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Identification of energy saving potentials of the government infrastructure of the city of Savannah

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Abstract

Reducing energy consumption is an important step to stabilize shaky budgets, even more in such financially unpredictable times like lately. This is one reason why the city of Savannah takes important steps to be a forerunner in energy efficiency. Already in 2008 the city accepted the governor's energy challenge and committed itself to reduce the energy consumption by 15 percent until 2020 based on 2007 consumption data. Another important step was the decision to support and host the Savannah International Clean Energy Conference. As part of this conference cooperation between the city of Savannah, the University of Applied Sciences Upper Austria and the Georgia Institute of Technology was established and a student exchange was organized.

The key part of the exchange program was the identification and evaluation of energy saving opportunities. The hot and humid climate in Savannah with its resulting heating and cooling patterns, building construction methods and equipment selection was a main issue. The results of the exchange program have been presented at the Savannah International Clean Energy Conference.

Historic consumption data of the city's infrastructure was analyzed to identify sample buildings for further investigations. The final list was presented during a committee meeting and allowance for four buildings was granted. Detailed data concerning lighting, heating and cooling systems and other equipment has been gathered during two on-site visits in each building. User patterns were analyzed with data loggers and illumination levels have been metered to evaluate saving measures.

A list of energy saving opportunities highlight easy to accomplish and high profitable retrofits and upgrades. Outstanding payback times for lighting control measures were identified. Savings due to lighting control for all 4 buildings sum up to nearly $280{,}000\,kWh$ or more than $\$25{,}000$ per year.

Incremental payback periods for heating and cooling systems of less than 6 years were identified.

Implementation opportunities for renewable energy sources into the existing infrastructure in Savannah are listed. Ground source heat pump systems are a key to reduce energy consumption without reducing human comfort. Photovoltaic systems help to utilize the high solar radiation levels in Savannah and produce energy close by the customer.

Based on the results of the energy audit general approaches discussed. Efficient lighting technologies along with lighting control systems are the key to reduce consumption in existing buildings and new constructions. Lifetime cost based decisions ensure savings in the long term. Renewable energy implementation into existing buildings does not necessarily reduce costs. Generally, energy saving measures have quicker payback periods than renewable energy utilization. Savannah has got high potentials to reduce energy consumption and therefore costs.

Conversion table

Table 1 shows conversion factors between the Inch-Pound (IP) and System International (SI) units used in this thesis. All energy saving opportunities are calculated in the United States Customary System Units (USCS). Within the thesis the American punctuation system is used. Therefore "," stands for the thousands separator and "." for the separation between pre decimal place and decimal place.

Table 1: Conversion table IP to SI and SI to IP units [Lechner, 2009]

From	To	Factor
$inches\ (in.)$	$millimeters\ (mm)$	25.4
$feet\ (ft)$	$meters\ (m)$	0.305
$yards\ (yd)$	$meters\ (m)$	0.914
$miles\ (mi)$	$kilometers\ (km)$	1.61
ft^2	m^2	0.0929
mi^2	km^2	2.59
$\frac{British\ thermal\ unit\ (Btu)}{h}\ \frac{Btu}{h}$	$Watt\ (W)$	0.293
$therms$	BTU	100,000
ton	kW	3.5169
$MMBtu$	kWh	293
$\frac{\$}{MMBtu}$	$\frac{¢}{kWh}$	0.3412
$US\ gallons$	$liters$	3.79
$quarts$	$liters$	0.946
$\frac{m}{s}$	mph	2.24
$footcandle$	lux	10.8
F	C	$-32\ *\frac{5}{9}$
C	K	$+273.15$

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1 Introduction and scope

Communities worldwide as well as companies and institutions face difficult financial times. The inconsistent financial market situation forces extensive economics. Making redundancies will not remedy shortcomings on the long term due to already high unemployment rates and resulting social problems. Other approaches have to be identified.

The city of Savannah addressed its high energy expenses. The enormous amount of infrastructure owned by the city account for huge energy expenses. Already in 2008 the city committed itself to energy saving by accepting the Governor's Energy Challenge. To cut 2007 energy consumption by 15 percent until 2020 is the main goal. This first step encourages the city's objective to become a forerunner in Energy topics.

Beginning with the first energy crisis during the 1970's the USA encouraged small and medium sized industrial enterprises to reduce their energy consumption. State universities offer free of charge energy audits for interested companies to reduce their costs and increase their competitive edge. During the recent financial difficulties energy audits get on a roll again. The outcome of energy audits helps companies to reduce their cost, save energy, work more efficient and furthermore help to protect the environment and therefore improve their reputation.

The city of Savannah is keen on performing energy audits to professionally escort the energy reduction target. Therefore the city hosted the first Savannah International Clean Energy Conference from November 11th – 13th, 2012. In view of occasion a fruitful cooperation between the city of Savannah, the Georgia Institute of Technology and the University of Applied Sciences, upper Austria has been established. This cooperation arranged an exchange program for three Austrian students to perform energy audits for city's infrastructure in collaboration with Georgia Institute of Technology.

2 Background

The chapter background will provide the necessary information to perform an energy audit. Different technologies and corresponding efficiency measures are provided. Renewable Energy sources are described as well as the rate structure of electricity and gas bills.

2.1 Savannah

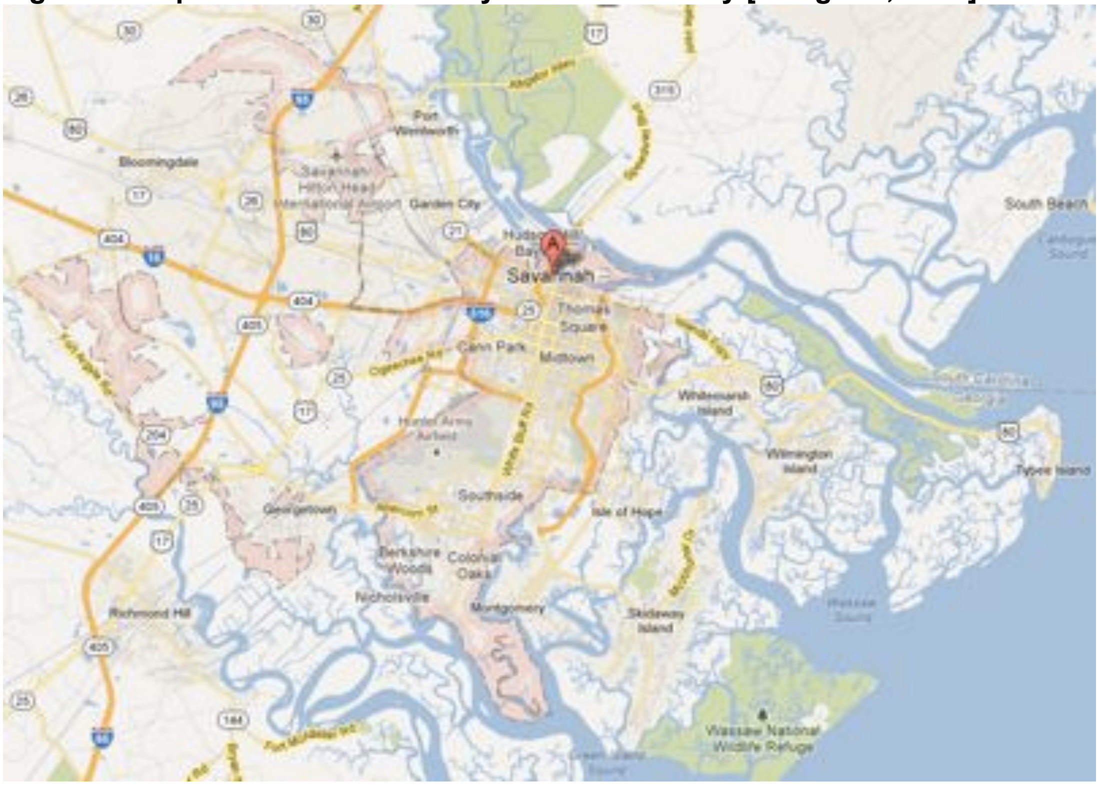
Savannah is a city located in the south east of the United States of America in the State of Georgia. The location on the map of the USA is shown in Figure 1 and the area of the city is displayed in Figure 2. The city is located next to the Savannah River and approximately 15 mi (25 km) on shore. The population in 2011 was estimated to be 139,491. The land area of the city covers 103.15 mi^2 (267.16 km^2). According to: [Census, 2012]

The average maximum temperature in Savannah in the year 2012 was 79°F (26.1°C) and the average minimum temperature was 57.7°F (14.3°C). The highest temperature of the year was 100°F (37.8°C) and the lowest temperature was 21°F (-6.1°C). The annual precipitation was 40.21 inches (1021 mm), which is 7,75 in (197 mm) below average. It was raining on 263 days in 2012. The average wind speed in 2012 was 6.7 mph (3 m/s).

According to: [NOAA, 2008]

Figure 1: Map of the United States of America [Google A, 2012]

Figure 2: Map of the area of the city of Savannah city [Google B, 2012]



2.2 Energy Audits

This section will give a definition of the term energy audit. The purpose of energy audits is highlighted and a classification of different facility assessments is provided. A step-by-step approach for a successful energy audit is presented.

2.2.1 Definition and purpose

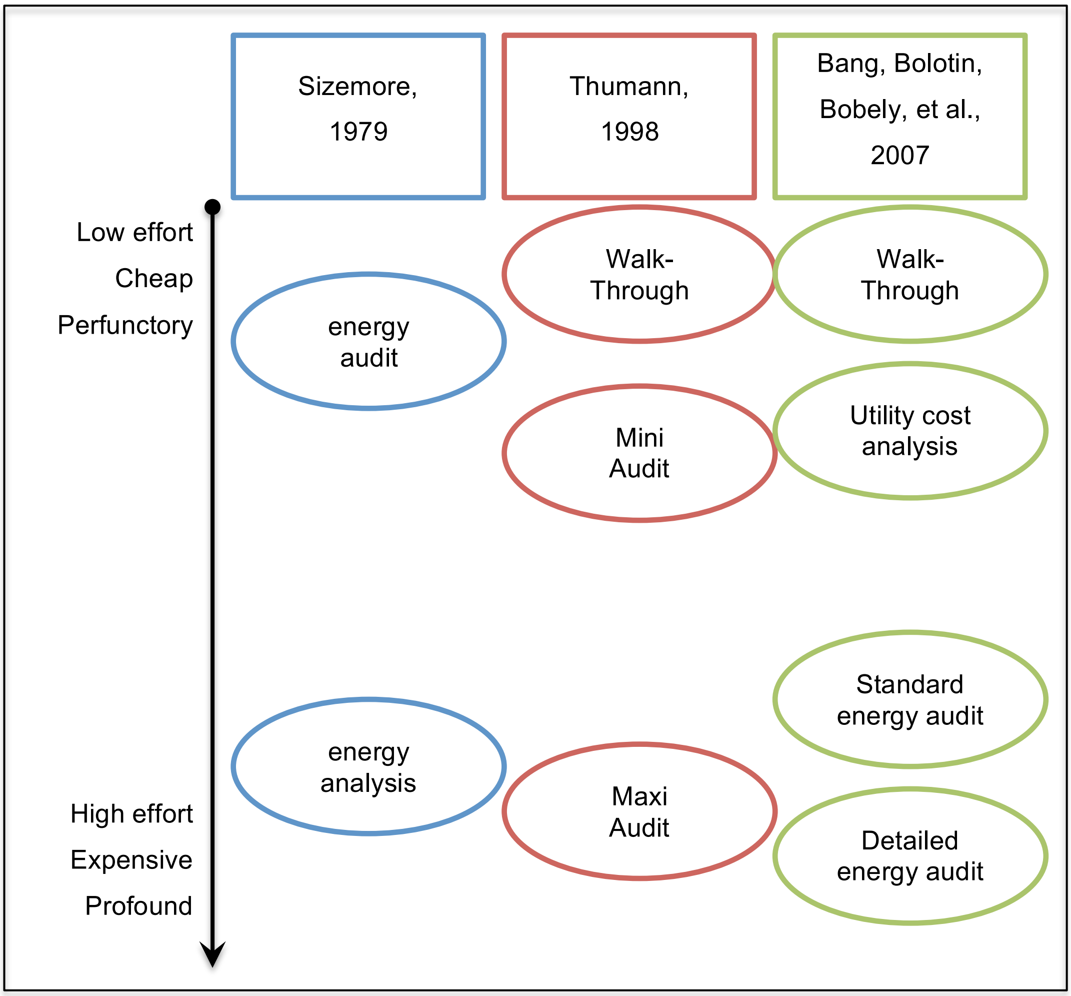
The term energy assessment is connected with different perceptions. Thumann defines energy audits in the following way: “An energy audit serves the purpose of identifying where a building or plant facility uses energy and identifies energy conservation opportunities.” [Thumann, 1998, p. 2] Turner describes the term energy audit as the first step towards an efficient energy cost control. Therefore the audit should define the way energy is used and the costs for energy. Furthermore some recommendations concerning the energy use or changes in the operating practices have to be added to highlight an efficient way to use energy. According to: [Turner, 2001, p. 21]

Both descriptions express that the energy use of a building is analyzed to derive some Energy Conservation Opportunities, short ECO’s. In some literature Energy Conservation Opportunities are called Energy Saving Opportunities, short ESO’s.

2.2.2 Classification of energy audits

The amount of ECO’s and the detail of the assessment can be segmented into different levels. In the literature you can basically find separations into two, three or four levels. The following chart gives an overview and shows the different profundity of different classifications.

Figure 3: Classification of energy assessment types



Sizemore defines an *energy audit* as first step for a full *energy analysis*. During an audit the past utility bills are compared with a simulation of the energy use. The occurring differences will lead to energy conservation opportunities. The results of the *energy audit* can help to zero in on specific areas of the building. *Energy analysis* will require a walk through the building, interviews with involved employees as well as measurements to be able to calculate costs and benefits of different energy conservation opportunities. According to: [Sizemore, 1979, p. 30f]

Thumann introduces three basic classifications of energy audits as shown in Figure 3. The *Walk-Through* gives a first impression of the audit site. This visual inspection results in first energy saving opportunities and determines subjects for further analysis. *Mini-Audits* and *Maxi-Audits* require tests and measurements to identify feasible energy conservation opportunities. The

Maxi-Audit includes detailed energy flow analysis and computer simulations to be able to predict the future energy consumption. [Thumann, 1998, p. 2f]
Furthermore Thumann presents a classification model, which categorizes Audits based on their focus. He mentions Envelope, Functional (like Lighting, Heating, ventilation and air- conditioning), Process, Transportation or Utility Audits. According to: [Thumann, 1998, p. 7-10]
Krarti tiers energy audits into four categories. The on-site visit of a *walk-through* audit results in inexpensive energy conservation opportunities, mainly operation and maintenance measures recommendations. The *utility cost analysis* focuses on utility data to be able to distinguish energy saving potentials, peak demand, weather effects and pattern of energy consumption. Krarti writes about the *standard energy audit* as appraisal of cost and efficiency calculations of selected energy conservation opportunities. The detailed energy audit furthermore includes measurements of whole buildings or selected equipment and corresponding computer simulations. According to: [Bang, Bolotin, Bobely, et al., 2007, p. 16-4]
Even if Turner does not provide any classification model the concept goes hand in hand with Thumann, Sizemore and Krarti's approach. They coincide that any audit process starts with analysis of the utility bills and/or an on-site visit to be able to benchmark the focused system. The results are used to determine the needs for further measurements and tests. The more time and money spent the more detailed energy conservation opportunities will derive. First saving potentials will come up right after the first analysis. The accurate attention to details of different energy saving opportunities depends on the saving potentials and the implementation costs.
As another interesting fact the detail of the analysis increases over time. The help of computer simulation and electronic data evaluation are a main topic nowadays. By reducing the required time to look at numerous utility bills, utility cost analysis become more easily. According to: [Sizemore, 1979, p. 30f] [Thumann, 1998, p. 2f] [Turner, 2001, p. 21f] [Bang, Bolotin, Bobely, et al., 2007, p. 16-4]

2.2.3 Procedure of an energy audit

A profound energy audit of a building consists of different steps. These steps should be performed one by one. As every building and every audit is different these steps can be slightly different, not adequate at all or not performable in this order.

First of all the facility and utility data has to be analyzed. Therefore all energy bills for at least one year, better three years, should be collected and evaluated to identify energy use patterns and seasonal fluctuations. Furthermore the different fuel types and their purpose of use have to be identified. Additional the rate structure has to be understand to be able to calculate savings correctly. The design of the building and its size can be identified from architectural, mechanical or electrical drawings. According to: [Bang, Bolotin, Bobely, et al., 2007, p. 16-5] [Turner, 2001, p. 23]

Second the auditor or the auditing team should be introduced to the facility manager, maintenance supervisors and other responsible persons like a finance manager. During this meeting important information concerning the use of energy, the habits of the employees and operational hours has to be collected. Employees can also support the auditor with information about problems in the production process or inconvenient spots in the building, like to dark areas or to hot or cold temperatures. This will help to identify opportunities for ESO's. According to: [Bang, Bolotin, Bobely, et al., 2007, p. 16-5] [Turner, 2001, p. 26f]

Third a walk through the facility should be performed. This can be at the same time as the meeting. The purpose is not to collect detailed data. This should help to identify the main energy consumers, the current operating conditions. As much general information as possible should be collected. According to: [Bang, Bolotin, Bobely, et al., 2007, p. 16-5] [Turner, 2001, p. 27]

Fourth the auditor has to define possible ECO's. Ones they are defined further measurements have to be performed and more detailed data collected. The data should be categorized. Table 2 provides a guide what to look at and which data to look for during the collection of detailed data.

Table 2: Important aspects for collecting detailed data for an energy audit

Look at	Look for
Lighting	A detailed inventory list is important ➢ Type of fixture and lamp ➢ Wattages of lamps ➢ Ballast type ➢ Operation hours ➢ Light intensity of different areas ➢ Use patterns of rooms/areas
HVAC Equipment	Complete list of equipment including data concerning: ➢ Size ➢ Model number ➢ Age ➢ Fuel use ➢ Electrical specification ➢ Estimated operation hours ➢ Condition of parts (e.g. coils, filter, insulation) Air velocity measurement to define efficiency and tightness
Electric Motors	List of motors with more than 1 horsepower including: ➢ Size ➢ Model number ➢ Age ➢ Electrical characteristic ➢ Power factor ➢ Operation hours Current, Voltage and power factor should be measured for important motors (high operation hours or high power)
Water Heaters	All water heaters should be listed with data including: ➢ Type ➢ Size ➢ Model number ➢ Age ➢ Fuel use ➢ Water temperature ➢ Water used for

Waste Heat Sources	Location of waste heat Possibility for heat recovery Location of heat requirement
Peak Equipment Load	Electrically powered equipment with infrequent use patterns should be listed Main focus on equipment with possibility to shift consumption to off peak times (water heater, pumps for storages, heating and cooling devices)
Other Energy-Consuming Equipment	List of equipment with a substantial energy consumption, which is not listed above. Record all necessary data to define energy consumption and usage profile.

According to: [Turner, 2001, p. 27f]

As next step the energy use of the building should be simulated. Therefore a model has to be created with inputs of all collected data. The operating hours for lighting, HVAC systems and other equipment has to be edited. This model has to be calibrated to correspond the metered data. According to: [Bang, Bolotin, Bobely, et al., 2007, p. 16-5]

Finally the preliminary defined ECO's should be reviewed. A cost-benefit analyzes helps to evaluate the saving opportunities. Possible savings, estimated implementation costs and payback times should be provided in the final energy audit report. The cost saving potential should be defined with the use of the baseline simulation. According to: [Bang, Bolotin, Bobely, et al., 2007, p. 16-5] [Turner, 2001, p. 28]

Sizemore states "The degree of detail of analysis should reflect the level of savings possible for the item being analyzed." [Sizemore, 1979, p. 41] The detail of time invested in a saving opportunity should always consider the possible savings not only in financial aspects. The reduced amount of energy consumed should also be taken into account. The accuracy of the saving calculation and the simulation can never be exact and should be adapted to the anticipated saving potential. According to: [Sizemore, 1979, p. 41]

2.3 Lighting

This chapter describes how to quantify light and how to define the quality of light. A categorization of light sources including a brief description of these categories is presented. The advantages of the sun as light source are pronounced, best practice examples highlighted and techniques for new constructions provided.

2.3.1 Quantity and Quality

The quantity of light is easy to measure and can be expressed in different units. The primary units are the power input (W) and the light output ($Lumen$). Watt defines the electricity consumption, whereas Lumen defines the strength of a light source. Lumens can also be called Candela. According to: [Turner, 2001, p. 349f] [Lechner, 2009, p. 452]
To be able to compare different light sources the efficiency is used. The output divided by the input defines the quality of the source. The efficacy of a light source is defined with the unit Lumen per Watt ($\frac{lm}{W}$).

The light level, or illuminance, is defined as Lumen per area. The unit is called foot-candle (fc) if calculated in the P-I system and Lux if calculated in the SI system. In Formula 1 the calculation of both units as well as the corresponding conversion factor is displayed. A list of recommended illuminance levels for different areas published by the Illumination Engineering Society (IES) can be found in the appendix on page A. According to: [Lechner, 2009, p. 452] [Turner, 2001, p. 349f] [Thumann, 1998, p. 186]

Formula 1: Conversion from fc to lux [Lechner, 2009, p. 452 & 673]

$$fc = \frac{Lumen}{ft^2} * 10.8 \approx \frac{Lumen}{m^2} = Lux$$

The quality of light is more difficult to define and measure as quality is in the eye of the beholder. Basically two different units are most important.

The first one is the Coordinated Color Temperature (CCT) of the light source relative to a black body at a certain temperature. CCT is measured in degree Kelvin (K). Low temperatures of around 2000K appear red. Increasing the temperature will change the appearance into yellow into warm white (~4000K) into cold white (~5000K) and into bluish at above 6000K.
The second criterion is the Color Rendering Index (CRI). It defines how color appears under the given light source compared to a black body at the same color temperature. The range is between 0 and 100. A light source with a CRI above 75 is considered to be good, whereas CRI below 55 is considered to be weak. According to: [Turner, 2001, p. 352f] [Thumann, 1998, p. 186f]

2.3.2 Types of light sources

Electric light sources can be categorized into three different groups based on their technology. They are Incandescent, Discharge and Solid State. Each technology has got different advantages and disadvantages.
Incandescent (INC) is the oldest technology used. This category includes also halogen lamps. The technology has got a comparable low efficiency. It only converts about 7 percent of the power input into useful light. The lifetime is relatively short, but the CRI is excellent. The investment costs are low but the operational costs are high.
The category Discharge consists of Neon lamps, Fluorescent (FL) including Compact Fluorescent Lamps (CFL) as well as High Intensity Discharge (HID) lamps like mercury, Metal Halide (MH) and High Pressure Sodium (HPS). These types of lamps have got a medium to high efficiency and a medium to high lifetime. The CRI depends on the lamp and varies from poor to excellent. Investment costs are moderate and operation costs are lower than Incandescent. Most Discharge lamps require ballasts to control the supplied voltage and current. Magnetic and electronic ballasts are available. Turner states: “Electronic ballasts are superior to magnetic ballasts because they are typically 30 percent more energy efficient, they produce less lamp flicker, ballast noise, and waste heat.” [Turner, 2001, p. 357]

Solid State Lighting (SSL) is used in Light Emitting Diode (LED) and Organic LED (OLED). The efficiency and the CRI are medium to high. The investment costs are comparable high, but the operational costs are very low. This technology is developing quiet fast and has got good potential to become the main light source for buildings.

According to: [Turner, 2001, p. 354-358], [Lechner, 2009, p. 435-445]

Figure 4 shows the usual lumen per watt ranges of different light sources. Efficiencies above 60 Lumens per Watt for white LED's are state of the art in 2012. Lechner states: "SSL is extremely resistant to physical abuse and also very long-lasting. It is developing very rapidly, and it has the potential to become the ideal light source, with 200 lumens per watt for white light" [Lechner, 2009, p. 443f]

According to: [Lechner, 2009, p. 436]

Figure 4: Lumen per Watt for different light sources [Lechner, 2009, p. 436]

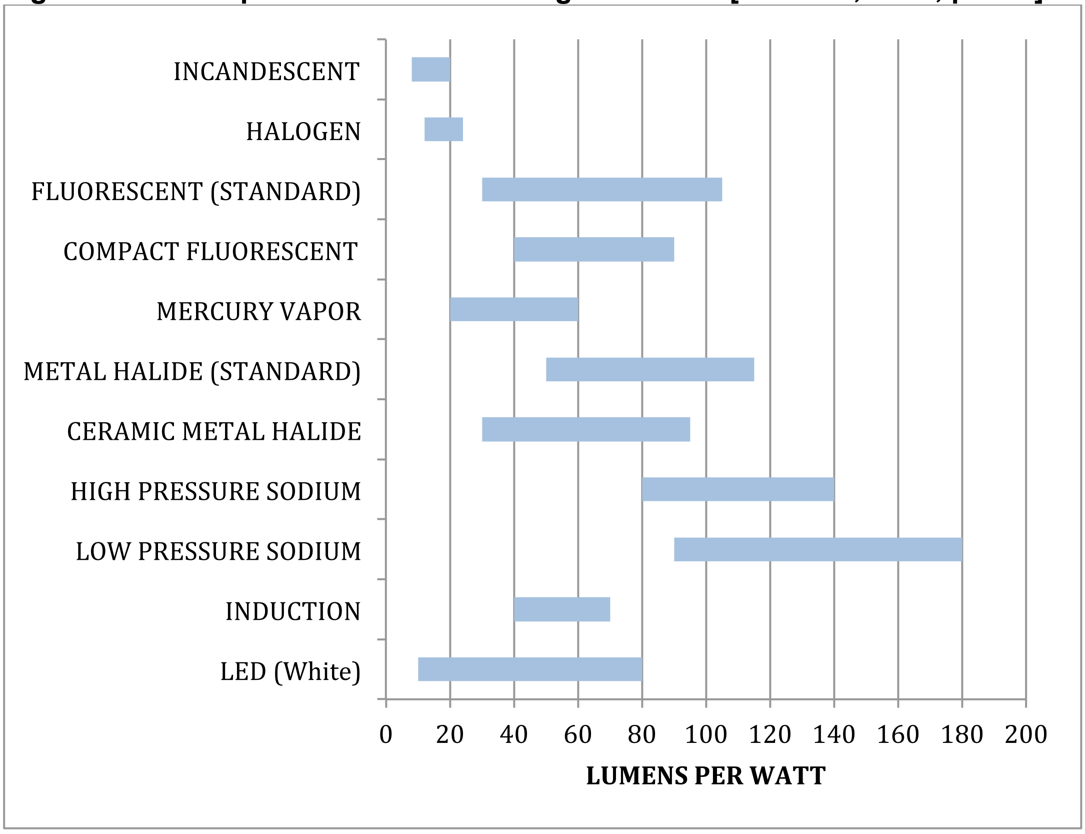
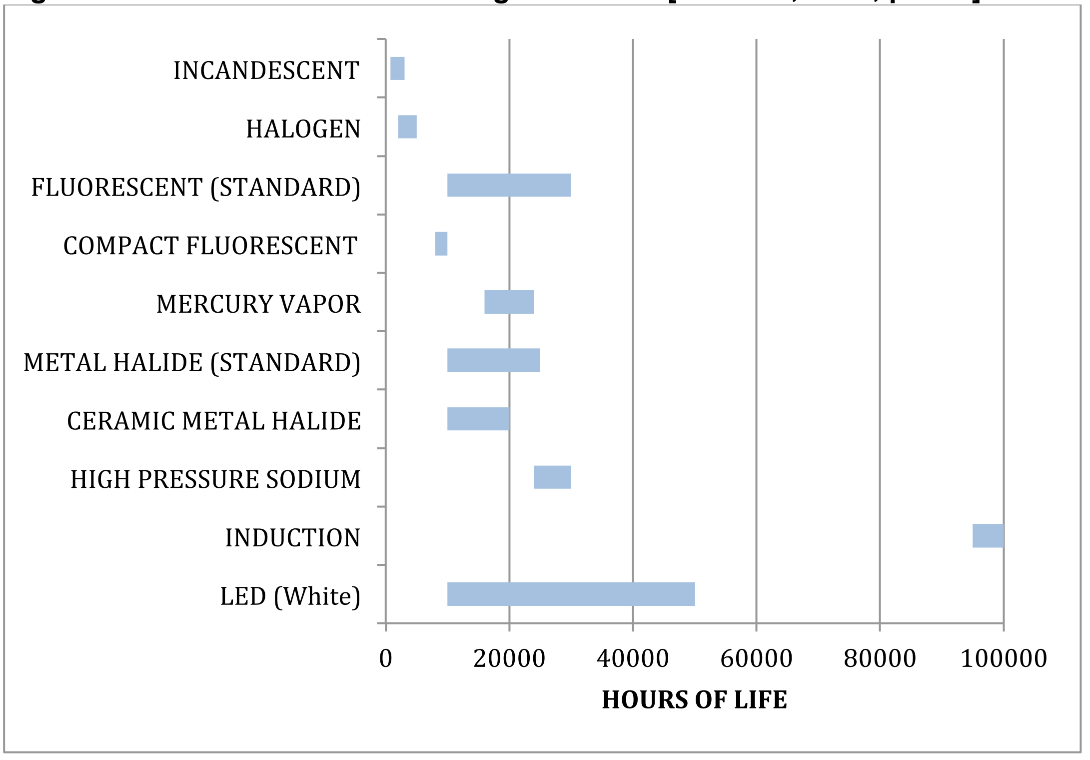


Figure 5 shows typical lifetimes of selected lamp types. Incandescent lamps have got the shortest lifetime. All other technologies are more durable.

