0.5	525
108										AC		2	1200	1.5	3600
	F	4	80	6	1920	5		6	3090	AB		2	25	6	300
										XX	Water Cooler	1	650	24	15600
112a										AC		2	1200	1.5	3600
	F	8	80	6	3840	9	ViewSonic	6	5562	AB		6	25	6	900
										XX	Copier	1	25	6	150
										S		1	275	24	6600
										AC		1	1200	1.5	1800
112										AD		2	1000	1.5	3000

Individual Room Data – Floor 1 (3 of 5)															
Building:	*Academic Building 1*								**Floor:**	*Main floor, 1*					
Room Number	**Lighting**					**Computers**				**Other Appliances**					
	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
113	F	3	80	6	1440	2		6	1236	AB		1	25	6	150
										AC		1	1200	1.5	1800
114a	F	5	80	6	2400	1	ViewSonic	6	618						
						1	Samsung	6	618						
114	F	4	80	6	1920	7		6	4326	AB		5	25	6	750
										O		1	1050	0.5	525
115						4	ViewSonic	6	2472	AB		4	25	6	600
Wardrobe	G1	3	80	6	1440										
116	F	4	80	6	1920	4		6	2472	AB		2	25	6	300
										AC		1	1200	1.5	1800
										XX	Water Cooler	1	650	24	15600
117, connect to 119a	E	22	30	6	3960	15	ViewSonic	6	9270	AB		5	25	6	750
										XX	Water Cooler	1	650	24	15600
										O	LG	1	1050	0.5	525
										S		1	275	24	6600
										AD		4	1000	1.5	6000

Individual Room Data – Floor 1 (4 of 5)															
Building:	*Academic Building 1*							**Floor:**	*Main floor, 1*						
Room Number	**Lighting**					**Computers**				**Other Appliances**					
	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
118	F	8	80	6	3840	6		6	3708	XX	Projector	1			0
						2	laptops	6	900	AB		2	25	6	300
										AG		1	25	6	150
										AC		1	1200	1.5	1800
120	E	6	30	6	1080	4	Intel	6	2472	AB		1	25	6	150
										XX	Water Cooler	1	650	24	15600
										AD		1	1000	1.5	1500
122	F	6	80	6	2880	7		6	4326	AB		6	25	6	900
										AD		1	1000	1.5	1500
										O		1	1050	0.5	525
Teacher's Room 1	E	2	30	6	360	1		6	618						
Teacher's Room 2	E	2	30	6	360										
Men's Bathroom	H	6	60	6	2160										

Individual Room Data – Floor 1 (5 of 5)															
Building:	*Academic Building 1*							**Floor:**	*Main floor, 1*						
Room Number	**Lighting**					**Computers**				**Other Appliances**					
	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
Women's Bathroom	H	6	60	6	2160										
Gymnasium	G1	30	80	6	14400										

Individual Room Data - Floor 1.5 (1 of 1)															
Building:	*Academic Building 1*							**Floor:**	*1.5*						
Room Number	**Lighting**					**Computers**				**Other Appliances**					
	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
Lobby	F	4	80	24	7680										
Library	F	44	80	6	21120	4		6	2472	AA	56"	3	150	2	900
	G1	28	80	6	13440	2	laptops	6	900	AB		5	25	6	750
						13	ViewSonic	6	8034	AD		5	1000	1.5	7500
										AG		1	25	6	150
										O		2	1050	0.5	1050
										S		1	275	24	6600
										XX	Heater	1	1200	2	2400
										XX	Projector	1			0
										XX	Copier	1	25	6	150

Individual Room Data – Floor 2 (1 of 5)

Building: *Academic Building 1* **Floor:** *2*

Room Number	Lighting					Computers				Other Appliances					
	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
Lobby	F	12	80	24	23040										
Left Corridor	F	1	80	12	960										
	E	14	30	12	5040										
Right Corridor	E	6	30	12	2160										
200 - office	E	5	30	6	900	3		6	1854	AD		1	1000	1.5	1500
										AB		1	25	6	150
201 - conference room	I	17	18	6	1836	1	Sony	6	618	AA	52"	2	150	2	600
	D	270	12	6	19440					AD		2	1000	1.5	3000
										XX	Projector	1			0
202 - dining	F	2	80	6	960					S		1	275	24	6600
	I	12	40	6	2880					XX	Heater	1	1200	2	2400
	D	20	12	6	1440					O		1	1050	0.5	525
										U		1			0
203 - office	F	2	80	6	960	1		6	618	AD		1	1000	1.5	1500
	H	22	60	6	7920					AB		2	25	6	300
	I	8	18	6	864					XX	Water Cooler	1	650	24	15600
	D	41	12	6	2952										0

Individual Room Data - Floor 2 (2 of 5)															
Building:	*Academic Building 1*								**Floor:**	*2*					
Room Number	**Lighting**					**Computers**				**Other Appliances**					
	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
207 - office	E	8	30	6	1440	2	laptop	6	1236	AB		2	25	6	300
						5		6	3090	AD		1	1000	1.5	1500
										XX	Shredder	1	25	6	150
210 - office	F	3	80	6	1440	5		6	3090	AB		3	25	6	450
										O		1	1050	0.5	525
										S		1	275	24	6600
										AD		1	1000	1.5	1500
										XX	Copier	1	25	6	150
212 - office with 2 adjacent rooms	F	14	80	6	6720	2	Lenovo	6	1236	AB		3	25	6	450
						1	Lenovo	6	618	AC		1	1200	1.5	1800
										AD		1	1000	1.5	1500
										S		1	275	24	6600
										O		1	1050	0.5	525
213 - office	G1	10	80	6	4800	9		6	5562	AB		1	25	6	150
	E	5	30	6	900					AD		2	1000	1.5	3000
										S		1	275	24	6600
										O		1	1050	0.5	525
215 - comp lab	G	4	40	6	960	40	ViewSonic	6	24720	AB		3	25	6	450
	I	24	18	6	2592					AD		2	1000	1.5	3000

Individual Room Data - Floor 2 (3 of 5)															
Building:	*Academic Building 1*							**Floor:**	*2*						
Room Number	**Lighting**					**Computers**				**Other Appliances**					
	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
216 - office with 2 adjacent rooms	F	6	80	6	2880	2	Acer	6	1236	AB	printer	5	25	6	750
	E	8	30	6	1440	1		6	618	AC		1	1200	1.5	1800
						1		6	618	S		1	275	24	6600
217 - classroom	E	6	30	6	1080	1		6	618	XX	Projector	1			0
															0
218 - office with 2 adjacent rooms	G1	15	80	6	7200	3		6	1854	AB	printer	2	25	6	300
						1		6	618	AC		1	1200	1.5	1800
						1		6	618	AB		2	25	6	300
219 - office	F	6	80	6	2880	3		6	1854	AC		2	1200	1.5	3600
						2	laptops	6	900	AB		3	25	6	450
										XX	Water Cooler	1	650	24	15600
Bathroom	I	8	18	6	864										0
	H	2	60	6	720										0
	I	7	18	6	756										0
rectors office						1	laptop	6	450	AB		1	25	6	150
										AD		1	1000	1.5	1500
										S		1	275	24	6600

Individual Room Data - Floor 2 (4 of 5)															
Building:	*Academic Building 1*							**Floor:**	*2*						
	Lighting					**Computers**				**Other Appliances**					
Room Number	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
closet (2 of the same)	H	1	60	6	360					S		1	275	24	6600
	I	1	18	6	108					AC		1	1200	1.5	1800
220 - office with 2 adjacent rooms	F	6	80	6	2880	6		6	3708	AB		5	25	6	750
						1		6	618	AC		3	1200	1.5	5400
						1		6	618	O		1	1050	0.5	525
										XX	Water Cooler	1	650	24	15600
221 - comp room	F	9	80	6	4320	12		6	7416						0
															0
225 - hallway/class?, offices	F	10	80	6	4800	0		6	0	AB		5	25	6	750
	F	2	80	6	960	1		6	618	AC		1	1200	1.5	1800
						4		6	2472	O		1	1050	0.5	525
						3		6	1854	S		1	275	24	6600
226a - office	H	12	60	6	4320	1		6	618						0
															0
226 - office	F	4	80	6	1920	3		6	1854	AC		2	1200	1.5	3600
										AB		2	25	6	300
										S		1	275	24	6600

Individual Room Data - Floor 2 (5 of 5)															
Building:	*Academic Building 1*								**Floor:**	*2*					
Room Number	**Lighting**					**Computers**				**Other Appliances**					
	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
228a - classroom	F	2	80	6	960	0		6	0						0
															0
228 - office	F	4	80	6	1920	6		6	3708	AB		3	25	6	450
										AC		2	1200	1.5	3600
										O		1	1050	0.5	525
										S		1	275	24	6600
										XX	Water Cooler	1	650	24	15600

Individual Room Data - 2.5 (1 of 1)															
Building:	*Academic Building 1*								**Floor:**	*2.5*					
Room Number	**Lighting**					**Computers**				**Other Appliances**					
	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
	F	4	80	24	7680					AA	LG, 47"	1	150	2	300
Lobby	D	40	12	24	11520										
	E	54	30	6	9720					AD		10	1000	1.5	15000
										XX	Projector	1			0
Auditorium										XX	Speakers	2	20	6	240

Individual Room Data - Floor 3 (1 of 4)