Figure 5: Hours of life of different light sources [Lechner, 2009, p. 440]



2.3.3 Lighting control

The ability to control the light either manually or automatically reduces consumption. Simple switches in proper locations are the easiest way. More complex solutions are vacancy sensors. They can be categorized into personal sensors and lighting compensators.

Personal or Occupancy Sensors scan an area for occupancy and proper control the light due to a time delay. Different technologies and mounting strategies are available. The sensor can be placed in the former switch, mounted to the ceiling or attached to the light source, which is mostly used for outdoor lighting. The occupancy can be verified by the use of an Ultrasonic Sensor (US), which transmit and receive high frequency sound, Infrared Sensors (IR), which sense motion due to temperature changes, Audio Sensors (AS), which are sensitive to noise or Dual Technology sensors (DT), which combine US and IR sensors.

Lighting compensators can be either manual dimmers or automated systems. The automated systems mostly use photocells to sense the illuminance of the surrounding. Corresponding to the situation they control the level of the light.

Furthermore the lighting control can also be implemented into a Facility Management System. This system can dim and switch lighting due to predefined settings. Furthermore a central light control can be established to switch each light from a central point.

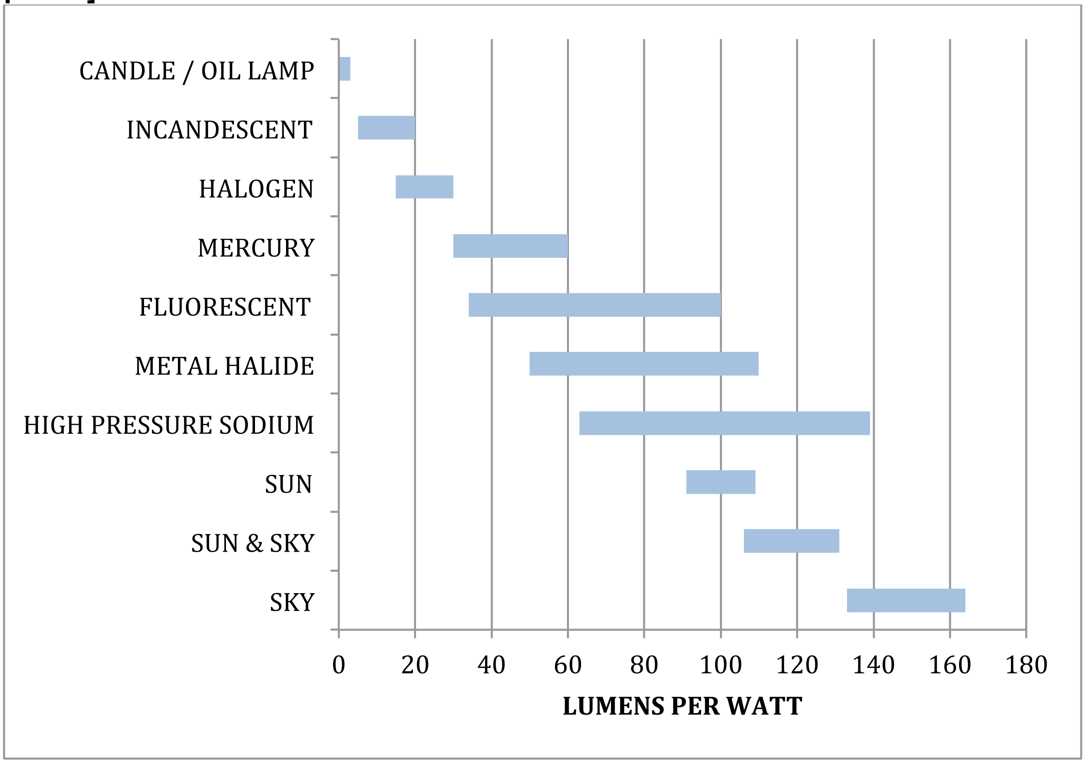
Finally it has to be said that the light control can reduce the lifetime of certain lamps by approximately 25 percent. This is caused by switching the light more often on/off. The reduced operation hours compensate the shortened lifetime. Therefore the period until re-lamp will not decrease.

According to: [Turner, 2001, p. 360-363] [Thumann, 1998, p. 202-205]

2.3.4 Use of daylight

Daylight became more irrelevant due to the availability of electrical lighting and cheap electricity, but it has got the potential to reduce the energy demand for lighting by about 70 percent in schools and offices. Furthermore the use of daylight can reduce the heating and cooling demand. Figure 6 illustrates that the direct sunlight contributes to heating whereas the illuminance of the sky is the most efficient light source available and therefore has got the lowest heating potential which can reduce cooling demand. The design is essential. According to: [Lechner, 2009, p. 384-386]

Figure 6: Heat production potential of different light sources [Lechner, 2009, p. 391]



Three basic strategies to utilize daylight are common, skylights, building perimeter daylighting and building core daylighting. Skylights can be accomplished in different varieties. Figure 7 shows common approaches. Figure 8 and Figure 9 show the skylight of the Southface office building in Atlanta, GA, USA as best practice example for a well performing skylight. Windows perform building perimeter daylighting. Intelligent shading systems can prevent direct sunlight to enter the building during the cooling season and allow the sunlight to enter the building during heating season. Such an intelligent shading system is displayed in Figure 10 and Figure 11. The shading system does not reduce perspicuity. Building core daylighting is more difficult to accomplish. The use of daylight within the building core should be considered during the design of the building. Skylights or constructions designs like in Figure 12 can perform well and reduce lighting demand significant. According to: [Lechner, 2009, p. 394-403] [Turner, 2001, p. 374-376]

Figure 7: Different skylight approaches [Lechner, 2009, p. 395]

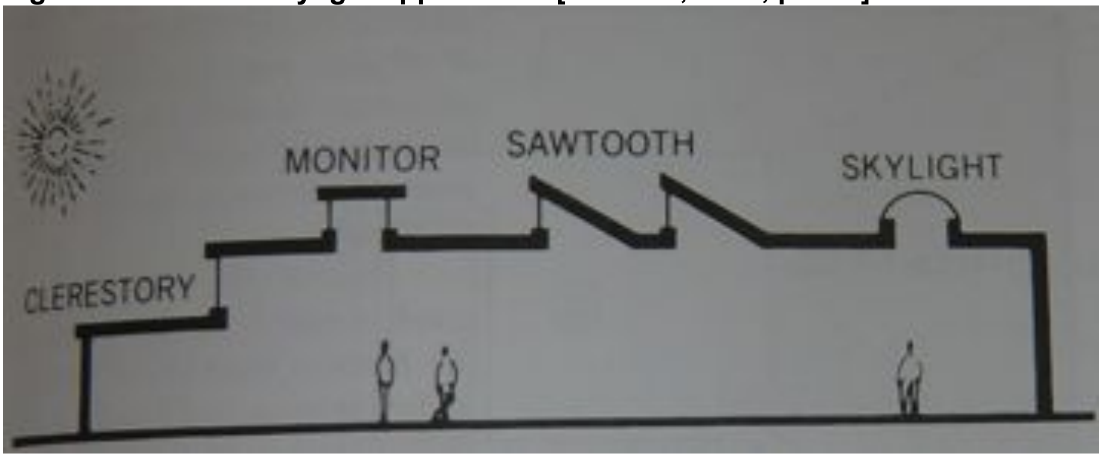


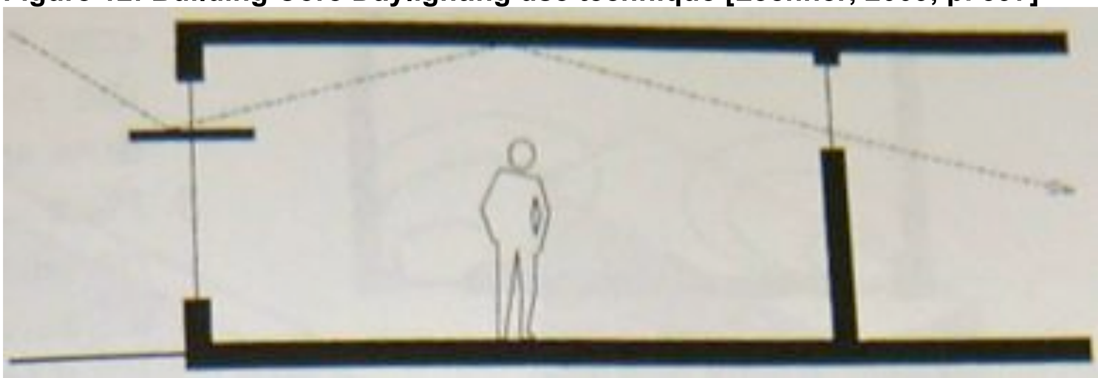
Figure 8: Skylight outside the Southface office building in Atlanta, GA, USA

Figure 9: Skylight inside the Southface office building in Atlanta, GA, USA

Figure 10: Shading system of the south facing facade of the Southface office building in Atlanta, GA, USA

Figure 11: Shading system of the south facing entrance of the Southface office building in Atlanta, GA, USA

Figure 12: Building Core Daylighting use technique [Lechner, 2009, p. 397]



2.4 Air conditioning

The following chapter describes key figures for equipment efficiency. The criteria for a high quality air conditioning are presented. Proper strategies for Heating Ventilation and Air Conditioning (HVAC) system layout are presented as well as load handling strategies.

2.4.1 Equipment Efficiency

The Energy Efficiency Ratio (EER) defines the peak performance of air conditioning equipment and is widely used in the USA. It is directly related to the Coefficient Of Performance (COP) by the conversion factor of 3,414, which is shown in Formula 2. The second widely used performance parameter in the USA is the Seasonal Energy Efficiency Ratio (SEER). It takes varying efficiency due to seasonal load fluctuations into account.

Formula 2: Conversion from EER to COP [Turner, 2001, p.263]

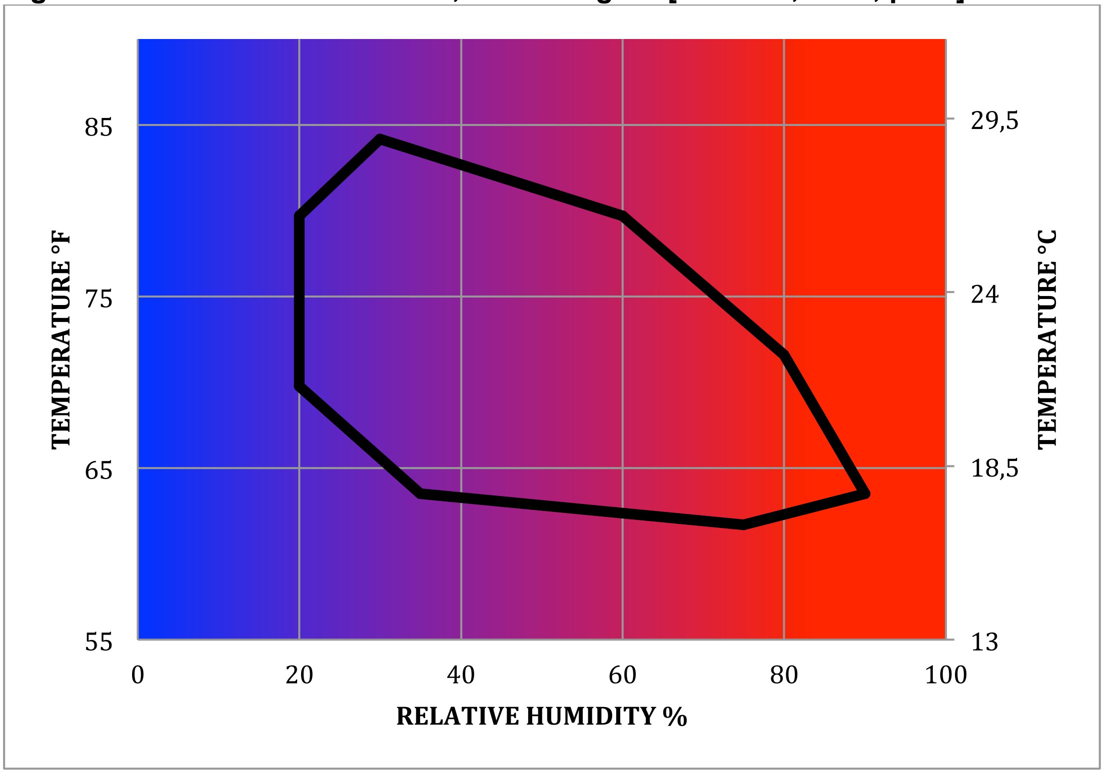
$$EER = 3.414 * COP$$

The efficiency of an air conditioning system is highest close before the maximum performance is demanded. Therefore the equipment must be proper designed to perform well. A to small or to big layout of an air conditioning system always leads to a lower performance and therefore higher costs.
[Turner, 2001, p. 263f]

2.4.2 Human Thermal Comfort

The main purpose of most air conditioning systems is to provide a comfortable environment for humans. Air temperature, humidity, air motion and the surface temperature of surroundings influence the comfort of a human being. The surface temperature can hardly be changed in existing buildings. Additional insulation can benefit the indoor comfort. Air motion can be influenced by the design of the inlets of the HVAC system. During operation of air conditioning units the air temperature and the humidity can be influenced. Figure 13 shows the boundaries of the human comfort zone concerning humidity levels and temperature.

Figure 13: Human Comfort Zone, According to: [Lechner, 2009, p. 62]



It is shown that a reduced humidity level allows higher temperature set points without reducing the comfort. A humidity level above 70 percent can still be comfortable for humans, but it allows mold formation. Humidity levels should never be below 20 percent to prevent lung diseases, which is most critical during heating periods in winter. According to: [Turner, 2001, p. 244f] [Brager, Olesen, 2004] [Lechner, 2009, p. 56-66]

2.4.3 Indoor Air Quality

Indoor Air Quality (IAQ) is also commonly called Indoor Environment Quality (IEQ) and influences the human comfort. The increased usage of electronic equipment and plastic surfaces within a building influence the IAQ. Furthermore changes in the usage of a room can influence the IAQ because of insufficient fresh air supply.

> *"Value Engineering" has lost its once positive connotation. Now we know it really means devalued and "cheapened." This "least cost" mentality led to many design/construction decisions and tactics that save on first cost. However both the owner and the occupants too often pay a deferred price in increased life/cycle costs, discomfort, illness and health costs, and low productivity. In the extreme, first cost savings return their dubious "value" multifold in the form of lost lease income, expensive remediation, and even litigation.* [Turner, 2001, p. 489]

Turner describes the influences, which can occur due to willful neglecting of IAQ issues. It is important to understand the issue and to address it. Adequate supply with fresh air is key for a good IAQ. Take into account that the provided air has to be pure, otherwise filtration is required. Furthermore material selection plays a mature role. Low Volatile Organic Compound (VOC) emitting materials reduce the amount of hazardous compound released into the indoor air. In companies a responsible person should be defined to address the issue of indoor air quality. Furthermore the quality should be monitored to be able to act in a sustainable way. According to: [Turner, 2001, p. 489-497] [Thumann, 1998, p. 107f] [EPA, 2012]

2.4.4 Temperature set points for HVAC systems

A well-chosen temperature set point reduces operation hours of the HVAC system and therefore reduces the energy consumption and saves costs. A list of recommended temperature set points for different rooms is displayed in the Appendix on page B and C.

Furthermore rooms with different occupancy hours should be controlled separately. This will optimize the energy consumption and provide comfort due to the possibility of different temperature set points. The HVAC systems have to be designed to meet all occupancy and comfort requirements.

A nighttime set back of the temperature reduces costs. The temperature can be set back by up to $20°F$ $(4°C)$ during hours of no occupancy. The cool down and heat up cycle of the building has to be considered. This means that the HVAC system does not have to work until the last person leaves but the desired daytime temperature has to be reached when the first person arrives in the building. According to: [Thumann, 1998, p. 114-119] [Turner, 2001, p. 257-259]

2.4.5 Cooling demand reduction

Especially in hot and humid climate zones like in Savannah the reduction of the cooling demand is essential. In existing buildings more efficient lighting and equipment will reduce the cooling demand. These energy saving measures to reduce the cooling load should be executed before a new HVAC system is installed. This can lead to a substantial size reduction and therefore additional cost savings. [Brown, 2012, oral]
During the construction of new buildings different aspects have to be considered to reduce the demand. In hot and humid climates it is essential to provide the ability for good cross ventilation. Furthermore the building should have more north and south wall area than east and west wall area to reduce the solar heat gains. The same rule is suitable for windows. Plants around the building can provide shading and reduce the solar gains. If a mechanical shading system is installed it should provide shade during the summer months and allow solar heat gains during the winter months. The shading devices should be mounted outside the thermal envelope. The color of the outside walls and the roof should be bright to reflect most solar radiation. Due to this measures the cooling demand is reduced significantly. According to: [Baruch, 1994, p. 21-35] [Brown, 2012, oral]

2.4.6 Technology

A great variety of different HVAC technologies are available. Categorizations can be defined by the distribution system or the energy source. During the energy audit three different distribution systems were detected and two different energy sources used.

The Single Zone system is the most common all-air system design. It is a central air conditioning system controlled by one thermostat, which switches the air handler unit (AHU) on and off. The design is very simple, but the system delivers air to all supported rooms at the same time. Therefore no occupancy control can be realized. A variable speed control for the AHU increases the efficiency of the HVAC system.

Multi Zone systems are more complex than single zone systems. It is a central air conditioning system, which can handle different load and temperature situations for different zones. This allows occupancy control and different operation schedules. A separate control and air inlet for each zone (e.g. room) as well as a separate duct has to be provided.

Packaged systems are stand-alone systems, which provide heating and cooling close to the demand. No distribution is required. The efficiency of stand-alone systems is lower than the efficiency of central systems, but the local and direct distribution can overcome the gap of efficiency. Packaged systems allow diverse load situations and occupancy.

According to: [Thumann, 1987, p. 29-38] [Turner, 2001, p. 245-255]

HVAC systems can use different energy sources for operation. All the inspected HVAC systems have been air/air systems. Air source heat pumps (AHP) use the outside air as heat sink and distribute energy for cooling and heating via air. A heat pump between the outside air and the indoor distribution system is required. The heat pump is powered with electricity

Alternatively geothermal heat pumps (GHP) can be used. GHP use the earth or ground water as heat source or heat sink. The temperature of the soil or the ground water is more stable than the outside air temperature, which increases the efficiency of the system. GHP are up to more than double as efficient as AHP.

According to: [Baruch, 1994, p. 15f] [Turner, 2001, p. 246 & 251f] [DOE A, 2012] [DOE B, 2012]

2.5 Purchase decisions

This section deals with the decision making progress. The different efficiency ratings are presented. Furthermore some economic calculation tools to support every purchase decision are described.

2.5.1 Efficiency Ratings

Energy efficient equipment reduces demand and consumption. The ENERGY STAR label is awarded to highly efficient equipment. Products have to meet the requirements of their category. The product specification requirements are revised if the technology has improved.

The ENERGYGUIDE label is a required label for all appliances. It has to display the estimated annual energy consumption and costs as well as the performance compared to similar products. Furthermore the label has to show the model and product number, key figures of the product as well as the ENERGY STAR logo if applicable.

According to: [DOE C, 2012] [ENERGY STAR, N.D.]

2.5.2 Economic Decisions

Most energy saving measures require an investment. To be able to verify the economic feasibility different analyses can be made. The calculation method has to be geared to the company regulations. Different calculation methods can have different outcomes and therefore imply different recommendations.

An easy calculation method is the Payback (PB) period calculation. The investment divided by the anticipated savings after tax result in a time period in years. Formula 3 displays this calculation method.

Formula 3: Payback period calculation [Thumann, 1998, p. 68]

$$Payback\ Period\ (PB) = \frac{initial\ investment}{after\ tax\ savings}$$

A more complex calculation method is the life cycle cost analyze. The time value of money is included into this calculation. Some companies take fuel price development into account. According to: [Thumann, 1998, p. 67-70]

2.6 Renewable Energy Sources

Renewable energy sources are considered as low CO_2 emitting power source. The local production goes hand in hand with the consumption. The following chapter will give a brief overview about the potential of different renewable energy sources in the city of Savannah.

2.6.1 Solar Radiation and Orientation

The solar radiation in Savannah is approximately 480 $\frac{Wh}{ft^2\,day}$ (5.2 $\frac{kWh}{m^2-day}$) corresponding to the Department of Energy. This is a value in the upper third of the US solar radiation chart. Figure 14 shows the solar radiation levels of the southeast USA. The solar radiation defines the maximum output of a solar system. [DOE D, 2012]

Figure 14: Solar radiation map of the southeast USA [DOE D, 2012]

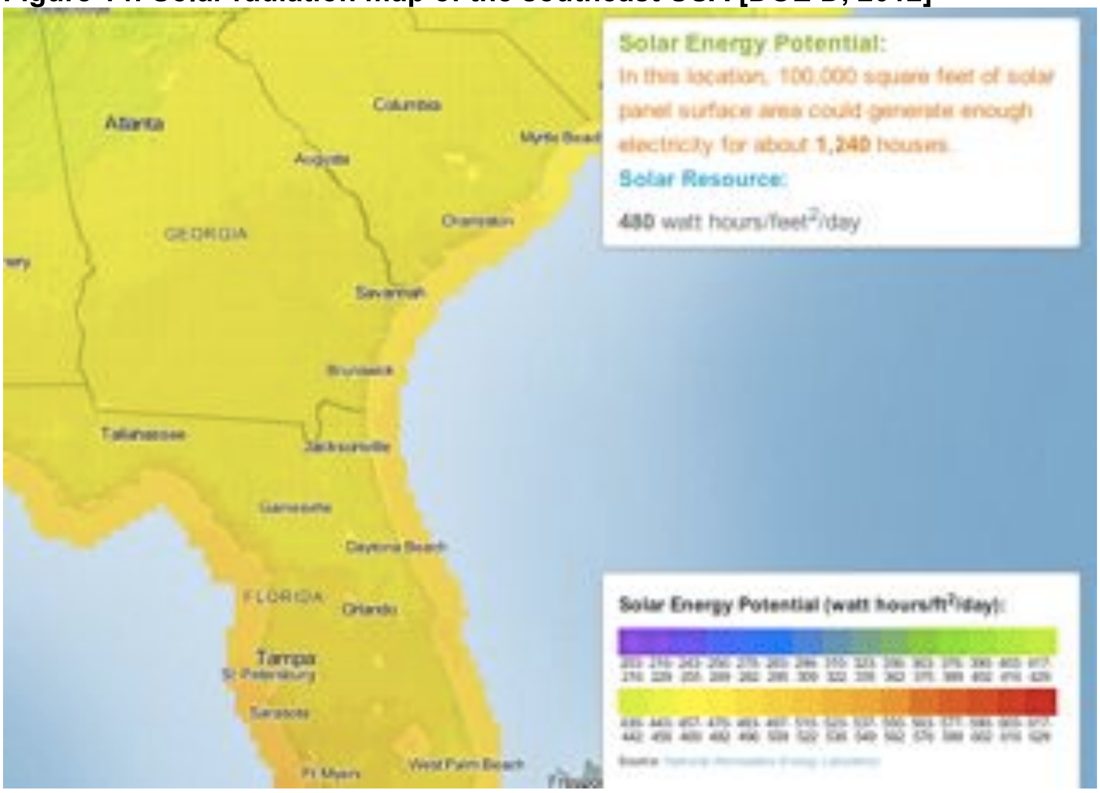


Figure 15 shows the optimum tilt angle of solar hot water and photovoltaic systems in the USA. Figure 16 shows the losses caused by the orientation.

The maximum output of a solar system is achieved with a south-facing collector at an angle of around 30° in Savannah. A slightly different orientation does not cost high losses. [DOE, 2011]

Figure 15: Optimum tilt for different locations in the USA [DOE, 2011]

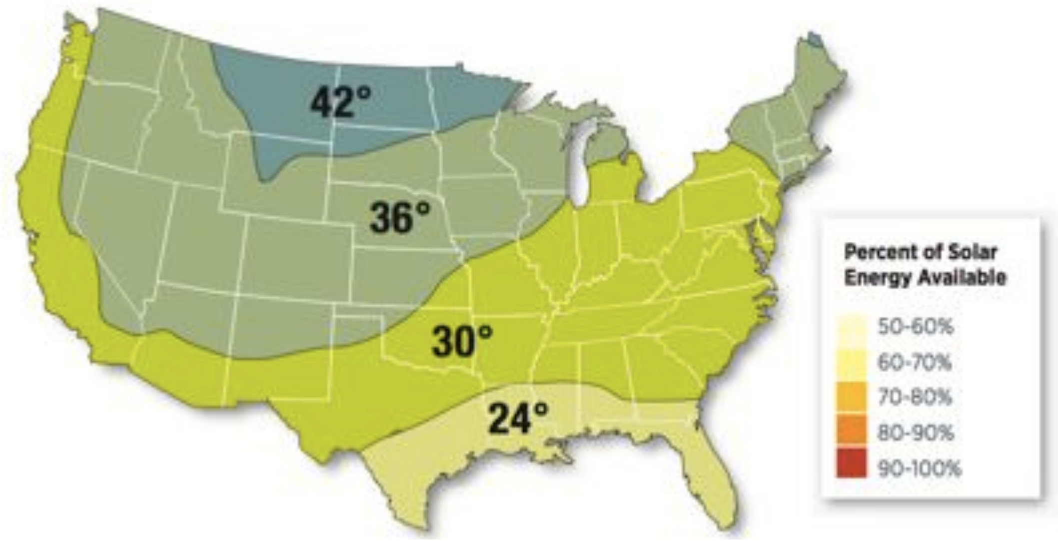
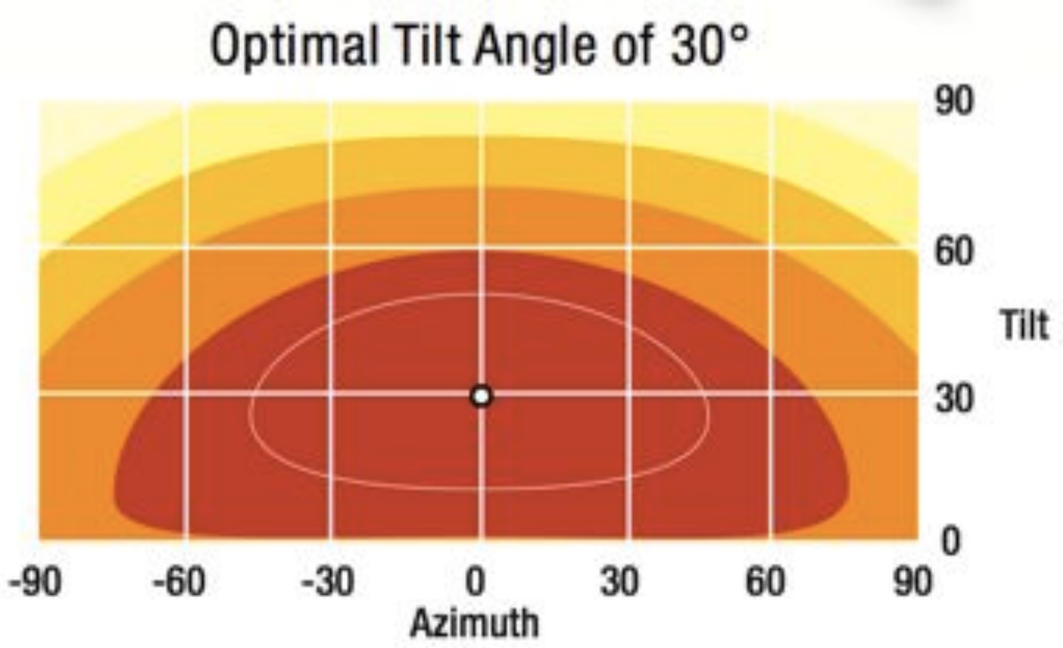


Figure 16: Solar orientation losses [DOE, 2011]



The annual average solar radiation since 1961 is listed in Table 3. It shows that the radiation level increased over time. The average solar radiation within the last 10 years was 1884 $\frac{kWh}{m^2-year}$ for a south-facing area with 30°tilt. [NSRDB, N.D.]