Building: *Academic Building 1* **Floor:** *3*

Room Number	Lighting					Computers				Other Appliances					
	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
Lobby	F	12	80	24	23040										
Left corridor	E	7	30	12	2520										
Right Corridor	E	7	30	12	2520										
300 - office	F	1	80	6	480	1		6	618	AB		1	25	1.5	37.5
301 - auditorium,	F	10	80	6	4800	1		6	618	XX	Projector	1			
	G	8	40	6	1920										
	G1	12	80	6	5760										
302 - office	G1	1	80	6	480	1		6	618	AD		1	1000	1.5	1500
303 - locked															
304 - office	F	10	80	6	4800	6		6	3708	AB		3	25	6	450
						1		6	618	S		1	275	24	6600
										O		1	1050	0.5	525
										AC		1	1200	1.5	1800
										XX	Water Cooler	1	650	24	15600

Individual Room Data - Floor 3 (2 of 4)															
Building:	*Academic Building 1*							**Floor:**	*3*						
Room Number	**Lighting**					**Computers**				**Other Appliances**					
	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
	F	6	80	6	2880	1		6	618	XX	Projector	1			
305 - class										AD		1	1000	1.5	1500
306a - conference	F	2	80	6	960	0		6	0						
306 - lecture hall	F	12	80	6	5760	1		6	618	XX	Projector	1			
	F	6	80	6	2880	1		6	618	AA	Panasonic, 72"	3	150	2	900
										XX	Water Cooler	1	650	24	15600
307 - class										AD		1	1000	1.5	1500
308 - classroom	F	6	80	6	2880	5		6	3090	AB		1	25	6	150
	F	3	80	6	1440	2		6	1236	AD		1	1000	1.5	1500
309 - office										AB		1	25	6	150
	I	6	18	6	648	4		6	2472	O		1	1050	0.5	525
	I	12	40	6	2880					S		1	275	24	6600
										AB		2	25	6	300
310 - office										AC		1	1200	1.5	1800

Individual Room Data - Floor 3 (3 of 4)															
Building:	*Academic Building 1*							**Floor:**	*3*						
Room Number	**Lighting**					**Computers**				**Other Appliances**					
	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
311 - conference room	F	3	80	6	1440	1		6	618	AD		1	1000	1.5	1500
										AB		1	25	6	150
Bathroom	I	7	18	6	756										
312 - office	F	6	80	6	2880	5		6	3090	AB		5	25	6	750
										S		1	275	24	6600
										O		1	1050	0.5	525
313a - office	F	2	80	6	960	3		6	1854	AB		3	25	6	450
										AC		1	1200	1.5	1800
										AD		1	1000	1.5	1500
										O		1	1050	0.5	525
313 - office	F	4	80	6	1920	3		6	1854	AB		4	25	6	600
	E	2	30	6	360	1		6	618	AC		2	1200	1.5	3600
						1	laptop	6	450	O		1	1050	0.5	525
314 - class	F	6	80	6	2880	1		6	618	XX	Projector	1			
315 - class	F	12	80	6	5760	1		6	618	XX	Projector	1			
										AD		1	1000	1.5	1500

Individual Room Data - Floor 3 (4 of 4)																
Building:	*Academic Building 1*								**Floor:**	*3*						
Room Number	**Lighting**					**Computers**				**Other Appliances**						
	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
316 - class	F	12	80	6	5760	1		6	618	XX	Projector	1			
										AD		1	1000	1.5	1500
318 -	F	1	80	6	480										
Women's Bathroom	I	8	18	6	864										
office	F	1	80	6	480					O		1	1050	0.5	525
										S		2	275	24	13200
320 - auditorium	G	10	40	6	2400	1		6	618	XX	Projector	1			
	G1	25	80	6	12000					AD		4	1000	1.5	6000

Individual Room Data - Floor 3.5 (1 of 1)															
Building:	*Academic Building 1*								**Floor:**	*3.5*					
Room Number	**Lighting**					**Computers**				**Other Appliances**					
	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
Lobby	F	2	80	24	3840										
425	F	9	80	6	4320	1		6	618	AB		1	25	6	150
						2		6	1236	O		1	1050	0.5	525
										AD		1	1000	1.5	1500
										AD		1	1000	1.5	1500
										AB		1	25	6	150
										S		1	275	24	6600
Department Office	F	3	80	6	1440										

Individual Room Data - Floor 4 (1 of 4)															
Building:	*Academic Building 1*								**Floor:**	*4*					
Room Number	**Lighting**					**Computers**				**Other Appliances**					
	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
Lobby	F	6	80	24	11520										
Left Corridor	E	7	30	12	2520										
Right Corridor	E	7	30	12	2520										
Left Stairs	G	6	40	6	1440										
Right Stairs	G	7	40	6	1680										
400 - office	F	2	80	6	960	4		6	2472	AB		2	25	6	300
						3		6	1854	XX	Water Cooler	2	650	24	31200
										AD		1	1000	1.5	1500
										S		1	275	24	6600
401	F	4	80	6	1920										

Individual Room Data - Floor 4 (2 of 4)															
Building:	*Academic Building 1*								**Floor:**	*4*					
	Lighting					**Computers**				**Other Appliances**					
Room Number	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
402 - conference/AV room	F	12	80	6	5760	2	Apple	6	1236	AA	Philips, 57"	2	150	2	600
						10		6	6180	AB		3	25	6	450
						12		6	7416	AD		1	1000	1.5	1500
										XX	Stand Fan	1			
										XX	Water Cooler	1	650	24	15600
404 - office	F	3	80	6	1440	5		6	3090	AC		1	1200	1.5	1800
										AB		4	25	6	600
405 - class	F	9	80	6	4320	15		6	9270	AD		2	1000	1.5	3000
406 - office	F	3	80	6	1440	7		6	4326	AC		1	1200	1.5	1800
										AB		1	25	6	150
407 - class	F	6	80	6	2880	15		6	9270	AD		2	1000	1.5	3000
										AC		1	1200	1.5	1800
408 - connected to 410	F	3	80	6	1440	5		6	3090						
409- office	F	8	80	6	3840	6		6	3708	AB		4	25	6	600
										AD		1	1000	1.5	1500
										XX	Water Cooler	1	650	24	15600
410 - office	F	3	80	6	1440	6				AC		2	1200	1.5	3600
										AB		4	25	6	600
										O		1	1050	0.5	525

Individual Room Data - Floor 4 (3 of 4)															
Building:	*Academic Building 1*							**Floor:**	*4*						
Room Number	**Lighting**					**Computers**				**Other Appliances**					
	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
412 - office	F	4	80	6	1920	3		6	1854	AC		1	1200	1.5	1800
						1	laptop	6	450	AB		1	25	6	150
										O		1	1050	0.5	525
413 - comp room	F	8	80	6	3840	13		6	8034	AC		1	1200	1.5	1800
										AD		1	1000	1.5	1500
415 - locked	F	3	80	6	1440										
417 - office	F	6	80	6	2880	5		6	3090	AB		3	25	6	450
										AD		1	1000	1.5	1500
										O		1	1050	0.5	525
418 - office	F	9	80	6	4320	6		6	3708	AB		9	25	6	1350
	I	12	18	6	1296	3		6	1854	AC		3	1200	1.5	5400
						2		6	1236	S		1	275	24	6600
										XX	Water Cooler	2	650	24	31200
419 - office	F	4	80	6	1920										
422 - office						1		6	618						

Individual Room Data - Floor 4 (4 of 4)

Building:	*Academic Building 1*								**Floor:**	*4*					
Room Number	**Lighting**					**Computers**				**Other Appliances**					
	TC	#	W	hr/day	ΣWh/day	#	Brand	hr/day	ΣWh/day	TC	Note/Brand	#	W	hr/day	ΣWh/day
424 - study room	F	6	80	6	2880	11		6	6798	AC		2	1200	1.5	3600
										AB		1	25	6	150
426 - office	H	8	60	6	2880	4		6	2472	AC		2	1200	1.5	3600
	I	16	18	6	1728	1		6	618	AB		2	25	6	300
	D	24	12	6	1728					AA	Samsung, 42"	1	150	2	300
428 - comp lab	F	11	80	6	5280	15		6	9270	XX	Projector	1			
										AC		2	1200	1.5	3600
429	F	4	80	6	1920	3		6	1854	AC		2	1200	1.5	3600
						1	laptop	6	450						

Appendix E. - Lighting Recommendations

Cost of Replacement*							
	Cost (Rubles)		Academic Building	Hostel 3	Hostel 1	All Buildings	
Light Bulbs	Per Unit	Installation*	Quantity			Quantity	Total (Rubles)
Armstrong	1,100	150	501	157	66	724	905,000
DPO 2x9	900	120	35	46	64	145	147,900
DPO 2x18	1,100	120	131	399	0	530	646,600
DBP 7w	450	25	74	269	35	378	179,550
E27 7	180	25	182	72	716	970	198,850
G4 LED	150	25	395	0	0	395	69,125
Total							**2,147,025**

Table E.1: Estimated costs of each replacement bulb.

*Installation cost includes the cost of disposing old bulbs as well as maintenance costs.

Energy Consumption Comparison for Efficient Bulb						
Building	Academic Building		Hostel 3		Hostel 1	
Floor	**Current (W)**	**Replacement (W)**	**Current (W)**	**Replacement (W)**	**Current (W)**	**Replacement (W)**
Ground	35,400	15,432	15,840	15,840	29,520	9,948
1	104,736	49,254	99,384	49,992	41,988	15,330
1.5	42,240	16,440	N/A	N/A	N/A	N/A
2	130,572	49,626	106,776	65,364	25,488	8,754
2.5	28,920	15,192	N/A	N/A	N/A	N/A
3	105,588	45,300	78,312	36,150	43,260	14,466
3.5	9,600	3,240	N/A	N/A	N/A	N/A
4	79,152	29,928	93,888	40,674	34,548	13,734
5	N/A	N/A	90,768	38,220	39,996	14,964
Total	536,208	224,412	484,968	246,240	214,800	77,196

Table E.2: Comparing the energy consumption of the current light bulbs to the new more efficient bulbs.