Table 3: Historic solar radiation data for Savannah

Year	$\frac{kWh}{m^2-year}$	
	south 0°	**south 30°**
2010	1777,57	1955,32
2009	1665,93	1832,52
2008	1712,06	1883,26
2007	1738,33	1912,17
2006	1782,95	1961,25
2005	1699,04	1868,94
2004	1714,03	1885,44
2003	1639,83	1803,81
2002	1704,40	1874,84
2001	1694,73	1864,20
2000	1769,72	1946,69
1999	1722,67	1894,94
1998	1721,65	1893,81
1997	1653,32	1818,66
1996	1793,95	1973,35
1995	1621,93	1784,13
1994	1598,68	1758,54
1993	1648,86	1813,74
1992	1533,01	1686,31
1991	1562,84	1719,12
1961-1991	1679,00	1846,90

2.6.1.1 Solar Hot Water

Solar hot water systems have got a good potential in Savannah due to the high radiation level. An active, indirect circulation system is required to prevent frost damage. Even though it is not freezing very often a non-freezing heat transfer fluid is required to prevent damage. A backup system is recommended to provide hot water during cloudy days and to keep the storage tank small and cheap.
According to: [DOE D, 2012] [NOAA, 2008]

2.6.1.2 Photovoltaic

The solar radiation can be converted into electricity due to a photovoltaic system. The performance of a system is measured in Watt. The measurement can refer to the peak power or the average production during one day. A grid-connected system is preferable due to lower costs and grid availability. [DOE E, 2012]

2.6.2 Wind energy

The wind energy potential within the city limits of Savannah is quiet low. Figure 17 shows the wind energy potential of the USA. Figure 18 shows the potential of the Savannah area. With approximately 10 mph (4.5 $\frac{m}{s}$) average wind speed at an altitude of 262 $feet$ (80 m) the potential is rather low. The potential offshore would be good, but Savannah has not got direct access to the sea.
According to: [NREL A, 2012]

Figure 17: Map of the annual wind speed at 80m in the USA [NREL B, N.D.]

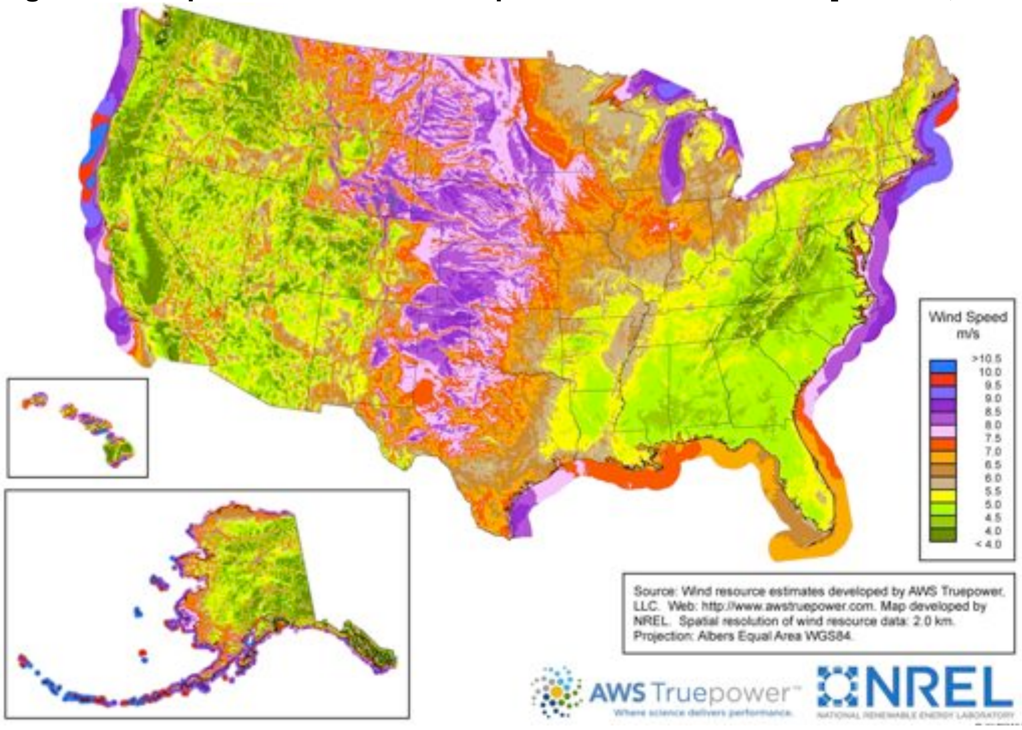
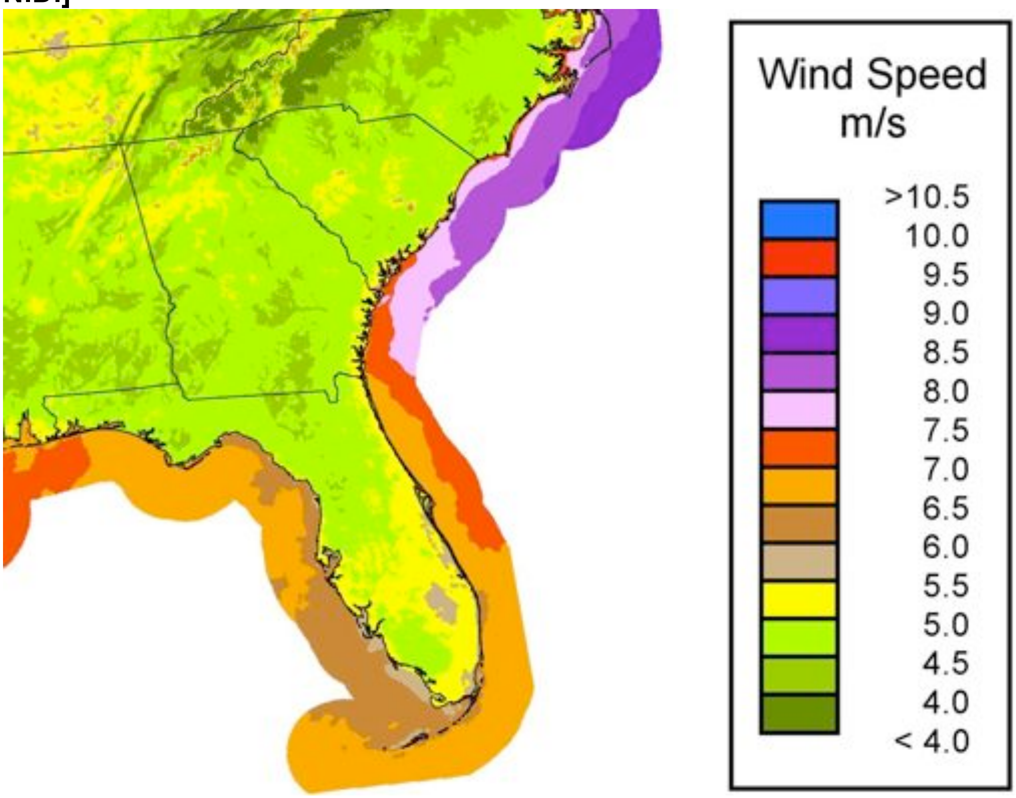


Figure 18: Map of the annual wind speed at 80m in southeast USA [NREL B, N.D.]



2.7 Bill information

The following chapter will give a basic understanding of utility bills. The electricity bill with its different charges and some different rate plans will be highlighted. A brief overview of gas bills will be provided.

2.7.1 Electricity Bill

Electric bills consist of different parts. One non variable part is the charges section. The customer cannot influence them besides changing to a different contract. These charges are the Service Charge, the Environment Compliance Cost Recovery, the Nuclear Construction Cost Recovery and the Municipal Franchise Fee.

The other part is influenced by the usage pattern of the costumer. It consists of two components, the Electrical Energy measured in kWh, which is the quantity of electricity used by a customer and the Electrical Demand measured in kW, which is the peak usage of a customer. The price depends on the rate plan.

The Electric Demand is complex to define. The charge is either the peak consumption of the customer of the actual month or 95 percent of the highest peak consumption during the last 11 months. The higher of both values will be charged.

The Electrical Energy consumption is measured each month. Different rate plans have got completely different charge structures. Flat Energy rates have a fixed price per kWh and per kW. Power and Light rates have got higher prices for the first kWh used than for the last kWh used as well as blocked demand charges based on hours use of demand (HUD) calculations. Time Of Use rates charge different prices for energy usage depending on the time of use and month of the year.

According to: [Georgia Power, 2012] [Georgia Power, N.D.]

2.7.2 Natural Gas Bill

There are four components to natural gas costs.

Natural Gas Consumption Charge is the cost of the natural gas purchased from the commodity supplier, which may be a local utility or other third party. The consumption measured in cubic feet is converted into therms. The price per therm varies depending on the rate plan.

Dedicated Design Day Capacity (DDDC) describes the virtual dimensioning of the pipe required to support the costumer with gas. This dimensioning is calculated once a year. The size defines the monthly costs for transportation through the grid.

Customer Service Charges are a fixed rate. It is used to cover administrative costs for the distributor.

State and Local taxes vary depending on the consumption and destination of the customer.

According to: [SCANA, N.D.]

2.8 Methods

This chapter deals with the methods of data acquisition. The building selection process is described. The measurement devices are listed and the method of data collection during on-site visits is mentioned.

2.8.1 Building selection

The selection of appropriate buildings for an energy assessment was based on the buildings energy consumption. The city provided electricity consumption data for the years 2010, 2011 and for the beginning of 2012. The electricity consumption and price were saved on a monthly base in Excel.

The company Johnson Control Facility Dude has read in the consumption data into their software UtilityTrac Plus. Furthermore the consumption data had been entered into Portfolio Manager, a program from Energy Star. As both programs had been free trials only the results and not the details could be compared. A primary list of buildings with high energy consumption per area was identified. This first list of buildings was reduced by criteria like accessibility or size. Therefore police stations and to large buildings were deleted. The result of the selection is shown in Table 4.

Table 4: List of buildings identified for energy assessments

Building	Address	Area [ft^2]
Hospitality Center	1 W. River Street	1,675
Fire Station #9	2235 Capitol Street	2,500
Delware Center	1815 Lincoln Street	12,000
Fire Station #14	480 Highland Blvd	2,788

The selection was presented during a meeting of the Thrive Committee. It turned out that the access to the selected buildings was not granted. Instead it was agreed to execute audits for Fire station #8 and Fire station #11. Furthermore it was agreed that the parking area of Robinson and State Street parking garages could be entered at any time to perform an audit.

2.8.2 Data acquisition

Two on-site visits in both Fire stations have been arranged to collect data to derive with energy conservation opportunities. Both stations have been visited on the same days. The visits started in Fire station #8 and ended in Fire station #11 and lasted for approximately one hour each. The date of the visits and the attendees are shown in Table 5. During the visits information concerning the mechanical equipment, lighting and the HVAC systems were collected. During the second visit data loggers have been placed in different rooms.

Table 5: Date and list of attendance for fire station visits

	Aug. 15th, 12 10am-1pm	Oct. 11th, 12 08^{30}-11^{30}am
Alex Heyward, Fire Department City of Savannah	X	
Garrison Marr, Housing Department City of Savannah	X	X
Mike Brown Enterprise Innovation Institute, Georgia Institute of Technology	X	X
Robert Ballentine Georgia Innovation Institute		X
Daniela Bachner University of Applied Sciences, Upper Austria	X	X
Matthias Watzak-Helmer University of Applied Sciences, Upper Austria	X	X

The visit to the parking garages took place on October 13th 2012 between 12am and 3pm. The second visit took place on October 20th 2012 during night between 19pm and 12pm. Data concerning the lighting equipment was collected. The light level on several positions has been measured during both visits.

2.8.3 Measurement equipment

Two different measurement devices were used to collect data. A SpectraCine SPECTRA professional IV-A was used as illumination measurement device in the parking garages. This measurement device is design for motion picture video and digital photography. Some basic features are listed in the Table 6. Figure 19 shows the measurement device. [SPECTRA CINE A, 2005]

Table 6: Features of Spectra professional IV-A [SPECTRA CINE B, N.D.]

Dimension	5.5 x 2.5 x 2 $inches$ (140 x 64 x 51 mm)
Illuminance range	0.1 to 70,000 $footcandles$ 1 to 100,000 lux
Light sensor	Silicon photovoltaic cell

An onset HOBO U12 data logger was used to measure temperature, relative humidity (RH) and light levels in fire stations. Table 7 displays the main features of the data logger. In Figure 20 a picture of the device is provided. [ONSET, N.D.]

Table 7: Features of onset HOBO U12 data logger [ONSET, N.D.]

Dimension	2.3 x 2.9 x 0.9 $inches$ (58 x 74 x 22 mm)
Temperature range	-4° to 158$°F$ (-20° to 70$°C$)
Temperature accuracy	± 0.63$°F$ from 32° to 122$°F$ (± 0.35$°C$ from 0° to 50$°C$)
Temperature resolution	0.05$°F$ at 77$°F$ (0.03$°C$ at 25$°C$)
RH range	5% to 95%
RH accuracy	±2.5% from 10% to 90% RH
RH resolution	0.03%
Light intensity range	1 to 3000 $footcandles$ ($\frac{lumen}{ft^2}$)
Analog channel range	0 to 2.5 Vdc / 0 to 5 Vdc / 0 to 10 Vdc

Figure 19: Spectra Cine Spectra professional IV-A [SPECTRA CINE A, 2005]

Figure 20: Onset HOBO U12 data logger [onset, N.D.]

3 Building description

This section provides an overview of the analyzed buildings. For each building a general description is given. Furthermore the energy consumption data used for the price calculations for electricity and for natural gas if applicable is displayed. More historic energy consumption data is listed in the appendix starting page E.

3.1 Robinson Garage

Robinson garage is an 180,000 ft^2 (16,722 m^2) parking garage located at 132 Montgomery Street, Savannah, Georgia. The facility is staffed with one cashier 24/7. The cashier is located in a small, integrated office area. It is equipped with a little kitchen part and a video control of the whole parking garage.

The facility was built in 1986, has got 4 stories with roof top parking, concrete walls and 2 elevators. All stories are above ground and opened to the surrounding. The picture in Figure 21 shows the outside of the building to provide an impression of the construction. Lighting in the building is mostly HPS with a few fluorescent lamps. Most of the HPS lamps are 150W. All fluorescent lamps are T-8.

Figure 21: Robinson Garage, West facing stairway

3.1.1 Historic Utility Consumption

The monthly consumption and cost of the facility can be found in Table 8. Following this table the bar chart in Figure 22 graphically displays this data. This bar chart is included to give visual indications of any unusual patterns of usage in the plant. Calculation of the average electricity costs resulted in 0.088 $\frac{\$}{kWh}$.

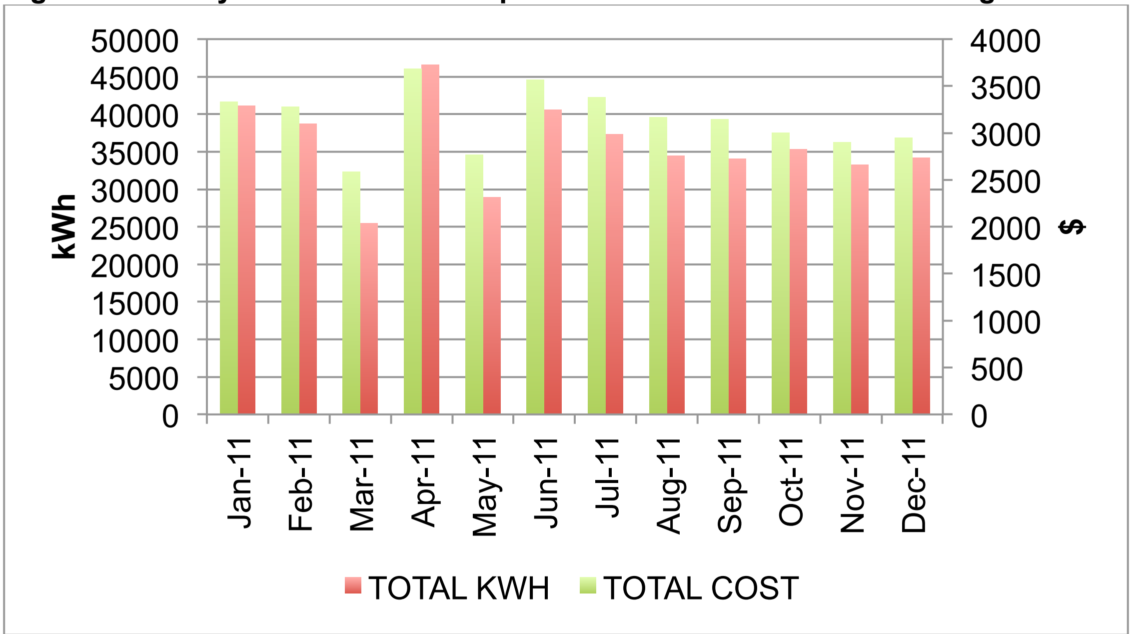
The electricity bar graph in Figure 22 shows stable electricity consumption. The consumption was lowest in March, which correlates with the shortest billing period. The high consumption in April followed by the comparable low consumption in May might be the result of billing period fluctuations.

Table 8: Utility costs and consumption data for Robinson Garage used for price calculations

MONTH	DAYS	TOTAL kWh	TOTAL COST	$\frac{¢}{kWh}$	COST PER DAY
Jan-11	31	41,160.00	$3,332.30	8.10	107,49
Feb-11	31	38,760.00	$3,279.88	8.46	105,80
Mar-11	28	25,500.00	$2,588.70	10.15	92,45
Apr-11	31	46,620.00	$3,683.80	7.90	118,83
May-11	30	28,920.00	$2,768.39	9.57	92,28
Jun-11	31	40,620.00	$3,567.19	8.78	115,07
Jul-11	30	37,320.00	$3,382.30	9.06	112,74
Aug-11	31	34,500.00	$3,168.12	9.18	102,20
Sep-11	31	34,080.00	$3,144.57	9.23	101,44
Oct-11	30	35,340.00	$3,004.36	8.50	100,15
Nov-11	31	33,240.00	$2,899.22	8.72	93,52
Dec-11	30	34,200.00	$2,947.29	8.62	98,24
PERIOD	365	430,260.00	$37,766.12	8.78	103,47

Billing period: 12/20/2012 – 12/19/2011

Figure 22: Utility costs and consumption data 2011 for Robinson Garage



3.2 State Street Garage

State street garage is a 167,265 ft^2 (15,539 m^2) parking garage located at 110 East State Street, Savannah, Georgia. The facility is staffed with one cashier 144 hours a week. The cashier is located in a small, integrated office area. It is equipped with a little kitchen part and a video control of the whole parking garage. The garage is opened 24/7 for customers with a permanent parking permission.

The facility was built in 1985, has got 7 stories with roof top parking, concrete walls and 2 elevators. All stories are above ground and opened to the surrounding. The picture in Figure 23 shows the outside of the building to provide an impression of the construction. Lighting in the building is mostly HPS with a few fluorescent lamps. Most of the HPS lamps are $150W$. All fluorescent lamps are T-8.

Figure 23: State Street Garage, Southeast facing corner

3.2.1 Historic Utility Consumption

The monthly consumption and cost of the facility can be found in Table 9. The bar chart in Figure 24 graphically displays this data. This bar chart is included to give visual indications of any unusual patterns of usage in the plant. Average electricity costs were 0.086 $\frac{\$}{kWh}$.

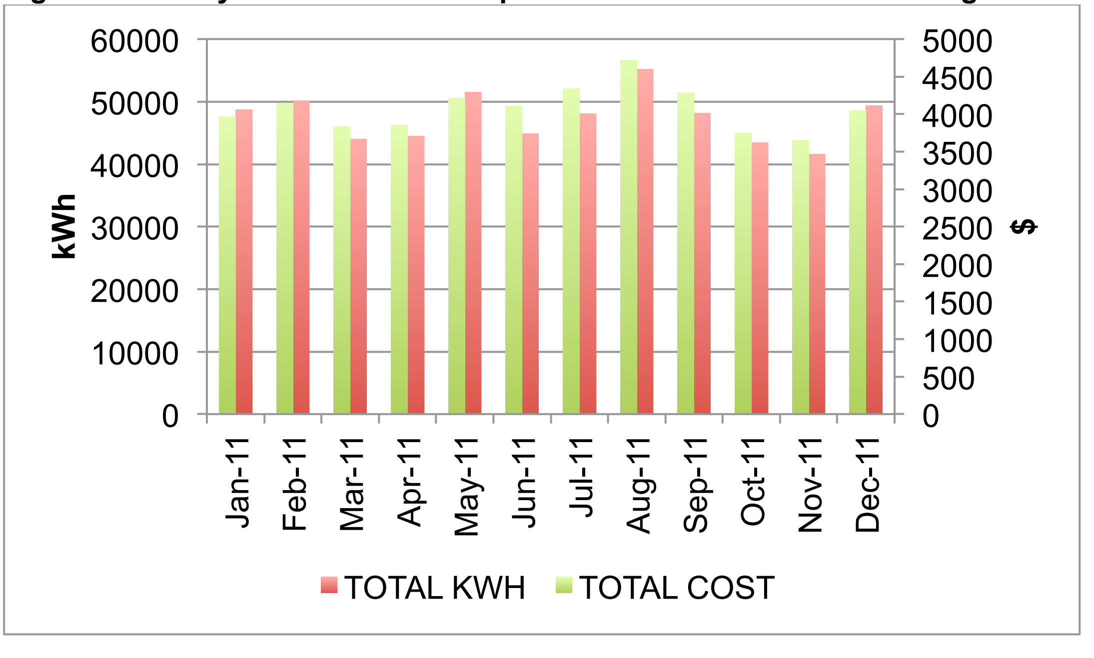
The electricity bar graph in Figure 24 shows the typical seasonal change. The consumption during spring and autumn is lower than during winter and summer. The difference between the lowest consumption (November) and the highest (August) is around 30 percent. Therefore the cooling load has to be high. The reason could be a large conditioned space or a leaky building. The answer cannot be given with the amount of data collected, but it is very likely that the office space located on the 1st floor receives its electricity via the same electricity meter. The office space was not part of the requested energy assessment and therefore was not inspected.

Table 9: Utility costs and consumption data for State St. Garage used for price calculations

MONTH	DAYS	TOTAL kWh	TOTAL COST	$\frac{¢}{kWh}$	COST PER DAY
Jan-11	31	48,720	$3,967.91	8.14	128.00
Feb-11	31	50,200	$4,147.97	8.26	133.81
Mar-11	28	44,040	$3,832.25	8.70	136.87
Apr-11	31	44,480	$3,854.90	8.67	124.35
May-11	30	51,520	$4,216.18	8.18	140.54
Jun-11	31	44,880	$4,105.52	9.15	132.44
Jul-11	30	48,120	$4,343.21	9.03	144.77
Aug-11	31	55,160	$4,718.91	8.55	152.22
Sep-11	31	48,160	$4,289.29	8.91	138.36
Oct-11	30	43,480	$3,748.56	8.62	124.95
Nov-11	31	41,640	$3,654.22	8.78	117.88
Dec-11	30	49,400	$4,045.31	8.19	134.84
PERIOD	365	569,800	$48,924.23	8.59	134.04

Billing period: 12/20/2012 – 12/19/2011

Figure 24: Utility costs and consumption data 2011 for State St. Garage



3.3 Fire Station #8

Fire Station #8 is a 4,300 ft^2 (399 m^2) service facility located at 2824 Bee Road, Savannah, Georgia. The facility is staffed with 3 firefighters 24/7. Around one half of the building is dedicated living area and sleeping area while the other half of the space is used as garage for the fire trucks.

The facility was built in 1955, has masonry walls and a slightly pitched wooden roof construction. It is equipped with single-glazed wooden windows around the entrance and double-glazed wooden windows throughout the rest of the building. The picture in Figure 25 shows the outside of the building to provide an impression of the construction.

HVAC is provided with two 3.5-ton (12,31 kW) air-cooled split systems and two 40,000 $\frac{Btu}{h}$ (11,72 kW) natural gas furnaces plus three different window units. Lighting in the building is mostly fluorescent with a few incandescent lamps. Most of the fluorescent lamps are four-foot T-12's with electronic ballasts.

Figure 25: Fire Station #8, Main Entrance facing West

3.3.1 Historic Utility Consumption

The monthly consumption and cost of each utility account at the facility can be found in the Table 10 for electricity in Table 11 for Natural Gas. Figure 26 and Figure 27 display the consumption data graphically. These bar charts are included to give visual indications of any unusual patterns of usage in the plant. Average electricity costs were 0.108$\frac{\$}{kWh}$ and average natural gas costs were 13.205$\frac{\$}{MMBtu}$ (4,48$\frac{¢}{kWh}$).

3.3.1.1 Electricity consumption data

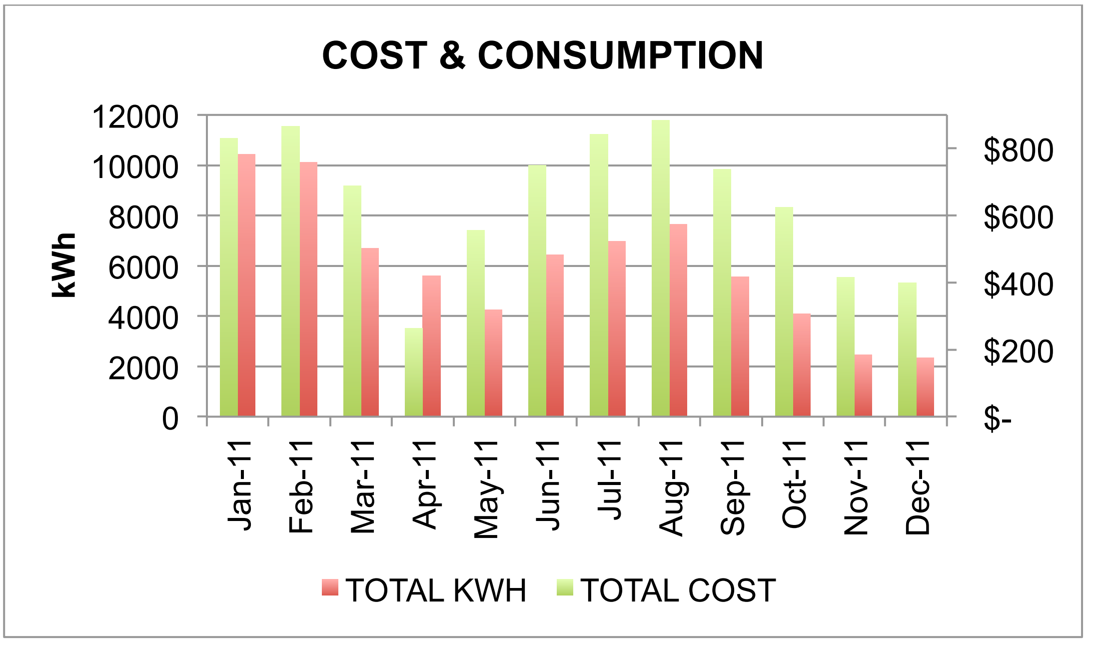
The electricity bar graph in Figure 26 shows the seasonal variation of electricity consumption. The consumption peaked in the winter months while during the summer months the electricity consumption was lower. The lowest monthly electricity consumption occurred in April 2011. A tendency to reduce electricity at the end of the year is visible. This development continued in 2012. The reason for the reduction is not clear and could not be verified during interviews during the audit.