Cost Comparison for Efficient Bulb						
Building:	**Academic Building 1**		**Current**		**Replacement**	
Period	**Days***	**Rubles/kWh****	**kWh/day**	**Cost (Rubles)**	**kWh/day**	**Cost (Rubles)**
Sept 2016 - Dec 2016	120	4.50	536	289,552	224	121,182
Jan 2017 - Jun 2017	185	4.95	536	491,032	224	205,505
Jul 2017 - Aug 2017	60	4.95	107	31,850	45	13,330
Yearly Total				**812,435**		**340,018**
Sept 2017 - Dec 2017	120	4.95	536	318,508	224	133,301
Jan 2018 - Jun 2018	185	5.45	536	540,632	224	226,263
Jul 2018 - Aug 2018	60	5.45	107	35,067	45	14,677
Yearly Total				**894,207**		**374,241**
Sept 2018 - Dec 2018	120	5.45	536	350,680	224	146,765
Jan 2019 - Jun 2019	185	6.00	536	595,191	224	249,097
Jul 2019 - Aug 2019	60	6.00	107	38,606	45	16,158
Yearly Total				**984,477**		**412,020**

Table E.3: Comparing the cost of running current light bulbs to the new more efficient bulbs for the next three years in Academic Building 1.
*It was estimated that the total consumption is reduced to 20% during the summer.
**It was estimated that the price will inflate by 10% each year.

Cost Comparison for Efficient Bulb						
Building:	**Hostel 3**		**Current**		**Replacement**	
Period	**Days***	**Rubles/kWh****	**kWh/day**	**Cost (Rubles)**	**kWh/day**	**Cost (Rubles)**
Sept 2016 - Dec 2016	120	4.50	486	262,423	246	132,970
Jan 2017 - Jun 2017	185	4.95	486	445,025	246	225,494
Jul 2017 - Aug 2017	60	4.95	97	28,866	49	14,627
Yearly Total				**736,314**		**373,091**
Sept 2017 - Dec 2017	120	4.95	486	288,665	246	146,267
Jan 2018 - Jun 2018	185	5.45	486	489,977	246	248,271
Jul 2018 - Aug 2018	60	5.45	97	31,782	49	16,104
Yearly Total				**810,425**		**410,642**
Sept 2018 - Dec 2018	120	5.45	486	317,823	246	161,041
Jan 2019 - Jun 2019	185	6.00	486	539,424	246	273,326
Jul 2019 - Aug 2019	60	6.00	97	34,990	49	17,729
Yearly Total				**892,237**		**452,097**

Table E.4: Comparing the cost of running current light bulbs to the new more efficient bulbs for the next three years in Hostel 3.

*It was estimated that the total consumption is reduced to 20% during the summer.

**It was estimated that the price will inflate by 10% each year.

Cost Comparison for Efficient Bulb						
Building:	**Hostel 1**		**Current**		**Replacement**	
Period	**Days***	**Rubles/kWh****	**kWh/day**	**Cost (Rubles)**	**kWh/day**	**Cost (Rubles)**
Sept 2016 - Dec 2016	120	4.50	215	115,992	77	41,686
Jan 2017 - Jun 2017	185	4.95	215	196,703	77	70,692
Jul 2017 - Aug 2017	60	4.95	43	12,759	16	4,604
Yearly Total				**325,454**		**116,982**
Sept 2017 - Dec 2017	120	4.95	215	127,591	77	45,854
Jan 2018 - Jun 2018	185	5.45	215	216,572	77	77,833
Jul 2018 - Aug 2018	60	5.45	43	14,048	16	5,069
Yearly Total				**358,211**		**128,756**
Sept 2018 - Dec 2018	120	5.45	215	140,479	77	50,486
Jan 2019 - Jun 2019	185	6.00	215	238,428	77	85,688
Jul 2019 - Aug 2019	60	6.00	43	15,466	16	5,580
Yearly Total				**394,373**		**141,754**

Table E.5: Comparing the cost of running current light bulbs to the new more efficient bulbs for the next three years in Hostel 1.

*It was estimated that the total consumption is reduced to 20% during the summer.

**It was estimated that the price will inflate by 10% each year.

Total Daily Energy Consumption Comparison for Efficient Bulbs			
	Current	Replacement	
Building	kWh/day		Percent Savings
Academic Building 1	1,802	1,490	
Hostel 3	1,180	941	
Hostel 1	1,203	1,065	
Total	4,185	3,496	16.46%

Table E.6: Daily energy consumption comparison from current bulbs to more efficient bulbs.

Appendix F. - Motion Sensor Recommendations

Lighting Energy Consumption Comparison for Motion Sensors						
	Current			Replacement*		
Building	With Motion Sensors	Without Motion Sensors	Total	With Motion Sensors	Without Motion Sensors	Total
Academic Building 1	148	388	536	129	388	517
Dorm 1	97	118	215	84	118	202
Dorm 3	153	348	501	133	348	481

Table F.4: Table demonstrating the reduction in energy.
*Based on reported savings of motion sensors, our team assumed the motion sensors would reduce the total lighting consumption by 13% (CMU, 2013).

Cost Comparison for Motion Sensors						
Building:	Academic Building 1		Current		Replacement	
Period	Days*	Rubles/kWh**	kWh/day	Cost (Rubles)	kWh/day	Cost (Rubles)
Sept 2016 - Dec 2016	120	4.50	536	289,552	517	279,045
Jan 2017 - Jun 2017	185	4.95	536	491,032	517	473,214
Jul 2017 - Aug 2017	60	4.95	107	31,850	103	30,695
Yearly Total				**812,435**		**782,954**
Sept 2017 - Dec 2017	120	4.95	536	318,508	517	306,950
Jan 2018 - Jun 2018	185	5.45	536	540,632	517	521,013
Jul 2018 - Aug 2018	60	5.45	107	35,067	103	33,795
Yearly Total				**894,207**		**861,758**
Sept 2018 - Dec 2018	120	5.45	536	350,680	517	337,955
Jan 2019 - Jun 2019	185	6.00	536	595,191	517	573,593
Jul 2019 - Aug 2019	60	6.00	107	38,606	103	37,206
Yearly Total				**984,477**		**948,753**
Installation Cost* **				**0**		**79,464**

Table F.5: Comparing the current scenario with using motion sensors for the next three years in Academic Building 1.

*It was estimated that the total consumption is reduced to 20% during the summer.

**It was estimated that the price will inflate by 10% each year.

***This represents the total cost of installing the motion sensors.

Cost Comparison for Motion Sensors						
Building:	**Hostel 3**		**Current**		**Replacement**	
Period	**Days***	**Rubles/kWh****	**kWh/day**	**Cost (Rubles)**	**kWh/day**	**Cost (Rubles)**
Sept 2016 - Dec 2016	120	4.50	486	262,423	481	259,718
Jan 2017 - Jun 2017	185	4.95	486	445,025	481	440,439
Jul 2017 - Aug 2017	60	4.95	97	28,866	96	28,568
Yearly Total				**736,314**		**728,726**
Sept 2017 - Dec 2017	120	4.95	486	288,665	481	285,690
Jan 2018 - Jun 2018	185	5.45	486	489,977	481	484,928
Jul 2018 - Aug 2018	60	5.45	97	31,782	96	31,454
Yearly Total				**810,425**		**802,072**
Sept 2018 - Dec 2018	120	5.45	486	317,823	481	314,548
Jan 2019 - Jun 2019	185	6.00	486	539,424	481	533,866
Jul 2019 - Aug 2019	60	6.00	97	34,990	96	34,628
Yearly Total				**892,237**		**883,042**
Installation Cost***				**0**		**94,600**

Table F.6: Comparing the current scenario with using motion sensors for the next three years in Hostel 3.
*It was estimated that the total consumption is reduced to 20% during the summer.
**It was estimated that the price will inflate by 10% each year.
***This represents the total cost of installing the motion sensors.

Cost Comparison for Motion Sensors						
Building:	**Hostel 1**		**Current**		**Replacement**	
Period	**Days***	**Rubles/kWh****	**kWh/day**	**Cost (Rubles)**	**kWh/day**	**Cost (Rubles)**
Sept 2016 - Dec 2016	120	4.50	215	115,992	202	109,193
Jan 2017 - Jun 2017	185	4.95	215	196,703	202	185,174
Jul 2017 - Aug 2017	60	4.95	43	12,759	40	12,011
Yearly Total				**325,454**		**306,378**
Sept 2017 - Dec 2017	120	4.95	215	127,591	202	120,113
Jan 2018 - Jun 2018	185	5.45	215	216,572	202	203,878
Jul 2018 - Aug 2018	60	5.45	43	14,048	40	13,224
Yearly Total				**358,211**		**337,215**
Sept 2018 - Dec 2018	120	5.45	215	140,479	202	132,245
Jan 2019 - Jun 2019	185	6.00	215	238,428	202	224,453
Jul 2019 - Aug 2019	60	6.00	43	15,466	40	14,558
Yearly Total				**394,373**		**371,257**
Installation Cost***				**0**		**54,868**

Table F.7: Comparing the current scenario with using motion sensors for the next three years in Hostel 1.
*It was estimated that the total consumption is reduced to 20% during the summer.
**It was estimated that the price will inflate by 10% each year.
***This represents the total cost of installing the motion sensors.