Table 10: Electricity utility costs and consumption for Fire Station #8 used for price calculations

MONTH	DAYS	TOTAL kWh	TOTAL COST	$\frac{¢}{kWh}$	COST PER DAY
Jan-11	31	10,436.00	$830.44	7.96	26.79
Feb-11	31	10,119.00	$866.14	8.56	27.94
Mar-11	28	6,688.00	$688.06	10.29	24.57
Apr-11	31	5,601.00	$263.40	4.70	8.50
May-11	30	4,260.00	$556.70	13.07	18.56
Jun-11	31	6,435.00	$749.43	11.65	24.18
Jul-11	30	6,969.00	$842.36	12.09	28.08
Aug-11	31	7,653.00	$883.38	11.54	28.50
Sep-11	31	5,572.00	$738.06	13.25	23.81
Oct-11	30	4,103.00	$625.16	15.24	20.84
Nov-11	31	2,454.00	$415.98	16.95	13.42
Dec-11	30	2,352.00	$399.40	16.98	13.31
PERIOD	365	72,642.00	$7,858.51	10.82	21.54

Billing period: 12/20/2012 – 12/19/2011

Figure 26: Electricity utility costs and consumption data 2011 for Fire Station #8



3.3.1.2 Natural gas consumption data

The consumption data of natural gas in Figure 27 shows a consumption peak in January 2011. This may be due to cold temperatures in that period. The consumption is constant from April to October where only the gas-fueled kitchen range drives consumption. Natural gas costs are comparatively high during that period due to the distribution charge.

Figure 27: Natural Gas utility costs and consumption data 2011 for Fire Station #8

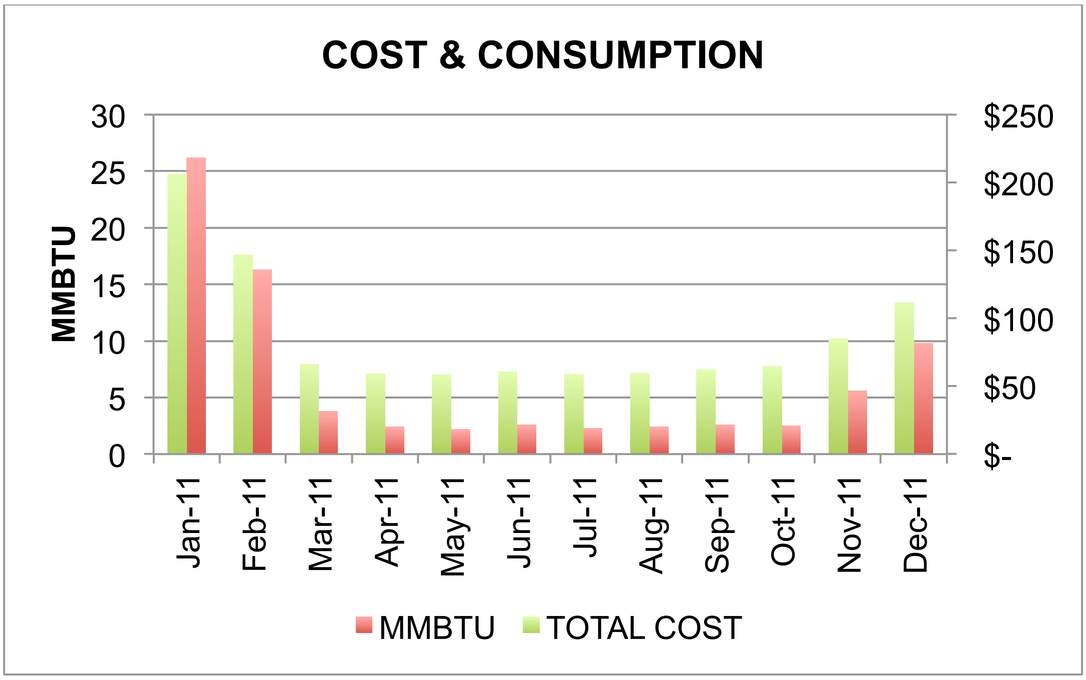


Table 11: Natural Gas utility costs and consumption for Fire Station #8 used for price calculations

MONTH	DAYS	$MMBtu$ (kWh)	$\frac{\$}{MMBtu}$ $(\frac{¢}{kWh})$	COMMUDITY CHARGE	DDDC	TOTAL COST	COST / DAY
Jan-11	31	26.2 (7720)	6.172 (2,09)	$161.71	$44.42	$206.13	$6.65
Feb-11	28	16.3 (4803)	6.272 (2,12)	$102.23	$44.42	$146.65	$5.24
Mar-11	32	3.8 (1120)	5.749 (1,95)	$21.85	$44.42	$66.27	$2.07
Apr-11	30	2.4 (707)	6.196 (2,10)	$14.87	$44.42	$59.29	$1.98
May-11	30	2.2 (648)	6.333 (2,15)	$13.93	$44.42	$58.35	$1.95
Jun-11	32	2.6 (766)	6.282 (2,13)	$16.33	$44.42	$60.75	$1.90
Jul-11	30	2.3 (678)	6.313 (2,14)	$14.52	$44.42	$58.94	$1.96
Aug-11	30	2.4 (707)	6.326 (2,15)	$15.18	$44.42	$59.60	$1.99
Sep-11	32	2.6 (766)	5.813 (1,97)	$15.11	$46.92	$62.03	$1.94
Oct-11	30	2.5 (737)	6.956 (2,28)	$17.39	$47.29	$64.68	$2.16
Nov-11	29	5.6 (1659)	6.721 (2,23)	$37.64	$47.29	$84.93	$2.93
Dec-11	31	9.8 (2888)	6.561 (2,14)	$64.30	$47.28	$111.58	$3.60
PERIOD	365	78.70 (23191)	6.308 (2,14)	$495.06	$544.14	$1,039.20	$2.85

Billing period: 12/20/2010 – 12/19/2011

3.4 Fire station #11

Fire Station #11 is an 8,295 ft^2 (771 m^2) service facility located at 11844 Apache Avenue, Savannah, Georgia. The facility is staffed with 8 firefighters 24/7. Around one half of the building is dedicated living area while the other half of the space is used as garage for the fire trucks. The living area is divided into a common room, bunkrooms, bathrooms, office space and storages. The truck bay has separate rooms for service works, a filling station and wardrobes.

The facility was built in 2011, has concrete and masonry walls and a pitched roof. It is equipped with double-glazed aluminum windows throughout the building. The picture in Figure 28 shows the outside of the building to provide an impression of the construction.

HVAC is provided with two systems: an estimated 5 ton (17.58 kW) air-cooled multi-zone system and a 3.5 ton (12.31 kW) air-cooled split system. Lighting in the building is provided with four-foot T-12's with electronic ballasts throughout the building. LED exit signs are installed.

Figure 28: Fire Station #11, Main Entrance facing northwest

3.4.1 Historic Utility Consumption

Consumption and cost of the facility for each month can be found in the Table 12. Figure 29 displays the consumption data graphically. This bar chart is included to give visual indications of any unusual patterns of usage in the plant. Average electricity costs were $0.135\frac{\$}{kWh}$. The consumption of July 2011 and July 2012 were not taken into average price considerations due to abnormalities.

The electricity bar graph in Figure 29 shows a relatively constant consumption with seasonal increases during heating and cooling seasons. However in July 2012 a doubling in consumption occurred while the monthly costs stayed constant. It is likely that an error occurred in the data sheet of the city or maybe with the provider. In July 2011 the costs were extremely high compared to the consumption. This is most likely the result of additional fees due to the installation of the meter.

Figure 29: Utility costs and consumption data 2011 for Fire Station #11

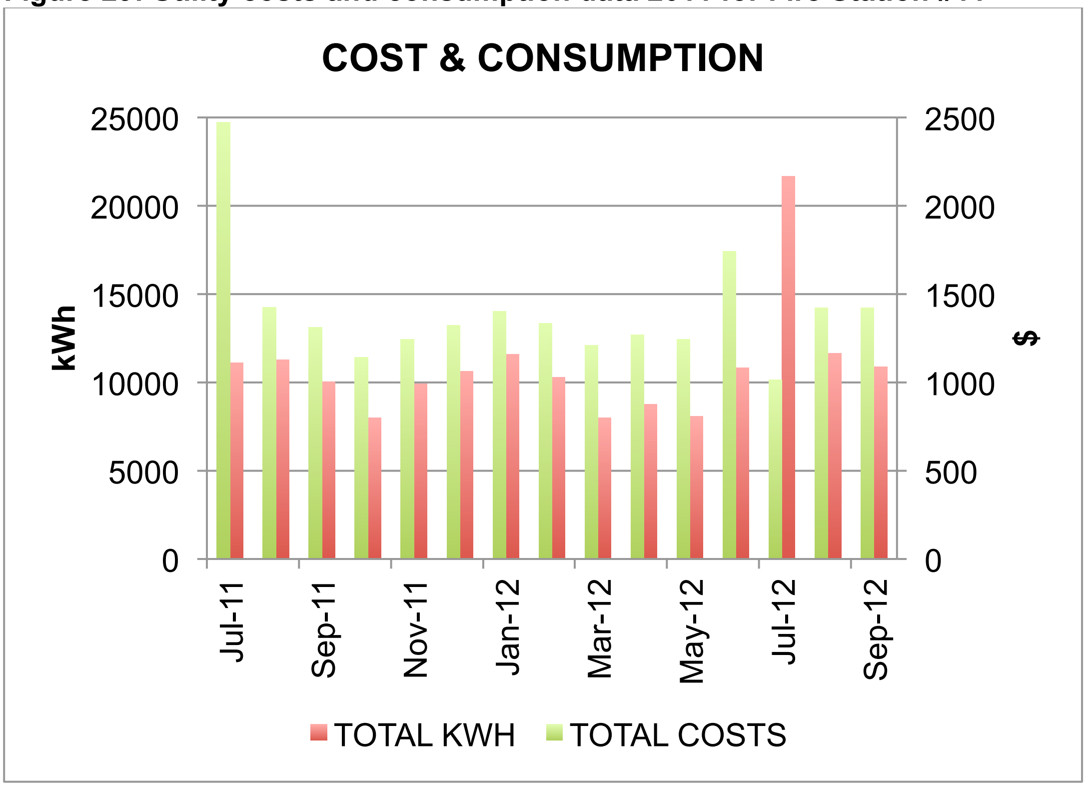


Table 12: Utility costs and consumption data for Fire Station #11 used for price calculations

MONTH	DAYS	TOTAL kWh	TOTAL COSTS	$\frac{¢}{kWh}$	COST PER DAY
Jul-11	30	11,120.00	$2,473.02	22.24	82.43
Aug-11	31	11,280.00	$1,425.55	12.64	45.99
Sep-11	31	10,040.00	$1,311.85	13.07	42.32
Oct-11	30	8,000.00	$1,141.12	14.26	38.04
Nov-11	31	9,920.00	$1,245.45	12.55	40.18
Dec-11	30	10,640.00	$1,324.28	12.45	44.14
Jan-12	31	11,600.00	$1,403.23	12.10	45.27
Feb-12	31	10,280.00	$1,334.34	12.98	43.04
Mar-12	29	8,000.00	$1,210.15	15.13	41.73
Apr-12	31	8,760.00	$1,269.46	14.49	40.95
May-12	30	8,080.00	$1,242.89	15.38	41.43
Jun-12	31	10,840.00	$1,742.13	16.07	56.20
Jul-12	30	21,680.00	$1,015.07	4.68	33.84
Aug-12	31	11,640.00	$1,421.33	12.21	45.85
Sep-12	31	10,880.00	$1,422.17	13.07	45.88
PERIOD	458	162,760.00	$20,982.04	12.89	45.81
REDUCED PERIOD	398	129,960.00	$17,493.95	13.46	43.95

Billing period: 06/20/2011 – 09/19/2012

4 Concepts and Results

This chapter deals with all the results of the different energy audits. The energy saving opportunities for the assessed buildings are gathered. Furthermore general approaches are provided for each section.

4.1 Lighting

Each assessed building was equipped with a different lighting system. The approaches to reduce the energy consumption can be split into two parts, the upgrade of existing lamps and fixtures with new ones and the automated control of the lighting.

4.1.1 Lighting upgrade

During the energy assessments different type of lamps have been identified. Most of them could be replaced with higher efficient lamps without a significant reduction of the brightness. Table 13 below shows the different type of recommended retrofits.

Table 13: Lighting upgrade ESO result overview

Building	Existing lamp type	Replacement lamp type	Ann. kWh savings	Ann. $ savings	PB years
Fire station #8	FL T12	FL T-8	1,453	156.92	1.41
Fire station #8	INC	CFL	676	73.01	0.59
Fire station #8	CFL	LED	263	28.40	6.14
Fire station #8	MH 400W	MH 320W	403	43.52	4.10
Fire station #11	INC	CFL	120	12.96	0.98
Robinson Garage	CFL exit signs	LED exit signs	1,051	92.49	8.37
State St. Garage	CFL exit signs	LED exit signs	1,840	158.24	8.56
Total			5,806	565,54	

4.1.1.1 Fluorescent lighting upgrade with FL T-8 lamps in Fire station #8

The energy consumption of fluorescent lighting can be reduced significantly with the use of energy-efficient lamps and electronic ballasts. Because a ballast test indicated that electronic ballasts are used throughout the facility, energy-efficient T-8 lamps to replace T-12 are recommended for all of the plant's fluorescent fixtures.

T-12 fluorescent lamps drawing $40W$ in the 4-lamp, 4-foot fixtures should be replaced with energy-efficient T-8 lamps that are rated at $32\,W$ each. The ballast does not have to be changed for this upgrade. Energy-efficient lamps have been available for several years. If standard lamps were replaced at burnout with energy-efficient lamps, the simple payback period would be about 1.41 years when cooling energy savings are included. Please note that these paybacks do not include labor costs as they are considered to be as high as for replacement with non energy-efficient lamps.
According to: [Grainger T12, 2011] [Grainger T8, 2011]

The calculation results for the fluorescent replacement are summarized in Table 14. The average electricity cost of $10.8\frac{¢}{kWh}$ was used in the analysis. An example calculation is attached in the appendix starting page L.

Table 14: Results of FL lighting upgrade with FL T-8 lamps in Fire station #8

Location	Type	#	Op Hours	Existing $Watt$	Retrofit $Watt$	Saved kWh^*	Ann. $ saved	PB years
Kitchen	4 x 4 ft T-12	4	4,500	142	109	690	74.52	0.97
Living Room	4 x 4 ft T-12	3	2,500	142	109	287	31.00	1.75
Captain bedrm	4 x 4 ft T-12	1	2,500	142	109	96	10.37	1.74
Captain Bathrm	2 x 4 ft T-12	1	2,000	71	58	30	3.24	2.79
Truck Bay	4 x 4 ft T-8	18	4,500	109	109	-		
Recruits Bedrm	4 x 4 ft T-12	3	2,500	142	109	287	31.00	1.75
Recruits Bathrm1	1 x 4 ft T-12	1	2,000	44	30	33	3.56	1.27
Recruits Bathrm2	2 x 4 ft T-12	1	2,000	71	58	30	3.24	2.79
Total						1,453	156.92	1.41

*-Savings include HVAC energy saved

Total # bulbs: 49

Price per bulb: $4,52 [Grainger T8, 2011]

4.1.1.2 Incandescent lighting upgrade with CFL's in Fire station #8

The energy consumption used for lighting can be reduced by nearly 80 percent by the use of Compact Fluorescent Lamps (CFL) compared to incandescent lamps. When a light source is replaced, the lumens of the replacement should be equal to the lumens of the original light source. Therefore an existing 60W incandescent lamp can be replaced by a 13W CFL.

Additional to the lower consumption of CFL's the lifetime is expected to be 8 times higher in average. Therefore, the maintenance costs are reduced, which are not included in the payback time calculation.
LED lamps are more efficient and last even longer than CFL's. The price for LED lamps is still too high to be competitive for most application in the USA today. This can change in the near future, as prices for LED's are dropping significantly. It is not recommended to wait with the replacement until LED lamps are cheaper, for the fast payback time of CFL replacement.
According to: [Grainger Inc 40,2011] [Grainger Inc 60,2011] [Grainger Inc 75, 2011] [Grainger CFL 10, 2011] [Grainger CFL 13, 2011] [Grainger CFL 20, 2011]

Energy efficient lamps have been available for several years. If standard lamps were replaced at burnout with energy efficient lamps, the simple payback period would be about 0.59 years when cooling energy savings are included. Please note that these paybacks do not include labor costs as they are considered to be as high as for replacement with non energy-efficient lamps.

The calculation results for the incandescent lamp replacement are summarized in Table 15. The average electricity cost of $10.8\frac{¢}{kWh}$ was used in the analysis. An example calculation is provided in the appendix starting page L.

Table 15: Results of Incandescent lighting upgrade with CFL's in Fire station #8

Location	Type	#	Op Hours	Retrofit $Watt$	Retrofit price $**	Saved kWh*	Ann. $ saved	PB years
Recruits Bathrm1	INC 40W	1	2,000	10	7,53	69	7.45	1.01
Recruits Bathrm2	INC 60W	2	2,000	13	6,38	218	23.54	0.54
Recruits Bathrm2	INC 40W	1	2,000	10	7,53	70	7.56	1.00
Storage	INC 60W	1	3,500	13	6,38	191	20.63	0.31
Captain Bathrm	INC 75W	1	2,000	20	9,05	128	13.82	0.65
Total						676	73.01	0.59

*-Savings include HVAC energy saved

Total # bulbs: 2 x 40W + 3 x 60W + 1 x 75W = 6

**[Grainger CFL 10, 2011] [Grainger CFL 13, 2011] [Grainger CFL 20, 2011]

4.1.1.3 CFL lighting upgrade with LED's in Fire station #8

Spiral compact fluorescent lamps are used in all 5 outside light fixtures. The CFL lamps consume $26W$ at $110V$. The compact fluorescent lamp provides light output of 1380 mean lumens. The replacement LED lamps that provide similar light output are the $14W$ LED with screw-in base and A19 lamp design. The $14W$ LED has got 1100 Lumens. The expected mean lumen reduction for this particular retrofitting is 280 $lumens$ or a reduction of about 20 percent.

In addition to energy savings, another advantage of LED replacement lamps is their long lamp life. LED lamps have a rated life of 25,000 hours or more. A 25,000 hours lamp has an expected life of about 6 years. The reasons for choosing LED replacement lighting include lower operating cost, fewer lamp replacements and energy conservation.

According to: [Grainger CFL 26, 2011] [BulbConnection, N.D.]

The calculation results for the CFL lamp replacement is summarized in Table 16. This ESO results in a simple payback period of 6.14 years. The average electricity cost of $10.8\frac{¢}{kWh}$ was used in the analysis. The detailed calculation is attached in the appendix starting page P.

Table 16: Results of CFL lighting upgrade with LED in Fire station #8

Location	Type	#	Op Hours	Existing $Watt$	Retrofit $Watt$	Saved kWh	Ann. $ saved	PB years
Outside	CFL	1	4,380	26	14	263	28.40	6.14

Price per LED: $34,85 [BulbConnection, N.D.]

4.1.1.4 MH 400W lighting upgrade with MH 320W in Fire station #8

Although the current $400W$ metal halide lamp with magnetic ballast has a higher initial lumen output than a $320W$ lamp with pulse-start ballast, the probe start fixture's light output deteriorates quickly. Because of this light reduction over time, the mean lumen output for the $400W$ probe-start fixture is lower than the output of the $320W$ pulse start fixture. Replacing the $400W$ metal halide lamps with $320W$ lamps and pulse-start ballasts saves energy.
According to: [Grainger MH 320, 2011] [Grainger MH 400, 2011] [Grainger MHB 320, 2011] [Grainger MHB 400, 2011]

The outside pole lamp is controlled with a photocell. The light operates approximately 12 hours per day for 365 days per year. This daily operation of 12 hours per day equals 4,380 $\frac{hr}{yr}$. The payback calculation of the retrofit ballast retrofit results in 4.10 years payback period.

The calculation results for the Metal Halide lamp and ballast replacement is summarized in Table 17. The average electricity cost of 10.8$\frac{¢}{kWh}$ was used in the analysis. The detailed calculation is attached in the appendix starting page P.

Table 17: Results of MH lighting upgrade with MH with pulse-start ballast in Fire station #8

Location	Type	#	Op Hours	Existing $Watt*$	Retrofit $Watt*$	Saved kWh	Ann. $ saved	PB years
Outside	MH	1	4,380	460	368	403	43.52	4.10

*includes the ballast watt

Price for ballast retrofit: $178,25 [Grainger MHB 320, 2011]

4.1.1.5 Incandescent lighting upgrade with CFL in Fire station #11

The energy consumption used for exhaust hood lighting can be reduced by nearly 80 percent by the use of CFL's compared to Incandescent lamps. An existing 60W Incandescent lamp can be reduced by a 13W CFL without the reduction of lumens.

Additional to the lower consumption of CFL's the lifetime is expected to be 8 times higher in average. Therefore, the maintenance costs are reduced, which are not included in the payback time calculation.
LED lamps are more efficient and last even longer than CFL's. The price for LED lamps is still too high to be competitive for most application in the USA today. This can change in the near future, as prices for LED's are dropping significantly. It is not recommended to wait with the replacement until LED lamps are cheaper, for the fast payback time of CFL replacement.
According to: [Grainger Inc 60,2011] [Grainger CFL 13, 2011]

If standard lamps were replaced at burnout with energy efficient lamps, the simple payback period would be about 0.98 years when cooling energy savings are included. Please note that these paybacks do not include labor costs as the considered to be equal high as for a normal lamp replacement after burnout. The calculation results are summarized in Table 18. The average electricity cost of 0.135$\frac{\$}{kWh}$ was used in the analysis. Detailed calculations can be found in the appendix starting page R.

Table 18: Results of Incandescent lighting upgrade with CFL's in Fire station #11

Location	Type	#	Op Hours	Retrofit $Watt$	Retrofit price \$	Saved kWh*	Ann. \$ saved	PB years
Kitchen Exhaust	INC 60W	2	1,000	13	6,38	120	12.96	0.98

*-Savings include HVAC energy saved

4.1.1.6 CFL exit sign upgrade with LED exit sign in Robinson Garage

Replacing the existing exit signs with LED exit signs will reduce the energy consumption and decrease the peak demand. Both will help to decrease the monthly costs.

This building is equipped with 8 exit signs, 2 on each floor. More efficient exit signs can replace all of them. This would reduce the operational costs. The safety would not be influenced by the change of the exit signs. The existing exit signs demand was read $18W$ during an on site visit on September 25th. LED exit signs require only $3W$.

The implementation costs of $96.75 per exit sign include the price for the sign as well as labor costs. The price for the sign is $84.35. The price for labor cost was estimated with $50 per hour. The duration to change one exit sign was estimated with 15 minutes, which results in $12.50 per sign.
According to: [Grainger EXITLED, 2011]

The calculation results are summarized in Table 19. The average electricity cost of $8.8\frac{¢}{kWh}$ was used in the analysis. The simple payback time calculation results in an 8.37 years return on investment. A more detailed calculation is provided in the appendix starting page S.

Table 19: Results of CFL exit sign upgrade with LED exit sign in Robinson Garage

Location	Type	#	Op Hours	Existing $Watt$*	Retrofit $Watt$	Saved kWh	Ann. $ saved	PB years
Stairway East	Exit sign	4	8,760	18	3	525	46.24	8.37
Stairway West	Exit sign	4	8,760	18	3	525	46.24	8.37
Total						1,051	92.49	8.37

*-Exit sign wattage read during on site visit on Sep 25th. The exit sign is not sold anymore.

4.1.1.7 CFL exit sign upgrade with LED exit sign in State St. Garage

Replacing the existing exit signs with LED exit signs will reduce the energy consumption and decrease the peak demand. Both will decrease the monthly cost.

This building is equipped with 14 exit signs, 2 on each floor. More efficient exit signs can replace all of them. LED exit signs demand $3W$ for operation. The existing exit signs were read with $18W$ during the on site visit on September 26th. Replacement would reduce the operational costs. The safety would not be influenced by the change of the exit signs.

The implementation costs of \$96.75 per exit sign include the price for the sign as well as labor costs. The price for the sign is \$84.35. The price for labor cost was estimated with \$50 per hour. The duration to change one exit sign was estimated with 15 minutes, which results in \$12.50 per sign.
According to: [Grainger EXITLED, 2011]

The calculation results are summarized in Table 20. The simple payback time calculation results in an 8.6 years return on investment. The average electricity cost of $8.6\frac{¢}{kWh}$ was used in the analysis. A more detailed calculation is provided in the appendix starting page T.

Table 20: Results of CFL exit sign upgrade with LED exit sign in State St. Garage

Location	Type	#	Op Hours	Existing $Watt$*	Retrofit $Watt$	Saved kWh	Ann. $ saved	PB years
Stairway East	Exit sign	7	8,760	18	3	920	79.12	8.56
Stairway West	Exit sign	7	8,760	18	3	920	79.12	8.56
Total						1,840	158.24	8.56

4.1.2 Lighting control

During the energy assessments different lighting control measures have been recommended. Most of the recommendations have got a quick payback. Table 21 below shows the different type of recommended retrofits.

Table 21: Lighting control ESO result overview

Building	Locations	Ann. kWh savings	Ann. $ savings	PB years
Fire station #8	Bathrooms	967	104.44	9.28
Fire station #11	Bathrooms, Bunk, Hallways, Storage, Office, Dressing, Technic	6,809	926.02	4.15
Robinson Garage	Stairways	2,616	230.21	4.09
State St. Garage	Stairways	9,812	843.83	1.95
Robinson Garage	Use of daylight	103,912	9,144.26	1.22
State St. Garage	Use of daylight	163,779	14,086.71	1.04
Total		287,895	25,335.47	

4.1.2.1 Install Occupancy Sensors in Bathrooms in Fire station #8

Due to the use of motion sensors the duration of lighting can be reduced significantly. The light is switched off, if the room is not occupied. Furthermore, due to the integrated timer function the light, and especially the fan do not go off immediately. This helps to remove moisture in bathrooms very efficiently.

In fire stations the savings are even higher than in normal buildings. In case of a fire run it is not possible to switch off all lights in every room. As a result, the light stays on until the fire brigade returns. Occupancy sensors could solve this issue.

It is recommended to use multi technology sensors for bathrooms. This ensures that the light will not go out during occupancy. The disadvantage of multi technology sensors is the higher price..

The calculation results are summarized in Table 22. The average electricity cost of 10.8$\frac{¢}{kWh}$ was used in the analysis. The simple payback time calculation results in a 9.28 years return on investment. A detailed calculation is provided in the appendix starting page V.