Lighting Energy Consumption Comparison for Motion Sensors						
	Current			Replacement*		
Building	With Motion Sensors	Without Motion Sensors	Total	With Motion Sensors	Without Motion Sensors	Total
Academic Building 1	148	388	536	129	388	517
Dorm 1	97	118	215	84	118	202
Dorm 3	153	348	501	133	348	481

Table F.8: Comparing the reduction in total energy in all three buildings. The total savings will be approximately 1%.

Appendix F.1. - Criteria for Implementing Motion Sensors

Rooms Where Motion Sensors Will Be Installed					
Building	**Academic Building 1**		**Current Lighting**		
Floor	**Type***	**Sensors Needed**	**Watts**	**hrs/day**	**Wh/day**
1	Lobby	0	888	24	21,312
1	Corridor	8	920	12	11,040
1	Men's locker	1	360	6	2,160
1	Women's locker	1	360	6	2,160
1	Toilet	1	144	6	864
1.5	Lobby	1	320	24	7,680
2	Lobby	1	960	24	23,040
2	Corridor	8	680	12	8,160
2	Toilets	3	390	6	2,340
2.5	Lobby	1	800	24	19,200
3	Lobby	1	960	24	23,040
3	Corridor	6	420	12	5,040
3	Toilets	2	270	6	1,620
3.5	Lobby	1	160	24	3,840
4	Lobby	1	480	24	11,520
4	Corridor	6	420	12	5,040
Total		**42**			**148,056**

Table F.1: Table tallying the amount of motion sensors needed to be installed in Academic Building 1. *Only certain rooms were estimated to contain sensors, such as bathrooms and hallways.

Rooms Where Motion Sensors Will Be Installed					
Building	**Hostel 1**		**Current Lighting**		
Floor	**Type***	**Sensors Needed**	**Watts**	**hrs/day**	**Wh/day**
1	Lobby	0	616	24	14,784
1	Corridor	5	680	12	8,160
2	Lobby	1	320	24	7,680
2	Corridor	5	440	12	5,280
3	Lobby	1	600	24	14,400
3	Corridor	5	740	12	8,880
4	Lobby	1	508	24	12,192
4	Corridor	5	320	12	3,840
5	Lobby	1	400	24	9,600
5	Corridor	5	1,000	12	12,000
Total		**29**			**96,816**

Rooms Where Motion Sensors Will Be Installed					
Building	**Hostel 3**		**Current Lighting**		
Floor	**Type***	**Sensors Needed**	**Watts**	**hrs/day**	**Wh/day**
1	Lobby	0	760	24	18,240
1	Corridor	3	1,040	12	12,480
2	Lobby	1	320	24	7,680
2	Corridor	7	1,960	12	23,520
2	Toilets	2	348	6	2,088
3	Lobby	1	480	24	11,520
3	Corridor	7	1,120	12	13,440
3	Toilets	2	320	6	1,920
3	Showers	2	600	6	3,600
3	Washroom	1	160	6	960
4	Lobby	1	320	24	7,680
4	Corridor	7	920	12	11,040
4	Toilets	2	348	6	2,088
4	Shower	1	240	6	1,440
4	Washroom	1	180	6	1,080
5	Lobby	1	720	24	17,280
5	Corridor	7	1,040	12	12,480
5	Toilets	2	348	6	2,088
5	Shower	1	240	6	1,440
5	Washroom	1	100	6	600
Total		**50**			**152,664**

Table F.2&3: Table tallying the amount of motion sensors needed to be installed in Hostel 1 &3.
*Only certain rooms were estimated to contain sensors, such as bathrooms and hallways.

Appendix G. - Siemens System Recommendations

Lighting Energy Consumption Comparison for Siemens System		
	Current	Replacement*
Building	Total	Total
Dorm 1	215	183
Dorm 3	501	426
Academic Building 1	536	456

Cost Comparison for Siemens System						
Building:	**Academic Building 1**		**Current**		**Replacement**	
Period	**Days***	**Rubles/kWh****	**kWh/day**	**Cost (Rubles)**	**kWh/day**	**Cost (Rubles)**
Sept 2016 - Dec 2016	120	4.50	536	289,552	456	246,121
Jan 2017 - Jun 2017	185	4.95	536	491,032	456	417,381
Jul 2017 - Aug 2017	60	4.95	107	31,850	91	27,075
Yearly Total				**812,435**		**690,576**
Sept 2017 - Dec 2017	120	4.95	536	318,508	456	270,733
Jan 2018 - Jun 2018	185	5.45	536	540,632	456	459,540
Jul 2018 - Aug 2018	60	5.45	107	35,067	91	29,809
Yearly Total				**894,207**		**760,083**
Sept 2018 - Dec 2018	120	5.45	536	350,680	456	298,080
Jan 2019 - Jun 2019	185	6.00	536	595,191	456	505,916
Jul 2019 - Aug 2019	60	6.00	107	38,606	91	32,818
Yearly Total				**984,477**		**836,814**

Cost Comparison for Siemens System						
Building:	**Hostel 3**		**Current**		**Replacement**	
Period	**Days***	**Rubles/kWh****	**kWh/day**	**Cost (Rubles)**	**kWh/day**	**Cost (Rubles)**
Sept 2016 - Dec 2016	120	4.50	486	262,423	426	229,873
Jan 2017 - Jun 2017	185	4.95	486	445,025	426	389,826
Jul 2017 - Aug 2017	60	4.95	97	28,866	85	25,287
Yearly Total				**736,314**		**644,985**
Sept 2017 - Dec 2017	120	4.95	486	288,665	426	252,860
Jan 2018 - Jun 2018	185	5.45	486	489,977	426	429,202
Jul 2018 - Aug 2018	60	5.45	97	31,782	85	27,841
Yearly Total				**810,425**		**709,903**
Sept 2018 - Dec 2018	120	5.45	486	317,823	426	278,401
Jan 2019 - Jun 2019	185	6.00	486	539,424	426	472,516
Jul 2019 - Aug 2019	60	6.00	97	34,990	85	30,650
Yearly Total				**892,237**		**781,568**

Cost Comparison for Siemens System						
Building:	**Hostel 1**		**Current**		**Replacement**	
Period	**Days***	**Rubles/kWh****	**kWh/day**	**Cost (Rubles)**	**kWh/day**	**Cost (Rubles)**
Sept 2016 - Dec 2016	120	4.50	215	115,992	183	98,593
Jan 2017 - Jun 2017	185	4.95	215	196,703	183	167,198
Jul 2017 - Aug 2017	60	4.95	43	12,759	37	10,846
Yearly Total				**325,454**		**276,637**
Sept 2017 - Dec 2017	120	4.95	215	127,591	183	108,453
Jan 2018 - Jun 2018	185	5.45	215	216,572	183	184,086
Jul 2018 - Aug 2018	60	5.45	43	14,048	37	11,942
Yearly Total				**358,211**		**304,481**
Sept 2018 - Dec 2018	120	5.45	215	140,479	183	119,407
Jan 2019 - Jun 2019	185	6.00	215	238,428	183	202,664
Jul 2019 - Aug 2019	60	6.00	43	15,466	37	13,147
Yearly Total				**394,373**		**335,218**

Daily Energy Consumption Comparison for Siemens System			
	Current	**Replacement**	
Building	**kWh/day**		**Percent Savings**
Academic Building 1	1,802	1,722	
Hostel 3	1,180	1,107	
Hostel 1	1,203	1,171	
Total	4,185	4,000	4.42%

Appendix H. - Piezoelectric Floor

Assumptions for Piezoelectric Flooring Tile

Piezoelectric Flooring Assumptions and Analysis	
Cost of Piezoelectric flooring ($/ft^2)	75
Exchange Rate*	62.48
Cost of Piezoelectric flooring (Rubles/ft^2)	4686
Area in front of door way (ft^2)	12
Amount of people crossing floor per day	3000
Amount of steps per person	20
Energy generated per step (W)	5
Total Energy generated per day (Wh)	100
Days used per year	230
Energy generated per year (kWh)	23

Table H.1: Assumptions used in estimating the price of implementing the Piezoelectric Flooring in the main entrance of Academic Building 1.

*Current exchange rate between dollars and rubles as of October 5, 2016.

Appendix I. - Vertical Garden System

Assumptions for Vertical Garden System

The Vertical Garden System is to be installed in Academic Building #1	
The total area of the wall in Academic Building 1* (m^2)	1,416
Total area covered by windows* (m^2)	121
Total area to be covered by the garden (m^2)	1,294
Total area to be covered by the garden (ft^2)	13,932
Cost ($/$ft^2$)**	130
Cost (Rub/ft^2)	8,123
Total cost (Rubles)	113,163,970

Table I.1: Assumptions used in estimating the price of the Vertical Garden System.

*Estimated from floor plans.

**Average price range from $95-160/$ft^2$

Appendix J. - Eco Machine

Analysis for Eco Machines

Eco Machines Analysis and Assumptions	
Estimated cost per machine (£)	14,285.70
Exchange Rate (Rubles/£)*	79.5204
Estimated cost per machine (Rubles)	1136004.6
Number of machines	5
Total cost (Rubles)	5680023
Average energy produced per machine per hour (Wh)	100
Time each machine would work per day (hrs)	7
Total energy produced by 5 machines per day (kWh)	3.5
Days per year the gym is open (days)	300
Total electricity produced in a year (kWh)	105
Price of 105 kWh of electricity (Rubles)	472.5

Table J.1: Assumptions used in estimating the price of implementing the Eco Machines in the gym.
*Current exchange rate between pounds and rubles as of October 5, 2016.