Table 22: Results of lighting control in bathrooms in Fire station #8

Location	Type	#	Existing $Watt$	Op Hours	Reduced Op Hours	Saved kWh*	Ann. $ saved	PB years
Recruits Bathrm1	1 x 4 ft T-12	1	44					
	INC	1	40					
	FAN	1	60					
	Sub		144	2000	700	217	23.44	13.78
Recruits Bathrm1	2xT-12 U-bend	1	71					
	INC	3	160					
	FAN	1	60					
	Sub		291	2000	700	439	47.41	6.81
Captain Bathrm	2xT-12 U-bend	1	71					
	INC	1	75					
	FAN	1	60					
	Sub		206	2000	700	311	33.59	9.62
Total						967	104.44	9.28

*-Savings include HVAC energy saved

Price for multi technology sensor: $323 ($195 material + $128 labor)
According to appendix page D

4.1.2.2 Install Occupancy Sensors in different rooms in Fire station #11

The use of motion sensors will reduce the duration of lights turned on in a given space. The light is automatically switched off, if the sensor determines the room is not occupied. Furthermore due to the integrated timer function included with the motion sensor, the light, and especially the fan does not go off immediately. This helps to remove excess moisture in bathrooms very efficiently.

It is recommended that multi-technology sensors be used in fire station bathrooms. This ensures that the light will not go out during occupancy. The disadvantage of multi-technology sensors is the higher price. Therefore, this sensor type should be installed only when necessary. Cheaper single technology sensors should work proper in other room types such as bunkrooms or storage rooms.

The average electricity cost of $13.6\frac{¢}{kWh}$ was used in the analysis. The simple payback time calculation results in a 4.15 years return on investment. The calculation results are summarized in Table 23. The selected sensors for each room are shown in Table 24. The price for the different sensor types is displayed in Table 25. The detailed calculation can be found in the appendix starting page X

The operation time of lights in the Men's bathroom and in the Hallway was measured with data loggers for a three-day period. The evaluation shown in Table 26 lists the amount of time the light was off (light intensity below 10 $\frac{Lumen}{ft^2}$) and on (light intensity above 10 $\frac{Lumen}{ft^2}$). Figure 30 displays the measurement results graphically.

Table 23: Results of lighting control in different rooms in Fire station #11

Location	Type	#	Total $Watt$	Op Hours	Red. Op Hours	Saved kWh*	Ann. $ saved	PB years
Bath W	4 x 4ft T12	3	423					
	2 x 4ft T12	3	213					
	CFL	2	26					
	Fan	2	120					
	Sub		782	2,200	700	1,333	181.29	3.56
Bath M	4 x 4ft T12	3	423					
	2 x 4ft T12	4	284					
	CFL	2	26					
	Fan	2	120					
	Sub		853	2,200	700	1,454	197.75	3.27
Bunk	4 x 4ft T12	1	141	1,500	500			
	Sub (8x)		1,128	1,500	500	1,282	174.35	3.30
Office	4 x 4ft T12	1	141	1,500	500			
	Sub (2x)		282	1,500	500	320	43.52	2.62
Entrance	4 x 4ft T12	4	564	1,000	800	128	17.41	12.12
Hallway	4 x 4ft T12	9	1269	700	350	505	68.68	9.22
Technic room	4 x 4ft T12	1	141	1,000	500	80	10.88	6.62
Dress. room	2 x 8 ft T-8	2	210	1,000	200	168	22.85	9.23
Storage	2 x 8 ft T-8	1	105	1,500	800	84	11.42	6.30
Office garage	2 x 8 ft T-8	6	630	1,500	500	716	97.38	2.17
Compres sor	2 x 8 ft T-8	3	315	1,500	500	358	48.69	4.33
Storage 2nd floor	2 x 8 ft T-8	6	630	1,000	500	358	48.69	4.33
Total						6,809	926.02	4.15

*-Savings include HVAC energy saved

Table 24: List of motion sensor type for each room in Fire station #11

Location	Sensor type	No Sensors	Investment costs $
Bath W	MTC	2	646
Bath M	MTC	2	646
Bunk	OSS	8	576
Office	OSS	2	114
Entrance	OSC	1	211
Hallway	OSC	3	633
Technic room	OSS	1	72
Dressing room	OSC	1	211
Storage	OSS	1	72
Office garage	OSC	1	211
Compressor	OSC	1	211
Storage 2nd floor	OSC	1	211
Total		24	3,844

Table 25: Pricelist for occupancy sensors used in Fire station #11

Type	Shortcut	Price material $	Price Labor $	Price total $
Occupancy sensor in switch	OSS	22*	50***	72
Occupancy sensor Ceiling mounted	OSC	115	96	211**
Multi technology occupancy sensor	MTC	195	128	323**
		TOTAL		323

* [Homedepot, N.D.]

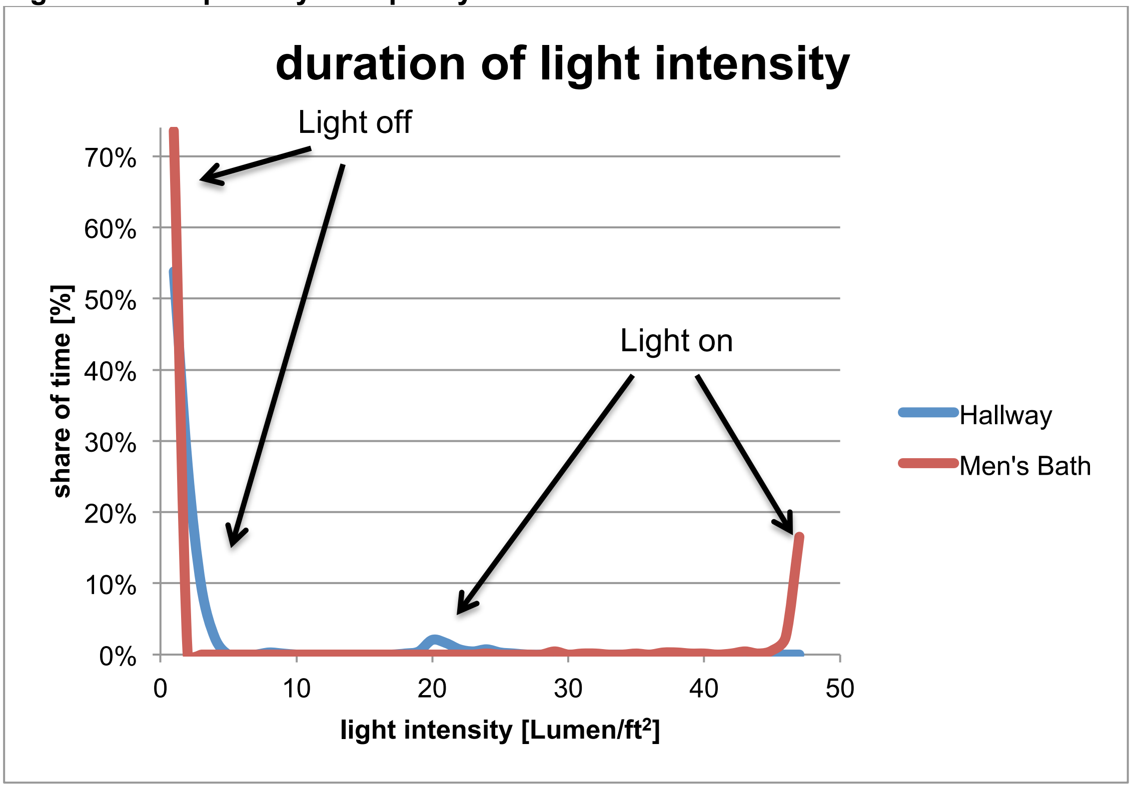
** Appendix page D

*** Estimation: $1h$ work @ $50\frac{\$}{h}$

Table 26: Occupancy measurement evaluation of Fire station #11

Light intensity $[\frac{Lumen}{ft^2}]$			
between		Men's Bath	Hallway
0	5	73.56%	92.32%
5	10	0.00%	0.44%
10	15	0.00%	0.00%
15	20	0.00%	2.66%
20	25	0.15%	3.84%
25	30	0.44%	0.30%
30	35	0.44%	0.00%
35	40	0.89%	0.00%
40	45	1.33%	0.15%
45	50	23.19%	0.00%
50		0.00%	0.30%

Figure 30: Graphically occupancy measurement evaluation of Fire station #11



4.1.2.3 Install Occupancy Sensors in stairways in Robinson Garage

Installing vacancy sensors in stairways will ensure that the light is off if not used. Furthermore the included photocell harvests daylight and therefore reduces the operation hours further more. The integrated timer ensures that everyone can reach his destination without the light switching off all the time.

It is recommended to use infrared technology sensors with an integrated photocell for opened stairways. This ensures on the one hand that street noises do not influence the sensor and therefore increase the operation hours. On the other hand the photocell can sense ambient light and ensures that the stairway light only switches on if necessary. The price for the sensor is $92.60 and labor costs were estimated with 30 min for a worker with a $50 per hour rate. This results in total costs per sensor of $117.60. One sensor per floor and stairway has to be used. [Grainger OCC, 2011]

The calculation results are summarized in Table 27. The average electricity cost of $8.8\frac{¢}{kWh}$ was used in the analysis. The simple payback time calculation results in a 4.09 years return on investment. An example calculation for a stairway is attached in the appendix starting page Z.

Table 27: Result of lighting control in stairways in Robinson Garage

Location	Type	#	Total $Watt$	Op Hours	Red Op Hours	Saved kWh	Ann. $ saved	PB years
East	2x 4 ft T-8	4	224	8,760	2,920	1,308	115.10	4.09
West	2x 4 ft T-8	4	224	8,760	2,920	1,308	115.10	4.09
Total						2,616	230.21	4.09

4.1.2.4 Install Occupancy Sensors in stairways in State St. Garage

Due to the use of vacancy sensors the duration of lighting can be reduced significantly. The light is switched off, if the room is not occupied. Furthermore, due to the integrated photocell daylight can be harvested and the operation hours of the light can be reduced further. The included timer function ensures that every person has got enough time to reach the desired floor without the light going out.

It is recommended to use infrared technology sensors with an integrated photocell for opened stairways. This ensures on the one hand that street noises do not influence the sensor and therefore increase the operation hours. On the other hand the photocell can sense ambient light and ensures that the stairway light only switches on if necessary. The price for the sensor is $92.60 and labor costs were estimated with 30 min for a worker with a $50 per hour rate. This results in total costs per sensor of $117.60. One sensor per floor and stairway has to be used. [Grainger OCC, 2011]

The calculation results are summarized in Table 28. The average electricity cost of $8.6\frac{¢}{kWh}$ was used in the analysis. The simple payback time calculation results in a 1.95 years return on investment. A detailed calculation is attached in the appendix starting page BB.

Table 28: Result of lighting control in stairways in State St. Garage

Location	Type	#	Total Watt	Op Hours	Red Op Hours	Saved kWh	Ann. $ saved	PB years
East	2x 4 ft T-8	15	840	8,760	2,920	4,906	421.92	1.95
West	2x 4 ft T-8	15	840	8,760	2,920	4,906	421.92	1.95
Total						9,812	843.83	1.95

4.1.2.5 Use of daylight in Robinson Garage

The opened construction of the parking garage allows daylight to infiltrate the building. This daylight illuminates the parking area much more than the electrical light does. Therefore daylight sensors should be installed to harvest the daylight. The price for a daylight sensor is $300 and $50 for labor, which results in total $350 per sensor. [Harper, 2012, oral]

To be able to evaluate the influence of the sunlight measurement points have been identified. The brightness was measured during a sunny day and during night. The artificial lighting was switched on during both data collection periods. Therefore the influence of the sun results in the difference between the two values of each data point. The results of the measurement of the third floor are displayed in Figure 31 for daylight situation and in Figure 32 for nighttime situation. Figure 33 displays the calculated influence of the sun.

These figures show the position of the measurement points as well as the electric light sources. The symbol ⊗ stands for a HPS lamp with $150W$ in a ceiling fixture. The symbol ⊠ stands for a $70W$ ceiling mounted HPS spotlight. The measuring results are displayed in fc. For parking garages an illumination level of 5 fc is reasonable.
Figure 34 shows the areas which qualified for the use of daylight and which area did not. The best daylighting results will be achieved, if the area is split up into 4 subsections. Suggested subsections are North, South, East and West, where every section should have 2 daylight sensors.

HPS lamps are not designed to be switched on and off within short time periods. Most HPS lamps need at least 2 minutes to cool down after shut down before they can be switched on again. Furthermore they need up to 15 minutes to reach the maximum brightness. Therefore a timer has to be integrated in the daylight control. Otherwise the lifetime of the lamps would be reduced.

The calculation results are summarized in Table 29. The average electricity cost of $8.8\frac{¢}{kWh}$ was used in the analysis. The simple payback time calculation results in a 1.22 years return on investment. The fifth floor was not taken into consideration as the light was switched off during the day visit. Therefore an existing daylight control was assumed. A detailed calculation is attached in the appendix starting page CC.

Table 29: Result of use of daylight in Robinson Garage

floor	Type	#	Total $Watt$*	Op Hours	Reduced hours	saved kWh	Ann. $ saved	PB years
1st	HPS 170W	35	5,950	8,760	4,910	22,908		
	HPS 170W	10	1,700	8,760	8,760	0		
	HPS Spot 80W	2	160	8,760	4,910	616		
	Subtotal					23,524	2,070.11	1.35
2nd	HPS 170W	40	6,800	8,760	4,910	26,180		
	HPS 170W	10	1,700	8,760	8,760	0		
	HPS Spot 80W	2	160	8,760	4,910	616		
	Subtotal					26,796	2,358.05	1.19
3rd	HPS 170W	40	6,800	8,760	4,910	26,180		
	HPS 170W	10	1,700	8,760	8,760	0		
	HPS Spot 80W	2	160	8,760	4,910	616		
	Subtotal					26,796	2,358.05	1.19
4th	HPS 170W	40	6,800	8,760	4,910	26,180		
	HPS 170W	10	1,700	8,760	8,760	0		
	HPS Spot 80W	2	160	8,760	4,910	616		
	Subtotal					26,796	2,358.05	1.19
Total						10,3912	9,144.26	1.22

* includes the ballast wattage

Figure 31: Light intensity measurement in fc during daytime in Robinson Garage

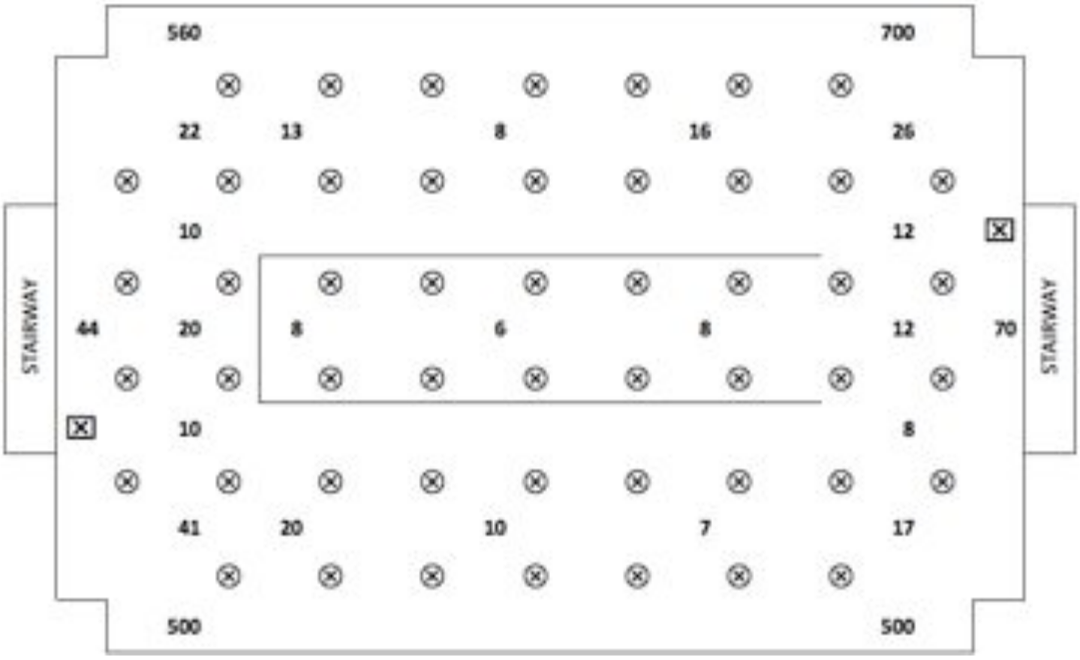


Figure 32: Light intensity measurement in fc during night in Robinson Garage

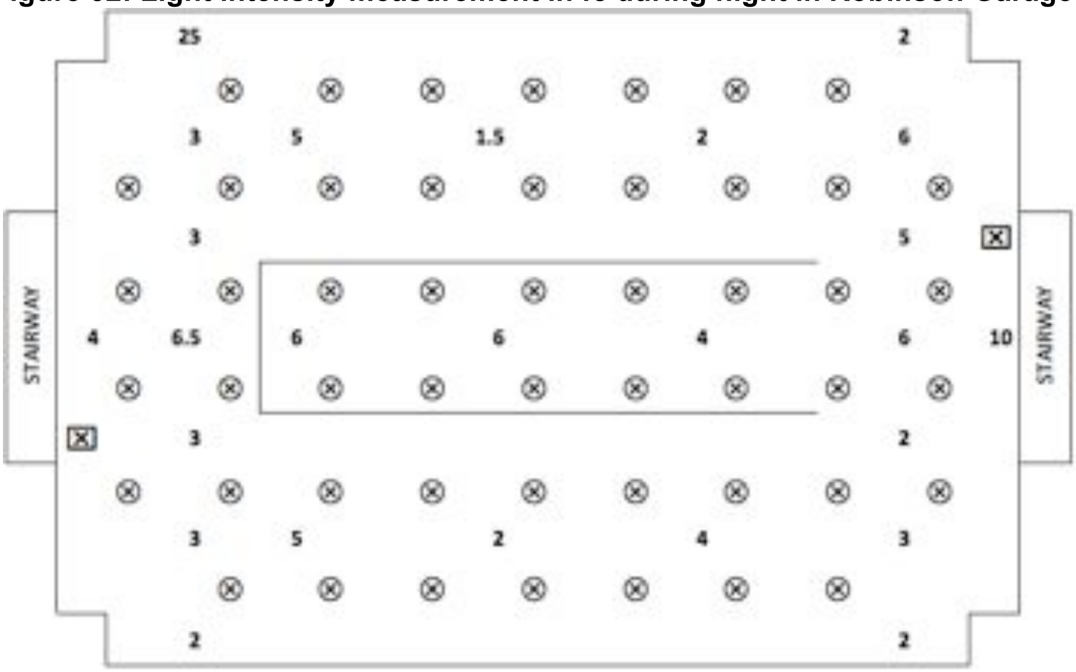


Figure 33: Light intensity calculation for the sun in fc in Robinson Garage

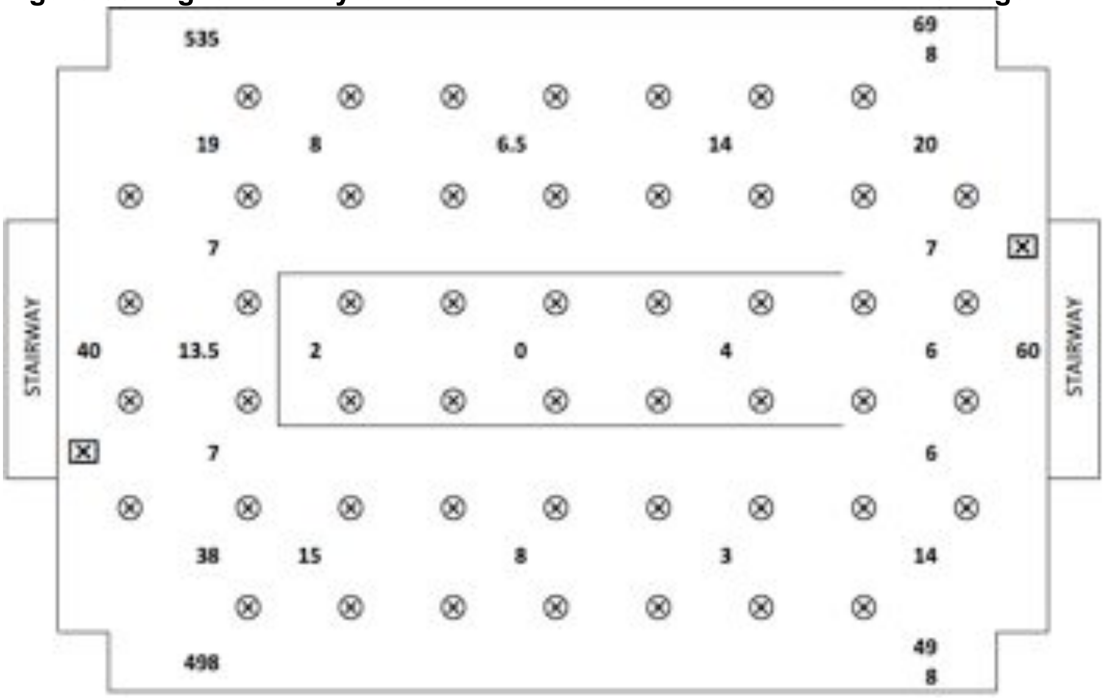
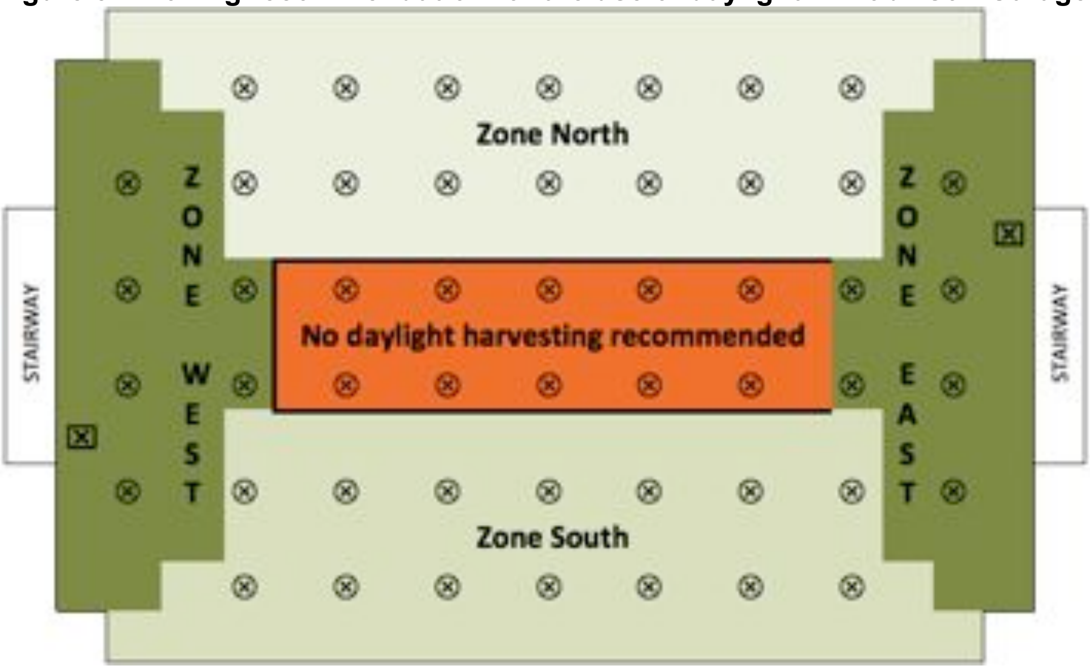


Figure 34: Zoning recommendation for the use of daylight in Robinson Garage



4.1.2.6 Use of daylight in State St. Garage

The opened construction of the parking garage allows daylight to infiltrate the building. This daylight illuminates the parking area much more than the electrical light does. Therefore the artificial light should be switched off. To be able to evaluate the influence of the sunlight measurement points have been identified. The brightness was measured during a sunny day and during night. The artificial lighting was switched on during both data collection periods. Therefore the influence of the sun results in the difference between the two values of each data point.

The results of the measurement in fc of the third floor are displayed in the Figure 35 for daytime and Figure 36 for nighttime. Figure 37 shows the calculated sun illuminicance. These figures show the position of the measurement points as well as of those of the electric light sources. The symbol ⊗ stands for a HPS lamp with 150W ceiling mounted.

Figure 38 shows recommended zoning for the implementation of daylight use. The best daylighting results will be achieved, if the area is split up into 4 subsections. Suggested subsections are Northeast, Southeast, Northwest and Southwest, where every section should have 2 daylight sensors. The 7th floor does not require zoning. Two daylight sensors can serve this area.

HPS lamps are not designed to be switched on and off within short time periods. Most HPS lamps need at least 2 minutes to cool down after shut down before they can be switch on again. Furthermore they need up to 15 minutes to reach the maximum brightness. Therefore a timer has to be integrated in the daylight control. Otherwise the lifetime of the lamps would be reduced. This is one of the main reasons why LED lighting should be preferred in future lighting constructions. LED’s are 100 percent dimmable and can be switched without any delays, which results in higher savings due to reduced runtimes.

The price for a daylight sensor is \$300 and \$50 for labor, which results in total \$ 350 per sensor. [Harper, 2012, oral] The calculation results are summarized in Table 30. The average electricity cost of $8.6\frac{¢}{kWh}$ was used in the analysis. The simple payback time calculation results in a 1.04 years return on investment. Detailed calculations are attached in the appendix starting page EE. The first floor was not taken into consideration, as the light was not very bright as a result of the construction.

Table 30: Result of use of daylight in State St. Garage

floor	Type	#	Total $Watt*$	Op Hours	Reduced hours	Saved kWh	Ann. \$ saved	PB years
2nd	HPS 170W	48	8,160	8,760	4,910	31,416	2,701.78	1.04
3rd	HPS 170W	48	8,160	8,760	4,910	31,416	2,701.78	1.04
4th	HPS 170W	48	8,160	8,760	4,910	31,416	2,701.78	1.04
5th	HPS 170W	48	8,160	8,760	4,910	31,416	2,701.78	1.04
6th	HPS 170W	48	8,160	8,760	4,910	31,416	2,701.78	1.04
7th	HPS 170W	2	340	8,760	4,910	1,309		
	HPS 170W High Bay	5	1,400	8,760	4,910	5,390		
	Subtotal					6,699	576.11	1.22
Total						163,779	14,086.71	1.04

* includes ballast wattage

Figure 35: Light intensity measurement in fc during day in State St. Garage

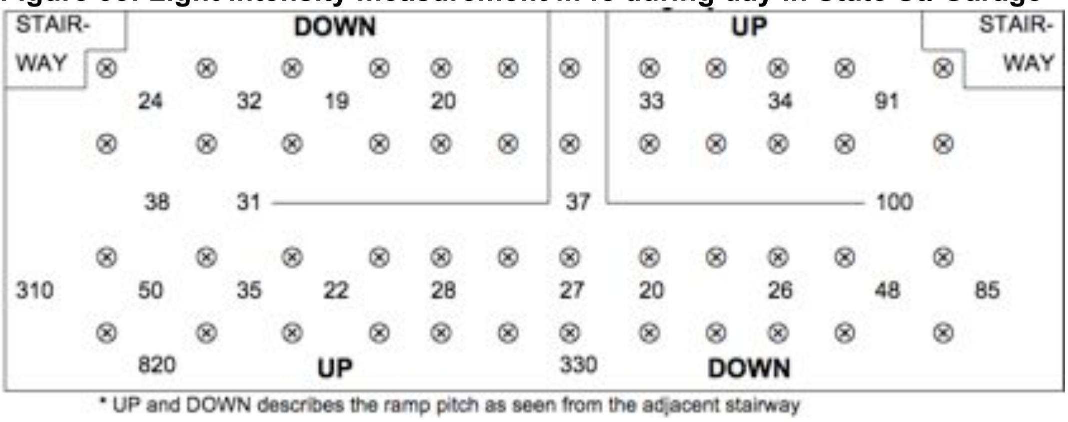


Figure 36: Light intensity measurement in fc during night in State St. Garage

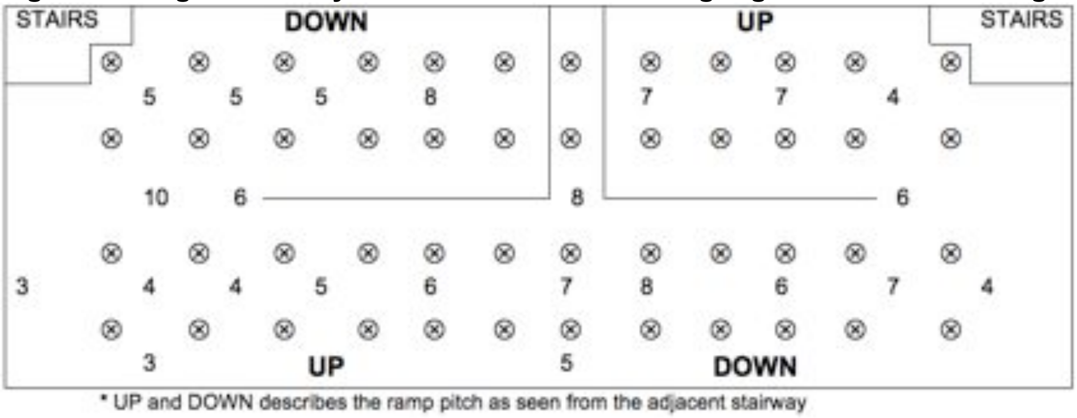


Figure 37: Light intensity calculation for the sun in fc in State St. Garage

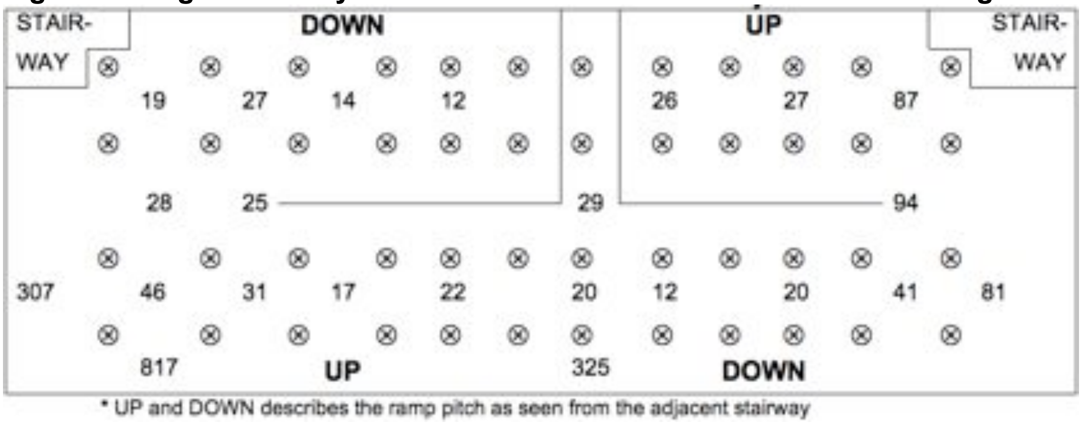
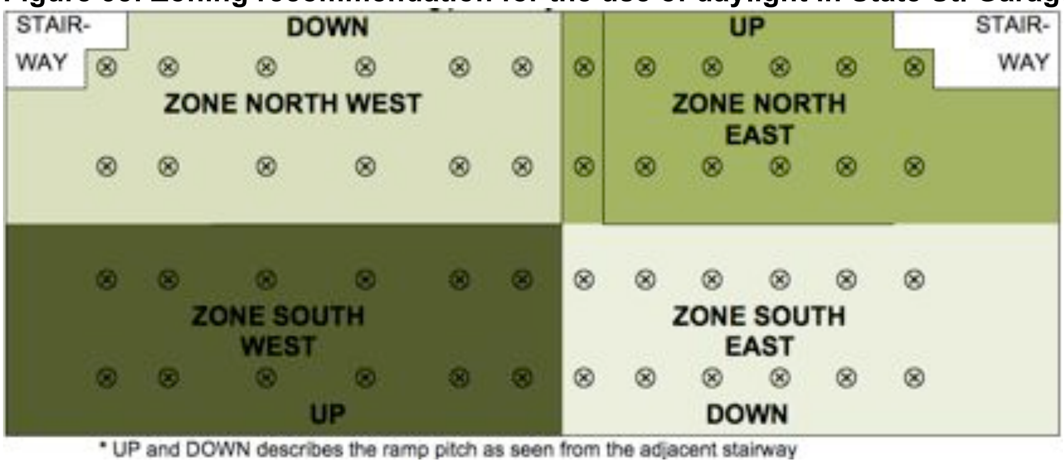


Figure 38: Zoning recommendation for the use of daylight in State St. Garage



4.2 Heating, Cooling and Air Conditioning

Each assessed building was equipped with different HVAC systems. The approaches to reduce the energy consumption can be split into two sections. The first part deals with heating equipment only. The second part deals with complex HVAC systems.

4.2.1 Replace electric resistance space heater in truck bay in Fire station #8

A 7.5kW electric resistance heater heats the truck bay in Fire station #8. The heating efficiency can be improved by installing a radiant heater in the space. This type of heater uses radiant heating instead of convective heating. A proper distance between the heater and the objects has to be installed.

In the savings calculation, heater load has been reduced because the installation of weather-stripping is assumed. The calculation results are summarized in Table 31. The simple payback time calculation results in a 6.5 years return on investment. The average electricity cost of 10.8$\frac{¢}{kWh}$ was used in the analysis. A more detailed calculation is provided in the appendix starting page FF.

Table 31: Results of heater upgrade in truck bay in fire station #8

Location	Actual Type	Retrofit Type	Retrofit price $	Saved kWh*	Ann. $ saved	PB years
Truck bay	Resistance heater	Infrared heater	1,440*	2,051	221.51	6.50

* Estimation based on practical value [Brown B, 2012, oral]

4.2.2 Replace Air-Cooled Split System with Ground-Source Heat Pump in Fire Station #8

The building's environmental control is provided with two 3.5 ton air cooled split systems and two 100,000 $Btuh$ natural gas furnace. Cooling and heating efficiency can be greatly improved by replacing the existing systems with a ground-source heat pump. The building is located in an area with a soil composed of moist sand, which is an excellent medium for heat transfer.

The cost of a residential size ground-source unit is approximately \$2,200 per ton. This includes the cost of installing a ground loop, which is about \$1100 per ton. This gives a total estimated cost of \$15,400 for a 7-ton unit. The calculation results are summarized in Table 32. The simple payback time calculation results in a 15.99 years return on investment The average electricity cost of 10.8$\frac{¢}{kWh}$ and the average natural gas cost of 13.205$\frac{\$}{MMBtu}$ was used in the analysis. A more detailed calculation is provided in the appendix starting page II.

Table 32: Results of HVAC upgrade in Fire station #8

Actual Type	Retrofit Type	Retrofit price \$	Saved kWh*	Saved $MMBtu$	Ann. \$ saved	PB years
3.5 ton air cooled split system & two 100000 Btuh natural gas furnance	Ground source heat pump	15,400*	2,860	49.51	963	15.99

* Estimation based on practical value [Brown B, 2012, oral]

4.3 Renewable Energy

This chapter deals with the implementation of renewable energy sources into existing buildings. The main focus is on photovoltaic systems. Especially the parking garages qualified due to their large roof and exposure to the sun. All requests for proposal were not answered. Therefore a break-even point calculation is provided instead.

One renewable energy utilization opportunity is described in chapter 4.2.2. It deals with a ground-source heat pump system.

4.3.1 Photovoltaic system for Robinson Garage

The installation of a photovoltaic system on the top level would serve different purposes. First of all it provides shading, which increases the value of the parking space. Secondly a photovoltaic system is a promotion for the city. Finally the system can offset the total annual electricity consumption.

The calculation of the required space for an electricity consumption offset after realization of ESO's is provided in the appendix starting on page PP. Around $\frac{1}{3}$ of the top level has to be covered with south-facing PV panels with $30°$ tilt to completely offset the electricity consumption. The prize of $4.14\frac{\$}{Wp}$ should not be exceeded to avoid additional costs. A prize below this limit will reduce costs compared to 2011 electricity prize. Table 33 provides an overview of the calculation results.

Table 33: Photovoltaic system calculation results for Robinson Garage

System Size	11,507 ft^2 (1,070 m^2)
Share of available area	32 %
Rated power	171 kWp
Break even prize	4.14 $\frac{\$}{Wp}$

4.3.2 Photovoltaic system for State St. Garage

The installation of a photovoltaic system on the top level would serve different purposes. First of all it provides shading, which increases the value of the parking place. Secondly a photovoltaic system is a promotion for the city. Finally the system can offset the annual electricity consumption.

To be able to offset the annual electricity consumption a photovoltaic system with south-facing modules with $30°$ tilt would have to cover an area of more than 14,000 ft^2 or 50 percent of the available roof area. Savings would be achieved if the prize of the system is below $4.04 \frac{\$}{Wp}$. The calculation is provided in the appendix starting on page RR. The results of the calculation are summarized in Table 34.

Table 34: Photovoltaic system calculation results for State St. Garage

System Size	14,063 ft^2 (1,308 m^2)
Share of available area	50 %
Rated power	209 kWp
Break even prize	4.04 $\frac{\$}{Wp}$

5 Conclusion

This part will derive conclusions from the Concept and result chapter. These conclusions are either for the implementation into existing buildings or for new constructions. A categorization into scopes of energy saving opportunities is provided.

5.1 Lighting

Inefficient lighting systems are wide spread in the cities infrastructure. A ban for inefficient Incandescent bulbs and fluorescent T-12 lamps could reduce the energy consumption and demand for lighting by approximately $\frac{1}{3}$. This could be easy to accomplish. A general rule for all employees would solve this issue.

Lighting control in existing buildings is complex to evaluate if the vacancy is not measured beforehand. A sensor in bathrooms and infrequent used rooms is still recommended and in most cases easy to accomplish. The minimum requirement for light control has to be a manual switch. Every room should have a separate switch and every lamp has to be switchable. Different locations did not meet the minimum requirement.

For new locations the use of daylight has to play a mayor role. Sunlight is the most efficient light source. An intelligent shading concept can furthermore reduce heating and cooing demand. In the core of a new building efficient light sources are essential. An intelligent light control system can be implemented in new constructions without huge extra costs. For example in Fire stations a main switch near the truck bay exit to shut down all lights is reasonable.

5.2 HVAC

A huge variety of different HVAC equipment is used throughout the cities infrastructure. A replacement of the equipment could increase the cooling and heating efficiency. It is preferable to install ground-source heat pump systems instead of the commonly used air-source heat pumps. The existing HVAC systems should not be replaced prior to other energy conservation measures. In general the heating and cooling demand will decline due to energy saving measures. The equipment has to fit to the requirements. A request for Manual J could guarantee a properly sized and therefore efficiently working HVAC system. Furthermore the maintenance cycles for air filters and other HVAC equipment parts must be adhered.

A proper set point selection in existing infrastructure including a set back during unoccupied times reduces costs and energy consumption. Programmable thermostats or a general rule for all employees supports the realization.

In new constructions a ground-source heat pump is preferable. The extra costs for a ground-source driven system are negligible compared to the higher efficiency of the system. The lifetime costs for different systems have to be compared. This will result in the implementation of higher efficient HVAC systems and reduce costs in long term.

5.3 Equipment

The equipment has to be used proper. This includes the shut down of equipment not in use. As example energy saving settings for al IT infrastructure can be implemented without troubles. The employees have to be involved. Transparent energy consumption for buildings can encourage employees to save energy and reduce costs if the idea of saving energy is desireable is conveyed.

For new equipment lifetime costs are key. Before any investment decision costs for a certain period, or lifetime, have to be compared. This will result in more efficient equipment. All new purchased equipment has to be Energy Star certified.

5.4 Renewable Energy

Renewable energy can offset energy costs. The implementation of any kind of renewable energy source should not be the first choice of measures. Cheaper energy savings can be achieved in most cases. For existing buildings upgrades are not always feasible. If equipment, especially HVAC equipment, has to be replaced renewable energy utilization is generally feasible. Photovoltaic systems are at the moment not feasible without any funding. The price for PV is declining worldwide, which can make installation profitable in a near future.

For new constructions implementation of renewable energy sources should be taken into account. Ground-source heat pumps have proven their reliability and feasibility in Savannah. Further the implementation of solar hot water generation has to be taken into consideration.

6 Summary

The city of Savannah wants to take a leading role in energy efficiency. They first strengthened their goal by accepting the governor's energy challenge, which obligates energy consumption cuts by 15 percent until 2020 based on 2007 consumption data. Another milestone to fulfill the city's target was the Savannah International Clean Energy Conference in November 2012 including its originated cooperation between the city of Savannah, Georgia Institute of Technology and University of Applied Sciences Upper Austria. The cooperation was established to perform energy assessments for the city's infrastructure.

The hot and humid climate in Savannah represents a new challenge. Heating and cooling patterns, construction methods and standard equipment of buildings differ compared to Austria. To be able to evaluate the user patterns, historic consumption data of all buildings operated by the city has been evaluated. A list of buildings with extraordinarily high energy consumption derived as suggestion for further observation. During a committee meeting access to appropriate buildings for energy assessments was granted.

During two on-site visits in each selected building data concerning equipment, lighting and HVAC systems was collected. Furthermore data loggers have been placed to identify occupancy patterns and time of use periods. Illumination measurements have been performed to evaluate saving opportunities. As a result of the energy assessments building specific saving opportunities have been derived as well as general saving potentials highlighted.

The largest saving potentials have lighting upgrades. For all four buildings savings sum up to more than $293{,}000 kWh$ or nearly $26,000 per year. The payback for most of these saving opportunities has been below three years. HVAC system replacements appeared to have longer payback periods. This period can be reduced tremendously if the unit has to be replaced and only the incremental costs are taken into account.

General conclusions for new constructions and retrofit options are summarized in “Green Building Guidance” for homeowners and small businesses. The guideline will be published on the homepage of the city of Savannah. The recommendations include the following.
Efficient lighting technology like LED or CFL is the key to reduce consumption. Intelligent lighting controls can reduce operation hours in common areas tremendously. Each light source has to be at least switchable.
Highly efficient cooling and heating equipment saves in the long term. Ground-source heat pumps are widely available and known technology with a high savings potential. Proper sizing of the equipment is as important as high efficiency.
Every purchase decision has to be based on lifetime costs to guarantee low costs and highest efficient.

7 List of figures

8 List of tables

9 List of formulas

10 Literature

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11 Appendix

11.1 Illuminating Engineering Society IES Lighting recommendations

IES Footcandle Recommendations

The following selected footcandle ranges represent the Illuminating Engineer Society's (IES) current illuminance recommendations. Indiviudal applications will determing exact footcandle levels. Please refer to the IES Lighitng Handbook for more detailed evaluation.

Airplane Manufacturing
- Drilling, riveting, screw fastening.................75
- Final assemble, hangar.............................100
- Inspection...50-200
- Welding...50

Assembly
- Rough easy seeing...............................20-50
- Rough difficult seeing..........................50-100
- Medium...100-200
- Fine...200-500(a)
- Extra fine....................................500-1000(a)

Auditoriums
- Social activities..5-10
- Assembly only..10-20
- Exhibitions...10-20

Automobile Manufacturing
- Final assembly, finishing, inspecting...........200
- Body & chassis assembly..........................100
- Body parts manufacturing..........................100
- Frame assembly..50

Banks
- Lobby general..10-50
- Writing areas..20-70
- Teller stations, posting & keypunch.......50-150

Barber Shops
- Beauty Parlors.....................................50-100

Chemical Works..30

Clothing Manufacturer
- Receiving, storing, shipping, winding, measuring...............................20-50
- Pattern making, trimming......................50-100
- Shops, marking...................................50-200
- Cutting, pressing............................100-500(a)
- Sewing, inspection..........................200-500(a)

Electrical Equipment Manufacturing
- Impregnating..20-50
- Insulating coil winding, testing..............50-100

Food Service Facilities
- Dining areas
- Cashier..20-50
- Cleaning..10-20
- Dining..5-20
- Food displays.......................................30-100
- Kitchen..50-100

Foundries
- Annealing furnaces................................20-50
- Cleaning..20-50
- Core making...50-200
- Inspection
- Fine..100-500
- Medium...50-100
- Molding...50-200
- Pouring, sorting...................................50-100

Garages-Motor Vehicles
- Storage...5
- Traffic Lanes
  - Parking garage...10
  - Service garage.......................................10-20
  - Entrances................ 50
  - Repair area...50-100

Gymnasiums
- Assemblies...10
- General exercise & recreation.....................30
- Exhibitions, matches....................................50

Hospitals
- Rooms...10-30
- Corridors...5-30
- Emergency rooms................................50-100
- Operating rooms................................100-200

Hotels
- Bathrooms...20-50
- Bedrooms for reading............................20-50
- Corridors, elevators and stairs................10-20
- Front desk...50-100
- Linen room
  - Sewing...100-200
  - General..10-20
- Lobby
  - General lighting....................................10-20
  - Reading and working areas.......................................20-50

Iron & Steel Manufacturing
- Stock, hot top, checker cellar, calcining...................................10-30
- Building, slag pits, stripping yard.................20
- Control platforms, repairs, mixer building...30
- Rolling mills...30-50
- Shearing..50
- Tin plate..50
- Motor room, machine room..........................30
- Inspection..100

Laundries
- Washing..20-50
- Ironing...20-100

Library
- Ordinary reading, stacks.........................20-50
- Book repair and binding..........................20-50
- Study & notes, cataloging, card files, check desk..........................20-100

Machine Shops
- Rough bench..20-50
- Medium bench, rough grinding, buffing..................................50-100
- Fine bench and work......................200-500(a)

Materials Handling
- Loading trucking....................................10-20
- Picking stock classifying........................20-50
- Wrapping, packing, labeling....................20-50

Offices
- Accounting..50-100
- Audio-visual areas.................................20-50
- Conference areas.................................20-70
- Corridors, stairways..............................20(k)
- Drafting...50-200
- General and private offices...................50-100
- Lobbies, lounges and reception areas...0-20
- Mail sorting..50-100
- Off-set printing and duplicating area......................................20-50
- Spaces with VDT's.....................................75

Paint Shop
- Spraying, rubbing, hand art, stencil.....................................20-50
- Fine hand painting & finishing..............50-100

Paper Manufacturing
- Beaters, grinding....................................20-50
- Finishing, cutting..................................50-100
- Hand couting...50-100
- Paper manchine reel, inspection.........100-200
- Rewinder..100-200

Printing
- Photo engraving, etching. blocking....................................20-50
- Color inspecting.................................100-200
- Presses...50-100
- Proofreading.......................................100-200
- Composing room.................................50-100

Schools
- Reading...20-100
- Typing...20-100
- Demonstrations.................................100-200
- Sewing..20-100

Sheet Metal Works
- General...100
- Tin plate inspection, galvanized, scribing...........................100-200

Stores
- Circulation area stockroom.....................10-30
- Merchandising, serviced.......................30-100
- Merchandising, self-service.......................200

Textile Mills
- Cotton picking, carding, roving, spinning...50
- Beaming & slashing..................................150
- Drawing..200
- Others..100

Warehousing, Storage
- Inactive..5-10
- Active
  - Rough bulky...10-20
  - Medium..20
  - Fine...20-50

Welding
- General...20-50

Woodworking
- Rough sawing and bench work..............20-50
- Sizing, planing, rough sanding, medium quality machine and bench work, gluing, veneering, cooperage.............................20-50
- Fine bench and machine work, fine sanding and finishing.....................50-100

Footnotes:
- (a) Obtained with a combination of general light plus specialized supplementary lighting
- (k) Or not less than 1/5 the level in adjacent areas

source: http://www.ncat.org/energy/images/IES%20footcandles.pdf

11.2 Recommended temperature set points in the heating season

	Dry Bulb °F occupied hours maximum	*Dry Bulb °F unoccupied hours (set-back)*	
1. OFFICE BUILDINGS, RESIDENCES, SCHOOLS			
Offices, school rooms, residential spaces	68°	55°	
Corridors	62°	52°	
Dead Storage Closets	50°	50°	
Cafeterias	68°	50°	
Mechanical Equipment Rooms	55°	50°	
Occupied Storage Areas, Gymnasiums	55°	50°	
Auditoriums	68°	50°	
Computer Rooms	65°	As required	
Lobbies	65°	50°	
Doctor Offices	68°	58°	
Toilet Rooms	65°	55°	
Garages	Do not heat	Do not heat	
2. RETAIL STORES			
Department Stores	65°	55°	
Supermarkets	60°	50°	
Drug Stores	65°	55°	
Meat Markets	60°	50°	
Apparel (except dressing rms)	65°	55°	
Jewelry, Hardware, etc.	65°	55°	
Warehouses	55°	50°	
Docks and platforms	Do not heat	Do not heat	
3. RELIGIOUS BUILDINGS			
		24 Hrs or less	*Greater than 24 Hrs*
Meeting Rooms	68°	55°	50°
Halls of Worship	65°	55°	50°
All other spaces	As noted for office buildings	50°	40°

Source: Guidelines For Saving Energy in Existing Buildings—Building Owners and Operators Manual, ECM-1

source: [Thumann, 1998, p. 115]

11.3 Recommended temperature set points in the cooling season

I. COMMERCIAL BUILDINGS	Occupied Periods	
	*Dry Bulb Temperature**	*Minimum Relative Humidity*
Offices	78°	55%
Corridors	Uncontrolled	Uncontrolled
Cafeterias	75°	55%
Auditoriums	78°	50%
Computer Rooms	75°	As needed
Lobbies	82°	60%
Doctor Offices	78°	55%
Toilet Rooms	80°	
Storage, Equipment Rooms	Uncontrolled	
Garages	Do Not Cool or Dehumidify	

II. RETAIL STORES	Occupied Periods	
	Dry Bulb Temperature	*Relative Humidity*
Department Stores	80°	55%
Supermarkets	78°	55%
Drug Stores	80°	55%
Meat Markets	78°	55%
Apparel	80°	55%
Jewelry	80°	55%
Garages	Do Not Cool	

* Except where terminal reheat systems are used. With terminal reheat systems the indoor space conditions should be maintained at lower levels to reduce the amount of reheat. If cooling energy is not required to maintain temperatures, 74°F would be recommended instead of 78°F.

Source: Guidelines For Saving Energy In Existing Buildings—Building Owners and Operators Manual, ECM-1

source: [Thumann, 1998, p. 116]

11.4 Quotation for occupancy sensors

AIKEN HARPER
ELECTRICAL SERVICES, INC.

August 14, 2012

City of Savannah
Attn: Garrison Marr

Re: Gamble Hall Sensors

Aiken-Harper Electrical Services, Inc. would like to offer an estimate for installing occupancy sensors in Gamble Hall for the City of Savannah. This is only a budget number and could cost a little more due to unforeseen conditions or could be low if everything goes as planned.

Here are unit prices to install the following sensors:

- Ceiling mount occupancy sensor for hallways and conference rooms
  Materials $115.00
  Labor $96.00 Journeymen and Helper
  Total $211.00
- Multi-Technology occupancy sensor for bathrooms
  Materials $195.00
  Labor $128.00 Journeyman and Helper
  Total $323.00

If you have any questions, please feel free to contact us at our numbers listed below. Tim Aiken's cell number (912) 660-1012, and Buzz Harper's cell number (912) 660-1330. Our email address is aikenharper@bellsouth.net.

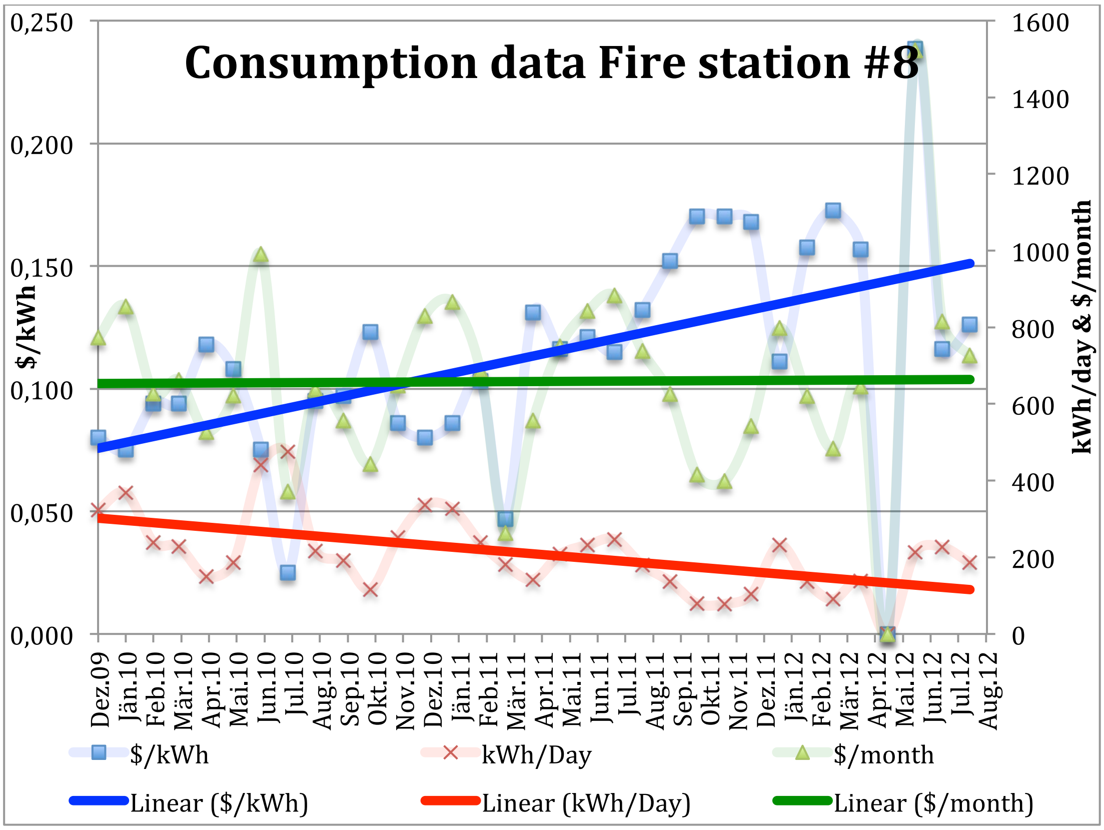
Respectfully Submitted,

Buzz Harper
Aiken-Harper Electrical Services, Inc.

1336 LYNAH AVENUE, SUITE 102 • GARDEN CITY, GA 31408 • PH: 912-966-2196 • FAX: 912-966-2197

11.5 Historic energy consumption data

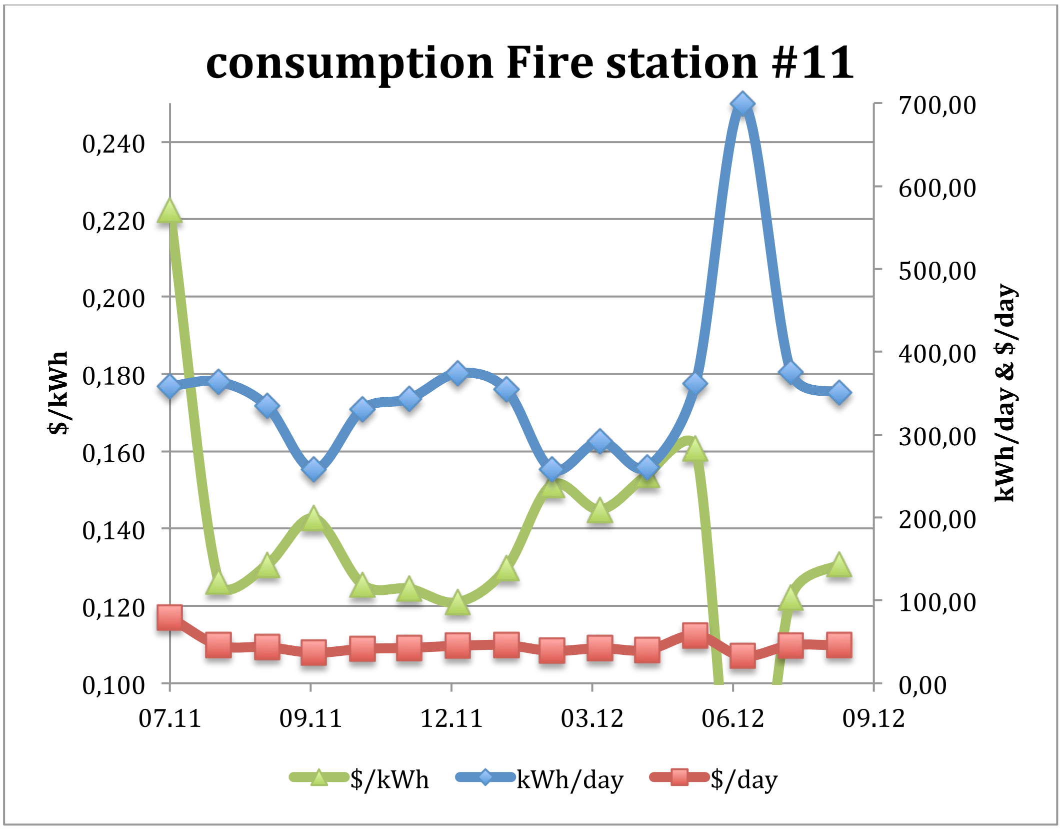
11.5.1 Fire station #8



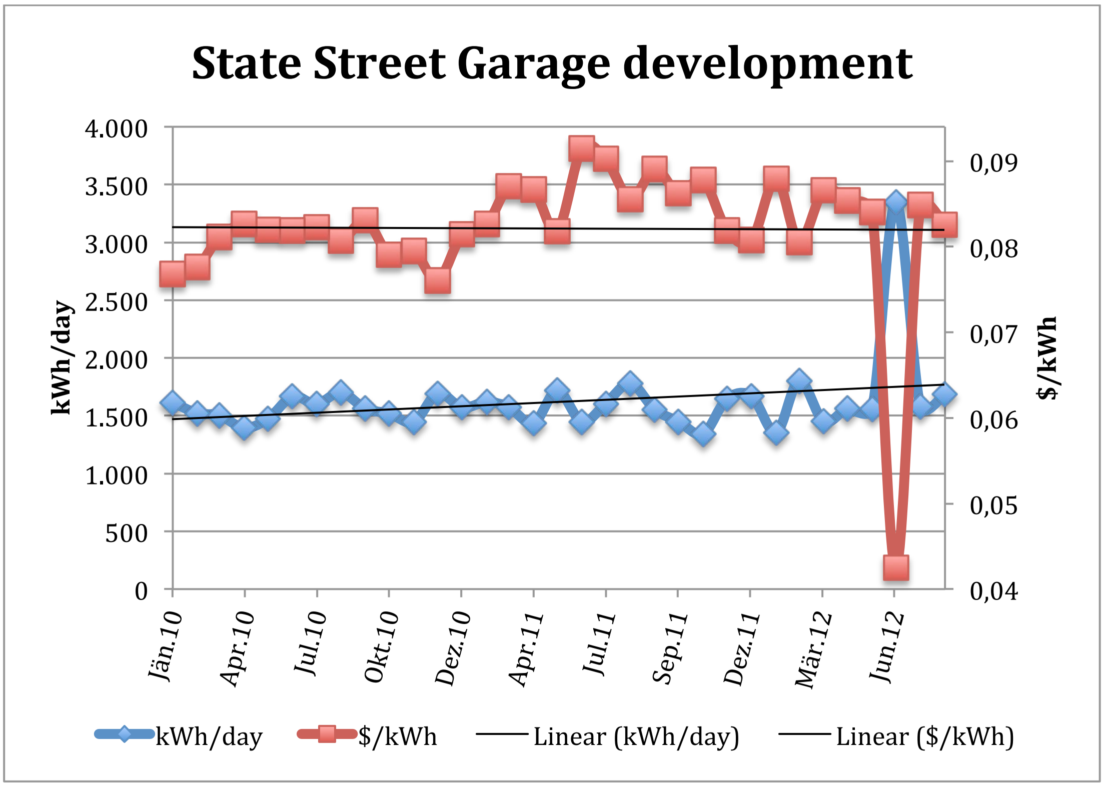
Period	Use (KWH)	Cost	Use/Day	Cost/Day	Enery Costs [ct/kWh]
Dez.09	9.700,00	773,24	323,33	25,77	8,00
Jän.10	11.402,00	854,20	367,81	27,55	7,50
Feb.10	6.688,00	627,63	238,86	22,42	9,40
Mär.10	7.073,00	663,40	228,16	21,40	9,40
Apr.10	4.485,00	527,56	149,50	17,59	11,80
Mai.10	5.768,00	621,82	186,06	20,06	10,80
Jun.10	13.221,00	991,46	440,70	33,05	7,50
Jul.10	14.716,00	371,78	474,71	11,99	2,50
Aug.10	6.735,00	637,46	217,26	20,56	9,50
Sep.10	5.745,00	557,14	191,50	18,57	9,70
Okt.10	3.610,00	444,20	116,45	14,33	12,30
Nov.10	7.531,00	648,20	251,03	21,61	8,60
Dez.10	10.436,00	830,44	336,65	26,79	8,00
Jän.11	10.119,00	866,14	326,42	27,94	8,60
Feb.11	6.688,00	688,06	238,86	24,57	10,30
Mär.11	5.601,00	263,40	180,68	8,50	4,70
Apr.11	4.260,00	556,70	142,00	18,56	13,10
Mai.11	6.435,00	749,43	207,58	24,18	11,60
Jun.11	6.969,00	842,36	232,30	28,08	12,10
Jul.11	7.653,00	883,38	246,87	28,50	11,50
Aug.11	5.572,00	738,06	179,74	23,81	13,20
Sep.11	4.103,00	625,16	136,77	20,84	15,20
Okt.11	2.454,00	415,98	79,16	13,42	17,00
Nov.11	2.352,00	399,40	78,40	13,31	17,00
Dez.11	3.230,00	542,87	104,19	17,51	16,80
Jän.12	7.184,00	797,58	231,74	25,73	11,10
Feb.12	3.946,00	621,59	136,07	21,43	15,75
Mär.12	2.800,00	483,33	90,32	15,59	17,26
Apr.12	4.118,00	645,55	137,27	21,52	15,68
Mai.12					
Jun.12	6.386,00	1523,24	212,87	50,77	23,85
Jul.12	7.023,00	815,16	226,55	26,30	11,61
Aug.12	5.757,00	726,75	185,71	23,44	12,62

11.5.2 Fire station #11

Period	kWh/month	$/month	kWh/day	$/day	$/kWh
07.11	11120	2.473,02	358,71	79,77	0,222
08.11	11280	1.425,55	363,87	45,99	0,126
09.11	10040	1.311,85	334,67	43,73	0,131
10.11	8000	1.141,12	258,06	36,81	0,143
11.11	9920	1.245,45	330,67	41,52	0,126
12.11	10640	1.324,28	343,23	42,72	0,124
01.12	11600	1.403,23	374,19	45,27	0,121
02.12	10280	1.334,34	354,48	46,01	0,130
03.12	8000	1.210,15	258,06	39,04	0,151
04.12	8760	1.269,46	292,00	42,32	0,145
05.12	8080	1.242,89	260,65	40,09	0,154
06.12	10840	1.742,13	361,33	58,07	0,161
07.12	21680	1.015,07	699,35	32,74	0,047
08.12	11640	1.421,33	375,48	45,85	0,122
09.12	10880	1.422,17	350,97	45,88	0,131



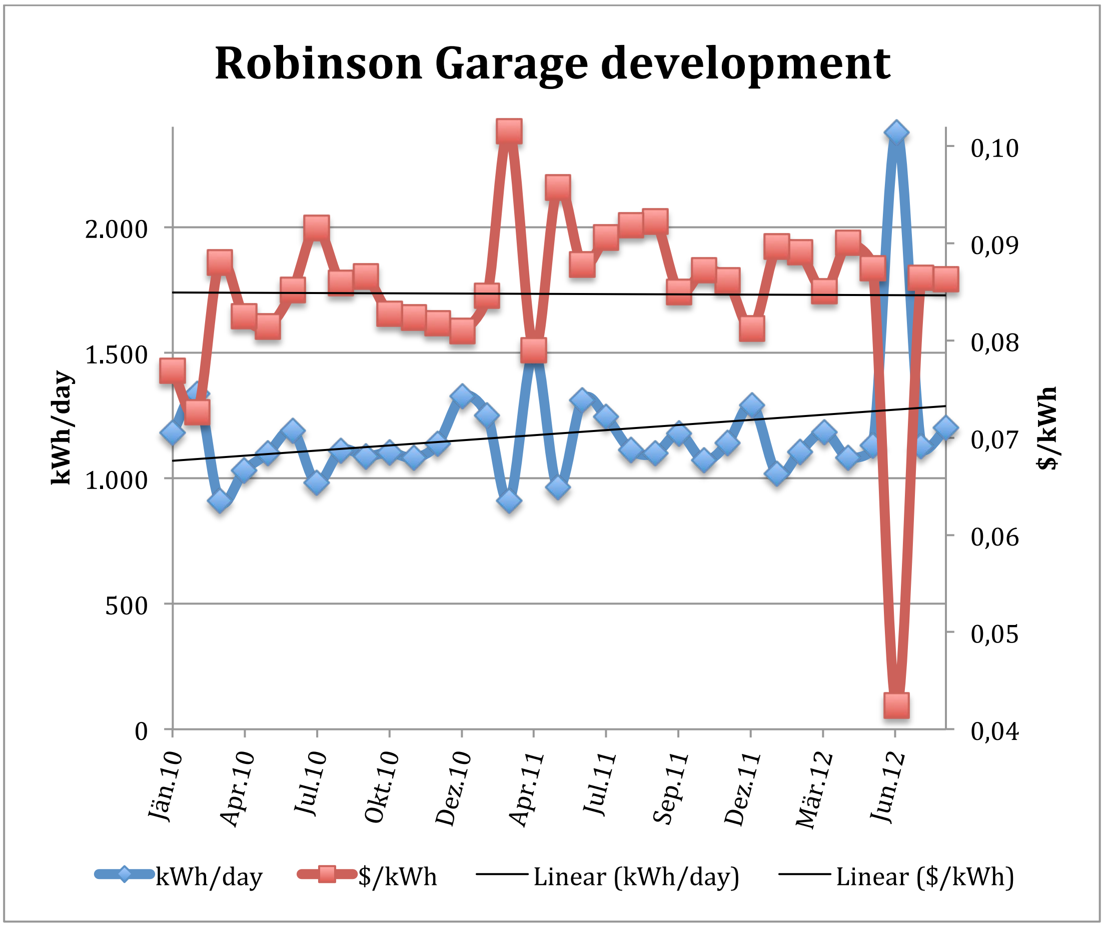
11.5.3 State Street Garage



Period	$/month	kWh/month	$/day	kWh/day	$/kWh
Sep.12	$4.174,24	50560	139,14	1685,33	0,083
Aug.12	$4.015,69	47320	133,86	1577,33	0,085
Jul.12	$4.268,19	100440	142,27	3348,00	0,042
Jun.12	$4.066,58	48360	131,18	1560,00	0,084
Mai.12	$4.001,27	46840	133,38	1561,33	0,085
Apr.12	$3.895,95	45000	125,68	1451,61	0,087
Mär.12	$4.211,34	52280	145,22	1802,76	0,081
Feb.12	$3.693,59	42000	1354,84	1354,84	0,088
Jän.12	$4.178,84	51760	1669,68	1669,68	0,081
Dez.11	$4.045,31	49400	1646,67	1646,67	0,082
Nov.11	$3.654,22	41640	1343,23	1343,23	0,088
Okt.11	$3.748,56	43480	1449,33	1449,33	0,086
Sep.11	$4.289,29	48160	1553,55	1553,55	0,089
Aug.11	$4.718,91	55160	1779,35	1779,35	0,086
Jul.11	$4.343,21	48120	1604,00	1604,00	0,090
Jun.11	$4.105,52	44880	1447,74	1447,74	0,091
Mai.11	$4.216,18	51520	1717,33	1717,33	0,082
Apr.11	$3.854,90	44480	1434,84	1434,84	0,087
Mär.11	$3.832,25	44040	1572,86	1572,86	0,087
Feb.11	$4.147,97	50200	1619,35	1619,35	0,083
Jän.11	$3.967,91	48720	1571,61	1571,61	0,081
Dez.10	$3.860,48	50760	1692,00	1692,00	0,076
Nov.10	$3.564,36	44840	1446,45	1446,45	0,079
Okt.10	$3.600,39	45560	1518,67	1518,67	0,079
Sep.10	$4.019,91	48400	1561,29	1561,29	0,083
Aug.10	$4.255,14	52720	1700,65	1700,65	0,081
Jul.10	$3.953,04	48040	1601,33	1601,33	0,082
Jun.10	$4.227,82	51640	1665,81	1665,81	0,082
Mai.10	$3.623,61	44200	1473,33	1473,33	0,082
Apr.10	$3.574,60	43240	1394,84	1394,84	0,083
Mär.10	$3.413,90	42080	1502,86	1502,86	0,081
Feb.10	$3.660,91	47160	1521,29	1521,29	0,078
Jän.10	$3.722,09	48440	1614,67	1614,67	0,077

11.5.4 Robinson Garage

Time	$/month	kWh/month	$/day	kWh/day	$/kWh
Sep.12	$3.112,82	36060	103,76	1202,00	0,086
Aug.12	$2.925,98	33840	97,53	1128,00	0,086
Jul.12	$3.026,81	71340	100,89	2378,00	0,042
Jun.12	$3.062,90	35040	98,80	1130,32	0,087
Mai.12	$2.924,24	32460	97,47	1082,00	0,090
Apr.12	$3.124,77	36720	100,80	1184,52	0,085
Mär.12	$2.854,34	32040	98,43	1104,83	0,089
Feb.12	$2.829,68	31560	1018,06	1018,06	0,090
Jän.12	$3.251,31	40020	1290,97	1290,97	0,081
Dez.11	$2.947,29	34200	1140,00	1140,00	0,086
Nov.11	$2.899,22	33240	1072,26	1072,26	0,087
Okt.11	$3.004,36	35340	1178,00	1178,00	0,085
Sep.11	$3.144,57	34080	1099,35	1099,35	0,092
Aug.11	$3.168,12	34500	1112,90	1112,90	0,092
Jul.11	$3.382,30	37320	1244,00	1244,00	0,091
Jun.11	$3.567,19	40620	1310,32	1310,32	0,088
Mai.11	$2.768,39	28920	964,00	964,00	0,096
Apr.11	$3.683,80	46620	1503,87	1503,87	0,079
Mär.11	$2.588,70	25500	910,71	910,71	0,102
Feb.11	$3.279,88	38760	1250,32	1250,32	0,085
Jän.11	$3.332,30	41160	1327,74	1327,74	0,081
Dez.10	$2.792,24	34140	1138,00	1138,00	0,082
Nov.10	$2.761,62	33540	1081,94	1081,94	0,082
Okt.10	$2.737,11	33060	1102,00	1102,00	0,083
Sep.10	$2.920,23	33720	1087,74	1087,74	0,087
Aug.10	$2.960,16	34440	1110,97	1110,97	0,086
Jul.10	$2.699,07	29460	982,00	982,00	0,092
Jun.10	$3.138,44	36840	1188,39	1188,39	0,085
Mai.10	$2.688,62	33000	1100,00	1100,00	0,081
Apr.10	$2.633,50	31920	1029,68	1029,68	0,083
Mär.10	$2.244,35	25500	910,71	910,71	0,088
Feb.10	$3.011,75	41460	1337,42	1337,42	0,073
Jän.10	$2.726,12	35460	1182,00	1182,00	0,077


Robinson Garage development
kWh/day
$/kWh
2.000
1.500
1.000
500
0
0,10
0,09
0,08
0,07
0,06
0,05
0,04
Jän.10
Apr.10
Jul.10
Okt.10
Dez.10
Apr.11
Jul.11
Sep.11
Dez.11
Mär.12
Jun.12
kWh/day
$/kWh
Linear (kWh/day)
Linear ($/kWh)

11.6 Detailed ECO calculations

11.6.1 Fluorescent lighting upgrade with FL T-8 lamps & Incandescent lighting upgrade with CFL's in Fire station #8

The following information is needed to calculate the savings for CFL lamps located in the bathroom 2 in the sleeping area.

Lamp	- Incandescent 60W / 40W
Number of lamps	- 3 (2 x 60W, 1 x 40W)
Connected Load of Inc lamps with 800 Lumens	- 0.06 kW
Connected Load of Inc lamps with 400 Lumens	- 0.04 kW
Connected Load of CFL's with 800 Lumens	- 0.013 kW
Connected Load of CFL's with 400 Lumens	- 0.01 kW
Hours of Operation	- 2,000 hrs/yr
Average Electricity Cost	- $0.108/kWh

Electricity Savings CFL:

= Number of Lamps x (Connected Load with Incandescent Lamp - Connected Load with CFL) x Hours of Operation

= 2 lamps x (0.06 kW/lamp - 0.013 kW/lamp) x 2,000 hrs/yr + 1 lamp x x (0.04 kW/lamp - 0.01 kW/lamp) x 2,000 hrs/yr

= 248 kWh/yr

Demand Savings CFL:

= Electricity Savings /Hours of Operation

= 248 kWh/yr / 2,000 hrs/yr

= 0.124 kW

HVAC Savings CFL:

= Added Heat From Old Lights x Conversion Factor x 6-mth/12-mth

= 248 kWh/yr x 3,412 Btu/kWh x (1.13 kW/ton /12,000 Btu/ton-hr) x 0.5 y

= 40 kWh_{HVAC}

Total Savings CFL:

= Fixture Savings + HVAC Savings

= 248 kWh/yr + 40 kWh/yr

= 288 kWh/yr

Energy savings for all CFL upgrades is **676 kWh/yr**.

Cost Savings CFL:

= [(kWh Saved x Electricity Cost)

= (288 kWh/yr x $0.108/kWh)

= $31/yr

Cost savings for all CFL upgrades is **$73/yr**.

The following information is needed to calculate the savings for energy-efficient lamps and electronic ballasts for 4', 4-lamp fluor fixtures in the kitchen.

Lamp	- F40T12/SP
Number of 4' Fixtures	- 4
Connected Load of 4' Fixture with 4 Standard Lamps, electronic ballast	- 0.142 kW
Connected Load of 4' Fixture with 4 Energy-Efficient Lamps & Ballast	- 0.109 kW
Hours of Operation of 4' Lamps	- 4,500 hrs/yr
Average Electricity Cost	- $0.108/kWh

Electricity Savings T8:

= Number of Fixtures x (Connected Load with T12 Lamp - Connected Load with T8 Lamp) x Hours of Operation

= 4 fixtures x (0.142 kW/Fixture - 0.109 kW/Fixture) x 4,500 hrs/yr

= 594 kWh/yr

Demand Savings T8:

= Electricity Savings /Hours of Operation

= 594 kWh/yr / 4,500 hrs/yr

= 0.132 kW

HVAC Savings T8:

= Added Heat From Old Lights x Conversion Factor x 6-mth/12-mth

= 594 kWh/yr x 3,412 Btu/kWh x (1.13 kW/ton /12,000 Btu/ton-hr) x 0.5 y

= 96 kWh_{HVAC}

Total Savings T8:

= Fixture Savings + HVAC Savings

= 594 kWh/yr + 96 kWh/yr

= 690 kWh/yr

Energy savings for all T8 upgrades is **1,453 kWh/yr**.

Cost Savings T8:

= [(kWh Saved x Electricity Cost)

= (690 kWh/yr x $0.108/kWh)

= $74/yr

Cost savings for all T8 upgrades is **$157/yr**.

Implementation Cost

Lamp Investment = Sum of (Number of lamps x Cost for Each Lamp)

Type	Amount	Price each	Price total
CFL 400 Lumen	1	7.53	7.53
CFL 800 Lumen	2	6.38	12.74
CFL 1200 Lumen	0	9.05	0.00
		TOTAL	20.27

Cost for all CFL’s is **$43.**

Investment T8:

= Number of Fixtures x Number of Lamps per Fixture x Cost/Lamp

= 4 x 4 x $4.52

= $ 72.3

For all fixtures, there are 49 lamps. The cost to replace all lamps is **$221**

Simple Payback Period

Total Energy Savings:

= Total Savings CFL + Total Savings T8

= 676 kWh/yr + 1,453 kWh/yr

= **2,129 kWh/yr**

Total Cost Savings:

= Cost Savings CFL + Cost Savings T8

= $ 73/yr + $ 157/yr

= **$ 230/yr**

Total Investment Costs:

= Investment CFL + Investment T8

= $ 43 + $ 221

= **$ 264**

Simple Payback Period:

= Investment / Savings

= $ 264 / $ 230

= **1.2 years**

11.6.2 CFL lighting upgrade with LED's & MH 400W lighting upgrade with MH 320W in Fire station #8

An LED replacement for a 26W, 110V compact fluorescent lamp has a power consumption of approximately 14 watts. The whole facility has a total of 5 exterior floodlights. The total energy cost savings are $29/year.

Number of CFL floodlights	- 5
CFL wattage	- 26W
LED replacement lamp wattage	- 14W
LED lamp cost	- $34.85
Time to replace lamp	- 15 minutes
Number of 400W Metal Halide Fixtures	- 1
Power Consumption of 400W Fixture	- 460 W
Power Consumption of 320W Fixture	- 368 W
Electricity Cost	- $0.108/kWh
Labor Cost	- $30/hr
Annual Operating Hours	- 4,380 hr/yr

Demand Savings LED:

= No. fixtures x (Watts Existing – Watts LED)

= 5 Lamps x (26W – 14W) x 1 kW/1000W

= 0.06 kW

Energy Savings LED:

= Demand Savings x Annual hours

= 0.06 kW x 4,380 hr/yr

= 263 kWh/yr

Cost Savings LED:

= (263 kWh/yr x $0.108/kWh)

= $28/yr

Demand Savings MH:

= #Fixtures × (Current Consumption - Proposed Consumption)

= 1 fixture × (460 W – 368 W) ÷ 1,000 W/kW

= 0.092 kW/mo

Energy Savings MH:

= Demand Savings × Annual Hours of Operation

= 0.092 × 4,380 hr/yr

= 403 kWh/yr

Cost Savings MH:

= Energy Savings × Average Energy Cost

= 403 kWh/yr × $0.108/kWh

= $44/yr

Total Cost Savings

= Cost Saving LED + Cost Savings MH

= $28/yr + $44/yr

= $72/yr

Implementation Cost LED

Lamp: $34.85 per lamp, total is 5 x $34.85 $174.25

Implementation cost MH

Retrofit cost for 400W metal halide: $178.25

Total Investment:

= Investment LED + Investment MH

= $174.25 + $178.25

= $352.50

Simple Payback Period

= Investment/Savings

= $352.50/ $72/yr

= 4.90 years

11.6.3 Incandescent lighting upgrade with CFL in Fire station #11

The following information is needed to calculate the savings for CFL lamps located in the kitchen exhaust fan.

Connected Load of 800 Lumen Inc lamp	- 0.06 kW
Connected Load of 800 Lumen CFL lamps	- 0.013 kW
Number of lamps	- 2
Hours of Operation	- 1,000 hrs/yr
Average Electricity Cost	- $0.135/kWh

Electricity Savings, Due to Lamps:

= Number of Lamps x (Connected Load with Incandescent Lamp - Connected Load with CFL) x Hours of Operation

= 2 lamps x (0.06 kW/lamp - 0.013 kW/lamp) x 1,000 hrs/yr

= 94 kWh/yr

Demand Savings:

= Electricity Savings /Hours of Operation

= 94 kWh/yr / 1,000 hrs/yr

= 0.094 kW

HVAC Savings:

= EI Savings from Light Replacement x Conversion x 6-mth/12-mth

= 94 kWh/yr x 3,412 Btu/kWh x (0.96 kW/ton /12,000 Btu/ton-hr) x 0.5 yr

= 13 kWh_{HVAC}

Total Savings

= Fixture Savings + HVAC Savings

= 94 kWh/yr + 13 kWh/yr

= 107 kWh/yr

Cost Savings:

= [(kWh Saved x Electricity Cost)

= (107 kWh/yr x $0.135/kWh)

= $14.45/yr

Implementation Cost

= Number of lamps x Cost for Each Lamp

= 2 lamps x 6.38 $/lamp

= $ 12.76

Simple Payback Period

= Investment / Savings

= $12.76 / $14.45

= 0.88 years

11.6.4 CFL exit sign upgrade with LED exit sign in Robinson Garage

The following information is needed to calculate the savings for the exit sign replacement.

Connected Load of CFL Exit sign existing	- 0.018 kW
Connected Load of LED Exit sign replacement	- 0.003 kW
Number of signs	- 8
Average Electricity Cost	- $0.088/kWh

Electricity Savings, Due to reduced load:

= (Load of CFL sign – Load of LED sign) x Hours of Operation

= (0.018 kW - 0.003 kW) x 8,760 hrs/yr

= 131 kWh/yr

Energy savings due to all signs is **1,051 kWh/yr**.

Cost Savings:

= [(kWh Saved x Electricity Cost)

= (131 kWh/yr x $0.088/kWh)

= $11.5 /yr

Cost savings due to all signs is **$92/yr**.

Implementation Cost

Price per sign:	$84.35	
Labor costs:	$12.50	(1/4 h @ $50/h)
Total per sign:	$96.75	

Cost for all signs is $774**.**

Cost for all sensors after rebate is **$719**.

Simple Payback Period

= Investment / Savings

= $774 / $92

= 8.41 years

The payback time including rebates is **7.8 years**.

11.6.5 CFL exit sign upgrade with LED exit sign in State St. Garage

The following information is needed to calculate the savings for the exit sign replacement. This example calculation is provided to show how savings for all signs were calculated.

Connected Load of CFL Exit sign existing	- 0.018 kW
Connected Load of LED Exit sign replacement	- 0.003 kW
Number of signs	- 8
Average Electricity Cost	- $0.086/kWh

Electricity Savings, Due to reduced load:

= (Load of CFL sign – Load of LED sign) x Hours of Operation

= (0.018 kW - 0.003 kW) x 8,760 hrs/yr

= 131.4 kWh/yr

Energy savings due to all signs is **1,839.6 kWh/yr**.

Cost Savings:

= [(kWh Saved x Electricity Cost)

= (131.4 kWh/yr x $0.086/kWh)

= $11.28 /yr

Cost savings due to all signs is **$157.95/yr**.

Investment:

Price per sign:	$84.35	
Labor costs:	$12.50	(1/4 h @ $50/h)
Total per sign:	$96.75	

Cost for all signs is $1,355.90**.**

Cost for all sensors after rebate is **$1,257.9**.

Simple Payback Period

= Investment / Savings

= $1,356 / $158

= 8.58 years

The payback time including rebates is **7.96 years.**

11.6.6 Install Occupancy Sensors in Bathrooms in Fire station #8

The following information is needed to calculate the savings for multi technology occupancy sensors located in bathroom 2 in the sleeping area. This example calculation is provided to show how savings for all bathrooms were calculated.

Lamp	- Inc 60W / 40W
Number of Incandescent lamps	- 3 (2 x 60W, 1 x 40W)
Connected Load of all 3 Incandescent lamps	- 0.16 kW
Lamp	- F40T12/U6
Number of U-shape Fixtures	- 1
Connected Load of U-shape Fixture with 2 U-shape Lamps, electronic ballast	- 0.071 kW
Load of exhaust fan	- 0.06 kW
Hours of Operation without sensor	- 2,000 hrs/yr
Hours of Operation with sensor	- 700 hrs/yr
Average Electricity Cost	- $0.108/kWh

Electricity Savings, Due to reduced operation hours:

= (Load of Inc lamps + Load of FL including fixture + load of exhaust fan) x (Hours of Operation without sensor – Hours of Operation with sensor)

= (0.16 kW + 0.071 kW + 0.06 kW) x (2,000 hrs/yr - 700 hrs/yr)

= 378 kWh/yr

HVAC Savings:

= Added Heat From Old Lights x Conversion Factor x 6-mth / 12-mth

= 378 kWh/yr x 3,412 Btu/kWh x (1.13 kW/ton /12,000 Btu/ton-hr) x 0.5 yr

= 61 kWh_{HVAC}

Total Savings

= Fixture Savings + HVAC Savings

= 378 kWh/yr + 61 kWh/yr

= 439 kWh/yr

Energy savings due to all sensors is **967 kWh/yr**.

Cost Savings:

= [(kWh Saved x Electricity Cost)

= (439 kWh/yr x $0.108/kWh)

= $47/yr

Cost savings due to all sensors is **$104/yr**.

Investment:

Sensor Investment = Price for Sensor + Price for Labor

Type	Amount	Price material	Price Labor	Price total
Occupancy sensor	0	115	96	211
Multi technology occupancy sensor	1	195	128	323
		TOTAL		323

Cost for all 3 bathrooms is **$969.**

Simple Payback Period

= Investment / Savings

= $969 / $104

= 9.27 years

11.6.7 Install Occupancy Sensors in different rooms in Fire station #11

The following information is needed to calculate the savings for multi-technology occupancy sensors located in men's bathroom.

Lamp type	- CFL
Number of CFL's	- 2 x 13W
Connected Load of all CFL lamps	- 0.026 kW
Lamp type	- F40T12
Number of 2 lamp Fixtures	- 4
Wattage of 2 lamp Fixtures	- 71 W/fixture
Number of 4 lamp Fixtures	- 3
Wattage of 4 lamp Fixtures	- 141 W/fixture
Connected Load of all Fixture with 2 and 4 lamps per fixture including electronic ballast	- 0.707kW
Load of exhaust fan	- 60 watts
Number of exhaust fans	- 2
Exhaust fan connected load	- 0.12 kW
Hours of Operation without sensor	- 2,200 hrs/yr
Hours of Operation with sensor	- 700 hrs/yr
Average Electricity Cost	- $0.136/kWh

Electricity Savings due to reduced operation hours:

= (Load of CFL's + Load of FL including fixture + load of exhaust fan) x (Hours of Operation without sensor – Hours of Operation with sensor)

= (0.026 kW + 0.707 kW + 0.12 kW) x (2,200 hrs/yr - 700 hrs/yr)

= 1,279 kWh/yr

HVAC Savings:

= Added Heat From Existing Lights x Conversion Factor x 6-mth/12-mth

= 1,279 kWh/y x 3,412 Btu/kWh x (0.96 kW/ton /12,000 Btu/ton-h) x 0.5 y

= 175 kWh_{HVAC}

Total Savings

= Fixture Savings + HVAC Savings

= 1,279 kWh/yr + 175 kWh/yr

= 1,454 kWh/yr

The savings from all sensors is **6,809 kWh/yr** as presented in Table 3.1.1

Cost Savings:

= [(kWh Saved x Electricity Cost)

= (1,454 kWh/yr x $0.135/kWh)

= $196/yr

The cost savings for all sensors is $919/yr

= kWh Saved x Electricity Cost

= 6,809 kWh/yr x $0.135/kWh

= $919/yr

Investment:

Sensor Investment = Price for Sensor x Amount of Sensors

Location	Sensor type	No Sensors	Investment costs $
Bath W	MTC	2	646
Bath M	MTC	2	646
Bunk	OSS	8	576
Office	OSS	2	114
Entrance	OSC	1	211
Hallway	OSC	3	633
Technic room	OSS	1	72
Dressing room	OSC	1	211
Storage	OSS	1	72
Office garage	OSC	1	211
Compressor	OSC	1	211
Storage 2nd floor	OSC	1	211
Total		24	3,844

Cost for all sensors including labor is **$3,844.**

Energy savings due to all sensors is **6,809 kWh/yr**.

Cost savings due to all sensors is **$919/yr**.

Simple Payback Period:

= Investment / Savings

= $3,844 / $919

= 4.2 years

At the moment Georgia Power offers $10/sensor installed. The company should be contacted prior to the investment. The discount would sum up to $240.

Simple Payback Period with discount:

= (Investment – Rebate) / Savings

= ($3,844 - $240) / $919

= 3.9 years

11.6.8 Install Occupancy Sensors in stairways in Robinson Garage

The following information is needed to calculate the savings for infrared technology vacancy sensors located in the stairway. This example calculation is provided to show how savings for both stairways were calculated. The reduced hours of operation result from the assumption that no light is required during daytime and one third of the night the stairway is empty.

Lamp	- F32T8
Number of Fixtures	- 4
Connected Load of Fixture with 2 Lamps, electronic ballast	- 0.056 kW
Hours of Operation without sensor	- 8,760 hrs/yr
Hours of Operation with sensor	- 2,920 hrs/yr
Average Electricity Cost	- $0.088/kWh

Electricity Savings, Due to reduced operation hours:

= Load of Fluorescent including fixture x Number of Fixtures x (Hours of Operation without sensor – Hours of Operation with sensor)

= 0.056 kW x 4 x (8,760 hrs/yr – 2,920 hrs/yr)

= 1,308 kWh/yr

Energy savings due to all sensors is **2,616 kWh/yr**.

Cost Savings:

= [(kWh Saved x Electricity Cost)

= (1,308 kWh/yr x $0.088/kWh)

= $115/yr

Cost savings due to all sensors is **$230/yr**.

Investment:

Price per sensor:	$92.60	
Labor costs:	$25.00	(1/2 h @$50/h)
Total per floor:	$ 117.60	

$$ per stairway = Investment per floor x number of floors

= $117.60 x 4

= $470.40

Cost for all sensors is $941**.**

Cost for all sensors after rebate is **$861**.

Simple Payback Period

= Investment / Savings

= $940 / $230

= 4.09 years

The payback time including rebates is **3.7 years**.

11.6.9 Install Occupancy Sensors in stairways in State St. Garage

The following information is needed to calculate the savings for infrared technology vacancy sensors located in the stairway. This example calculation is provided to show how savings for both stairways were calculated. The reduced hours of operation result from the assumption that no light is required during daytime and one third of the night the stairway is empty.

Lamp	- F32T8
Number of Fixtures	- 15
Connected Load of Fixture with 2 Lamps, electronic ballast	- 0.056 kW
Hours of Operation without sensor	- 8,760 hrs/yr
Hours of Operation with sensor	- 2,920 hrs/yr
Average Electricity Cost	- $0.086/kWh

Electricity Savings, Due to reduced operation hours:

= Load of Fluorescent including fixture x Number of Fixtures x (Hours of Operation without sensor – Hours of Operation with sensor)

= 0.056 kW x 4 x (8,760 hrs/yr – 2,920 hrs/yr)

= 4,905.6 kWh/yr

Energy savings due to all sensors is **9,811 kWh/yr**.

Cost Savings:

= [(kWh Saved x Electricity Cost)

= (4,905.6 kWh/yr x $0.086/kWh)

= $421/yr

Cost savings due to all sensors is **$842/yr**.

Investment:

Price per sensor:	$92.60	
Labor costs:	$25.00	(1/2 h @$50/h)
Total per floor:	$ 117.60	

$$ per stairway = Investment per floor x number of floors
= $117.60 x 7
= $823.20

Cost for all sensors is $1,646.4**.**

Cost for all sensors after rebate is **$1,506.4**.

Simple Payback Period

= Investment / Savings

= $823 / $421

= 1.95 years

The payback time including rebates is **1.79 years**.

11.6.10 Use of daylight in Robinson Garage

The following information is needed to calculate the savings for daylight harvesting sensors located in the parking garages. This example calculation for the 3rd floor is provided to show how savings for all levels were calculated.

Lamp	- HPS
Number of Fixtures with daylight harvesting	- 40
Connected Load of Fixture with electronic ballast	- 0.170 kW
Lamp	- HPS Spot
Number of Fixtures	- 2
Connected Load of Fixture with electronic ballast	- 0.080 kW
Hours of Operation without sensor	- 8,760 hrs/yr
Hours of Operation with sensor	- 4,910 hrs/yr
Average Electricity Cost	- $0.088/kWh

Reduced operation hours calculation:

Hours = annual hours – full sunshine hours – slight overcast hours

= 8,760 – 2,850 – 1,000

= 4,910

Electricity Savings, due to reduced operation hours:

= (Load of HPS x Number of Fixtures + Load of HPS Spot x Number of Fixtures) x (Op. hours without sensor – Op. hours with sensor)

= (0.17 kW x 40 + 0.08 kW x 2) x (8,760 hrs/yr – 4,910 hrs/yr)

= 26,796 kWh/yr

Energy savings due to all sensors is **103,912 kWh/yr**.

Cost Savings:

= [(kWh Saved x Electricity Cost)

= (26,796 kWh/yr x $0.088/kWh)

= $2,358/yr

Cost savings due to all sensors is **$9,144/yr**.

Investment:

Price per sensor:	$300.00	
Labor costs:	$ 50.00	(1 h @$50/h)
Total per floor:	$350.00	

$$ per floor = price per sensor x number of areas x sensors per area

= $350.00 x 4 x 2

= $2,800

Cost for all sensors is $11,200**.** - after rebate **$10,880**

Simple Payback Period

= Investment / Savings

= $11,200 / $9,144

= 1.22 years

The payback time including rebates is **1.19 years.**

11.6.11 Use of daylight in State St. Garage

The following information is needed to calculate the savings for daylight harvesting sensors located in the parking garages. This example calculation for the 5th floor is provided to show how savings for all levels were calculated.

Lamp	- HPS
Number of Fixtures with daylight harvesting	- 48
Connected Load of Fixture with electronic ballast	- 0.170 kW
Hours of Operation without sensor	- 8,760 hrs/yr
Hours of Operation with sensor	- 4,910 hrs/yr
Average Electricity Cost	- $0.086/kWh

Reduced operation hours calculation:

Hours = annual hours – full sunshine hours – slight overcast hours

= 8,760 – 2,850 – 1,000

= 4,910

Electricity Savings, due to reduced operation hours:

= (Load of HPS x Number of Fixtures) x (Hours of Operation without sensor – Hours of Operation with sensor)

= (0.17 kW x 48) x (8,760 hrs/yr – 4,910 hrs/yr)

= 31,416 kWh/yr

Energy savings due to all sensors is **163,779 kWh/yr**.

Cost Savings:

= [(kWh Saved x Electricity Cost)

= (31,416 kWh/yr x $0.086/kWh)

= $2,697/yr

Cost savings due to all sensors is **$14,062/yr**.

Investment:

Price per sensor:	$300.00	
Labor costs:	$ 50.00	(1 h @$50/h)
Total per floor:	$350.00	

$$ per floor = price per sensor x number of areas x sensors per area
= $350.00 x 4 x 2
= $2,800

Cost for all sensors is $14,700**.**

Cost for all sensors after rebate is **$14,280**.

Simple Payback Period

= Investment / Savings

= $14,700 / $14,062

= 1.05 years

The payback time including rebates is **1.02 years**.

11.6.12 Replace electric resistance space heater in truck bay in Fire station #8

The conventional forced air heater is rated at 7.5 kW (25,600 Btu/hour) and is controlled by a thermostat. The unit is sized to maintain the garage at approximately 60°F. The runtime is dependent on the ambient temperature. At the winter design temperature of 17°F the unit is assumed to run all the time to maintain space temperature and at 57°F it is assumed to run only 10% of the time. For temperatures between the winter design and 60°F, the runtime varies linearly.

Because a portion of the heating load is dependent on the infiltration rate of outside air around the door perimeter, the load on the heater must be reduced assuming weather-stripping is installed.

Heating energy consumption for each temperature is presented in the table below. An example calculation for the 50/54°F (52°F mid-point) is presented below.

Reduction in Heater Load from Weather-Stripping Installation

Heat Loss, as found	- 648,002 Btu/yr ÷ 643 hr/yr	= 1,007.8 Btu/hr
Heat Loss, with seal	- 31,154 Btu/yr ÷ 643 hr/yr	= 48.5 Btu/hr
Reduction in Heat Loss		= 959.3 Btu/hr
Effective Reduction in Heater Load		
= 959.3 Btu/hr ÷ 3412 Btu/kWh		= 0.28 kW

Convective Heater Energy Consumption

= [(Heater kW x Heater Load) – Load Reduction] x Bin Hours

= [(7.5 kW x 0.2125) - 0.28 kW] x 643 hr/yr

= [1.31375 kW] x 643 hr/yr

= 844 kWh/yr

Radiant electric heaters are estimated to double the heating efficiency. This will reduce the energy used for heating by half. Radiant heaters of 7.5 kW capacity are assumed to be installed.

Radiant Heater Energy Consumption

= Heater kW x Heater Load x Efficiency Improvement x Bin Hours

= [(7.5 kW x 0.2125) - 0.28 kW] x 0.5 x 643 hr/yr

= 1.31375 kW x 0.5 x 643 hr/yr

= 422 kWh/yr

Annual Energy Use Savings

= Current heater energy use - Energy use for radiant heater system

= 4,102 kWh/yr – 2,051 kWh/yr

= 2,051 kWh/yr

Annual Energy Cost Savings

= Energy Savings x Energy Cost

= 2,051 kWh/yr x $0.108/kWh

= $222 / year

Implementation Cost

It is suggested that three electric radiant heaters be mounted on the ceiling. For this analysis, we assume that one 3.2 kW heater will be installed above each engine and one 700 watt heater be installed above the washer and dryer. These three heaters will provide heating for all the critical areas in the garage bay. Prior to installation, radiant heater vendors should be consulted to determine the recommended heater size, type and location to achieve best efficiency and satisfactory operation.

Cost of two 3.2 kW radiant heaters ($500 ea.)	$1,000
Cost of 700 W radiant heater	$240
Heater Installation (4 hr. @ $50/hr)	$200
Total Cost	$1,440

Simple Payback Period

= Implementation Cost / Annual Cost Savings

= $1,440 / $222 per year

= 6.5 years

Rated kW 7.5

IR_{eff} improvement 0.5

Bin Mid-pts	Temp. Range DB (F)	Annual Hrs	Heating kW	Door Seal Savings kW	Net Heater Load kW	Resist Heater kWh	Radiant Heater kWh
57	55/59	739	0.75	0.00	0.75	554.3	277.1
52	50/54	643	1.59	0.28	1.31	844.0	422.0
47	45/49	539	2.44	0.92	1.52	819.4	409.7
42	40/44	412	3.28	1.49	1.79	736.7	368.4
37	35/39	252	4.13	1.93	2.19	552.5	276.3
32	30/34	138	4.97	2.48	2.49	343.1	171.6
27	25/29	60	5.81	2.92	2.90	173.7	86.9
22	20/24	19	6.66	3.31	3.35	63.6	31.8
17	15/19	4	7.50	3.81	3.69	14.8	7.4
Total						4,102.1	2,051.1

11.6.13 Replace Air-Cooled Split System with Ground-Source Heat Pump in Fire Station #8

The calculations for this ECO are based on estimated cooling and heating system performance and historical weather data.

Heat Pump Performance

Condition	Cooling EER	Heating COP
Base: Air-cooled Chiller	13.0	0.8
Retrofit: Ground-source	17.0	5.0

Split System Air-Conditioner Capacity - 2 @ 3.5 tons

Natural Gas Furnace Capacity - 2 @ 100,000 Btu/yr

Example Cooling Savings for 95°F:

System Load: 95%

Annual Hrs: 6 hr/yr

Cooling Performance @ 95°F:

Goodman: 1.043 kW/ton

ICP: 1.363 kW/ton

Geothermal: 0.706 kW/ton

Current Cooling System Consumption:

kWh/yr = Performance x Load x tons x hr

Goodman = 1.043 kW/ton x 0.95 x 3.5 tons x 6 hr/yr

= 20.8 kWh/yr

ICP = 1.363 kW/ton x 0.95 x 3.5 tons x 6 hr/yr

= 27.2 kWh/yr

Total = Goodman + ICP

= 20.8 kWh/yr + 27.2 kWh/yr

= 48.0 kWh/yr

Geothermal Cooling System Consumption:

= Performance x Load x tons x hr

= 0.706 kW/ton x 0.95 x 7 x 6 hr/yr

= 28.17 kWh/yr

Energy Savings:

= Current – Geothermal

= (20.8 + 27.2 – 28.2) kWh/yr

= 19.8 kWh/yr

Cooling energy savings for all temperatures is **3,371 kWh/yr**.

Example Heating Savings for 17°F:

System Load: 31.5%

Annual Hrs: 2 hr/yr

Heater Performance @ 17°F:

Gas furnace: 200,000 Btu/hr

Geothermal: COP-5.0

Current Heating System Consumption:

= Rated Capacity x Load x hr/Conv. Factor

= 200,000 Btu/hr x 0.315 x 2 hr/yr/(1,000,000 Btu/MMBtu)

= 0.13 MMBtu/yr

Geothermal Heating System Consumption:

= Capacity x Load x hr/(3,412 Btu/kWh x COP)

= 200,000 Btu/hr x 0.315 x 2 hr/yr/(3,412 Btu/kWh x 5)

= 7.39 kWh/yr

The second table below shows that the heating energy consumption for all temperatures is **49.51 MMBtu/yr** and **2,902 kWh/yr**.

Additional savings will accrue because the three window units will no longer be necessary to provide supplemental cooling. The table below shows the window unit consumption for all temperatures. It is assumed that window units are used at ambient temperatures above 80°F.

Net Electrical Savings = Current Usage – Geothermal Usage

= 11,583 kWh/yr + 2,391 kWh/yr – 8,212 kWh/yr – 2,902 kWh/yr)

= **2,860 kWh/yr**

Net Natural Gas Savings = Furnace Usage

= **49.51 MMBtu/yr**

Cost Savings = (Electrical Savings x Average Electric Cost) + (Gas Savings x Gas Cost
=(2,860 kWh/yr x $0.108/kWh) + (49.51 MMBtu/yr x $13.205/MMBtu)
= $309/yr + $654/yr
= **$963/yr**

Investment

The implementation cost for installation of ground-source heat pumps would include removal of the existing air-source equipment, installation of the ground source units, installing the ground loop PVC piping and connecting the ground loops to the heat pump. The cost of a residential size ground-source unit is approximately $2200 per ton. This includes the cost of installing a ground loop, which is about $1100 per ton. This gives a total estimated cost of $15,400 for a 7-ton unit.

Simple Payback

= Investment / Savings
= $15,400 / $963/yr
= **16.0 years**

The estimated sixteen-year payback on a geothermal heat pump system appears excessive. Instead of replacing a functioning HVAC system, a more attractive economic return is achieved by installing a geothermal system when the existing air-cooled system must be replaced. The estimated cost of a seven ton air-cooled system is $9,800.

Incremental Cost = Cost of Geothermal – Cost of conventional System
= $15,400 - $9,800
= $5,600

Incremental Payback = Incremental Cost / Geothermal Savings
= \$5,600 / \$963/yr
= **5.8 years**

Mid-pts	Temp. DB (F)	Annual Hrs	Split sys Load-%	window unit load-%	Usage kWh/yr
97	96 to 98	0			
95	94 to 96	6	100.0%	100.0%	22.1
93	92 to 94	35	93.9%	100.0%	129.0
91	90 to 92	97	87.9%	85.7%	306.5
89	88 to 90	172	81.8%	71.4%	452.9
87	86 to 88	247	75.7%	57.1%	520.3
85	84 to 86	317	69.6%	42.9%	500.8
83	82 to 84	274	63.6%	28.6%	288.6
81	80 to 82	325	57.5%	14.3%	171.1
79	78 to 80	384	51.4%	0.0%	0.0
77	76 to 78	382	45.4%		
75	74 to 76	548	39.3%		
73	72 to 74	749	33.2%		
71	70 to 72	500	27.1%		
69	68 to 70	490	21.1%		
67	66 to 68	428	15.0%		
65	64 to 66	391	0.0		
63	62 to 64	329	0.0		
TOTAL					2,391.2

Mid -pts	Temp. DB (F)	Ann. Hrs	Enthalpy (Btu/lb)	Est. Cooling Load	Est. Htg Load	Cooling Energy Current kWh/yr	Cooling Energy Geoth kWh/yr	Cooling Energy Savings kWh/yr	Heating Energy Furnace MMBtu	Heating Energy Geothm kWh
97	96 to 98	0	40.3	-	-	-	-	-	-	-
95	94 to 96	6	39.4	95.0%	-	48.0	28.2	19.8	0.0	0.0
93	92 to 94	35	39.3	88.4%	-	254.1	152.8	101.3	0.0	0.0
91	90 to 92	97	38.8	81.7%	-	634.9	391.7	243.2	0.0	0.0
89	88 to 90	172	38.3	75.1%	-	1,007.6	638.0	369.5	0.0	0.0
87	86 to 88	247	37.2	68.4%	-	1,284.0	835.2	448.8	0.0	0.0
85	84 to 86	317	36.6	61.8%	-	1,447.4	967.8	479.7	0.0	0.0
83	82 to 84	274	35.5	55.1%	-	1,085.4	746.6	338.8	0.0	0.0
81	80 to 82	325	34.9	48.5%	-	1,099.8	778.9	320.9	0.0	0.0
79	78 to 80	384	34.3	41.9%	-	1,088.3	794.2	294.1	0.0	0.0
77	76 to 78	382	33.6	35.2%	-	883.0	664.7	218.3	0.0	0.0
75	74 to 76	548	32.6	28.6%	-	995.5	773.6	221.8	0.0	0.0
73	72 to 74	749	31.8	21.9%	-	1,010.3	811.6	198.8	0.0	0.0
71	70 to 72	500	30.7	15.3%	-	454.4	377.6	76.7	0.0	0.0
69	68 to 70	490	29.1	8.6%	-	243.0	209.3	33.8	0.0	0.0
67	66 to 68	428	28	2.0%	-	47.4	42.3	5.1	0.0	0.0
65	64 to 66	391	26.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
63	62 to 64	329	25	0.0	0.0	0.0	0.0	0.0	0.0	0.0
61	60 to 62	345	24	0.0	0.0	0.0	0.0	0.0	0.0	0.0
59	58 to 60	206	22.6	-	0.0%	0.0	0.0	0.0	0.00	0.00
57	56 to 58	264	21.6	-	1.5%	0.0	0.0	0.0	0.79	46.42
55	54 to 56	341	20.5	-	3.0%	0.0	0.0	0.0	2.05	119.93
53	52 to 54	197	18.8	-	4.5%	0.0	0.0	0.0	1.77	103.93
51	50 to 52	205	18.4	-	6.0%	0.0	0.0	0.0	2.46	144.20
49	48 to 50	178	17.4	-	7.5%	0.0	0.0	0.0	2.67	156.51
47	46 to 48	192	16.5	-	9.0%	0.0	0.0	0.0	3.46	202.58
45	44 to 46	166	15.5	-	10.5%	0.0	0.0	0.0	3.49	204.34
43	42 to 44	201	14.9	-	12.0%	0.0	0.0	0.0	4.82	282.77
41	40 to 42	118	14.2	-	13.5%	0.0	0.0	0.0	3.19	186.75
39	38 to 40	168	13.6	-	15.0%	0.0	0.0	0.0	5.04	295.43
37	36 to 38	162	12.6	-	16.5%	0.0	0.0	0.0	5.35	313.36
35	34 to 36	94	11.8	-	18.0%	0.0	0.0	0.0	3.38	198.36
33	32 to 34	69	11	-	19.5%	0.0	0.0	0.0	2.69	157.74
31	30 to 32	44	10.3	-	21.0%	0.0	0.0	0.0	1.85	108.32

29	28 to 30	75	9.6	-	22.5%	0.0	0.0	0.0	3.38	197.83
27	26 to 28	28	8.8	-	24.0%	0.0	0.0	0.0	1.34	78.78
25	24 to 26	17	8.3	-	25.5%	0.0	0.0	0.0	0.87	50.82
23	22 to 24	3	7.8	-	27.0%	0.0	0.0	0.0	0.16	9.50
21	20 to 22	9	7.2	-	28.5%	0.0	0.0	0.0	0.51	30.07
19	18 to 20	2	6.4	-	30.0%	0.0	0.0	0.0	0.12	7.03
17	16 to 18	2	5.8	-	31.5%	0.0	0.0	0.0	0.13	7.39
Total		8760				11,583.0	8,212.3	3,370.7	49.51	2,902.05

11.6.14 Photovoltaic system for Robinson Garage

Table 35: PV area requirement calculation for Robinson Garage

Description	Value	Unit	Calculation
Annual reduced el. Consumption	322,681	kWh	
Available area	36000	ft^2	
Conversion factor	10,75	$\frac{ft^2}{m^2}$	
Solar radiation south facing 30°	1,884	$\frac{kWh}{m^2}$	
System overall performance	16	$\%$	
Used radiation	301	$\frac{kWh}{m^2}$	$Solar\ rad.\ \left[\frac{kWh}{m^2}\right] * System\ performance[\%]$
Required area	1.070	m^2	$\frac{Consumed\ kWh\ [kWh]}{Used\ radiation\ [\frac{kWh}{m^2}]}$
Required area	11.507	ft^2	$Required\ area\ [m^2] * Convers. factor[\frac{ft^2}{m^2}]$
Share of area	32	$\%$	$\frac{Required\ area\ [ft^2]}{Available\ area\ [ft^2]}$

Table 36: Break-even point calculation for a PV system for Robinson Garage

Description	Value	Unit	Calculation
Annual reduced el. Consumption	322,681	kWh	
Electricity rate	0.088	$\frac{\$}{kWh}$	
Solar performance south facing 30°	1,884	$\frac{kWh}{kWp}$	
Photovoltaic system lifetime	25	$Years$	
Rated power	171	kWp	$\frac{Ann. red. el. consumption}{Solar\ performance\ south\ facing}$
Annual reduced el costs	28,396	$	$Ann. red. el. cons. * El\ rate$
Lifetime reduced el costs	709,898	$	$Ann. red. el\ costs * Lifetime$
Break even prize	4144.80	$\frac{\$}{kWp}$	$\frac{Lifetime\ reduced\ el\ costs}{Rated\ power}$
Break even prize	4.14	$\frac{\$}{Wp}$	

Calculations do not include price increase of electricity rate, system degradation or any interest rates on capital

11.6.15 Photovoltaic system for State St. Garage

Table 37: PV area requirement calculation for State St. Garage

Description	Value	Unit	Calculation
Annual reduced el. Consumption	394370	kWh	
Available Area	27878	ft^2	
Conversion factor	10,75	$\frac{ft^2}{m^2}$	
Solar radiation south facing 30°	1884	$\frac{kWh}{m^2}$	
System overall performance	16	%	
Used radiation	301	$\frac{kWh}{m^2}$	$Solar\ rad.\ \left[\frac{kWh}{m^2}\right] * System\ performance[\%]$
required area	1.308	m^2	$\frac{Consumed\ kWh\ [kWh]}{Used\ radiation\ [\frac{kWh}{m^2}]}$
required area	14.063	ft^2	$Required\ area\ [m^2] * Convers.factor[\frac{ft^2}{m^2}]$
Share of area	50	%	$\frac{Required\ area\ [ft^2]}{Available\ area\ [ft^2]}$

Table 38: Break even point calculation for a PV system for State St. Garage

Description	Value	Unit	Calculation
Annual reduced el. Consumption	394370	kWh	
Electricity rate	0,086	$\frac{\$}{kWh}$	
Solar performance south facing 30°	1884	$\frac{kWh}{kWp}$	
Photovoltaic system lifetime	25	$Years$	
Rated Power	209	kWp	$\frac{Ann.red.el.consumpti}{Solar\ performance\ south\ f}$
Annual reduced el costs	33861	$\$$	$Ann.red.el.cons.*\ El\ rate$
Lifetime reduced el costs	846536	$\$$	$Ann.red.el\ costs$ $*\ Lifetime$
Break even	4044,48	$\frac{\$}{kWp}$	$\frac{Lifetime\ reduced\ el\ costs}{Rated\ power}$
Break even	4,04	$\frac{\$}{Wp}$	

Calculations do not include price increase of electricity rate, system degradation or any interest rates on capital